
Annual Report 2021



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



ICAR-CPRI Annual Report-2021

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PREFACE

It is my great pleasure to present the Annual Report 2021 of ICAR-Central Potato Research Institute (CPRI), Shimla. Since the inception of the institute in 1949, the development of potato varieties and technologies has led our country as the second largest producer of potato contributing to ~12% of global production. As per the second advance estimate for 2021-22 (DAC&FW), India produced 53.58 million tonnes of potatoes from 2.20 million ha area with average productivity of 24.35 t/ha. This significant growth became possible only after the development of technologies by the institute. This Annual Report presents an overview of research and development conducted at the institute during the year.

Presently more than 4600 accessions of cultivated and wild potato species, obtained from 30 countries, are conserved at the institute. A total of 44 accessions were imported from 3 different countries including 26 diploid accessions from the USA, 5 processing varieties from Ireland, and 13 processing varieties from The Netherlands. Furthermore, 54 accessions free from quarantined pests were introduced to germplasm repository. Diploid TPS of 7 accessions/ populations were imported including 3 populations *viz.*, SOLHY007, SOLHY008 and SOLHY012 for M/s Tierra Agrotech from The Netherlands, 2 populations *viz.*, IN007 and IN012 for M/s Sungrow Seeds from The Netherlands and 2 populations *viz.*, D20HY-0377 and D20HY-0742 for M/s Mahindra HZPC from The Netherlands. A total of 11 advanced stage hybrids namely MSP/15-60, MSP/16-216, MSP/16-300 (nutritionally superior), J/13-97, J/13-175, J/13-200 (early bulking), PS/12-15, PS/15-33 (red skin), MP/15-651 (processing), SS/11-295 (late blight resistant) and N/11-89 and N/12-12 (nitrogen use efficient) have been introduced in AICRP for multi-location testing. New improved advanced stage clone MS/11-664 (Kufri Kanchan x Kufri Khyati) has been recommended for release in the 39th group meeting of ACIRP (Potato).

In the biotechnology program, a total of 119 conserved miRNAs (20-24 nt) belonging to 41 miRNAs families, and 1002 putative novel miRNAs (15-25 nt) were identified responsive to low N stress in potato by small RNA sequencing in potato cv. Kufri Jyoti. Draft genome sequences of unique potato genotypes i.e. somatic hybrid P8 (J1), wild species *S. pinnatisectum* (J2), progeny MSH/14-112 (P8 x cv. Kufri Jyoti) (J3), and *S. tuberosum* dihaploid C-13 (J4) had been deciphered. Further, 39260 (J1), 25711 (J2), 39730 (J3) and 30241 (J4) genes were identified and 17411 genes were found common in the genotypes, particularly late blight resistance genes (*R3a*, *RGA2*, *RGA3*, *R1B-16*, *Rpi-blb2*, *Rpi* and *Rpi-vnt1*). Total production of 3010.98 tons of nucleus and breeder seed was achieved from an area of 131.03 ha. Out of which, 2135.16 tons production from 95.53 ha was through conventional and 875.91 tons from 35.51 ha through hi-tech seed production systems respectively. A total of 21997.17 tons of breeder seed was supplied to various government and private agencies. Total revenue of Rs.10 crores have been generated by the disposal of breeder seed. VEGFAST systems have been developed and popularized for the production of vegetables, herbs, medicinal plants, ornamental plants etc. on the rooftops/yards/balconies, especially in cities and towns. HYDROFAST systems have been developed which can be used for the production of leafy vegetables, and herbs using hydroponic principles. A prototype of a remote-operated unmanned ground (UGV) vehicle has been designed and developed for spraying agrochemicals on the potato crop.

One step reverse transcriptase-recombinase polymerase amplification (RT-RPA) assays were developed for rapid detection of *Potato virus A* and *Potato leaf roll virus* from potato leaves and tubers (periderm). The *in-vitro* method for estimation of Glycemic index in potatoes and products was validated and found to correlate with Goni's Protocol. Glycemic index could be reduced up to 12% and resistant starch could be increased up to 58% by using different potato-pulse combinations. Saccharification with enzyme showed high efficiency of conversion of starch to sugars in potato slurry (up to 96% theoretical) and its further fermentation for bio-

ethanol production was found highly efficient (84 g/L). A new product 'Gluten-free potato *Gulab Jamun*' was developed using potato flour, which may be stored under frozen conditions for up to 6 months.

Level adoption of improved potato production technologies was accessed by interviewing 120 potato growers of Bihar (60 each from Patna and Nalanda districts). The survey revealed that that technology like use of improved varieties, pre-sprouting of seed tubers, use of whole seed tubers, seed retention period, maintenance of spacing, maintenance of irrigation interval, late blight management and earthing up were followed by the majority of farmers. However, there was very poor adoption of technologies like the use of certified/quality potato seeds, FYM application, recommended dose of NPK fertilizers and pre-sowing irrigation. Overall, about 32 percent of farmers applied excess nitrogen fertilizers, 70 percent applied excess phosphatic fertilizers and about 59 percent applied fewer potash fertilizers. The study also revealed that varieties developed by the institute like Kufri Pukhraj and Kufri Sindhuri were adopted by about 51 percent of potato growers and covered about 60 percent of the total potato area. A total of 703 FLDs were conducted at farmer's fields of states UP, MP, Bihar, Tamil Nadu and Meghalaya. The institution also conducted 55 trainings/awareness programmes/events at the headquarters and its regional stations for the officials and farmers of the country under *Atmanirbhar Bharat*. More than 20 exhibitions, fairs, the celebration of important days, chat shows, *kisan goshthies* were also organized. Expert scientists from different disciplines of ICAR-CPRI, Shimla and its regional stations participated in 09 live phone-in programmes on *doordarshan* and *aakashwani*. Under HRD Cell, 29 Scientists, 32 Technical officers and 18 Administrative officers were sent to participate in various training programmes and several attend seminars/ symposia/ workshops/ conferences etc.

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



(NK Pandey)
Director (Acting)

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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 66 scientists, 123 technical staffs and 66 administrative staff & 72 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 12 externally funded research projects sponsored by different agencies *viz.* ICAR, DBT, PPV & FRA, CIP, IASRI, NARS, NEC and UPCR are also under operation. Production of Breeders' seed is being done by the Institute under a Revolving Fund Scheme and National Seed Programme.

STAFF & FINANCE

The institute has 472 sanctioned staff strength comprising of 87 scientific, 178 technical, 102 administrative and 105 supporting staff excluding RMP. The staff position as on 31.12.2021 was 327 including 66 scientific, 123 technical, 66 administrative and 72 supporting staff. In 2021-22, total allocation was ₹79,62,30,000/- and total expenditure was ₹79,60,48,530/-. The institute generated about ₹11.23 crore under Revolving Fund Scheme (RFS) by sale of breeder seed etc. During the year, four new Scientists joined as inter-institutional transfer, 14 Scientists were promoted to scientists (SS), 10 Scientists (SS) were promoted to Sr. Scientist, 3 Scientists were promoted to Sr. Scientist RGP 9000/- & one Scientist was promoted from Sr. Scientist to Principal Scientist. In

technical category, 8 were promoted, 6 were transferred, 11 were retired and one expired. Under administrative category, 4 were promoted, 1 was expired, 3 were transferred on selection basis. In skilled supporting staff, 2 got promoted, 6 retired and 2 transferred (Intra-Institutional).

FACILITIES

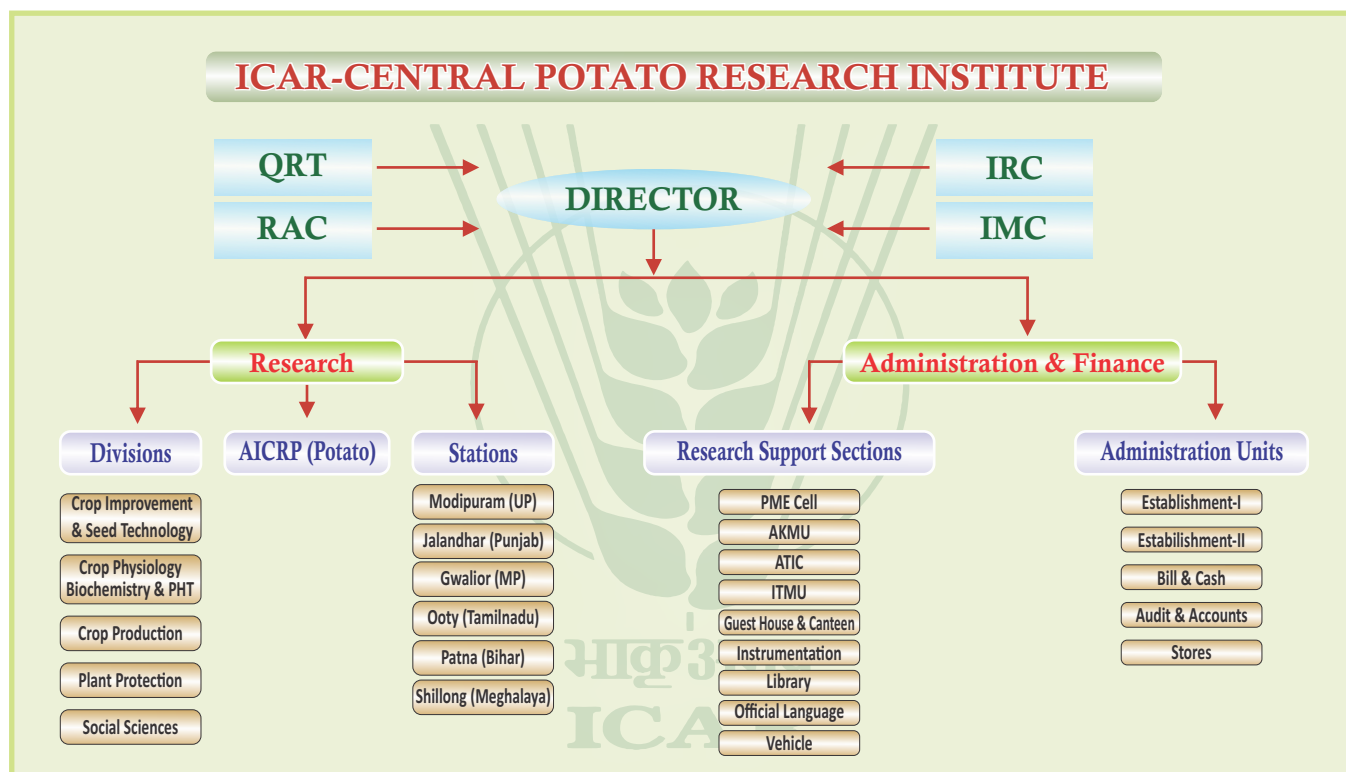
The institute created state-of-the-art laboratories for conducting basic and strategic research in the field of biotechnology, genetics and plant breeding, plant protection, soil science and agronomy, plant physiology, biochemistry, and post-harvest technology. The ICAR-CPRI is the first institute, among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

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

The institute has 521 ha farm lands distributed over 15 units for conducting field experiments and undertaking breeders' seed production. Recently, Aeroponic facility was created at ICAR-CPRI, Shimla, ICAR-CPRI, RS, Modipuram, ICAR-CPRI, RS, Patna and ICAR-CPRI, RS, Shillong for soil less disease free seed potato production. A BPD Unit has been established at ICAR-CPRI, RS, Jalandhar for commercialization of potato technologies developed by the institute. The institute library is the second largest library in the

world in case of potato research & development. 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, projectors, 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

Plant genetic resources are the most valuable and essential basic raw materials to meet the current and future needs of crop improvement. A total of 44 accessions were imported in *in-vitro* form from 3 different countries including 26 diploid accessions from the USA, 5 processing varieties from Ireland, and 13 processing varieties from The Netherlands. During the year 54 accessions free from quarantined pests were introduced to germplasm repository. Diploid TPS of 7 accessions/ populations were imported including 3 populations viz., SOLHY007, SOLHY008 and SOLHY012 for M/s Tierra Agrotech from The Netherlands, 2 populations viz., IN007 and IN012 for M/s Sungrow Seeds from The Netherlands and 2 populations viz., D20HY-0377 and D20HY-0742 for M/s Mahindra HZPC from The Netherlands. The representative samples of imported TPS populations were quarantine tested and the remaining TPS were sent to concerned firms. Besides, TPS of 67 populations were also imported from USDA for use in the institute diploid potato breeding programme. Presently more than 4600 accessions of cultivated and wild potato species, obtained from 30 countries, are conserved at the institute. The collection is evaluated, characterized, and documented in an easily retrievable form for use by the researchers. These are being conserved in field gene banks, in vitro repositories and also as true seeds. A large number of accessions were evaluated for various biotic and abiotic stresses, keeping quality, processing attributes, quality attributes and also adaptability to various thermos-photoperiods and promising accessions were identified. Generated information has been maintained in electronic databases. Three elite genetic stocks were registered with the ICAR-NBPGR, New Delhi.

The hybridization program resulted in the production of 10,23,010 true potato seeds from 521 crosses involving superior parents for yield, quality and resistance/tolerance to biotic and abiotic stresses. In all, 1,98,194 seedlings were recovered from 5,46,390 true potato seeds of 318 crosses and at harvest 18,515 promising clones were selected. In initial clonal generation, 30,088 clones were evaluated and at harvest 5,919 promising clones were

selected. In advanced stage hybrids trials, 382 advanced clones were assessed in 32 trials for yield, quality and resistance/tolerance to biotic and abiotic stresses and at harvest 163 promising advanced clones were retained. Based on tuber yield, nutritional and processing attributes, selections were made aiming prevalence of high nutritional and mineral values in clones essential for human health. Investigated late blight resistance and keeping attributes of nutritionally superior advanced clones. In order to develop SSR profiles of potato clones for genetic fidelity, a total of 84 genotypes were analyzed by two well-known potato SSR markers (STU6SNRN and STIICA). Both markers together clearly distinguish the genotypes studied. High polymorphism was observed in STIICA (PIC: 0.93) than in STU6SNRN (PIC: 0.82). The predominant alleles of STU6SNRN were 174, 179, 182, 190 and 200 bp; whereas in STIICA alleles 191, 195, 198, 201, 221, 223, 231, 242, 245 and 256 were observed frequently in more than 50 percent of the genotypes. Based on consistently good performance over the years, 11 advanced stage hybrids namely MSP/15-60, MSP/16-216, MSP/16-300 (nutritionally superior), J/13-97, J/13-175, J/13-200 (early bulking), PS/12-15, PS/15-33 (red skin), MP/15-651 (processing), SS/11-295 (late blight resistant) and N/11-89 and N/12-12 (nitrogen use efficient) have been introduced in AICRP for multi-location testing. Worked out optimum NPK requirement (kg/ha) of varieties/advanced clones namely, MS/11-664 (240N, 60P, 80K), MS/8-1148 (240N, 60P, 80K), MS/9-2196 (240N, 60P, 80K), Kufri Thar-2 (240N, 40P, 100K), Kufri Sangam (240N, 40P, 160K) and WS/7-113 (180N, 40P, 100K). Twenty-one heterozygous diploid lines and 120 seedlings of initial inbreeding stages were evaluated for ploidy using flow cytometry and all were confirmed as diploids. The 21 heterozygous diploid clones were evaluated for glycoalkaloid content and it varied from 1.35 mg/100 (BS240-1) to 57.50 mg/100g (BS240-17). ICAR- CPRI developed and used 10 KASPTM markers for high throughput screening of self-compatible (SC) clones in diploid germplasm. The results of KASPTM markers used in the study were perfect with an efficiency of >95% based on allele analysis for 9 out of 10 markers. New improved advanced stage clone MS/11-664 (Kufri Kanchan x Kufri Khyati) has been recommended for release in

the 39th group meeting of ACIRP (Potato) held during 27-29 September 2021. The new variety is medium maturing (75-90 days) with yield potential of 35-38 t/ha and having moderate level of late blight resistance, excellent keeping and culinary quality. It possesses 17-18% tuber dry matter, very good taste and mealy texture. It has an edge over prevailing red skin varieties like Kufri Manik, Kufri Lalit and Kufri Lalima for tuber yield and quality attributes. It produces attractive red ovoid uniform tubers with shallow eyes and cream flesh colour. The new variety is suitable for growing in north Indian plains.

In the Biotechnology program, a total of 119 conserved miRNAs (20-24 nt) belonging to 41 miRNAs families, and 1002 putative novel miRNAs (15-25 nt) were identified responsive to low N stress in potato by small RNA sequencing in potato cv. Kufri Jyoti. The differential expression analysis of conserved miRNAs shows that miR397 and miR398 play crucial role in potato under low N and their targets were validated. Methylome and transcriptome analysis revealed candidate genes for tuber shape variation in tissue culture-derived variant plant of potato cv. Kufri Bahar. Draft genome sequences of unique potato genotypes i.e. somatic hybrid P8 (J1), wild species *S. pinnatisectum* (J2), progeny MSH/14-112 (P8 × cv. Kufri Jyoti) (J3), and *S. tuberosum* dihaploid C-13 (J4) had been deciphered. Draft genome sequencing using Illumina platform and reference-based assemblies with the potato genome yielded genome assembly size of 725.01 Mb (J1), 724.95 Mb (J2), 725.01 Mb (J3), and 809.59 Mb (J4). Further, 39260 (J1), 25711 (J2), 39730 (J3) and 30241 (J4) genes were identified and 17411 genes were found common in the genotypes particularly late blight resistance genes (R3a, RGA2, RGA3, R1B-16, Rpi-blb2, Rpi and Rpi-vnt1). Quantitative real-time polymerase chain reaction analysis showed differential expression of late blight resistance genes. Simple sequence repeat (SSR) markers linked to interspecific potato somatic hybrids were identified. A total of 50 breeding lines (parents and progenies) were analysed using 59 simple sequence repeat (SSR) markers. Of which, SSR marker STM0003 clearly distinguished the parents i.e. somatic hybrid P8 (*Solanum tuberosum* dihaploid C-13 + wild species *S. pinnatisectum*) and potato cv. Kufri Jyoti, and their progenies (MSH-

14/112, MSH-14/113, MSH-14/114, MSH-14/115, MSH-14/116, MSH-14/122 and MSH-14/123). STM0003 showed three distinct alleles (103, 132 and 144 bp), where both P8 and progenies contained 103 and 144 bp, and Kufri Jyoti had 132 and 144 bp alleles. On the other hand, STI0001 distinguished progenies namely MSH/17-16 (Kufri Garima × Crd10), MSH/17-25 (Kufri Garima × P10), and MSH/17-27 (Kufri Jyoti × Crd 16) with respect to their parents, and STI0001 contained six alleles (169, 172, 175, 178, 184 and 188 bp).

The Mendelian pattern of segregation of RB event SP951 in Kufri Jyoti progenies revealed the absence of marker gene and plasmid backbone KJ66 line to conduct the biosafety research trial for evaluating the field resistance to late blight disease. Further, 735 and 60 mutant lines from potato cv. K. Jyoti and K. Chipsona 1, respectively have been generated using activation tagging vector pSKI015 via *Agrobacterium tumefaciens* mediated genetic transformation. These lines were screened by using PCR with Bar, Hpt and 35S enhancer gene specific primers. Positive lines showed varied plant phenotyping compared to control plants. Further, positioning of T-DNA using Genome Walker technology revealed the activation of R3b gene for late blight resistance in lines 26(3) and 111 (2), photosystem II reaction center protein C in line 106 (2) and integrase zinc binding domain gene in line 102 (2). Multi RNAi constructs (786 bp) of potato cyst nematode (PCN) pathogenicity genes [flp32c, flp32p, flp12&ams1] were synthesized and confirmed by high fidelity restriction enzymes. After confirmation, transformation was done under in vitro in PCN susceptible potato cultivar Kufri Jyoti using *Agrobacterium* mediated transformation. Molecular analyses of the transformants of potato cultivar Kufri Jyoti revealed the presence of multi gene construct (786bp) and Npt II gene (520bp) in 18 plants out of 24 which will be taken for further screening under pot condition against the PCN population for further confirmation of resistance.

Genetically diverse potato core collection of 288 accessions was characterized through Genotype by Sequencing (GBS) for genome wide SNP detection. Genotyping of 288 accessions generated 100.758 GB and 100.623 GB raw and processed data using RAD sequencing. A set of 23517 and 5389 SNPs were identified at 75 and 90% site

coverage, respectively. Phenotype data was generated on nutritional, agronomic and biotic stress traits and checked for quality before use in GWAS analysis. The GWAS analysis showed 40 highly significant marker trait associations (MTAs) for 10 nutritional traits and 2 each for late blight and PCN at the 0.001 probability level.

Total production of 3010.98 tons of nucleus and breeder seed was achieved from an area of 131.03 ha. Out of which, 2135.16 tons' production from 95.53 ha was through conventional and 875.91 tons from 35.51 ha through hi-tech seed production systems respectively. The percentage of nucleus and breeder seed from the conventional system was 70.91 and 29.10 through the hi-tech system respectively. The percentage of nucleus and breeder seed from the conventional system was 67.33 and 32.67 through the hi-tech system. A total of 21997.17 tons of breeder seed was supplied to various government and private agencies. A total no. of 40 pots of 20 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. A total of 163 virus-free in vitro culture tubes of basic seed material of 29 varieties were supplied to 18 different seed-producing organizations in India and a revenue of Rs. 8,15,000/- 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. Total revenue of Rs. 10 crores have been generated by the disposal of breeder seed. In an experiment, delayed planting has resulted in less number of AR cuttings and rate of multiplication as well. Only 3-4 cuttings are recommended based upon the identified seed window (30th Sept- 7th Oct.) as per Seed Plot Technique. *In-vivo* rapid multiplication through sprouts can be utilized a under rapid multiplication seed potato production scheme. It was observed that planting of two successive microplant crops under net-house has a scope of getting higher productivity per unit area, as compared to a single crop. In variety K. Karan, for obtaining the maximum yield/ha in Gen. 1, 3-10g mini-tubers should be planted at 60x10cm, 10-20g at 60x15cm and 20-40g at 60x20cm respectively. A total of 31.75 tons of quality seed was produced at Shillong and Ooty stations.

DIVISION OF CROP PRODUCTION

Work on different aspects of potato production

technologies was carried out under nine research activities during 2021 under this programme in Division of Crop Production. In an trial on early export at Modipuram, advanced water stress tolerant hybrid WS/07-113 with export-grade yield (tuber size >55 mm) of 11.5 t/ha and cv. Kufri Neelkanth (9 t/ha) were found promising. Exporters have shown keen interest in newly released cv. Kufri Ganga, Kufri Mohan, Kufri Neelkanth and Kufri Sangam from western UP and Gujarat in main season. Quick Response (QR) codes have also been developed for potato technologies for the benefit potato growers and other stakeholders. These QR codes can be used using smartphone set for downloading whole information. Field studies are in progress at Shimla, Modipuram, Gwalior and Shillong for selecting better genotypes for export and organic farming, and refining seed/ production/ protection technologies for organic farming. Potato-garlic (PEY: 74.6 t/ha) in mid-hills, potato + cauliflower 1:2 intercropping (PEY: 21.3 t/ha) in NE hills and rice-potato-green manure (*Sesbania sps.*) cropping system showed marked superiority among different evaluated sequences. Potato cultivation under zero-tillage in rice-potato sequence evaluated at 7 locations was also found promising and technology shall be in place after next crop season. Spray of pre-emergence herbicide metribuzin @ 750g/ha through drone has recorded 27-33% better weed control efficiency. No phytotoxicity was observed with other insecticides and fungicides sprays by drone. Refinement in production technology from aeroponic minitubers (cv. Kufri Jyoti, Kufri Chipsona-1, Kufri Gaurav and Kufri Khyati) and *in vitro* hardened micro-plants (Kufri Himalini and Kufri Pukhraj) in soilless media under insect proof net house has continued in this season. Seed size tuber enhancement by CPRI formulation in cv. Kufri Jyoti and Kufri Pukhraj has recorded significant results. VEGFAST systems have been developed for production of vegetables, herbs, medicinal plants, ornamental plants etc. on the rooftops/yards/balconies especially in cities and towns. HYDROFAST systems have been developed which can be used for production of leafy vegetables, herbs using hydroponic principles. Minituber production in controlled environment system (CES) has been developed and is under testing phase. Hand tools like single bottom furrower for opening deep

furrows, two bottom furrower for covering of seeds, earthing-up and ridge making operation, and ridging tool for covering potato seeds has been designed and tested for potato cultivation by marginal farmers. Prototype of a remote operated unmanned ground (UGV) vehicle has been designed and developed for spraying of agrochemicals on potato crop.

Under this programme, seven research activities are in operation since 2020 in the Division of Crop Production. Field studies on nutrient management options alongwith drip, sprinkler and furrow irrigation in potato at Modipuram revealed that both drip irrigation method (32.9 t ha^{-1}) and 100% RDF produced higher yield (30.6 t ha^{-1}) over other counterparts. Another experiment revealed that irrigation at 20 mm CPE produced significantly higher tuber yield (32.8 t ha^{-1}) in potato cultivar Kufri Thar 3. At Gwalior, highest yield (43 t/ha) was obtained with drip irrigation followed by furrow irrigation. Studies at Jalandhar and Gwalior revealed that effect of crop stage specific and weather based variable rate drip irrigation (VRDI), drip irrigation (DI @ 100% ETref), drip irrigation (DI @ 75% ETref), drip irrigation (DI @ 50% ETref) was non-significant on tuber yields which ranged between 22.9 – 24.2 t ha^{-1} , but the highest value was observed in drip irrigation @ 100 % ETref. At Gwalior, Kufri Jyoti exhibited highest yield and tuber numbers under variable rate drip fertigation. At Jalandhar, foliar sprays of Thio-Urea @ 400 ppm; KNO_3 @ 10 g L^{-1} and microbial bio-polymer formulation @ 150 ml L^{-1} at critical crop stages and paddy straw mulch @ 5 t/ha did not differ significantly w.r.t. potato tuber yield. Effect of organic and inorganic production practices on heavy metal content (Pb, Cd, As, Cr) was studied in 10 varieties where large variations were observed amongst varieties though their concentrations were within safe limits under both production systems. Foliar sprays of selenium revealed that Se exerted a positive effect on crop growth and stress tolerance at low concentrations in pot studies. Studies on graded doses of P and rice husk ash revealed a significantly higher tuber yield (30.5 t/ha) with 20 t/ha RHA applied along with 75% of recommended P compared to 75% P dose. A glass-house pot experiment at Shimla indicated an important role of microbial inoculants like AMF along with PSB in P bio-availability, tuber yield and P-economy in potato. Studies on genotypic variations in phosphorus use efficiency revealed that P content in leaves of 10 genotypes/varieties ranged from 0.40% in Kufri

Himsona to 0.68% in MS/17-629. This variability can serve as a reservoir of potentially useful genes to develop commercial cultivars with high PUE. An experiment at Ooty revealed that application of lime and PSB along with SSP significantly increased the potato yield. At Shillong, application of 100% RDF and lime, alone or in combination had a significant influence on potato yield.

The progress report includes the research work carried out during 2021 under the programme “Impact, adaptation and management strategies for climate resilient potato production” (concluded in March, 2021) and “Vulnerability and resilience to climate change for sustainable potato production” (initiated from April, 2021). Under this programme, simulation studies were carried-out using InfoCrop Potato Model for developing adaptation strategies against climate change for Madhya Pradesh (MP) while using three potato cultivars viz., Kufri Badshah (late), Kufri Jyoti (medium), and Kufri Pukhraj (early maturity groups) at five representative locations of the state for RCP 4.5 and RCP 6.0 projection of IPCC – 5AR. In another study, estimation of GHG-emissions and carbon footprints under potato production was done in Himachal Pradesh and Uttarakhand in NW Himalayas. In Himachal Pradesh, primary data of an 'on-farm' experimentation under two crop management scenarios [integrated crop management (ICM) vs farmers' practice (FP)] in four potato varieties viz. Kufri Himalini, Kufri Giriraj, Kufri Shailja alongwith Kufri Jyoti (as check); was used. The ICM resulted in slightly higher carbon footprints ($0.08 \text{ kg CE kg}^{-1}$ fresh potato tuber yield) compared to FP ($0.069 \text{ kg CE kg}^{-1}$ fresh potato tuber yield) due to higher carbon inputs used in plant nutrition, crop management and plant protection measures under ICM. In second study in Uttarakhand, we used the primary data of a field experiment conducted at Bharsar where INM proved better option over organic nutrient management w.r.t. potato productivity and carbon footprints in diverse potato production systems of Uttarakhand in wet-temperate NW Himalayas. Effect of elevated temperature ($+3^{\circ}\text{C}$) on tuber yield and carbon dynamics in soils with different organic amendments was also studied at Jalandhar where a clear-cut decline in tuber yield was noticed with a rise in temperature. The extent of decrease was 2.0 and 3.9 t/ha^{-1} with paddy straw incorporation and vermicompost, respectively. Field studies conducted at Modipuram revealed that drip irrigation applied at 125% CPE produced significantly higher total tuber

yield (30.3 t ha⁻¹) over 75% CPE. Paddy straw mulch @ 5 t/ha also gave higher yield (31.7 t ha⁻¹) compared to black polythene mulch. Sprinkler irrigation applied at 150% CPE produced significantly higher tuber yield compared to 100% CPE. At Gwalior, highest tuber yield (25.9 t ha⁻¹) was recorded with polythene mulch which was closely followed by spray of CFs and paddy straw mulch. Chemical formulation (CFT₂) evaluated at Modipuram and Gwalior had promising results for sustaining tuber yield and quality (reduced tuber defects) under water stress. The population of peach-potato aphid, *Myzus persicae* (Sulzer) other aphid species, and white fly was monitored at weekly interval in unsprayed potato fields in early planted (September planting) and main crop (October planting) at Modipuram. The study revealed that the buildup of population of aphids and whiteflies was directly correlated with temperature. An experiment on seven potato varieties with differential resistance to late blight revealed that the variations in AUDPC may be due to make up of different genes structure of the varieties and environmental conditions which existed at different dates of planting.

DIVISION OF PLANT PROTECTION

More species of *Fusarium* i.e. *F. proliferatum* was found associated with dry rots, *Alternaria tenuissima* with leaf spots and *Pectobacterium brasiliense* with soft rots of potatoes. Few isolates of *Phytophthora infestans* were still observed resistant and intermediate resistant to metalaxyl while all isolates were observed sensitive to new molecules (cymoxanil, dimethomorph, and fenamidone). Indo-Blightcast model predicted appearance of late blight accurately across agro-ecologies and accordingly agro-advisories were issued for its management. Spray schedule of mancozeb 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. Soil application of chlorine dioxide (100 kg/ha) and tuber disinfection (0.03%) either before cold storage or after cold storage (before sprouting) resulted in significant reduction in common scab severity as compared to control. Tuber seed treatment with Pencycuron @0.25% (dip method) and thifluzamide @0.35% (spray method) at the time of planting recorded lowest incidence of black scurf. Four cultures namely SM/92-338, SM/03-23, SM/11-93 and *Assomia Alu* showed good

resistance to bacterial wilt. One line JEX/A-197 exhibited resistance to thaxtomin A toxin production by *Streptomyces scabies*. Inorganic salt (sodium metabisulfite, 0.3M) and essential oils (cinnamon & clover oils) exhibited *in-vitro* efficacy against dry rot pathogen, *Fusarium sambucinum*.

Virus infected samples collected from fields of Jalandhar (Punjab) were subjected to enumeration of potato viruses and development of potato virome map/database. Results revealed prevalence of PVM, PVX, PVY, PLRV, PVS, ToLCNDV and Alfalfa mosaic virus. Developed one step reverse transcriptase-recombinase polymerase amplification (RT-RPA) assays for rapid detection of *Potato virus A* and *Potato leafroll virus* from potato leaves and tubers (periderm). Transgenic lines developed for ToLCNDV- potato (GTLC2-127 and KPLC2-53) resistance were screened this year also and found resistant. Exogenous application of melatonin resulted in enhanced activity of catalase, peroxidase, superoxide mutase and ascorbate peroxidase in PLRV infected plants. Studies of transmission of ToLCNDV by *Bemisia tabaci* revealed that transmission efficiency is sex dependent and female whiteflies transmit the virus with higher efficiencies than males. Batch certification of 5.07 lakh plants of potato and 4.00 lakh plants of apple was done under NCS-TCP by testing mother cultures and random samples of standing crops.

Insect vectors (aphids, whiteflies, leafhoppers, thrips) and soil pests were monitored at Gwalior, Shimla and Modipuram on potato (unsprayed crop) during 2021. *Myzus persicae* did not cross the critical level till last week of December at Modipuram. The population of whiteflies, *Bemisia tabaci* remained below ETL (< 2 whiteflies/plant) from fourth week of November to last week of December. Initially the leaf hoppers, *Amrasca biguttula biguttula* population was high for the first four weeks till second week of December and then started declining. Initially aphid population dominated by *Aphis gossypii*, subsequently it was predominated by *Myzus persicae*. Similarly, the incidence of whitefly and thrips was started in 4th week of November and reached its peak population (40 whiteflies/10 plants and 65 thrips/10 plants) in third and fourth week of December, respectively at Gwalior. The population of aphids and whiteflies was monitored on sprayed potato at Murana (MP). Six white grub species were captured using the light trap installed at Fagu farm of ICAR-CPRI, Shimla. Morphological and molecular characterization of

serpentine leaf miner identified the species as *Liriomyza huidobrensis*. Preliminary draft genome analysis of *Aulacorthum solani* provides new insights to understand molecular basis of aphid biology, host-aphid interactions and adaptation mechanism. Yellow sticky trap along with basil oil increased the efficacy of trap catches of aphids in potato field by 98%. The EPN, *Steinernema cholasanense* was able to penetrate and reproduce within the haemocoel of fourth-instar larvae of *P. operculella*. PCN infested plots treated with Dazomet resulted in highest yield (33.85 t/ha) and improved growth parameters. Results of different cropping sequences followed for management of PCN revealed that oat-oat-mustard resulted in 64.3% reduction, potato-mustard-rajmash (42.8%), oat-trap-potato (64.9%), oat-mustard-rajmash (64.8%), and oat-potato-oat (63.6%) in PCN population. Soil fumigation with methyl bromide resulted in 33 to 58% (Av 47%) reduction in PCN count after 30 days of treatment.

DIVISION OF CROP PHYSIOLOGY, BIOCHEMISTRY AND POST-HARVEST TECHNOLOGY

A combinations of nine volatile oils was found highly effective for sprout suppression up to 120 days of storage at 10-12°C in large scale potato trials using eleven varieties. A cocktail of new volatiles suppressed 100% sprouting in stored potatoes. Application of melatonin reduced *Fusarium* infection in stored potatoes. The *in-vitro* method for estimation of Glycemic index in potatoes and products was validated and found to correlate with Goni's Protocol. Glycemic index could be reduced up to 12% and resistant starch could be increased up to 58% by using different potato-pulse combinations. Coloured potato chips showed higher anti-oxidative and antidiabetic properties compared to white-golden chips. Fortification of peeled potatoes and French fries with Ascorbic acid using Vacuum Impregnation, could increase ascorbic acid 10 folds. Saccharification with enzyme showed high efficiency of conversion of starch to sugars in potato slurry (up to 96% theoretical) and its further fermentation for bio-ethanol production was found highly efficient (84 g/L). A new product 'Gluten-free potato *Gulab Jamun*' was developed using potato flour, which may be stored under frozen conditions up to 6 months.

DIVISION OF SOCIAL SCIENCES

Level adoption of improved potato production technologies were accessed by interviewing 120 potato growers of Bihar (60 each from Patna and Nalanda districts). The survey revealed that technologies like use of improved varieties, pre-sprouting of seed tubers, use of whole seed tubers, seed retention period, maintenance of spacing, maintenance of irrigation interval, late blight management and earthing up were followed by majority of farmers. However, there was very poor adoption of technologies like use of certified/quality potato seeds, FYM application, recommended dose of NPK fertilizers and pre-sowing irrigation. Overall, about 32 percent of farmers applied excess nitrogen fertilizers, 70 percent applied excess phosphatic fertilizers and about 59 percent applied less potash fertilizers. The study also revealed that varieties developed by the institute like Kufri Pukhraj and Kufri Sindhuri was adopted by about 51 percent of potato growers and covered about 60 percent of total potato area. The major constraints as perceived by farmers in the study areas were price fluctuation every year and low price of produce, lack of guidance by extension staffs, good quality seed, region-specific suitable potato varieties, knowledge about improved cultivation practices, storage and processing facilities, training on scientific potato production technologies and production inputs at right time, and high cost of production inputs. A total of 703 FLDs were conducted at farmer's fields of states UP, MP, Bihar, Tamil Nadu and Meghalaya. The institution also conducted 55 training programmes/ events at the headquarters and its regional stations for the officials and farmers of the country under *Atmanirbhar Bharat*. More than 20 exhibitions, fairs, celebration of important days, chat shows, *kisan goshthies* were also organized. Expert scientists from different disciplines of ICAR-CPRI, Shimla and its regional stations participated in 09 live phone-in programmes on *doordarshan* and *aakashwani*. Under HRD Cell, 29 Scientists, 32 Technical officers and 18 Administrative officers were sent to participate in various training programmes and several attend seminars/ symposia/ workshops/ conferences etc.



RESEARCH PROGRAMMES

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

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



DIVISION OF CROP IMPROVEMENT & SEED TECHNOLOGY

PROGRAMME: MANAGEMENT OF POTATO GENETIC RESOURCES

Plant genetic resources are the most valuable and essential basic raw materials to meet the current and future needs of crop improvement. This program is aimed at conserving and providing diverse genetic material to potato researchers. The collection is evaluated, characterized, and documented in an easily retrievable form for use by the researchers.

Collection

A total of 44 accessions were imported in *in-vitro* form from 3 different countries including 26 diploid accessions from the USA for the institute, 5 processing varieties from Ireland for Sri Aditya Biotech, 5 and 8 processing varieties from The Netherlands for Technico AgriSciences and Siddhivinayak, respectively. During the year 54 accessions free from quarantined pests were introduced to germplasm

repository. Diploid TPS of 7 accessions/ populations were imported including 3 populations viz., SOLHY007, SOLHY008 and SOLHY012 for M/s Tierra Agrotech from The Netherlands, 2 populations viz., IN007 and IN012 for M/s Sungrow Seeds from The Netherlands and 2 populations viz., D20HY-0377 and D20HY-0742 for M/s Mahindra HZPC from The Netherlands. The representative samples of imported TPS populations were quarantine tested and the remaining TPS were sent to concerned firms. Besides, TPS of 67 populations were also imported from USDA for use in the institute diploid potato breeding programme. Presently more than 4600 accessions of cultivated and wild potato species, obtained from 30 countries, are conserved at the institute.

Table 1. Potato germplasm holding at CPRI, Shimla

Material	No. of accessions				No. of donor countries
	Tuber	<i>In vitro</i>	True seed	Total	
a) Tuberosum (Cultivars / parental lines)					
Indian					
Cultivars bred at CPRI	56	60		60	
Advanced hybrids	86	50	-	96	
Indigenous varieties	51	107	-	107	
Indigenous samples	97	42		97	
Exotic	1837	2754	-	3004	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				4662	

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, 1454 cultivated potato germplasm were conserved. This includes CPRI bred varieties (57 nos.), indigenous varieties (117 nos) and CP No. (*Solanum tuberosum* ssp. *tuberosum*) (1280 nos.). Besides this, 159 Tuberosum accessions were maintained at Modipuram. In wild species, 347

clones of 119 accessions representing 40 *Solanum* species were multiplied for maintenance breeding whereas, 294 accessions of 70 species were maintained in TPS form. In total, 540 accessions (in tuber / TPS/ *in vitro* form) of 125 species were conserved at CPRI, Shimla.

***In vitro* conservation:** Nearly 2750 Tuberosum accessions and 130 accessions of 29 wild species were maintained in *in-vitro* form. Keeping in view the high incidence of viruses at Jalandhar, one more location

has been identified at Modipuram for field conservation. Minutubers of 183 accessions from *in vitro* repository were produced and added to the germplasm collection maintained under field conditions at Modipuram. Mericlones of different hybrids and varieties were excised and sent for testing for their freedom from all viruses.

Evaluation

Adaptability

Temperate long days

Kufri: In a single row trial set, 84 indigenous genotypes were evaluated along with Kufri Jyoti, Kufri Himalini and Kufri Girdhari as control. Rangpuria and Kanpuria Safed performed well at Kufri condition with higher avg. yield per plant over best control Kufri Girdhari (Avg. tuber yield per plant 370 gms). Both these accessions were highly resistant to late blight also.

Sub-tropic short days

Jalandhar: One hundred (100) Tuberosum accessions were evaluated under spring planting conditions. The yield of germplasm accessions ranged from 20 to 350 g/plant, while the best control variety was Kufri Jyoti (300 g/plant). The other control Kufri Pukhraj yielded 320g/plant. Only one accession (CP 3433) out yielded the better control (350 g/plant).

Modipuram: 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 Sindhuri (246g), K Arun (240g) and K Neelkanth (235g).

Under normal planting, fifty-six genotypes including germplasm lines, advanced stage hybrids and control varieties were evaluated in a single row trial for identifying promising parents at 90 DAP. Promising genotypes namely CP3273, CP4143, Kufri Neelkanth, Kufri Bahar, Kufri Lima and SKL2019, were identified based on genotypes fulfilling the criteria of 80% germination, 450/500 gram marketable/ total tuber yield /plant, very good general impression and > 18% tuber dry matter.

Reaction to late blight: Eighty-four indigenous genotypes with controls Kufri Jyoti, Kufri Girdhari, and Kufri Himalini were screened for foliar blight resistance under the natural open epiphytotic

condition at Kufri. Based on late blight incidence recorded four times at an interval of seven days between two subsequent readings, only 4 accessions viz., Rangpuria, Kanpuria Safed, JG-1 & Desi alu were highly resistant (AUDPC < 250) while no accessions were resistant (AUDPC 251-350). The moderately resistant genotypes were Australian White & G-4 (AUDPC 351-650) and remaining genotypes were either susceptible (AUDPC 651-1200) or highly susceptible (AUDPC > 1200).

In detached leaf method, 37 germplasm accessions were tested for foliage resistance to late blight. Thirteen accessions (CP Nos. 1443, 1653, 1827, 1918, 2060, 2231, 2254, 2468, 3005, 3090, 3115, 3297, and 3447) were resistant, whereas 4 accessions (CP 1578, CP 1597, CP 3700 and CP 4311) were moderately resistant. The remaining accessions were susceptible. Out of 50 accessions tested for tuber resistance by the tuber slice method, only two accessions (CP 1213 and CP 3552) were highly resistant and 29 accessions namely CP Nos. 1375, 1515, 1596, 1827, 1860, 1918, 1949, 2468, 3005, 3090, 3112, 3115, 3197, 3246, 3447, 3452, 3564, 3585, 3614, 3672, 3674, 3677, 3683, 3735, 3880, 4098, 4236, 4311 and 4353 were resistant. The remaining accessions were either moderately resistant or susceptible.

Viruses: Fifty germplasm accessions were screened for resistance through DAS-ELISA against PVX and PVY. Twenty-one accessions namely CP Nos. 1312, 1536, 1736, 2120, 3089, 3360, 3452, 3500, 3507, 3659, 3688, 3730, 3732, 3815, 4242, 4364, 4383, 4386, 4398, 4405 and 4579 had combined resistance to PVX and PVY while 26 and 42 accessions showed resistance to PVX and PVY, respectively.

Field screening of 43 potato germplasm was carried under field conditions at Modipuram against ToLCNDV & 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 ToLCNDV.

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 A may be an effective way of preliminary screening of potato lines for resistance to *Streptomyces* sp. A total of 164 core collection genotypes and varieties were screened for their tolerance to thaxtomin A toxin produced by *Streptomyces scabies* through tuber slice assay. Only one line 'JEX/A-197' 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.

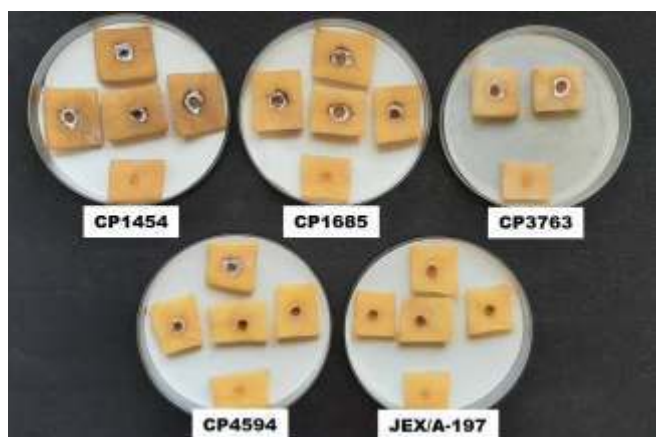


Fig 1. Screening potato lines for tolerance to thaxtomin A toxin produced by *Streptomyces scabies* through tuber slice assay

Leaf-hopper and mites: Out of 68 accessions, 42 accessions had hopper burn below 1% whereas 61 accessions had no mite damage.

Cyst nematode: Fifty-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, 2 accessions i.e. Jeevan Jyoti and Garlentic were highly resistant to both the species while only 1 accession ie Phulwa Red was resistant to *G. pallida*. The remaining accessions fall in the category of either moderately resistant, susceptible or highly susceptible.

At Ooty out of 33 accessions, 13 accessions (CP 1435, CP 1584, CP 1687, CP 1736, CP 1800, CP 2418, CP 3799, CP 3871, CP 3939, JEX/A-329, JEX/A-612, JEX/A-15 and SM/11-120) were resistant to *Globodera rostochiensis*, however, none of the accession was resistant to *G. pallida*.

Keeping quality: One hundred accessions were evaluated for keeping quality at room temperature (14-38°C, 44-75% RH) in comparison to three control cultivars namely, Kufri Dewa, Kufri Ashoka and Kufri Pukhraj. Periodical observations on weight

loss, sprouting and rotting in tubers were recorded at 30 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 most firm as freshly harvested/cold-stored potatoes. Accessions were rated in different categories on the basis of storage performance viz., weight loss, rotting, total loss and physical appearance of tubers after 90 DOS.

Out of the 100 accessions only 3 accessions (CP 1475, CP 1525 & CP 2428) were found as best keeper having less than 10% total storage losses whereas 33 accessions (CP Nos. 1059, 1414, 1443, 1461, 1474, 1516, 1519, 1576, 1594, 1595, 1633, 1644, 1649, 1659, 1661, 1691, 1706, 1711, 1713, 1722, 1729, 1731, 1746, 1747, 1750, 1751, 1754, 1892, 1902, 1905, 2042, 2055 and 2366) as good keeper with storage losses in the range of 10.00 to 15.00%.

Chipping and Physico-chemical constituents: At Jalandhar, 100 Tuberosum accessions were evaluated for processing quality parameters viz. chip colour, dry matter and reducing sugar and sucrose contents. Based on-chip colour (acceptable score up to 3 on a 1-10 scale of increasing dark colour), dry matter (>21%) and reducing sugar (<100 mg/100g fresh tuber wt.), four accessions (CPNos. 1747, 2078, 2159 and 2366) were found highly suitable for chipping.

Seventy-five accessions were also evaluated for vitamin C content which varied widely between 17.68 to 42.30 (mg/100 g fr. wt.) with minimum and maximum values registered by CP 3116 and CP 3145, respectively. Ten top most accessions for vitamin C content (mg/100g fr. wt.) were: CP 3145 (42.30), CP 3188 (41.82), CP 3048 (41.19), CP 3115 (41.04), CP 3021 (40.40), CP 3094 (39.93), CP 2939 (39.14), CP 3192 (38.98), CP 2994 (38.67) and CP 3143 (38.51).

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 chaibi) to 28.68 mg/kg (Lal mitti-1) on dry weight basis. The topmost 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).

Protein Content: Total soluble protein contents of 50 accessions of potato were estimated. Five tubers (freshly harvested) of each accession were washed thoroughly and peeled. Subsequently, potato tubers of each accession were cut separately into small pieces and mixed. Samples were drawn from the mixed pieces. Pieces were further cut into smaller pieces, weighed and stored at -80°C for further use. Soluble protein contents were measured using the Bradford method. Three replicates of each sample were used for protein estimation.

The estimated soluble protein content of the 50 accessions is presented in Fig. 2. The protein contents were found in the range of 0.15 % (Lal Mitti-2) to 1.09 % (Lah Arpor) on fresh weight (FW) basis. Of the 50 accessions, 5 were found to have more than 1 % soluble protein (FW basis). These were: Lah Arpor (1.09%), Ranpuria (1.04%), Lah Smit (1.04%), Alpha (1.03%), and VK/JG-1 (1.02%)

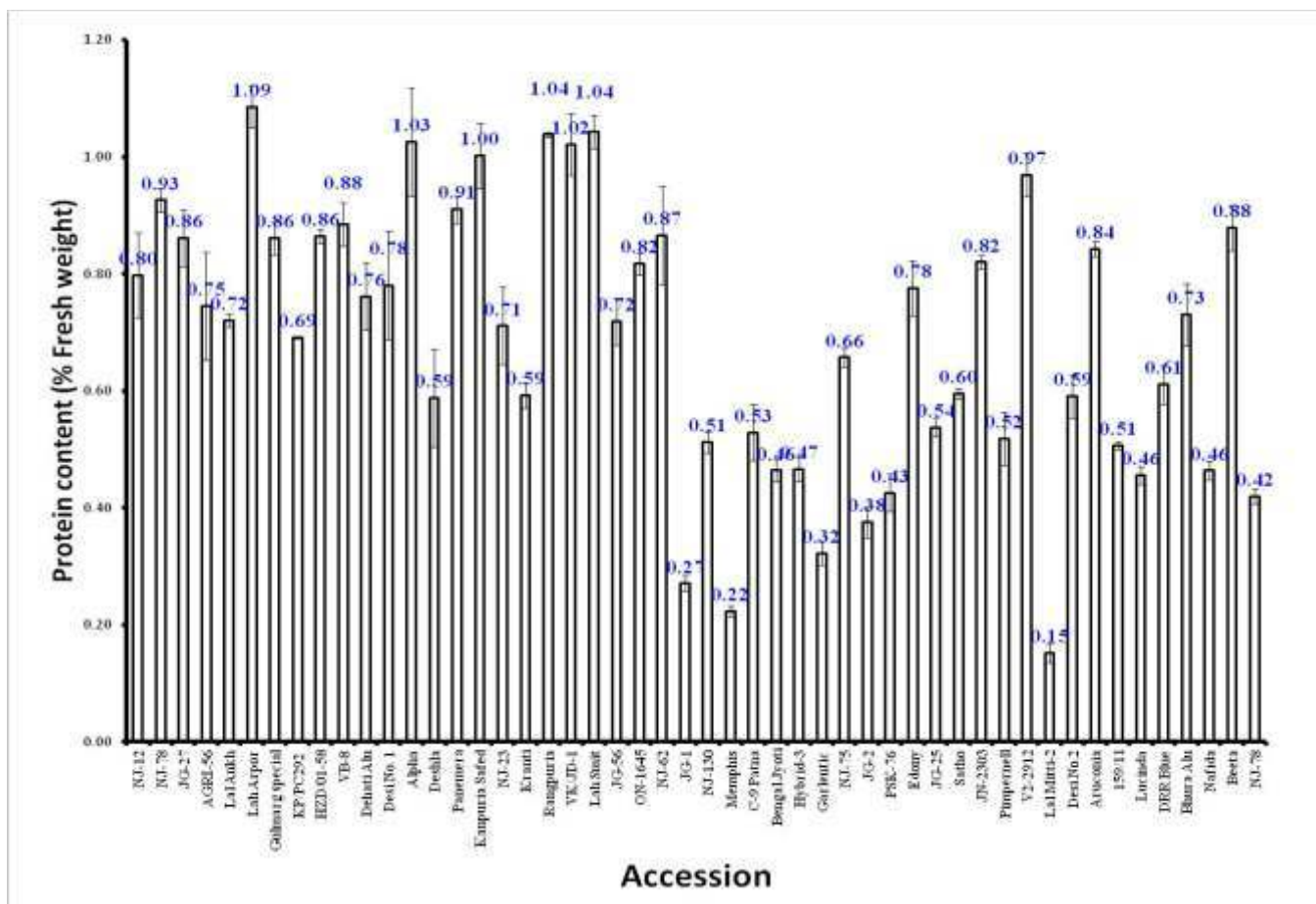


Fig. 2: Total soluble protein content of 50 accessions of potato

Water use efficiency: Germplasm accessions are being evaluated at 3 moisture regimes i.e. 0.20-0.25, 0.40-0.45 and 0.60-0.65 bars/atm soil moisture tension at 15 cm soil depth for higher yield and water use efficiency. Three accessions namely CP 3359, CP 3464 and CP 3599 found promising during last year were re-evaluated, but only one accession (CP 3464) gave equal yield as produced by the control variety Kufri Bahar at all irrigation levels. In another lot, 20 accessions were evaluated and 9 accessions namely CP Nos. 3770, 3780, 3797, 3850, 3853, 3881, 4030,

4140 and 4388 gave equal or higher yields as produced by var. Kufri Bahar, and seems to be promising for higher water use efficiency.

Foliage maturity: Out of 100 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-eight clones of 23 accessions belonging to 7 species were screened for late blight resistance under natural epiphytotic conditions at Kufri. Five clones viz. SS2837-08 (*Solanum acaule*), SS2837-09 (*Solanum acaule*), SS2894-03 (*S. brevicaule*), SS2895-02 (*S. brevicaule*), SS3013-02 (*S. verrucosum*) were highly resistant, and another 5 viz., SS2846-05 (*S. berthaulti*), SS2847-0 (*S. berthaulti*), SS2895-01 (*S. brevicaule*), SS3013-0 (*S. verrucosum*) and SS3114-02 (*S. verrucosum*) were resistant to late blight. The average AUDPC values ranged from 0-1565, with 11 clones having below 50 AUDPC.

In another lot, a group of 40 potato genotypes including wild species, somatic hybrids and control varieties were tested for late blight resistance under the controlled conditions by challenge inoculation of *P. infestans*. These genotypes were: somatic hybrids viz., P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14, *S. pinnatisectum* (PIN 17745), *S. cardiophyllum* (CPH), Crd6, Crd10, Crd16, Crd23; wild potato species ACL38, STO40, PNT44, PLT50, PLD47, BER57, CPH62, VEN30, IOP80, PLD48, CHC60, MCD24, LES29, TRF65, PNT43, JAM07, IOP59 and control varieties Kufri Jyoti (MR/S), Kufri Girdhari (HR), Kufri Bahar (S). In this study, most genotypes were highly resistant to late blight except (P1, P2, P3, P4, P5, P8 and P9) which were resistant, whereas PLD48 and TRF65 were moderately resistant and Kufri Bahar and Kufri Jyoti were susceptible.



Fig. 3. Screening of wild species for late blight resistance under controlled condition

SSR analysis and DUS characterization of wild potato species:

Selected wild species were analysed by two SSR markers, which clearly distinguished them. SSR profile of these species would be useful in research on the identification of trait-specific alleles for late blight resistance, their utilization in biotechnological research, and also in genetic fidelity issues related to true-to-type genotypes in future. Fifty-one phenotypic traits were recorded as per the DUS (distinctness, uniformity and stability) guidelines on the potato of PPV & FRA, Govt. of India. These 51 traits are associated with various plant parts like light sprout, plant foliage structure, stem colour, stem cross-section, plant height, plant wings, leaf, flowers, plant maturity and tubers. Morphological characterization based on DUS traits showed variation in the species. This study shows that these wild species are characterized for SSR profiles, late blight resistance and DUS traits.

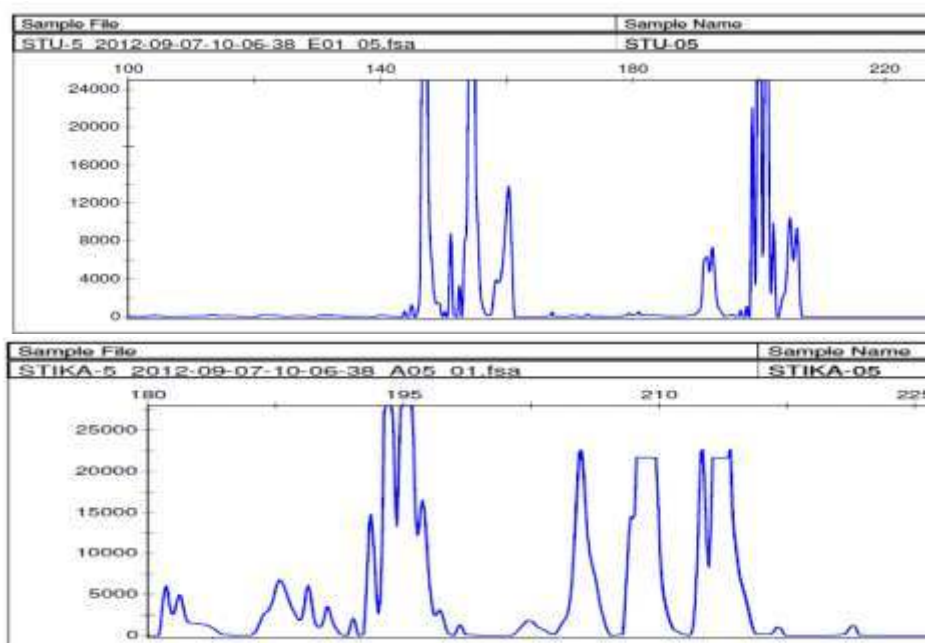


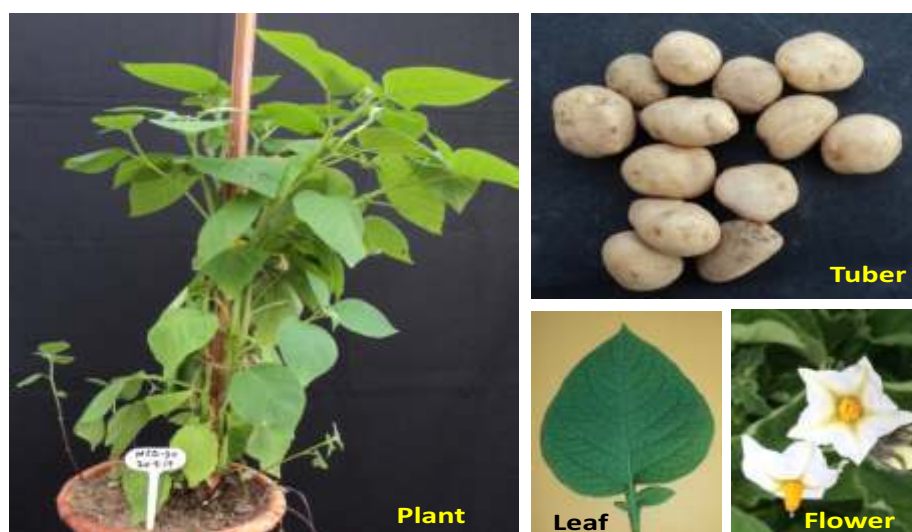
Fig. 4. SSR analysis of wild potato species *S. lesteri* (LES-29) using STU and STIKA markers

Germplasm registered with the NBPGR, New Delhi

1. MCD24 (INGR21075)

An elite genetic stock of wild potato species was MCD24 (INGR21075) (*Solanum microdontum*, Acc. no. PI 218224) was registered with the NBPGR, New

Delhi for high resistance to late resistance disease and diploid wild species for the widening of the genetic base of potato.



Phenotype of wild species potato clone 'MCD24'

Fig. 5. Wild species potato *Solanum microdontum* clone MCD24 (INGR21075)

2. MSH/14-129 (INGR21074)

An elite genetic stock of interspecific somatic hybrid-derived clone MSH/14-129 (INGR21074) was registered with the NBPGR, New Delhi. This is

hybrid of potato cv. Kufri Gaurav × somatic hybrid 'P2' (*S. tuberosum* + *S. pinnatisectum*) having wider genetic base and high yield combined with late blight resistance.



Fig. 6. Phenotype of interspecific potato hybrid 'MSH/14-129' (INGR21074)

Documentation

Computer databases of cultivated as well as wild species were updated by incorporating the evaluation

data for various accessions. Databases of availability of various accessions at different conservation sites were also updated.



PROGRAMME: GENETIC ENHANCEMENT OF POTATO THROUGH MOLECULAR AND GENOMIC TOOLS

Genome-wide identification and characterization of microRNAs by small RNA sequencing of low nitrogen stress in K Jyoti

Nitrogen is an important nutrient for plant growth and tuber quality of potato. Since potato crop requires high dose of N, improving nitrogen use efficiency (NUE) of plant is an inevitable approach to minimize N fertilization. The aim of this study was to identify and characterize microRNAs (miRNAs) by small RNA sequencing in potato cv. Kufri Jyoti plants grown in aeroponic under two contrasting N (high and low) regimes (Fig. 1). A total of 119 conserved miRNAs (20-24 nt) belonging to 41 miRNAs families, and 1002 putative novel miRNAs (15-25 nt) were identified responsive to low N stress in potato. From total, 52 and 54 conserved miRNAs, and 404 and 628 putative novel miRNAs were differentially expressed in roots and shoots, respectively under low N stress (Tables 1 and 2). The differential expression analysis of conserved miRNAs shows that miR397 and miR398 play crucial role in potato under low N and their targets were validated. Of total 34,135

predicted targets, the gene ontology (GO) analysis indicated that maximum targets belong to biological process followed by molecular function and cellular component. Expression levels of the selected miRNAs and targets were validated by real time-quantitative polymerase chain reaction (RT-qPCR) analysis. Two predicted targets of potential miRNAs (miR397 and miR398) were validated by 5' RLM-RACE (RNA ligase mediated rapid amplification of cDNA ends). In general, predicted targets are associated with stress-related, kinase, transporters and transcription factors such as universal stress protein, heat shock protein, salt-tolerance protein, calmodulin binding protein, serine-threonine protein kinase, Cdk10/11-cyclin dependent kinase, amino acid transporter, nitrate transporter, sugar transporter, transcription factor, F-box family protein, and zinc finger protein etc. Our study highlights that miR397 and miR398 play crucial role in potato during low N stress management (Figs. 2, 3 and 4). This study provides insights to modulate miRNAs and their predicted targets to develop N-use efficient potato using transgenic/ genome- editing tools in future.

Table 1. Identification of conserved and putative novel miRNAs in potato

Sample	# Conserved miRNAs	# Putative novel miRNAs
KJ_HN_Root (control) vs.	52	391
KJ_LN_Root	47	233
KJ_HN_Shoot (control) vs.	52	585
KJ_LN_Shoot	47	451

HN: High nitrogen; LN: Low nitrogen

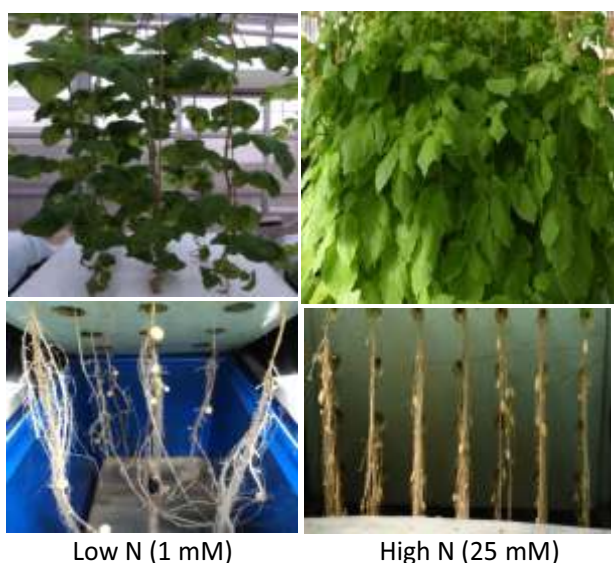


Fig. 1. Plant growth of potato cv. Kufri Jyoti in aeroponics under contrasting N regimes.

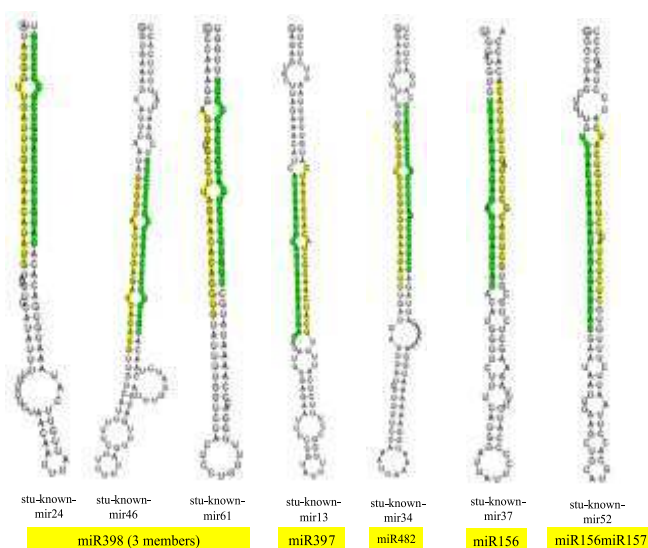


Fig. 2. Secondary structures of selected precursor miRNAs identified under low N stress in K Jyoti.

Table 2. Summary of differentially ($p < 0.05$) expressed miRNAs in potato

Samples	Known miRNAs		Novel miRNAs	
	Up-regulated	Down-regulated	Up-regulated	Down-regulated
KJ_LN_Root vs. KJ_HN_Root (control)	38	9	92	128
KJ_LN_Shoot vs. KJ_HN_Shoot (control)	32	13	252	156

HN: High nitrogen; LN: Low nitrogen

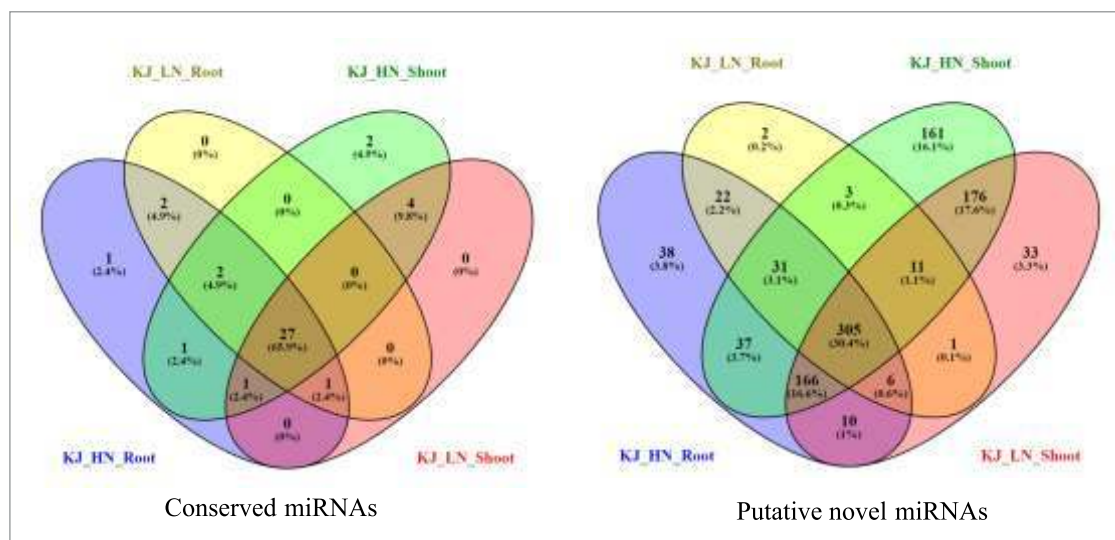


Fig. 3. Venn diagram shows distribution of conserved and putative novel miRNAs in root and shoot tissues of KJ grown in aeroponics

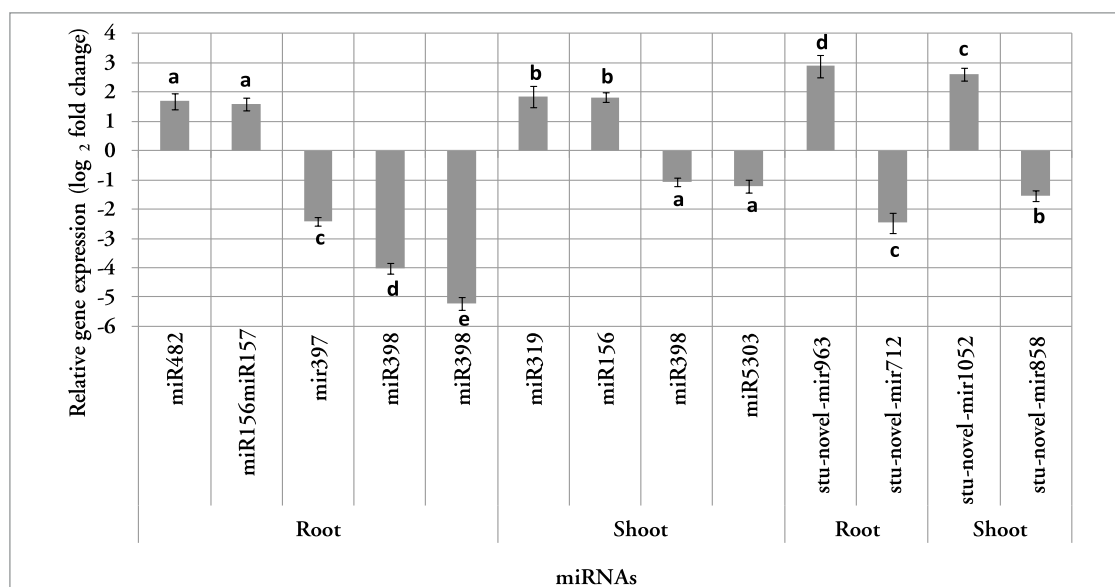


Fig. 4. Validation of miRNAs (A) and their predicted targets (B) by RT-qPCR analysis

Prospects of improving nitrogen use efficiency in potato through transgenics to genome editing strategies

Plant N metabolism involves a network of genes associated in N uptake, transport, utilization, remobilization and storage processes. NUE is a

complex multigenic trait and therefore its improvement becomes difficult particularly in tetraploid potato. A substantial success has been achieved through transgenic and little via CRISPR/Cas in plants. CRISPR/Cas9 has been mostly applied to negative regulators of genes, and therefore in future it is expected to discover such

additional genes. Potato is a tetraploid and therefore application of CRISPR/Cas9 is more challenging. Albeit, all four alleles of *StGBSS* gene in potato have been knocked out and genome-edited mutants have been regenerated by the researchers. Moreover, various transformation methods like *Agrobacterium*, geminivirus replicon, protoplasts and polyethylene glycol have been suggested for Cas9 application in potato, of which protoplasts is an excellent one. Further, suitable sgRNA promoters like *Arabidopsis* (*AtUp*) and potato (*StUp*), and plant promoters like *CAMV35S* have been suggested for potato. Nevertheless, selection of target gene, design of guide RNA, efficient CRISPR/Cas9, plant transformation and off-target mutants are the major issues of genome

editing in potato. Here, we have suggested a few candidate genes based on our research findings for improving NUE in potato applying transgenics or CRISPR/Cas9 technologies. Further, strengthening the knowledge on genes, TFs, and microRNAs and elucidating underlying molecular and physiological mechanisms of N pathways are vital for NUE research. Collectively, CRISPR/Cas9 coupled with base-editing strategies represents an invaluable system for precise genome editing. Nonetheless, robust Cas9 array system with multiplexing of targets, transformation and regeneration, phenotypes and people awareness would be challenges in genome editing research (Fig. 5).

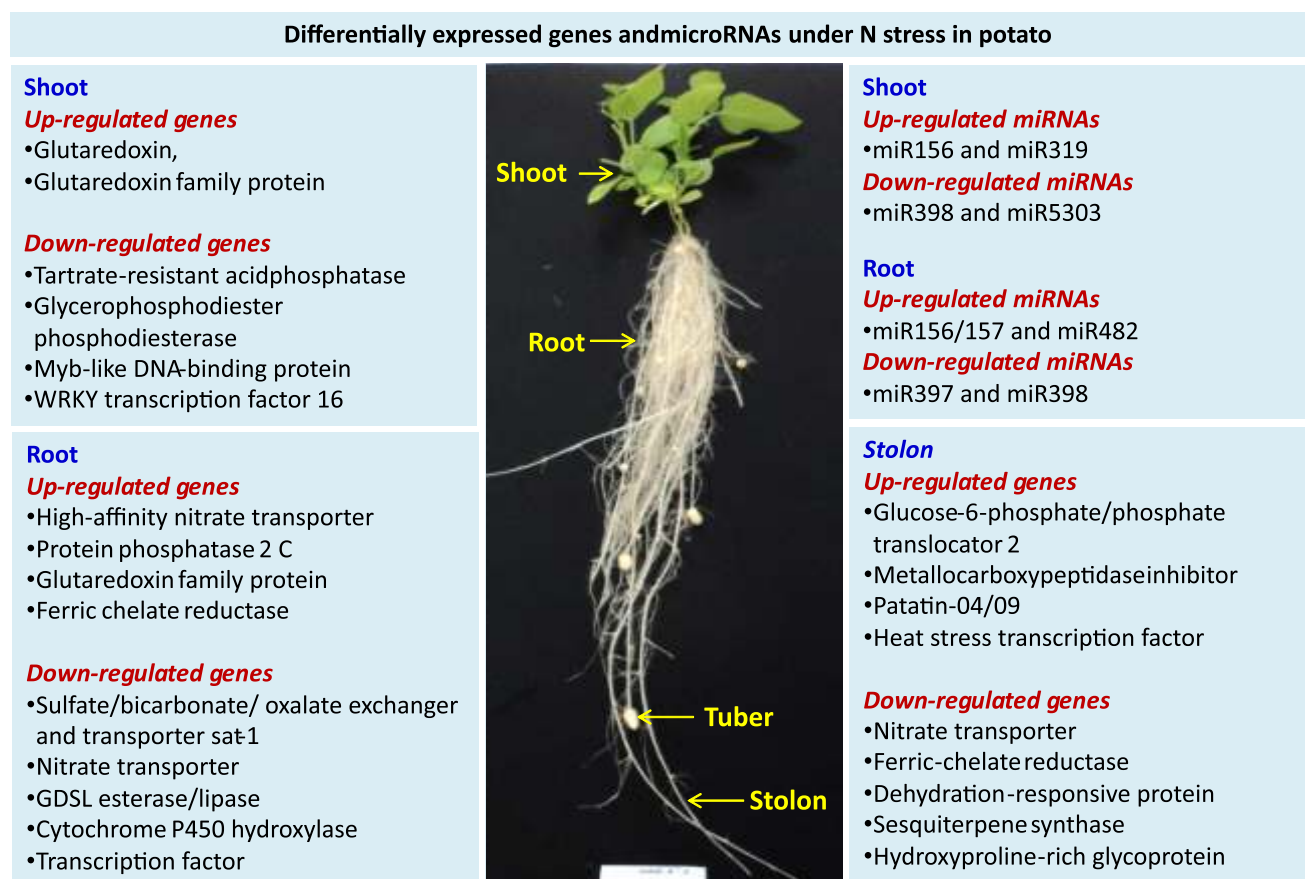


Fig. 5. An outline of selected differentially expressed genes identified in potato under N stress based on transcriptome (RNA-seq and small RNA) sequencing

Introduction of nitrogen use efficient hybrid NUE/15-8 in AICRP (Potato)

Global agriculture faces problems of environmental pollution due to excess application of nitrogen (N) fertilizers in potato. Hence, aim of this study was to develop potato hybrids with enhanced nitrogen use efficiency (NUE) and yield traits under limited N availability. We generated here a bi-parental

population of 116 progenies by crossing two contrasting varieties viz., Kufri Jyoti (N inefficient) and Kufri Gaurav (N efficient). After six years (2015-21) of breeding, clonal selection and field trials, we developed advance hybrids based on 20 traits of agronomic, physio-biochemical and NUE parameters. The potato hybrid NUE/15-8 was developed by crossing between Kufri Jyoti (female)

and Kufri Gaurav (male) (Fig. 6). This advance hybrid NUE/15-8 is a nitrogen use efficient and tubers are white cream, ovoid shape, shallow eyes and cream flesh colour, and very good keeping quality. NUE/15-8 produces about 20% higher yield (47.20 t/ha) than the best control Kufri Gaurav (39.11 t/ha) under limited nitrogen (50 kg N/ha) fertilizer application in the field at ICAR-CPRI, Regional Station, Modipuram (UP). The hybrid NUE/15-8 has significantly ($p < 0.05$) higher Nitrogen Use Efficiency (NUE) parameters than the best control such as NUE (4.11 vs. K. Gaurav: 2.23), Agronomic NUE (AgNUE) (11.79 vs. K. Gaurav: 9.17), Nitrogen Uptake Efficiency (NUpE) (0.12 vs. K. Gaurav: 0.07), and Nitrogen Utilization Efficiency (NUtE) (35.11 vs. K. Gaurav: 34.20). DNA fingerprinting was performed using SSR markers for true-to-type identification (STU: 173, 178, 181, 189, 198, 199 bp; and STIKA: 175, 194, 214, 223, 230, 234, 243, 247 bp). A few DUS descriptors of NUE/15-8 are: red-purple sprout, compact plant foliage, medium plant height, green predominant stem colour, open leaf structure, medium leaf length, medium leaf width, no anthocyanin colouration on flower bud, white flower corolla, small flower size, orange anther colour, normal anther cone, normal pistil, longer stylar length, white cream tuber colour, smooth skin, ovoid tuber shape, shallow eye depth and cream tuber flesh colour. This hybrid has potential for cultivation for low input agriculture mainly under limited N.



Fig. 6. Nitrogen use efficient hybrid NUE/15-18

Methylome and transcriptome analysis reveals candidate genes for tuber shape variation in tissue culture-derived variant plant of potato cv. Kufri Bahar

We investigated genome-wide DNA methylation and transcriptome (RNA-seq) profiling for tuber shape variation in potato. Mother plant (M1, round) and

tissue culture-derived clonal variant plant (M2, elongated) were used. Genomic DNA of the leaf tissues of mother plant (M1, round) and tissue culture-derived plant (M2, elongated) plants was used for bisulphite conversion, paired-end libraries preparation, and sequencing using Illumina NextSeq500 with 2 x 75 bp chemistry (Illumina Inc., San Diego, CA, USA). High quality reads (without adapters and phred score > 20) resulted into 63.93% (M1) and 64.18% (M2) reference mapping with the potato genome. Genome-wide DNA methylation pattern was analyzed at three cytosine contexts (CpG, CHG and CHH). Total number of DNA methylation sites at cytosine contexts (CpG, CHG and CHH) was higher in M2 than M1, where CHH was the highest followed by CHG and CpG. Total methylation ratio (M2/M1) was 1.15, whereas ratios in CpG, CHG, and CHH contexts were 1.19, 1.20 and 1.08, respectively (Table 3). Differential methylation regions (DMRs) analysis in M1 (control) and M2 revealed maximum DMRs number on chromosome 5 in CHG context and hypo-methylation was higher than hyper-methylation. Further, transcriptome analysis revealed that a total of 20,747 genes were differentially expressed between M1 (control) and M2, of which 280 (over-expressed) and 612 (under-expressed) genes were statistically significant ($p < 0.05$). The gene ontology (GO) annotation showed predominance of molecular function, whereas signal transduction and carbohydrate metabolism were major KEGG (Kyoto encyclopedia of genes and genomes) pathways. RNA-seq gene expression was validated for the ten selected genes by real-time quantitative polymerase chain reaction (RT-qPCR) analysis. Based on the comparative analysis, we observed a few candidate genes associated with tuber developmental processes such as phytohormones-related (e.g. SAUR family protein, abscisic acid environmental stress-inducible protein TAS14), sugar metabolism (e.g. UDP-glucosyltransferase, glycosyltransferase family GT8 protein), transcription factors (e.g. F-box family protein, MYB, WRKY, MADS-box), stress-responsive proteins (e.g. early-responsive to dehydration 3, cytochrome P450, proline-rich protein) and cell wall modifying genes (e.g. endo-1,4-beta-glucanase, glycine-rich cell wall structural protein 1.8, 3-ketoacyl-CoA synthase 10) (Fig. 7). Our study suggests that these candidate genes probably play key roles in tuber shape variation in potato.

Table 3. Summary of number of DNA methylation sites in mother plant (M1, round tuber) and tissue culture-derived plant (M2, elongated tuber)

Methylation context	Number of cytosines (Cs) sites		
	Methylated	Unmethylated	Total analysed
a) Mother plant (M1)			
CpG	308088682 (9.90%)	78853732	386942414
CHG	341476464 (10.98%)	131604547	473081011
CHH	528722469 (17.00%)	1720803429	2249525898
Unknown	93012	76490	169502
Total	1178380627 (37.89%)	1931338198	3109718825 (100%)
b) Tissue culture-derived plant (M2)			
CpG	368015018 (10.15%)	92007683	460022701
CHG	411729735 (11.36%)	149937989	561667724
CHH	575681120 (15.88%)	2024919337	2600600457
Unknown	1036325	2436882	3473207
Total	1356462198 (37.41%)	2269301891	3625764089 (100%)
c) Methylation ratio (M2/M1)			
CpG	1.195	1.167	1.189
CHG	1.206	1.139	1.187
CHH	1.089	1.177	1.156
Unknown	11.142	31.859	20.491
Total	1.151	1.175	1.166

Methylation ration (M2/M1) is calculated based on number of cytosines sites, not per cent.

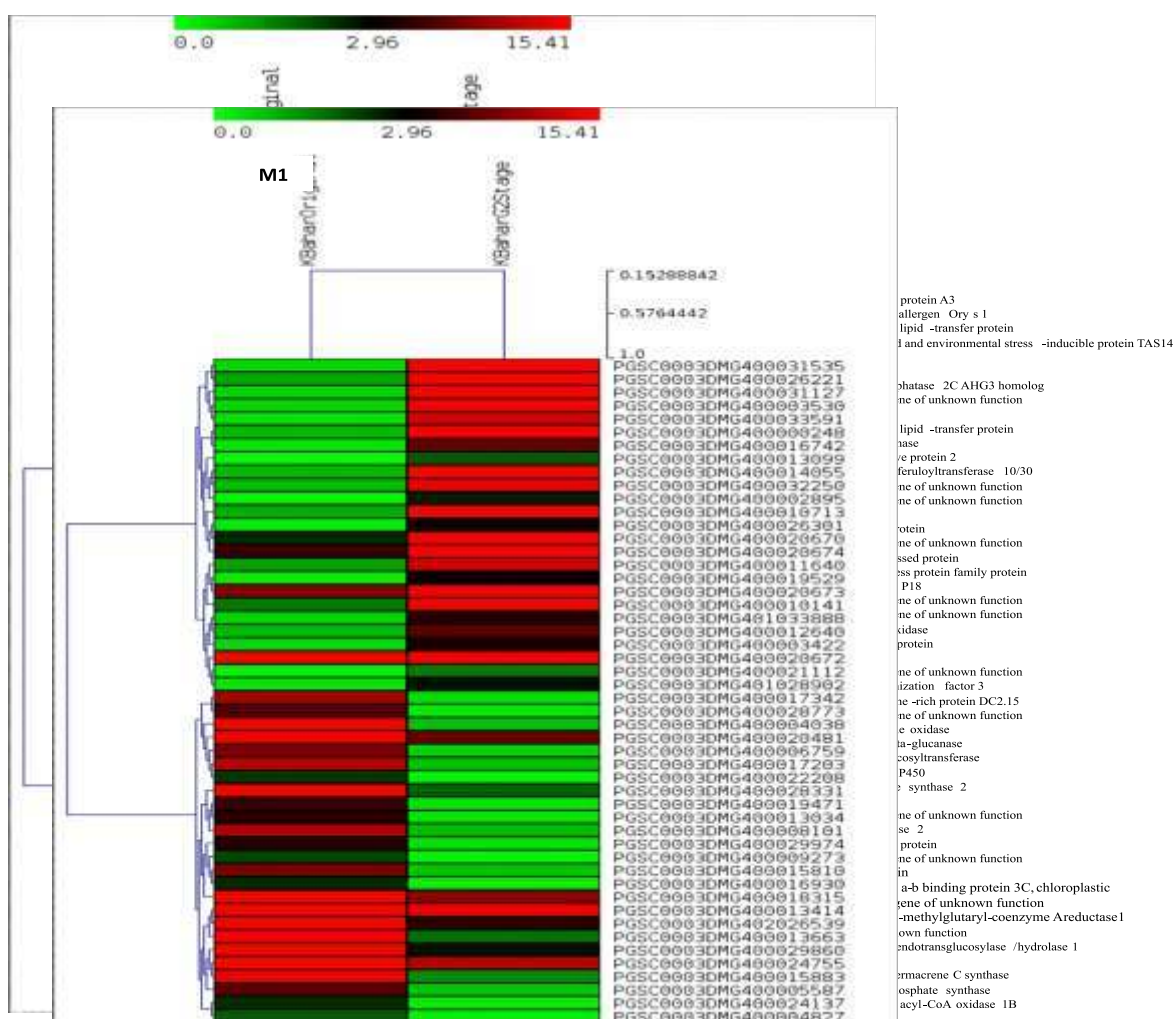


Fig. 7. Heat map showing top 50 differentially expressed genes based on the fold change value by total RNA sequencing analysis in tissue culture-derived variant plant (M2) and mother plant (M1) of potato cv. Kufri Bahar

Genome sequence analysis provides insights on genomic variation and late blight resistance genes in potato somatic hybrid

Wild *Solanum* species are the important resources for potato improvement. With the availability of potato genome and sequencing progress, knowledge about genomic resources is essential for novel genes discovery. Hence, the aim of this study was to decipher draft genome sequences of unique potato genotypes i.e. somatic hybrid P8 (J1), wild species *S. pinnatisectum* (J2), progeny MSH/14-112 (P8 × cv. Kufri Jyoti) (J3), and *S. tuberosum* dihaploid C-13 (J4). Draft genome sequencing using Illumina platform and reference-based assemblies with the potato genome yielded genome assembly size of 725.01 Mb (J1), 724.95 Mb (J2), 725.01 Mb (J3), and 809.59 Mb (J4). Further, 39260 (J1), 25711 (J2), 39730 (J3) and 30241 (J4) genes were identified and 17411 genes were found common in the genotypes particularly late blight resistance genes (*R3a*, *RGA2*, *RGA3*, *R1B-16*, *Rpi-blb2*, *Rpi* and *Rpi-vnt1*) (Table 4). Gene ontology (GO) analysis showed that molecular function was predominant and signal

transduction was major KEGG pathways. Further, gene enrichment analysis revealed dominance of metabolic process (GO:0008152) in all the samples. Phylogeny analysis showed relatedness with potato and other plant species. The dendrogram clearly indicated that the tetraploid genotypes J1 (somatic hybrid P8) and J3 (progeny MSH/14-112) were most closely associated in the phylogeny tree. On the other hand, cultivated *S. tuberosum* background genotypes (J1, J3, and J4) were closely related together, while wild J2 (*S. pinnatisectum*) was on distant. Heterozygous single nucleotide polymorphism (SNP) was more than homozygous, and SNP in genic region was more than inter-genic region. Copy number variation (CNV) analysis indicated greater number of deletions than duplications. Sequence diversity and conserved motifs analysis revealed variation for late blight resistance genes (Figs. 8, 9 and 10). Quantitative real-time polymerase chain reaction (qRT-PCR) analysis showed differential expression of late blight resistance genes. Our study provides insights on genome sequence, structural variation and late blight resistance genes in potato somatic hybrid (parents and progeny) for future research.

Table 4. Summary of draft genomes sequences of potato somatic hybrid, parents and progeny

Data description	Potato genotype			
	J1	J2	J3	J4
Number of reads	244363910	228954522	255779978	344,794,016
Number of bases	36,654,586,500 (~36.65 Gb)	34343178300 (~34.34 Gb)	38366996700 (~36.36 Gb)	50,476,752,284 (~50.47 Gb)
Fold coverage (X)	43.42	40.69	45.45	59.80
Base % (≥ Q20)	96.90	94.31	96.81	98.57
Base % (≥ Q30)	92.72	88.58	92.51	94.78
Average read length (bp)	150	150	150	150
GC content (%)	36.09	35.84	35.90	44.01
Mapping (%)	98.40	96.34	98.72	91.01
Genome coverage (%)	96.18	71.43	96.69	80.68
Genome assembly (bp)	725,016,527 (~725.01 Mb)	724,954,436 (~724.95 Mb)	725,016,803 (~725.01 Mb)	809,590,264 (~809.59 Mb)
Number of genes	39,260	25,711	39,730	30,241
Maximum gene length (bp)	56,875	45,749	56,875	53,925
Minimum gene length (bp)	221	221	221	300

J1 = Somatic hybrid P8 (*Solanum tuberosum* dihaploid C-13 (+) *S. pinnatisectum*; J2 = *S. pinnatisectum*; J3 = MSH/14-112 (P8 × cv. Kufri Jyoti); J4 = *S. tuberosum* dihaploid C-13

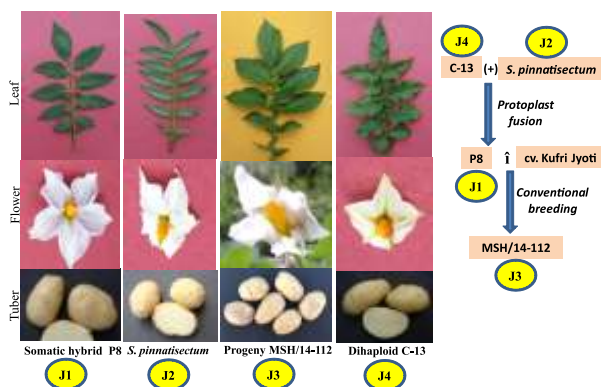


Fig. 8. Phenotypes of potato genotypes viz., J1 (P8: interspecific potato somatic hybrid of *S. tuberosum* dihaploid C-13 (+) wild species *S. pinnatisectum*), J2 (diploid wild potato species: *S. pinnatisectum*), J3 (MSH/14-112: progeny of P8 x cv. Kufri Jyoti), and J4 (C-13: *S. tuberosum* dihaploid C-13)

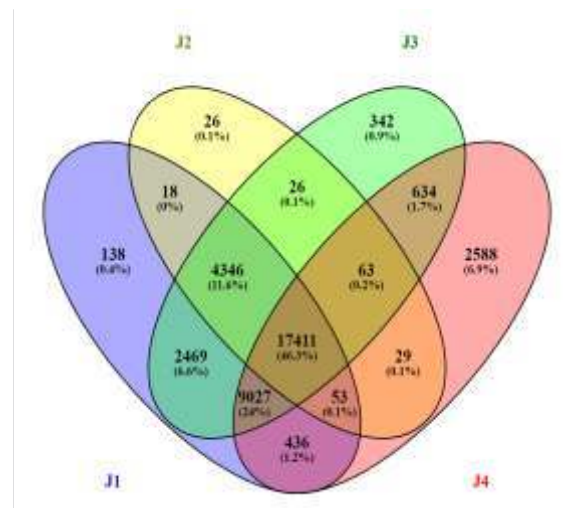


Fig. 9. Venn diagram shows common and exclusive genes in J1, J2, J3 and J4 genotypes

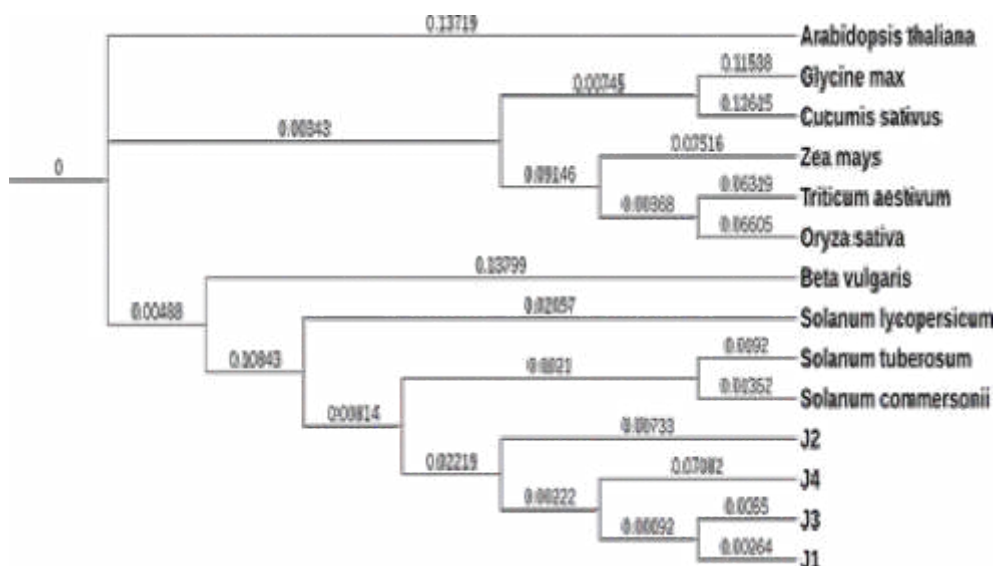


Fig. 10. Phylogeny analysis using the nucleotide sequences of genotypes viz., J1 (P8), J2 (*S. pinnatisectum*), J3 (MSH/14-112), and J4 (C-13) with other plant genomes

Identification of simple sequence repeat (SSR) markers linked to interspecific potato somatic hybrids

The aim of this study was to identify simple sequence repeat (SSR) markers linked to potato somatic hybrid progenies. A total of 50 breeding lines (parents and progenies) were analysed using 59 simple sequence repeat (SSR) markers. Of which, SSR marker STM0003 clearly distinguished the parents i.e. somatic hybrid P8 (*Solanum tuberosum* dihaploid C-13 + wild species *S. pinnatisectum*) and potato cv. Kufri Jyoti, and their progenies (MSH-14/112, MSH-14/113, MSH-14/114, MSH-14/115, MSH-

14/116, MSH-14/122 and MSH-14/123). STM0003 showed three distinct alleles (103, 132 and 144 bp), where both P8 and progenies contained 103 and 144 bp, and Kufri Jyoti had 132 and 144 bp alleles. On the other hand, STI0001 distinguished progenies namely MSH/17-16 (Kufri Garima x Crd10), MSH/17-25 (Kufri Garima x P10), and MSH/17-27 (Kufri Jyoti x Crd 16) with respect to their parents, and STI0001 contained six alleles (169, 172, 175, 178, 184 and 188 bp). The study suggests that STM0003 and STI0001 are diagnostic markers to identify these somatic hybrid derived progenies and parents (Figs. 11-12).

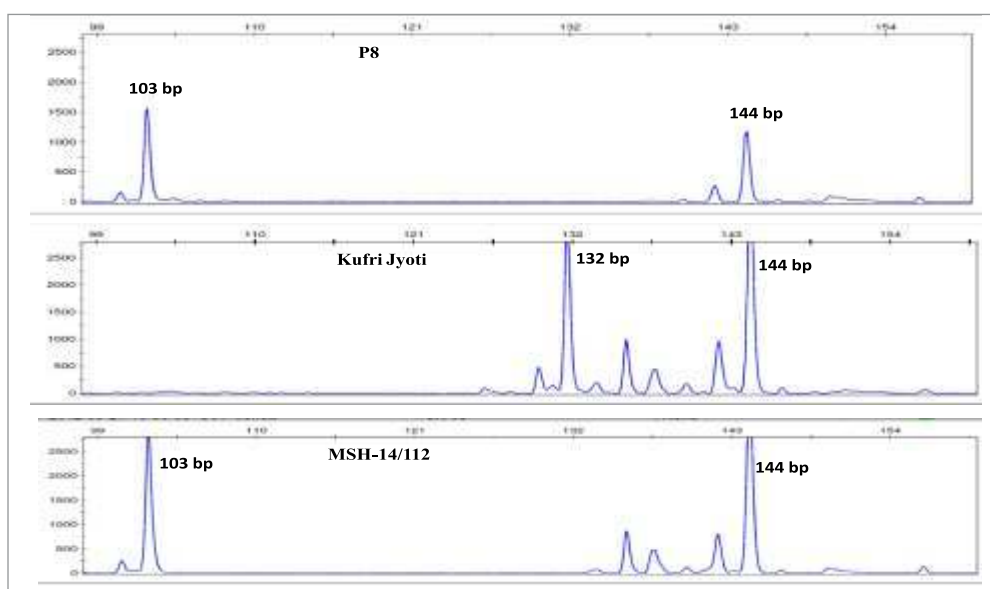


Fig. 11. FAM labelled SSR marker (STM0003) profile of parents (somatic hybrid: P8, and potato cv. Kufri Jyoti) and their progeny (MSH/14-112)

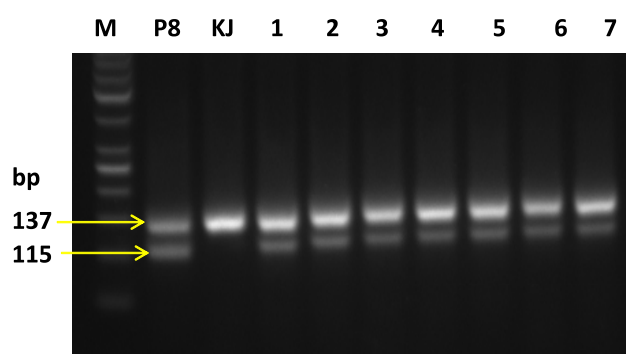


Fig. 12. Diagnostic SSR markers (STM0003) showing distinct banding profile on high resolution agarose (3%) in parents (somatic hybrid: P8, and potato cv. Kufri Jyoti, KJ) and their progenies (1: MSH/14-112, 2: MSH/14-113, 3: MSH/14-114, 4: MSH/14-115, 5: MSH/14-116, 6: MSH/14-122, and 7: MSH/14-123)

The mendelian pattern of segregation of RB event SP951 in Kufri Jyoti progenies revealed the free of marker gene and plasmid backbone KJ66 line to conduct the Biosafety research trial for evaluating the field resistance to late blight disease

Transgenic potato event KatSP951, which was used as the male parent in crossing with the Indian potato cultivar Kufri Jyoti to produce line KJ66, is an example of a complex T-DNA integration. The complete molecular characterization of event KatSP951 has recently been published wherein the T-DNA integration pattern is elucidated. Event KatSP951 contains two sites of inserted DNA, one segment inserted on chromosome 3 that includes the NPTII encoding gene, the T-DNA left border (LB),

and 14.6 kb of vector backbone sequence from plasmid pRGA2-PCR. A second insert is located on chromosome 4 that includes the T-DNA right border (RB) and the *Rpi-blb1* gene together with its native promoter and termination sequences (Fig. 13). Because, there are, however, many cases of T-DNA transformed plants that deviate from the ideal insertion process where there have been truncations, deletions, and rearrangements of T-DNA sequences, and the integration of plasmid vector backbone sequences.

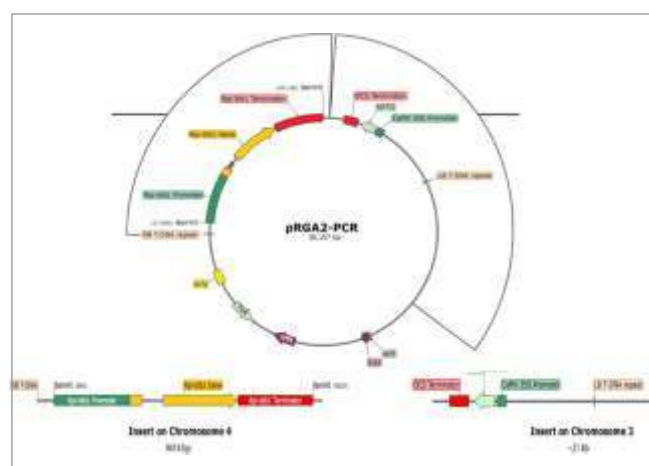


Fig. 13. Illustration of the integration pattern of the pRGA2-PCR T-DNA in transgenic potato event KatSP951. The insert on chromosome 3 contained only the *Rpi-blb1* gene and its native promoter and termination sequences, while the insert on chromosome 4 contained the NPTII encoding gene and regulatory sequences together with approximately 14.6 kb of plasmid vector backbone sequence. The inserts segregate independently and only the insert on chromosome 3 is present in KJ66 potato

The inserts in event KatSP951 segregated as unlinked genetic loci according to Mendelian rules of inheritance such that the expected ratio among progeny was 1:1:1:1, i.e., 25 percent with both segments (*Rpi-blb1* and *NPTII/Backbone*), 25 percent with the *Rpi-blb1* segment only, 25 percent with the *NPTII/Backbone* only, and 25 percent with neither segment. As previously noted, event KatSP951 was crossed with cultivar Kufri Jyoti and approximately 1,000 hybrid true potato seed were obtained and progeny F1 plants were screened for the presence of the *Rpi-blb1* and *nptII*-containing inserts. Progeny line KJ66 was identified as containing only the *Rpi-blb1* insert on chromosome 4.

Overview of VIGS approach for assigning molecular function to tuberization pathway and heat tolerance genes

Based on an earlier microarray experiment the illustration figure model (Fig. 14) describes the experimental protocol and mechanism of gene silencing through VIGS. The target gene sequence to

be silenced is cloned in a modified pTRV2 virus vector and is transferred to the plants, mediated by *A. tumefaciens*. These can direct the RISC (RNA induced silencing complex) to target and degrade the specific mRNA of the gene of interest, causing a phenotypic effect. The phenotypic effect due to silencing of *StSSH2*, *StWTF*, *StUGT*, *StBHP* and *StFLTP* include stunting of growth, the onset of senescence, decrease in tuber number and weight. The phenotypic effect of silenced genes through VIGS could help in indicating their functions with accuracy and in a short time span. The present study not only exemplifies the efficacy of this technology for high-throughput screening but also elucidates the molecular functions of sugar transporters, metabolites, signal transporter, tuberization signals in tuber formation and potato physiology in relation to thermo tolerance. Results of this experiment could aid in understanding the molecular function and physiology for the development of heat-tolerant potato varieties for tropical and sub-tropical regions by employing VIGS technique.

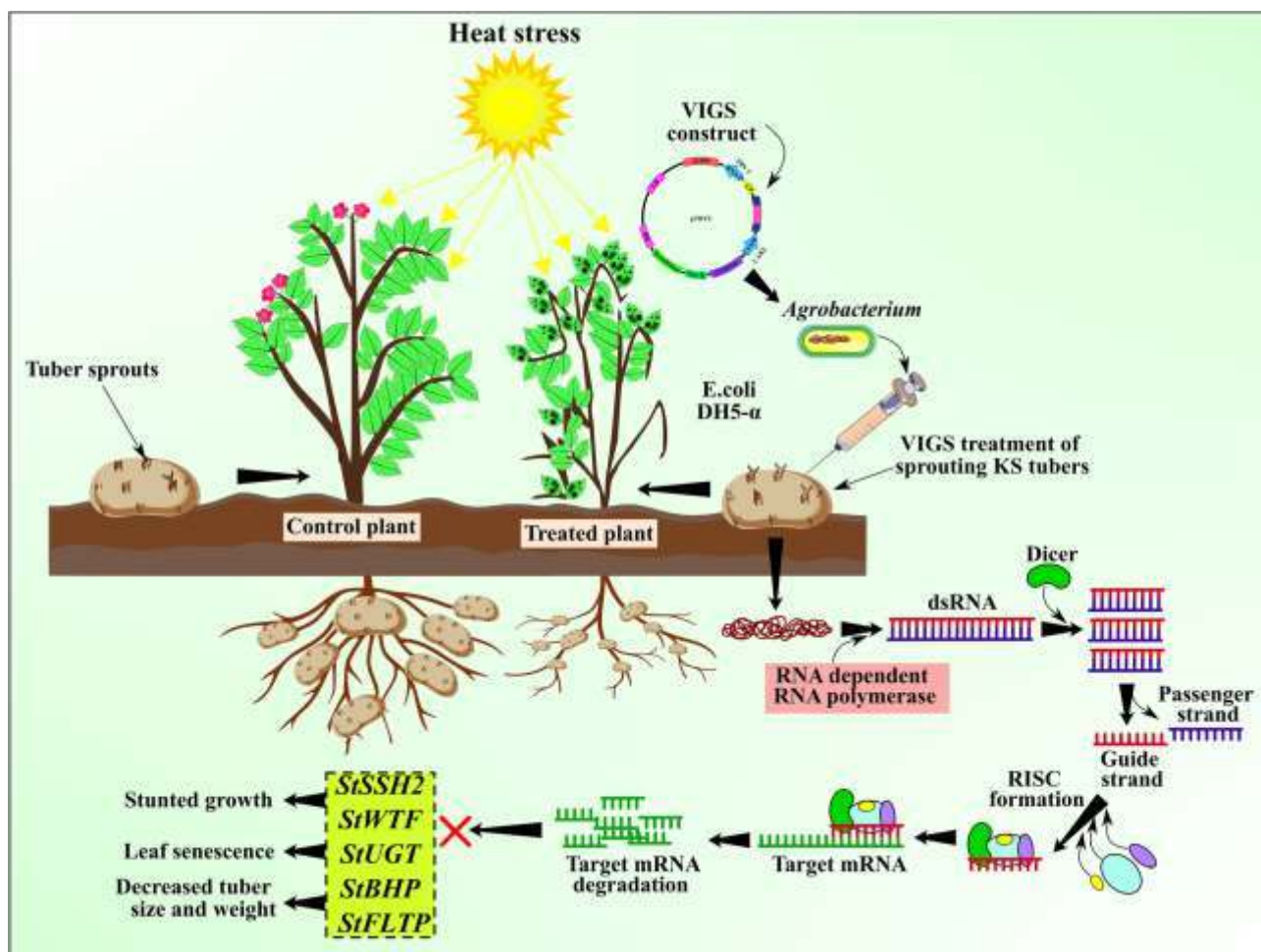


Fig. 14. Schematic illustration of the mechanism of gene silencing by VIGS and the phenotypic effect of *StSSH2*, *StWTF*, *StBHP*, *StFLTP*, and *StUGT* silencing on tuberization and plant growth under heat stress

Molecular dissection of activation tagged functional mutants for gene discovery and trait improvement in potato

Activation tagging is a gain of function approach in which T-DNA vector containing tetrameric cauliflower mosaic virus (CaMV) 35S enhancer elements are randomly integrated into the plant genome and has the ability to activate nearby genes in either direction. The generation of activation tagged mutants lines in potato have wide applicability for development of biotic, abiotic and quality improvement programme aiding in development of new potato varieties. In the current study, 735 and 60 mutant lines from potato cv. K. Jyoti and K. Chipsona 1, respectively have been generated using activation tagging vector pSKI015 via *Agrobacterium tumefaciens* mediated genetic transformation. These

lines were screened by using PCR with Bar, Hpt and 35S enhancer gene specific primers. Positive lines showed varied plant phenotyping compared to control plants. Out of which 6 activation tagged lines of K. Jyoti viz. 1(17), 1(23), 2(5), 4(4), 4(11) and 26(3) showed lateral shoot outgrowth and 5 mutant lines of K. Chipsona 1 viz. 102(2), 102(3), 102(4), 106 (2), 111(2) showed high tuber yield with distorted and elongated tuber shapes compared to control plants. Further, positioning of T-DNA using Genome Walker technology revealed the activation of R3b gene for late blight resistance in lines 26(3) and 111 (2), photosystem II reaction center protein C in line 106 (2) and integrase zinc binding domain gene in line 102 (2) (Fig. 15). Hence, activation tagging approach can generate functional genetic mutants for specific genetic improvement of potato in the era of food and nutritional security.



Fig. 15 (a) Sample 106 (2)-1 (450bp), (b) sample 106 (2)-2 (480bp), (c) sample 111 (2)-1 (480bp) showing similarity with Pskio5 vector and plant genome sequence. Where , photosystem II reaction center protein D chr05 , photosystem II reaction center protein C chr04, pSKI105 Vector , Integrase zinc binding domain containing protein chr06, Solanum demissum R3b genotype

Genome wide association study in potato

Genetically diverse potato core collection of 288 accessions was characterized through Genotype by Sequencing (GBS) for genome wide SNP detection (Fig. 16). Genotyping of 288 accessions generated 100.758 GB and 100.623 GB raw and processed data using RAD sequencing. The average sequencing depth was 3.38 to 11.55x and genome coverage at 4x depth was 1.38% to 7.03%. Mapping rate on the reference genome varied from 94.07% to 98.15% on the reference genome. The Variant Call Format (VCF) file was generated considering auto-tetraploid genome and further processed to identify SNPs in the population. A set of 23517 and 5389 SNPs were identified at 75 and 90% site coverage, respectively i.e. the allele information was present at the SNP loci in at

least 75 and 90 percent of the genotypes for use in genome wide association studies. Chromosome wise SNP information for both 75 and 90% site coverage have been presented in Fig. 17. Phenotype data was generated on nutritional, agronomic and biotic stress traits and checked for quality before use in GWAS analysis. The GWAS analysis using additive and dominance marker effects models showed 40 highly significant marker trait associations (MTAs) for 10 nutritional traits and 2 each for late blight (Fig. 18) and PCN at the 0.001 probability level. The percentage of phenotypic variation (R^2) of an individual trait explained ranged from 2.3 to 20.5%. The associated SNPs are being evaluated for their presence in the potato genome for their annotation and further validation.

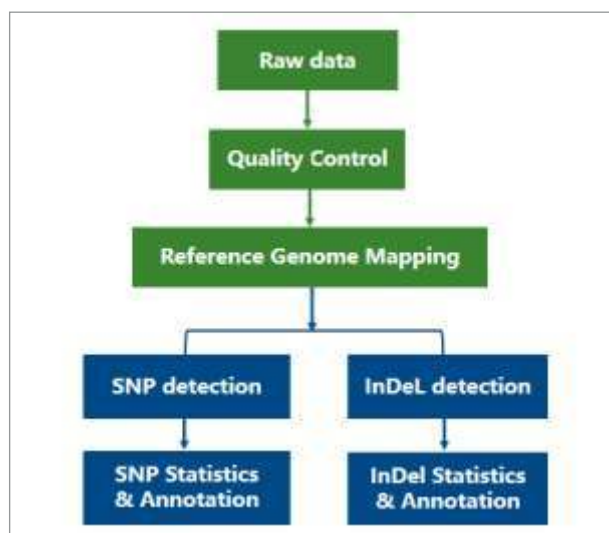


Fig. 16. Flow chart for SNP and InDel identification and annotation using Genotyping by Sequencing

Increase root branching enhanced ferric chelate reductase activity under iron stress in potato

The roots of dicotyledonous plants cause a series of reactions in response to Fe deficiency, allowing Fe to be absorbed more efficiently by rhizosphere. These adaptive reactions were found to occur on the root surface of potato and include an increased FCR activity, acidification of the rhizosphere to increase Fe mobility and root morphology changes. These responses became apparent 10 days after the onset of Fe-deficient conditions. At the 10th day of Fe-deficiency treatment, the root FCR activity was poorly associated with root biomass ($r = 0.134$) (Fig 19a) in each plant. However, the total lateral root number ($r = 0.713^{**}$) (Fig 19c) correlated well. In addition, it had a much better comparison to lateral root density ($r = 0.917^{**}$, $P < 0.05$) (Fig 19e). Almost the entire analysed root area shows high FCR activity on the 20th day of Fe-deficient treatment. The radical FCR behavior of individual plants therefore was very much correlated with the root biomass ($r = 0.565^{**}$, $P < 0.05$) (Fig 19b), with total lateral root number or lateral root density (Fig 19d, f). These findings show that FCR is involved in root Fe uptake in potato and they suggest a role in Fe distribution throughout the plant. In view of these findings, the Fe deficiency-induced increases of the lateral root can serve as useful trait for the identification of chlorosis tolerance and/or nutrient deficiency stress.

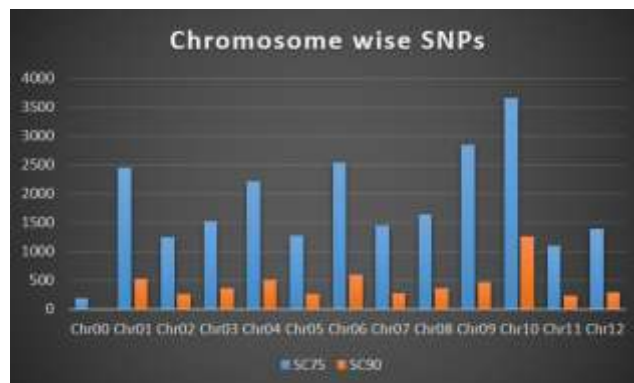


Fig. 17. Chromosome wise SNP information in SC75 and SC90

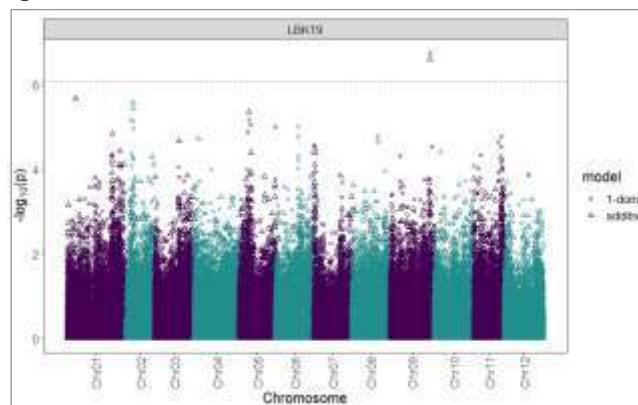


Fig. 18. Manhattan plot displaying significant SNPs for late blight displayed on Chromosome 9

Development of multi RNAi constructs and transformation of popular Indian potato cultivars

Multi RNAi constructs (786 bp) of potato cyst nematode (PCN) pathogenicity genes [*flp32c*, *flp32p*, *flp12* & *ams1*] synthesized and confirmed by high fidelity restriction enzymes. After confirmation, transformation was done under in vitro in PCN susceptible potato cultivar Kufri Jyoti using *Agrobacterium* mediated transformation. Further, virus free cultures were multiplied and maintained under in vitro conditions using standard B₅ medium and selective medium supplemented with sucrose, growth regulators and antibiotics. To confirm the gene transformation, leaf samples from the progeny plants were analyzed for the presence of the introduced genes. Genomic DNA was isolated following the procedure of Dellaporta et al. (1983). Molecular analyses of the transformants of potato cultivar Kufri Jyoti revealed the presence of multi gene construct (786bp) and Npt II gene (520bp) in 18 plants out of 24 which will be taken for further screening under pot condition against the PCN population for further confirmation of resistance (Fig. 20).

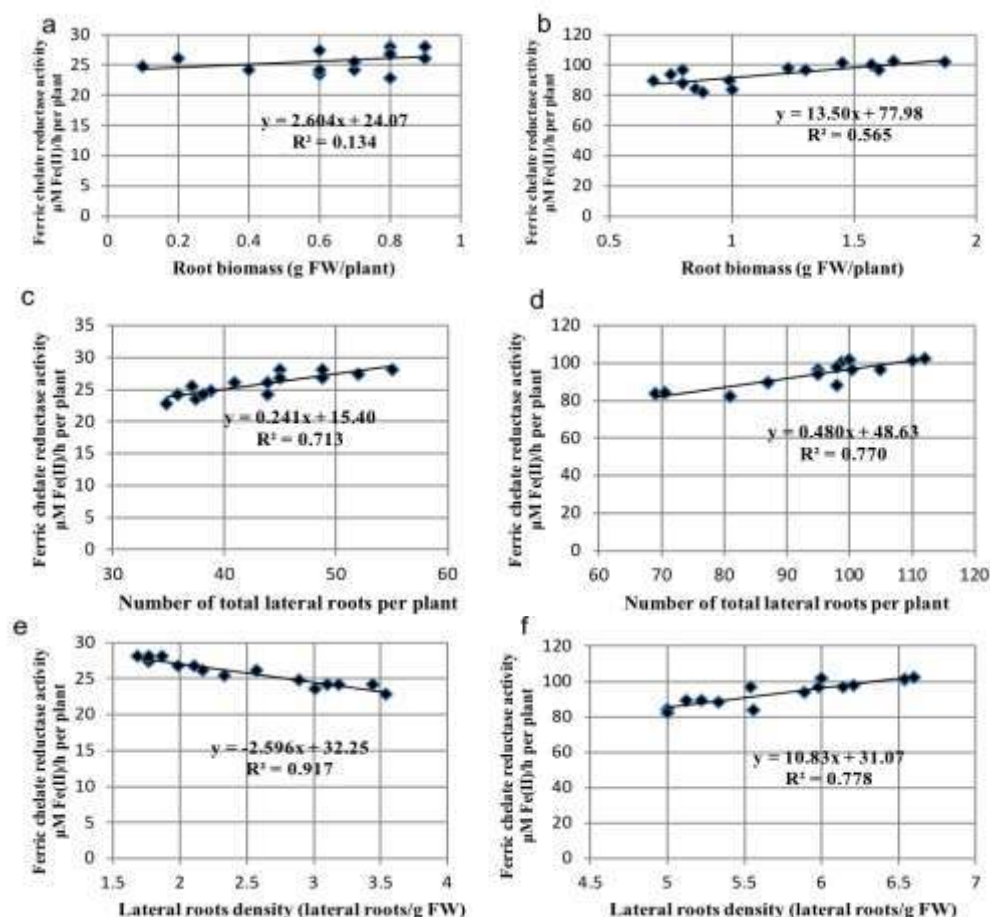


Fig. 19. The relationship between ferric chelate reductase (FCR) activity and root biomass or lateral root development. (a & b) The relationship between FCR activity and root biomass at 10 and 20 days; (c & d) The relationship between FCR activity and lateral roots number at 10 and 20 days; (e & f) The relationship between FCR activity and lateral roots density of root at 10 and 20 days

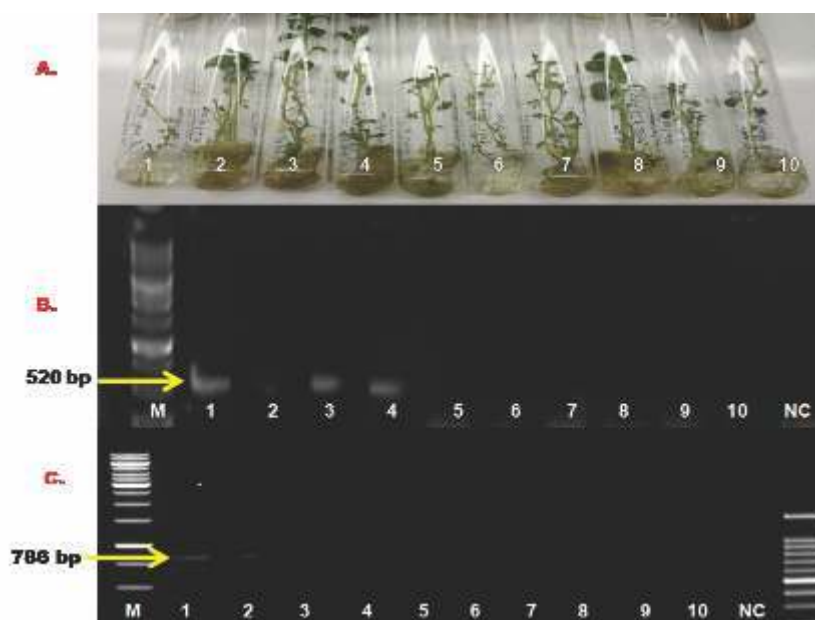


Fig. 20. Analysis of the T0 generation transformants of potato cultivar Kufri Jyoti (T0 plants) - Clone1 by PCR: A. Transformants of potato cultivar Kufri Jyoti (T0 plants) -Clone1 B. PCR with *NptII* gene specific primers (520 bp). Lane M: DNA ladder (1 kb); Lane NC: negative control (DNA from un-transformed plants); Lanes 1–10: DNA from samples of transformants. C. PCR analysis of the PCR positives with primers for multiRNAi gene construct (786 bp) gene. Lane M: DNA ladder (1 kb); Lane NC: negative control (DNA from untransformed plants); Lanes 1–10: DNA from transformants



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, Components workers: Drs Babita Chaudhary, Dalamu, Jagesh Kumar Tiwari, G. Vanishree, Pinky Raigond, Brajesh Singh, Jagdev Sharma, VK Dua, Bandana, Arvind Kumar Jaiswal, Sanjay Rawal, Mehi Lal, Milan Kumar Lal, Pooja Mankar)

Hybridization: A total of 1, 87, 002 hybrid TPS were generated at Kufri/Modipuram from 73 diverse crosses involving diverse parental lines.

Seedling stage: A total of 987 promising clones of 36 families were selected from 23,520 seedlings raised by sowing of 95,274 true potato seeds of 43 crosses.

Initial clonal stages: In initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 280 promising clones of 67 families were selected from the 1405 clones of 97 families evaluated at 90 days

Advanced stage trials: In all, 59 advanced clones were evaluated in 4 yield trials at 75/90 days at Modipuram 35 promising advanced clones were selected. In Preliminary yield trial (white), our promising hybrids namely MS/17-444, MS/17-605, MS/17-621 and MS/17-739 were selected from the 15 advanced clones evaluated. In preliminary yield trial (Red) five promising advanced clones namely MS/17-198, MS/17-629, MS/17-643, MS/17-648 and MS/17-848, were retained from the 13 advanced clones evaluated. In preliminary yield trial (nutritionally superior) 10 promising advanced clones namely MSA/16-126, MSA/16-140, MSA/16-144, MSA/16-159C, MSP/17-333, MSA/16-353B,

MSP/17-7, MSP/17-89, MSP/17-147, MSP/17-212 were retained from the 12 advanced clones evaluated. In confirmatory yield trial, nine advanced clones were CP4393, MS/11-664, MSP/15-60, MSP/16-216, MSP/16-272, MS/16-300, MSP/16-300, MSP/16-307 and MSP/16-375 were retained. In confirmatory/final Yield Trial, 9 advanced clones namely MS/8-1148, MS/9-2196, MS/10-1529, MS/11-2116, MS/15-758, MS/15-1001, MS/15-1422, MS/15-1505 and MS/16-1157 were retained.

Transcriptome profiling for identification of genes involved in multi-coloured contrasting advanced clones: Multi-coloured fleshed advanced potato clones having health benefits (rich in antioxidants like anthocyanin and carotenoids, iron and zinc) were processed for transcriptome analysis. Contrasting tuber flesh coloured advanced potato clones such as MSH/17-16 (yellow), MSP/16-375 (purple), MSP/17-89 (red) and Kufri Bahar (white) were used for identification of genes involved therein. Samples were collected in liquid nitrogen.

Molecular profiling of superior multi-coloured fleshed potato hybrids: In order to develop SSR profiles of potato clones for genetic fidelity, a total of 84 genotypes (MSP/15-1 to MSP/15-64: 64 lines; Bareilly Red CP3770; MSP/16-4, MSP/16-150, MSP/16-216, MSP/16-272, MSP/16-300, MSP/16-307, MSP/16-375 (Fig.1); MSP/17-7, MSP/17-89, MSP/17-147, MSP/17-212, MSP/17-341, MSP/17-345, MSP/17-532, MSP/17-537; JEX/A-122; Kala Aaloo, and CP4242) were analysed by two well-known potato SSR markers (STU6SNRN and STI1KA), and developed a database for genetic fidelity purpose and other applications. Both markers



Fig. 1. Tubers of hybrids MSP/15-60 (white-red), MSP/16-375 (purple) and MSP/17-89 (red) have multi-coloured fleshed tubers

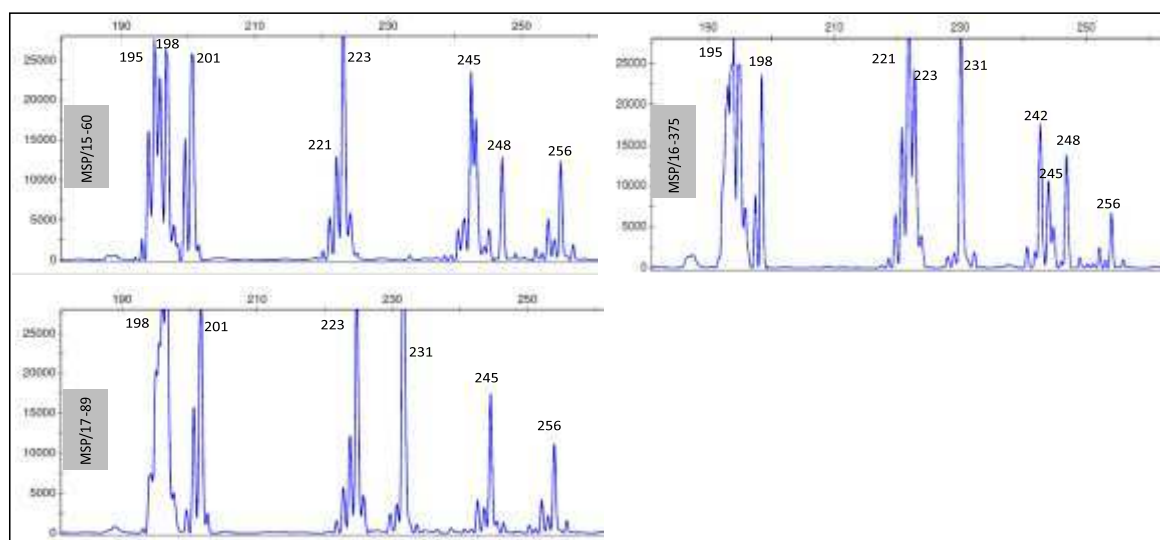


Fig. 2. SSR allelic profile of promising advanced stage hybrids by STIKA marker

together clearly distinguish the genotypes studied. High polymorphism was observed in STIKA (PIC: 0.93) than STU6SNRN (PIC: 0.82). The predominant alleles of STU6SNRN were 174, 179, 182, 190 and 200 bp; whereas in STIKA alleles 191, 195, 198, 201, 221, 223, 231, 242, 245 and 256 (Fig.2) were observed frequently in more than 50 per cent of the genotypes. Diversity analysis showed a clear distinction among the genotypes based on the Jaccard dissimilarity coefficient by the Neighbour-joining tree method using the DARwin software. Further, SSR fingerprints would also be valuable resources in resolving issues related to identification of true-to-type clones.

Processing attributes at Modipuram: Processing attributes investigated in 31 advanced clones/varieties revealed mean values of chip colour from 2.0 (Lady Rosetta) to 8.0 (MS/08-1148) on visual score. Among advanced clones, MSA/16-353 indicated acceptable chip colour, however, French fry colour was reported with dark colour sugar ends. MSP/16-216 performed well for acceptable chip and French fry colour. Reducing sugars (mg/100g FW) ranged from 89 (MSP/16-216) to 156 (K. Bahar). Sucrose content (mg/100g FW) was maximum in MSP/16-300 (563) followed by MSA/16-140 (546), MS/17-198 (542) and MSP/15-60 (537 mg/100g FW) (Table 1). Phenols retained more than 30 mg/100g FW were MSP/16-307 (36), MSA/16-333 (36), MSP/14-147(36), K.Frysona (34) and K. Neelkanth (34).

Biochemical analysis at Shimla: In all 63 genotypes were assessed for nutritional components.

Antioxidants' content: The total carotenoids ranged

from 37 (MS/17-444) to 653 µg/100g FW (MSP/15-26). The content was the maximum in MSP/15-26 followed by Kala Aloo, MSP/15-51, MSP/17-212, Barielly red, MSP/15-60 and K. Neelkanth. Total phenols ranged from 97 (K. Frysona) to 229 mg/100g FW (MSP/16-216). The total phenols were high in MSP/15-51, MS/13-527, MS17-198, MSA16-140, MS/18-722, MS17-643, MSP/16-300, MSA/16-353B and MS/17-739. Total anthocyanin in flesh ranged from 0.1 (MS/18-101) to 149 mg/100g FW (MSP/15-51). The genotypes with high anthocyanin content were MSP/16-375, MS17-648, MSP/16-300, MSP/16-307, JEX/A122, Barielly red, Kala Aloo and MSP/15-26. Peel contained more anthocyanin content and content ranged from 1 (K. Bahar) to 635 mg/100g FW (MSP/15-51). The peel of MSP/16-375, Kala Aloo, Barielly red, Badami Aloo, JEXA122 and MS17-648 contained higher anthocyanin content. The ascorbic acid content ranged from 18 (MSP/17-212) to 63 mg/100g FW (MS08-1148). The content was high in varieties/crosses Barielly red, MSA/16-144, MSP/15-51, JEX/A122 and MSA/16-333.

Carbohydrates' content: High reducing sugars are undesirable in potatoes meant for processing. The sugars were the minimum in K. Sindhuri (115 mg/100g FW) and maximum in MSP/17-212 (278 mg/100g FW). The genotypes viz. CP3770, LR, JEXA122, K. Frysona, MS/17-643, Kala Aloo, MSA/16-144, K. Manik and MS/11-664 contained low reducing sugars. Sucrose was low in MSP/16-307 (43 mg/100g FW) and high in Badami Aloo (128 mg/100g FW). Sucrose was also low in K. Sindhuri, MSP/17-212, MSA/16-333, MSP/17-089, MSA/16-

144, Barielly red and MSP/16-272. Amylose content ranged from 19 % (MSA16-140) to 35% (MSP/17-007). The genotypes viz. MSP/15-51, MS/17-444, K. Frysona, MSP/15-26, MSA16-126, MS/18-722, K. Chipsona 3, MS15-758 and SKL-2019 contained more than 30% amylose content.

Mineral content: Zinc content (flesh) on dry weight basis ranged from 13.42 (MSA/16-353B) to 27.21 ppm (MS/08-1148) followed by 26.06 (K. Mohan), 25.50 (MSP/18-68), 24.15 (JEX/A-122 and 23.95 (MS/09-2196); whereas, zinc content on whole tuber basis ranged from 14.71 (MCIP/14-211) to 28.47ppm (MS/08-1148) followed by 28.287 (JEX/A-122), 27.90 (K Mohan), 27.15 (CP4393) and 27.06 (MSP/18-68). Iron content (flesh) on dry weight basis ranged from 27.18 (Bareilly Red) to 39.20 ppm (K Mohan) followed by 38.20 (Kala Aaloo), 38.12 (MSP/15-26), 37.70 (K Lalit) and 37.55 (MS/17-848), whereas iron content on whole tuber basin ranged from 37.06 (K. Chip-3) to 53.74 ppm (Badami Aaloo) followed by 48.90 (MS/9-2196), 47.20 (K Mohan), 47.04 (MSH/18-01) and 46.47 (MSP/15-26)

Analysis of Glyco-alkaloids in nutritionally superior genotypes: Glycoalkaloids are naturally synthesized in potato tubers and sometimes their concentration in peels exceeds the threshold levels of 20mg/100g fresh tuber weight, therefore, regular monitoring of the contents of glycoalkaloids (solanine and chaconine) is required in advanced clones and varieties. Among the 40 clones/varieties assessed, the glycol-alkaloid content ranged from 0.18 (MSH-17-975) to 14.16 mg/100g fresh tuber weight (MS-17-648). The results indicate that the advanced clones and varieties have safer limits of glycoalkaloids contents.

Glycemic index of potato: The glycemic index (GI) of food or food product is the ability of food to enhance the blood sugar level after consumption which is

measured in the range of 0-100. The GI is defined as the increment in the blood sugar area concerning test food (glucose) and expressed as a percentage response to an equivalent amount of carbohydrate taken as reference food taken by the same subject. The GI of food depends upon the factor such as the method and duration of cooking, age of the test subject, activity and health of the digestive system. However, it has been claimed that the precision of *in vivo* GI method is enough to distinguish between high GI (GI >70, glucose scale) and low-GI (GI <55, glucose scale) foods with 95% certainty. The values of *in vivo* and *in vitro* methods were correlated strongly. The critic against rapid analysis methods (in vitro) is that the methods do not provide a numerical GI value. Rapid analysis methods only produce an indication of the specific food's glycemic response as high, intermediate or low. However, greater precision with high reproducibility is quite feasible using the proposed in vitro method. Several authors have advocated the use of in vitro starch hydrolysis method as a better alternative to the in vivo method since the former is simple and inexpensive in determining the glycemic response of carbohydrate-rich meals.

The GI of potato ranged range from 60 to 90 depending upon the cooking method and type of cultivars. The minimum GI value of table variety in the experiment was 70, 72, 73 respectively for Kufri Sahabahar, Kufri Arun and Kufri Bahar. The maximum GI value of table variety in the experiment was 77, 89 and 80 respectively for Kufri Khyati, Kufri Jyoti and Kufri Jyoti. The GI value of processing variety in the experiment was 71, 76 and 76 for Kufri Chipsona 3, Kufri Chipsona 4 and Kufri Chipsona 1 respectively (Fig. 3).

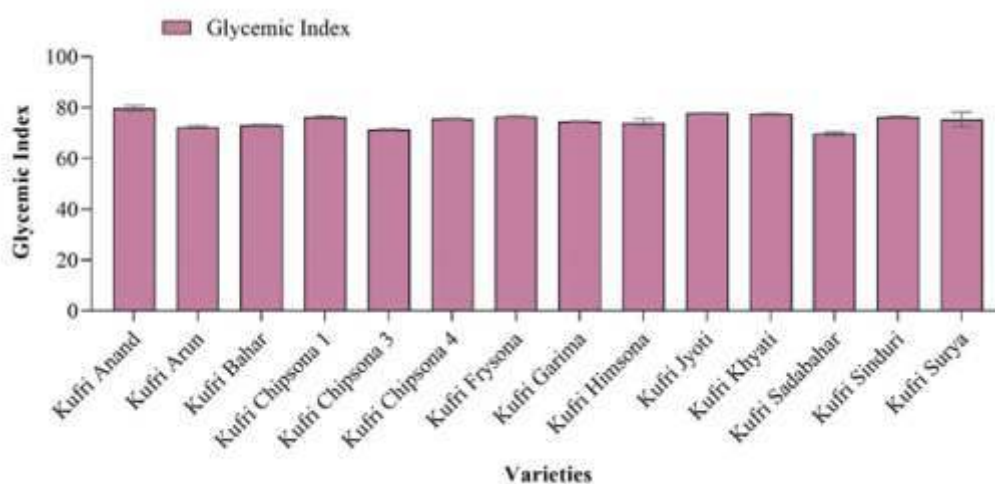


Fig. 3: Variation in glycemic index of cultivars. Data represented as mean ± standard error mean

Evaluation at Jalandhar: Among the 11 genotypes evaluated marketable tuber yield ranged from 39 t/ha (MSP/16-307) to 17 t/ha (MSP/15-60) and total tuber varied from 48 t/ha (MSP/16-307) to 28 t/ha (MSP/16-216). Highest fry grade tuber (>75mm) and chip grade tuber (45-75mm) yield was recorded in MSP/16-307 and lowest in MSP/15-60. Among the control genotypes marketable tuber yield varied from 34 t/ha (K Lalima) to 36 t/ha (K Lalit) and total tuber yield varied from 45 t/ha (K Neelkanth) to 41 t/ha (K Lalima). High dry matter was found in MSP/16-216 (20%) followed by MSP/16-272 (20%), MSP/16-375 (19%) and lowest in MSP/15-60 and MSP/16-300 (18%). Chips colour score (CCS) for fresh fried chips ranged from 2.58 to 6.83. CCS of only one genotype (MSP/16-216) was within acceptable range (on scale of 1-10, chips colour score up to 3 is acceptable). For dehydrated-fried chips CCS ranged from 1.92 to 5.83. CCS of only two genotypes (MSP/16-216 and K Lalima) was within acceptable range. Findings suggest that MSP/16-216 was suitable for fresh fried as well as dehydrate chips.

Biochemical analysis at Jalandhar: Among the 29 genotypes grown at Modipuram, tuber dry matter content varied from 17% in MSP/16-307 to 25% in MS/17-198. Dry matter content of 3 genotypes (LR, MSA/16-159C, MSA/16-353B) was 23%, for 9 genotypes (K Chipsona-3, K Neelkanth, Atlantic, MSP/16-216, MS/17-621, MSP/18-68, MSP/17-212, MS/17-648 and MSA/16-126) ranged between 20 to <23%. For fresh fried chips, chip colour score (CCS) ranged from 2.50 to 7.75. For only 4 genotypes (ATL, MSP/16-216, MSA/16-159C and MSP/17-212) CCS was within acceptable range. Whereas, for dehydrated-fried chips CCS of 12 genotypes (MSA/16-333, MS/17-198, Atlantic, MSA/16-353B, K Frysona, MSP/17-212, LR, MSP/17-89, MSP/16-216, MSA/16-159C, MS/17-629 and MSP/16-272) was within the acceptable range. It was found that genotype MSP/16-216, MSA/16-159C, MSP/17-212 and MS/17-198 were

promising genotypes for fresh as well dehydrated-fried chips. Whereas, MSA/16-333, MSA/16-353B, MSP/17-89, MS/17-629 and MSP/16-272 were found promising for only dehydrated-fried chips. The results revealed that MSP/16-216, MSP/17-212 and MS/17-198 were found suitable for preparation of coloured chips (Fresh-fried as well as dehydrated-fried chips) and MSA/16-159C for white chips (Fresh-fried as well as dehydrated-fried chips).

Introduction of promising advanced clones in AICRP: Introduced advanced clones MS/15-60, MSP/16-216 and MSP/16-300 (Fig. 4) in AICRP for multi-location testing.

MS/15-60 (*Bareilly Red* x *CP3770*): The advanced clone with total tuber yield of 35 t/ha (90 days) produces 22-25 tubers/plant with average tuber weight of 20-25gram. It produces attractive red round-ovoid tubers, medium-deep eyes, yellow flesh, red vascular bundle. It possesses 20% tuber dry matter at 90 days, excellent keeping quality, waxy texture, high total anthocyanins (34.89 mg/100g FW), carotenoids (435ug/100g FW in flesh) and ascorbic acid (44 mg/100g FW in flesh) than controls.

MSP/16-216 (*Kufri Chipsona 4* x *CP4242*): The advanced clone with total tuber yield of 33 t/ha (90 days) produces 9-10 tubers/plant. It produces attractive Red, ovoid, shallow, pink; outside VB cream. MSP/16-216 possesses high tuber dry matter (22%) at 90 days, low reducing sugars and produces multi-colored chips in acceptable chip colour score of (3) in fresh fried /dehydrated fried form. It possesses excellent keeping quality, flour/mealy texture, high total anthocyanins (31.31 mg/100g FW), carotenoids (176ug/100g FW in flesh) and ascorbic acid (37mg/100g FW in flesh), Flavouring compounds (AMP+GMP) (4.34ug/g) than controls. It is slightly resistant to late blight.

MSP/16-300 (*MS/8-1148* x *CP4242*): The advanced clone with total tuber yield of 37 and 47 t/ha (75 & 90 days) showed superiority of 12 and 2% over Kufri



Fig. 4. Advanced clones: MSP/15-60, MSP/16-216 and MSP/16-300 introduced in AICRP

Lalit (42 t/ha). It produces attractive Dark purple, oblong, shallow, purple. It possesses tuber dry matter 18%) at 90 days, excellent keeping quality, flour/mealy texture, high total anthocyanins (86.29 mg/100g FW), carotenoids (339ug/100g FW in flesh), ascorbic acid (32 mg/100g FW in flesh) and flavouring compounds (AMP+GMP) (4.43ug/g) than controls. It is slightly resistant to late blight. It possess slight resistance (AUDPC: 672) to late blight as compared to Kufri Bahar (AUDPC: 872) and Kufri Lalit (AUDPC: 862).

Sharing of breeding material: About 1,05,505 TPS of 47 crosses were sent to 5 AICRP centers (Bhubaneswar (16650), Kanpur (44000), Dholi (22525), Patna (22330) for seedling raising and further selection as per institute breeding protocol for promotion of region specific breeding.

For hybridization purpose 56 promising parental lines were sent to Kufri.

Release of new red skin variety: An improved red coloured advanced potato variety MS/11-664 (Kufri Kanchan x Kufri Khyati) has been recommended for release in 39th group meeting of ACIRP (Potato) held during 27-29 September, 2021 organised by ICAR-CPRI, Shimla through virtual mode. The new variety is medium maturing (75-90 days) with yield potential of 35-38 t/ha and possesses moderate level of late blight resistance, excellent keeping and culinary quality. It possesses 17-18% tuber dry matter, very good taste and mealy texture. It has edge over prevailing red skin varieties like Kufri Manik, Kufri Lalit and Kufri Lalima for tuber yield quality attributes. It produces attractive red ovoid uniform tubers with shallow eyes and cream flesh colour (Fig.5). The new variety is suitable for growing in north Indian plains. The new potato variety will improve the productivity by 10-15% of the farmers, thus improving their profitability and socio-economic conditions.



Fig.5. MS/11-664: Leaf, Inflorescence, tubers and sprout

Optimizing agro-technology: Dose of 240 N+ 60 P₂O₅ + 80 K₂O kg/ha was found optimum for advanced hybrid MS/11-664 with marketable yield level of 33.0, 34.6 and 33.8 t/ha, respectively. Its tuber dry matter content was in the range of 16.04-17.42%. MS/08-1148 attained optimum marketable tuber yield of 41.7, 44.8 and 42.6 t/ha at 240 kg N, 60 kg P₂O₅, and 80 kg K₂O/ha. Tuber dry matter content varied between 15.62- 16.62%. Optimum nitrogen, phosphorous and potassium doses for advanced hybrid MS/09-2196 were 240 N, 60 P₂O₅, and 80 K₂O kg/ha and marketable tuber yields at these levels were 43.0, 45.9 and 44.4 t/ha, respectively. While tuber dry matter content was in the range of 15.44- 16.42%. Advanced clone CP 4175 released as cv. Kufri Thar-2 recorded optimum marketable tuber yield of 40.0, 39.7 and 44.6 t/ha at 240 kg N, 40 kg P₂O₅, and 100 kg K₂O/ha. Tuber dry matter content varied between 21.66- 22.62%.

Late blight screening at Kufri: Fifty-seven advanced

clone and varieties were screened for late blight resistance undertaken under natural epiphytotic field condition and based on late blight data recorded thrice and AUDPC calculation, only two hybrids MSP/19-178 and MSP/18-13 were highly resistant (AUDPC<250), MSP/19-190& MCIP/14-211 were resistant (AUDPC 251-350), MCIP/16-209, MS/17-621, MSA/16-140, MS/15-758 were moderately resistant and remaining were susceptible or highly susceptible.

Evaluation for late blight resistance at Modipuram: Among the 65 advanced clones along with 15 varieties evaluated for late blight resistance under field (Fig.6) and lab condition, all genotypes showed less Area Under Disease progress Curve (AUDPC) than highly susceptible control variety K. Bahar (1275). Among advanced clones, less AUDPC was found in MSH/18-13 (0.0), MCIP/17-05 (211), MCIP/14-211 (230), MCIP/17-03 (237), MS/17-595 (141), MS/13-527 (154), MS/17-619 (154),

MS/17-998 (263), MSA/16-126 (109), MSA/16-333 (187), MSA/16-159C (250); MSP/16-159A (151), MSP/17-212 (279) than K. Bahar (1275). The rAUDPC values ranged from 0.00 to 0.61. The advanced clones showed less rAUDPC. The lowest rAUDPC was recorded in MSH/18-13 (0.00) and highest in MS/17-162 (0.59) than K. Bahar (0.61). Under laboratory condition, through detach leaf method, advanced clones MSH/18-13 was resistant and 30 genotypes (CP4393, MCIP/16-209, MCIP/17-01, MCIP/17-03, MCIP/17-05, MCIP/17-34, MS/08-1148, MS/11-664, MS/13-527, MS/15-1505, MS/16-1156, MS/16-1157, MS/17-35, MS/17-379, MS/17-605, MS/17-619,

MS/17-621, MS/17-739, MS/17-975, MSA/16-126, MSA/16-140, MSA/16-159C, MSH/17-16, MSP/16-159A, MSP/16-216, MSP/16-272, MSP/16-307, MSP/17-07, MSP/17-147, MSP/17-212) were moderately resistant and remaining were susceptible. Under laboratory condition, by tuber slice method, clone MCIP/17-34 showed high resistance and 19 clones (MCIP/14-211, MCIP/17-05, MS/08-1148, MS/15-1422, MS/16-1156, MS/17-169, MS/17-198, MS/17-35, MS/17-621, MS/17-975, MSA/16-126, MSA/16-140, MSA/16-144, MSA/16-159C, MSH/18-1, MSP/16-159A, MSP/16-272, MSP/16-375, MSP/17-07) were moderately resistant and remaining were susceptible.



Fig.6. Screening of advanced potato clones under field conditions for late blight resistance

Weightage scale development: To compare the performance of advanced clones with the prevailing popular varieties, breeders used a scale-based comparison approach. However, this method is selective, qualitative and varies from person to person. Therefore, a multiple Criterion Decision Making (MCDM) approach was followed to compare performances from the yield and yield attributing traits ranking and weighing approach. In this procedure, the main challenge was data normalization, as plant traits are measured in different scales. Therefore, minimize to maximize method and sum scalar approach for data normalization was found suitable. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is one of the most widely used techniques of MCDM. It is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. The preliminary findings have shown promising results for plant performance comparison based on yield contributing traits using this method.

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

(Dr Raj Kumar, Components workers: Dr Ratna Preeti Kaur)

Hybridization: A total of 162782 seeds of 86 crosses were obtained.

Seedling stage: A 5761 promising clones were selected from 39,442 seedlings raised by sowing of 79,784 true potato seeds of 45 crosses.

Initial clonal stages: In initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 1447 promising clones were selected from the 441 clones evaluated.

Advanced stage trials: In all, 72 advanced clone were evaluated in 6 yield trials at 65/75/days at Jalandhar and 31 promising advanced clones were selected. In preliminary yield trials (three) at 60 and 75 days, 20 clones namely J/15-19, J/15-55, J/15-74, J/15-93, J/15-116, J/15-206, J/15-236, J/15-375, J/15-36, J/15-75, J/15-152, J/15-263, J/15-34, J/15-57, J/15-

87, J/15-91, J/15-173, J/15-214, J/15-332 and J/15-354 were selected of the 52 advanced clones evaluated. In confirmatory yield trial, 11 advanced clones J/14-174, J/14-10, J/14-15, J/14-185, J/14-201, J/14-203, J/14-242, J/14-245, J/13-97, J/13-175 and J/13-200 were selected from the 20 advanced clones evaluated.

Introduction of hybrids in AICRP: Based on consistently good performance over years, three advanced clones namely J/13-97, J/13-175 and J/13-200 (Fig. 7) were introduced in All India Coordinated Research Project on Potato (AICRP Potato).



Fig. 7. Tubers of advanced clones J/13-97, J/13-175 and J/13-200

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

(Dr Shambhu Kumar, Components workers: Dr Sarala Yadav)

Hybridization: A total of 22550 seeds of 26 crosses were obtained.

Seedling stage: A 739 promising clones were selected from 19605 seedlings raised by sowing of 22550 true potato seeds of 26 crosses.

Initial clonal stages: In initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 289 promising clones were selected from the 1029 clones evaluated at 75 days.

Advanced stage trials: In all, 16 advanced clone were evaluated in 2 yield trials at 75/90 days at Patna and 6 promising advanced clones were selected. In preliminary yield trials, 4 clones namely PS/15-3, PS/15-8, PS/15-11 and PS/15-12 were selected of the 8 advanced clones evaluated at 60 and 75 days. In confirmatory yield trial, 2 advanced clones namely PS/15-12 and PS/15-33 were selected from the 8 advanced clones evaluated.

Introduction in AICRP: Advanced clones namely

J/13-97: It gave 26.2 % and 13.0% higher yield over control Kufri Khyati at 60 and 75 days harvests, respectively. It produces yellow oblong tubers with shallow to medium deep eyes and cream flesh colour.

J/13-175: It gave 9.8 % and 13.0% higher yield over control Kufri Khyati at 60 and 75 days harvests, respectively. It produces white oval flattened tubers with shallow eyes and cream flesh colour.

J/13-200: It gave 23.3 % and 20.1% higher yield over control Kufri Khyati at 60 and 75 days harvests, respectively. It produces yellow oval flattened tubers with shallow eyes, and yellow flesh colour.

PS/15-12 and PS/15-33 (Fig. 8) has been introduced in AICRP for multi-location testing.

PS/15-12 (K. Arun x CP 3770): It produces red round tubers with fleet eyes and red vascular ring. It possess 19% tuber dry matter, good keeping quality and moderate level of late blight resistance to late blight.

PS/15-33 (K. Pushkar x CP 2340): It produces red oval flattened tubers with fleet eyes and yellow flesh. It possess 19% tuber dry matter, good keeping quality and moderate level of late blight resistance to late blight.



Fig. 8. Tubers of PS/15-12 and PS/15-33

Research activity 4: Breeding for processing varieties

(Dr VK Gupta, Components workers: Drs Vinay Bhardwaj, Bandana, Arvind Jaiswal, Sanjay Rawal, Salej Sood, Mehi Lal)

Hybridization: A total of 2,67,129 TPS of 73 crosses were produced at Kufri/Modipuram.

Seedlings stage: A total of 2009 clones of 42 crosses were selected from 26761 seedlings of 52 crosses recovered from sowing of 109766 TPS in nursery bed.

Initial clonal evaluation: A total of 583 promising clones in F_1C_1 , F_1C_2 and F_1C_3 stage were selected based on superior tuber characters and chip colour, dry matter from the 1446 clones evaluated.

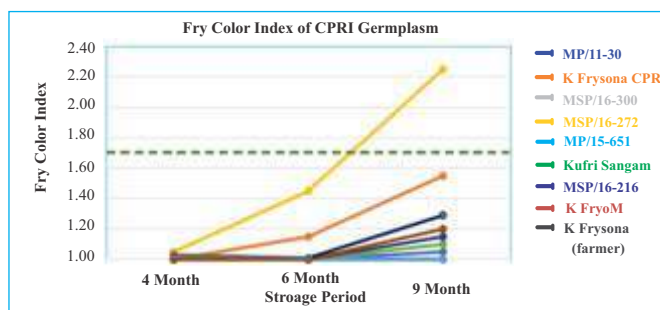
Preliminary yield trial: In F_1C_4 stage 10 advanced clones namely MP/16-86, MP/16-157, MP/16-173, MP/16-178, MP/16-315, MP/16-316, MP/16-334, MP/16-373, MP/16-431 and MP/16-442 having superior yield and processing attributes were selected from the 16 evaluated at 75 and 90 days.

Confirmatory yield trial: Seven promising clones namely MP/13-662, MP/14-169, MP/14-1029, MP/15-207, MP/15-651, MP/15-698 and MP/15-750 having superior yield (total and processing), dry matter, Chip colour and synchrony as compared with control varieties were selected from 15 clones evaluated at 75, 90 and 110 days.

Evaluation trial in early planting at Modipuram: Among the 22 advanced clones and six control varieties evaluated at 75 and 90 DAP in early season planting, advanced clones MP/16-173, MP/16-178, MP/15-750, MP/14-169, MP/14-171, K FryoM and MP/15-207 were found to have better yield as well as acceptable quality traits than to their respective controls.

ICAR-CPRI-JRS India Foods trials in Gujarat: Among the 8 CPRI advanced processing and speciality clones/varieties, total yield and process tuber yield was highest for MSP/16-300 (41 t/ha) K Frysona (40.6 t/ha) followed by MP/11-30 (39 t/ha), K Sangam & K FryoM (38 t/ha), whereas MSP/16-216 resulted lowest yield (20 t/ha). K FryoM performed well and resulted highest SG (1.096) and % size (45%) for French fry purpose with lowest defects (0.23 t/ha). The total tuber yield and process tuber yield were not higher but remain at par with other genotypes. Among the genotypes evaluated, all the genotypes showed acceptable fry colour index up

to 6 months of storage, however, MP/15-651, Kufri Sangam, MP/11-30, MSP/16-216 showed the acceptable fry colour index during the whole storage period (9 months) and have long term storability for processing purposes (Fig.9).



Note: Fry Colour Index Score

Fry Color Index	Fry Color	Processing Status
Below 1.5 score	Good	Accept
Above 1.5 score	Poor	Reject

Fig.9. Fry colour index and sugar ends of CPRI advanced clones/varieties after 9 months of storage at Gujarat

ICAR-CPRI- McCains foods trials in Gujarat: The trials at Idar, Banaskantha showed that total yield and process tuber yield was highest in K Sangam (55 t/ha) followed by MP/15-651 (48 t/ha) and K Frysona (43 t/ha).

ICAR-CPRI-ITC-Potato trials in South, East and Northern India (rabi): The multi-location field trials were conducted at Karnatka (25 genotypes at Hiriyalachenahalli- Chikaballapur), West Bengal (24 genotypes at Kotulpur – Bankura), Telangana (21 genotypes at Zaheerabad) and UP (16 genotypes- Meerut). Based on yield and quality parameters the promising clones were shortlisted for Karnataka (MP/12-105, MP/12-126, MP/14-171, MP/15-750 and MP/14-169), Telangana (MP/13-1045 and HT/12-830), West Bengal (MP/9-45, MP/13-662, MP/12-126 and MP/15-698), Uttar Pradesh (MP/9-45, MP/13-662, MP/9-28, K Chip-3, K FryoM & K Frysona) based on yield and quality parameters..

ICAR-CPRI-ITC-Potato trials in South India (kharif): The multi-location field trials involving 29 processing and heat tolerant clones were conducted at Lingadahalli, Chikamagalur (Karnatka), Kamalappur, Dharwad (Karnatka), and Igglur, Thalavadi, (Tamilnadu) in Kharif 2021. Based on field performance, yield and quality short-listed potential entries. In, Thalavadi- (TN) shortlisted 5 entries – (MP/10-172, MP/12-105, MP/13-662, MP/12-126 and MP/15-651) and quality accepted varieties are (MP/9-45, MP/13-1045, MP/13-662, MP/9-28, MP/15-667, MP/16-173, MP/15-651, MP/16-315, MP/16-157 & MP/17-296). In Dharwad (KA) shortlisted 5 entries – (MP/10-172, MP/12-105, MP/13-662, MP/9-28 and MP/12-126) and quality accepted (MP/13-662, MP/9-28, MP/16-86 & MP/16-431). In Chikamagalur (KA) shortlisted 3 entries– (MP/ 13-1045, MP/12-105 and MP/15-651).

CPRI – ITC Technico joint Potato breeding programme for development of early maturing processing varieties: A total of 452 single plant clones selected from promising TPS crosses imported from James Hutton Institute were planted in F1C1 stage on 15-16 Oct, 2020 at Ludhiana, Punjab by ITC and during harvesting February, 2021 a total of 137 clones.

Evaluation trial under APART, CIP (Assam): Four advanced hybrids (MP/13-602 and MP/13-662 processing and HT/12-830 and HT/12-834 heat tolerant) found promising in primary screening in Assam.

Storage behaviour of advanced hybrids under ambient conditions: Tubers of sixteen advanced hybrids were evaluated for their storage behaviour under ambient temperatures at Modipuram. Lesser total weight loss (%) were noted after 75 days of storage in MP/9-73 (7%), K.Sangam (8%), K. Fryom (9%), MP/9-45, MP/15-207 (12%), MP/15-651 (13%), MP/13-662, MP/13-169 (14%) as compared to other genotypes.

Advanced hybrids introduced into AICRP: Advanced hybrid MP/15-651 (MP/9-90 x MP/9-11) for processing into chips based on performance during 2019-20 & 2020-21 at Modipuram is introduced into AICRP for multi-location trials. Advanced hybrid MP/15-651 produced 15% higher mean processing (40 t/ha) and 8% higher total (45 t/ha) tuber yields than K. Chipsona-3. MP/15-651 produces attractive white cream, ovoid-tubers with shallow eyes & cream flesh (Fig. 10). The hybrids possess 21% dry matter and acceptable fry colour score (2.8).



Fig. 10. Leaf, Flower, sprouts, tubers of MP/15-651

Biochemical analysis of advanced processing clones at Modipuram: Nearly 205 clones from initial clonal stage were analysed for chip colour and tuber dry matter and 52 promising clones with processing trait were identified. In advanced stage trials, 28 advanced clones were analysed for processing traits (chip colour, dry matter glucose and sucrose contents). The results revealed identification of processing clones namely MP/16-173, MP/16-178, MP/16-315 and MP/16-334 (F₁C₄ Stage at 75/90-days), MP/13-662, MP/13-1045, MP/14-169, MP/14-1029, MP/15-651,

MP/15-698 and MP/15-750 (confirmatory trial at 90/110 days).

Biochemical analysis of advanced processing clones at Jalandhar: Among the 10 advanced clones evaluated, total tuber yield varied from 30 (ATL) to 49 t/ha (K. Frysona). Similarly, the yield of marketable (Fry grade and Chip grade) grade tuber varied from 28 (ATL) to 39 t/ha (K. Sangam). Dry matter content of the advanced clones ranged from 19 (K. Sangam) to 24% (ATL). Fry colour score of 7 advanced clones/varieties (K. Chipsona-1, MP/13-

602, LR, MP/13-662, ATL, MP/12-105, K. Sangam) was within acceptable range (Score up to 4). Chip colour score of only 3 advanced clones/varieties (LR, MP/13-662, ATL) was within acceptable range. After curing only 3 clones/varieties (LR, MP/13-662, ATL) were found suitable for processing in to chips and fries.

Processing quality of genotypes during storage at 10-12°C with CIPC: During 180 days of storage all advanced clones recorded more than 20% tuber dry matter. It was found that during 180 days of storage all clones and varieties recorded acceptable chip colour. Except Kufri FryoM and Kufri Frysona and MP/13-602 throughout the 180 days of storage, all genotypes recorded fries' colour within acceptable range. It was found that from processing perspective, among all hybrids MP/13-662 MP/12-105 found suitable for making chips.

Optimizing agro-technology for newly released variety Kufri Sangam: Optimum nitrogen, phosphorous and potassium doses for variety Kufri Sangam was 240 N, 40 P₂O₅, and 160 K₂O kg/ha. Crop geometry of 66 X 20 cm was found better for optimum marketable and net tuber yield

Late blight screening at Modipuram: Twenty advanced stage clones along with 15 varieties were evaluated for late blight resistance under field and lab condition. All clones showed less Area under Disease Progress Curve (AUDPC) against highly susceptible variety K. Bahar (1275). Among 20 advanced clones, lesser AUDPC was noted in MP/13-662 (107), MP/13-1040 (252), MP/14-908 (293) and MP/13-1045 (366) as compared to K. Bahar (1275). These advanced clones also showed less rAUDPC. Among the clones, lowest rAUDPC was recorded in MP/13-662 (0.05) and highest was in MP/16-440(0.48) as against K. Bahar (0.61). Under lab condition, by detached leaf test, 10 clones (MP/12-105, MP/13-1045, MP/13-662, MP/14-169, MP/14-1029, MP/14-908, MP/15-698, MP/16-440, MP/16-445 and MP/16-525) were moderately resistant and remaining were susceptible. Under laboratory condition, by tuber slice method, five clones i.e. MP/13-1040, MP/13-1045, MP/13-662, MP/14-171 and MP/15-318 were resistant and nine (MP/13-602, MP/14-1003, MP/14-635, MP/14-908, MP/14-171, MP/16-171, MP/16-440, MP/16-445 and MP/16-498) were moderately resistant and

remaining were susceptible.

Research activity 5: Breeding for biotic stresses (late blight, viruses & cyst nematodes) (Dr Vinay Bhardwaj, Components workers: Drs Salej Sood, Dalamu, Vikas Mangal, Sanjeev Sharma, EP Venkatasalam, Priyank Hanuman Mhatre, Clarissa Challam, Mehi Lal, Babita Chaudhary, AartiBairwa, R Baswaraj, S. Sundaresha, Ravinder Kumar, Gaurav Verma, Kailash Chandra Naga, Vinod Kumar, Ashwani Sharma, VK Dua, TanujaBuckseth)

Hybridization: Ninety-five 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 1,61,187 hybrid TPS from 764 berries.

Seedling raising and screening for late blight resistance: A total of 9900 seedlings from 25000 TPS of 12 crosses were screened under controlled conditions against complex races of *Phytophthora infestans* at Shimla. At harvest 245 clones were obtained from 940 resistant seedlings of 12 crosses (Fig.11 and 12). The highest number of resistant seedlings (%) were obtained in the cross HR9-3 × Kufri Karan (15%) followed by the crosses CP2379 × Kufri Karan (13%) and Navigator × Santana (13%). At Ooty and Shillong out of 40666 and 10,000 hybrid TPS, 161 and 1857 clones, respectively were selected under natural epiphytotic conditions.



Fig.11: Status of seedlings screened and clones obtained in different cross combinations



Fig.12: Screening seedlings for late blight resistance a) Infestation of disease on seedlings b) Resistant seedlings c) Resistant and susceptible clones in the field

Initial clonal evaluations: In the initial stages (F_1C_2 to F_1C_4), 727 genotypes were evaluated under natural field conditions at Kufri/Ooty/Shillong for their disease resistance and adaptability and 283 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 and five clones viz., SM/15-486, SM/14-347, SM/14-333, SM/13-149 and SM/09-02 (trial 1) and 3 clones viz., SM/14-339, SM/15-103 and SM/15-122 (trial 2) yielded significantly better or >10% yield superiority over Kufri Bahar.

Yield trials at Kufri: In F_1C_5 stage, among five advanced clones SM/03-32, SM/08-04 and SM/10-164 showed 58%, 45% and 20% yield superiority over the best control K. Karan, while two other hybrids viz., SM/08-12 and SM/09-163 were statistically at par to best control. In F_1C_6 stage, among six clones, SM/10-103 showed 22% yield gain over the best control K. Girdhari and two other clones namely SM/09-91 and SM/09-13 were also selected based on statistically at par yield performance to best control. All the selected hybrids were highly resistant to late blight disease. In F_1C_7 stage, among 10 advanced clones, SM/10-243 (37 t/ha) showed yield advantage of 6 and 13% over the best controls K. Girdhari (35 t/ha) and K. Karan (33 t/ha) in the first trial and SM/10-10, SM/10-67 and SM/10-101 were significantly superior to the best control in second trial. All the selected hybrids were resistant to late blight disease.

Yield trials at Ooty: Among 23 advanced clone evaluated, OS/07-63 and OS/06-66 recorded maximum yield (14 and 13 t/ha respectively). The hybrids were found moderately resistant to late blight and showed resistance to golden cyst nematode, *Globodera rostochiensis*.

Yield trials at Shillong: Among 10 advanced clones evaluated, four promising clones namely SS/16-60, SS/16-56, SS/16-57 and SS/16-06 were selected based on tuber characteristics, AUDPC and yield. Besides, in yield confirmation trial, among four advanced clones evaluated, clone SS/11-295 yielded significantly higher than the controls with medium resistant to late blight disease and was approved for introduction to AICRP (P) for conducting multi-location testing.

Evaluation of potato germplasm for tolerance to PCN at Kufri: A total of 286 accessions were screened along with 19 susceptible potato cultivars against both the species of PCN. Out of these, 14 accessions (JEX/A-317, CP3799, CP3577, CP1674, CP3881, CP1687, CP3222, CP4398, CP3871, CP2418, CP3439, CP1736, CP1800 & CP1736) were found highly resistance (HR) while 6 accessions (CP 1012, CP1706, JEX/A-865, JEX/A-15, CP1689 & CP1581) were resistant (R) to both the species. The remaining accessions were either moderately resistant or susceptible to PCN.

Evaluation for late blight resistance at Modipuram: Among 339 accessions of association panel, the terminal disease severity ranged from 0-85%. It was observed that 10 accessions (0.0% DS) and 75 accessions along with two control (K. Girdhari & K. Karan) varieties showed less terminal disease severity (1.0-10% DS) followed by 137 accessions along with five control varieties (10.1-25.0%); 90 accessions along with 13 varieties (25.1-60.0%) and remaining 60 accessions along with four varieties showed more than 60.0% terminal disease severity. Under laboratory condition, by detach leaf method two advanced clones viz., SM/09-13, SM/10-174 were found moderately resistant while remaining were susceptible. In tuber slice method, two hybrids, SM/10-253 and SM/13-172 were highly resistant and SM/09-13 was resistant. These potato hybrids

are potential recurrent parents for enhancing late blight resistance in different breeding programmes.

Evaluation against leaf spot complex diseases: Among the 26 advance clones, 13 clones viz., SM/10-05B, SM/10-209, SM/10-220, SM/13-122, SM/13-154, SM/14-202, SM/14-111, SM/15-486, SM/14-333, SM/14-347, SM/15-103, SM/15-739, SM/15-522) showed below 5% disease severity of early blight disease. Also in six parental lines, CP659, CP1012, CP1137, CP1140, CP1405 & CP1710 the disease severity was up to 5.0%.

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

(Dr Devendra Kumar, Components workers: Drs VK Gupta, Sanjay Rawal, Name Singh, Babita Chaudhary, Anuj Bhartnagar, Brajesh Singh, Som Dutt, Sugani Devi, Sushil Sudhakar Changan, Milan Kumar Lal, Pinky Raigond)

Breeding for heat tolerance

Hybridization: A total 1,05,098 TPS were recovered from the 86 crosses were attempted both at Kufri and Modipuram..

Seedling stage: In all 20,985 seedlings were recovered from 50,000 TPS (70 crosses) and 1115 clones were selected.

Initial clonal stages: In all 285 promising clones were selected from the 798 clones evaluated in F_1C_1 , F_1C_2 and F_1C_3 stage. Besides, 30 clones were selected from 96 clones evaluated under heated glass house.

Advanced stage trial: Amongst the 18 advanced clones (F_1C_4 & F_1C_5) evaluated at 75 days under early planting, six clones namely HT/17-223 (22 t/ha), HT/17-162 (20 t/ha), HT/17-257, HT/18-487 (17 t/ha), HT/15-240, HT/17-202 (16 t/ha) were found to be promising or yielded at par with either of the controls (K. Bahar, K. Lauvkar, K. Lima, K. Surya and K. Kiran). In another trial 6 advanced clones namely HTMK/17-1, HTMK/17-9 (20 t/ha), HTMK/17-10 (18 t/ha), HTMK/17-13 (16 t/ha), HTMK/17-12 (15 t/ha) and HTMK/17-8 (14 t/ha) were selected from the 10 evaluated under early planting. Five advanced clones of water stress group were evaluated in early season at 75 DAP and high or at par total tuber yield was obtained in WS/7-113 (25 t/ha), WS/14-32 (24 t/ha) as compared to best control Kufri Kiran (25 t/ha).

Advance stage trial at Pune and Bhubaneswar: At Pune, 23 advanced clones were evaluated under kharif season and higher total tuber yield (21 t/ha) was obtained in HTMK/17-11, HTMK/17-2, HTMK/17-12 and about 20 t/ha in K. Surya, K. Kiran and K. Lima. At Bhubaneswar, 33 advanced hybrids were evaluated in *rabi* season at 90 DAP and high total tuber yield was obtained in HTMK/17-6 (21 t/ha), HTMK/17-4 (16 t/ha) followed by HTMK/17-13 (13 t/ha), HT/15-240 and HT/12-830 outperformed (14 t/ha).

Breeding for drought tolerance

Parent selection and multiplication: Twenty accessions has been multiplied and will be screened for drought tolerance by analyzing various physio-chemical parameters (RWC, MSI, ABA, proline etc. for identification of best parents for use in breeding.

Seedling stage: In all 6626 seedlings were recovered from 53000 TPS (7 crosses) and 656 clones were selected.

Initial clonal stages: In all 124 promising clones were selected from the 334 clones evaluated in F_1C_1 , F_1C_2 and F_1C_3 stage.

Advanced stage trial: A total of 6 advanced clones were evaluated under water stress and well-watered along with K. Thar-1 and K. Thar-3. Irrigations were regulated to be in equal quantity of water, using digital water meter. Besides, intermittent rains were recorded. 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 clones WS/13-135, WS/14-06, WS/14-32 and WS/15-17 were retained for further evaluation.

In silico analysis of WRKY transcription factor family protein for drought tolerance in potato: Among various molecular factors, WRKY transcription factors are one of the largest families of transcriptional regulators in plants and form integral parts of signalling webs that modulate many plant processes. The WRKY domain is found in one or two copies in a super family of plant transcription factors involved in the regulation of various physiological programs that are unique to plants, including pathogen defence, senescence, trichome development and the biosynthesis of secondary metabolites. The WRKY domain binds specifically

to the DNA sequence motif (T)(T)TGAC(C/T), which is known as the W box. The invariant TGAC core of the W box is essential for function and WRKY binding. Its over expression of the WRKY gene might enhance drought tolerance by regulating stress-responsive related genes, regulating stomatal aperture and activating the ROS scavenging system in potato plants. *WRKY* might have potential application

prospects in improving the drought tolerance of potato plants. We have *in silico* analysed the WRKY transcription factor. It is situated in chromosome number 9 and the length of the coding sequence is 485 bp. The length of protein expressed was reported to be 161 amino acids. The detail of the gene and protein sequence is provided below.

Gene details		Protein Sequence
Scaffold	chr09	(>Soltu.DM.09G009860.1 Protein)
mRNA Genomic Coords (5'-3')	12707771-12707286	MSCSSHLTDTLGFSGVFLLFVHFMNLAV
Locus name	Soltu.DM.09G009860	YMYVPISLEISSISTSAAATDNKDLSPVTAE
CDS length:	485 bp	RSSSENGYNWGKYGGQKLKVGTEFPRSY
Protein length:	161 aa	KYTYPNCEVKKTFERSPDGQITEIVYKGF
		HDHPKPQPSDRFTPGALTSIQEDRDACLT
		LLVQAVLYDIQSRKPSCI

Response of advanced clones/ varieties under water stress at Jalandhar: Seven advanced clones/ varieties namely K. Thar-1, K. Thar-2, WS-7/133, MP/9-11, HT 7/-620, K. Pukhraj and K. Kiran were evaluated along with controls (K. Surya and K. Gaurav). Water stress was given at 60 DAP by complete stop of irrigation, however rain occurred at 75 DAP and haulm cutting was done 80 at DAP. Yield reduction (t/ha) was observed with deficit irrigation in most of the genotypes except MP/9-11 (5.71%), HT 7/-620(3.70%) and K. Thar-1 (-0.3%). Similarly tuber number ('000/ha) was also increased in HT 7/-620 (27.77%), MP/9-11 (10.54%), K. Gaurav (4.14%) and K. Thar-1(2.68%) with deficit irrigation as compared to sufficient irrigation.

Optimizing agro-technology for advance water stress tolerant clone WS/07-113: The optimum nutritional requirements of WS/07-113 were 180 N, 40 P₂O₅, and 100 kg K₂O/ha leading to marketable tuber yield of 34.5, 36.1, 32.2 t/ha, respectively. Tuber dry matter ranged between 17- 18%.

Breeding for salt tolerance

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

Seedling stage: In all 1024 seedlings were recovered from 4686 TPS (16 crosses) and 200 clones were selected

F₁C₁ stage: The selected 200 clones were divided in two sets and under fast breeding one set was multiplied / screened at Shimla out of which 115 were selected and planted after dormancy breaking on 6/11/2021 at Modipuram

In-vitro screening for salinity tolerance: A set of 24 varieties were screened following standard protocol. Single node cutting from established cultures was planted on MS culture media containing four concentrations of NaCl (25, 75, 100 and 150 mM) and compared to MS medium without NaCl (0 mM). These cultures were maintained at 25±2°C with 16/8 h light/dark cycle for 5 weeks. Data on morphological traits revealed that among 24, sixteen varieties showed root formation along with shoot elongation at the highest concentration of NaCl (150 mM). Of these, K. Kuber, K. Kumar and K. Giriraj were found promising and potential candidate to use as parent.



Fig. 13. Response of Kufri Kumar to NaCl concentrations

Activity 7.: Development of nitrogen use efficient varieties

(Dr Raj Kumar, Components workers: Drs Manoj Kumar, Prince Kumar)

Hybridization: A total of 105062 true potato seeds were obtained from 63 crosses.

Seedling stage: A total of 7125 selections were made from 51231 F₁ seedlings transplanted from sowing of 106330 TPS.

Evaluation in initial clonal stages: In all 13439 clones were evaluated and at harvest 3534 promising clones were selected in comparison to Kufri Gaurav.

Advanced clone evaluation: Among the 66 advance clone evaluated in 4 preliminary yield trials at 90 days under normal planting condition, 24 promising advanced clones namely N/16-32, N/16-77, N/16-128, N/16-138, N/16-216, N/16-264, N/16-56, N/16-60, N/16-92, N/16-118, N/16-120, N/16-198, N/16-261, N/16-38, N/16-69, N/16-103, N/16-105, N/16-119, N/16-234, N/16-249, N/16-19, N/16-20, N/16-116 and N/16-217 were selected. In three confirmatory yield trials, 25 advanced clones were evaluated at 90 days yield trial under normal planting condition and 12 promising clones namely N/15-4, N/15-96, N/15-101, N/15-104, N/15-183, N/15-48, N/15-53, N/15-128, N/15-169, N/14-151, N/14-256 and N/15-180 were selected.

Supply of germplasm accessions for evaluation: Sixty tubers each of 20 accessions were supplied for evaluation for nutrient use efficiency at Jalandhar and sixty tubers each of same 20 accessions were supplied for evaluation for water use efficiency at Modipuram.

Evaluation for nitrogen use efficiency: Among the nine advanced evaluated at 90 days in replicated yield trial with different doses of N for evaluation of

nitrogen use efficiency, clones N/11-89, N/12-12, N/12-25, N/13-49 and N/14-85 performed better for yield at no N applied. Average yield over all 4 N doses were better for N/11-89, N/12-12 and N/12-25 than controls. N.11-89, N/12-12 and N/12-25 possessed better agronomic use efficiency than controls Kufri Gaurav and Kufri Pukhraj.

Introduction in AICRP: Based on consistently good performance over years, advanced clone N/11-89 and N/12-12 have been introduced in AICRP Potato. On the basis of yield average over years, N/11-89 and N/12-12 gave 11 and 15% higher yield over best control Kufri Gaurav at 90 days harvests, respectively. At N stress with no external N applied N/11-89 and N/12-12 gave 10 and 18% higher yield over best control Kufri Gaurav (Table 1). Agronomic nitrogen use efficiency of N/11-89 and N/12-12 was 11 and 15% higher yield over best control Kufri Gaurav (Table 2). Tuber dry matter of N/11-89 (18%) was better than both the controls (15%). N/12-12 is moderately resistant to late blight.



Fig.14. Tubers of N/11-89 & N/12-12

Table 1. Tuber yield (tonnes/ha) in (Average of 2018-2019, 2019-2020 and 2020-2021)

Genotypes	Tuber yield at nitrogen dose (kg/ha)				
	0	80	160	240	Mean
N/11-89	16.83	28.72	34.38	40.31	30.06
N/12-12	17.98	31.57	34.77	40.28	31.15
K. Pukhraj	14.99	26.15	30.57	34.24	26.49
K. Gaurav	15.26	26.00	31.03	36.12	27.10

Table 2. Agronomic use efficiency (kg tubers produced/kg N supply) (Average of 2018-2019, 2019-2020 and 2020-2021)

Genotypes	AUE at nitrogen dose (kg/ha)			
	80	160	240	Mean
N/11-89	148.57	105.5	97.85	117.31
N/12-12	169.88	102.33	92.95	121.72
K. Pukhraj	139.53	93.02	80.17	104.24
K. Gaurav	134.22	95.22	86.91	105.45

Activity 8.:Diploid F₁ hybrid breeding in potato

(Dr Salej Sood, Components workers: Drs Vikas Mangal, Vinay Bhardwaj, Dalamu, Tanuja Buckseth, AK Sharma, RK Singh, Brajesh Singh, Sanjeev Sharma, Babita Chaudhary, S Sundaresha)

Elite lines selection for inbred development: A set of 132 heterozygous diploid clones were multiplied in the field at Modipuram and 21 clones were selected for inbreeding based on visual observation on tuber size, shape and number in the field. The selected diploid heterozygous lines were used at Kufri for transferring self-compatibility gene from elite *Sli* homozygous donor lines. The flowering in heterozygous diploid clones was sparse in most cases and introgression of self-compatibility gene through crossing observed few true potato seeds (TPS) in limited diploid lines. Successful crosses in 17 out of 21 lines resulted in 50-200 TPS in each cross.

Inbred development programme: Eight *Sli* introgressed crosses of S₀ generation were raised from TPS at Shimla and seedlings were grown in pots for selfing. Selfing was attempted in each plant, which resulted in 1350 selfed TPS of six S₀ lines in first selfing generation (S₁). Three way crosses were attempted in progenies of two diploid populations (DMxM18 and DMxM6) to introgress desirable traits from two elite self-compatible diploid lines viz., BS48 and BS49. Besides, S₃ generation TPS of three populations (DMxM18 8-2, DMxM6 2-2, DMxM6 9-2) was raised for selfing and 500 S₄ generation TPS were generated.

Ploidy analysis: The selected 21 heterozygous diploid lines and 120 TPS raised seedlings of initial inbreeding generations were evaluated for ploidy using flow cytometry. All the analysed samples were confirmed as diploids.

Table 3: Glycoalkaloids in peeled tubers of diploid lines

Diploid line	Solanine mg/100gm	Chaconine mg/100gm	Total Glycoalkaloids mg/100gm
BS-258-5	2.767	10.699	13.466
BS-240-15	3.462	11.954	15.416
BS-240-5	0.740	2.580	3.320
BS-265-10	1.718	3.061	4.776
BS-240-10	5.768	12.856	18.624
DMM 18 7-1 S1	2.258	9.218	11.476
BS-256-3	11.662	23.327	34.989
BS-243-1	2.291	4.902	7.193
BS-241-6	1.751	4.212	5.963
BS-240-17	22.395	35.103	57.498
BS-240-1	0.366	0.992	1.352
BS-48-6 So	2.601	6.598	9.199
BS-258-14	2.823	4.350	7.173
BS-48-1 So	5.821	12.264	18.085
BS-258-3	2.876	7.621	10.497
CP4722	9.912	14.657	24.569
BS-272-4	0.769	1.318	2.087
BS-49-1	4.360	9.224	13.584
BS-265-5	1.139	6.406	7.545
CP4601	10.686	18.259	28.945
BS-243-5	7.332	23.321	30.653

Glycoalkaloid analysis of elite diploid clones: The selected 21 heterozygous diploid clones were evaluated for glycoalkaloid analysis. Total glycoalkaloids varied from 1.35mg/100 in BS240-1 to 57.50mg/100g in BS240-17. Most of the lines had acceptable level of glycoalkaloids except five clones BS-256-3, BS-240-17, CP4722, CP4601 and BS-243-5 (Table 3). Glycoalkaloids above 20 mg/100g are considered to be unsafe for consumption.

Sli KASP™ markers for self-compatibility: ICAR-CPRI developed and used 10 KASP™ markers for high throughput screening of self-compatible (SC) clones in diploid germplasm. The results of KASP™ markers used in the study were perfect with an efficiency of >95% based on allele analysis for 9 out of 10 markers (Fig 15). The KASP™ markers results of 9 SNPs were statistically in agreement with self-compatible and self-incompatible phenotype as revealed through Chi-squared testing.

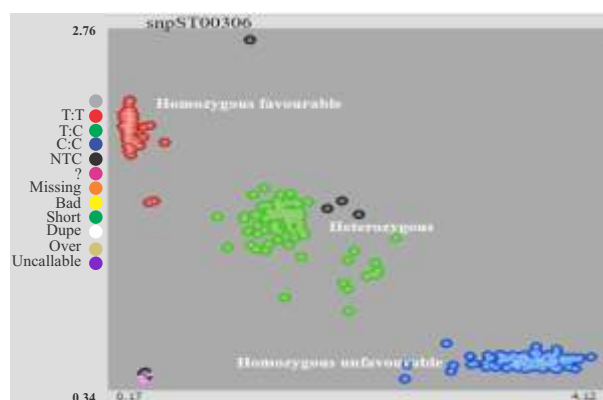


Fig 15: *Sli* KASP marker to identify self-compatible and self-incompatible diploid lines.

Identification of elite *Sli* donors: In the inbreeding generations of two diploid populations (DMxM18 and DMxM6), BS 49-1 and BS 48-6 were identified as vigorous and highly fertile *Sli* donor lines, which had improved tuber size and number in comparison to the original *Sli* donor line (Fig. 16). Both the lines were homozygous for *Sli* gene genotype.

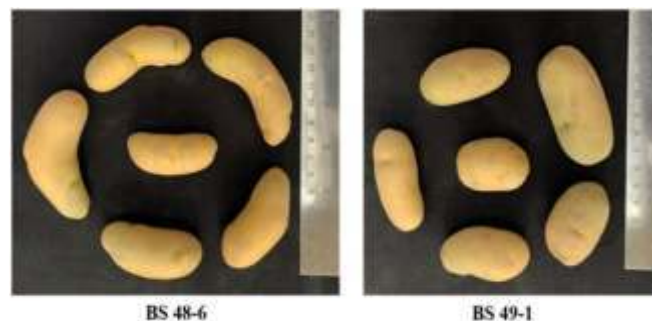


Fig 16: Elite *Sli* homozygous donor lines for self-compatibility

Hybridization for di-haploid induction: A set of 10 Indian potato varieties were grown under controlled conditions for hybridization with haploid inducer line, CP4590. Crosses were attempted in all the 10 varieties but berry and seed setting was observed in 5 varieties (ATL, KCH-1, Kufri Swarna, Kufri Himalini and CP2350) only. TPS was extracted and observed for morphological marker purple embryo spot to separate di-haploid TPS from hybrid TPS.



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

To maintain the higher productivity as well as yields, it is essential to have a scientifically sound seed production system through which high degree of health standard of the seed crop is maintained. Therefore, a program entitled “Production of nucleus and breeder seed of important notified varieties of potato” has been started under Revolving Fund Scheme. The nucleus and breeder seed production is being monitor by the scientists of the Division at different stations located in different regions of the country. The nucleus and breeder seed production and supply status of breeder seed during the 2020-21 is given below:

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

Seed Production

A. Plains

A total production of 30109.76 qtls nucleus and breeder seed was achieved from an area of 131.03 ha. Out of which, 21350.63 qtls production from 95.53 ha was through conventional and 8759.13 qtls from 35.51 ha through hi-tech seed production systems respectively. The percentage of nucleus and breeder seed from conventional system was 70.91 and 29.10 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 is given in table 2.

Stage-I: A total production of 183.39 qtls was achieved from an area of 2.92 ha (Table-2) with average production of 83.67, 35.20, 64.77 and 88.63 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-II: A total production of 893.25 qtls was from an area of 5.87 ha (Table-2) with average production of 121.86, 321.48, 161.52 and 109.67 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-III: A total production of 3890.13 qtls was from an area of 18.59 ha (Table-2) with average production of 237.06, 284.47, 151 and 166.31 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-IV: A total production of 16383.86 qtls was from an area of 68.14 ha (Table-2) with average

production of 273.86, 240.32, 202.39 and 178.55 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

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

(i) Generation-1: A total production of 1536.7 qtls was achieved in G-I from an area of 7.44 ha with average production of 190.27, 265.22, 104.87 and 290.62 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

(ii) Generation-2: A total production of 7222.43 qtls was achieved in G-2 from an area of 28.067 ha with average production of 270.85, 288.10, 145.91 161.60 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

Table 2: Station & variety wise area and production (Qts.) in conventional system 2021 (Plains)

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
I. Modipuram										
Kufri Anand	0.04	4.60	0.15	15.00	0.40	104.20	1.80	470.00	2.39	593.80
Kufri Bahar	0.50	46.15	1.48	190.00	3.75	894.00	15.00	4165.50	20.73	5295.65
Kufri Chipsona-1	0.08	5.90	0.31	35.00	1.10	256.50	3.30	963.00	.	.
Kufri Chipsona-3	0.04	3.35	0.18	15.00	0.45	91.80	0.90	310.00	4.79	1260.40
Kufri Frysona	0.04	4.00	0.17	20.50	0.40	75.00	1.00	302.50	1.61	402.00
Kufri Khyati	0.05	4.25	0.24	36.00	0.70	190.70	2.00	434.50	2.99	665.45
Kufri Pukhraj	0.05	4.20	0.21	34.50	0.75	209.60	1.35	307.00	2.36	555.3
Kufri Surya	0.05	4.95	0.23	17.50	0.40	74.20	1.10	350.00	1.78	446.65
Kufri Mohan	0.05	5.25	0.30	35.00	0.90	202.00	3.50	893.50	4.75	1135.75
Kufri Garima	-	-	-	-	-	-	1.65	458.19	1.65	458.19
Kufri Thar-2	0.03	0.35	-	-	-	-	-	-	0.03	0.35
Kufri Lima	0.03	0.70	-	-	-	-	-	-	0.03	0.70
Kufri Neelkanth	0.03	0.20	-	-	-	-	-	-	0.03	0.20
Kufri Sangam	0.015	1.10	-	-	-	-	-	-	0.015	1.10
Kufri Kiran	0.015	0.35	-	-	-	-	-	-	0.015	0.35
Total	1.02	85.35	3.27	398.50	8.85	2098.00	31.60	8654.19	44.74	11236.04
II. Jalandhar										
Kufri Jyoti	0.55	15.39	0.24	101.00	1.50	399.00	7.51	1644.00	9.80	2159.39
Kufri Pukhraj	0.286	11.84	0.176	47.50	0.49	160.00	2.10	635.00	3.052	854.34
Kufri Badshah	0.03	1.47	0.038	9.50	0.068	22.14	0.23	53.00	0.366	86.11
Kufri Khyati	0.03	1.28	0.025	6.00	0.099	31.18	0.51	105.00	0.664	143.46
Kufri Surya	0.006	0.37	0.008	1.00	-	-	-	-	0.014	1.37
Kufri Himalini	0.031	3.02	0.046	10.82	0.054	15.70	0.55	180.00	0.681	209.54
Kufri Chipsona-1	0.029	0.50	0.031	5.50	0.105	29.11	0.165	26.50	0.33	61.61
Total	0.962	33.87	0.564	181.32	2.316	657.13	11.065	2643.5	14.907	3515.82
III. Gwalior										
Kufri Chandramukhi	0.11	5.90	0.22	38.50	0.90	100.00	3.55	703.50	4.78	847.9
Kufri Jyoti	0.12	6.67	0.25	47.50	0.83	136.50	5.13	1061.35	6.33	1252.02
Kufri Sindhuri	0.08	4.13	0.25	44.00	1.00	154.00	2.51	385.00	3.84	587.13
Kufri Lauvkar	0.09	4.82	0.15	22.36	0.36	60.00	0.78	100.00	1.38	187.18
Kufri Chipsona-I	0.10	7.95	0.32	43.77	1.50	290.50	6.36	1449.50	8.28	1791.72
Kufri Chipsona-3	0.08	5.09	0.17	24.00	0.71	94.00	2.38	459.00	3.34	582.09
Kufri Surya	0.08	8.29	0.21	30.50	1.17	142.000	1.80	397.50	3.26	578.29
Kufri Pukhraj	0.08	6.19	0.16	28.80	-	-	-	-	0.24	34.99
Kufri Khyati	0.03	2.15	-	-	-	-	-	-	0.03	2.15
Kufri Lima	0.01	0.44	-	-	-	-	-	-	0.01	0.44

Kufri Sangam	0.01	0.17	-	-	-	-	-	-	0.01	0.17
Kufri Thar-2	0.01	0.32	-	-	-	-	-	-	0.01	0.32
Kufri Kiran	0.01	0.35	-	-	-	-	-	-	0.01	0.35
Total	0.81	52.47	1.73	279.43	6.47	977.00	22.51	4555.85	31.52	5864.75
IV Patna										
Kufri Himalini	0.012	1.00	0.01	3.00	0.06	10.00	-	-	0.082	14.00
Kufri Jyoti	0.015	1.30	0.06	6.00	0.16	26.00	1.00	146.65	1.235	179.95
Kufri Kanchan	0.006	0.50	0.01	1.00	-	-	-	-	0.016	1.50
Kufri Kesar	0.015	1.50	0.03	3.50	0.02	5.00	-	-	0.065	10.00
Kufri Khyati	0.030	3.10	0.08	7.50	0.40	64.50	1.17	220.00	1.68	295.10
Kufri Lailt	0.018	1.60	0.05	5.00	0.12	19.00	0.45	80.27	0.638	105.87
Kufri Manik	0.006	0.50	-	-	-	-	-	-	0.006	0.50
Kufri Neelkanth	0.006	0.50	-	-	-	-	-	-	0.006	0.50
Kufri Pukhraj	0.009	0.80	0.03	3.50	0.09	17.00	0.25	70.30	0.379	91.60
Kufri Sindhuri	0.015	0.90	0.04	4.50	0.10	16.50	0.10	13.10	0.255	35.00
Total	0.132	11.7	0.31	34	0.95	158	2.97	530.32	4.362	734.02
Plains' Total	2.924	183.39	5.874	893.25	18.586	3890.13	68.145	16383.86	95.529	21350.63

Table 3: Station & variety wise area and production (Qts.) in Hi-Tech system 2021 (Plains)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
I. Modipuram						
Kufri Chipsona-1	1.58	274.20	5.30	1563.00	6.88	1837.20
Kufri Chipsona-3	0.40	65.50	0.80	284.00	1.20	349.5
Kufri Frysona	0.03	9.80	0.60	184.00	0.63	193.8
Kufri Ganga	0.17	58.00	-	-	0.17	58.00
Kufri Khyati	0.30	75.80	3.00	651.00	3.30	726.80
Kufri Mohan	1.25	218.00	3.00	757.00	4.25	975.00
Kufri Pukhraj	0.20	42.00	1.00	249.00	1.20	291.00
Kufri Surya	0.30	58.50	0.50	155.50	0.80	214.00
Kufri Sukhyati	0.11	24.00	-	-	0.11	24.00
Kufri Garima	-	-	0.50	138.00	0.50	138.00
Total	4.34	825.80	14.70	3981.50	19.04	4807.30
II Jalandhar						
Kufri Chandramukhi	0.367	80.20	1.196	328.27	1.563	408.47
Kufri Jyoti	0.27	73.50	1.08	212.37	1.35	285.87
Kufri Badshah	0.058	16.50	0.12	28.02	0.178	44.52
Kufri Pukhraj	0.59	191.50	4.22	1282.33	4.81	1473.83
Kufri Chipsona-1	0.2804	57.20	-	-	0.2804	57.20
Kufri Khyati	0.0185	4.72	0.45	98.47	0.4685	103.19

Kufri Himalini	0.246	60.18	1.485	516.13	1.731	576.31
Kufri Gaurav	0.006	1.50	0.206	55.29	0.212	56.79
Kufri Surya	0.0085	2.35	-	-	0.0085	2.35
Kufri Karan	0.0089	3.00	-	-	0.0089	3.00
Total	1.85	490.65	8.757	2520.88	10.61	3011.53
III Gwalior						
Kufri Lauvkar	-	-	0.33	45.00	0.33	45.00
Kufri Chipsona-1	0.13	11.50	0.10	24.00	0.23	35.50
Kufri Mohan	-	-	0.18	36.50	0.18	36.50
Kufri Surya	-	-	0.24	51.00	0.24	51.00
Kufri Pukhraj	0.09	11.75	0.17	30.50	0.26	42.25
Kufri Khyati	0.13	17.90	0.57	45.00	0.70	62.90
Kufri Himalini	0.14	12.50	-	-	0.14	12.50
Kufri Garima	0.13	14.00	-	-	0.13	14.00
Kufri Karan	0.15	13.10	-	-	0.15	13.10
Total	0.77	80.75	1.59	232.00	2.36	312.75
IV Patna						
Kufri Chip-3	0.10	26.50	0.05	10.40	0.15	36.90
Kufri Himalini	0.03	23.00	1.10	183.60	1.13	206.60
Kufri Jyoti	-	-	0.17	40.00	0.17	40.00
Kufri Kesar	0.01	2.00	-	-	0.01	02.00
Kufri Khyati	0.25	49.00	0.80	128.47	1.05	177.47
Kufri Mohan	0.02	10.50	0.80	108.58	0.82	119.08
Kufri Neelkanth	0.03	9.50	-	-	0.03	09.50
Kufri Pukhraj	0.02	6.50	0.10	17.00	0.12	23.50
Kufri Surya	0.02	12.50	-	-	0.02	12.50
Total	0.48	139.5	3.02	488.05	3.50	627.55
Plains Total	7.44	1536.7	28.067	7222.43	35.51	8759.13

3. Total supply of breeder seed

During 2021, total 21997.17 qtls breeder seed was supplied to various government and private agencies, from plains Table-4 (A & B).

B. Hills (2021)

Multiplication of basic material maintenance of mother stock: A total no. of 40 pots of 20 varieties were planted and tested with ELISA/PCR against different potato viruses. After carrying out series of

testing through PCR/ELISA all healthy varieties were shifted *in vitro* & were included in the microplants multiplication and supply chain. A total 16059 culture tubes of 30 varieties were multiplied under tissue culture. In aeroponics, 27655 minitubers of different varieties were harvested.

Maintenance of buffer stock in 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. Karn under different seed stages of

Conventional and Hi-tech systems are being maintained. The produce obtained from such buffer seed stages is used in planting the trap crop (as a measure to eradicate the PCN from farms) and as seed for planting buffer seed stages during next year. The surplus quantities if any, are disposed of in local subzi mandi as ware potatoes.

Table-4 (A): Station and variety wise supply (qtls) during 2021

S. N.	Variety	Modipuram	Jalandhar	Gwalior	Patna	Total
1.	Kufri Anand	414.00	-	-	-	414.00
2.	Kufri Badshah	81.02	-	-	-	81.02
3.	Kufri Bahar	3612.10	-	-	-	3612.10
4.	Kufri Chandramukhi	-	328.27	694.50	-	1022.77
5.	Kufri Chipsona-1	2298.00	29.11	1473.50	-	3800.61
6.	Kufri Chipsona-3	496.50	-	468.00	10.40	974.90
7.	Kufri Frysona	418.50	-	-	-	418.50
8.	Kufri Garima	464.19	-	-	-	464.19
9.	Kufri Gaurav	55.19	-	-	-	55.19
10.	Kufri Himalini	-	689.19	-	183.60	872.79
11.	Kufri Jyoti	-	1856.37	1061.35	186.65	3104.37
12.	Kufri Khyati	1002.00	203.47	45.00	348.47	1598.94
13.	Kufri Lauvkar	-	-	145.00	-	145.00
14.	Kufri Lalit	-	-	-	80.27	80.27
15.	Kufri Mohan	1389.00	-	56.50	108.38	1553.88
16.	Kufri Pukhraj	472.40	1908.84	30.50	87.30	2499.04
17.	Kufri Sindhuri	-	-	385.00	13.10	398.10
18.	Kufri Surya	453.00	-	448.50	-	901.50
Total		11155.9	5015.25	4807.85	1018.17	21997.17

C. Supply of Microplants to Different Seed Agencies

A total 163 virus-free in vitro culture tubes of basic seed material of 29 varieties (Fig 1) were supplied to 18 different seed producing organizations in India (Table-5) and a revenue of Rs. 8,15,000/- 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.

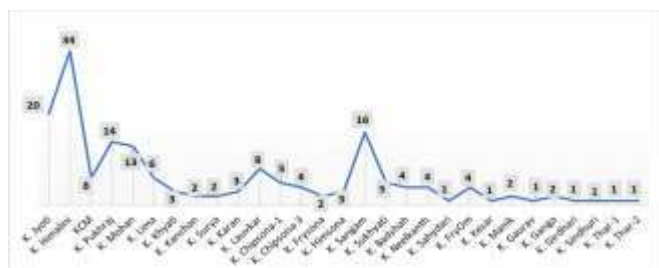


Fig 1. Variety wise supply to different seed organizations

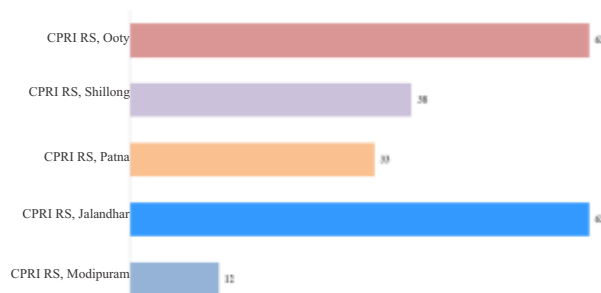


Fig 2. Station wise microplant supply to different seed centres

Table- 4 (B) Variety/stage & agency wise breeder seed supply from plains (qtls) during 2021

S. N.	Variety	AS *	CG*	HP*	J&K*	MP*	ML*	MN*	PB*	TG*	UK*	UP*	RJ*	WB*	NHRDF*	NSC*	Uni.*	ICAR	Farmers / Pvt.	Total
1.	Kufri Anand	-	-	-	-	-	-	-	-	-	-	414.0	-	-	-	-	-	-	-	414.00
2.	Kufri Badshah	-	-	-	25.5	-	-	-	32.50	-	-	10.0	-	-	-	-	-	-	13.02	81.02
3.	Kufri Bahar	-	50.0	-	-	-	-	-	-	-	-	2476.0	100.0	40.0	60.0	-	-	790.0	96.10	3612.10
4.	Kufri Chandramukhi	-	66.0	60.0	17.5	-	-	-	58.00	4.00	-	-	-	136.0	-	-	51.0	200.0	430.27	1022.77
5.	Kufri Chipsona-1	-	-	-	8.5	95.5	-	-	38.00	-	-	2669.0	-	29.0	49.0	-	4.0	168.0	739.61	3800.61
6.	Kufri Chipsona-3	-	-	-	40.0	200.0	-	-	-	-	-	300.0	-	-	60.0	-	14.0	105.5	255.40	974.90
7.	Kufri Frysona	-	-	-	30.0	-	-	-	-	-	-	100.0	47.0	-	-	-	-	85.0	156.50	418.50
8.	Kufri Garima	-	-	-	-	-	-	-	-	-	-	377.19	-	27.0	-	-	-	40.0	20.00	464.19
9.	Kufri Gaurav	-	-	-	-	-	-	-	6.72	-	-	41.5	-	-	-	-	-	-	6.97	55.19
10.	Kufri Himalini	-	-	79.0	99.	-	-	-	35.09	-	-	-	-	78.0	15.0	25.0	-	23.47	518.225	872.79
11.	Kufri Jyoti	-	73.0	150.0	71.50	146.0	37.0	7.0	280.35	-	120.0	-	-	434.0	30.0	100.0	1.0	15.0	1639.52	3104.37
12.	Kufri Khyati	-	-	-	40.0	-	-	-	32.00	-	-	962.52	-	2.0	125.0	-	16.0	102.5	318.92	1598.94
13.	Kufri Lauvkar	-	-	-	-	-	-	-	32.00	-	-	-	-	-	-	-	40.0	-	73.00	145.00
14.	Kufri Lalit	-	-	-	-	-	-	-	-	-	-	33.67	-	-	-	-	5.0	2.5	39.10	80.27
15.	Kufri Mohan	-	230.0	-	-	33.5	-	-	64.00	2.00	-	800.0	-	133.0	70.0	5.0	22.0	20.0	174.38	1553.88
16.	Kufri Pukhray	-	-	-	-	-	-	-	480.00	-	-	300.0	-	25.0	144.0	-	30.5	46.72	1472.815	2499.04
17.	Kufri Sindhuri	-	33.0	-	52.0	-	-	-	-	-	-	258.0	-	-	-	-	-	-	55.10	398.10
18.	Kufri Surya	6.0	-	-	34.0	35.0	-	-	-	2.00	-	524.0	-	-	31.0	-	7.0	25.0	237.50	901.50
Total		6.0	452.0	289.0	418.0	510.0	37.0	7.0	1058.66	8.00	120.0	9265.88	147.0	904.0	584.0	130.0	190.5	1623.7	6246.43	21997.17

*AS: Asam; CG: Chhattisgarh; HP: Himachal Pradesh, J&K: Jammu & Kashmir; MP: Madhya Pradesh; ML: Meghalaya; MN: Manipur; PB: Punjab; TG: Telangana; UK: Uttarakhand; UP: Uttar Pradesh; RJ: Rajasthan; WB: West Bengal; NHRDF: National Horticulture Research and Development Foundation; NSC: National Seeds Corporation; Uni.: University.

Table 5: Microplants supply to different Seed Producing Organization

S.No	Firms	Varieties Supplied
1.	District Manager, West Bengal State Seed Corporation Limited. Midhapore- West Bengal	K. Jyoti, K. Himalini, KCM, K. Pukhraj, K. Mohan, K. Lima, K. Khyati, K. Kanchan, K. Surya
2.	M/s Technico Agri Sciences Ltd Tehsil - Baddi, Solan	K. Karan, K. Sangam, K. Sukhyati, K. Sahyadri
3.	M/S Sekhon Biotech, Jalandhar	K. Jyoti, K. Pukhraj, K. Lauvkar, K. Chipsona-1, K. Chipsona-3, K. Frysona, KCM, K. Himalini, K. Mohan, K. Himsona, K. Khyati, K. Karan, K. Sangam
4.	M/s Merino India, Potato Pre-basic Seed Production	K. Sangam, K. Himsona
5.	M/s Centre of Excellence for Potato, Dhogri, Distt-Jalandhar, Punjab	K. Jyoti, K. Mohan, K. Pukhraj, K. Chip-1, K. Himalini
6.	Institute for Empowerment by Arts Science & Technology, Sanepat, Haryana	K. Sangam, K. Jyoti, K. Mohan, K. Pukhraj, K. Chip-3, K. Badshah
7.	M/s Bhatti Tissue Tech. Vill.-Alipur, PO-Mithapur, The & Distt.- Jalandhar, PB	K. Pukhraj, K. Himalini, K. Jyoti, K. Khyati, K. Lauvkar, K. Badshah, K. Chip-1, K. C.M, K. Sukhyati, K. Mohan K. Sangam, K. Lima,
8.	M/s Honda Biotech, Shahbad, Kurushetra	K. Pukhraj, K. Sangam, K. Chip-1, K. Surya
9.	M/s GMS Agritech Pvt. Ltd., Research & Development, West Bengal	K. Jyoti, K. Himalini, K. Pukhraj, K. Sangam KCM, K. Neelkanth, K. Mohan
10.	M/s Advent Plantech LLP, Nasik, Maharashtra	K. Jyoti, K. Himalini, K. Lauvkar
11.	M/s Hyfun Foods, Bangalore, Karnataka	K. Fry-Om
12.	M/s Jain Irrigation Systems Ltd, Jalgaon, Maharashtra	K. Lauvkar, K. Sangam, K. Sukhyati, K. Himalini
13.	VC Uttar Banga Krishi Vishwavidyalaya Pundipari, Cooch Behar, West Bengal	K. Chip-3, K. Mohan, K. Sukhyati, K. Himalini, K. Frysona, K. Chip-1, K. Neelkanth, K. Kesar, K. Manik, K. Lima, K. Karan, K. Kanchan, K. Gaurav, K. Ganga, K. Girdhari, K. Sindhuri, K. Sindhuri, K. Pukhraj, KCM, K. Jyoti
14.	Mr. Ravindra Nath Reddy, Project Manager, International Potato Centre, Karnataka	K. Mohan, K. Himalini, K. Jyoti, K. Lima, K. Sangam
15.	M/s DS Agro Service, Yamunanagar, Haryana	K. Mohan, K. Himalini, K. Sangam
16.	Deputy Director Horticulture, Potato Technology Center, Shamghah, Karnal	K. Sangam, K. Mohan, K. Lima, K. Pukhraj, K. Neelkanth
17.	M/s Sashanka Agro Tech Pvt. Ltd. Ranchi, Jharkhand	K. Thar-1, K. Thar-2, K. Ganga, K. Neelkanth, K. Manik, K. Sangam
18.	M/s Shampanur Agro Tech. Davanagere Karnataka	K. Himalini

A total of 207 culture tubes of 28 varieties were supplied to different seed production stations/centers i.e. Modipuram, Jalandhar, Patna, Ooty and Shillong.

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

1. Identification of seed window for the integration of ARC into breeder seed production: Four different planting dates (15 Sept, 30 Sept, 15 Oct., 30 Oct.) with different potato varieties were considered to identify the seed window with respect to the ARC multiplication. It was observed that survival percentage was less during first planting date as the temperature was too high (35-40°C). However, most of the plants survived with the subsequent DOP (Fig 1). To fit into the seed window, delayed in planting dates affected the number of cuttings to be taken off which ultimately affects the rate of multiplication. (Fig.2). Only 3-4 cuttings are recommended based upon the identified seed window (30th Sept- 7th Oct.) as per Seed Plot Technique. Pedigree of the raised ARC plants was maintained so as even if any plant out of a cutting found infected during testing, all the counterpart of the cutting/sister counterpart tubers can be traced and rejected. Harvesting is yet to be done.

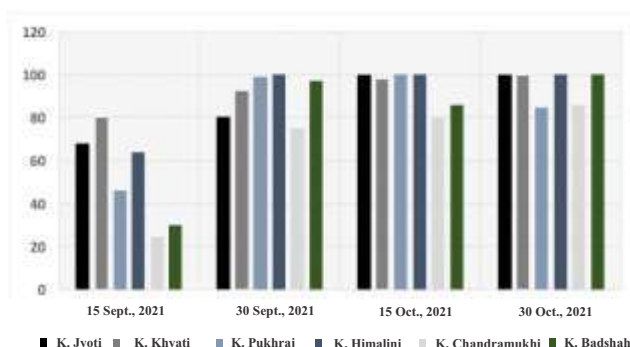


Fig 1. Percent Survivability of Mother Nursery

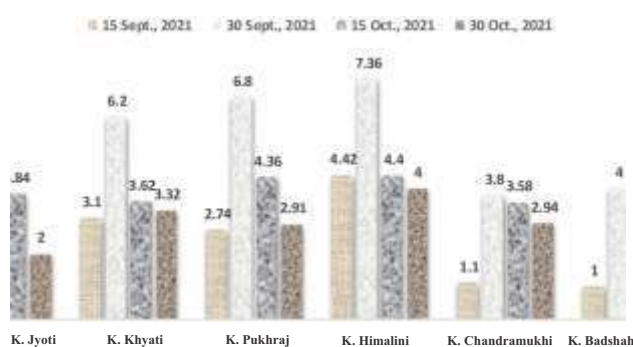


Fig 2. Rate of Multiplication as per DOP



Fig 3. ARC multiplication at Jalandhar

2. In-vivo rapid multiplication through sprouts: As per RAC's recommendations, this study was undertaken. Use of sprouts for rapid multiplication was advocated as early as mid-forties in India. Medium to big sized tubers are ideal for multiplication through sprouts because they can nutritionally support growth of number of sprouts emerging from well-spaced eyes (in small tubers the eyes are crowded). De-sprouted mother tubers can also be used as normal seed. Mother Tubers of varieties viz., K. Pukhraj and K. Himalini (Jalandhar), K. Jyoti, K. Lauvkar, K. Chipsona-3, K. Sindhuri, K. Surya and K. Chandramukhi (Gwalior) were taken out from cold store. Apical eye of the tubers was removed by scooping and giving 2-3 small cuts between eyes on the tuber. Apical eye was scooped out to break apical dominance. These tubers were treated with a mixture of 0.2 per cent Dithane M-45 and Gibberellic acid (2 mg/l) and were spreaded in a layer in a shed. Tubers were allowed to sprout in shed by exposing the tubers to alternate dark (5 days) and fluorescent light (2 days). Sprouts were repeatedly harvested from mother tubers at an interval of 10-15 days. No. of harvested sprouts progressively increase after 1st sprout harvest. Planting of harvested sprouts was done in pro-trays filled with soil-FYM (1:1) under shade. Thereafter, sproutlings were allowed to grow in pro-trays under shade. Transplanting of established sproutlings was done in net-house. In a period of 40-45 days (to fit into seed window), de-sprouting was done 4 times which led to the multiplication rate of 15-22 sproutlings/tuber. Harvesting is yet to be done. This system can be utilized under rapid multiplication seed potato production scheme.



Fig.4: Rapid multiplication through sprouts: a) Desprouting; b & c) Planting of sprouts in pro-trays and in nursery under net house; d) Sproutlings ready for transplanting

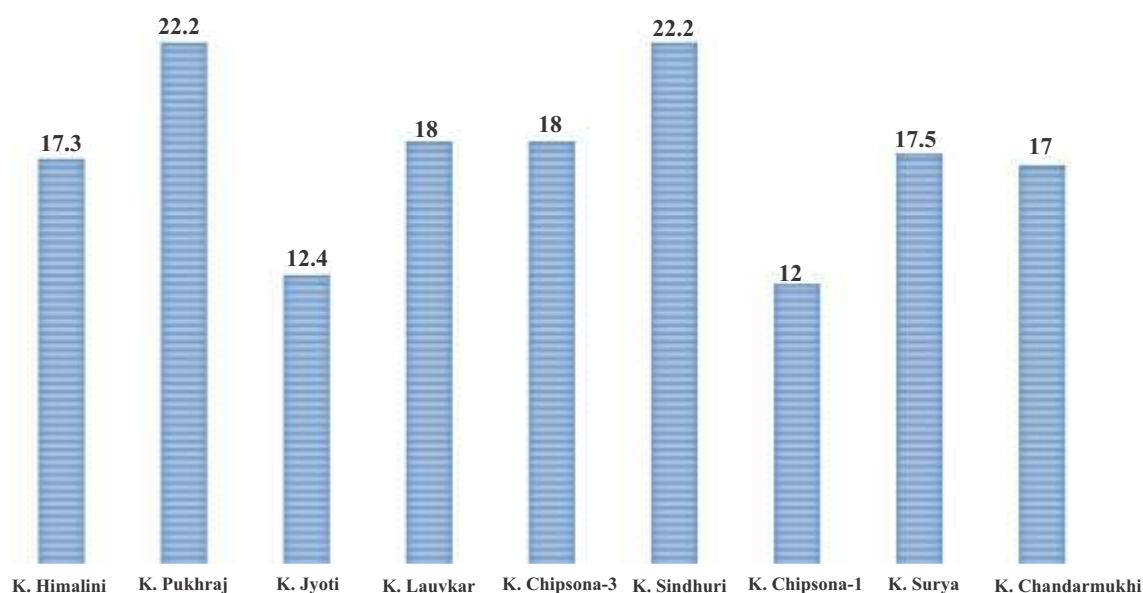


Fig 5. Rate of multiplication as per variety

3. Productivity assessment of of successive planting of disease-free microplants under net house for single (SC) cropping and successive double cropping (DC) systems: In the present study productivity of successive planting of disease-free microplants under net house for single (SC) cropping and successive double cropping (DC) systems under net house for seven potato varieties namely Kufri Pukhraj, Kufri Himalini, Kufri Jyoti, Kufri Badshah, Kufri Khyati, Kufri Karan and Kufri Sukhyati with

first and second planting dates viz. 17/10/20 (DCE) and 10/1/20 (DCL) respectively for successive double crop and 13/11/20 for single cropping (SC) planted in ridge and furrow at 30 cm row to row and 15 cm plant to plant spacing. Double cropping produced average 374.39 tubers weighing 2.85 kg per sq. mt. area as compared to average 277.43 tubers of 2.6 kg produced from single cropping. Varietal differences were also observed for these characters. Growth parameters (plant height and number of leaves) of the

three crops revealed more vigorous but at par growth of DCE and DCL over the SC. The DC yielded 1.34 times higher number of tubers as compared to SC, and a further scope of improvement is envisaged by

increasing the cropping period of DCL upto mid-April. Planting of two successive microplant crops under net-house has scope of getting higher productivity per unit area, as compared to single crop.

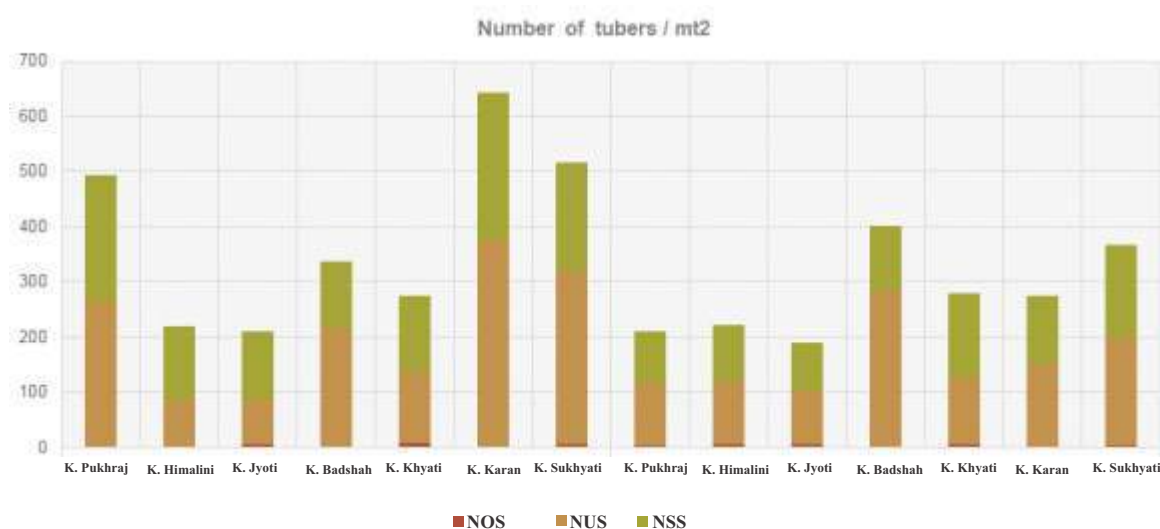


Fig. 6: Number of different seed categories of varieties (seed, oversize and undersize) produced in Double cropping and single cropping systems on per m² basis

4. 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: A new variety of potato named Kufri Karan, known to be resistant to late blight and many more biotic stresses like viruses etc. has been released recently by CPRI especially for hilly region of India. Since, every potato genotype / cultivar is known to behave differently in its production behaviour, so 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 mini-tubers in Gen. 1 during the *Kharif* 2021 at Fagu farm. The results obtained revealed that both the factors viz. size of mini-tuber as

well as planting geometry significantly affected the number of tubers/ha. A gradual increasing trend was noticed for number of tubers/ha with increasing size of mini-tubers as well as with closer intra-row spacing. The number of tubers/ha were found to be significantly higher with >10g mini-tubers than smaller (3-10g) tubers and the number of tubers obtained was statistically at par between 10-20g and 20-40g mini-tubers. Among the different planting geometries, number of tubers was maximum at closest intra-row spacing of 60x10cm. An increase in number of tubers at 60x15cm over 60x20cm was found but the differences were statistically at par. The interaction between size of mini-tuber planted and planting geometry was non-significant for the number of tubers/ha (Table 6).

Table 6: Production behaviour of different grades of mini-tubers of K. Karan at different planting geometries in Gen. 1

Treatments	Total tubers/ ha (lakh)			Mean	Total yield/ m ²			Mean
	60x20cm	60x15cm	60x10cm		60x20cm	60x15cm	60x10cm	
20-40g	7.86	8.23	9.58	8.55	406.8	342.6	311.1	353.5
10-20g	8.04	8.23	9.41	8.56	333.3	365.3	311.3	336.6
3-10g	6.5	7.59	8.25	7.43	316.4	308.8	331.6	318.9
Mean	7.5	8.02	9.08		352.1	338.9	318.0	

CD_{0.05}

Grade of mini-tuber (A) 1.01 26.7

Planting Geometry (B) 1.01 26.7

A x B NS 46.3

For obtaining the maximum yield/ha in Gen. 1, 3-10g mini-tubers should be planted at 60x10cm, 10-20g at 60x15cm and 20-40g at 60x20cm respectively

5. Effect of planting period on the production behaviour of <3g aeroponic mini-tubers of new potato variety Kufri Karan under polyhouse conditions: To standardize the period of planting for the multiplication of aeroponic tubers of new potato cultivar Kufri Karan under polyhouse conditions, an experiment was conducted at Fagu farm during the *Kharif* 2021. Planting was done on three dates viz. 1st July, 15th July and 30th July 2021 at 30 x 10 cm spacing using 01 tuber/hill. With delay in planting, a gradual decrease in the average weight of mini-tuber at the time of planting was observed but the differences were not statistically significant. Percent establishment was significantly low with 1st July

planting over the next two periods viz. 15th and 30th July, where it was almost cent per cent. Delay in planting also resulted in a gradual and significant decrease in the height of plants, number of compound leaves and haulms weight /plant (Table 2). The number of tubers/m² were not affected significantly with delay in planting but the yield of mini-tubers/m² was significantly higher and almost similar with two early periods of planting (1st and 15th July) over last planting (30th July). The proportion of extremely small (<3g) and large sized mini-tubers was almost similar and statistically at par among all the three periods of planting (Table 7).

Table 7: Effect of planting period on the production behaviour of <3g aeroponic mimi-tubers under polyhouse conditions

Date of planting in polyhouse	% estab.	Av. wt. of mini-tubers at planting(g)	Height / Plant (cm)	No. of Leaves/ plant	Haulms wt./plant (g)	No. of tubers /m ²	Yield /m ² (Kg)	>20g tubers (%)	<3g mini-tubers (%)
1 st July	85.8	1.27	150.8	23.1	62.6	142.0	2.49	33.9	22.9
15 th July	100.0	1.11	129.2	19.3	55.7	137.5	2.48	29.5	26.8
30 th July	99.7	1.05	94.9	15.0	58.0	134.9	2.36	27.2	24.5
CD 0.05	8.9	N/A	20.1	1.8	2.5	N/A	0.07	N/A	N/A

Thus, for the multiplication of aeroponic tubers, planting can be done any time in the month of July, as delay in planting from 1st July till 30th July does not significantly affect the rate of multiplication as well as tuber size distribution.

6. Standardization of seed production agronomy for aroonic minitubers of newly released varieties: An experiment was conducted with three newly released varieties viz Kufri Ganga, Kufri Neelkanth and Kufri Kesar and two spacing combinations 30×10 cm (333333 plants/ha) and 30×15 cm (222222 plants/ha). No significant difference was recorded among varieties for germination, among spacing 30 x 15 cm recorded significantly higher germination (96.87%) over 30x10cm (93.33%). No significant difference was recorded among varieties for total number of tuber, but among spacing 30 x 10 cm recorded significantly higher total tuber number (2263 thousand/ha) over 30 x 15cm (1811 thousand/ha). Among interaction Kufri Ganga with 30x10 cm spacing (2511 thousand/ha) recorded significantly highest total tuber number among other treatment combinations. For weight Kufri Neelkanth (30.67 t/ha) recorded significantly higher total tuber wight over Kufri Kesar (26.96 t/ha). 30×10 cm spacing (29.41 t/ha) recorded non significantly higher total tuber weight over 30×15 cm

spacing (27.10 t/ha). Kufri Ganga recorded higher <3g minituber% (40.59) over Kufri Neelkanth (31.89) and Kufri Kesar (30.39). Similarly, 30×10 cm spacing (37.26%) recorded higher <3g minituber% over 30×15 cm spacing (30.85).

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

1. Evaluation of potato varieties under different spacing and canopy management practices: At Patna centerexperiment was conducted with potato variety Kufri Himalini. A total of ten treatment combinations (Five Treatments-Ridge and furrow planting with 20 cm tuber distance, Ridge and furrow planting with 15 cm tuber distance, Flat bed Paired row 90 cm bed length (two rows 20 cm plant to plant spacing) - 3 beds, Flat bed Paired row 90 cm bed length (two rows 15 cm plant to plant spacing) - 3 beds and Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) - 3 beds. Two days of haulm cutting 70 days and 80 days after planting were used. The treatments were replicated thrice

under split plot design. Recommended package of practices at Patna center were adopted to grow a good potato crop. The potato seed were sorted and spread in diffused light for proper chitting before plating. The data on various aspects are being recorded.

At Gwalior center experiment was conducted with potato variety Kufri Khyati. A total of ten treatment combinations, five spacing Treatments-Ridge and furrow 60x20 (6 rows), Ridge and furrow 60x15cm (6 rows), Flat bed Paired row 90 cm bed length (two rows 20 cm plant to plant spacing) - 3 beds, Flat bed Paired row 90 cm bed length (two rows 15 cm plant to plant spacing) - 3 beds and Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) - 3 beds and two haulm killing dates. Two days of haulm cutting 70 days and 80 days after planting were used. The treatments were replicated thrice under split plot design. The crop was planted on 29/10/2020. The crop was raised as per seed plot technique. Various observations viz Emergence (%), Days to 50% emergence, No. of shoots per plant at 45 and 60 days after planting (five randomly selected plants), Plant height at 45 and 60 days after planting (five plants), No. of leaves per plant at 45 and 60 days after planting, Canopy cover at 10 days' interval and Incidence of viruses (MM, SM and offtype) at 25, 50 and 70 DAP were recorded.

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

2. Standardization of Nitrogen requirement of potato variety Kufri Kesar: At Patna center experiment was conducted with newly released potato variety Kufri Kesar. Five doses of nitrogen i.e. Nitrogen @ 0kg/ha, Nitrogen @75 kg/ha, Nitrogen

@ 150 kg/ha, Nitrogen @ 225 kg/ha and Nitrogen @ 300 kg/ha was used. The treatments were replicated thrice in randomized block design. The crop was planted timely and managed properly for growing a good potato crop. The seeds were sorted and spread in diffused light for proper chitting before planting. The data on various aspects is being recorded.

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

The experiment was conducted at Gwalior center with factor A (varieties) seven varieties under seed production at Gwalior station viz Chandramukhi, K. Lauvkar (Early), K. Surya (Early), K. Jyoti (Medium), K. Chipsona – 1 (Mid - late), K. Chipsona – 3 (Mid - late) and K. Sindhuri (late) and factor B (seed type) three seed type viz S1. Fresh breeder seed will be used as control every year, S2. Breeder seed will be raised as per “Seed Plot Technique” methodology (Roguing and plant protection measures are taken from time to time). This seed will be carried forward for next year and S3. No roguing and plant protection measures will be taken in this treatment and the seed will be carried forward for next year. The experiment was replicated three times. The observations on various parameters were viz, Emergence (%). No. of shoots per plant, Plant height, No. of leaves per plant, Incidence of viruses (MM, SM and offtype) at 25, 50 and 70 DAP and Counting of virus vectors viz Aphid and whitefly at weekly interval were recorded.

4. Effect of crop duration on the production behaviour of potato cultivars of hills: To study the effect of crop duration on the production behaviour, an experiment was conducted with 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. The total number of tubers/ha was significantly affected by the genotype only. No. of tubers was significantly higher in Kufri Girdhari followed by and at par with Kufri Karan and was minimum in Kufri Jyoti. Although, a gradual increase in the number of tuber with increasing crop duration was noticed but the differences were statistically at par among the crop durations evaluated (Table 8). Like number, yield/ha was also significantly affected by the genotype as well as the crop duration. Yield/ha also showed an increasing trend with increasing crop duration but it was statistically similar with 120 and 140 days' crop duration (Table 8). Yield in Kufri Jyoti and Kufri

Himalini was found to be maximum after 120 days of planting and in Kufri Karn and Kufri Girdhari after 140days. This may be due to the fact that some loss may have occurred beyond 120 days on account of

tuber rotting due to late blight in both these cultivars whereas; maximum yield after 140days in Kufri Karn and Kufri Girdhari is due to their high resistance against late blight.

Table 8: Production behaviour of potato cultivars of hills under different crop durations.

Cultivar	Haulms wt. / m ² (Kg)				Total tubers/ha ('000)			
	Crop duration			Mean	Crop duration			Mean
	100 days	120 days	140 days		100 days	120 days	140 days	
K. Jyoti	2.29	1.05	0.18	1.17	515.0	515.0	484.0	504.7
K. Himalini	2.98	0.35	0.19	1.17	510.0	539.5	552.5	534.0
K. Karn	3.12	1.58	0.34	1.68	523.0	608.5	608.0	579.8
K. Girdhari	2.27	1.68	0.62	1.52	532.5	632.0	689.0	617.8
Mean	2.66	1.17	0.33		520.1	573.8	583.4	
CD 0.05								
Cultivar (A)				0.272	62.1			
Crop duration (B)				0.235	NS			
A x B				0.470	NS			

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

Production and supply of quality seed

1. CPRS, Ooty

- **Production of quality seed during summer 2021:** Summer crop was planted in an area of 1.50 ha with Kufri Swarna, Kufri Girdhari, Kufri

Himalini, and Kufri Sahyadri the total quality seed produced was 8.69t. More problem of PCN was noticed in Kufri Himalini and Kufri Girdhari, whereas, late blight was severe in Kufri Swarna. In addition to this a new problem of leaf miner was severe on Kufri Sahyadri and other varieties which resulted in reduced yield of all the varieties (Table 9).

Table 9: Quality seed production details of summer crop

Summer season crop- 2020-21			
Variety	Area (ha)	Quantity harvested (t)	Average yield (t/ ha)
Kufri Swarna	0.85	4.72	5.55
Kufri Girdhari	0.46	2.35	5.11
Kufri Himalini	0.09	0.73	8.11
Kufri Sahyadri	0.1	0.89	8.9
Total	1.50	8.69	6.91 (Avg.)

Supply of quality seed potato: A total of 21.37 t of quality seed was harvested from seed crop and experimental area during 2020-21 (spring and summer season). Out of which 7.19 t of quality seed was supplied to the farmer's/government agencies, 0.94 t was disposed as table potatoes and miscellaneous to the staff of ICAR- CPRS/ market. About 2.22 t of quality seeds was used for seed and experimental crop during autumn season. Remaining

11.00 t is left for sale, seed crop and experimental crop planting during spring 2021. A total revenue of Rs. 3, 01, 950 /- (Rupees two lakh eighty-nine thousand six hundred and fifty only) was generated during the year 2020 from quality seed tubers.

2. CPRS, Shillong: For quality seed production, Kufri Himalini, K. Jyoti, K. Giriraj, K. Megha, K. Girdhari, K. Kanchan, K. Chipsona-1 and Chipsona-

3 were grown. 1st planting was done on 1st February, 2021, 15 days earlier than the previous year planting. Total lockdown due to pandemic of Covid-19 have a negative impact on labour availability and monitoring of field. A total of 23.06 t was produced

from 2.00 ha area. A total of 79q has been supplied to various stakeholder. 23.99 q has been sold as Table potato. The quality seed supplied to stakeholders of different states are given in table10.

Table 10. Quality seed supplied (q) from CPRS, Shillong to various state (2021-22)

S. No.	Variety	States/ Organisation						Total (q)
		Arunachal Pradesh	ICAR/ CAU UMIAM	CIP	Mizoram	Meghalaya	Tripura	
1	K.Jyoti				4.00	13.50		17.5
2	K.Giriraj	10.00	10.00					20.00
3	K.Girdhari	5.00				10.50		14.5
4	K.Megha		3.00					3
5	K.Himalini	2.00		6.00	2.00	3.00	10.00	23
Total		17.00	13.00	6.00	6.00	27.00	10.00	79

A total of 15,535 mini tubers of notified varieties were produced for further multiplication in the station which will be used for local requirement of the NEH region.



DIVISION OF CROP PRODUCTION

PROGRAMME: CLIMATE CHANGE: IMPACT ASSESSMENT AND ADAPTATION FOR POTATO

Climate change is posing a threat to human existence by affecting every walk of the life, be it the health, food security or the environment. 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 2021 under the programme "Impact, adaptation and management strategies for climate resilient potato production" (concluded in March, 2021) and "Vulnerability and resilience to climate change for sustainable potato production" (initiated w.e.f. April, 2021)

Impact of irrigation and nitrogen management scenario to climate change in potato cultivars in Madhya Pradesh (VK Dua and Paresh Chaukhande)

Simulation studies were carried out using InfoCrop Potato Model for developing adaptation strategies against climate change for Madhya Pradesh (MP) while using three potato cultivars *viz.*, Kufri Badshah

(late), Kufri Jyoti (medium), and Kufri Pukhraj (early maturity groups) at five representative locations (Balaghat, Chattarpur, Khandwa, Mandsaur and Raisen) of the state for RCP 4.5 and RCP 6.0 projection of IPCC – 5AR. In MP, farmers usually apply irrigations (50 mm each) at 7 days interval and 150 kg N/ha in 2 splits (75 kg N/ha each as basal and at 26 days after planting) to potato crop. We carried-out the simulation study for two irrigation schedules [irrigations (50 mm each) at 5 or 7 days interval] and two nitrogen (N) management schedules [150 or 180 kg N/ha in 2 equal splits ($\frac{1}{2}$ N as basal and $\frac{1}{2}$ N at 26 days after planting for potato crop)].

Simulation results showed that under RCP 4.5 when irrigation (50 mm each) was applied at 5 days interval along with N application @ 180 kg/ha in two equal splits the tuber yield of medium maturity cultivar Kufri Jyoti improved by 5.9% in 2030, 5.5% in 2050 and 4.3% in 2080 future climate scenario of temperature and CO₂ fertilization over the farmers' practice. Under similar situation, the productivity in late maturity cultivar Kufri Badshah was improved by 4.4% in 2030, 4.8% in 2050 and 4.8% in 2080 scenario while that of early maturity cultivar Kufri Pukhraj improved to the tune of 5.8, 6.5 and 6.4% under 2030, 2050 and 2080 scenario, respectively over the farmers' practice under RCP 4.5 (Fig. 1).

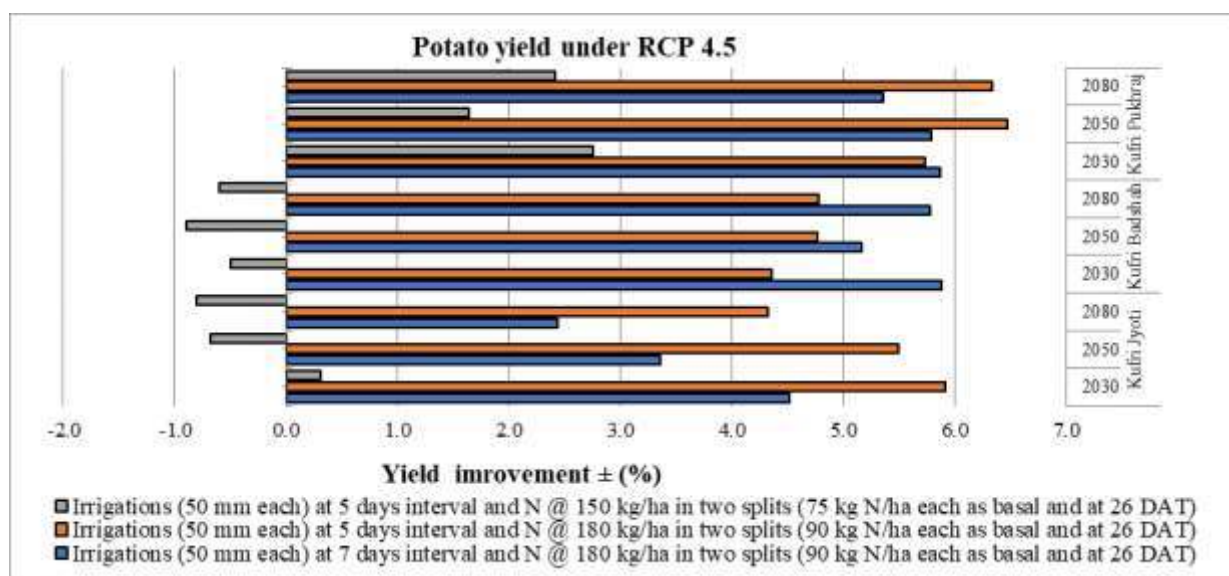


Fig. 1. Projected changes in InfoCrop simulated yield (t/ha) of potato cultivars under refined irrigation and nitrogen management practices compared to farmers' practice under RCP-4.5 in Madhya Pradesh

However, under RCP 6.0, when irrigation (50 mm each) was applied at 7 days interval along with N application @ 180 kg/ha in two equal splits (90 kg N/ha each) model results showed that tuber yield of medium maturity cultivar Kufri Jyoti is likely to improve by 6.5% in 2030, 6.6% in 2050 and 6.0% in 2080 future climate scenario of temperature and CO₂ fertilization over the farmers' practice [irrigations (50 mm each) at 7 days interval and 150 kg N/ha in 2 splits (75 kg N/ha each as basal and at 26 days after planting)]. Under this irrigation and N management,

the tuber productivity in late maturity cultivar Kufri Badshah may improve by 6.2% in 2030, 4.8% in 2050 and 4.2% in 2080 scenario. However, the highest improvement in productivity of early maturity cultivar Kufri Pukhraj is likely when irrigation (50 mm each) is given at 5 days interval along with N @ 180 kg/ha in two splits (90 kg N/ha each as basal and at 26 days after planting) leading to yield improvement by 6.3% each under 2030, 2050 and 2080 scenario, respectively over the farmers' practice under RCP 6.0 (Fig. 2).

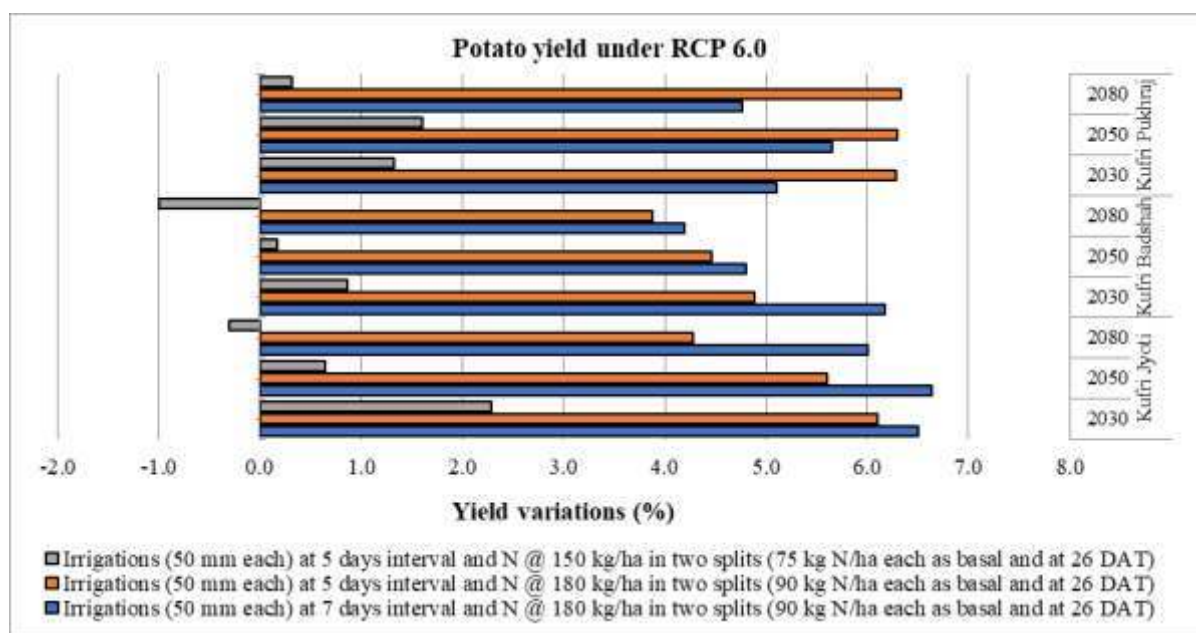


Fig. 2. Projected changes in InfoCrop simulated yield (t/ha) of potato cultivars under refined irrigation and nitrogen management practices compared to farmers' practice under RCP-4.5 in Madhya Pradesh

Estimation of GHG-emissions and carbon footprints under potato production in north-western Himalayas (Anil K Choudhary, VKDua, Jagdev Sharma and Paresh Chaukhande)

During 2020-21, GHG-emissions and carbon footprints under potato production in two hilly states of India i.e. Himachal Pradesh and Uttarakhand in north-western Himalayas were estimated. In first study in Himachal Pradesh, primary data of an 'on-farm' experimentation conducted by CSK HPKV, Farm Science Centre, Sundernagar (HP) during 2006-2011 in Seraj block of Mandi district (HP) in high-hill wet-temperate NW Himalayas under two crop management scenarios [integrated crop management (ICM) vs farmers' practice (FP)] in four potato varieties *viz.*, Kufri Himalini, Kufri Giriraj, Kufri Shailja along with Kufri Jyoti (as check); was used. The energy dynamics, GHG-emissions and

carbon footprints were worked out using the respective equivalents for the farm inputs/operations and the farm output from the recently published work. The ICM technology imbedded with improved potato varieties like Kufri Shailja and Kufri Giriraj; had higher productivity (27.8%) and bio-energy production (58.1%) compared to FP. Total bio-energy input under all the tested potato varieties ranged between 20,583–32,538 MJ/ha with highest magnitude under ICM compared to FP; while energy output varied between 46,161–63,235 MJ ha⁻¹ under ICM and 37,613–45,534 MJ ha⁻¹ under FP among different potato varieties. Under ICM technology, net energy (21879 MJ/ha) and specific energy (2.56 MJ/kg) were higher owing to higher productivity. Total GHG-emission equivalents from the inputs were also higher under ICM (3738.1 CO₂-e kg ha⁻¹) compared to FP (2541.4 CO₂-e kg ha⁻¹) with respective field level emissions of 249.2–339.8 and

232.1–278.4 CO₂-e kg Mg⁻¹ for fresh tuber yield, and 1298–1827 and 1149–1481 CO₂-e kg Mg⁻¹ on tuber dry matter yield basis, respectively (Table 1). Highest

share of total emissions was computed for the seed tubers (34-40%) and the N₂O emissions from the farm (17-23%) both in ICM and FP (Fig. 3).

Table 1. Effect of crop management practices and potato cultivars on carbon footprints of potato cultivation in Himachal Pradesh

Crop management practices	Potato cultivars	GHG-emissions (CO ₂ -e kg ha ⁻¹)									CFy (CO ₂ -e kg Mg ⁻¹)	
		Machinery	Diesel	Human labour	Planting tubers	NPK fertilizers	FYM	Herbicides/fungicides/pesticides	N ₂ O from farm	Total	Fresh tuber yield basis	Dry tuber yield basis
ICM	Kufri Himalini	59.8	239	510.3	1275	580	181.0	51	842	3738.1	339.8	1827.0
	Kufri Giriraj	59.8	239	510.3	1275	580	181.0	51	842	3738.1	287.5	1445.0
	Kufri Shailja	59.8	239	510.3	1275	580	181.0	51	842	3738.1	249.2	1298.0
	Kufri Jyoti	59.8	239	510.3	1275	580	181.0	51	842	3738.1	299.0	1465.9
FP	Kufri Himalini	59.8	239	415.1	1020	290	94.5	2	421	2541.4	278.4	1480.6
	Kufri Giriraj	59.8	239	415.1	1020	290	94.5	2	421	2541.4	250.6	1326.1
	Kufri Shailja	59.8	239	415.1	1020	290	94.5	2	421	2541.4	232.1	1149.0
	Kufri Jyoti	59.8	239	415.1	1020	290	94.5	2	421	2541.4	251.0	1184.0

[**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 Oxiflorofen (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].

Amongst the varieties, highest total carbon input were observed under ICM treatment (1020 kg CE ha⁻¹) compared to FP (693 kg CE ha⁻¹) (Table 2). Under ICM, total carbon output varied between 1273 to 1792 kg CE ha⁻¹ among different varieties with carbon footprints of 0.068–0.093 kg CE kg⁻¹ of fresh tuber yield and 0.354–0.498 kg CE kg⁻¹ of tuber dry matter

yield among different potato varieties with least footprints under Kufri Shailja. FP exhibited carbon footprints of 0.063–0.076 kg CE kg⁻¹ of fresh tuber yield and 0.313–0.404 kg CE kg⁻¹ of tuber dry matter yield among different potato varieties with least footprints again under Kufri Shailja owing to comparatively higher productivity.

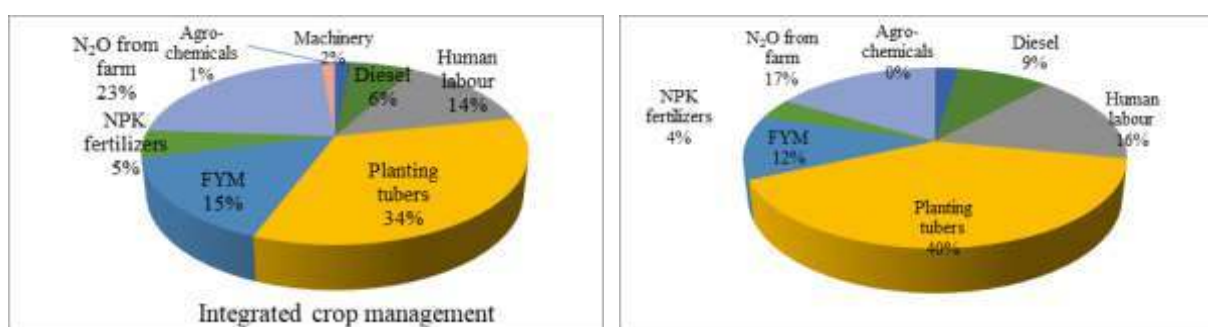


Fig. 3. Influence of integrated crop management technology on carbon footprints of potato cultivation in H.P.

Table 2. Carbon footprints as influenced by crop management and potato cultivars in H.P.

Inputs	ICM					FP				
	Kufri Himalini	Kufri Giriraj	Kufri Shailja	Kufri Jyoti	Mean	Kufri Himalini	Kufri Giriraj	Kufri Shailja	Kufri Jyoti	Mean
Total carbon input (kg CE ha ⁻¹)	1020	1020	1020	1020	1020	693	693	693	693	693
Total carbon output (kg CE ha ⁻¹)	1273	1610	1792	1587	1566	1025	1144	1321	1282	1193
Carbon footprint (kg CE kg ⁻¹ tuber dry matter yield)	0.498	0.394	0.354	0.400	0.412	0.404	0.362	0.313	0.323	0.350
Carbon footprint (kg CE kg ⁻¹ fresh tuber yield)	0.093	0.078	0.068	0.082	0.080	0.076	0.068	0.063	0.068	0.069

The ICM resulted in slightly higher carbon footprints ($0.08 \text{ kg CE kg}^{-1}$ fresh potato tuber yield) compared to FP ($0.069 \text{ kg CE kg}^{-1}$ fresh potato tuber yield) due to higher carbon inputs used in plant nutrition, crop management and plant protection measures. The total carbon output under ICM was $\sim 31.3\%$ higher over FP, indicating that ICM adoption may be a possible mitigation strategy to climate change owing to higher carbon sequestration under ICM. Overall, ICM is a better option over FP w.r.t. potato productivity, bio-energy and carbon output in diverse potato production systems of Himachal Pradesh in wet-temperate NW Himalayas.

In second study in Uttarakhand, we used the primary data of a field experiment conducted by the GPBUAT, College of Horticulture, Bharsar (UK) in high-hill wet-temperate NW Himalayas in a randomized block design replicated 5-times during 2007-2011 under six nutrient management practices [T_1 = control

($N_0P_0K_0$); T_2 = FYM @ 25 t ha^{-1} + microbial consortia (MC); T_3 = chicken manure (CM) @ 7.5 t ha^{-1} + MC; T_4 = vermicompost (VC) @ 10 t ha^{-1} + MC; T_5 = FYM @ 10 t ha^{-1} + CM @ 2.5 t ha^{-1} + VC @ 2.5 t ha^{-1} + MC; and T_6 = FYM @ 10 t ha^{-1} + chemical fertilizers to meet remaining 100% RDF of $N_{150}P_{75}K_{75}$ + MC]. It was observed that T_6 exhibited highest total tuber yield (23.43 t ha^{-1}) and marketable tuber yield (22.22 t ha^{-1}), followed by T_3 , T_5 , T_4 , and T_2 , respectively. The GHG-emissions and carbon footprints were worked out using the respective equivalents for the farm inputs/operations and the farm output from the recently published work. The judicious combination of organic and inorganic fertilizers in T_6 enhanced the total tuber yield by 3.7, 25.9, 51.3, 84.9, and 153% over T_3 , T_5 , T_4 , T_2 , and T_1 , respectively. Highest total GHG-emission equivalents from the inputs were observed under T_2 ($2831 \text{ CO}_2\text{-e kg ha}^{-1}$) compared to other treatments (Table 3; Fig. 4).

Table 3. Effect of nutrient management practices on carbon footprints of potato cultivation in Uttarakhand (5-years' mean.)

Practices	Carbon footprints ($\text{CO}_2\text{-e kg ha}^{-1}$)								Tuber yield (t/ha)		CFy ($\text{CO}_2\text{-e kg Mg}^{-1}$)	
	Machinery	Diesel	Human labour	Planting tubers	FYM	NPK	Microbial consortia	Total			Fresh tuber yield basis	Dry tuber yield basis
T_1	60	239	365	1275	0	0	0	1939	9.26	1.17	209.5	1662.6
T_2	60	239	493	1275	725	0	39	2831	12.67	2.00	223.4	1414.0
T_3	60	239	583	1275	218	0	39	2414	22.60	4.54	106.8	531.5
T_4	60	239	491	1275	290	0	39	2394	15.49	2.77	154.5	863.3
T_5	60	239	584	1275	435	0	39	2632	18.61	3.61	141.5	729.2
T_6	60	239	619	1275	290	136	39	2658	23.43	4.78	113.4	556.1

[Note: T_1 = Control; T_2 = FYM @ 25 t ha^{-1} + MC; T_3 = Chicken manure (CM) @ 7.5 t ha^{-1} + MC; T_4 = Vermicompost (VC) @ 10 t ha^{-1} + MC; T_5 = FYM @ 10 t ha^{-1} + CM @ 2.5 t ha^{-1} + VC @ 2.5 t ha^{-1} + MC; and T_6 = FYM @ 10 t ha^{-1} + chemical fertilizers to meet remaining 100% RDF ($N_{150}P_{75}K_{75}$) + MC]

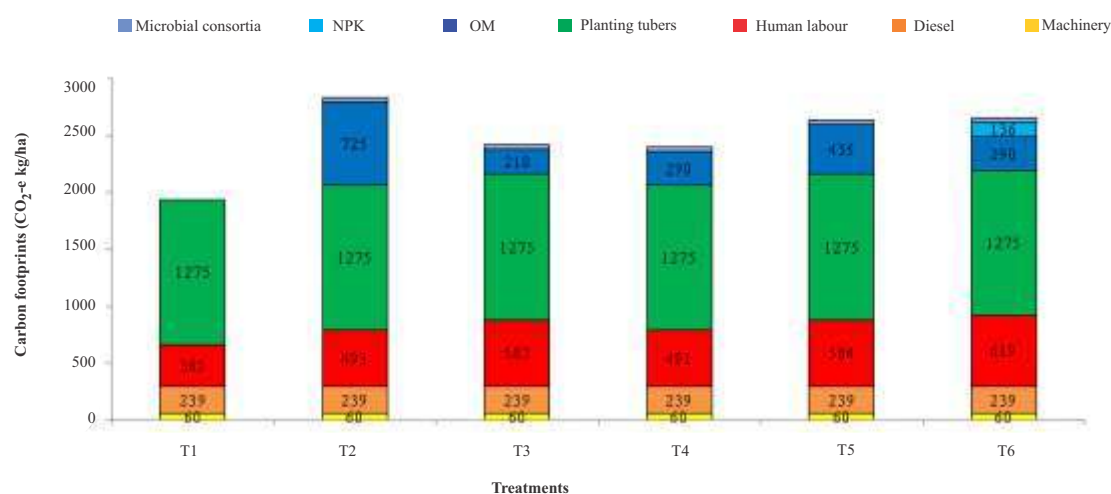


Fig. 4. Influence of nutrient management practices on carbon footprints of potato cultivation in Uttarakhand
[Note: T_1 = Control; T_2 = FYM @ 25 t ha^{-1} + MC; T_3 = Chicken manure (CM) @ 7.5 t ha^{-1} + MC; T_4 = Vermicompost (VC) @ 10 t ha^{-1} + MC; T_5 = FYM @ 10 t ha^{-1} + CM @ 2.5 t ha^{-1} + VC @ 2.5 t ha^{-1} + MC; and T_6 = FYM @ 10 t ha^{-1} + chemical fertilizers to meet remaining 100% RDF ($N_{150}P_{75}K_{75}$) + MC]

The field level emissions were least under organic treatment T_3 and INM treatment T_6 with 106.8 and 113.4 $\text{CO}_2\text{-e kg Mg}^{-1}$ for fresh tuber yield, and 531.5 and 556.1 $\text{CO}_2\text{-e kg Mg}^{-1}$ for tuber dry matter yield basis, respectively (Table 2). Highest share of total emissions was computed for the seed tubers and human labour in Uttarakhand hills (Fig. 4). In general, INM practice T_6 [FYM @ 10 t ha^{-1} + chemical fertilizers to meet remaining 100% RDF Mg^{-1} ($\text{N}_{150}\text{P}_{75}\text{K}_{75}$) + MC] proved better option over organic nutrient management practices w.r.t. potato productivity and carbon footprints in Uttarakhand hills in wet-temperate NW Himalayas.

Effect of elevated temperature on tuber yield and carbon dynamics in soils with different organic amendments (Anil Sharma, Prince Kumar, VK Dua, Jagdev Sharma and Anil K Choudhary)

Rise in ambient temperature pose a great concern to potato production in India. Rate of mineralization would affect the soil organic carbon content (SOC) in the anticipated changing climatic scenario. Addition of organic amendments may sustain the SOC besides influencing tuber yield. Hence, an experiment was planned to study the impact of organic amendments on tuber yield of cv. Kufri Jyoti under rising temperature ($+3^\circ\text{C}$) under OTC. The organic amendments comprised of vermicompost or paddy straw (Fig. 5). A clear-cut decline in tuber yield was noticed with a rise in temperature. It was also observed that the extent of decrease in tuber yield was more with vermicompost compared to chopped paddy straw incorporation. The extent of decrease was ~ 2.0 and 3.9 t ha^{-1} with paddy straw incorporation and vermicompost application, respectively (Fig. 6). A non-significant effect on SOC was noticed during first year of the experimentation.



Fig. 5. Micro-plots inside the Open top Chambers

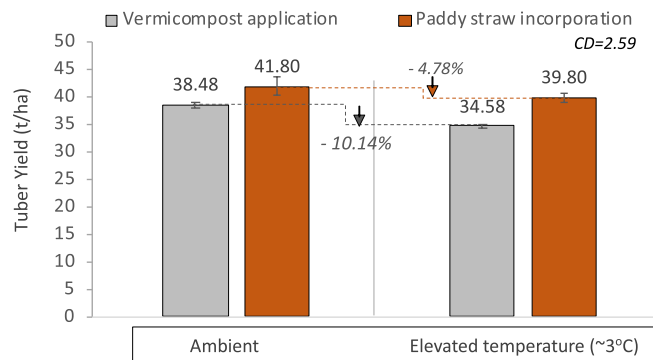


Fig. 6. Effect of elevated temperature on tuber yield in soils with different organic amendments

Improved agronomic practices for counteracting the climate change impact on potato productivity (Name Singh, SP Singh, Sanjay Rawal, Devendra Kumar and Vijay Paul)

Field studies were conducted at Modipuram with cv. Kufri Bahar during *rabi* 2020-21 with two water levels under drip irrigation (75 & 125% CPE) and sprinkler irrigation (100 & 150% CPE) in three mulching treatments (no mulch, paddy straw mulch @ 5 t/ha and black polythene mulch). Results revealed that the drip irrigation applied at 125% CPE (cumulative pan evaporation) produced significantly higher total tuber yield (30.3 t ha^{-1}) compared to 75% CPE (28.5 t ha^{-1}) (Fig. 7). Similar trend was also noticed in case of large size tuber yield; and the reverse trend was noticed in case of medium and small size tuber yields. However, the effect of water levels on production of total tubers as well as grade-wise tuber number ha^{-1} was non-significant. The paddy straw and polythene mulch showed significant effect on total tuber yield as well as large and medium grade tuber yield, however, total tuber number ha^{-1} did not differ significantly with mulch under drip irrigation. Application of paddy straw mulch @ 5 t/ha gave higher yield (31.7 t ha^{-1}) compared to black polythene mulch (29.8 t ha^{-1}), although, the interaction effect was non-significant on total tuber yield and tuber number ha^{-1} as well as graded tuber yield and tuber number ha^{-1} .

Sprinkler irrigation applied at 150% CPE produced significantly higher total tuber yield and tuber number (30.4 t ha^{-1} and 668 thousand ha^{-1}) as compared to 100% CPE (29.2 t ha^{-1} and 608 thousand ha^{-1} , respectively). 150% CPE water level was also found statistically superior over 100% CPE. Similar trend was noticed in case of medium size tuber yield. However, the effect of water levels on

small size tuber yield and tuber numbers was non-significant. The effect of mulching was significant on total tuber yield and tuber numbers as well as large and medium grade tuber yield and tuber number. Paddy straw and black polythene mulch, both showed significant effect on total tuber yield and numbers under sprinkler irrigation. Application of paddy straw mulch @ 5 t/ha gave higher yield (31.8 t

ha⁻¹) followed by polythene mulch (30 t ha⁻¹) and no mulch (27.7 t ha⁻¹) (Fig. 8). Similar trend was also noticed in case of large and medium grade tuber yield and tuber numbers. However, the interaction effect of water levels and mulch on tuber yield and tuber numbers was non-significant.

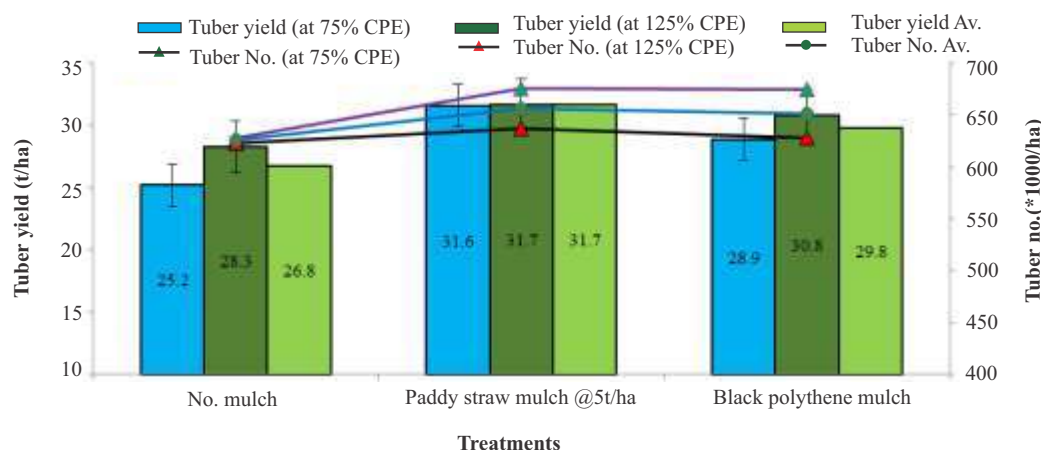


Fig. 7. Potato yield and tuber numbers as influenced by different water levels and mulching practices under drip irrigation

At Gwalior; cv. Kufri Jyoti was planted under drip and sprinkler systems in paired-row system on raised beds to study the effect of chemical formulation (CFs) and mulch treatments to mitigate water stress. Under drip irrigation at 75% CPE, the highest number of total tubers of all grades (549 thousands ha⁻¹) was recorded with spray of CFs which was closely followed by polythene mulch treatment (453 thousandsha⁻¹). Similarly, highest total tuber yield (25.9 t ha⁻¹) was recorded with polythene mulch which was closely followed by spray of CFs and paddy straw mulch. At 125% CPE in drip irrigation, the highest total tuber numbers (505 thousands/ ha⁻¹) were recorded with polythene mulch which was closely followed by no mulch. The highest total tuber yield (29.7 t ha⁻¹) was recorded with polythene mulch which was closely

followed by paddy straw mulch and no mulch. Under sprinkler irrigation system at 100% CPE, highest tuber numbers (581 thousands ha⁻¹) were recorded with paddy straw mulch treatment which was closely followed by polythene mulch treatment. At the same water level, the highest total tuber yield (33.7 t ha⁻¹) was recorded with paddy straw mulch which was closely followed by polythene mulch. At 150% CPE, the highest total tuber numbers (596 thous. ha⁻¹) recorded without mulch which was closely followed by polythene mulch. Similarly, the highest tuber yield (34.3 t ha⁻¹) was recorded with polythene mulch which was closely followed by no mulch.

Chemical formulation (*CFT*₂) evaluated at Modipuram and Gwalior earlier had promising

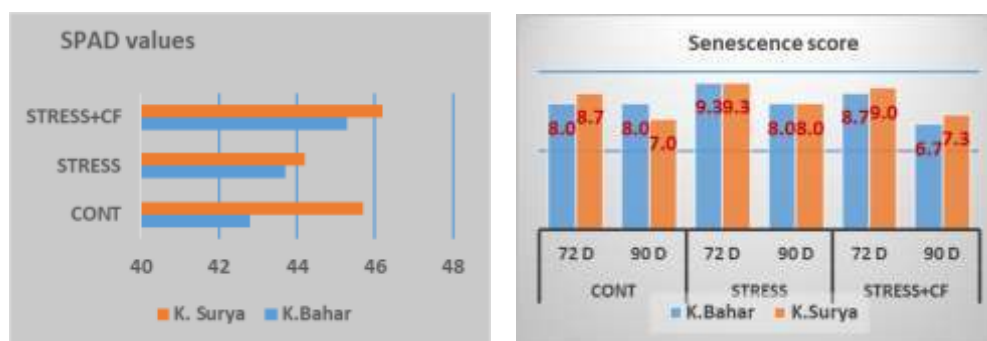


Fig. 9. Effect of foliar application of chemical formulation on leaf vigor/ nutritional status (SPAD value) at 70 DAP and mean plant senescence score (on a scale of 1 to 10, where 10=100 % green and 1= fully mature foliage) during progressive crop growth at 72 and 90 DAP. (Where, CONT=Well watered control, STRESS= water stress, STRESS+CF=water stress+CF foliar spray)

results for sustaining tuber yield and quality (reduced tuber defects) under water stress. Keeping this in view, CFT_2 was evaluated along with water spray in a 90-day field trial using cv K. Bahar & K. Surya under water deficit (about 20% less watering) in 90 days winter crop planted on October 28, 2020. Water stress was imposed by delayed (8-10 days) watering and two foliar sprays each at 35 and 68 DAP. The impact of mild stress (20% less water) was noticed in reduction of total tuber yield which ranged between 18-20%. Impact of CF was visible in mitigating the adverse effect of drought stress as less yield reduction was noticed by 8-10% in both potato varieties. The leaf vigor/nutritional status (SPAD value) during active tuber development (70 DAP) in CF treated stressed plants was better than control (Fig.9) and more photosynthates were made available to the developing tubers, particularly in small size (< 25g) during post stress period. Higher senescence (lower mean score 6.7 and 7.3 in K. Bahar and K. Surya, respectively, as compared to 8.0 under stress at 90 days), particularly at the terminal end of the crop, in CF treated plants (Fig. 9) appeared to help in mobilizing the photosynthates accumulated in the vines to the developing tubers and minimize the loss in yield under stress condition.

These results suggest that the improved chemical formulation CF (namely CFT_2) exhibits great potential in mitigating the adverse impact of water stress, imposed through delayed irrigation, on tuber yield. In conformity with last two years results, Kufri Surya responded better than K. Bahar to the formulation tested under water stress.

Periodic generation of data on arrival and build-up of aphid and whitefly population in potato (Subhash S, Anuj Bhatnagar and VK Dua)

The population of peach-potato aphid, *Myzus persicae* (Sulzer) other aphid species, and white fly was monitored at weekly interval in unsprayed potato fields in early planted (September planting) and main crop (October planting) at Modipuram from 3rd week of October, 2020 till first week of January 2021. In the early crop, aphids first appeared on the potato plants in the third week of October and crossed the threshold limit in the 3rd and 4th week of October (Fig. 10a). The aphid population started to decline afterwards and did not cross threshold level. The population of the aphids started out as 47 aphids per 100 compound leaves in the 3rd week of October. The

population declined thereafter and fluctuated between 01 to 29 aphids per 100 compound leaves. The population of whitefly adults showed a general decline in population over time which begun high

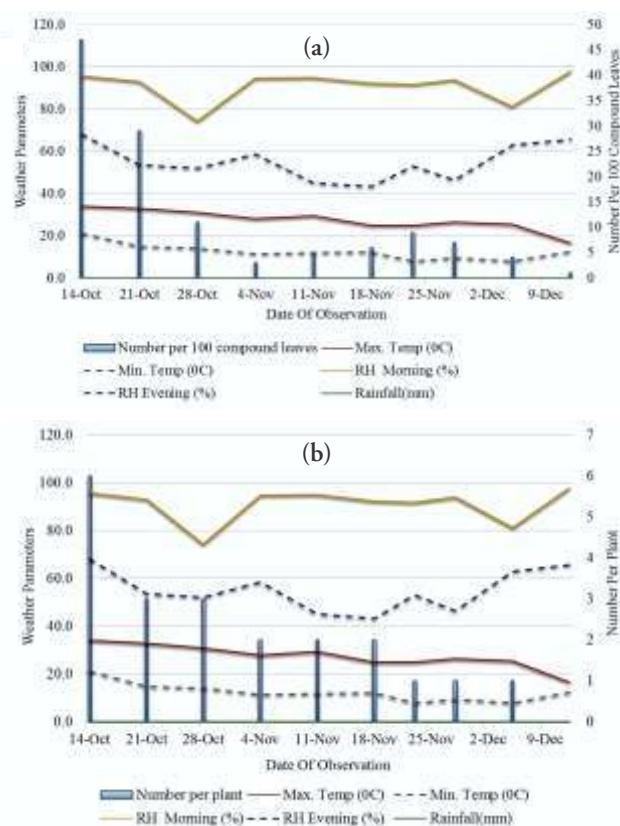


Fig.10. Population dynamics of the (a) aphids and (b) whiteflies on early potato crop (September planted) at CPRI RS, Modipuram (2020-21)

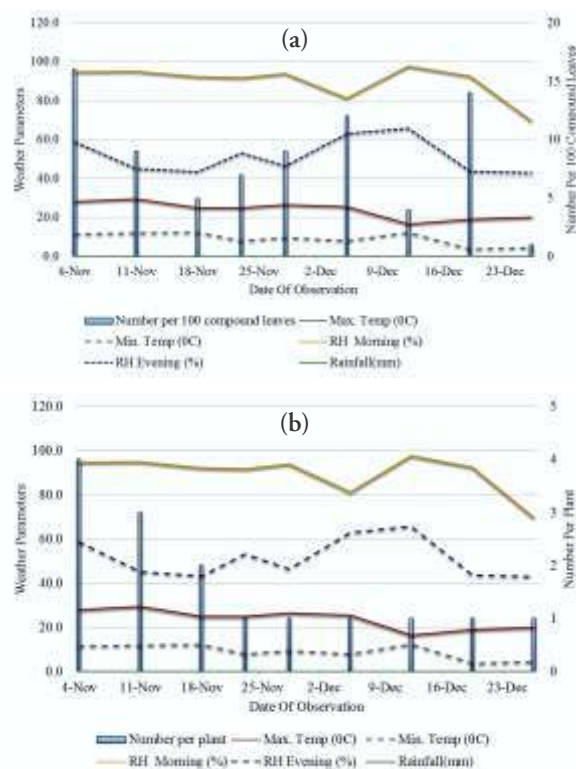


Fig. 11. Population dynamics of the (a) aphids and (b) whiteflies on main potato crop (Dp- October planted) at CPRI RS, Modipuram (2020-21)

initially (Fig. 10b). The population remained above economic threshold (2 per plant) till the 3rd week of November and after that, less than 2 whiteflies per plant were recorded. The temperature varied from 34°C with 96% RH in the third week of October to 16.5°C with 98% RH in the second week of December. The buildup of population of aphids and whiteflies directly correlated with temperature (Fig.10).

In the main crop, aphids first appeared on the potato plants in the first week of November, 2020 and did not cross the threshold limit till the haulm cutting (Fig. 11a). The population of the aphids started out as 16 aphids per 100 compound leaves and fluctuated between 2 to 14 aphids per 100 compound leaves. The population of whitefly adults showed a general decline in population over time (Fig. 11b) but it remained above economic threshold (2 per plant) till the 3rd week of November, later less than 2 whiteflies per plant were recorded. The temperature varied from 28°C with 95% RH in the first week of November to 17.6°C with 87.3% RH in the first week of January. The build-up of population of aphids and whiteflies directly correlated with temperature.

Effect on late blight incidence on different level of resistance cultivars at different dates of planting (Mehi Lal and VK Dua)

An experiment was conducted on seven potato varieties with differential resistance to late blight *viz.* Kufri Girdhari, Kufri Himalini, (High level of resistance to late blight), Kufri Chipsona-1, Kufri Garima and Kufri Mohan (medium level of resistance to late blight) and Kufri Bahar and Kufri Sindhuri (highly susceptible to late blight) during (2017-18 to 2020-21) to assess their behavior against *Phytophthora*

infestans under different climate change scenarios. Planting was done at three different dates (17th Oct., 2nd Nov. and 17th Nov.). Under laboratory condition, by detached leaf test, lesion area was measured after challenge inoculation of *P. infestans* and difference was observed among the varieties with three dates of planting. Higher lesion area was observed on 17th October and 2nd November planting than 17 Nov. planting. The result revealed that under highly susceptible group, AUDPC was highest on 17th November followed by 17th October on both Kufri Bahar and Kufri Sindhuri (Fig.12). The trends of results differed from 2019-20. In medium level of resistance (Kufri Chipsona-1, Kufri Garima and Kufri Mohan), AUDPC was highest on 17 Oct. followed by 2nd November and 17th November date of planting except on Kufri Garima. Similar trend was also found during 2019-20. In high resistant variety, Kufri Girdhari, highest AUDPC was recorded on 17th November followed by 2nd November and 17 October date of planting, whereas on Kufri Himalini, highest AUDPC was recorded on 2 November followed by 17th October and 2nd November planting. These variations in AUDPC may be due to make up of different genes structure of the varieties and environmental conditions which existed at different dates of planting. Now this study has been concluded (after four years experimentation) on the basis of laboratory and field results that at higher temperature, varieties with different level of resistance will behave in different ways against *P. infestans*. Resistant level of the varieties may be affected due to changing pattern of climatic conditions over the years, for example resistant cv. Kufri Himalini showed higher level of disease severity. For deeper understanding actual causes behind this, further in depth study is required.

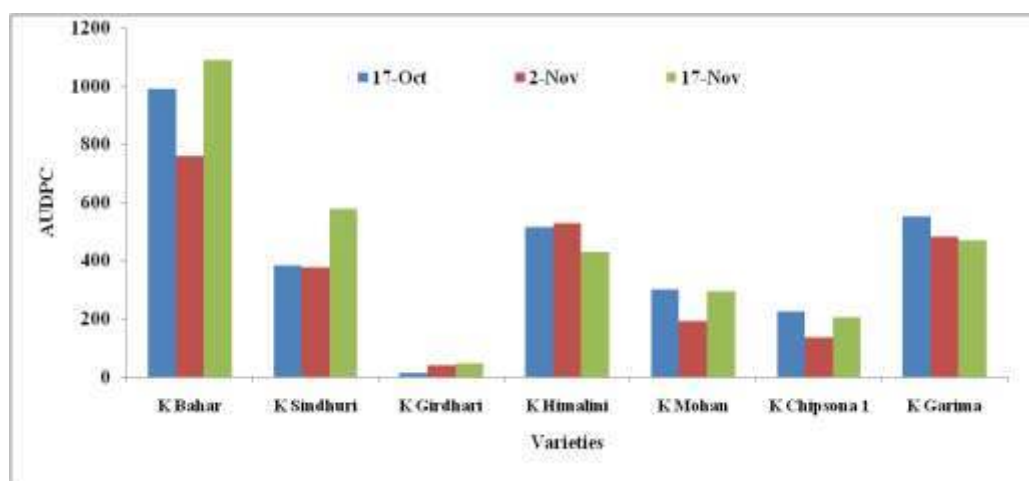


Fig 12. Area Under Disease Progress Curve (AUDPC) of seven cultivars at different climatic conditions



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

Fertilizers application in potato account for a major component of production cost as efficiency of applied nutrients is quite low in this crop. Under application of fertilizers results in low economic returns whereas over application of fertilizers besides increasing production cost, also causes environmental hazards, creates nutrient imbalances and degrades soil health. Thus, under this program experiments were conducted for enhancing nutrient use efficiency, Nutrient management options using crops, organic and inorganic sources of fertility and micro irrigation methods to reduce the excessive use of inputs especially irrigation water and chemical fertilizers through agronomic manipulations in potato and to develop low cost production technology and for judicious use of fertilizers in different regions of the country. Studies were also conducted to determine starter dose of P fertilizers, and foliar and split application of potassium.

Experiments on developing low cost technology capsule using organic and inorganic sources of nutrients and micro-irrigation methods.

(Name Singh, Manoj Kumar, SP Singh, Prince Kumar, Sunayan Saha, RK Singh)

Potato yield and tuber quality, both largely depends upon available soil moisture and nutrients in surface soil which can be achieved only by adopting better agro-techniques. Improved agro-techniques includes micro irrigation, integrated use of organic and inorganic fertility sources, FYM & crop residues (CR), raising of green manure and pulse crop which may improve soil fertility and soil productivity for cost effective quality output in potato. The studies on nutrient management options using GM/pulses, organic and inorganic sources of NPK with drip, sprinkler and furrow irrigation in potato at Modipuram revealed that drip irrigation produced maximum yield (32.9 t ha⁻¹) and tubers (632 thousands ha⁻¹) against furrow irrigation (28.3 t ha⁻¹). Sprinkler method was found intermediate in category (30.8 t ha⁻¹). In case of fertility levels, 100% NPK produced higher yield (30.6 t ha⁻¹) than other fertility options, however, CR (5 t/ha) +15 t FYM+ biofertilizer (BF) produced significantly less tuber yields under all irrigation methods (Table 4). Application of 180 kg N/ha and recommended irrigations (TWA 382 mm) produced significantly higher yield (33.9 t ha⁻¹), if water is constrain, then applying irrigations at critical crop stages with

recommended N and 15 t FYM/ha saved 26% water which produced tuber yield of 31.8 t ha⁻¹. Similar trend was also noticed in case of total tuber and graded tuber yield. Another experiment conducted to work out new variety specific water and NPK requirement of potato revealed that irrigation given at 20 mm CPE produced significantly higher tuber yield (32.8 t ha⁻¹) and numbers (766 thousands ha⁻¹) of potato cultivar Kufri Thar -3. 100% recommended NPK produced higher tuber yield and numbers (33.3 t and 713 thousands ha⁻¹) followed by 75% P+100% NK (32.0 t and 734 thousands ha⁻¹).

Table 4. Effect of irrigation methods & fertility options on potato at Modipuram

Treatment	Potato yield (t/ha)			Mean yield (t/ha)
	Furrow irrigation	Sprinkler irrigation	Drip irrigation	
100 % of NPK	28.3	30.8	32.9	30.6
75 % of NPK & preceding pulse	25.9	24.6	29.0	26.5
75 % of NPK & preceding GM	25.8	25.8	29.6	27.1
50 % of NPK + 15 t FYM/ha	25.1	26.4	30.3	27.3
CR + BF + 15 t FYM/ha	18.5	20.4	18.1	19.0
Mean	24.7	25.6	28.0	-
CD at 5%	Irrigation (I)=1.9	Fertility (F)=2.1	I X F = NS	

At Gwalior, the highest tuber yield (40.2 t/ha) was obtained with application of 75% RDF NPK followed by 50% RDF NPK+15 t FYM/ha (39.6 t/ha) and 100% RDF NPK (39.2 t /ha). However, the highest tuber numbers (712 thousands /ha) were recorded with 100% RDF NPK. In case of irrigation, the highest yield (43.0 t/ha) and tubers (708 thousands/ha) were obtained with drip irrigation followed by furrow irrigation (37.3 t and 657 thousands/ha) and sprinkler irrigation (32.0 t and 657 thousands/ha). Similar trend was also noticed in case of marketable yields (Fig. 13).

Studies on assessment of consumptive water use pattern and exploring water efficient technologies for potato under changing hydro-climatic regimes.

(Sunayan Saha, Name Singh, VK Dua, SP Singh, RK Singh, Prince Kumar, Jagdev Sharma, Anil Sharma, Manoj Kumar Nanda, Brajesh Nare): Experiments initiated during rabi season of 2020-21 at Jalandhar & Gwalior to assess the consumptive water use pattern of potato and evaluate different chemicals

(PGRs) and paddy straw mulch for yield under drip irrigation, revealed that effect of crop stage specific and weather based variable rate drip irrigation (VRDI), drip irrigation (DI @ 100% ET_{ref}), drip irrigation (DI @ 75% ET_{ref}), drip irrigation (DI @ 50% ET_{ref}) was non-significant on tuber yields

which ranged between 22.9 -24.2 t ha⁻¹, but the highest value was observed in drip irrigation @ 100 % ET_{ref}. An MS-Excel based protocol/methodology (for weather based irrigation scheduling in potato has been developed to implement the treatments of experiments (Table 5 , Fig.14).

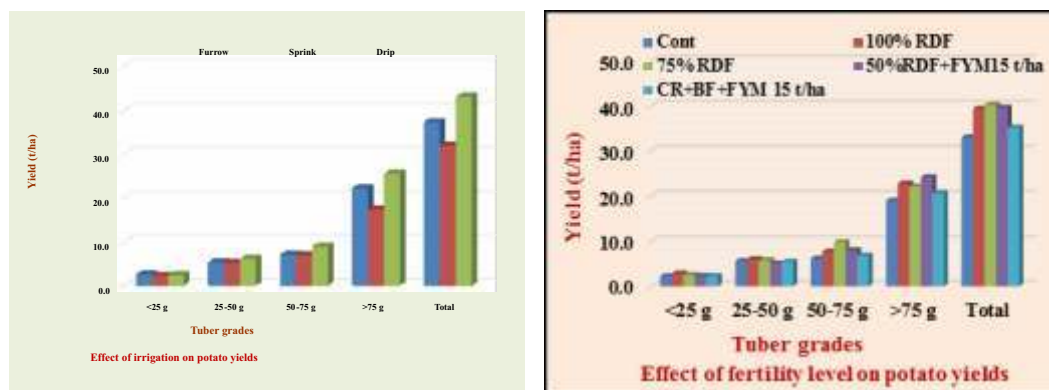


Fig.13. Effect of irrigation methods and fertility levels on potato yield

Table 5. Input and output details of the irrigation scheduling methodology

<i>Data at Daily Time Scale</i>	<i>Data at Monthly Time Scale</i>	<i>Constants</i>
I. Maximum Temperature (°C) II. Minimum Temperature (°C) III. Mean Temperature (°C) IV. Mean Relative Humidity (°C) V. Wind Speed (at 3 m height) (m s ⁻¹) VI. Insolation (MJ m ⁻²)	I. Extraterrestrial radiation at the top of atmosphere (MJ m ⁻²)	I. Latitude (in degree decimal) II. Longitude (in degree decimal) III. Altitude above mean sea level (m) IV. Angstrom coefficients (a, b) [unit less] V. Ground albedo VI. Dripper Spacing (cm x cm) VII. Crop Coefficients for initial, mid-development and senescence growth stages
Output: Irrigation requirement for the potato crop in terms of total volume of water discharge (ml) required per dripper on daily basis		

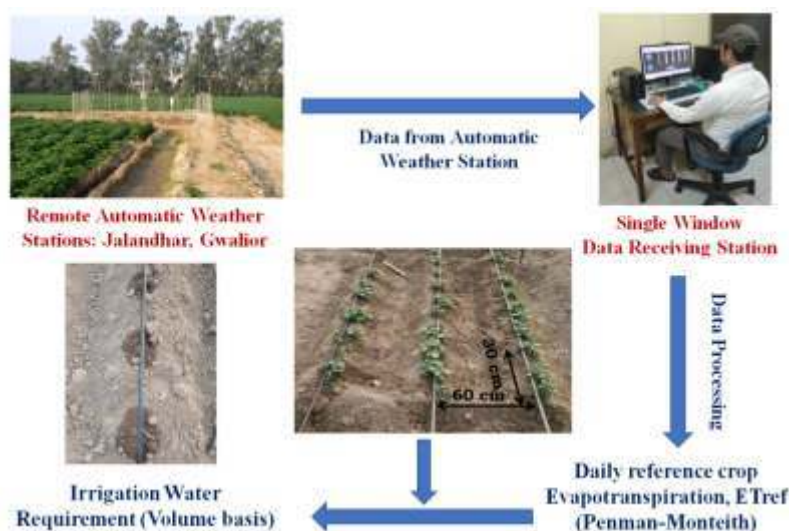


Fig. 14. Schematic diagram of irrigation scheduling protocol for potato crop at Jalandhar & Gwalior

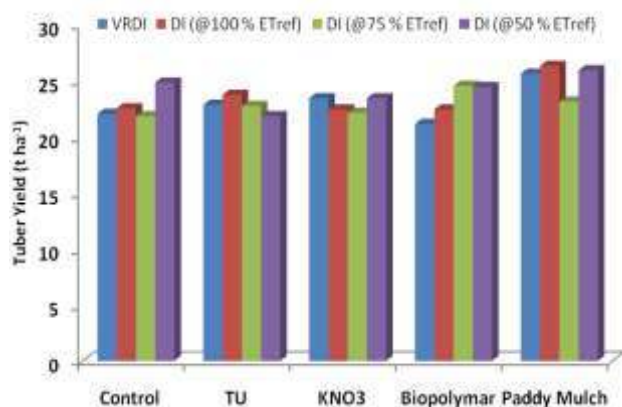


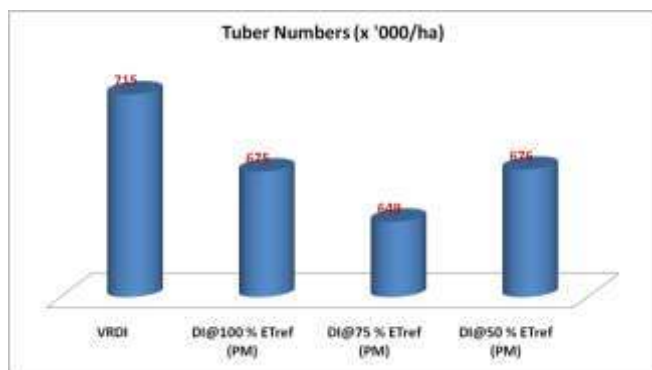
Fig.15. Tuber yields under various irrigation scheduling, and chemicals & paddy straw mulch treatments at Jalandhar

At Gwalior, Kufri Jyoti was raised as a table crop under drip fertigation system in split plot design. Among irrigation scheduling methods, highest yield and tuber numbers were obtained under variable rate drip fertigation. The mulch application sub-treatment gave significantly higher yield than control, however, the maximum yield was observed under microbial biopolymer formulation treatment (Table 6). In case of tuber numbers, mean values were higher in all chemical and mulch treatment plots as compared to control and the highest was in microbial biopolymer treatment followed by paddy straw mulch (Fig. 16. a,b).

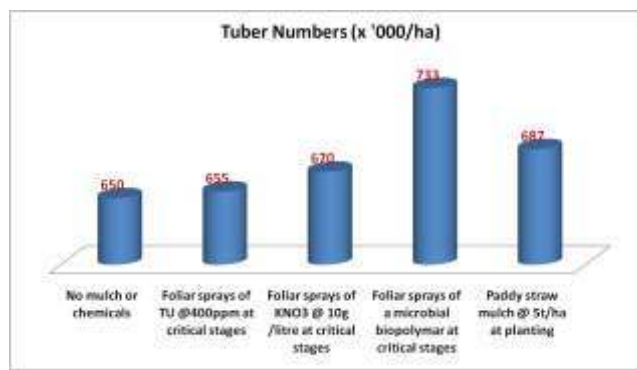
Table 6. A 2-way table on tuber yields under various irrigation scheduling with and without chemical or mulch treatments at Gwalior

Main (M) / Sub Treatment (S)	S1 (Control)	S2 (TU)	S3 (KNO3)	S4 (Biopolymer)	S5 (Mulch)	Means Main-plot
M1 (VRDI)	48.3	50.3	47.6	58.1	49.2	50.7
M2 (DI @ 100 % ETref-PM)	38.1	48.6	46.3	49.3	44.0	45.2
M3 (DI @ 75 % ETref-PM)	33.4	42.0	51.2	46.8	46.6	44.0
M4 (DI @ 50 % ETref-PM)	44.1	47.5	49.0	46.9	42.4	46.0
Means Sub-plot	41.0	47.1	48.5	50.2	45.5	

CD (5%) for main-treatments, sub-treatments and interactions were Non-Significant (NS), 4.9 and NS, respectively



(a)



(b)

Fig. 16. Tuber numbers (composite) under various irrigation scheduling (a) and chemicals or paddy mulch treatments (b) at Gwalior

Field experiment was carried out at ICAR-CPRS, Jalandhar to study the water productivity of potato in different irrigation scheduling strategies and usefulness of various chemicals and paddy mulching in enhancing yield under water stress condition. Potato yields with foliar sprays of Thio-Urea @ 400 ppm; KNO₃ @ 10 g L⁻¹ and microbial bio-polymer

formulation @ 150 ml L⁻¹ (developed at ICAR-NIASM) at critical crop stages (30, 50 & 65 DAP; and for biopolymer one extra dose applied at 75 DAP), and paddy straw mulch @ 5 t/ha treatments did not differ significantly (Fig. 15). However, among sub-plots, composite tuber yield was highest under paddy straw mulch (25.3 t ha⁻¹) followed by microbial

biopolymer (23.2 t ha^{-1}). The dynamic plant parameters, plant heights under paddy straw mulch treatment were significantly higher as compared to other treatments at 49, 68 and 78 DAP. Water productivity varied between 206 to 228 kg/ha-mm under sub-plot treatments.

Studies on trace and heavy metals

(Jagdev Sharma, VK Dua and S Rawal)

Metal content

in the tubers is affected by the fertilizer sources. Thus, the effect of organic and inorganic production practices on heavy metal content in potato tubers was studied. Effect of organic and inorganic production practices on tuber arsenic and cadmium concentration (ppb) 10 varieties. Although large variations were observed in heavy metal content (Pb, Cd, As, Cr) amongst varieties, the concentrations were within safe limits under both the production systems. Under inorganic production system the concentration of Cd and arsenic was slightly higher (Fig. 17).

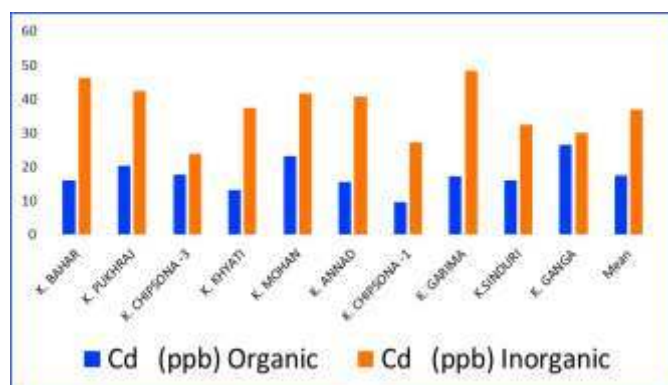


Fig. 17. Effect of organic and inorganic production practices on tuber arsenic and cadmium concentration (ppb)

Studies on graded doses of P and rice husk ash

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

Efficient use of phosphorus (P) fertilizers is essential, since it is a non-renewable resource and crucial for maintaining high productivity of potatoes as P use efficiency in potato is quite low. Further, there is a huge pressure on natural resources and a large amount of these fertilizers is being imported. Rice husk Ash (RHA) is a waste of rice husk mills and is abundantly available and can play an important role in improving use efficiency of nutrients like phosphorus. Keeping this in view, a field experiment using graded doses of phosphorus + RHA was conducted at CPRS

Effect of foliar sprays of selenium: Although it has not been confirmed to be an essential micronutrient in higher plants, but there is increasing evidence that Se functions as an antioxidant in plants. Selenium has been shown to exert a positive effect on crop growth and stress tolerance at low concentrations (Fig. 18). Besides, the Se (selenium) also plays an important role in plant and human health. Hence, the preliminary studies were conducted to standardize the selenium doses for foliar sprays and its effect on plant growth under moisture stress. The single spray of Selenium was found beneficial in moisture stress in pot studies. Mid-day relative leaf water content was significantly higher (24-30%) in plants receiving foliar application of selenium. The chlorophyll content was also higher in plants receiving foliar applications of Se. Foliar application of selenium also increased its content significantly in tubers.



Fig 18. Effect of foliar application of selenium under moisture stress LHS (unsprayed) and RHS (sprayed)

Jalandhar during 2020-2021. First year data revealed a significantly higher tuber yield (30.5 t/ha) with 20 t/ha RHA applied along with 75% of recommended P dose compared to 75% P dose alone which gave 26.65 t/ha (Fig. 19).

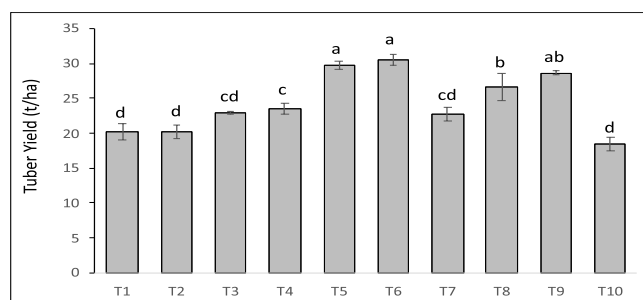


Fig. 19. Effect of graded doses of P and RHA (T1: 10 ton RHA + P_0 , T2: 20 ton RHA + P_0 ; T3: 10 ton RHA + $P_{50\%}$, T4: 20 ton RHA + P_{50} ; T5: 10 ton RHA + P_{75} ha; T6: 20 ton RHA + P_{75} ; T7: P_{50} , T8: P_{75} , T9: P_{100} ; T10: $N_{100}P_0K_{100}$ per ha)

Improving phosphorus use through co-inoculation of AM-fungi and PSB in potato

(Anil K Choudhary, Jagdev Sharma, VK Dua, Dharmendra Kumar, Name Singh)

In case of phosphorus, poor native-P status, low solubility and efficiency across acid soils, greatly limit the potato growth, yield and quality. Phosphorus-solubilizing bacteria (PSB) and AM-fungi hold great potential in solubilization and mobilization of native

and applied-P. Hence, a glass-house pot experiment was conducted during *Kharif*2020 & 2021 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 revealed that application of P_{50} +AMF+PSB exhibited significantly higher mycorrhizal root colonization (69%) in potato though it remained at par with P_{50} +AMF (Fig. 20).

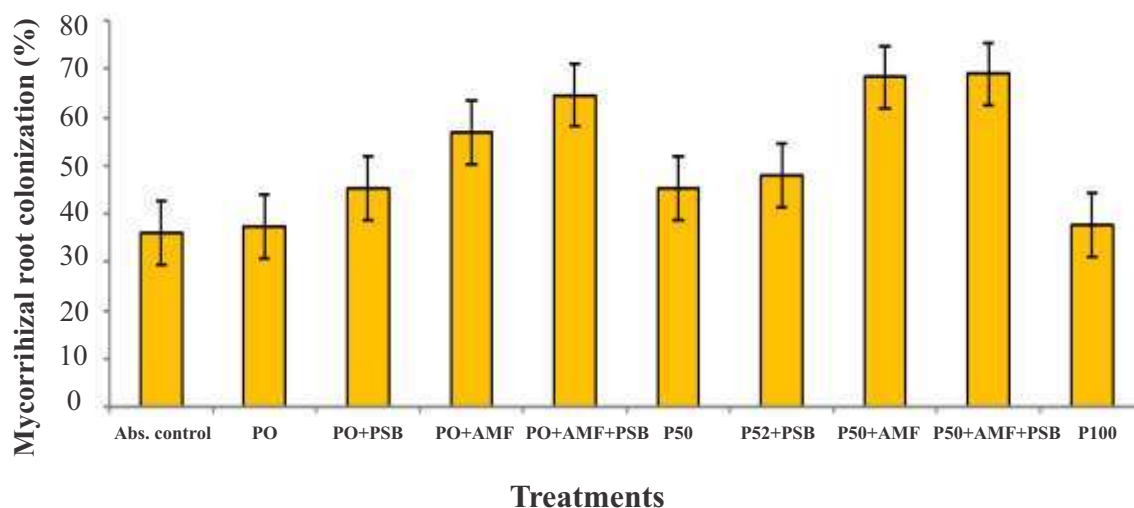


Fig. 20. Effect of AM-fungi and applied-P on mycorrhizal root colonization (%) in potato in NW Himalayan soil (*Kharif*2021)

Sole AMF or its combination with PSB exhibited significantly higher relative leaf water content (RLWC) both at tuber initiation and bulking stage during morning and evening times (Fig. 21). RLWC showed more contrasting results during afternoon over morning time at both stages in potato irrespective of treatments. P_{50} +AMF+PSB again

exhibited significantly higher root dry wt. while remaining at par with P_{50} +AMF and P_{100} (Fig. 22). P_{100} proved superior most in terms of tubers weight (57.9 g/pot), but it remained at par with P_{50} +AMF+PSB (57.0 g/pot), hence, indicating an important role of microbial inoculants like AMF along with PSB in P bio-availability, tuber yield and P-economy in potato.

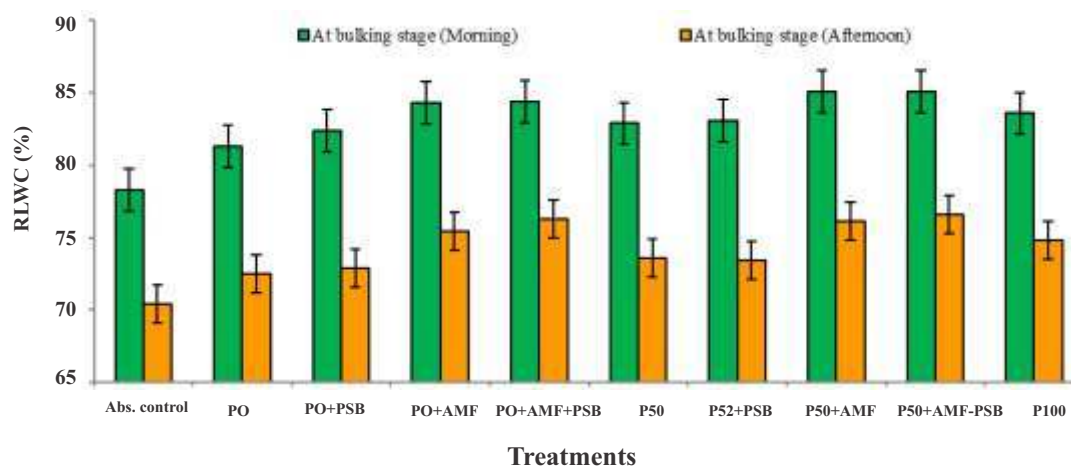


Fig. 21. Effect of AM-fungi and applied-P on relative leaf water content (RLWC) (%) during morning and evening, (a) tuber initiation stage and (b) bulking stage in potato in NW Himalayas (*Kharif*2021)

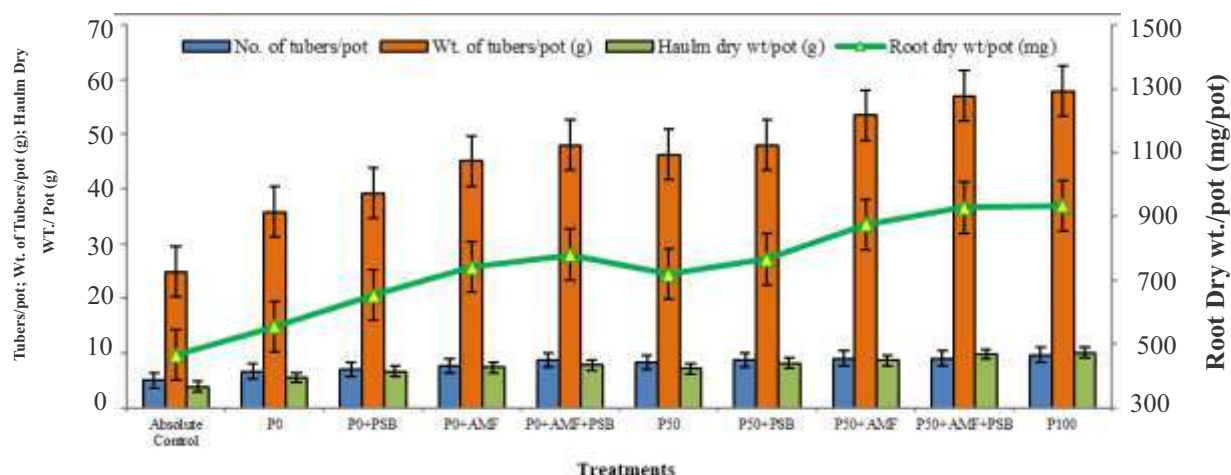


Fig. 22. Effect of AM-fungi and applied-P on number of tubers/pot, tuber wt./pot, haulm dry wt./pot and root dry wt./pot in potato crop in NW Himalayas (Kharif 2021).

Studies on genotypic variations in phosphorus use efficiency (PUE) in potato

(Jagdev Sharma, VK Dua and Prince Kumar)

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. Hence, there is a need to select/breed crop varieties which can withstand such stresses and screening of most efficient plant materials in nutrient-deficient conditions is therefore required.

Keeping it in view, variations in phosphorus (P) uptake were studied in different genotypes. These genotypes were raised on native soil P fertility. Phosphorus concentration was determined in youngest fully matured leaves. Significant variations were observed in leaf phosphorus concentration of different genotypes/varieties. Phosphorus content in leaves of genotypes/varieties ranged from 0.40% in Kufri Himsona to 0.68% in MS/17-629 (Fig. 23). This variability can serve as a reservoir of potentially useful genes to develop commercial cultivars with high PUE.

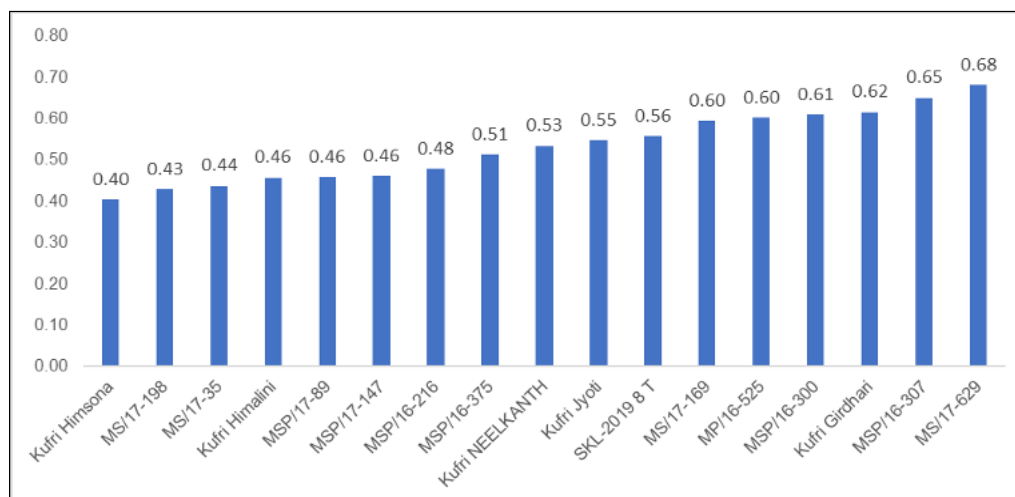


Fig. 23. Variation in leaf phosphorus concentration in potato genotypes

Phosphorus concentration was determined in youngest fully matured leaves. Significant variations were observed in leaf phosphorus concentration of different genotypes/varieties. Phosphorus content in leaves of genotypes/varieties ranged from 0.40% in

Kufri Himsona to 0.68% in MS/17-629 (Fig. 23). This variability can serve as a reservoir of potentially useful genes to develop commercial cultivars with high PUE.

Studies on foliar application of phosphorus

(Jagdev Sharma, Prince Kumar, Anil Sharma)

In potato, phosphatic fertilizer are normally applied to the soil. However, in different parts of world foliar application is sometimes used as a supplementary treatment to correct in season deficiency. The response to foliar application, however, varies with the genotypes. Thus the present experiment was conducted with the aim to determine the potato response to foliar-applied P. Two foliar sprays mono potassium phosphate (MKP) @ 5 g/L of were applied

to *Kufri Jyoti* variety at 25 and 35 DAP in different combination with graded doses of soil applied phosphorus (Table 7). Highest total tuber yield (24.9 t/ha) was obtained with two sprays of MKP +100% recommended dose of P. Foliar application of P resulted in marginal increase in tuber yield in all the treatments. The results indicated that foliar application of phosphorus has the potential as a supplementary treatment. Further experimentation is needed to study the effect of foliar P applications in relation to soil moisture and varietal difference etc.

Table 7. Effect of foliar application of phosphorus in potato

Treatments	Tuber yield (t/ha)
N ₁₀₀ P ₀ K ₁₀₀ RDF	18.12 (±0.67) ^b
N ₁₀₀ P ₅₀ K ₁₀₀ RDF	20.66 (±0.55) ^b
N ₁₀₀ P ₇₅ K ₁₀₀ RDF	23.12 (±1.77) ^{ab}
N ₁₀₀ P ₁₀₀ K ₁₀₀ RDF	23.96 (±1.61) ^{ab}
N ₁₀₀ P ₀ K ₁₀₀ RDF) + Spray MKP @ 5 g/L at 25 and 35 DAP	20.39 (±0.31) ^b
N ₁₀₀ P ₅₀ K ₁₀₀ RDF) + Sprays of MKP @ 5 g/L at 25 and 35 DAP	22.26 (±1.15) ^{ab}
N ₁₀₀ P ₇₅ K ₁₀₀ RDF) + Sprays of MKP @5 g/L at 25 and 35 DAP	24.33 (±1.75) ^{ab}
N ₁₀₀ P ₁₀₀ K ₁₀₀ RDF) + Sprays of MKP 5 g/L ate 25 and 35 DAP	24.86 (±1.29) ^a
C.D.	3.97

Isolation and characterization of phosphate-solubilizing bacteria (PSB) from potato fields

(Dharmendra Kumar, Jagdev Sharma, Anil Kumar Choudhary)

The collected soil samples from different potato growing sites (Modipuram) and phosphate solubilizing bacteria were isolated using Pikovskaya's Agar Medium, a selective medium for isolating PSB. Colonies showed a clear zone of phosphate solubilization bacteria. The PSBs were counted and expressed as a colony-forming unit (CFU) per gram of soil solubilization. Morphologically, all the bacterial isolates exhibited typical bacterial colonization characters. Some bacterial species produced white coloured colonies and some yellow. Most of the isolates formed well -developed colonies on Pikovskaya's agar medium within 3 to 4 days of incubation. All isolates were found positive to the starch hydrolysis test and negative for the catalase test (Fig. 24).

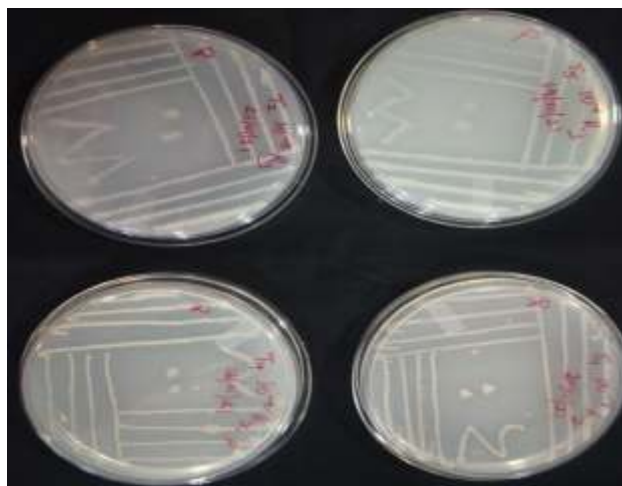


Fig. 24. Phosphorus solubilizing bacteria from potato fields

Soil management for improving nutrient availability in low pH soil

(Divya K. Lekshmanan, Janani. P, Priyank H. Mhatre, Venkatasalam E.P)

An experiment was conducted to evaluate the effect of lime and PSB (phosphorus solubilizing bacteria)

along with single super phosphate (SSP) in potato under acidic soils at Ooty. Trial was laid out during summer 2021 with cv. Kufri Swarna using different doses of P (0, 25, 50, 75 and 100% of recommended dose i.e. 135 kg P_2O_5 /ha), with and without recommended dose of lime (5 t/ha) and PSB (20 kg/ha). The treatment details shown in Fig. 25. Soil was sandy clay loam texture with pH 4. *Bacillus megaterium* was used as PSB. Results revealed that application of lime and PSB (along with SSP significantly increased potato yield. Maximum tuber yield was recorded where 100% P was applied along with PSB and lime (23.9 t/ha) which was at par with the produce of 75% P + PSB + lime and 75% P. However, the lowest yield was recorded in control treatment (17.0 t/ha), where no P, PSB or lime was applied (Fig.25).

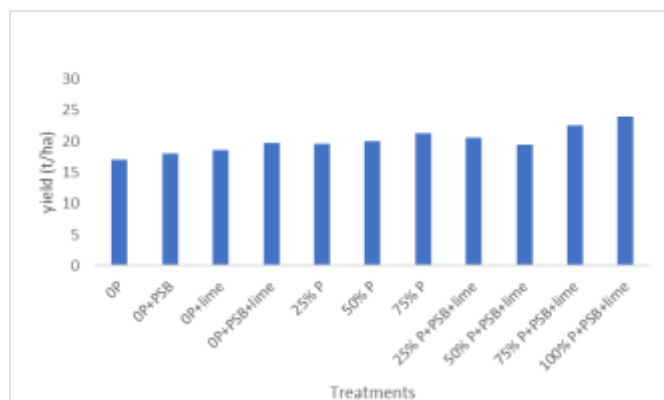


Fig. 25. Effect of lime and PSB on potato production in acidic soil

At Shillong, application of RDF NPK (140:120:60 kg/ha) and lime, alone or in combination had a significant influence on potato yield (Fig. 26). Broadcast application of lime at 17 t/ha resulted in an improvement in tuber yield by 17.6% and combined application of RDF (100%) + lime further boosted the yield to a tune of 146.1% over control. The highest potato tuber yield (13.7 t/ha) was obtained with the application of 100% recommended doses of fertilizer along with lime which was significantly higher than control plots (5.6 t/ha). The application of 100% RDF and 50% RDF + lime were statistically at par with each other.

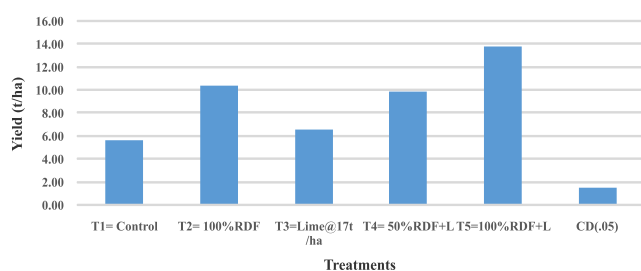


Fig. 26. Effect of liming on potato yield (t/ha)

Pot studies on use of biochar in potato: Biochar has the potential to increase soil carbon content which can help to reduce overall green house gas emissions and mitigate future climate change. Biochar may also provide additional agricultural benefits such as increased soil fertility and crop productivity. Hence, the pot experiments were initiated to study the effect of biochar on growth and yield of potato at Ooty and Shillong. Different treatment combinations (T_1 - control, T_2 - recommended NPK, T_3 - Biochar @ 5 t ha^{-1} , T_4 - Biochar @ 5 t ha^{-1} + RDF, T_5 - Biochar @ 10 t ha^{-1} , T_6 - Biochar @ 10 t ha^{-1} + RDF, T_7 - Biochar @ 20 t ha^{-1} , T_8 - Biochar @ 20 t ha^{-1} + RDF, T_9 - Biochar @ 30 t ha^{-1} , T_{10} - Biochar @ 30 t ha^{-1} + RDF) are being tried during spring season of 2021-22. At Shillong, the experiment to study the response of mustard stalk biochar on the growth and yield of potato variety Kufri Giriraj is in progress.

Studies on optimizing the organic phosphorus fertilizer in acidic soils: In this study, the rock phosphate was given with and without PSB and compared with recommended practice of application of single super phosphate (SSP) as phosphorus source (135 kg P /ha) during summer 2021 in acidic soils of Ooty. Treatment details is given in table 8. Soils of the experimental field was sandy clay loam texture with a pH value of 4.4. *Bacillus megaterium* was used as PSB. Application of 100% phosphorus as SSP recorded maximum yield of potato of 18.6 t/ha (Table 8). Among the different levels of phosphorous, 75% P applied as rock phosphate along with PSB recorded maximum potato yield (18.5 t/ha), and can be used as an alternative source of P for this region.

Table 8. Effect of different levels of rock phosphate on potato production (cv. Kufri Swarna)

Treatment	Yield of Kufri Swarna (t/ha)
0 % P	12.9
0 % P+PSB	14.9
25 % P	17.6
25 % P+PSB	17.9
50 % P	17.1
50 % P+PSB	17.0
75 % P	18.0
75 % P+PSB	18.5
100 % P	15.4
100 % P+PSB	15.1
100 % SSP	18.6
SE(d)	1.0
CD (0.05)	2.5

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

Field experiments and laboratory studies were carried out in this programme under nine research project activities during 2021. These were: Indian GAP for production of potato crop; developing production technology for certified organic seed potatoes; refining system based organic potato production technologies; refining organic potato protection technologies for sustainable yields; development of potato based cropping systems for different agro-ecologies; precision farming studies for sustaining potato productivity; development of rapid seed potato production technologies; engineering technologies for potato production and utilization and mechatronics in potato production.

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

(Pooja Mankar, Sanjay Rawal, Sanjeev Sharma, SK Luthra, VK Gupta, Devendra Kumar, Mehi Lal, Subhash S, Pinky Raigond, Bapidas)

Estimation of chemical residues in tubers: Residues of three chemicals applied at recommended levels in cv. Kufri Sangam and Kufri Neelkanth were estimated in potato tubers in a field trial at Modipuram during 2021. Residues of all the three chemicals were found below the Codex Alimentarius maximum residue level (MRL and within in safe limits in potato tubers after harvest (Table 9).

Table. 9. Chemical residue content in potato tubers after harvest

Chemical	Mean residues in tubers (mg (mg kg ⁻¹))	Codex MRL (mg kg ⁻¹)
Pendimethalin	Below detection limit	0.05
Chlorpyrifos	Below detection limit	2.00
Imidacloprid	Below detection limit	0.50

Promotion of early potato export from Western Uttar Pradesh: Western Uttar Pradesh has good potential for export of early season potatoes. Thus a field experiment was repeated during 2021 with five promising potato varieties and advanced hybrid at Modipuram. Water stress tolerant advanced hybrid WS/07-113 recorded maximum export-grade (>55 mm size) tuber yield (11.5 t/ha) followed by Kufri Neelkanth (9.0 t/ha). Exporters and progressive farmers have shown keen interest in Kufri Neelkanth as a specialty potato. Tubers of all the varieties were in acceptable range of specific gravity (Figs.27-29).

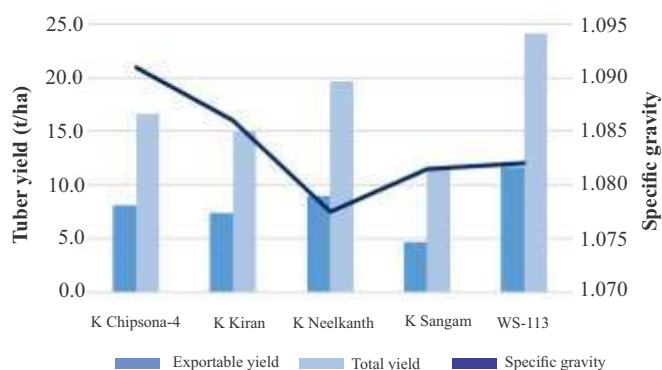


Fig. 27. Export grade tuber yield in early season of Rabi 2021 at Modipuram



Fig.28. Trial for early season export



Fig. 29. Potato farmers visiting harvest of early season export trial

Export potential of potato varieties at Agra and Sabarkantha: Field evaluation of eight promising potato varieties *viz.*, Kufri Bahar, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Frysona, Kufri Ganga, Kufri Mohan, Kufri Neelkanth and Kufri Sangam was carried out at two farmer's fields in district Agra (Uttar Pradesh) and Sabarkantha (Gujarat). Kufri Sangam and Kufri Ganga produced more than 30 t/ha export-grade yield at both locations with

acceptable tuber shape, size, and specific gravity. In addition, Kufri Neelkanth has excellent export potential as a specialty potato from Agra and Gujarat with 25 and 34 t/ha export-grade yields, respectively (Fig.30). Furthermore, in storage studies, Kufri Sangam, Kufri Frysona, Kufri Chipsona-3 and Kufri Neelkanth have shown good performance till eight months of storage. The same field evaluation is continuing at both the locations in 2021-22.

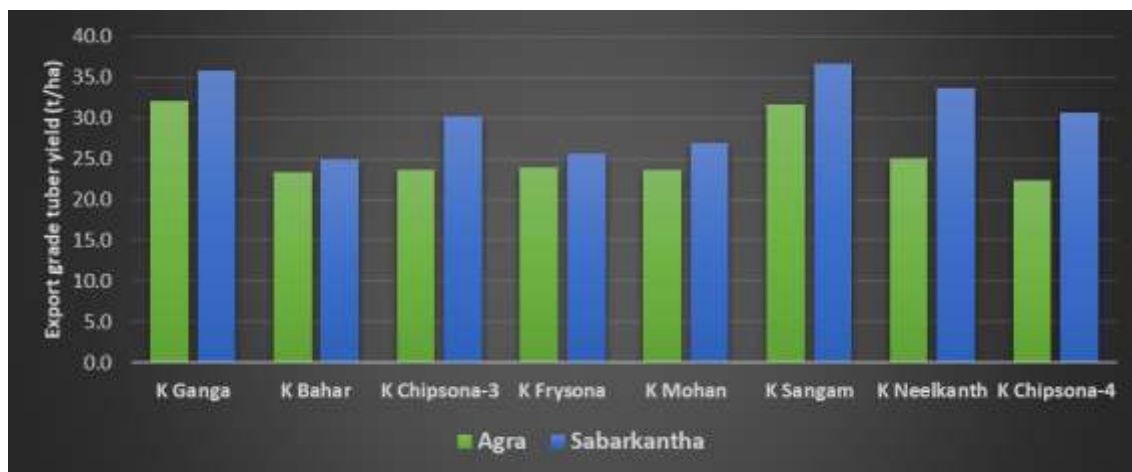


Fig. 30. Export grade tuber yield in different potato cultivars

Assessment of export potential of potato germplasm: A field study has been initiated at Modipuram for the screening of 84 potato germplasm accessions which were evaluated for shape (oblong, round), size (>55 mm) and cosmetic value skin color, shine, texture etc.) along with yield maintenance. Based on the recorded observations, 51 potential germplasm and varieties were selected and their field evaluation is continuing in second crop season. (Fig. 31)

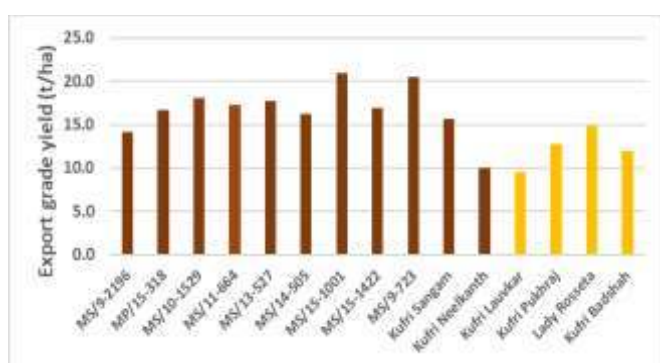


Fig. 31. Screening of potato germplasm for export potential in main season at Modipuram

QR codes for wider dissemination of potato production technologies: A conventional extension approach has limited space and time and results into lower impact. So, innovative technologies are to be developed and adopted for rapid spread of knowledge to end-users. An attempt has been made at

Modipuram to provide developed potato technologies to stakeholders of potato supply chain by developing QR (Quick Response) codes with many advantageous features (Fig. 32). Users need to scan QR codes using the camera of a smartphone set. This will generate a link and follow it to access the complete document. This cost-effective, new edge technological intervention has no paper wastage, and information can be sought without any time and space restrictions.



Fig.32. QR code for different potato technologies

Developing production technology for certified organic seed potatoes

(SP Singh, S Katare, M Sadawarti)

Organic seed potato production: A field experiment was conducted at Gwalior using six nutrient treatments (Control, 100% FYM+ neem cake, 200% FYM+ neem cake, 100% FYM+ neem cake+ biofertilizer, 200% FYM + neem cake+ biofertilizer, RDF NPK) and two varieties (Kufri Chipsona 1 and Kufri Chandramukhi). Highest number of <25g tubers were recorded with K Chipsona 1 (162 thousand/ha) which was significantly higher than Kufri Chandramukhi (Fig. 33). Total seed tuber number was also highest with Kufri Chipsona-1 (451 thousand/ha) as compared to Kufri Chandramukhi (350 thousand/ha). Highest total seed tuber yield (22.4 t/ha) was recorded with Kufri Chandramukhi followed by Kufri Chipsona 1 (18.2 t/ha) remaining at par. Application of nutrients could not exert any significant effect on number and yield of tubers (Fig. 34). However, highest mean seed tuber under organic treatments was observed with 200% FYM + neem cake, which was only 6% lower than inorganic treatment. Comparatively lower whitefly population (3.52-3.78/ 5 plants) was recorded with organic treatments in comparison to inorganic plots (4.52/ 5 plants).

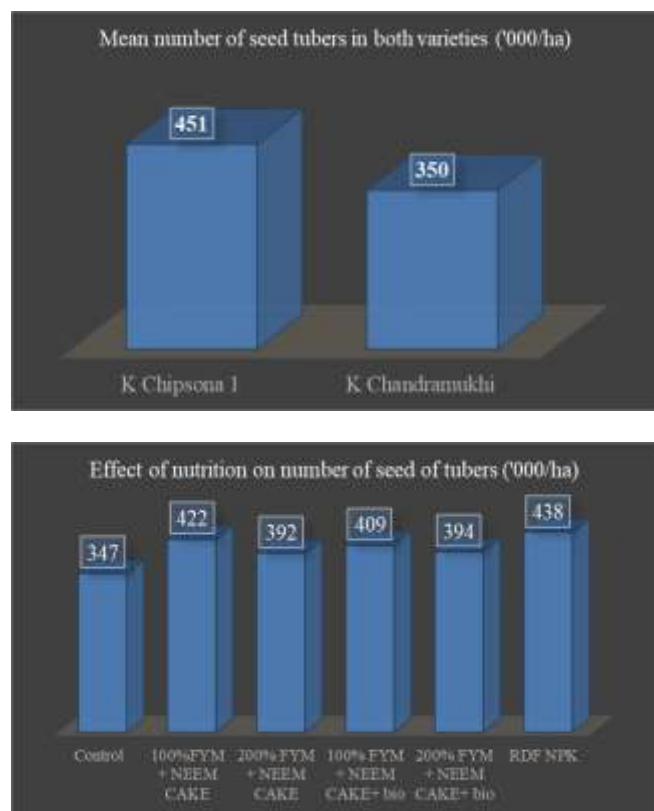


Fig. 33. Mean seed tuber number of both varieties and influence of nutrition on seed tuber number

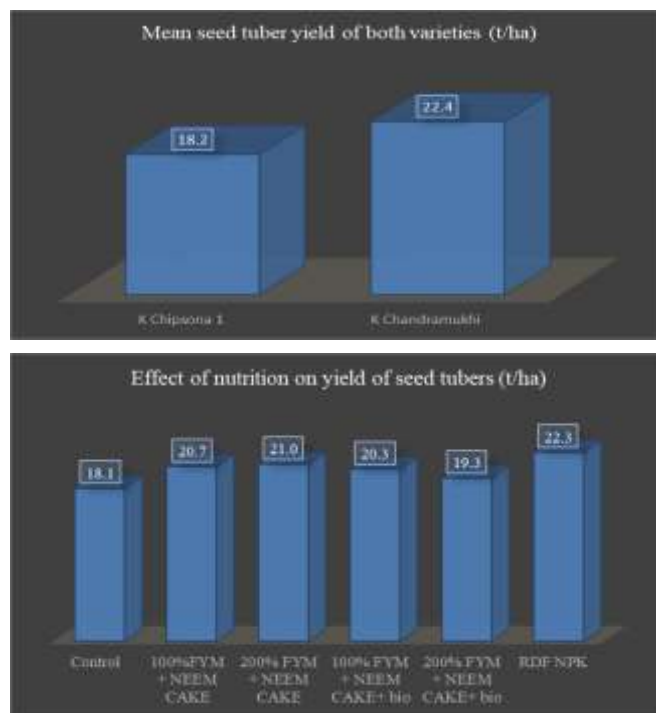


Fig. 34. Mean seed tuber yield of both varieties and influence of nutrition on seed tuber yield

Refining system based organic potato production technologies

(Janani P, SK Luthra, VK Gupta, Clarissa Challam, N Sailo, S Rawal, Anil K. Choudhary, Pooja Mankar, SP Singh, M Sadawarti, Pinky Raigond, Bapidas)

Evaluation of potato germplasm for organic farming

A field trial was initiated at Modipuram during Rabi 2020, wherein 84 potato germplasm accessions were evaluated under an organic production system and , a total of 51 potato accessions and varieties were selected based on yield maintenance, tuber shape, size, skin color, texture etc. (Fig. 35). The selected genotypes have been planted during 2021-22 for further evaluation along with inorganic production system to compare yield and yield contributing attributes.

Developing organic potato production technology for NEH region:

A field experiment was conducted during summer of 2021 season to identify a superior potato variety with higher tuber yield and yield attributes for commercial cultivation in Meghalaya. Among six commercial varieties (Kufri Jyoti, Kufri Himalini, Kufri Girdhari, Kufri Giriraj, Kufri Megha and Kufri Kanchan) cv. Kufri Himalini recorded the highest marketable (18.3 t/ha) and total tuber yield (22.7 t/ha) as well as B: C ratio (1.63) suggesting the suitability of this cultivar for table potato cultivation in this rainfed region (Fig.36).

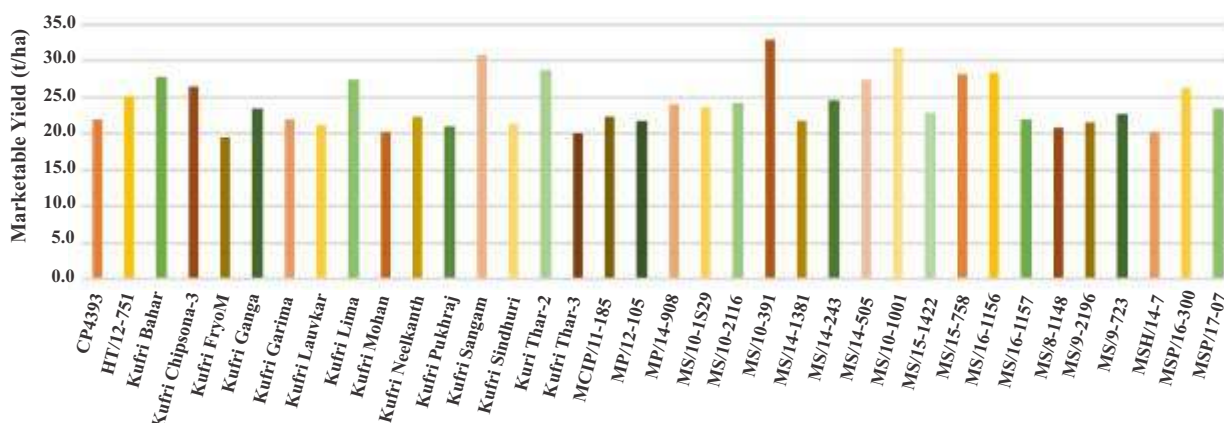


Fig.35. Yield performance of potential germplasm/varieties under organic system at Modipuram

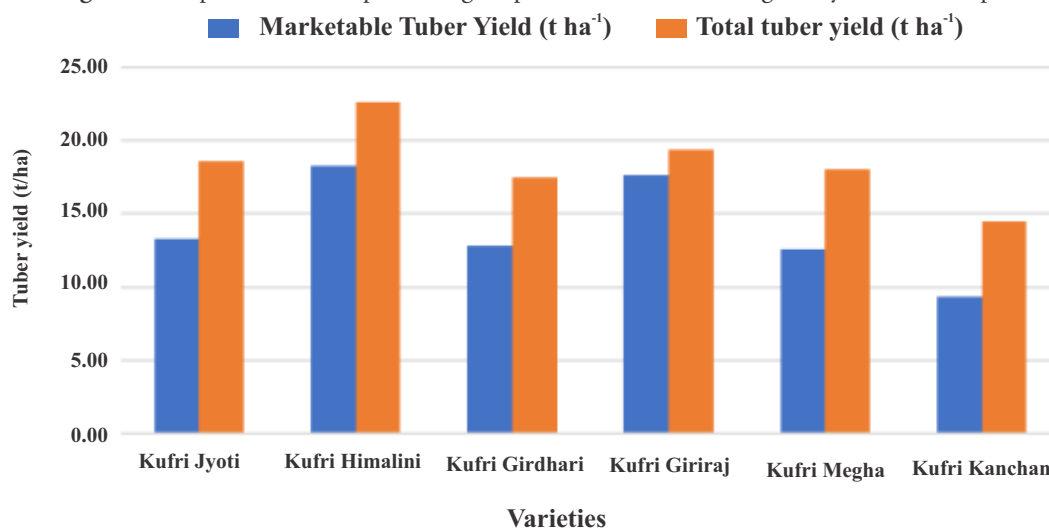


Fig. 36. Performances of six potato varieties at Shillong

Suitable potato varieties for organic farming: Among six potato varieties (Kufri Jyoti, Kufri Himalini, Kufri Girdhari, Kufri Giriraj, Kufri Megha and Kufri Kanchan) evaluated for their tuber yield maintenance under organic cultivation (50% RDN through FYM @15 t/ha⁻¹ + remaining 50% RDN through vermicompost @5 t/ha⁻¹ + P management through rock phosphate (667 kg/ha⁻¹). Kufri Giriraj (Fig.37)

recorded the maximum total tuber yield (17.0 t/ha) followed by K Himalini (16.9 t/ha), Kufri Girdhari (16.6 t/ha) K Jyoti (15.5 t/ha) and Kufri Megha (15.4 t/ha). Whereas, marketable tuber yield was highest in cv. K Himalini (13.3 t/ha) followed by K Giriraj (11.8 t/ha) and K Girdhari (11.6 t/ha). All three varieties recorded significantly higher marketable yield over control K Megha (8.0 t/ha).

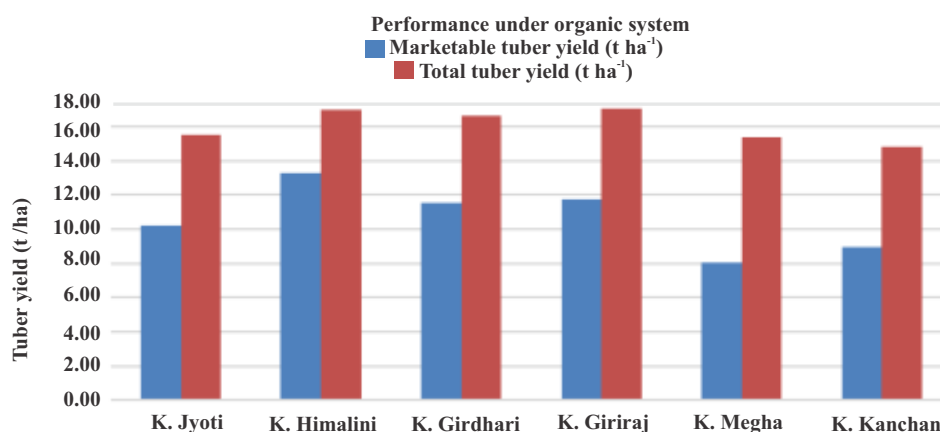


Fig. 37. Performances of potato varieties under organic farming at Shillong

Developing weed management technology for organic potatoes in NE hills: A field experiment was conducted under organic farming on potato during 2020-21 at Shillong. Among seven treatments, (*viz.* weedy, weed free, one hand weeding and 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) better

tuber yield was recorded with silver-black polythene mulch (17.7 t/ha) which was comparable to the highest yield under weed free condition (19.9 t/ha). Maximum reduction (65.2%) in tuber yield was observed in weedy check followed by farmers' practices (46.9 %) in comparison to weed free treatment (Fig.38).

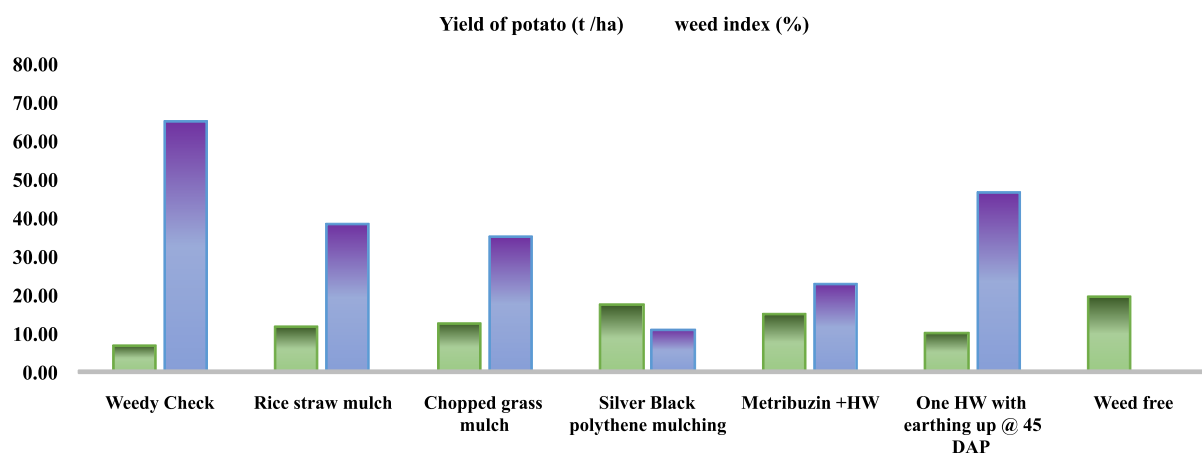


Fig. 38. Influence of weed management practices over tuber yield

Refining organic potato protection technologies for sustainable yields

(Mehi Lal, Anuj Bhatnagar, Sanjeev Sharma, Vinay Sagar, S Katare, Subhash S, P Janani)

Management of late blight disease: Chemicals permitted for restricted use and bio-agents (copper based products, neem oil and *Trichoderma viride*) were evaluated at Modipuram against late blight of potato during 2020-21 on cv. Kufri Bahar and Kufri Mohan. Lowest disease severity (18.0%) was recorded in treatment T4 (Neem oil @ 4.0%- copper hydroxide @ 0.3%-Neem oil @ 4.0%- copper hydroxide @ 0.3%) followed by treatment (T3: Neem oil @ 4.0%- copper oxychloride @ 0.25%- Neem oil @ 4.0%- copper oxychloride @ 0.25%) with disease severity of 23.0%

against control (71.7%) on cv K.Mohan (Fig. 39). Same treatments were also effective on susceptible cv. Kufri Bahar. This experiment is in progress in second year. In another experiments (cv. Kufri Bahar), four treatments in schedule based application were evaluated for managing late blight disease. Four applications of phosphorus acid @ 0.2% showed lowest disease severity (50.0%) followed by phosphorous acid @ 0.2% (before appearance)-*Bacillus subtilis* @ 0.25%+ *T. viride* @ 2.0% (on appearance of late blight)- phosphorous acid @ 0.2%-*B. subtilis* @ 0.25%+ *T. viride* @ 2.0%, which had disease severity of 60% as compared to control (96.5%). This experiment is in progress in second year.

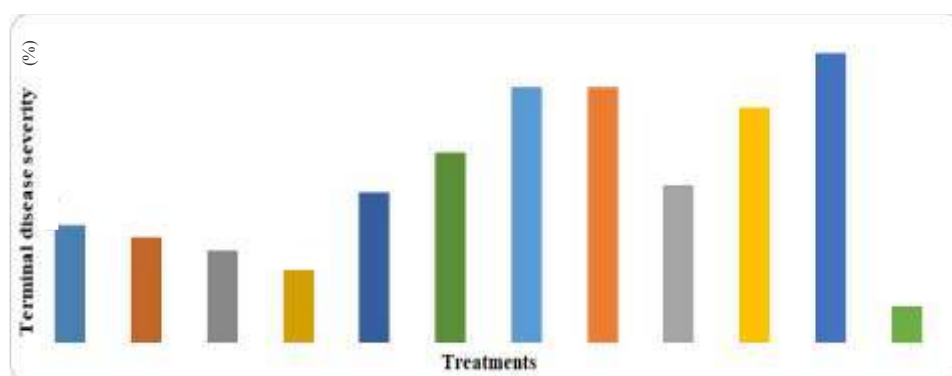


Fig. 39. Effect of organic based chemicals on late blight in cv. K Mohan

Organic management of black scurf of potato: Fifteen treatments were evaluated at Modipuram for management of black scurf of potato during *Rabi* season of 2020-21 on cv. Kufri Bahar. Treatment (T3: *Trichoderma* spp. TH1 in talc based formulation @ 1.0% as seed treatment) exhibited lowest disease incidence (22.7%) and severity (11.2%) followed by treatment T1 (*Trichoderma* spp. TH1 applied as @

100 g on compost multiplied/ 1.8m² as soil application) which had disease incidence and severity of 33.3 and 16.7%, respectively. Treatment T4 (talc based formulation of TH2) and treatment T9 (Talc based formulation @ 0.5%) also recorded less disease in comparison to control which recorded disease incidence and severity of 89.3% and 47.8% (Fig. 40).

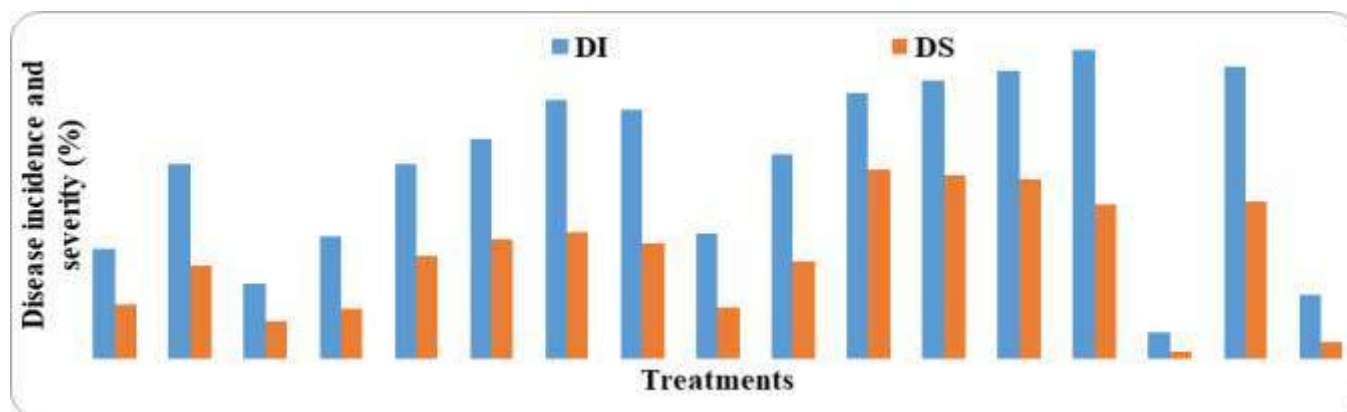


Fig. 40. Effect of organic based products on black scurf of potato

Efficacy of bio-pesticides as seed treatment against whitefly, hoppers and aphids: Seven treatments [T1- *Beauveria bassiana* (10 g/kg, dip-seed treatment: DST), T2- Shreya (10 ml/kg, DST), T3- *B. bassiana* (ST) + spray of Shreya (10 g/kg +10 ml/l, DST + Spray), T4- Shreya (ST) + spray of *B. bassiana* (10 ml/kg +10 ml/l, DST + Spray), T5- Imidacloprid 17.8 SL (ST) 0.5 ml/l, DST), T6- Imidacloprid 17.8 SL + spray of Thiamethoxam 25 WG (0.5 ml/l +0.4 g/l, DST + spray) and T7-Control (no spray)] were evaluated at Modipuram to study the effect of seed treatment using bio-pesticides along with standard insecticide control during *Rabi* season of 2020-21. Results revealed that after 30 days, the population of aphids, whiteflies and leaf hoppers was significantly lower in T5 and T6 (standard control). Among bio-pesticides, seed treatment with *B. bassiana* (T1) effectively reduced the sucking pest population and found to be on par with T5 and T6 (Fig.41). The results revealed that seed treatment of *B. bassiana* can be used as an alternative to synthetic insecticides in organic potato cultivation.

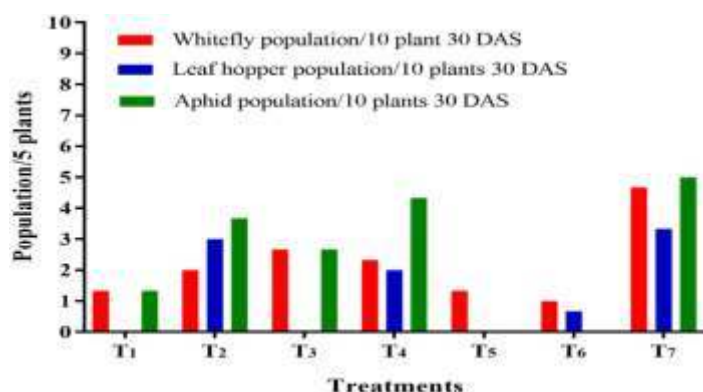


Fig. 41. Effect of seed treatment and spray of plant products on population of sucking pests of potato 30 days after planting

Evaluation of biorational insecticides against sucking pest-as a seed treatment: An experiment was conducted at Modipuram to study the effect of seed treatment using biorationals along with standard insecticide control. Among nine treatments, [T1-Neem oil spray (2 ml/l), T2-Neem oil dip (2 ml/l), T3- Spinosad 2.5% SC spray (1 ml/l), T4- Spinosad 2.5% SC dip (1 ml/l), T5- Abamectin benzoate 1.9% EC spray (0.75 ml/l), T6- Abamectin benzoate 1.9% EC dip (0.75 ml/l), T7- Imidacloprid 17.8% SL dip (0.5 ml/l), T8-Imidacloprid 17.8% SL spray (0.5 ml/l) and T9-Control] no substitute biorationals were available for standard check imidacloprid. Spinosad 2.5% SC dip (1 ml/l) performed on par with standard control in reducing the population of major sucking pests such as aphids, whiteflies and leaf hoppers of potato crop (Fig.42).

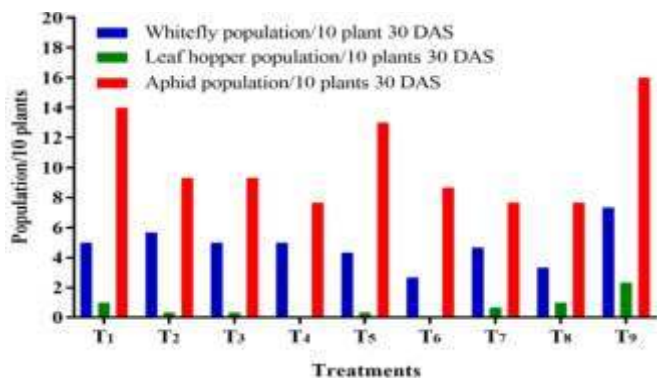


Fig. 42. Effect of seed treatment with bio-based formulations on incidence of sucking pests of potato

Evaluation of biorationals against potato tuber moth *Pthorimaea operculella* (Zeller) under laboratory conditions: As an alternate to persistent synthetic pyrethroid - deltamethrin, bio-rational pesticides were evaluated at Modipuram against PTM. Study consisted of six treatments of (T1-tubers sprayed with Spinosad 2.5 SC @ 1 ml/l; T2-tubers sprayed with Abamectin 1.9 EC @ 1 ml/l; T3-tuber dip treatment with *B. bassiana* @ 10 g/l; T4-tuber dip treatment with Neem oil @ 2 ml/l; T5-tuber dip treatment with *B.t* + *Saccharopolyspora spinosa* formulation @ 2 ml/ l and T6- Control). Results showed that 20 days after application 95% PTM infestation was recorded in treatments T3, T4 and T6 and above 50 % infestation in T5 (Fig. 43). After 90 DAT significant reduction (95%) in tuber infestation was recorded with T2 whereas in T1 the reduction was 92% (Fig. 44, 45). From this results it is evident that, these two synthesized natural analogues can be recommended for tuber treatment against PTM under storage conditions.

Evaluation of bio-pesticides for eco-friendly management of sucking pests in potato: A field experiment was conducted during Rabi 2020-21 at Gwalior using bio-pesticides and chemical

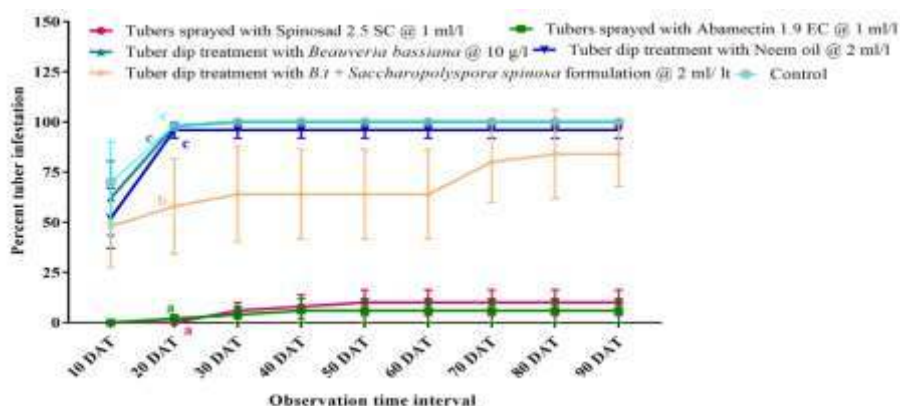


Fig. 43. Percent tuber infestation (mean ± SEM) of potato tubers by PTM in different treatments over a period of 90 days. Different letters indicate a statistically significant difference between individual treatments at $P < 0.05$



Fig. 44. Potato tubers treated with Spinosad 2.5 SC @ 1 ml/l (T1) and Abamectin 1.9 EC @ 1 ml/l (T2) after 90 days of treatment.



Fig. 45. Potato tubers showing infestation of PTM 20 DAT in T3, T4, T5 and T6

insecticides for managing whitefly, thrips, and aphid population on cv. Kufri Chandramukhi. Result showed that all the treatments (except Azadirachtin 1500 ppm and *Verticillium lecanii*) were effective in controlling the whitefly, thrips and aphid population three and seven days after spraying. *Metarhizium anisopliae* @3g/l, was found most effective against whitefly, thrips, and aphid population with percent reduction of 63.9 %, 62.6 % and 65.5 %, respectively over untreated control, which also gave higher tuber yield. Thiamethoxam 5 % WG @ 0.5 g/l, and farmer's practice i.e. imidacloprid 17.8 SL @ 0.5 ml/l were also found effective in reducing these pests. All the treatments were also effective in reducing the number of leaf curl disease.

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

Rice–potato–green manure (*Sesbania* sps.) crop sequence under zero budget nutrition: Experiment conducted at Gwalior comprised of four fertility types and two mulches. Results revealed that there was significant effect of paddy straw mulching on rice grain yield. Highest rice yield (2243 kg/ha) was recorded under mulching compared to non-mulching (1946 kg/ha). Application of 100% RDF NPK application recorded highest rice yield (3092 kg/ha) which was followed by FYM @ 25 t/ha + Jeevamrit (2614 kg/ha). Highest tuber yield (24.1 t/ha) was recorded with 100% RDF which was followed by crop residue @25 t/ha + *Azotobacter* + PSB + Jeevamrit (23.7 t/ha). Significantly higher tuber yield was recorded with paddy straw mulch (24.6 t/ha) compared to non-mulch treatment. Nutrient management practice significantly influenced the organic content of soil. Organic carbon contents varied in different treatments from 0.25% in control, 0.31% in RDF, 0.44% in crop residue and 0.44% in FYM treatment (Figs. 46-50).

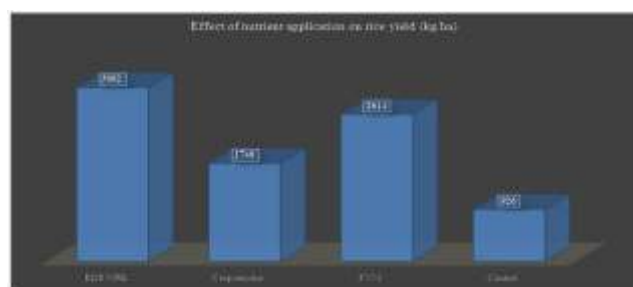


Fig. 46. Effect of nutrition on rice yield

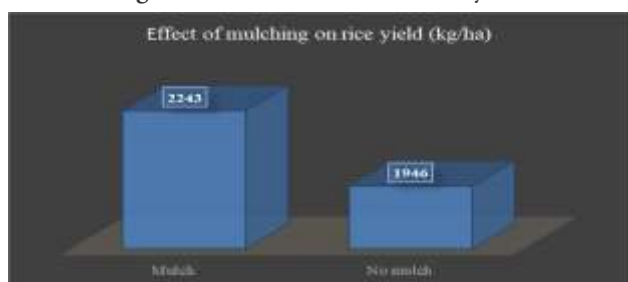


Fig. 47. Effect of mulching on rice yield

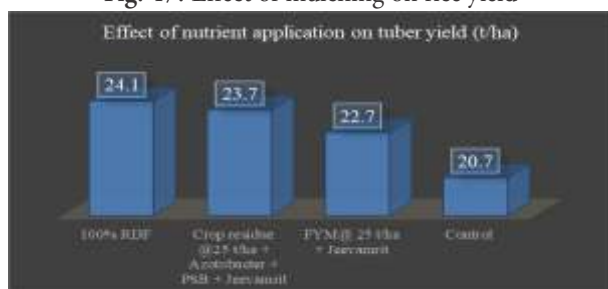


Fig. 48. Effect of nutrition on tuber yield

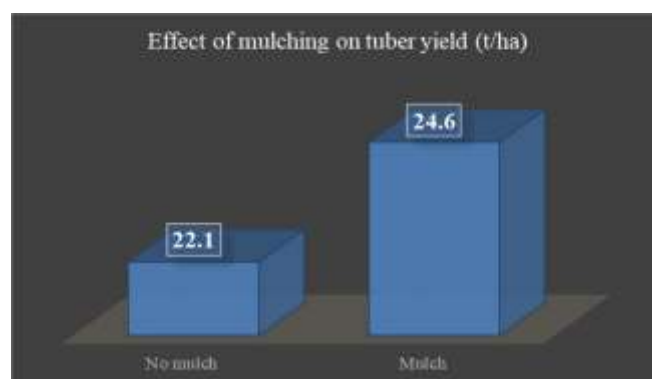


Fig. 49. Effect of mulching on tuber yield

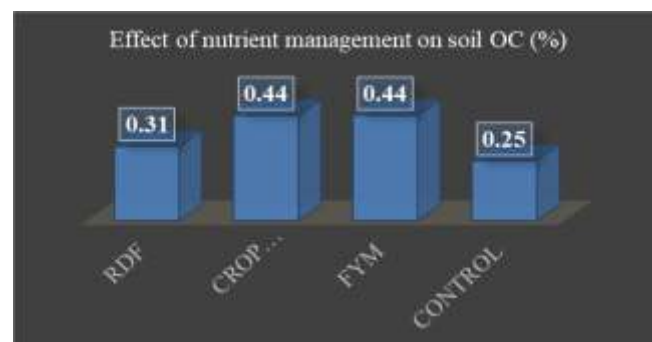


Fig. 50. Effect of nutrition on soil organic carbon

Potato production under minimum tillage: A field study was initiated with reduced tillage in potato crop at Gwalior. Treatments comprised of three levels of rice harvesting (ground level, 30 and 60 cm height cuttings) and three tillage operations (tuber zone tillage, tuber row tillage and normal tillage) for potato planting. Highest tuber number (576 thousand/ha) were recorded with ground level rice harvest + tuber row tillage while highest tuber yield (16.5 t/ha) was recorded with rice harvest at 30 cm + normal tillage which was significantly higher than all other treatments except ground level rice harvest + normal tillage. potato planting after rice harvesting with higher amount of crop residues and with minimum tillage resulted in a reduction in number of tubers. Harvesting of rice at 30 cm height attained tuber number in range of 506-562 thousand/ha. Lowest number of tubers were recorded when potato planting was done after harvest of 60 cm height. Almost similar trend was observed in tuber yield where in normal tillage after rice harvesting was done, highest potato tuber yields of 16.2, 16.5 and 13.7 t/ha, respectively were recorded when potato was planted after ground level, 30 and 60 cm levels rice harvest + conventional tillage. Lowest tuber yields were recorded when potato planting was done after rice harvest at 60 cm height with all the three tillage's i.e. tuber zone, tuber row zone and normal tillage (Figs. 51-52).

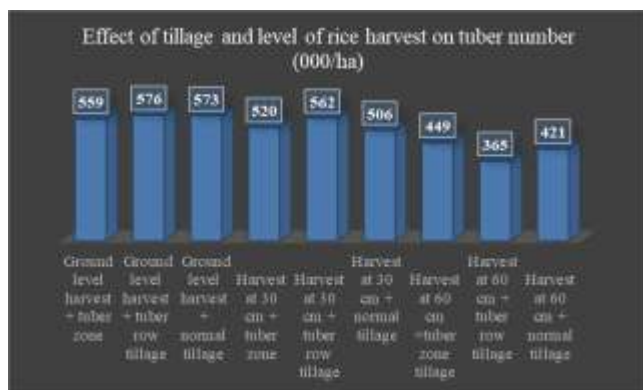


Fig. 51. Effect of tillage and level of rice harvest on tuber number

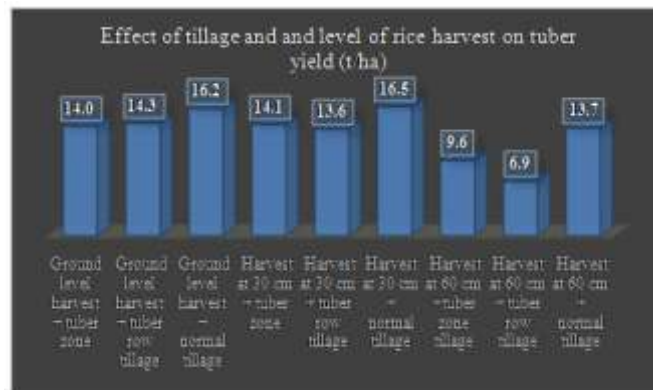


Fig. 52. Effect of tillage and level of rice harvest on tuber yield

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

A field experiment was initiated during 2020-2021 under four potato based cropping systems (i) Potato-peas (PPCS); (ii) Potato-broccoli (PBCS); (iii) Potato-garlic (PGCS); and (iv) Potato-Matricaria (PMCS); and four integrated nutrient management (INM) schedules on cropping system basis [INM₁: 100% NPK both in Crop-I and 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] (Fig. 53). The remaining P requirement after adding the required FYM in Crop-II was met through rock phosphate.



Fig. 53. A pictorial view of potato based diversified cropping systems in wet-temperate NW Himalayas.

The study revealed that total potato tuber yield of Kufri Himalini (Crop-I) across the four cropping systems was significantly higher under the INM₄ (100% NPK + FYM @ 10 t/ha + PSB + AMF) (17.9 t/ha) which was followed by INM₃ (16.8 t/ha), INM₁ (16.2 t/ha), and INM₂ (15.8 t/ha), respectively with average tuber yield of 16.7 t/ha across the cropping systems (Table 10). These results indicated that application of 100% RDF + FYM @ 10 t/ha + PSB + AM-fungi in potato crop can be highly beneficial to harness ~10.7 and 6.5% higher potato tuber yield over 100% RDF and INM₃, respectively in 1st potato crop across different cropping systems. Among *Rabi* crops, INM₂ was the best INM schedule to exhibit higher crop yields (Fig. 54). On cropping system basis, potato-garlic cropping system (PGCS) exhibited significantly highest system productivity in terms of potato equivalent yield (PEY) (74.6 t/ha) which was followed by PBCS (49.14 t/ha), PMCS (41.17 t/ha) and PPCS (34.6 t/ha), respectively. Hence, PGCS, PBCS and PMCS exhibited 115.6, 42 and 19% higher system productivity, respectively over conventional potato-peas cropping system (PPCS). On cropping system basis, the INM₂, INM₃ and INM₄ registered ~15.3, 9.9 and 2% 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 NW Himalayas. This was the first year of the trial which will be repeated further for confirmation of results.

Table 10. Potato equivalent yield (PEY) as influenced by potato based cropping systems and INM schedules

Treatments	Potato yield (t/ha)	PEY of <i>Rabi</i> crops (t/ha)	System productivity (t/ha)	
Cropping systems				
CS ₁ : Potato-Peas (PPCS)	16.68	17.92 ^d	34.60 ^d	
CS ₂ : Potato-Broccoli (PBCS)		32.46 ^b	49.14 ^b	
CS ₃ : Potato-Garlic (PGCS)		57.92 ^a	74.60 ^a	
CS ₄ : Potato-Matricaria (PMCS)		24.49 ^c	41.17 ^c	
Cropping system basis INM schedules				
Crop-I	Crop-II			
INM ₁ : 100% NPK	100 % NPK	16.18 ^b	30.58 ^c	46.76 ^b
INM ₂ : 75% NPK + FYM @ 10 t ha ⁻¹	75% NPK +25% NPK through FYM	15.83 ^b	38.07 ^a	53.90 ^a
INM ₃ : 75% NPK + FYM @ 10 t ha ⁻¹ + PSB+AMF	50% NPK+50% NPK through FYM	16.81 ^{ab}	34.59 ^b	51.40 ^a
INM ₄ : 100% NPK + FYM @ 10 t ha ⁻¹ + PSB+AMF	75% NPK	17.91 ^a	29.56 ^c	47.47 ^b

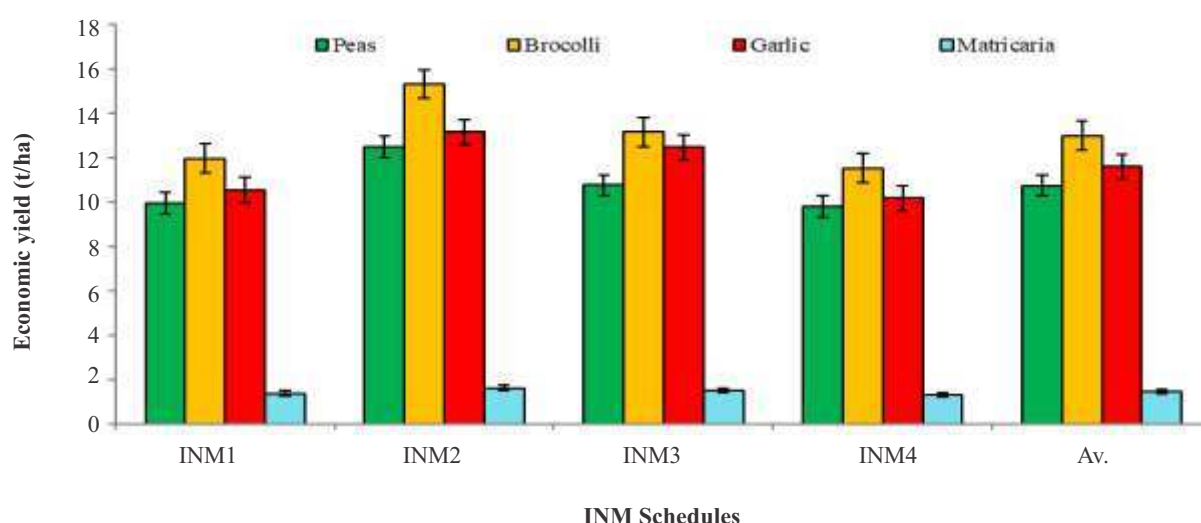


Fig. 54. Economic yield (t/ha) of *Rabi* crops (*Rabi* 2020-21) as influenced by INM schedules in potato based cropping systems.

Developing potato-based intercropping systems:

Eleven combinations of potato based inter cropping with french bean, cabbage, cauliflower, radish, carrot were evaluated at Shillong (Meghalaya). Results indicated that potato + cauliflower intercropping (1:2) produced highest and significantly better PEY (21.3 t/ha) and it was closely followed by potato + cabbage intercropping (20.8 t/ha). Productivity of potato (13.9 t/ha) was the highest and it was followed by cauliflower (13.04 t/ha) and cabbage (12.94 t/ha) in order as sole crops (Fig. 55).

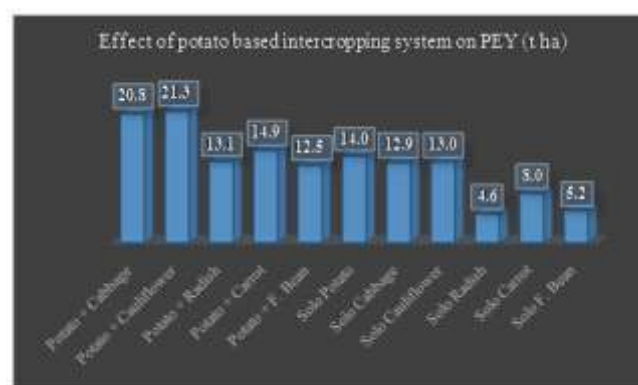


Fig. 55. Potato equivalent yields in various potato based inter- cropping systems

Precision farming studies for sustaining potato productivity

(Sanjay Rawal, Anil K Choudhary, Paresh Chaukhande, Pooja Mankar, Brajesh Nare)

Developing drone based potato crop management technologies: Drone, also known as Unmanned

Aerial Vehicle, (UAV) has very high scope in potato crop. Trials on spraying operation with drone were conducted at Modipuram and Jalandhar in potato crop for management of weeds, pests and late blight disease (Fig. 56). Potato cultivars Kufri Jyoti, Kufri Chandramukhi and Kufri Mohan were used for these

experiments. Several different pesticides and their combinations were applied using drone at ultra-low volume rate (20 l/ha). A hexa-copter drone was used for spraying operation having pay load capacity of 8 litre. Four centrifugal nozzles (atomizers) were employed for misting of the liquid chemicals. The drone was enabled to navigate automatically in the

field with the use of GPS based auto-navigation system. No phytotoxicity or crop damage was observed with the use of chemicals or down thrust of drone (Fig. 57). It was also observed that the system can cover one acre per flight in 5-6 minutes at an operational speed of 12 km/h.



Fig. 56. Spraying operation with drone in potato crop and droplets of chemical on WSP

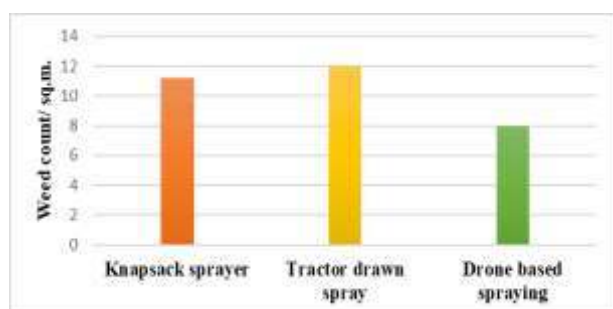


Fig. 57. Effect of metribuzin on weed population in potato crop

Development of rapid seed potato production technologies

(Sukhwinder Singh, Sugani Devi, Anil Sharma, Som Dutt, Brajesh Nare, Ratna Preeti Kaur)

Performance of Aeroponic minitubers with varied crop geometries in soilless media under insect proof net house: Effect of two plant densities (S-1 30 x 15 cm and S-2 10 x 10 cm) in soilless media was studied in crop raised from aeroponically produced minitubers of four varieties (Kufri Jyoti, Kufri Chipsona-1, Kufri Gaurav and Kufri Khyati) at Jalandhar. Experiment was conducted under 40 mesh insect proof net house. Results of tuber number and yield are as shown in Figure 58-59.

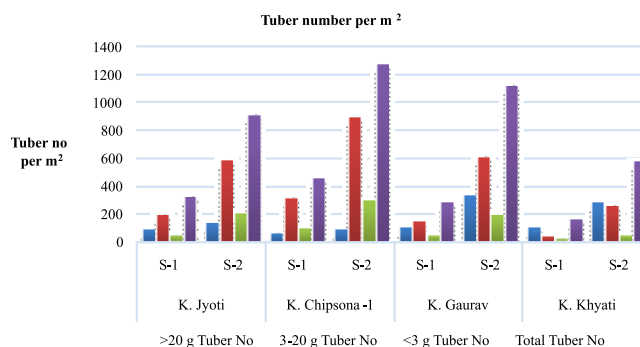


Fig. 58. Number of tubers with two plant spacing S-1 30 x15 cm and S-2 10 x10 cm

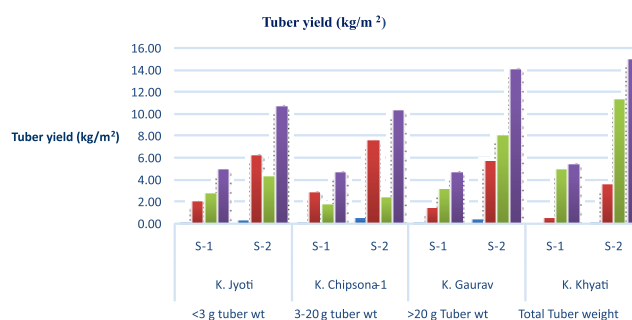


Fig. 59. Tuber yield with two plant spacing S-1 30x15 cm and S-2 10x10 cm

Evaluation of *in vitro* plants with different inter and intra-row spacing in soilless system under insect proof net house: The study was conducted at Jalandhar to find out the best planting geometry for

tissue cultured potato plants under cocopeat medium. Hardened microplants of two varieties (Kufri Himalini and Kufri Pukhraj) were shifted in soilless beds on 5 November 2020 in insect proof net house

with three plant spacing (S_1 -30 x 15 cm, S_2 -15x15 and S_3 -15 x 10 cm) replicated three times. Mini-tuber number and yield is shown in Figure 60 and 61.

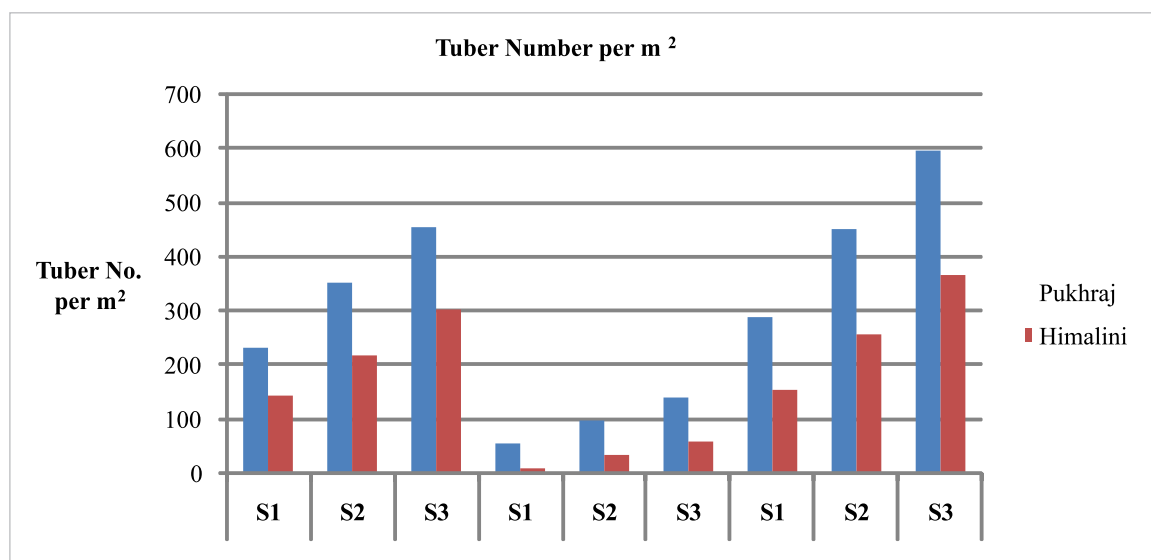


Fig. 60. Number of tubers under different spacing in soilless system

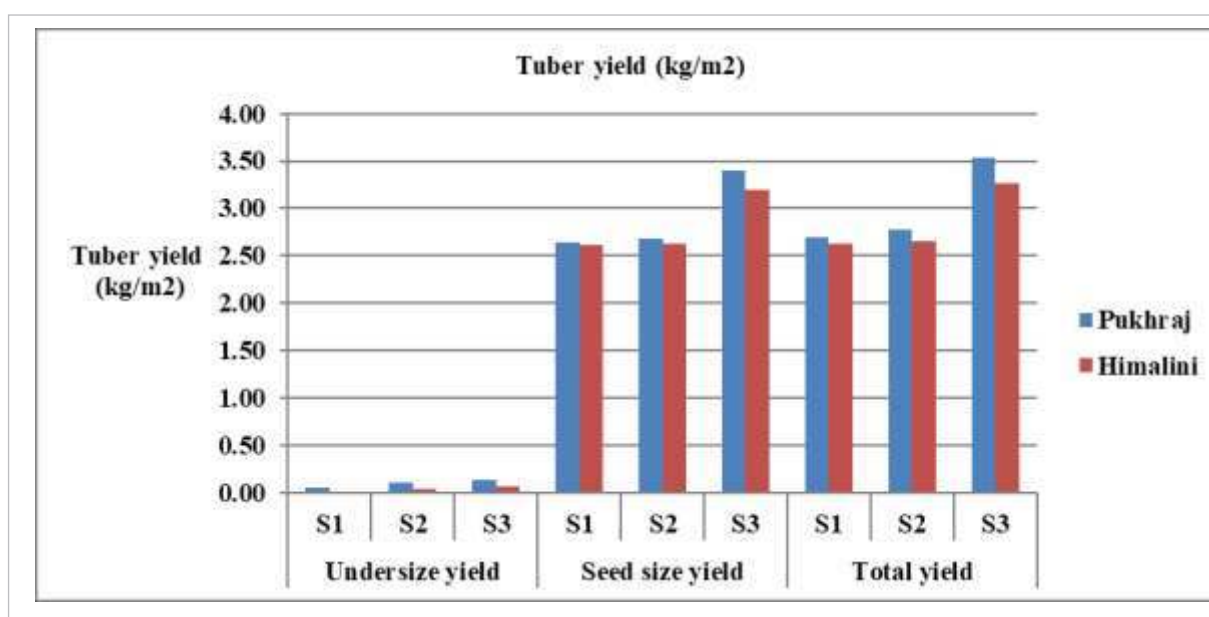


Fig. 61. Tuber yield (kg/m²) under different plant spacing in soilless system

Seed size tuber enhancement by CPRI formulation in potato crop: An experiment was conducted at Jalandhar to evaluate the effect of CPRI formulation for tuber number enhancement in two varieties K Jyoti and K Pukhraj during 2020-21. Both varieties were planted on 10th October 2020 and dehauling was done at 80 DAP. Results of weight and tuber

number of different grades are shown in figure 36 and 37. Total tuber number per hectare was enhanced by 27.9% in K Pukhraj and by 50.5% in K Jyoti. Results of this experiment indicate that in future this formulation can be used for enhancing availability of seed potatoes in Punjab from the existing acreage (Figs. 62-63).

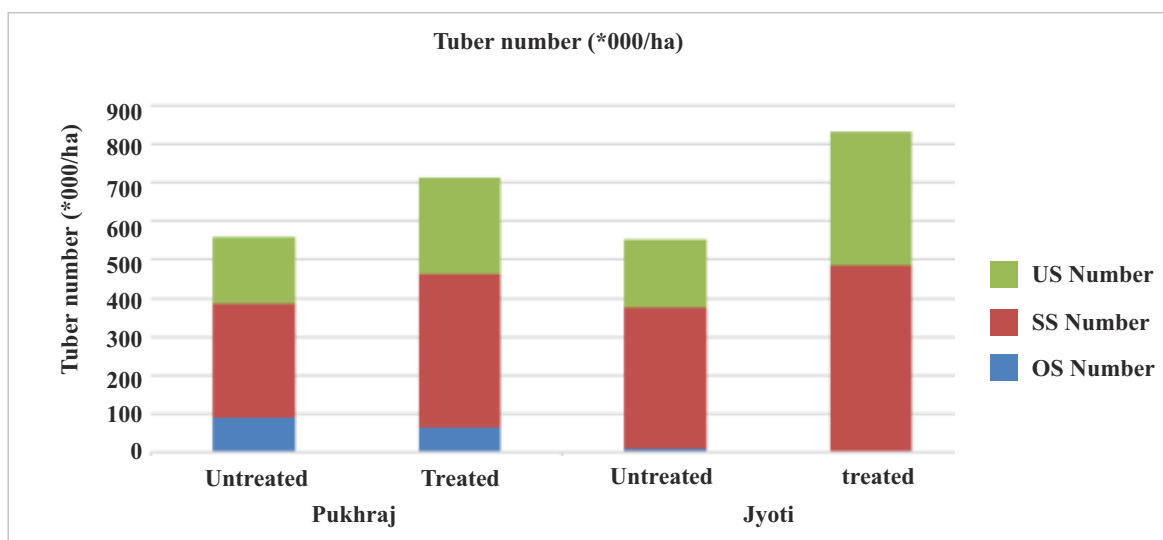


Fig. 62. Number of tubers per hectare in Kufri Pukhraj and K ufri Jyoti

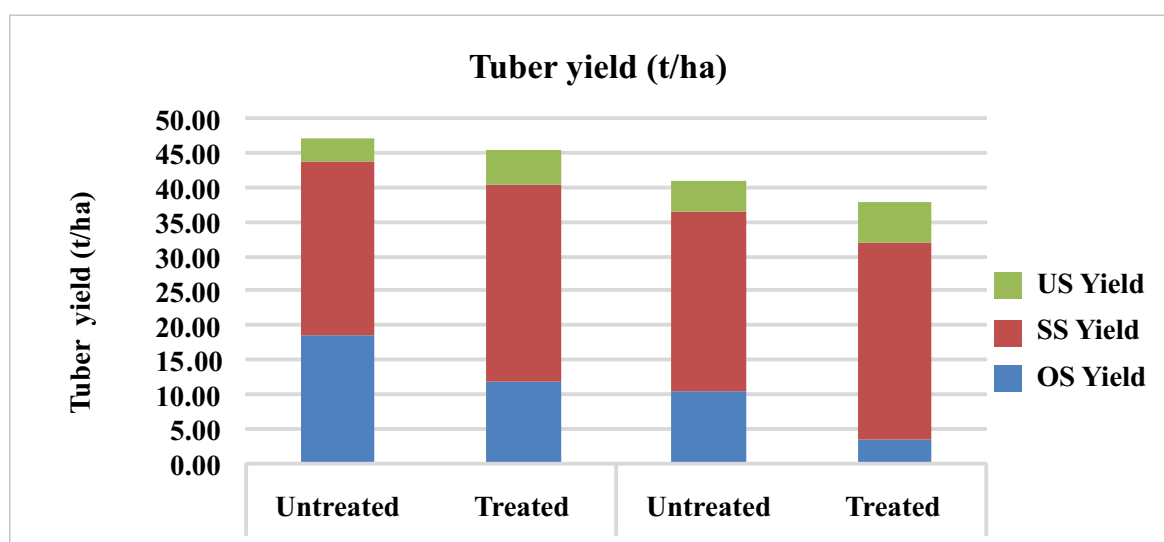


Fig. 63. Effect of CPRI formulation on tuber yield in K Pukhraj and K Jyoti

Minituber production in controlled environment system (CES): CPRI aeroponic technology is being used in various parts of the country for high quality seed potato production. Conventionally in this system potato crop is raised in a greenhouse under sunlight in winter season. Looking into future needs, work was initiated on minituber production using aeroponics under CES at Jalandhar. In CES temperature, humidity, CO₂ and light is managed to meet the crop requirements. A prototype of aeroponic system has been developed suiting indoor conditions. The system consists of a grow box, culture panel, a panel of LED lights, nutrient solution tank, nutrient supply system and a controller. In this system, tissue cultured potato plants were transplanted on the

culture panel of the system and a light intensity of about 250-300 micro mol per second was supplied over the plants for their growth. Preliminary experiments were conducted to evaluate the performance of the system and encouraging results were obtained. The system needs to be tested further (Fig. 64).



Fig.64. Potato crop in aeroponic system under artificial lights

Engineering technologies for potato production and utilization

(Sukhwinder Singh, Brajesh Nare, Prince Kumar)

Hand tools for potato cultivation: At Jalandhar, four different designs of hand ridger have been developed for ridging or earthing-up operation in potato and other vegetable crops (Fig. 65). Single bottom furrower is designed for opening of 10 cm deep furrow in prepared soil. It consists of a furrow opener attached with 4.5 m long handle for operation in standing posture. Two bottom furrower has been designed for covering of seeds, earthing-up and ridge making operation. In this design, two identical furrow openers are attached with a 4.5 m long handle at a bottom distance of 30 cm. This tool can also be used for marking purpose in field. Ridging tool is designed for covering potato seeds by making ridge and furrow. The tool is able to collect soil from 30 cm wide strip of a field, cover the seeds and make suitable ridge. All the tools are light in weight (2.5-4.0 kg) with ease in operation.



Fig. 65. Furrower and ridger for earthing-up operation

Paddy straw management in potato planting:

Under paddy-potato cropping system, very short time window is available for harvesting of paddy, seed bed preparation and potato planting. Different methods are being used for management of paddy straw in field just after harvesting of paddy. Straw management with use of the machinery is either time consuming or high fuel consuming methods. Therefore, experiments were conducted with nine different treatments for paddy straw management during potato planting (Fig. 66). The potato planting treatments were: T1: Opening of slit mechanically (10 cm wide and 15 cm deep) + placement of tubers + covering of tubers; T2: Opening of slit mechanically (10 cm wide and 15 cm deep) + placement of tubers + covering of tubers + earthing-up after 30 DAP; T3: Opening of slit mechanically (10 cm wide and 15 cm deep) + placement of tubers + covering of tubers + mulching with paddy straw; T4: Opening of slit mechanically

(10 cm wide and 15 cm deep) + placement of tubers + covering of tubers + earthing up + mulching with paddy straw; T5: placement of tubers on untilled field and covered with paddy straw; T6: Conventional method; T7: Removing of paddy straw + field preparation + mechanical planting; T8: Strip tilling with rotary tiller (30 cm wide and 7-10 cm deep strip) + placement of tuber on untilled surface + covering with soil and straw; and T9: Strip tilling with rotary tiller (30 cm wide and 7-10 cm deep strip) + placement of tuber on tilled surface + covering with soil and straw. Results are awaited and will be presented in next year's report.



Fig. 66. Field preparation in strips and planting of tubers

VEGFAST: VEGFAST systems have been developed for production of vegetables, herbs, medicinal plants, ornamental plants etc. on the rooftops/ yards/ balconies especially in cities and towns. Seven different designs of VEGFAST system are introduced by CPRI by which safe and fresh vegetables/ salads/microgreens can be grown in city environment (Fig. 67). The systems are simple in fabrication as well as easy and quick to install. In this system soil based media has been used for growing plants. The different designs of VEGFAST troughs are:

- *Rectangular trough:* suitable for vegetables on rooftop or front/back yard
- *Round trough:* suitable for root crops (beetroot, radish, carrot, etc.)
- *Wavy trough:* suitable for vegetables on rooftop or front/back yard
- *Four story vertical trough:* designed for leafy vegetables in balcony
- *Three step vertical trough:* designed for leafy vegetables in balcony



Fig. 67. VEGFAST system for rooftop gardening

HYDROFAST: HYDROFAST systems have been developed for production of leafy vegetables, herbs using hydroponic principles (Fig. 68). Plants can be grown in this system in outdoor conditions under sun light or under controlled conditions under artificial lights. Basically there are four components of HYDROFAST *viz.*, design of system, preparation of nutrient solution, stage-1 plants, stage-2 plants and business model. It consists of a trough/container, culture panel, plant holders, aeration unit and

nutrient solution. The design of the system facilitates end users to take continuous supply of vegetables. One unit of electricity per day is required in this system. Crop remains safe even if there is no power supply for 10-15 hr in a day. Less maintenance is required for crop production under this system. It can be used for domestic purpose (rooftop or indoor), education purpose in schools, universities, colleges and commercial purpose in restaurants, food courts etc.



Fig.68. Lettuce and coriander in HYDROFAST

Mechatronics in potato production

(Brajesh Nare, Sukhwinder Singh, Anil Sharma, RP Kaur)

Unmanned Ground Vehicle: Prototype of a remote operated unmanned ground (UGV) vehicle has been designed and developed for spraying of agrochemicals like pesticides, weedicides, liquid fertilizers etc. on potato crop. The system consists of a mounting frame, four wheels integrated with DC electric motors, all wheel steering system, microcontroller based controller and navigation

system, RF based remote controller, spraying system. Operation and navigation of the system can be controlled by a remote so that no human can be exposed with the harmful chemicals during spraying operation. The system is enabled to drive all the wheels with geared DC motors to generate more traction in the field conditions. A boom type spraying system has been installed with the mounting frame for precise application of the chemicals. Evaluation of the UGV needs to be done under field conditions.



DIVISION OF PLANT PROTECTION

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

Project 1: Emerging Pathogens of Potato and their Management

Disease Monitoring and Pathogens Profile

(Sanjeev Sharma, Mehi Lal, Rahul Kumar Tiwari & Vinay Sagar)

In most of the locations in the sub-tropical plains, late blight appeared during second-third week of January, 2021; hence losses were insignificant. However, in the hills it appeared early i.e. 35 days of planting at Ooty and intensity of blight was up to 100%; whereas at Shimla hills, it appeared on 25th June, 2021 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 - 39.5%.

Comparative Genomics of Potato Pathogens Characterization of *Phytophthora infestans*

(Sanjeev Sharma & Sundaresha S)

It is essential to understand pathogen variability for devising suitable management strategies. This year too the population of *P. infestans* was monitored for sensitivity to metalaxyl, cymoxanil, dimethomorph and fenamidone fungicides. Few isolates were still resistant and intermediate resistant to metalaxyl while all tested isolates were observed to be sensitive to cymoxanil, dimethomorph and fenamidone fungicides.

Characterization of *Alternaria* species

(Sanjeev Sharma, Vinay Sagar, Chandan Maharana & Sundaresha S)

Recent studies have shown that the *Alternaria* population on potato is much more elaborate than a two-species disease complex. Ten species of *Alternaria* have been reported to cause foliar diseases of potato worldwide and the knowledge of which *Alternaria* species are associated with potato foliar diseases is essential in designing management schedules. Last year, isolates collected from different agro-ecologies were purified and characterized for morphological parameters and this year the isolates were molecularly characterized for species identification. The internal transcribed spacer (ITS) region of ribosomal DNA (rDNA) of these isolates was amplified using universal primers ITS1 (5'-TCCGTAGGTGAACCTGCGG-3') and ITS4 (5'-TCCTCCGCTTATTGATATGC-3'). Purified amplicons were sequenced using ABI Prism 310 Genetic Analyzer (v3.1; Applied Biosystems) and manually edited, aligned and phylogenetic tree was constructed using Clustal X. The isolates were identified as *Alternaria alternata* and *A. tenuissima*; where *A. alternata* was found to be the most prevalent (Fig.1).

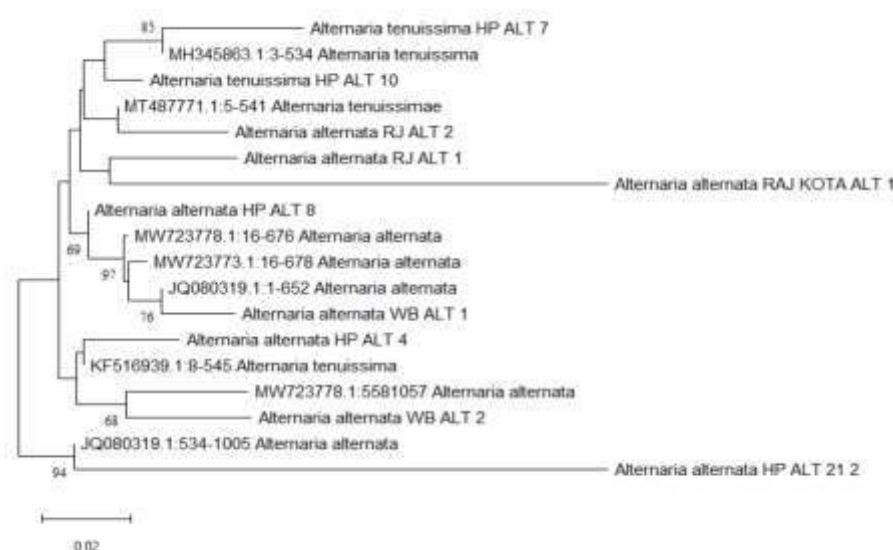


Fig.1: Phylogenetic tree constructed by neighbour-joining using the kimura two-parameter method from the alignment of ITS rDNA sequences of 9 *Alternaria alternata* isolates, 2 *A. tenuissima* isolate, and 7 reference sequences retrieved from GenBank. Bootstrap values >65% from 1000 pseudoreplicates are shown for major lineages within the tree.

The marker denotes a measure of relative phylogenetic distance

Characterization of *Pectobacterium brasiliense* (Vinay Sagar, Sanjeev Sharma & Sundaresha S)

The potato mini tuber samples with soft rot symptoms (Fig. 2) were received from Punjab. Isolations were made on nutrient agar media from infected tubers to obtain pure culture of the bacterium. The DNA of the four isolates was extracted and subjected to PCR with universal primer pair fD1 (5'-AGAGTTTGATCCTGGCTCAG-3') and rp2 (5'-ACGGCTACCTTGTTACGACTT-3') to amplify an expected 1.5kb fragment of 16S rRNA gene of bacterium. The amplified products were further purified, sequenced and sequence data were compared with sequences from NCBI through BLAST programme. The sequence analysis of all the four isolates identified them as *Pectobacterium brasiliense*. *Pectobacterium brasiliense* is known to infect potato, other vegetables and ornamentals.



Fig. 2: Soft rot of tubers due to *Pectobacterium brasiliense* (in right)

Characterization of *Fusarium* species

(Rahul Kumar Tiwari, Sanjeev Sharma, Ravinder Kumar, Milan K Lal & Kailash Naga)

Last year dry rot infected tubers of Kufri Pukhraj were collected from cold store (Fig.3) at Moga district of Punjab where the incidence of dry rot was ~ 30% and processed for isolation of fungus. Identification of the fungus was done morphologically (Fig. 4) and molecularly. Two primer pairs targeting translation elongation factor 1 alpha TEF1 and ITS 1/4 were used for amplification of genomic DNA. The amplicons were sequenced; blast analysed to reveal the species as *Fusarium proliferatum*. The pathogenicity was performed on cultivar 'Kufri Pukhraj' and revealed the pathogenic nature of fungi. The obtained sequences were compared alongside the GenBank nucleotide database by using the BLAST alignment. The TEF-1 sequence showed greater than 99 % identity with *F. proliferatum* [*F. proliferatum* strain NRRL 32155

(FJ538242.1), and *F. proliferatum* strain ITEM2400 (LT841259.1) and the ITS sequence showed 99 % identity with *F. proliferatum* (*F. proliferatum* (AB646795.1) and *F. proliferatum* strain BLE1 (FN868470.1, Fig.5)]. To our knowledge, this is the first report confirming dry rot of potato caused by *F. proliferatum* in India.

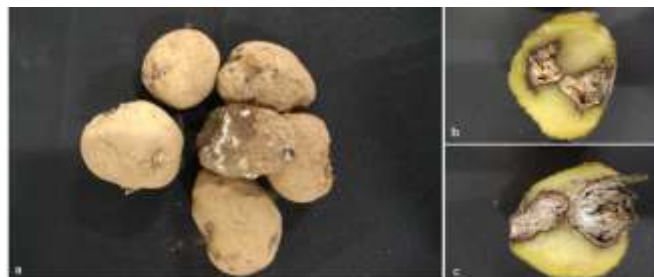


Fig. 3: a) Tubers of the cultivar 'Kufri Pukhraj' showing symptoms of Potato dry rot; b, c) the excised tubers showing internal necrosis and whitish mycelial growth

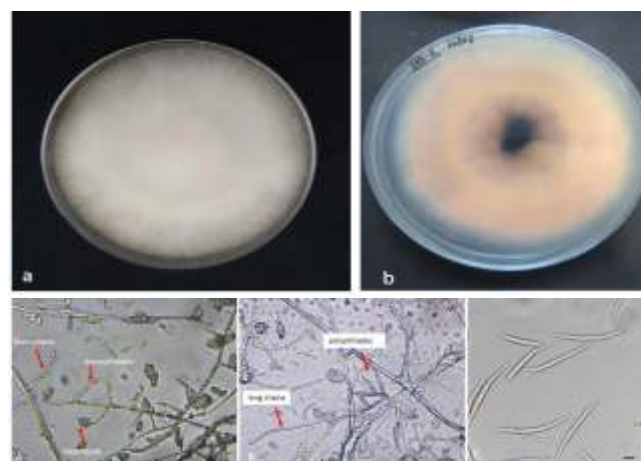


Fig. 4A: a, b) The colonies developed in the pure culture were sparsely white with abundant white mycelium and floccose growth patterns. Fig.4B a)The microconidia on monophiliade, short-chain and false heads; b) long chain of microconidia; c) macroconidia with 3-5 septa at 40X magnification

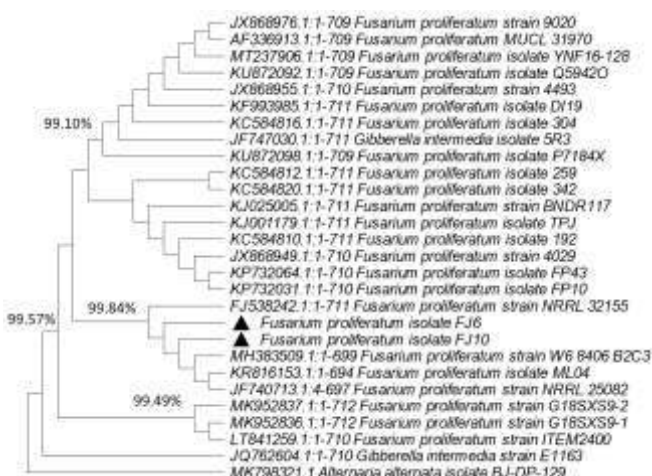


Fig.5: Phylogenetic tree constructed from ITS gene sequences depicting the phylogenetic relationships among *Fusarium proliferatum* using the neighbour-joining method. The bootstrap values were expressed as a percentage of 1000 replicates.

Molecular Diagnostics and Detection of Potato Pathogens

Development of event specific PCR method for detection of RB gene (Sundaresha S, Sanjeev Sharma & Vinay Bhardwaj)

An event-specific polymerase chain reaction (PCR) method was developed that provided positive detection of KJ66 potato DNA at a limit of detection (LOD) of 0.01 per cent. The method was based on the amplification of a 524-bp sequence spanning the junction of the 5' inserted DNA and the flanking genomic sequence on chromosome 4. For PCR,

template DNA dilutions were prepared that contained 10%, 1%, 0.1%, 0.05%, and 0.01% of KJ66 DNA in control Kufri Jyoti DNA (Fig.6A). PCR amplifications performed with the KJ66 event-specific primer pair resulted in the production of a single amplicon corresponding to the expected size of 524 bp, which was detected in all dilutions of KJ66 DNA from 10% to 0.01%. As a positive control for the quality of the isolated genomic DNA as a template for PCR, reactions were performed using primers designed to amplify a 862-bp sequence from the endogenous RNA polymerase 2 sub unit (RPB2) gene present on chromosome 2 (Fig. 6B).

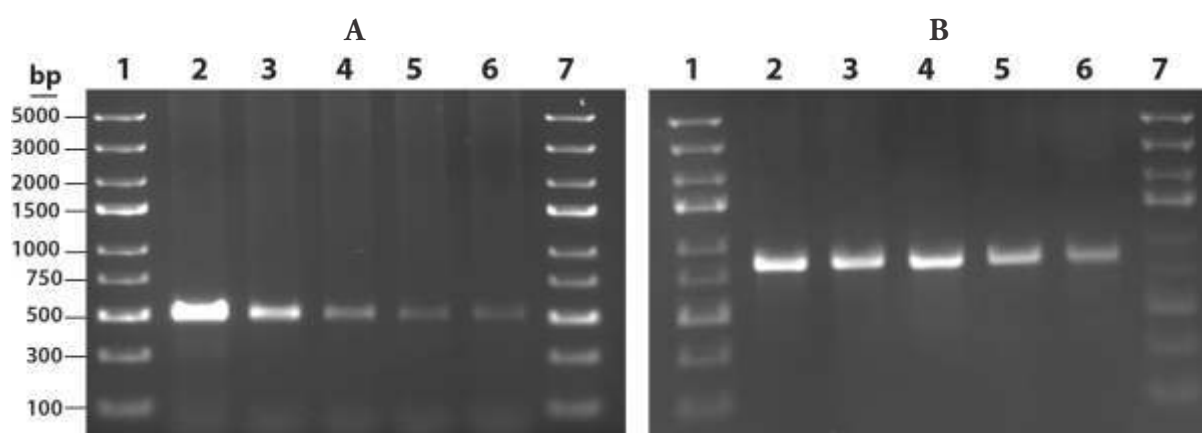


Fig. 6: Samples of KJ66 template DNA were prepared at dilutions of 10% (lane 2), 1% (lane 3), 0.1% (lane 4), 0.05% (lane 5), and 0.01% (lane 6) in control Kufri Jyoti DNA. An amount of 100 ng of each template DNA dilution was used for PCR amplification of a 524-bp sequence spanning the 5' junction of the inserted DNA in KJ66 potato with the flanking genomic sequence from chromosome 4 (panel A) or a 862-bp sequence derived from the endogenous RPB2 gene on chromosome 2 (panel B). DNA size markers are shown in lanes 1 and 7.

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 *rabi* 2020-21 and *kharif* 2021 and the model predicted late blight accurately at each location (Table 1). Accordingly, the agro-advisories were issued to respective regions through print and electronic media to protect the crop from late blight.

Table 1: Performance of Indo-Blightcast model during *rabi* 2020-21 and *kharif* 2021

Location	Prediction date of late blight	Actual date of late blight appearance
Dholi (Bihar)	18.01.2021	21.01.2021
Burdwan (WB)	04.01.2021	07.01.2021
West Midnapur (WB)	25.01.2021	30.01.2021
Hooghly (WB)	Did not predict	Did not appear
Kanpur (UP)	10.01.2021	13.01.2021
Jorhat (Assam)	12.01.2021	16.01.2021
Shimla (HP)	25.06.2021	01.07.2021

Pathogenicity of *Alternaria* isolates

(Sanjeev Sharma & Vinay Sagar)

Pathogenicity was proved by detached leaf inoculation method on cv. Kufri Jyoti. Injury was caused by needle on one side of the midrib and immediately inoculated by using micropipette to place 10 µl droplet of the *Alternaria* isolate spore suspension. The other side of the midrib received a 10 µl droplet of the inoculum without injury. Leaflets receiving only sterile water droplets were treated as control. The boxes were sealed with para-film and placed in an incubator at 25±1°C and 16-h photoperiod. The leaflets were observed regularly for the appearance of symptoms and lesion area (LA) was measured daily after determination of incubation period. The first method of inoculation (injury

inoculated) was found superior as it produced clear and early symptoms. Hence, data of this method were included only. All the isolates were found pathogenic with varying degrees of aggressiveness. Highest lesion size (2.36 mm²) was recorded with the isolate MH-ALT-3, followed by the isolate MP-ALT-1 (2.33 mm²), and PB-ALT-2 (2.31 mm²). On the other hand, least lesion size (0.49 mm²) was produced by the isolate RJ-ALT-3 followed by HP-ALT-5 (0.69 mm²) and HP-ALT-4 and MH-ALT-1 (0.76 mm²). On the basis of lesion size, isolates were grouped into different categories. Eight isolates were found least aggressive as they could produce lesion size of <1.0 mm² while seventeen isolates were grouped into the category of moderately aggressive. None of the isolates was aggressive and highly aggressive (Table 2).

Table 2: Progression of lesion size of *Alternaria* isolates on detached leaves

Lesion size (mm ²)	Isolate	Aggressiveness category
<1.0	HP-ALT-1, HP-ALT-2, HP-ALT-5, HP-ALT-4, HP-ALT-6, HP-ALT-10, RJ-ALT-3, MH-ALT-1	Least aggressive
1.1 - 2.50	HP-ALT-9, PB-ALT-1, PB-ALT-2, MH-ALT-3, RJ-ALT-1, RJ-ALT-2, UP-ALT-1, MP-ALT-2, MP-ALT-1, MH-ALT-2, HP-ALT-11, HP-ALT-3, HP-ALT-7, WB-ALT-1, WB-ALT-2, WB-ALT-3, MP-ALT-3	Moderately aggressive
2.51-5.00	NIL	Aggressive
>5.00	NIL	Highly aggressive

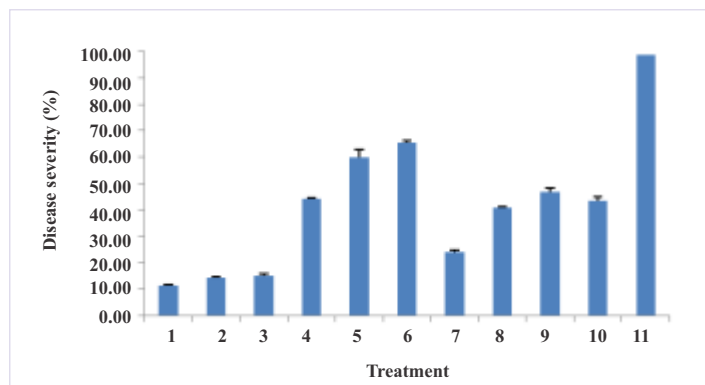
Management of Potato Pathogens

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

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 as the pathogen adapts very quickly to the fungicides after its regular application. In first experiment ten

treatments consisting of existing and new fungicides (Dimethomorph 12% + Pyraclostrobin 67% WG, Cyazofamid 34.5% SC) were evaluated against late blight of potato. Amongst the tested fungicides, dimethomorph 50% WP @ 0.1 % (11.17% DS), Cymoxanil8+mancozeb 64%WP @ 0.3% (14.17% DS) and Dimethomorph12%+Pyraclostrobin 67% WG @ 0.25% (24.00%), showed less disease severity as against control (98.67%) Fig. 7).

Fig. 7: 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%, 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 + Tebuconazol 12.5 SC @ 0.1%, T11: Control]

Similarly, fungicides were tested for two consecutive seasons (2019-20 & 2020-21) for developing spray schedules for managing late blight of potato. Amongst tested schedules, treatment (T1) consisted of mancozeb 75% @ 0.2% (before appearance of disease)-Fluopicolide 62.5 + propamocarb hydrochlorid 625 SC @ 0.3% (at onset of the disease)-Fluopicolide 62.5 + propamocarb hydrochlorid 625 SC @ 0.3% (after 7 days) after second spray recorded lowest disease severity (13.00% DS) followed by (T5) Mancozeb 75% @ 0.2% (before appearance of the disease) – Dimethomorph 50% WP @ 0.1% + Mancozeb 75% @ 0.2% (at onset of the disease) - Dimethomorph 50% WP @ 0.1% + Mancozeb 75% @ 0.2% (after 7 days) of second spray with disease severity 15.00 % followed by (T2) spraying of Mancozeb 75% @ 0.2% (Before appearance of disease)- Azoxystrobin 11.5% + Mancozeb 30% WP @ 0.25% (at onset of the disease) – Azoxystrobin 11.5% + Mancozeb 30% WP @ 0.25% (after 7 days) of second spray with 17.17% disease severity as against of 97.00% in control (Fig. 8). This experiment concluded that these spray schedules could be applied for effective management of late blight of potato.

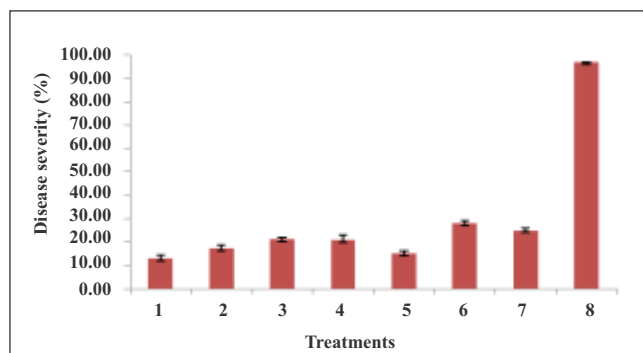


Fig. 8: Development of spray schedules (using one spray contact fungicide and two sprays of same systemic/translaminar fungicides) for management of late blight of potato

[T1: Mancozeb 75% @ 0.2%- Fluopicolide 62.5 + propamocarb hydrochloride 625 SC @ 0.3% - Fluopicolide 62.5 + propamocarb hydrochloride 625 SC @ 0.3%, T2: Mancozeb 75% @ 0.2% - Azoxystrobin 11.5% + mancozeb 30% WP @ 0.25% -Azoxystrobin 11.5% + mancozeb 30% WP @ 0.25% , T3: Mancozeb 75% @ 0.2% - Cymoxanil 8+ mancozeb 64% WP @ 0.3% -Cymoxanil 8+ mancozeb 64% WP @ 0.3%, T4: Mancozeb 75% @ 0.2% - Fenamidon 10+ mancozeb 50% WG @ 0.3% – Fenamidon 10+ mancozeb 50% WG @ 0.3%, T5: Mancozeb 75% @ 0.2% –Dimethomorph 50% WP @ 0.1%+ mancozeb 75% @ 0.2% - Dimethomorph 50% WP @ 0.1%+ mancozeb 75% @ 0.2%, T6: Mancozeb 75% @ 0.2%)- Metalaxyl 8+ mancozeb 64% WP @ 0.25% -Metalaxyl 8+ mancozeb 64% WP @ 0.25%, T7: Mancozeb 75% @ 0.2% -Ranman 0.02% + mancozeb 75 WP @ 0.1% - Ranman 0.02% + mancozeb 75 WP @ 0.1%, T8: Control]

In another experiment nine treatments were tested for developing sprays schedules. Amongst tested schedules, treatment (T7) consisted of mancozeb 75% WP @ 0.2% (before appearance of disease)- Ametoctradin 27% + Dimethomorph 20.27% SC @ 0.2% (at onset of disease)– Cymoxanil 8+ mancozeb 64% WP @ 0.3% (after 7 days) of second spray recorded lowest diseases severity (29.50 %) followed by (T6) Mancozeb 75% @ 0.2% (before appearance of disease)- Azoxystrobin 11.5% + mancozeb 30% WP @ 0.25% (at onset of disease) -Azoxystrobin 11%+tebuconazole 18.3% WS @ 0.1% (after 7 days) of second spray with 36.00 % disease severity and (T2) Chlorothalonil 75% WP @ 0.2% (before appearance of disease)- Ametoctradin 27% + dimethomorph 20.27% SC @ 0.2% (at onset of disease)- Dimethomorph 50% WP @ 0.1% (after 7 days) of second spray with 40.00% severity against 97.67% in control (Fig. 9). These spray schedules could be applied for effective management of late blight of potato with less chance for development resistance against these fungicides.

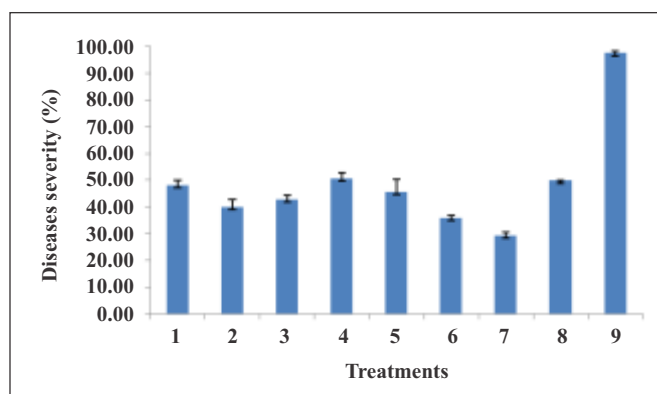


Fig. 9: Development of spray schedules (using one spray contact fungicide and two sprays of same systemic/translaminar fungicides) for management of late blight of potato

[T1: Mancozeb 75% WP @ 0.2%- Fluopicolide 62.5+propamocarb hydrochloride 625 SC @ 0.3%- Cymoxanil 8+ mancozeb 64% WP @ 0.3%, T2: Chlorothalonil 75% WP @ 0.2%- Ametoctradin 27% + dimethomorph 20.27% SC @ 0.2% - Dimethomorph 50% WP @ 0.1%, T3: Mancozeb 75% WP @ 0.2%- Fenamidon 10+ mancozeb 50% WG @ 0.3%- Azoxystrobin 11.5% + mancozeb 30% WP @ 0.25%, T4: Chlorothalonil 75% WP @ 0.2% -Cymoxanil 8+ mancozeb 64% WP @ 0.3% - Fluopicolide 62.5+propamocarb hydrochloride 625 SC @ 0.3%, T5: Chlorothalonil 75% WP @ 0.2% –Dimethomorph 50% WP @ 0.1% - Fenamidon 10+ mancozeb 50% WG @ 0.3%, T6: Mancozeb 75% @ 0.2% - Azoxystrobin 11.5% + mancozeb 30% WP @ 0.25% -Azoxystrobin 11%+tebuconazole 18.3% WS @ 0.1%, T7: Mancozeb 75% WP @ 0.2%- Ametoctradin 27% + Dimethomorph 20.27% SC @ 0.2% -Cymoxanil 8+ mancozeb 64% WP @ 0.3%, T8: Chlorothalonil 75% @ 0.2% - Azoxystrobin 11%+Tebuconazole 18.3% WS @ 0.1% - Dimethomorph 50% WP @ 0.1%, T9: Control]

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) followed by 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 recorded maximum yields (32.23 and 32.19 t/ha, respectively). This was followed by T4, T5, T6 and T3. All the fungicide treatments significantly reduced the intensity of late blight (AUDPC) compared to untreated control. The lowest yield (1.48 t/ha) and highest AUDPC value (299) was recorded in untreated control (T7) (Fig. 10).

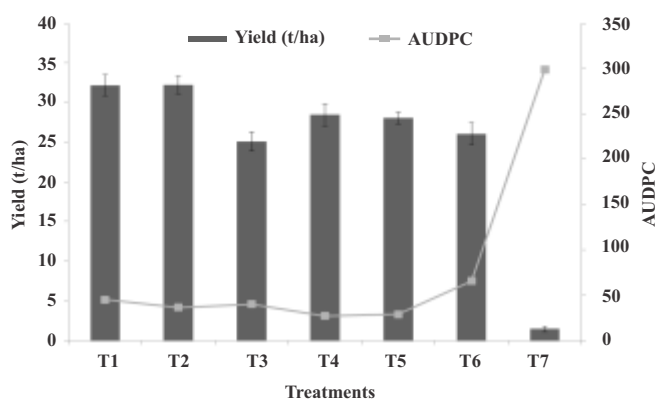


Fig. 10: Effect of different fungicides spray schedule on development of late blight

[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, 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]

Testing of new fungicides/ chemicals/ plant extracts for efficient and economical management of tuber borne diseases (Mehi Lal, Mohd Abas Shah, Vinay Sagar & Sanjeev Sharma)

In-vitro evaluation: There are some reports that farmers use copper oxychloride 50WP and copper hydroxide 53.8W/W as soil drench in the standing crop for management of bacterial wilt disease of tobacco, tomato etc. To see whether these two fungicides are really effective against the pathogen, both were tested *in-vitro* against *Ralstonia solanacearum* (R1bv3 and R3bv2) at concentrations 1500 ppm, 3000 ppm and 4500 ppm (Fig. 11 A&B) and were found ineffective.

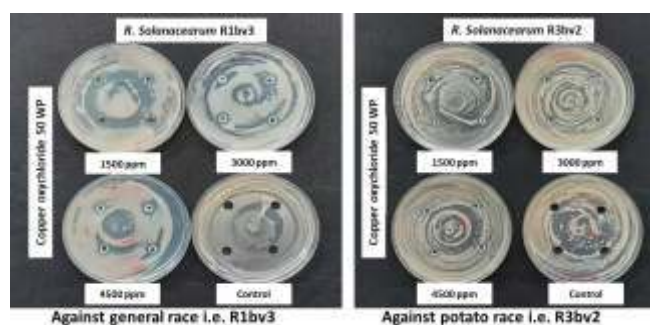


Fig. 11A: In-vitro efficacy of copper oxychloride 50WP against *R. solanacearum*

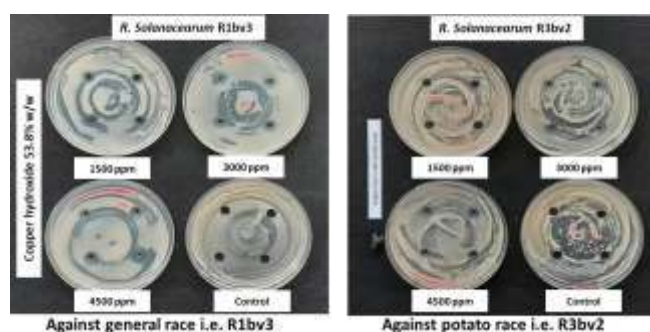


Fig. 11B: In-vitro efficacy of copper hydroxide 53.8% w/w against *R. solanacearum*

All sorghum plants are known to contain prussic acid (hydrocyanic acid) which is toxic to animals. The toxic potential is greatest in seedlings and new growths of sorghum until the plants are at least 18 to 24 inches tall. To ascertain its toxicity to soil borne pathogens of potato; foliage and root extracts of one month old crop of *Sorghum bicolor* (10 to 12 inches tall plants) were tested *in vitro* for its inhibitory effect against *Ralstonia solanacearum*, *Streptomyces scabies*, *Pectobacterium brasiliense*, and *Fusarium sambucinum* and found ineffective.

Field experiments: Ten tuber treatments/ soil applications of fungicides/ chemicals/ endophytic bacteria, namely, tuber treatment with mancozeb

72WP (0.3%), copper-oxchloride 50WP (0.3%), Streptocyclin (200ppm), $ZnSO_4$ (1000ppm a.i.), endophytic bacteria (E-20, E-23, E-44, E-48) and soil application of $ZnSO_4$ (50.0 Kg/ha), and ClO_2 @ 100.0 Kg/ha were tested in a field experiment at Jalandhar (2020-21 season) for management of common scab disease. Among these, soil application of ClO_2 resulted in minimum disease severity and incidence (3.67 and 29.7%, respectively) followed by tuber treatment with copper-oxchloride (5.68 and 37.44%, respectively) compared to control (11.46 and 62.87%, respectively).

In another field experiment at Jalandhar, different concentrations of ClO_2 varying from 0.1 to 0.3% were used as tuber treatment before cold storage and after cold storage prior to sprouting to see the effect on common scab disease development in the field. It was observed that the intensity of common scab decreased to 10.51 - 4.36% with increase in ClO_2 concentration compared to 12.78% severity in control in tubers treated prior to cold storage. However, when the tubers were treated after being taken out of cold storage and prior to sprouting, the intensity of common scab decreased to 8.77 - 2.34% with increase in ClO_2 concentration compared to 14.44% severity observed in untreated control. In none of the trials, the storage behaviour, germination percentage or tuber yield was affected significantly with the tuber treatments. It is concluded that tuber

disinfection with chlorine dioxide prior to cold storage or preferably after cold storage prior to sprouting can help manage the common scab disease.

In another experiment at Modipuram, 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. It was observed that all treatments showed less incidence and disease severity in comparison to control. However, lowest disease incidence (0.67%) and disease severity (0.17%) was recorded with Pencycuron @ 0.25% (T1) & spraying method with Thifluzamide @ 0.35% (T10) (Fig.12). Azoxystrobin @ 0.15% (T4) as spray method and Penflufen @ 0.083% (T7) also recorded less disease incidence and severity. Highest level of disease incidence (80.0%) and severity (46.67%) was recorded in Huwa San @ 10ml/L by dipping method (T24) followed by Carbendazim 12% + Mancozeb 63% WP @ 0.35% using spray (T18) (DI: 75.33% & DS: 46.83%) against control (T23) 81.36 DI and 51.67% DS.

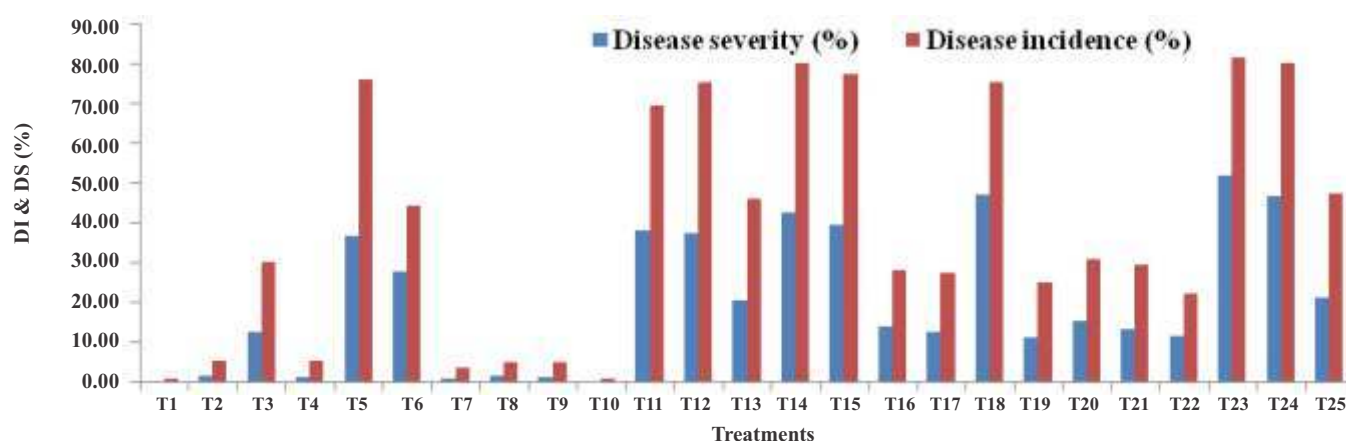


Fig. 12: Effect of different chemicals on black scurf development

Screening of potato varieties for resistance to *Ralstonia solanacearum* under controlled conditions

(Vinay Sagar, Sanjeev Sharma & Vinay Bhardwaj)

Eight potato lines/ collections namely, SM/92-338,

SM/03-23, Champaran Lal, Rangpuria, Badami, SM/11-93, K. Lauvkar and Assomia Alu having shown resistance to *Ralstonia solanacearum* in earlier *in-vitro* screening tests, were further tested in a pot experiment under controlled conditions in a growth chamber ($28 \pm 1^\circ\text{C}$ day and $20 \pm 1^\circ\text{C}$ night temperature

with 16 hrs light and 08 hrs dark period). Four lines/collections namely SM/92-338, SM/03-23, SM/11-93 and Assomia Alu showed good resistance to bacterial wilt till 28 days after inoculation (DAI)

compared to K. Jyoti which collapsed completely 13 DAI (Fig. 13). The experiment will be repeated under field conditions in sick plot.



Fig. 13: Screening of potato lines for resistance to *Ralstonia solanacearum* under controlled conditions

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

(Vinay Sagar, Sanjeev Sharma & Vinay Bhardwaj)

A total of 164 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 one line 'JEX/A-197' showed resistance (tested twice) 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.14).

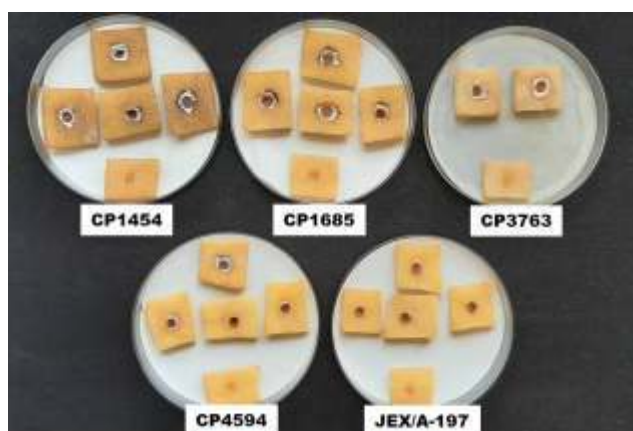


Fig.14: Screening potato lines for tolerance to thaxtomin A toxin produced by *Streptomyces scabies* through tuber slice assay

Screening of potato germplasm lines for dry rot tolerance

(Rahul Kumar Tiwari, Sanjeev Sharma, Vikas Mangal, Vinay Sagar & Vinay Bhardwaj)

Most of the cultivated varieties in India and world are susceptible to dry rot fungus *Fusarium sambucinum* which is most aggressive fungus responsible for dry rot development in cold stores. Based on this information, screening of 200 germplasm lines against dry rot disease was undertaken. On the apical end of tubers, a 6 x 6 mm wound was created using cork borer and the mycelial bits were applied to each wound. The control tubers were inoculated with water agar. The inoculated region was sealed with sterile wax strip. The tubers were kept at 18°C and 90% relative humidity for 21 days. The observation of lesion diameter, lesion depth and rot volume were taken and accordingly the level of tolerance was assigned using internationally acclaimed scale. Out of 200 germplasm lines, 8 lines (CP4594, JA947, CP1468, CP364, CP3211, CP1868, JA30, CP3809, Fig. 15) have shown tolerance in the first round of screening experiment. However, 24 lines have been found to be moderately susceptible to potato dry rot. Remaining 168 lines were observed to be highly susceptible to this disease. Further repetition of the screening experiment is required to establish the exact level of tolerance in the aforementioned germplasm lines.

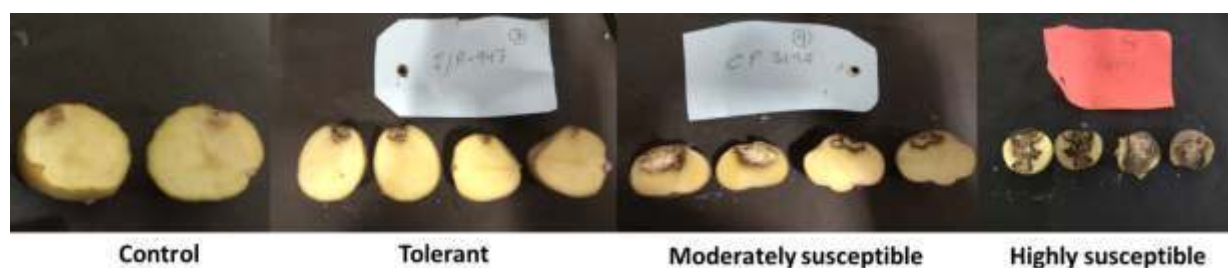


Fig. 15: A representative picture showing the lesion development in tolerant (J/A-497), moderately susceptible (CP 3192) and highly susceptible (CP 4096) lines

Efficacy of salts and essential oils on *in vitro* growth of *Fusarium sambucinum*

(Rahul Kumar Tiwari, Sanjeev Sharma, Ravinder Kumar, Milan K Lal & Kailash Naga)

There is need to identify safe and eco-friendly methods for the management of dry rot pathogens as synthetic chemicals and fungicides have raised critical concern of residual toxicity and fungicide resistance. Keeping this in view, we tested five different inorganic salts *viz.*, sodium benzoate, sodium carbonate, sodium bicarbonate, sodium metabisulfite, potassium sorbate and two essential oils (cinnamon and clove) *in vitro* for their efficacy. Three concentrations (0.1, 0.2, 0.3M) of each salt and pure essential oil were used in this experiment. Results revealed that two salts (sodium metabisulfite and potassium sorbate) had potential to inhibit mycelial growth in a concentration dependent manner. Within three days of fungal incubation, the mycelial growth in culture media treated with sodium benzoate, sodium carbonate, sodium bicarbonate was

similar in diameter as compared with respective controls. However, the fungal growth in sodium metabisulfite treated media had shown 60 and 100 % inhibition at 0.2 and 0.3M concentrations. The fungal growth did not appear even after keeping the plates for 21 days. However, potassium sorbate restricted the mycelial growth up to 40% only at 0.3M concentrations. Overall, among these salts only sodium metabisulfite had efficacy of inhibiting complete fungal growth at 0.3M concentration. It will be interesting to observe the in-tuber pathogen suppression under storage conditions. Similarly, both the oils completely restricted the mycelial growth as compared with control (Fig.16). The combination of oil was equally effective in complete inhibition of fungi. We performed the volatile assay using double disc diffusion assay with the combination of oil and observed similar pattern of complete inhibition of fungal growth over the incubation period on 21 days. In future experiments we will decipher the *in vivo* efficacy of these effective compounds and also standardize the lower doses of essential oils.

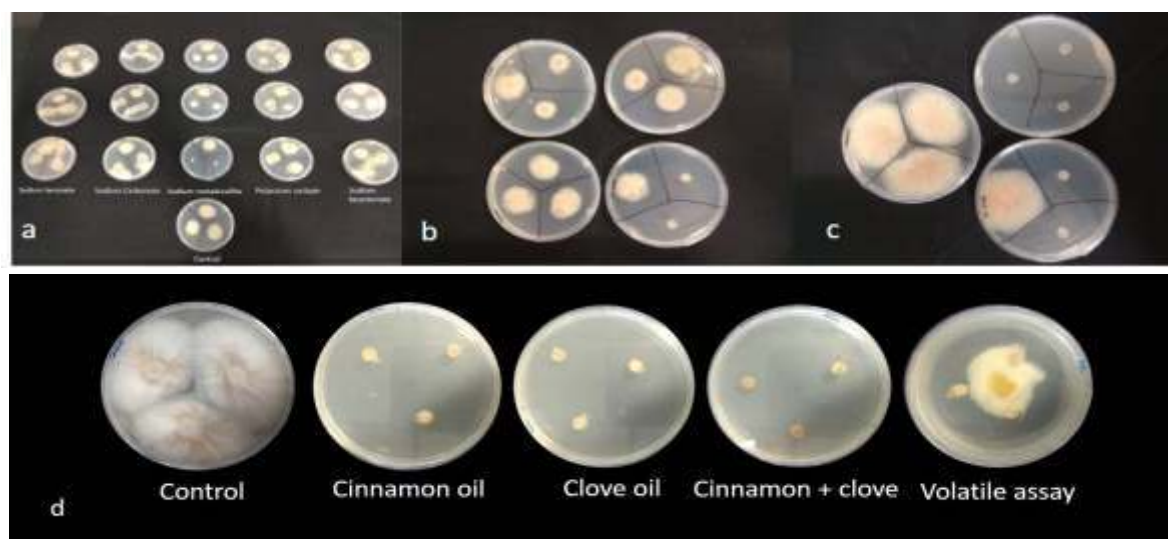


Fig.16: a) Effect of five different salts on *in vitro* growth of *F. sambucinum*; b) effect of three concentrations (0.1, 0.2 and 0.3M) of sodium metabisulfite (SMB) on mycelial growth of *F. sambucinum*; c) 0.3M SMB restricting complete growth of fungi; d) The effect of pure concentrations of essential oils on mycelial growth

Biotechnological Approaches

Silencing of PAP2 susceptible gene induces systemic production of ROS/cell death and innate defense against *Ralstonia solanacearum*

(Sundaresha S, Vinay Sagar, Sanjeev Sharma, & Vinay Bhardwaj)

In earlier experiments, identified and isolated a PAP2 gene responsible for bacterial wilt susceptibility in potatoes and developed resistant lines through RNAi and proved their functionality. This year, systemic induction of ROS/cell death, avirulent colony assay

was performed to authenticate the suppression of PAP2 in inducing the defense mechanism which showed low bacterial load in resistant lines. Systemic accumulation of ROS was sensed in all cellular compartments as indicated by brown spot accumulation in systemic leaf parts (Fig.17) of RNAi lines and it might be via different redox-based mechanisms and ROS produced in the apoplast and in chloroplasts; mitochondria and peroxisomes are involved in inter organellar communication to trigger the immune response (as supported by Mignolet-Spruyt et al., 2016).

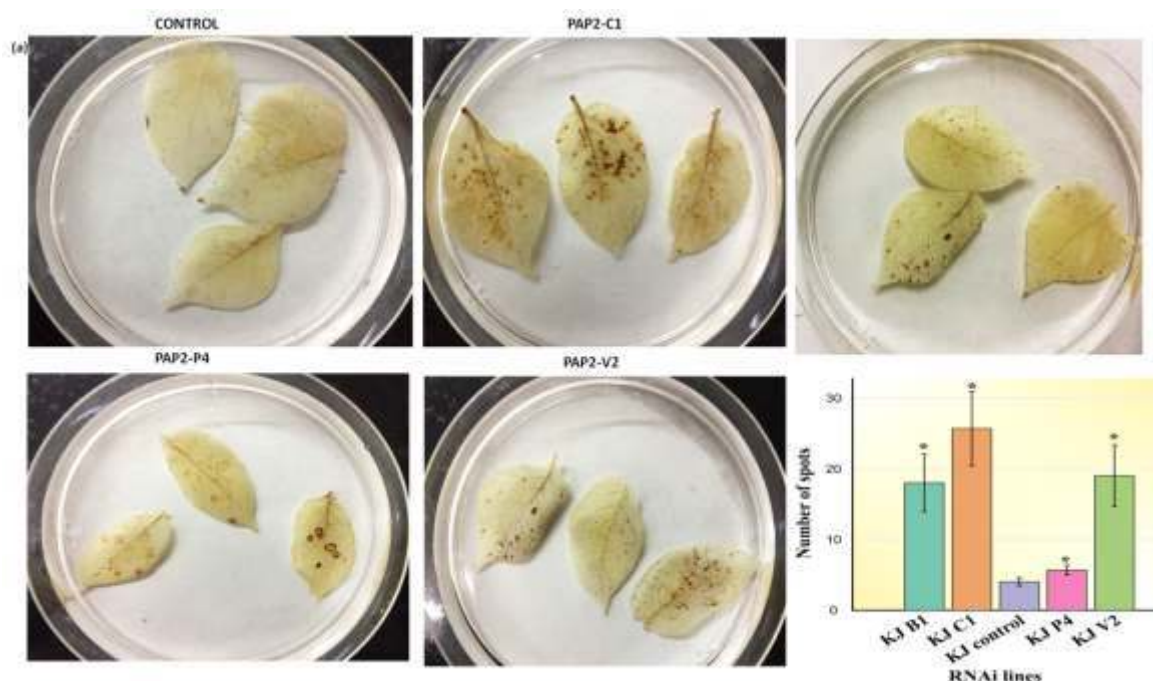


Fig. 17: DAB assay: ROS production was visualized after 48 hours of *R. solanacearum* inoculation of leaves of RNAi PAP2 lines and control KJ plant

Post entry quarantine testing of imported germ-plasm

(Vinay Sagar, Sanjeev Sharma, Ravinder Kumar & Vinay Bhardwaj)

Twenty nine *in-vitro* cultures of potato imported by M/s Technico Agri Sciences Pvt Ltd, 03 TPS line imported by M/s Tierra Agrotech Pvt Ltd and 02 TPS lines imported by Mahyaco Pvt Ltd were tested for post entry quarantined pathogens.

Project 2: Diagnostic and management of viral diseases of potato

Enumeration of potato viruses: Disease observation and sampling from Jalandhar,

Punjab (Baswaraj Raigond, Gaurav Verma & Sanjeev Sharma)

The virus infected potato leaf samples (>200) were

collected from Jalandhar (Punjab) and categorized as mentioned in Fig. 1. The samples were immediately stored in dry ice (on-field preservation) and transferred to deep-freezer (-80°C). Later, the samples were processed for Next Generation Sequencing (Illumina) Eurofins Genomics India Pvt. Ltd., Bangalore, Karnataka. Majority of the samples exhibited mild mosaic to severe mosaics, leaf rolling followed by leaf curling symptoms. Also observed necrosis on stem, veins and on apical portion of potato plants. Apart from the above described symptoms, some plants exhibited brownish discoloration of leaves (lower side) whereas its upper side appears healthy, necrosis of veins, midrib, and also necrosis on main and lateral stems. These plants were brittle & cracks upon gentle bend with a cracking sound.



Fig.1: Potato leaf showing different symptoms due to virus infection and their categorization in five samples. Sample no.1: mosaic and sever mosaic (1), sample no.2: leaf roll, leaf curl/ abnormal shape (2-3), sample no.3: venial/ stem necrosis (4-5), sample no.4: mixed infection/ unknown symptoms (6-8) and sample no.5: apparently healthy/ asymptomatic (9)

Enrichment of potato viruses by ribosomal RNA depletion methodology for unbiased high-throughput sequencing (Gaurav Verma, Baswaraj Raigond & Sanjeev Sharma)

The potato leaf samples with mixed infection were processed for total RNA extraction. The quality and quantity of the samples were determined on NanoDrop and denatured agarose gel (Fig. 2) followed by Agilent Tape station using RNA Screentape (Fig. 3). The method utilizes a Ribosomal RNA depletion step to remove unwanted host ribosomal and carrier RNA. Selective depletion enriches for viral content and improves the overall quality of sequencing data (Fig. 4) from sample. The

samples were processed with Illumina TrueSeq standard mRNA sample Prep kit and TrueSeq Total RNA Library Prep Kit. The qualities of libraries passed were processed for sequencing on NextSeq5000 platform using 2 x 150bp chemistry. A total of 3.6 and 4.1 Gb data high quality paired reads generated for 4T and 4T-depleted samples, respectively (Table 1). The reads were subjected to *de novo* assembly, using SPAdes v3.120. A total of 38,095 and 41,840 genes were predicted using Prodigal in 4T and 4T-depleted samples, respectively (Table 2 & 3). The resulting genes were considered for taxonomical classification. The taxonomical classification of genes found a total of 47 and 25 viral hits in 4T and 4T-depleted samples.

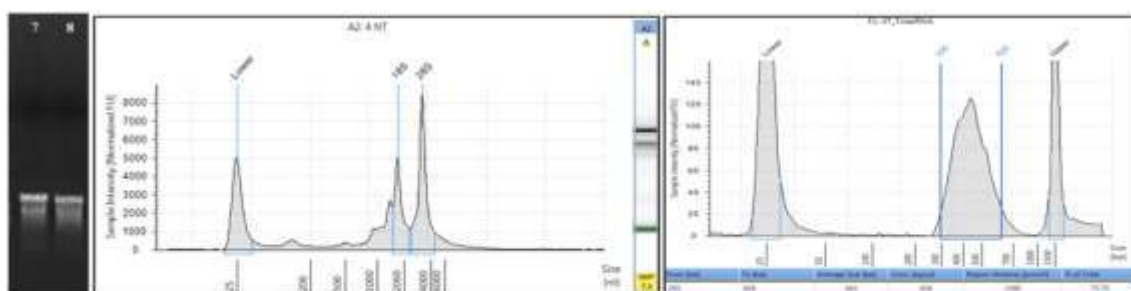


Fig 2: RNA on denature agarose gel;

Fig 3: QC of samples on Tape station

Fig4: Library profile on Tape station

Table 1: High Quality reads statistic of 4T and 4T-depleted samples

Description	4T	4T-Depleted
No. of PE Reads	12,597,804	13,923,928
Number of bases	3,675,752,359	4,089,775,079
Total data in Gb	3.6	4.1

Table 2: Assembly statistics of 4T and 4T-depleted samples

Description	Number of genes	Average gene length (bp)	Maximum gene length (bp)
4T	38,095	615	11,298
4T-Depleted	41,840	688	37,796

Table 3: Gene prediction statistics of 4T and 4T-depleted samples

Description	Number of Scaffolds	Total length of the assembly (bp)	Average length of scaffolds (bp)	Scaffold N50 (bp)	Maximum length of scaffold (bp)
4T	37,418	32,214,591	860	1,171	12,122
4T-Depleted	41,840	37,192,481	888	1,347	37,796

Determination of potato virome by high-throughput sequencing

(Gaurav Verma, Baswaraj Raigond & Sanjeev Sharma)

The potato samples collected from Jalandhar district of Punjab and exhibiting symptoms of mosaic and sever mosaic; leaf roll, leaf curl/ abnormal shape; venial/ stem necrosis; mixed infection/ unknown symptoms; and apparently healthy/ asymptomatic were undertaken for virome analysis. The samples were processed with ribosomal depletion methodology for selective depletion which enriches

viral content and improves the overall quality of sequencing data (Fig.5-7). The sequencing was performed in NextSeq5000 platform using 2 x 150bp chemistry. A total of 4.5, 4.3, 4.0, 4.1 and 3.7 Gb data with high quality paired reads generated for 1T, 2T, 3T, 4T and 5T samples, respectively (Table 4). The reads were subjected to *de novo* assembly, using SPAdes v3.120. A total of 39,611, 39,356, 34,570, 41,840 and 37,133 genes were predicted using Prodigal in 1T, 2T, 3T, 4T and 5T samples, respectively (Table 5 & 6). The resulting genes were considered for taxonomical classification.

Table 4: High quality read statistics of 1T, 2T, 3T, 4T and 5T samples

Description	1T	2T	3T	4T	5T
No. Of PE reads	15,738,691	14,963,665	13,955,932	13,923,928	12,963,842
Numbers of bases	4,509,339,409	4,312,362,914	4,067,102,228	4,089,775,079	3,722,015,181
Total data in Gb	4.5	4.3	4.0	4.1	3.7

Table 5: Assembly statistics of 1T, 2T, 3T, 4T and 5T samples

Description	Number of Scaffolds	Total length of the assembly (bp)	Average length of scaffolds (bp)	Scaffold N50 (bp)	Maximum length of scaffold (bp)
1T	39,973	32,967,321	822	1,096	33,294
2T	39,914	33,526,828	836	1,133	23,606
3T	34,451	27,634,420	798	1,043	26,566
4T	41,840	37,192,481	888	1,247	37,796
5T	37,366	31,329,015	836	1,130	31,393

Table 6: Gene prediction statistics of 1T, 2T, 3T, 4T and 5T samples

Description	Number of genes	Average gene length (bp)	Maximum gene length (bp)
1T	39,611	573	5,928
2T	39,356	595	9,186
3T	34,570	581	9,186
4T	41,840	888	37,796
5T	37,133	599	9,186

The taxonomical classification of genes found a total of 39, 70, 90, 25 and 20 viral hits in 1T, 2T, 3T, 4T and 5T samples. *Potato virus M* and *Potato virus X* were the most prevalent viruses present in all leaf samples. Other known potato viruses, such as *Potato virus Y*, *Potato leafroll virus*, *Potato virus S* and *Tomato leaf curl New Delhi virus* occurred in samples in low

incidences. Additionally, other viral sequences showing significant similarity to Alfalfa mosaic virus associated with potato samples 2T and 4T, 5T were found in the libraries. Besides, some unknown viruses were found in the libraries which need further validation.

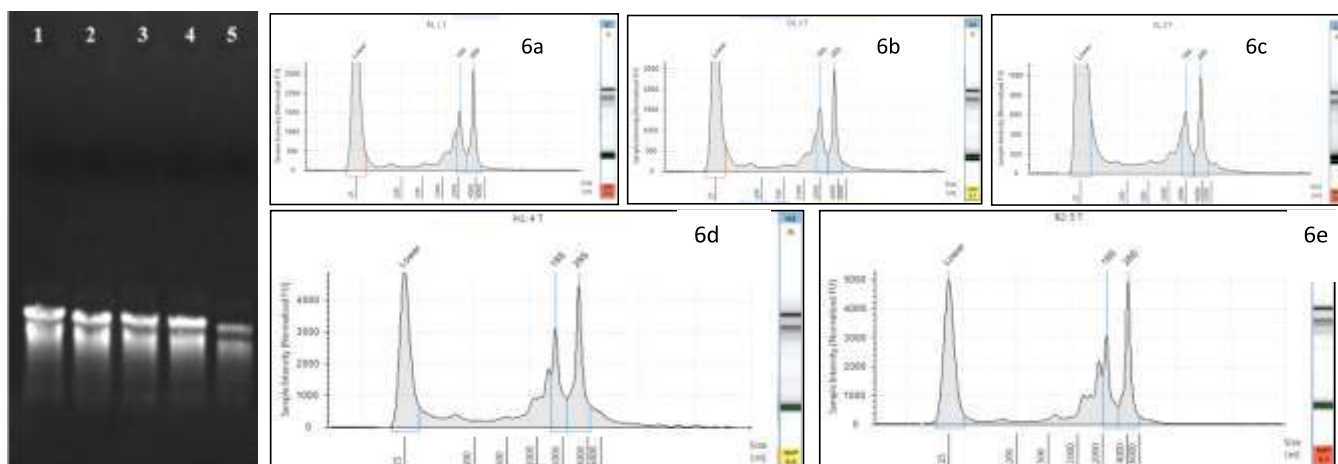


Fig. 5 Denature agarose gel

Fig. 6 (a-e) QC of Total RNA on TapeStation

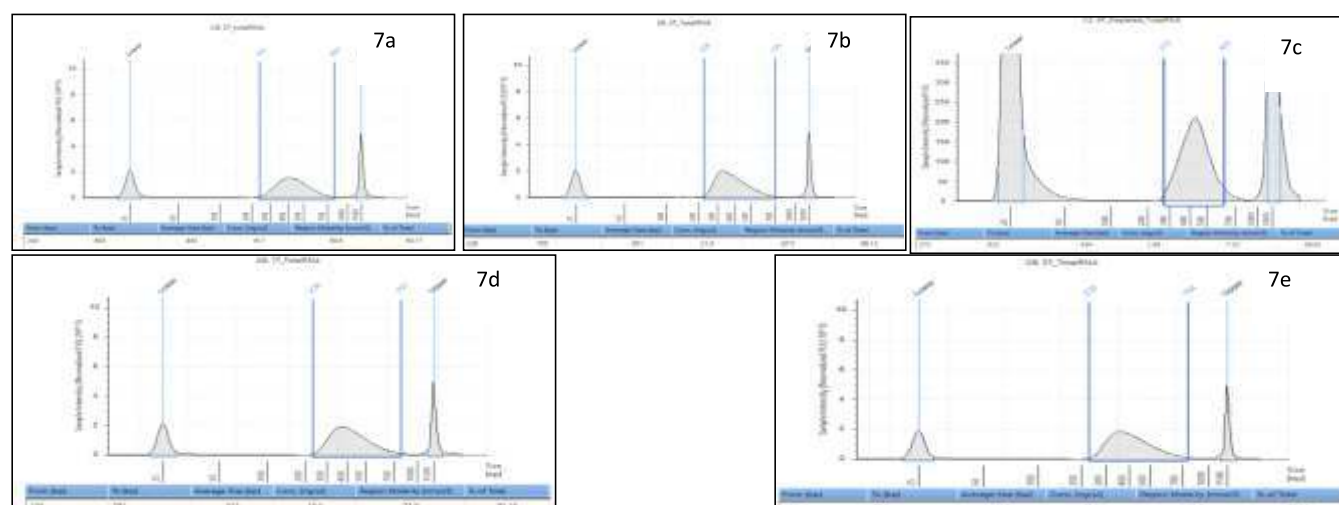


Fig. 7 (a-e) QC of Libraries on TapeStation

Development of Diagnostics Assays

Development of one step reverse transcriptase-recombinase polymerase assays for rapid detection of *Potato leafroll virus* (PLRV) and *Potato virus A* (Ravinder Kumar, Rahul Kumar Tiwari, Kailash Chandra Naga, Priyanka Kaundal and Sanjeev Sharma)

In this study, an isothermal one-step reverse transcription-recombinase polymerase amplification (RT-RPA) method was developed for the rapid and sensitive detection of *potato leafroll virus* (PLRV) and *potato virus A* (PVA) in potato leaves and tubers. Results showed that this one-step RT-RPA method was more efficient than the conventional reverse transcription-polymerase chain reaction (RT-PCR) as the amplification reaction can be completed within 30 min and there was no cross-reactivity with other common potato viruses. Moreover, unlike PCR that requires a thermocycler to carry out the DNA amplification through specific temperature phases, RT-RPA assay could be performed under an isothermal condition such as a heating block or water

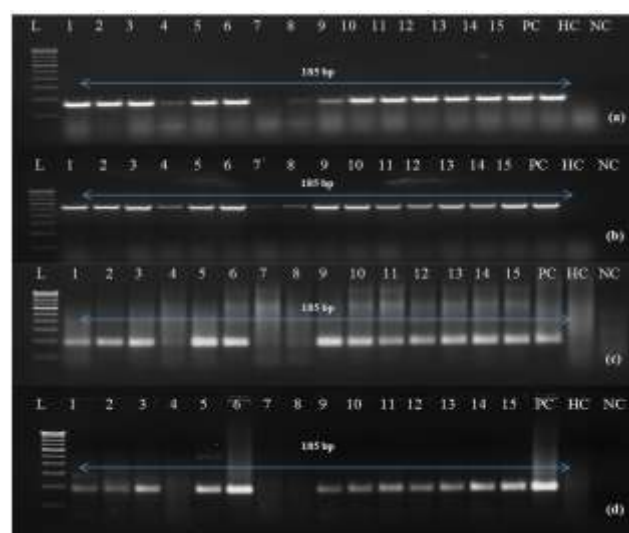


Fig. 8: Detection of PVA in field samples of potato (leaves) by one step RT-RPA and RT-PCR. a. One-step RT-PCR with existing primers (Kumar et al., 2017) using purified RNA, b. One-step RT-PCR with RPA primer using purified RNA, c. One step RT-RPA with RPA primer using purified RNA, d. One step RT-RPA with RPA primer using cellular disc paper-based RNA extract. Lane L (a, b, c, d)- 50bp DNA ladder. Lane 1-15 shows different samples of potato leaves, PC - known positive leaf sample of potato, HC-healthy potato leaf sample, NC- Negative (water) control.

bath at a temperature ranging from 39 to 42°C. A sensitivity assay showed that the developed one-step RT-RPA method was 100-fold more sensitive than a regular one-step RT-PCR. Initially, the assay was optimized for the detection of PLRV and PVA using purified total RNA as the template isolated from infected leaves of potato. One step RT-RPA was further simplified using cellular disc paper-based simple RNA extract as a template that could detect the virus greater to the purified total RNA.

In our RT-RPA assay, this modified disc paper-based RNA preparation method was found efficient and suitable for PVA & PLRV detection in leaves, while in the case of tubers it was not effective for RT-RPA. Isolation of high-quality RNA from potato tubers is too impeded by the existence of polyphenols and polysaccharides and perhaps, these compounds harm the sensitivity of potato virus detection by RT-PCR so that it would have not reported for RNA isolation from tubers. Then, the present study evaluated the effect of sodium sulphite in enhancing RNA yield and quality in a cellular disc paper-based RNA preparation from potato tuber. The addition of sodium sulphite in the extraction buffer increased the sensitivity of virus detection in potato tubers. We found the disc paper-based RNA preparation method feasible and successful for RNA preparation from potato tuber by adding (1%) sodium sulphite. Overall, the present

study describes the high throughput one-step RT-RPA detection method for PVA and PLRV from leaves and tuber samples using cellular disc paper-based RNA extract and a comparison of their sensitivity with ELISA and RT-PCR. This one-step RT-RPA assay was validated using 200 field samples of leaves and tubers representing different varieties and geographical regions (Fig. 8 & 9). To our knowledge, this is the first report of rapid, sensitive, and reliable diagnosis of PLRV and PVA infection by one-step RT-RPA using cellular disc paper-based simple RNA extract as a template in leaves and dormant tubers of potato. It is superior to the common RT-PCR assay in its versatility, quickness, and no need for a highly purified RNA template and can be adopted as a substitute to RT-PCR as an effective technique for seed potato certification, quarantine, breeding, and field surveys.

Management of viral diseases of potato

Transgenic approach

Multiplication and screening of selected transgenic lines resistant to ToLCNDV-potato under controlled conditions

(Ravinder Kumar, Sundaresha S & Sanjeev Sharma)

Fifty tubers each of two promising transgenic lines GTLC2-127 and KPLC2-53 against ToLCNDV were planted in containment facility for phenotypic observation. The tubers from these plants were harvested for further multiplication and studied tuber characters. GTLC2-90, GTLC2-127, KPLC2-13, KPLC2-37, KPLC2-53 and KPLC2-54 transgenic resistance lines were also maintained and multiplied under tissue culture. Out of these, two promising transgenic lines GTLC2-127 and KPLC2-53 were screened through agro inoculation technique and the result showed that transgenic lines did not show ToLCNDV- potato symptoms as against control plants (Fig. 10).

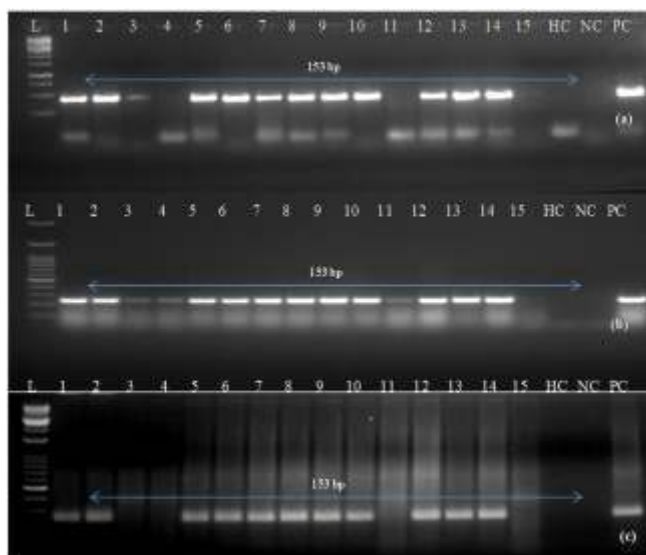


Fig. 9: Detection of PLRV in field samples of potato (leaves) by one step RT-RPA and RT-PCR. a. One-step RT-PCR with existing primers (Kumar et al., 2017) using purified RNA, b. One-step RT-PCR with RPA primer using purified RNA, c. One step RT-RPA with RPA primer using cellular disc paper-based RNA extract. Lane L (a, b, c)- 50bp DNA ladder. Lane 1-15 shows different samples of potato leaves, PC - known positive leaf sample of potato, HC-healthy potato leaf sample, NC-Negative (water) control



Fig. 10: Screening of KPLC2-53 transgenic line through agro inoculation technique. Control (left) and Transgenic line (right)

Nontoxic biomolecules based approach

Evaluation of antioxidant enzymes activity in melatonin treated potato plants infected with PLRV

(Rahul Kumar Tiwari, Ravinder Kumar & Milan Kumar Lal)

Previously, we evaluated the different concentrations (100 μ M, 200 μ M, 300 μ M and 400 μ M) of exogenous melatonin for symptomatic expression of *Potato Leaf Roll Virus* (PLRV) on potato plants and observed that morphological features were significantly improved in melatonin pre-treatment. Subsequently, we tested the enzyme catalase, peroxidase and superoxide mutase activities in the infected control and melatonin treated plants. These enzymes are well documented to curb the reactive species mediated oxidative burst in plants facing biotic and abiotic stresses. Leaf samples (0.1g) were ground in a chilled mortar with 1% (w/v) polyvinyl polypyrrolidone, and then homogenized with 1.2mL of 50mM potassium phosphate buffer (pH 7.8) containing 1mM EDTA- Na_2 and 0.3% TritonX-100. For the ascorbate peroxidase (APX) assay, 1mM ascorbate was added to this mixture. The activity of CAT was determined by monitoring the decrease in absorbance at 240nm due to the decomposition of hydrogen peroxide. Peroxidase (POD) was assayed at 470 nm (extinction coefficient $25.2 \text{ mM}^{-1} \text{ cm}^{-1}$). The activity of APX was determined by monitoring the decrease in absorbance at 290nm as reduced ascorbate was oxidized. For SOD, the system for the reaction, performed in the light included 1mL of 50mM buffer, 65mM methionine phosphate buffer, 0.5mM NBT, 0.1mM riboflavin, and 1mM EDTA- Na_2 . Absorbance of that enzyme solution was determined at 560 nm. The results revealed that the activities of

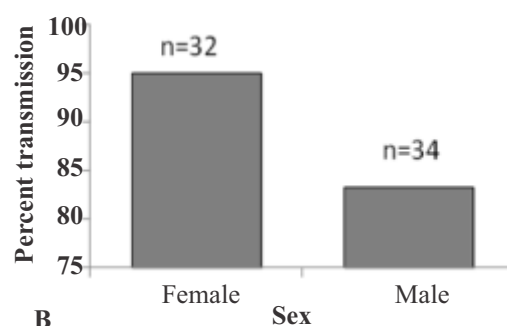
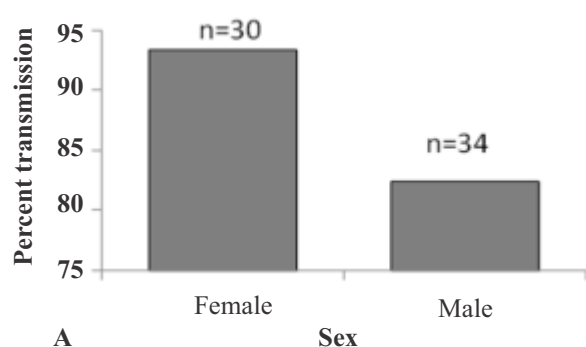
enzymes CAT, POD, APX, and SOD were induced in the virus infected plants. Interestingly, when we studied the response of these enzymes in combination with melatonin pretreatment, the SOD, POD, CAT, and APX activity was higher in 200 μ M treated seedlings than in those from the other treated seedlings and control. Altogether, Melatonin supplementation might reduce the ill effects of reactive species mediated oxidative burst and helps the plants in providing induced defiance against virus infection.

Virus vector relationship/ interactions studies

Transmission of tomato leaf curl New Delhi virus by whitefly *Bemisia tabaci* in sex dependent manner

(Kailash Chandra Naga, Ravinder Kumar, Rahul Kumar Tiwari, Gaurav Verma, Anuj Bhatnagar, Subhash S. & Sanjeev Sharma)

Tomato leaf curl New Delhi virus (ToLCNDV) (*Begomovirus: Geminiviridae*) is responsible for potato apical leaf curl disease in potato. Information about its vectors regarding acquisition, retention, and transmission of virus is crucial for understanding and managing outbreak of viral diseases. During the present study the transmission of ToLCNDV by *B. tabaci* and acquisition capacities were assessed in sex dependent manner and results revealed a clear cut difference in the virus transmission abilities by male and female whiteflies. The females transmitted the virus with higher efficiencies than male. Single female and male individuals transmitted the ToLCNDV with 93.33 % and 82.35 % efficiencies respectively (Fig. 11A &B). The virus transmission increased with increasing number of the male and female whitefly individuals. The virus was transmitted with 100 % efficiency by three female whiteflies whereas three males could transmit with 88.24 % efficiencies. Six and above male whiteflies can transmit the virus with cent percent efficiencies (Fig. 11 C&D).



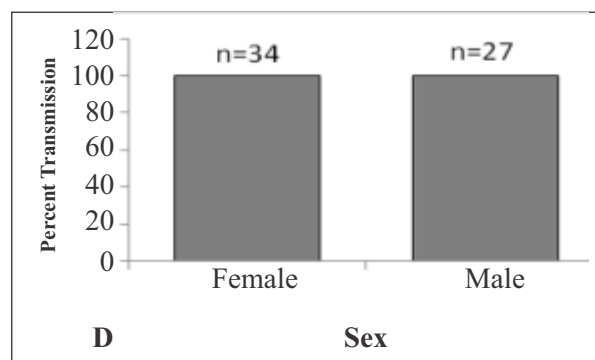
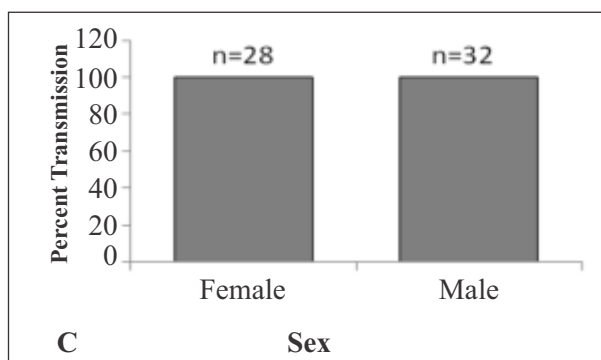


Fig. 11: Transmission efficiency of ToLCNDV-potato by male and female (Asia II 5 genetic group) with different numbers. A) transmission with single male and female; B) transmission with three individuals; C) transmission with 6 individuals; D) transmission with 12 individuals. The 'n' above the bars are the numbers of plants tested for the presence of ToLCNDV-potato at the end of the experiment

One of the important factors to test the virus transmission potential is to understand the ability to acquire the virus. Our results revealed that the females can acquire significantly higher virus ($P < 0.05$) at different acquisitions periods (3, 12, 24, 48 and 72 hrs) except at 6 hours of acquisition. In both male and female the virus accumulation increased with increase in the acquisition periods till 48h and decreased afterwards. The virus titer in terms of copy number increased from 2554.48 ± 397.31 to 293498.24 ± 6777.27 (Virus copies/ 23.0 ng of DNA) during 48 hrs of virus acquisition by female whitefly (Fig. 9). Likewise, copy number varied from 458.71 ± 189.24 to 161347.76 ± 4645.80 (Virus copies/ 23.0 ng of DNA) during same periods of virus acquisition by male whitefly. The virus titer estimated after 72 hrs of Acquisition revealed reduction in copy numbers i.e., 107169.73 ± 3095.33 and 141978.97 ± 4268.69 (Virus copies/23.0 ng of DNA) in both male and female whitefly, respectively (Fig. 12).

Testing of viruses under the National Certification System for tissue culture raised plants (NCS-TCP) through DAS-ELISA and PCR (Ravinder Kumar, Sundaresha S & Sanjeev Sharma)

One thousand nine hundred fifty one samples for batch certification and mother culture of potato received from M/s Technico Agric Science Pvt Ltd. Baddi, Solan (HP), M/s Bhatti Tissue Tech. Jalandhar and M/s PepsiCo India Holdings Pvt. Ltd.

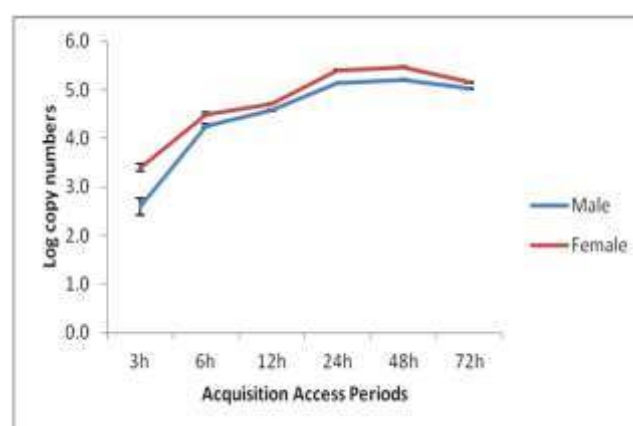


Fig. 12: Accumulation of ToLCNDV-potato by male and female Asia II 5 genetic group at different acquisition periods. The values are Log virus DNA copies (Mean $\pm$ SE)/ 23.0 ng in the male and female *B. tabaci* DNA. Virus accumulation at different acquisition periods were measured by qPCR as described in Materials and Methods based on standard curves. Quantification of ToLCNDV-potato is given by Slope:-3.33, Y-intercept: 3.252, R^2 :0.98, Efficiency %: 99.64. The log transformed virus copies at each acquisition period in both male and female were compared using Student t-test.

Hoshiarpur (Punjab) were tested for PVX, PVS, PVY, PVA, PVM, and PLRV by DAS- ELISA and GBNV, PSTVd and ToLCNDV-potato by PCR/RT-PCR and certified about 5.07 lakh plants. Besides, 400 samples of apple from M/s Nishant Biotech, Bilaspur, HP were tested for apple viruses namely ACLSV, AMV, ASGV, ASPV, PNRSV to certify the total batch size of 4.0 lakhs plants under NCS-TCP.



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 potato pests (Anuj Bhatnagar, Subhash Katare, Kailash C. N, Subhash S, Tiwari JK & Priyank M)

Sucking pests (Aphids, Whiteflies, Hoppers and Thrips) and Whitegrub

The population of aphid, whiteflies and leaf hopper species was monitored at weekly interval in unsprayed ware potato fields (K. Bahar) at Modipuram during crop (December, 2021) season. The population of whiteflies, *Bemisia tabaci* remained below ETL (<2 whiteflies/plant) from fourth week of November to last week of December (Fig. 1). Initially leaf hoppers, *Amrasca biguttula biguttula* population was high for the first four weeks till second week of December and then population started declining (Fig. 1). The population of aphids was higher in the initial four weeks from fourth week of November to second week of December (Fig. 1). The population remained above critical threshold (20 aphids/100 compound leaves) in the fourth week of November and reached 44 aphids/100 compound leaves in the second week of December and then declined below ETL. Initially aphid population dominated by *Aphis gossypii*, subsequently it was predominated by *Myzus persicae*.

Similarly, the incidence of whitefly in unsprayed

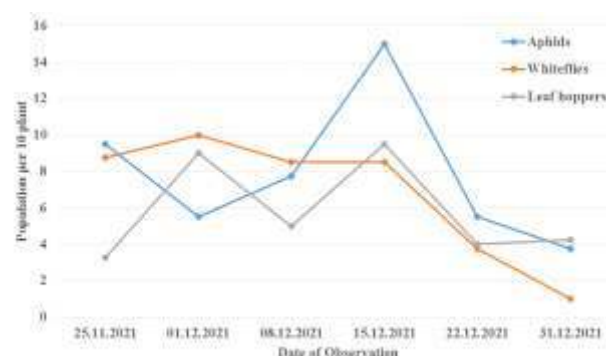


Fig. 1: Monitoring of aphids, whiteflies and leaf hoppers on in Ware (unsprayed) potato crop (K. Bahar) during 2021-22 at ICAR-CPRI, RS, Modipuram

potato crop was started in 4th week of November and reached its peak population (40 whiteflies/10plants) in third week of December at Gwalior. The thrips started appearing in 4th week of November and reached its peak population (65 thrips/10plants) in fourth week of December. Incidence of aphid, *Myzus persicae* was started in 4th week of November and reached its peak population (38 aphids/100 compound leaves) in fourth week of December. Relatively low populations of *Bemisia tabaci* and high population of thrips and aphids were recorded on ware crop in comparison to seed potato crop at Gwalior (Fig. 2). A maximum of 6.0 whiteflies/10plant, 16.0 thrips/10 plant and 4.00 aphids/100 compound leaves were recorded in seed crop at Gwalior.

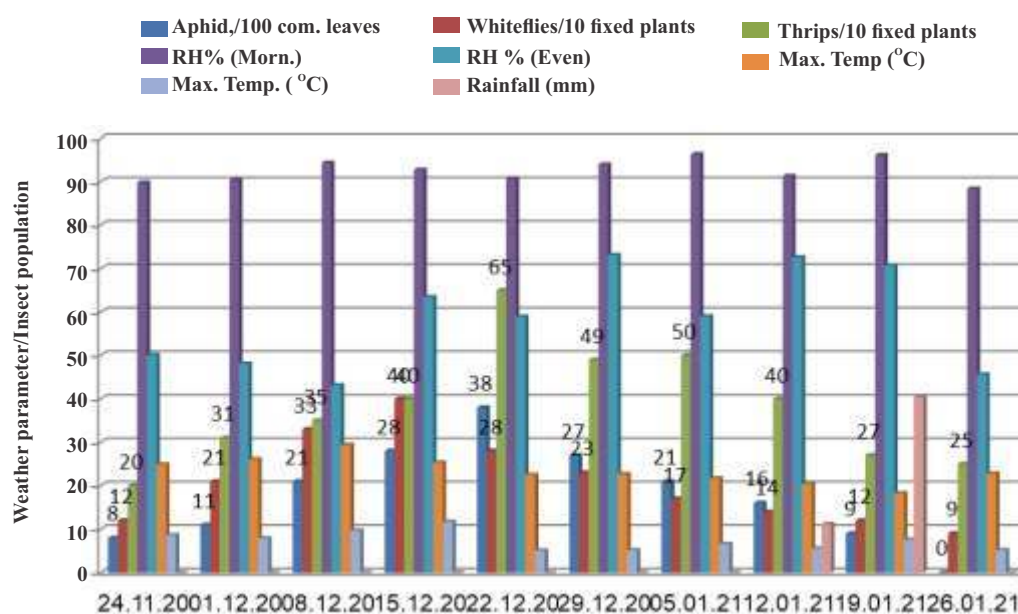


Fig. 2: Monitoring of aphids, whiteflies, thrips and hoppers in Ware (unsprayed) potato crop at Gwalior

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

The population of aphids and whiteflies remained above ETL since the beginning of crop season till second week of January and again population crossed the threshold in the first week of February on unsprayed potato crop (Fig. 3a). The highest population of 104 aphids/100 compound leaves and

8 whiteflies/10 plants were recorded in the third week of December (Fig. 3b). The temperature of this location varied from a minimum of 6 °C to maximum of 29 °C and maximum relative humidity at morning 77.71 % and evening 26.85 %. It is also found that temperature of 22 °C and above favorable for population buildup of sucking pests with RH of about 65 %.

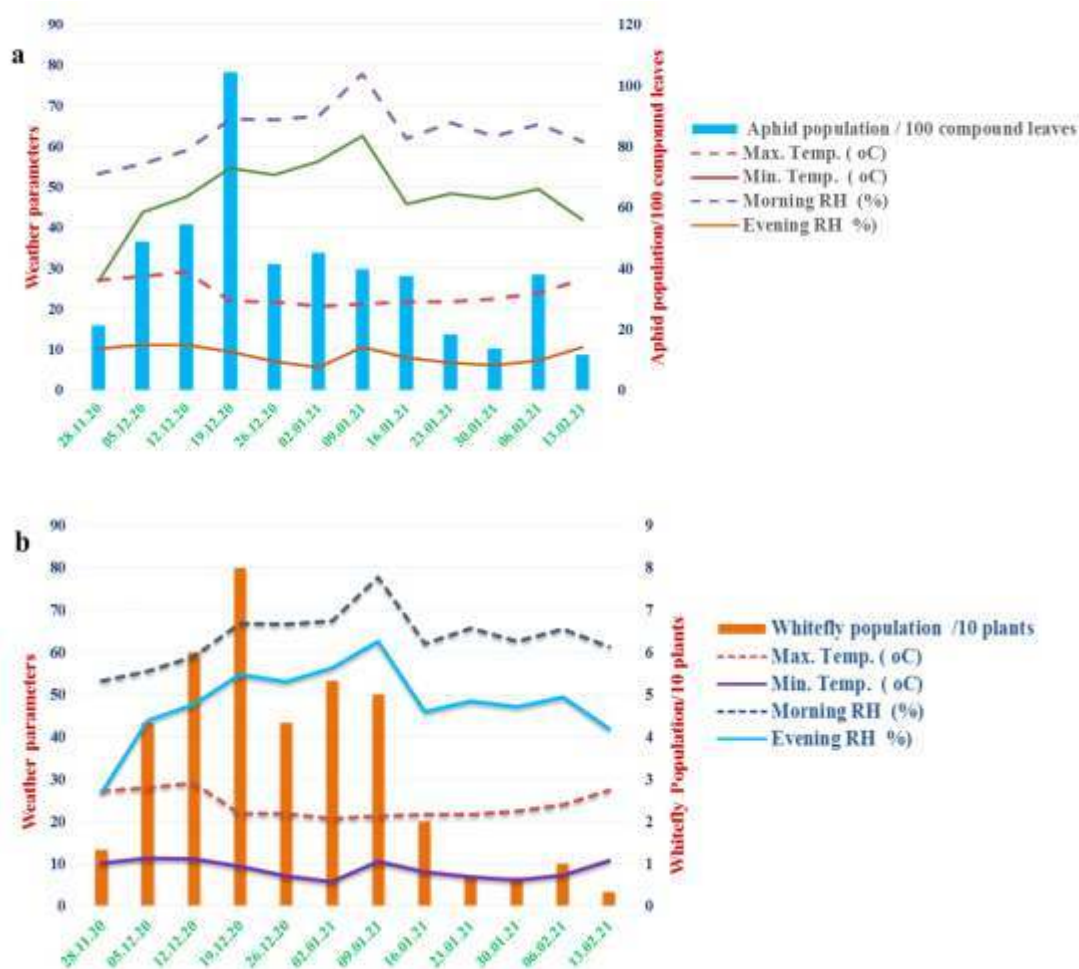


Fig. 3: Seasonal incidence of aphids and whiteflies on potato in Murena-MP during 2020-21

Monitoring of white grub at Shimla

Adults white grubs were captured using the light trap installed from March to end of July 2021 at Fagu farm of ICAR-CPRI, Shimla. Six white grub species namely *Brahmina flavosericea* (Brenske), *Brahmina coriacea* (Hope), *Mimela* sp., *Melolontha cuprescens* Blanchard, *Holotrichia longipennis* (Blanchard) and *Maladera* sp. were recorded.

Serpentine leaf miner, *Liriomyza huidobrensis* in Nilgiri Hills of Tamil Nadu

A survey was taken up to know the damage incidence, distribution and possible alternate weed hosts of leaf

miner due to outbreak on potato. The six important crops viz., carrot, beet root, garlic, beans, double beans, and broccoli, a cover crop (*Lupinus* spp.), and seven weeds viz., *Amaranthus* spp., *Bidens pilosa*, *Chenopodium* spp., *Solanum nigrum*, *Galinsoga parviflora*, *Hypochoeris glabra* and *Sonchus oleraceus* were identified as alternate hosts of leaf miner.

Morpho-molecular identification of Serpentine leaf miner, *L. huidobrensis*

Morphological identification was carried out using adult specimens of the leaf miner fly and the same were later subjected to molecular characterization

using the mitochondrial cytochrome c oxidase I gene [Forward (LCO1490 5'-GGTCAACAAAT CATAAGATATTGG-3') and reverse (HCO2198 5'-TAAACTTCAGGGTGACCAAAAAATCA-3') primers]. Based on the morphological observations, adult flies were identified as *Liriomyza huidobrensis* (Agromyzidae: Diptera) (Fig.4). Further, the samples were molecularly characterized and the PCR amplification yielded a single fragment of ~ 688 bp. The sequences were deposited in the GenBank (accession no. MW467885, MW467884 and MW467886) and the comparison of obtained sequences (MW467885, MW467884 and MW467886) revealed 100% sequence similarity with *L. huidobrensis*.

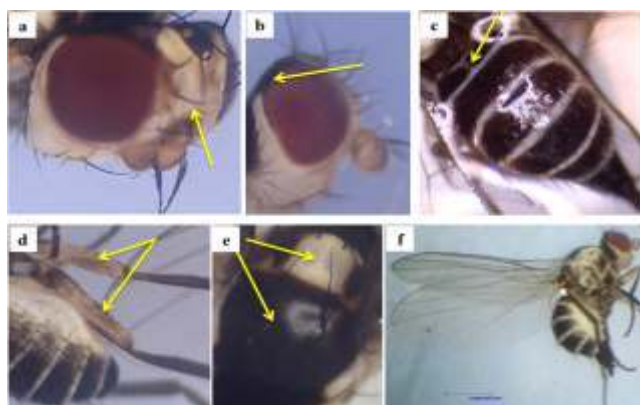


Fig. 4: Diagnostic characters of *Liriomyza huidobrensis*: a) yellow frons, b) black hind margin of eye, c) divided second visible tergite of abdomen, d) femora yellow with brownish striations, e) black and matt mesonotum with bright yellow scutellum, f) adult fly

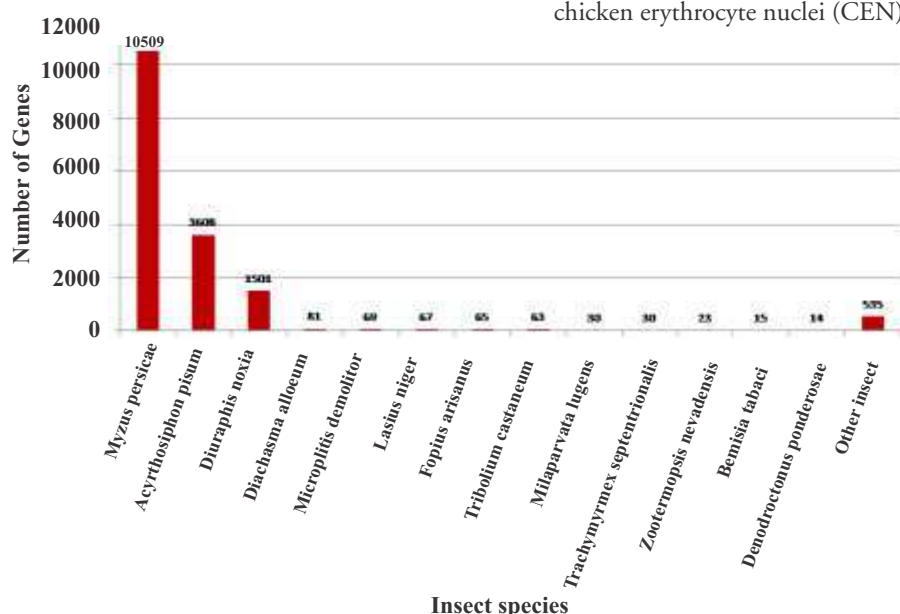


Fig. 6: Gene annotation of the foxglove aphid (*Aulacorthum solani*) draft genome showing major insect species based on NCBI BlastX 'Nr' (non-redundant) protein database

Draft genome sequencing of the foxglove aphid (*Aulacorthum solani* Kaltenbach), a vector of potato viruses, provides insights on virulence genes

A preliminary analysis of draft genome sequence to uncover virulence genes in the aphid revealed that genome assembly size (316.39 Mb) was very close to its genome size (318.19 Mb) estimated by flow cytometry (Fig. 5). The genome completeness (81.8%) was confirmed by the Benchmarking Universal Single Copy Orthologs (BUSCO) analysis indicating 14.90% transposable elements (TEs) in the genome. Of total 22021 predicted genes, 16610 were annotated with putative functions of other aphids mainly *Myzus persicae*, *Acyrtosiphon pisum* and *Diuraphis noxia* (Fig. 6). We identified virulence genes such as defensive and detoxification genes, salivary genes and chemoreceptors, insecticide resistance genes, virus transmission genes, transcription factors and mitochondrial genes. Importantly, analysis of detoxification genes particularly 53 cytochrome P450s (CYPs) indicated involvement of 23 CYPs families in aphid genome. Further, GO and KEGG pathways analyses showed

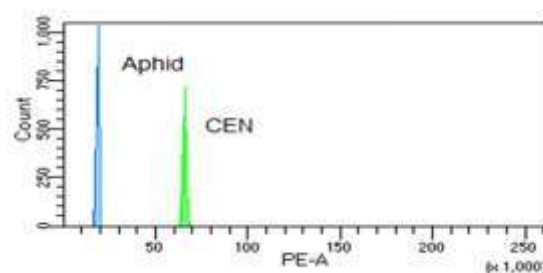


Fig. 5: Genome size estimation of the foxglove aphid (*Aulacorthum solani*) by flow cytometry analysis using chicken erythrocyte nuclei (CEN) as an internal standard

gene enrichment predominantly with molecular function and signal transduction, respectively. Phylogeny analysis revealed genetic divergence among 12 aphid species and *Au. solani* is closely related with *M. persicae* (Fig.7). Further, non-synonymous (Ka)/synonymous (Ks) substitutions (Ka/Ks) indicated positive selection for 6 (Ka/Ks > 1) and 122 (Ka/Ks = 0.5 to 1) single copy orthologous gene pairs between *Au. solani* and with the pea aphid. Thus, our preliminary draft genome analysis provides new insights of *Au. solani* to understand molecular basis of aphid biology, host-aphid interactions and adaptation mechanism.



Fig. 7: Phylogeny tree (unrooted) shows relatedness in the foxglove aphid (*Aulacorthum solani*) with the 12 other aphid species (*Acyrthosiphon pisum*, *Aphis glycines*, *Aphis glycines strain OH*, *Aphis gossypii*, *Diuraphis noxia*, *Melanaphis sacchari*, *Myzus cerasi*, *Myzus persicae*, *Rhopalosiphum maidis*, *Schizaphis graminum*, *Siphia flava* and *Sitobion miscanthi*) at genomic level based on the Neighbor-Joining method using the AAF tool

Studies on phyto-semiochemicals involved in insect-plant interactions of major potato pests

Oviposition preference assay of Potato tuber moth (PTM) between sprouted tubers and fresh tubers (Subhash S, Anuj Bhatnagar & Kamala Jayanthi P. D.)

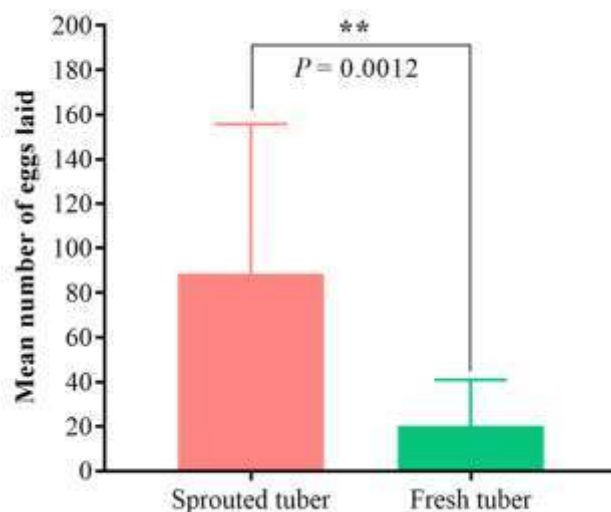


Fig. 8: Mean number of eggs (Mean $\pm$ SEM) laid by potato tuber moth on Sprouted tubers and Fresh tubers

The results revealed that PTM lays more number of eggs on sprouted tubers (88.6 ± 17.33) than fresh tubers (20.33 ± 5.324) (Paired *t* test: $P = 0.0012$; $t = 4.043$; $df = 14$) (Fig. 8) thereby indicating that damage by PTM in storage can be reduced if sprout initiation of tubers is suppressed.

Effectiveness of natural essential oils in the monitoring of potato aphid

(Subhash S, Anuj Bhatnagar, Kamala Jayanthi P. D. & Kailash Chandra Naga)

The effectiveness of natural essential oils in trapping potato aphids using yellow sticky trap and colourless sticky trap was evaluated under field conditions. The results revealed that in both the cases basil oil was found more effective attractant and resulted in 85% increase in trap catches in yellow sticky trap while 98% increase was observed in colourless sticky trap (Fig. 9).

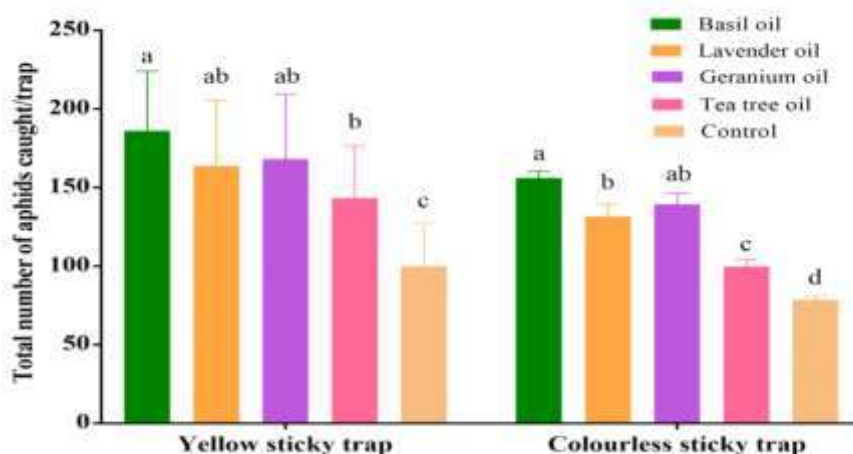


Fig. 9: Total number of aphids (mean $\pm$ SEM) found in field observations according to natural essential oils used. Different letters indicate a statistically significant difference between the individual treatments at $P < 0.05$

Conventional and novel strategies for the management of insect pests of potato

(Subhash S, Priyank H Mhatre, Anuj Bhatnagar, Kailash Chandra Naga & Subhash, K)

Bio-control potential of *Steinernema cholashanense* (Nguyen) on larvae of potato tuber moth, *Phthorimaea operculella* (Zeller)

The bio-control potential of entomopathogenic nematode (EPN), *Steinernema cholashanense* in

different concentration (0, 10, 20, 40, 80 and 120 larva/IJs) against PTM larvae was studied. The results revealed that *S. cholashanense* was able to penetrate and reproduce within the haemocoel of fourth-instar larvae of *P. operculella* (Fig. 10). The concentration of 20 IJs could induce PTM larval mortality after four days of inoculation (Fig. 11) thereby indicating its bio-control potential against PTM.



Fig. 10: Juveniles of *S. cholashanense* in the haemocoel of *P. operculella* larvae

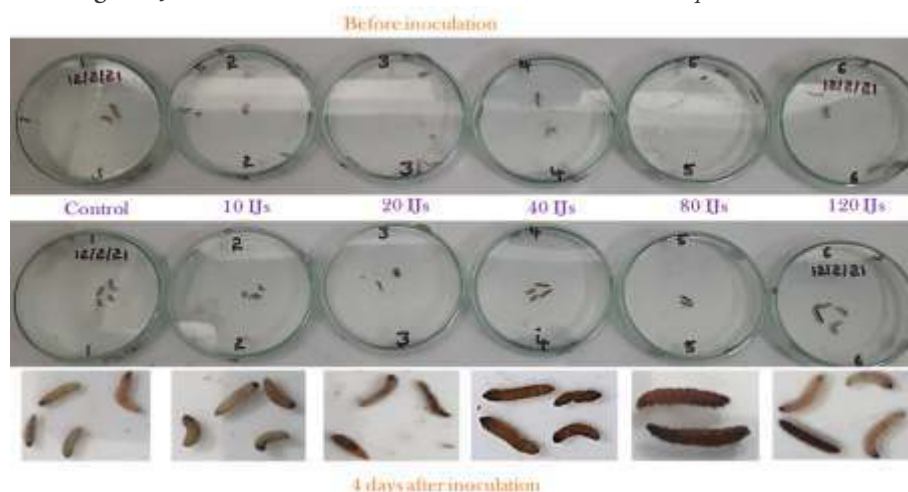


Fig. 11: Effect of EPN, *S. cholashanense* infectivity on fourth instar PTM larvae before and four days after inoculation

Screening of newer chemicals against *M. persicae* (Sulzer)

The flonicamid was recorded the highest toxicity with LC_{50} as 1.195 ppm which was on par with the LC_{50} of imidacloprid (4.214 ppm) against *M. persicae*. However, Pymetrozine was found to be the least effective against *M. persicae* with LC_{50} 142.77 ppm. Similar results were recorded against Jalandhar population.

Evidence of Systemic Acquired Resistance (SAR) against whitefly, *Bemisia tabaci* in SM/11-120 hybrid of potato

The two advance hybrids of potato were used to study the role of *mi1.2* gene (NBS-LRR gene family)

in host plant resistance against whitefly, *Bemisia tabaci*. The hybrid SM/11-120 was found least preferred host whereas SM/09-172 was found most preferred host by whiteflies in the choice assay. The expression of *mi1.2* significantly enhanced 24h after whitefly release, followed by a decrease at later stage. Similarly, the expression of *PR1* significantly enhanced 72h after whitefly release, followed by a decrease at later stage. However, the *PR1* expression was significantly higher in potato hybrid SM/11-120 (~104 fold) compared to SM/09-172 (Fig. 12). The present study indicates the role of *mi1.2* in host plant resistance against whitefly via SAR.

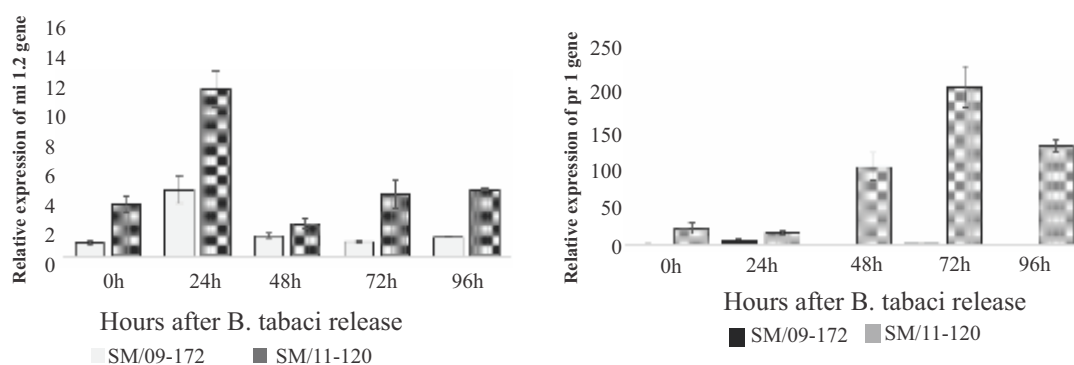


Fig. 12: Systemic Acquired Resistance (SAR) against whitefly, *Bemisia tabaci*

Management of Serpentine leaf miner

Bio-efficacy of seven insecticides viz., deltamethrin (@ 14 g ai/ha), cypermethrin (@ 62.5 g ai/ha), abamectine (@ 9.5 g ai/ha), dinotefuran (@ 100 g ai/ha), spinetoram (@ 58.5 g ai/ha), fenpyroximate (@ 25 g ai/ha), and novaluron (@ 26.25 g ai/ha) was evaluated against newly emergent pest. Results revealed that application of abamectin significantly reduced terminal damage incidence (23% and 18%) and improved the yield of the crop (24% and 20%) in Kufri Sahydari and Kufri Swarna.

Management of thrips at Gwalior

Eight treatments were evaluated against thrips under field conditions. Among them, *Beaveria bassiana* (ST@10 g/kg) + Thiomethoxam 5% WG (Sp.@ 0.5 ml/l) was found most effective against thrips with 72.84% reduction of thrips population, followed by *Beaveria bassiana* (ST @10 g/kg + *Beaveria bassiana* (ST@10 g/kg) + *Beaveria bassiana* (Sp@1200g/ha) with 57.50% reduction, over untreated control. However, all the treatments were effectively reducing % leaf curl disease, except seed treatment with *P. fluorescens* (Fig. 13 and 14).

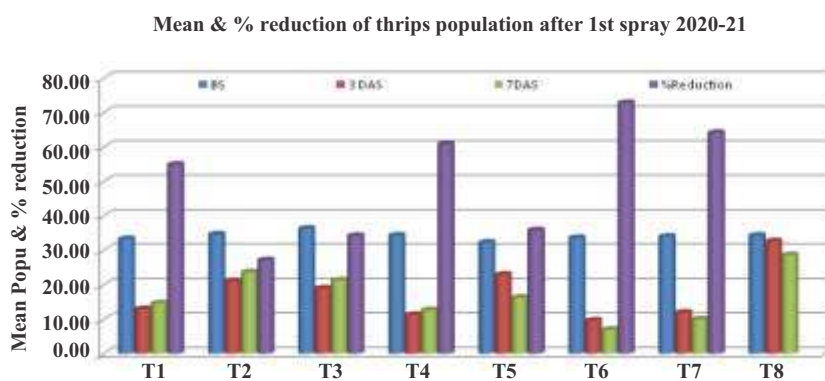


Fig. 13: Mean and % reduction of thrips population after 1st spray

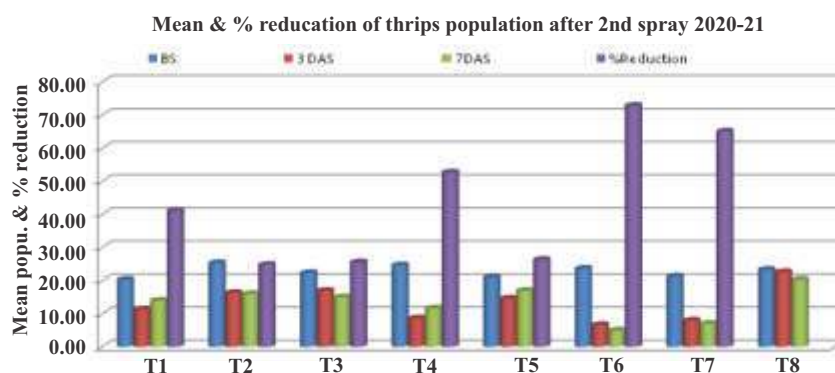


Fig. 14: Mean and % reduction of thrips population after 2nd spray

Project 2: Biology, ecology and management of nematodes pests of potato

Effect of PCN on absorption and translocation of nutrient (Priyank H Mhatre)

The experiment was conducted to see the effect of potato cyst nematode on absorption and translocation of nutrient, plant growth parameters and yield of potato cv. Kufri Jyoti. The experiment was majorly divided into three major treatments (T1-T3: sterilized soil i.e. without PCN infestation; T4-T6: PCN infected soil without nematicide; T7-T9: PCN infected soil with nematicide) and 3 sub treatments (with different doses of NPK fertilizers) in each. Treatments 7 to 9 were treated with carbofuran

(nematicide) per pot. Application of fertilizers had visible effects on the growth of the plant. Plants grown in the control and nematicide treated soil were taller, and greener than the ones grown in the infected soil. The plants in the infected soil looked short and stunted, lesser and pale leaves with weak stems. The plant height was significantly influenced by the treatments ($F = 30.272$; $df = 8,18$; $P < 0.001$). The significant differences in terms of tuber number ($F = 41.351$; $df = 8,18$; $P < 0.001$) and tuber weight ($F = 143.297$; $df = 8,18$; $P < 0.001$) were observed in the yield of Kufri Jyoti under different treatments. Highest tuber yield in terms of weight was observed in T3 (1.17 kg/treatment) followed by T2 (1.15 kg/treatment), whereas, T4 recorded the lowest yield (0.69 kg/treatment, Fig. 15).



Fig. 15: Effect of potato cyst nematode on yield parameters of potato cv. Kufri Jyoti

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

(Priyank H Mhatre)

Studies were conducted to see the effect of potato cyst nematode on potato yield reduction. Five treatments viz., Dazomet @40g ai/ha; Nimitz @ 50kg/ha; AVANA @ 60 kg/ha; Carbofuran @65 kg/ha and untreated control were evaluated. Results revealed that PCN is responsible for about 51% reduction in tuber yield in terms of weight and 33% reduction in tuber numbers. The highest yield (33.85 t/ha) was recorded in the plots treated with Dazomet, however the lowest yield of 22.28 t/ha was noted in untreated control (Fig. 16).

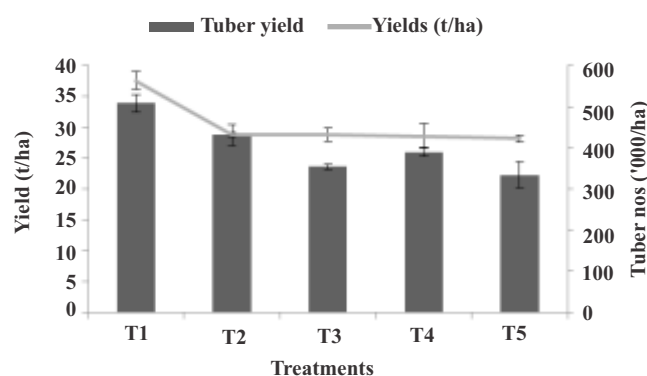


Fig. 16: Effect of potato cyst nematode on yield of potato susceptible cv. Kufri Girdhari

Potato cyst nematode (*Globodera* spp.) management strategies

(Aarti Bairwa, Sanjeev Sharma, Ashwani K Sharma, Dalamu and Manoj Kumar)

Different potato cyst nematode management strategies are being followed at PCN sick field of Kufri Farm to see their effects on PCN population dynamics. Out of twenty four treatments evaluated, application of Nimitiz @ 50kg/ha (100% dose) with potato trap crop (uprooted 35DAP) at the time of planting followed by non-host crop (mustard) followed by fallow resulted in 51% reduction in PCN population. This was followed by application of bleaching powder @40kg/ha followed by non-host crop (rajmash) followed by fallow (52%). The planting of resistant hybrid (SM/11-120) followed by fallow recorded more than 58% reduction in PCN population (Fig.17).

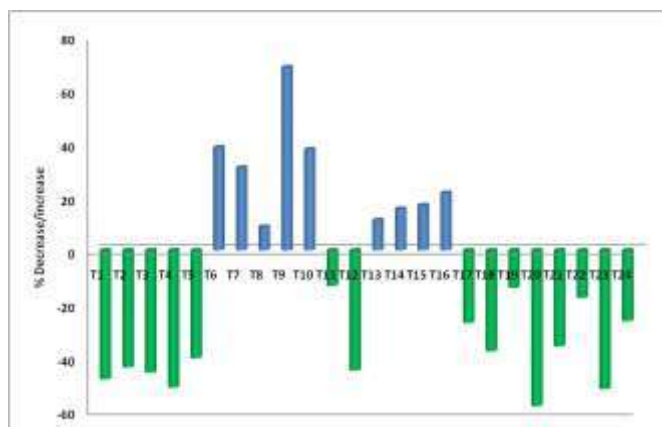


Fig. 17: Effect of PCN management strategies on PCN population dynamics

In another studies after following different cropping systems, it was observed that after three years of following Oat-Oat- Mustard system resulted in highest reduction (64.3%) of PCN population at Kufri Farm followed by Potato-Mustard- Rajmash (42.8%). At Fagu farm, Oat-Trap-Potato resulted in highest reduction (64.9%) followed by Oat-Mustard-Rajamsh (64.8%) and Oat-Potato-Oat (63.6%) cropping systems.

Optimization of potato trap crop age for the management of PCN

(Aarti Bairwa, Sanjeev Sharma, Ashwani K Sharma, Dalamu and Priyank H Mhatre)

Studies were carried out to optimize the age of potato trap crop uprooting for the management of PCN.

Accordingly, potato trap crop was up-rooted at 35, 38 and 43 days after planting (DAP). Results revealed that female of PCN started to develop on the roots of potato trap crop after 38 DAP and fully matured after 43 DAP. Hence, it is recommended that potato trap crop should be uprooted on or before 35 DAP to avoid the PCN population build up due to trap crop (Fig.18).



Fig. 18: Potato cyst nematode development after different days of planting on potato trap crop roots

Evaluation of dsRNA formulation against PCN under pot condition

(Aarti Bairwa, Sundresha S, Sanjeev Sharma and Priyank H Mhatre)

Drenching with multi construct dsRNA formulation at 20, 30 and 40 DAP recorded minimum reproduction factor (Rf: 08). The next best treatment was application of Carbofuran 3G@ 65kg/ha basal dose followed by drenching of dsRNA formulation 20 DAP (Fig. 19).

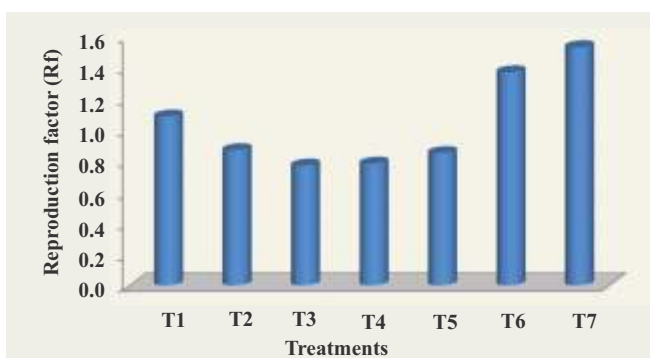


Fig.19: Effect of dsRNA formulation on PCN population

[T1: Drenching with multi construct dsRNA formulation 20 DAP, T2: Drenching of multi construct dsRNA formulation 20 and 30 DAP, T3: Drenching of multi construct dsRNA formulation 20, 30 and 40DAP, T4: Application of Carbofuran 3G@ 65kg/ha basal dose followed by drenching of multi construct dsRNA formulation 20 DAP, T5: Application of Carbofuran 3G@ 65kg/ha basal, T6: Drenching of kaolinite nano clay formulation 20DAP, T7: Untreated control]

Efficacy of methyl bromide soil fumigation on potato cyst nematodes (PCN) population dynamics

(Aarti Bairwa, Sanjeev Sharma, Ashwani K Sharma, Dalamu and Manoj Kumar)

Pilot studies were conducted on the efficacy of methyl bromide (Methyl bromide 98% + chloropicrin 2%) soil fumigation on potato cyst nematodes (PCN) population. Six different doses of methyl bromide (MBr) viz., 350, 400, 450, 600, 800 and 1000 lbs/acre were evaluated along with untreated control. After the application of MBr, the entire treated area was restricted for the entry of humans and animals until removal of tarpaulins (Fig. 20). The tarpaulins and tubes were removed after 96 hrs of treatment. Soil

sampling was done before fumigation, after 96 hrs of fumigation and one month after fumigation. Though no definite trend in dose response was observed but soil fumigation with methyl bromide resulted in reduction of PCN count by 12-45% (average 30%) after 96 h that was further increased to 33-58% (average 47%) after 30 days of treatment. After 30 days of fumigation, the percentage of mortality further increased to 88-95% while viability percentage decreased by 5-12%. On an average, mortality was 91% while viability was 9% in treated plots as against of 80% mortality and 20% viability in untreated plots (Fig. 21). No adverse effect on the germination of mustard and oats seeds was observed when sown immediately after soil fumigation i.e. 96 hrs after fumigation.



Fig. 20: Aerial view of plots fumigated with different doses of MBr under airtight tarpaulins

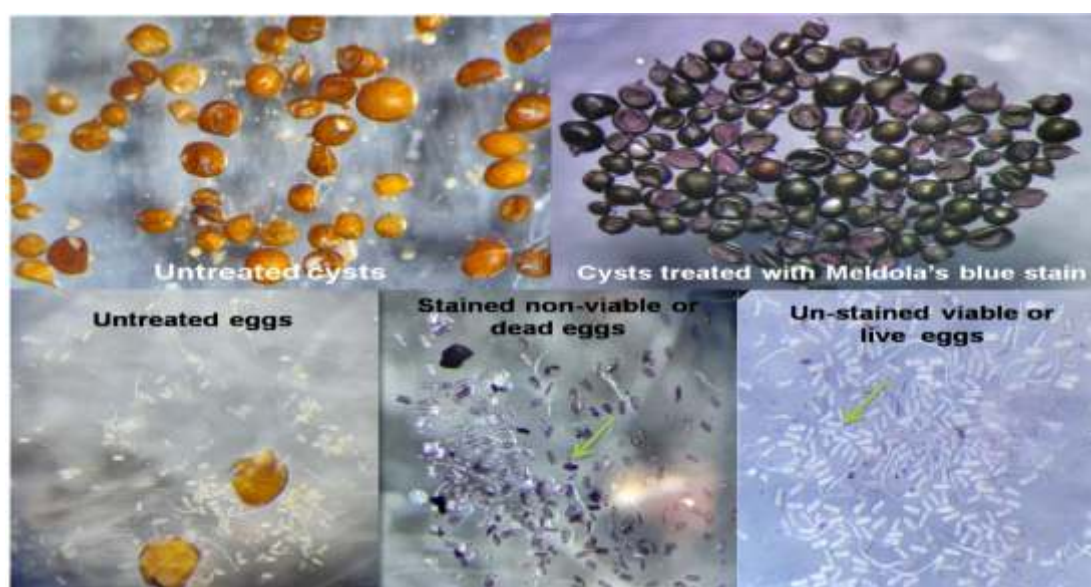


Fig. 21: Analysis of viable or nonviable eggs/ juveniles using Meldola's blue stain

DIVISION OF CROP PHYSIOLOGY, BIOCHEMISTRY AND POST-HARVEST TECHNOLOGY

PROGRAMME: POST-HARVEST MANAGEMENT AND NUTRITIONAL ENHANCEMENT OF POTATOES

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

Sprout suppression using volatile compounds

Identified mixture of naturally occurring volatile oil was evaluated in large scale experiment conducted during April to September 2021 under controlled bulk storage conditions (10-12°C, RH 95%). The diluted mixture of volatile oils was sprayed on eleven potato varieties namely Kufri Chandramukhi, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Surya, Kufri Pushkar, Kufri Dewa, Kufri Himalini, Kufri Khyati, Lady Rosetta and Atlantic. Twenty five kg of each variety was kept in lino bags. After treatment potatoes were kept in closed chamber

for 180 days. For each variety control (untreated) and CIPC treated potatoes were kept in separate chambers and the treated and control lots were observed for sprout suppression efficacy. For all varieties during 120 days of storage, eyes remained black but after that partial sprouting (sprout length 1 to 1.5 cm) was observed in some varieties (Fig.1). However, in control tubers 100% sprouting was observed within 100 days of storage. During storage, untreated tubers shrivelled to more than 50% of their initial volume, contrary to this in treated tubers shrivelling was less than 10%. Throughout the storage skin colour of treated tubers remained unaffected.

In another experiment, the efficacy of nine new oils/plants derivatives/ compounds namely Citral, Oil of peppermint, Citronellol, Citronella, 4-isopropylbenzaldehyde, Benzothiazole, Orange oil, Silicon oil and Cedarwood oil was tested. Each oil/compound was tested individually and as cocktail of 7 oils excluding Cedarwood oil and Silicon oil. The experiment was conducted in the first week of August 2021 on tubers of Kufri Chandramukhi already stored for 4 months at 2-4°C. For treatment 3 kg tubers were sprayed with appropriately diluted oils and their mixture and kept in closed containers stored at 10-12°C. The results revealed that during storage, Citral, 4-isopropylbenzaldehyde, Citronellol, Citronella, Orange oil and cocktail of 7 oils suppressed 100% sprout emergence up to 120 days of storage (Fig. 2). These findings suggest that identified oils of natural origin and their mixture have potential to suppress sprouting in potatoes even after cold storage. In future such type of oils may serve as novel alternative of CIPC.



Fig. 1: Effect of oil mixture treatment after 120 days of storage (1) K Chipsona-1, (2) K Chipsona-3, (3) K Chipsona-4, (4) K Chandramukhi, (5) K Surya, (6) Lady Rosetta, (7) Atlantic, (8) K Khyati, (9) K Dewa, (10) K Pushkar and (11) K Himalini



Fig. 2: Sprout suppression effect of new oils cocktail on K Chandramukhi at 120 DAT

Evaluation of post-harvest tuber quality under exogenous melatonin application

So far, only a few studies have been conducted to evaluate effects of exogenous melatonin application on post-harvest aspects of vegetables. Apparently healthy looking tubers sometimes carry *Fusarium* infection and such tubers are known to magnify tuber rot and cause greater weight loss particularly under non refrigerated storage. Keeping this in view, effect of melatonin was assessed on incipiently *Fusarium* infected tubers during 60 days storage (April-May 2021) at room temperature. Infected tubers of K. Bahar, K. Chip-1 and K. Mohan were surface cleaned, soaked in 200 μ M melatonin solution for 5 min, air dried and stored at room temperature with untreated but infected ones along with healthy as check. The results revealed that incipiently *Fusarium* infected potato tubers had very high wt. loss (46 to 77 %) as compared to healthy check (8 to 11 %) during 60 days storage at room temperature owing to rotting.

Tackling enzymatic browning problem in potato using molecular approaches

Polyphenol oxidases (PPO) catalyze the oxidation of phenolic compounds to quinones. This oxidation of polyphenols leads to the formation of dark-colored precipitates through the process, known as enzymatic browning. In potato, enzymatic browning is a serious problem which affects potato tubers during harvest and post-harvest stages including transportation, storage and processing. Keeping in view the important role of PPO in undesirable browning problem in potato, work was initiated to study the PPO in potato with the aim of inhibiting / minimizing PPO activity. Analysis of Potato genome revealed presence of PPO genes in potato genome, all of these located on chromosome 8. Coding sequences (CDS) revealed their size range varying from 415 to 2532 nucleotides. Further, their phylogenetic analysis revealed a degree of relatedness and variations in these 8 PPO genes of potato. For designing constructs for genome editing structure and conserved domain analysis was performed for all these 8 PPO genes (Fig.3) which revealed presence of 3 conserved domains in the potato PPOs. Work is under progress to clone PPOs from potato and to design SgRNA for these PPO genes.

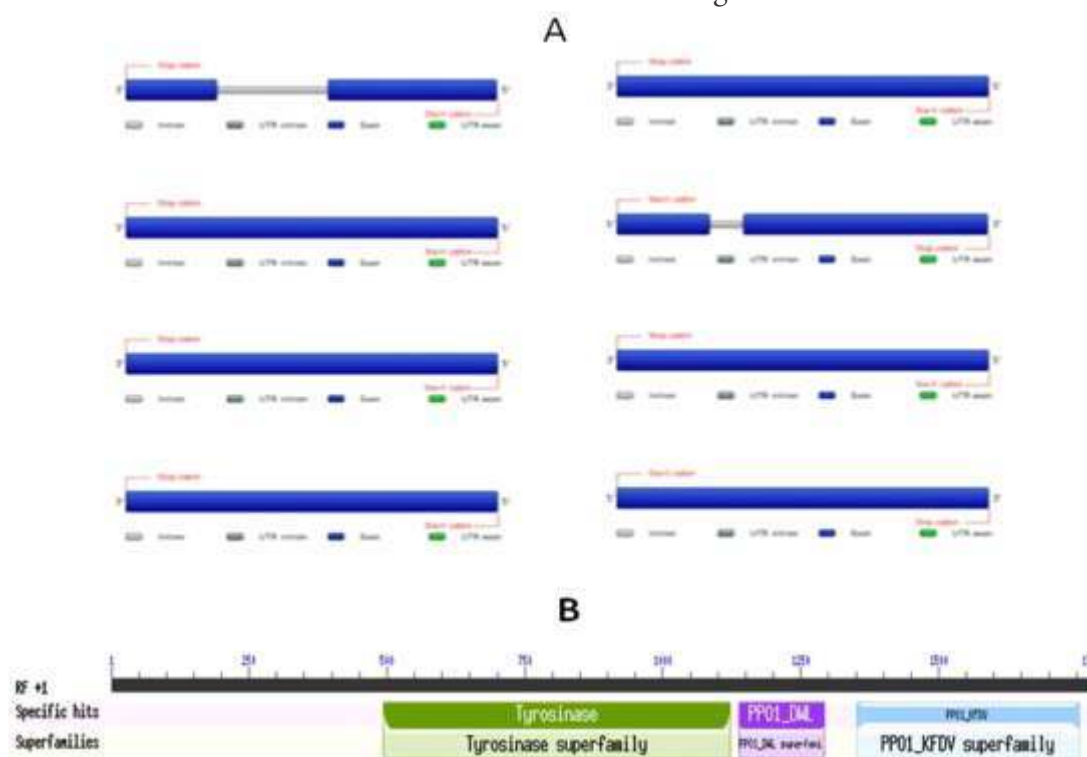


Fig. 3: Genes structure (A) and Conserved domains (B) in potato PPO: These domains are being targeted for genome editing.

Glycemic Index (GI) In Potato

Development of a method for in vitro SHI and GI estimation

A modified and improved version of the existing in-vitro method developed by Goñi et al., (1997) was

standardized and validated for the estimation of GI in potatoes and products. The dialysis membrane mimics smaller intestinal conditions where the digested material is transported through its wall by a simple diffusion process. The maltose resulting from

starch digestion permeates the membrane and is released into the ambient buffer, an aliquot of which is treated with amyloglucosidase hydrolyzing it into glucose units. The use of dialysis membrane in the modified method obviates the need for amylase

inactivation as done in the original method. Conventionally, the anthrone reagent is used for glucose estimation, known for low reproducibility. In contrast, the GOPOD reagent used by us gives a more uniform result with a high degree of precision (Fig. 4).

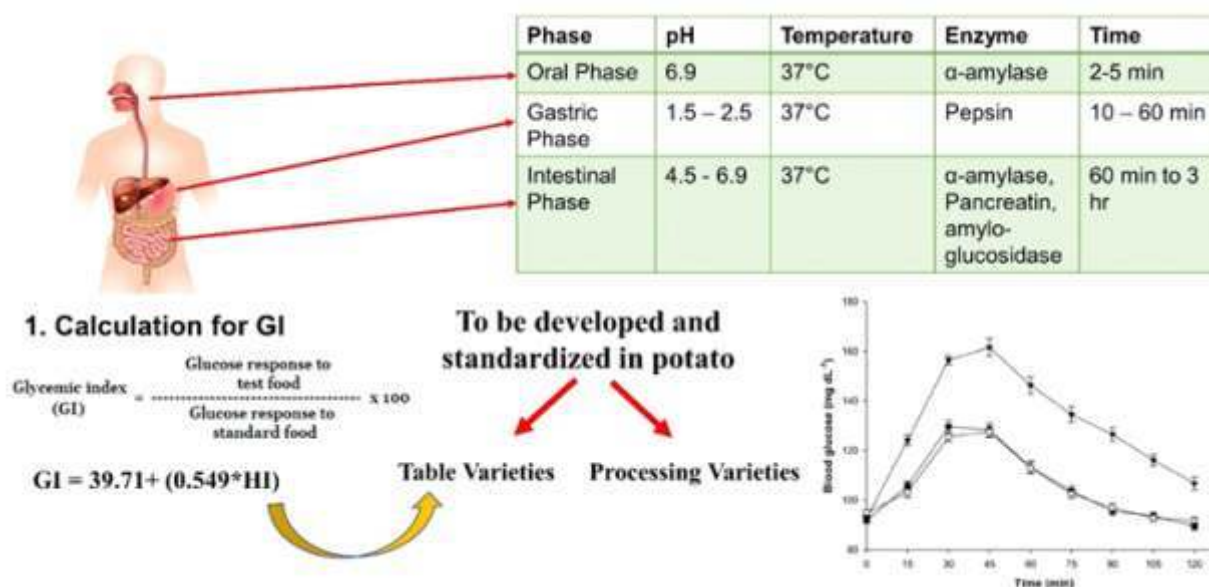


Fig. 4: The estimation of in vitro GI uses the mimicking component of small intestine as dialysis membrane.

Four different methods for the estimation of GI and its standardization were employed. The estimation of GI with Kumar's protocol revealed the GI of six cultivars to be 86.32, 87.31, 81.77, 77.29 and 80.53 in Kufri Chipsona 1, Kufri Chipsona 3, Kufri Frysona, Kufri Girdhari, Kufri Jyoti and Kufri Pukhraj, respectively. Similarly, when Pinheiro's

protocol was used the highest and lowest GI was observed in Kufri Chipsona and Kufri Jyoti, respectively (Fig. 5). Goni's protocol of estimation of GI suggested that GI values among the six cultivars varied from 76.86 to 88.03. Lastly, our modified protocol showed variation in GI of about 72.87 and 83.08, respectively in Kufri Jyoti and Kufri Chipsona-²

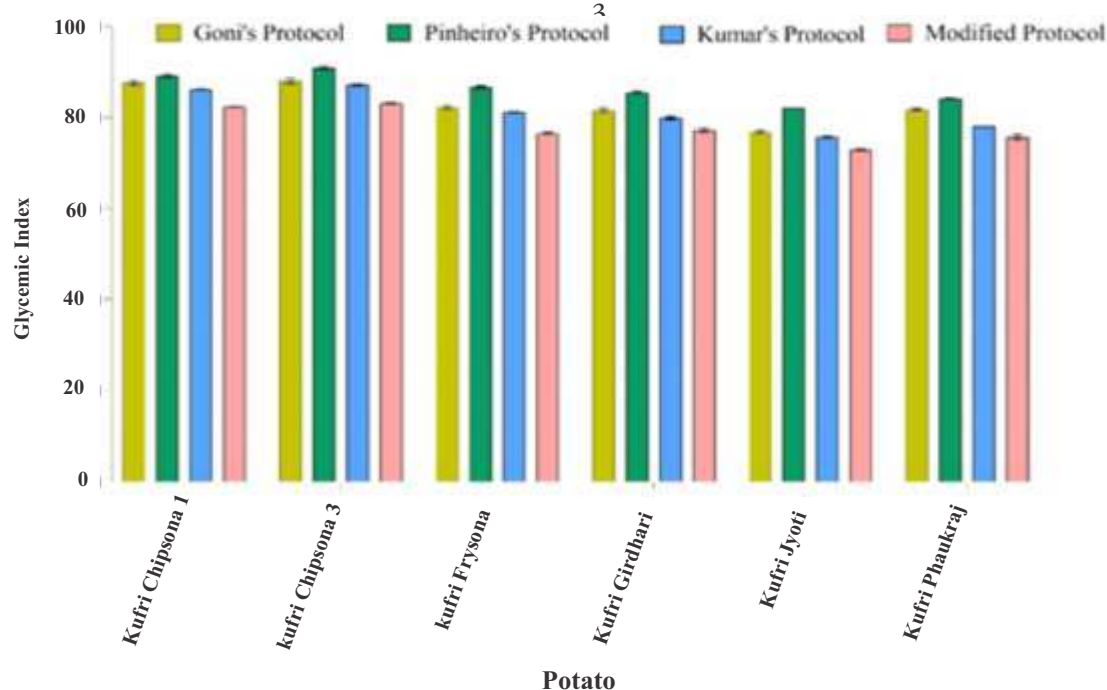


Fig. 5: Glycemic index of all the six cultivars viz., Kufri Chipsona 1, Kufri Chipsona 3, Kufri Frysona, Kufri Girdhari, Kufri Jyoti and Kufri Pukhraj with different methods of estimation such as Goni's protocol, Pinheiro's protocol, Kumar's protocol and our modified protocol

Validation for in vitro glycemic index

The validation of modified protocol was compared with other well established in vitro protocols. Our modified protocol was compared with Goni's protocol (GP), Pinheiro's protocol (GP), Kumar's protocol (KP). The mean average values of GI when compared with these protocols and violin graph revealed that GP showed higher GI values as compared to other methods. Our MP method showed a lower GI value in all the six cultivars of potato (Fig. 6A). The scatter plot matrix analysis revealed that there was a positive correlation between all the methods used for the estimation of GI (Fig. 6B). In the main diagonal, the marginal histogram and distribution of the GI in all the six cultivars.

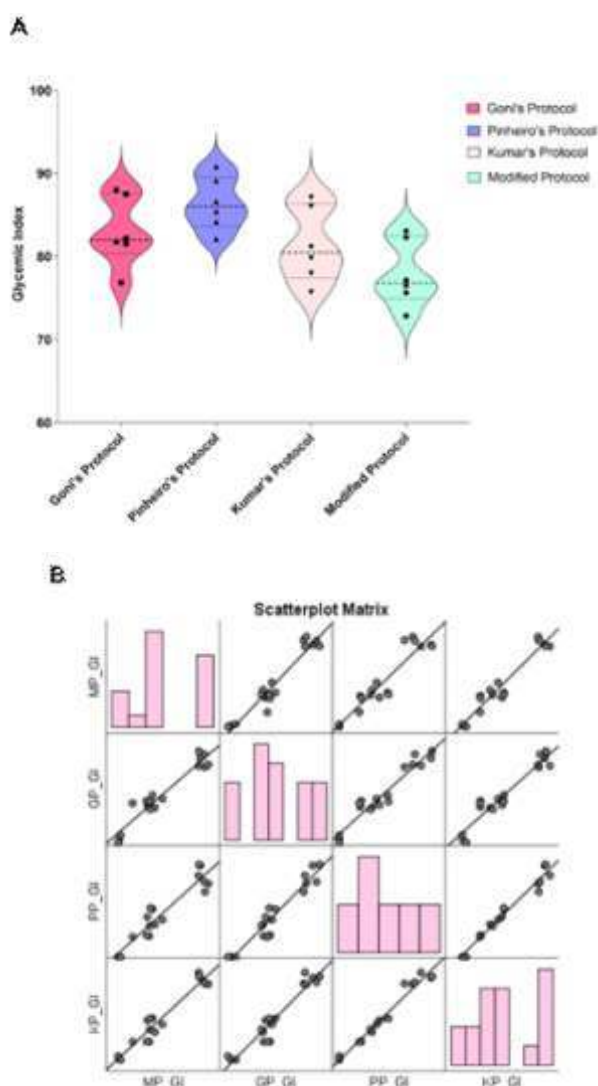


Fig. 6: (A) Validation of modified protocol of in vitro GI with other established methods such as Goni's protocol, Pinheiro's protocol, Kumar's protocol. (B) Scattered plot matrix showing correlation of Modified protocol (MP) with Goni's protocol (GP), Pinheiro's protocol (GP), Kumar's protocol (KP). In the main diagonal, the marginal histogram and distribution of the particular trait have been shown. The straight line in every box is shown to highlight the dependence pattern and regression line when two parameters were compared

The correlation analysis was performed to confirm the better method which can be used to estimate in vitro GI in Indian cultivars. The regression equations were obtained when MP was compared with GP, PP and KP (Fig.7). The results suggest that when MP is compared with GP the equation obtained was $Y = 1.0183X + 3.6372$ with an R^2 value of 0.962 (Fig. 7A). Similarly, when MP compared with PP, we found that the equation obtained was $Y = 0.7591X + 27.233$, $R^2 = 0.8887$ (Fig. 7B). Similarly, when KP was compared with our MP we reported that, $Y = 1.0884X - 3.4965$, $R^2 = 0.9371$ (Fig. 7C). From the above analysis, it was clear that our MP was more correlated with GP and KP. So we have modified our protocol according to these well-established protocols for screening of a large number of cultivars.

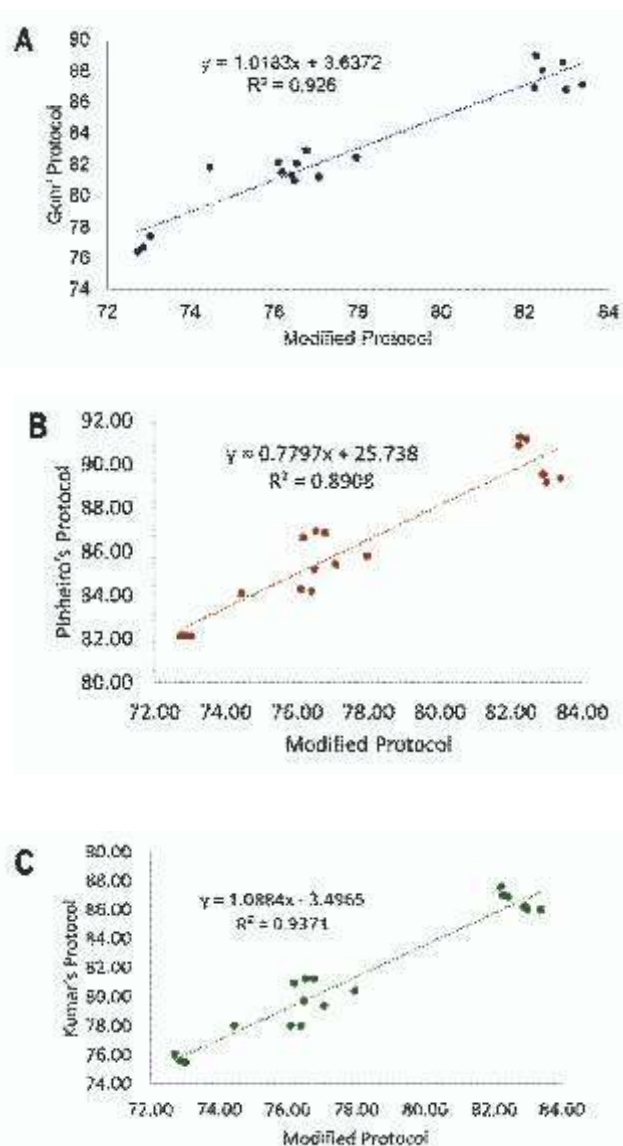


Fig. 7: The correlation analysis of modified protocol of GI when compared individually with (A) Goni's protocol (B) Pinheiro's protocol (C) Kumar's protocol

Validation for in vitro glycemic load

The efficacy of our modified GL procedure was compared to that of other well-known in vitro methods. Goni's protocol (GP), Pinheiro's protocol (GP), and Kumar's protocol were all compared to our modified protocol (KP). When the mean average GL values were compared to these protocols and the violin graph, it was discovered that GP had greater GL values than the other approaches. In all six potato varieties, our MP technique revealed a reduced GI value (Fig. 8A). The scatter plot matrix analysis indicated that all of the approaches used to estimate GL had a strong positive correlation (Fig. 8B). The marginal histogram and distribution of the GI in all six cultivars are shown in the main diagonal.

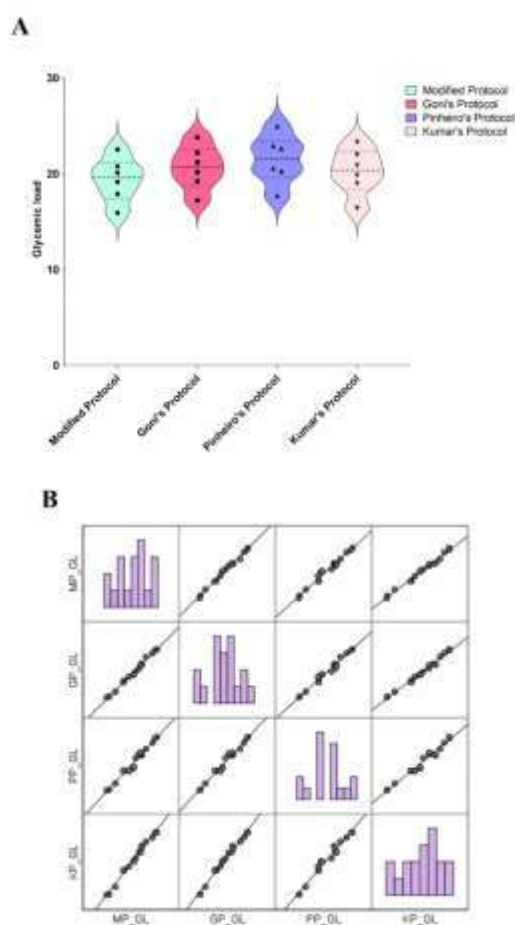


Fig. 8: (A) Validation of modified protocol of in vitro GL with other established methods such as Goni's protocol, Pinheiro's protocol, Kumar's protocol. (B) Scattered plot matrix showing correlation of Modified protocol (MP) with Goni's protocol (GP), Pinheiro's protocol (GP), Kumar's protocol (KP).

Effect of potato-pulse combination on in vitro glycemic index (GI)

Processing condition such as cooling can influence the glycemic impact of cooked potatoes through retrogradation of starch polymers. Low field nuclear magnetic resonance (LF-NMR) studies reported that

retrogradation is more extensive in boiled potatoes after 24-48h of cooling than after 1-2h. Our result showed that cooling/retrogradation had significant GI lowering effect when cooked potatoes were stored for 0h, 12h, 24h and 48h. Studies suggest that GI of potato was decreased significantly by 25% when cooled and again reheated for consumption. The retrogradation may change the starch structure under low temperatures, which ultimately leads to a lowering of GI.

The addition of pulses to the potato of KJ leads to a significant lowering of GI that ranged from 61.26 (potato-pigeon pea) to 71.44 (potato-black gram) in comparison to control (only cooked potato tuber) (76.14). So, in comparison to control, the GI of cooked potato tubers of KJ get lowered by 19.5, 19.5 and 13.4% when combined with pigeon pea, kidney bean and chickpea, respectively (Fig. 9A). Similarly, the addition of pulses viz., chickpea, kidney bean and pigeon pea with cooked potato of KC3 showed significant lowering of GI by 12.5, 12.4 and 11.1%, respectively as compared to the control (Fig. 9B). The lowest GI among the potato (KC3)-pulse combinations was with chickpea (Fig. 9B).

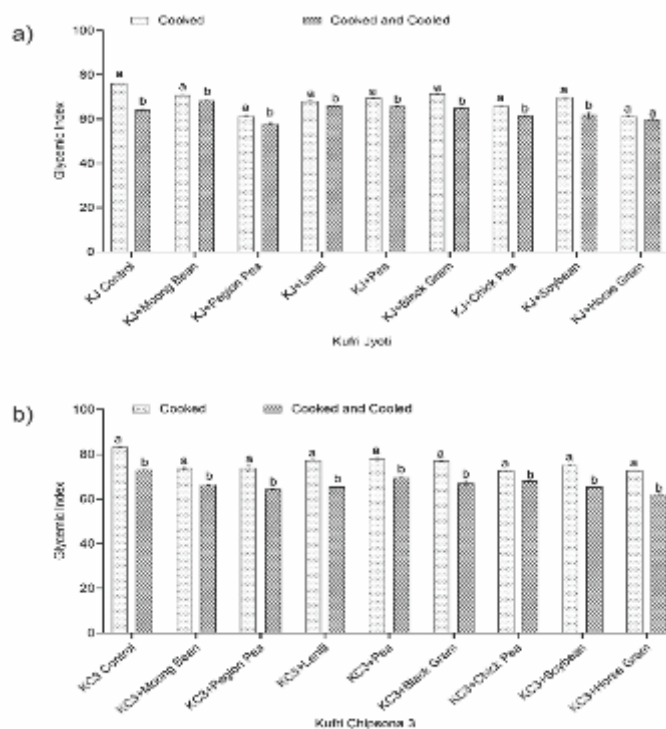


Fig. 9: Effect of cooking and cooking followed by cooling for potato alone and potato-pulse combinations on the glycemic index of when potato belongs to cultivars Kufri Jyoti, KJ (a) and Kufri Chipsona 3, KC3 (b). Statistical significance of difference between the means across the cultivars. Bar are represented as mean values $\pm$ SEM of three replicates.

Effect of potato-pulse combination on resistant starch content (RSC)

This study indicates that the combinations of pulses with any of the two potato cultivars resulted in a significant increase in the RSC (Fig. 10A and B). The RSC in KJ and KC3 was 1.63 and 1.10%, respectively in cooked potato. The RSC ranged from 1.7 to 2.3% for combinations of KJ with black gram and pigeon pea, respectively (Fig. 10B). The addition of pigeon

pea, kidney bean and chickpea to KJ tubers showed a significant increase in RSC by 43.9, 43.6 and 38.2 %, respectively. Similarly, the addition of pigeon pea and mung bean in KC3 showed significant increase in RSC by 58.9 and 49.1 %, respectively (Fig. 10B). The least effect of the addition of pulse in KC3 was for lentil and black gram (Fig. 10B) with RSC of 1.2 and 1.2%, respectively.

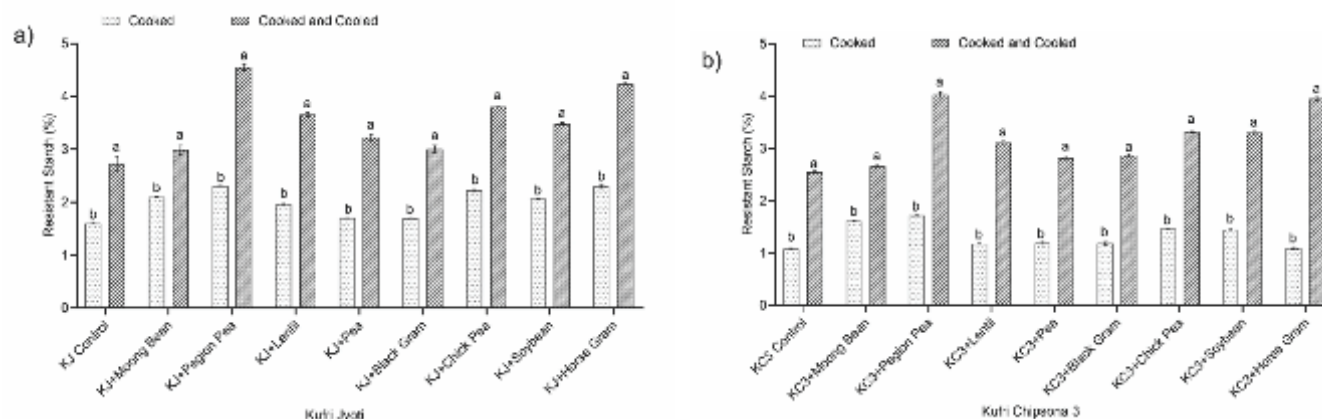


Fig. 10: Effect of cooking and cooking followed by cooling for potato alone and potato-pulse combinations on resistant starch (%) of when potato belongs to cultivars Kufri Jyoti, KJ (a) and Kufri Chipsona 3, KC3 (b). Statistical significance of difference between the means across the cultivars. Bar are represented as mean values $\pm$ SEM of three replicates.

Antioxidative and antidiabetic potential of dehydrated colored potato chips

Dehydrated colored potato chips were prepared from 17 advanced potato clones. Chips were deep-fried before analysis. Resistant starch in colored potato chips ranged from 6.48% (MSP/17-629) to 9.33% (MSP/17-89) (Fig.11). Biguanide related compounds were more in purple clone MSP/16-307 (5.79 mg/g) and least in MSP/17-198 (1.92 mg/g). glucosidase inhibitory activity was reported in almost all advanced

clones with 1% (MSP/18-16) to 52% (MSP/17-848) range. Glycoalkaloids and amylase inhibitory activity was not present in any of the tested clone. Malvidin was least in MSP/17-16 (2 mg/g) and the maximum in MS/16-307 (41 mg/g) (Fig.12). Clone MSP/17-198 contained high pelargonidin content (19 mg/g) and MSP/17-16 contained low content (2 mg/g). Total phenols ranged from 9 (MSP/17-35) to 27 (MSP/18-16, MSP/16-300). Results showed dehydrated colored potato chips to be good source of antioxidants, proteins and antidiabetic compounds.

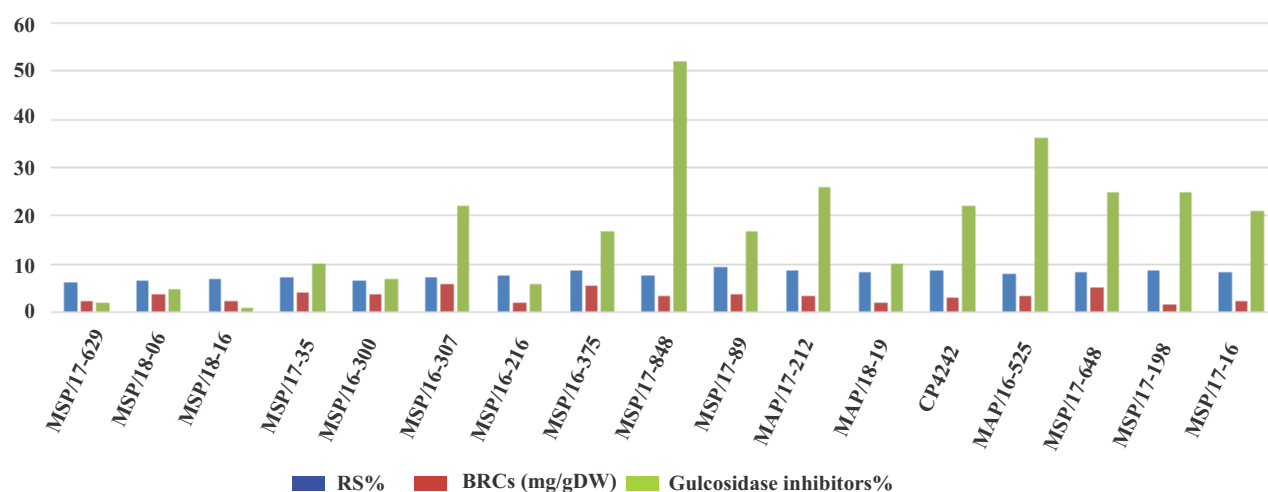


Fig. 11: Antidiabetic compounds and resistant starch in dehydrated colored potato chips

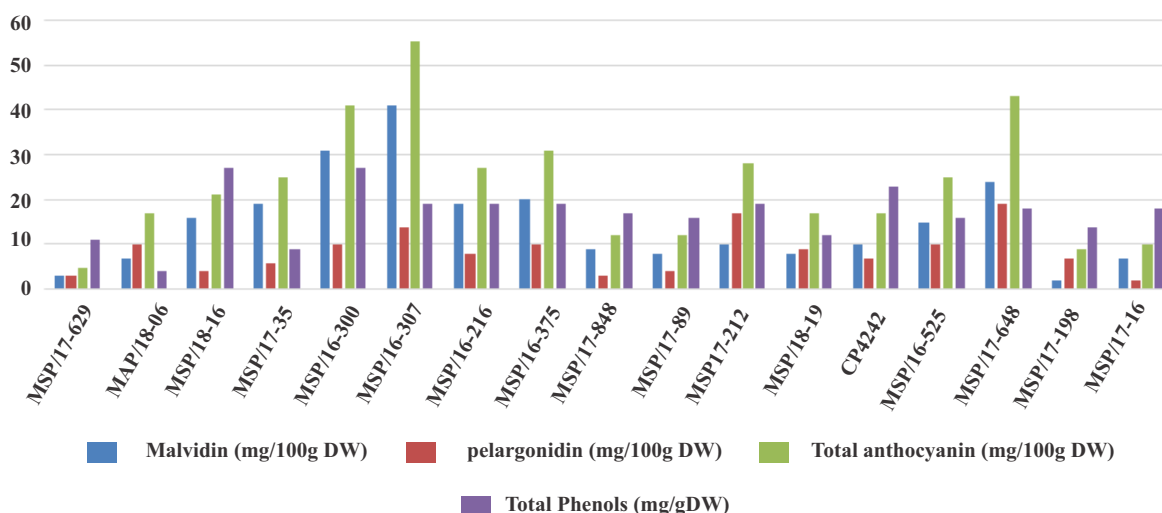


Fig. 12: Antioxidants in dehydrated colored potato chips

Effect of external application of antioxidants on rate of respiration and antioxidative behavior of potato slices

Effect of chlorogenic acid (CGA), ascorbic acid (AA), proline and melatonin treatment on rate of respiration, malondialdehyde, proline, phenols and polyphenol oxidase activity was studied in slices of K. Chipsona 3. Filter papers were soaked into known concentration of above-mentioned solutions. Rate of respiration was maximum at 6 h duration of incubation and decreased later up to 48 h. At 6 h the rate of respiration was least in slices treated with CGA followed by ascorbic acid and proline (Fig.13). The maximum rate of respiration was reported in control treatment. Proline content decreased in all treatments up to 24 h whereas increased at 48 h of incubation. Proline was maximum in control slices and least in melatonin and ascorbic acid treated slices. Melandialdehyde, a stress indicator, increased up to 24 h and then decreased at 48 h. At 24 h, it was the maximum in control slices. Least malondialdehyde content was reported in slices treated with ascorbic acid followed by CGA and melatonin (Fig.14). Phenols showed no clear trend at 6 h, increased at 24 h

and then decreased at 48 h. At 48 h, phenols were more in melatonin treated slices and least in ascorbic acid treated slices. Polyphenol oxidase activity increased up to 48 h of incubation (Fig.15). The activity was reported to be maximum in control slices and least in proline treated slices followed by melatonin and CGA treated slices. Rate of respiration showed positive correlation with proline (r 0.538), and malondialdehyde (r 0.432). Polyphenol oxidase showed positive correlation with proline (0.585) and malondialdehyde (r 0.656). Malondialdehyde showed negative correlation with proline (r -0.166) and phenol (r -0.166). Phenol and polyphenol oxidase showed negative correlation (r -0.485). The treatments that reduced the rate of respiration and suppressed the stress indicators such as malondiladehyde and proline can be further tried on whole tubers under different storage conditions. Chlorogenic acid needs to be tried for reduction in rate of respiration under storage conditions. Ascorbic acid can be tried for reduction in browning due to less phenol in ascorbic acid treated slices. Ascorbic acid also reduced the level of stress indicators to maximum extent, hence can be tried under storage conditions.

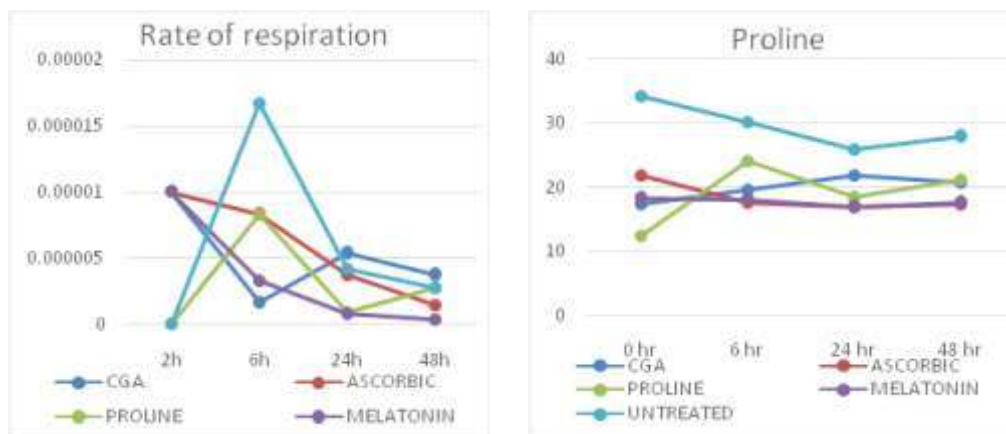


Fig. 13: Effect of different treatments on rate of respiration and proline content

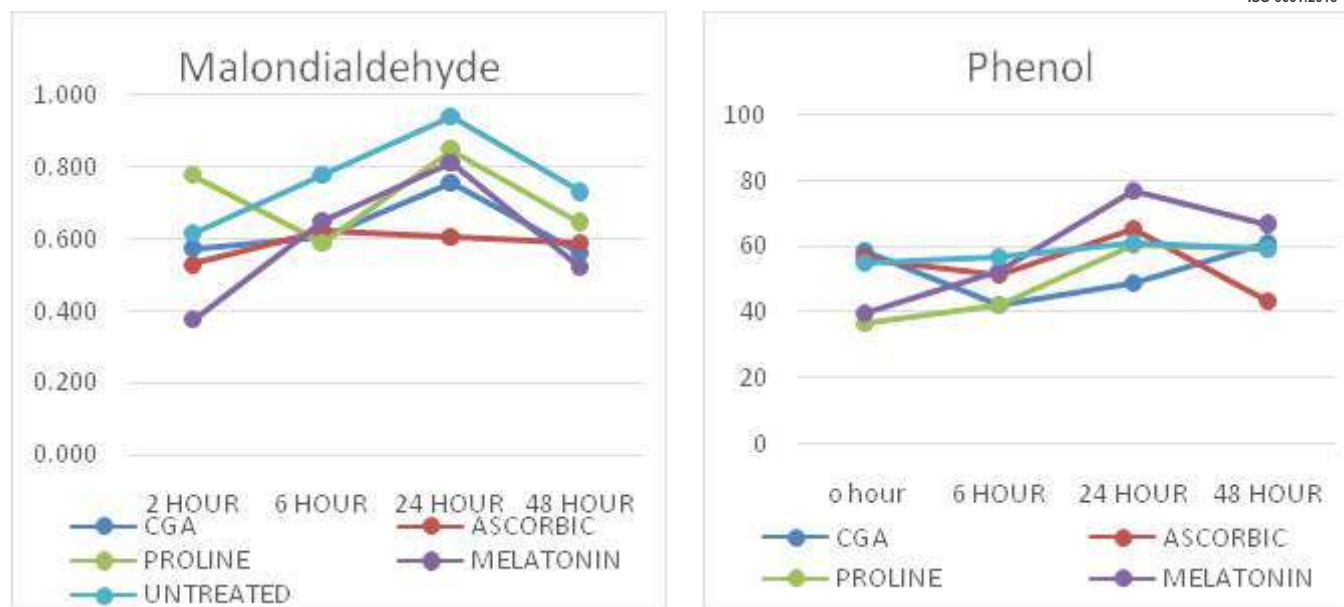


Fig. 14: Effect of different treatments on malondialdehyde and phenol content

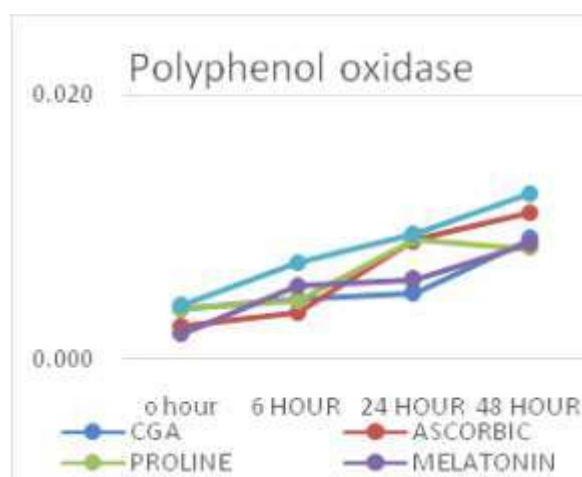


Fig. 15: Effect of different treatments on polyphenol oxidase activity

Novel Value-Added Products from Potatoes Vacuum Impregnation (VI) for development of ascorbic acid fortified potatoes

In present study, the whole potato and potato fries were used for VI treatment using ascorbic acid solution. Unpeeled and peeled potato tubers were dipped in ascorbic acid solution (12%) for 1 hour under vacuum. After completion of 1 hour of VI treatment, the samples were kept for 3 hours of restoration. Raw samples were kept for HPLC analysis of ascorbic acid. Then, potato tubers were cooked in steam cooker for 20 minutes. Again samples were kept for HPLC analysis of ascorbic acid. HPLC analysis showed that raw unpeeled control, peeled control, unpeeled treated and peeled treated samples contained 50.05, 50.36, 59.85, and 517.83 mg/100g FW respectively. After cooking, the ascorbic acid content reported as 43.06, 43.92, 53, and 155.40 mg/100g FW in unpeeled control, peeled control,

unpeeled treated and peeled treated samples, respectively. As ascorbic acid is heat labile vitamin, the cooking leads to degradation of its content as 18.23, 12.78, 11.44, and 69.99 % in unpeeled control, peeled control, unpeeled treated and peeled treated samples (Fig. 16). Results depicted that ascorbic acid was higher in peeled samples compared to unpeeled samples. There was a 10 times higher ascorbic acid content in VI treated peeled potatoes as compared to control peeled potatoes. In addition, after cooking there was 3 times higher ascorbic acid in peeled potatoes as compared to control. The ascorbic acid content in VI treated cooked potatoes is 155.40 mg/100g FW which is higher than the RDA value (100 mg/day) for ascorbic acid intake suggested by WHO. Similarly, the French fries were also given these treatments and they showed similar results. It may be derived that the VI is a promising technique for nutrient enrichment for potato and potato based products.

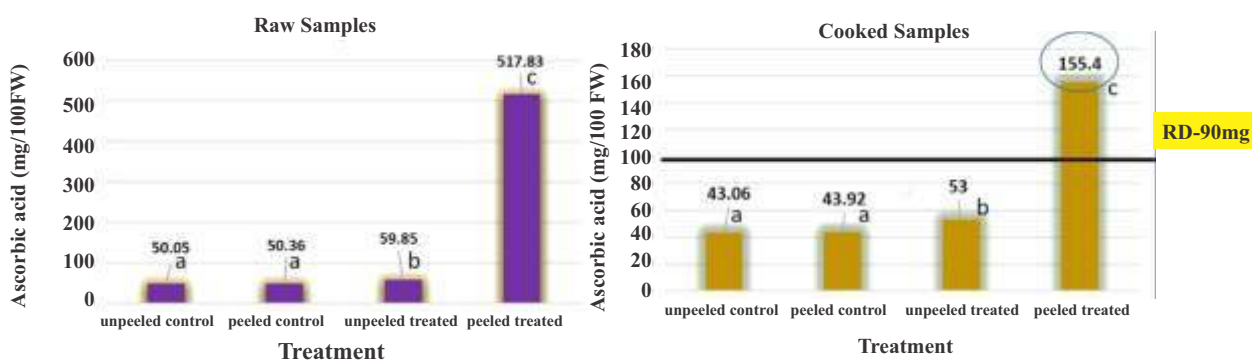


Fig. 16: Ascorbic acid content in raw and cooked potato samples

Production of fermentable sugars and bioethanol from waste potatoes

Culled potatoes are underutilised biomass in potato value chain and may be utilized as substrate for bioethanol production, through saccharification and fermentation. The saccharification was performed via thermal and enzymatic hydrolysis through the use of commercial enzymes such as cellulase, α -amylase, β -amylase and glucoamylase. The potato mash was mixed with 100 mL of distilled water. The mixture was treated with different enzyme concentrations of 10 U, 15 U and 20 U. The mixture was incubated at the temperature of 75 °C and pH 5.0. The saccharification process was completed with 10 U of amyloglucosidase at 60 °C, pH 4.5 for 72 h. Samples were withdrawn at different time intervals and the ethanol and consumed sugar assays were carried out by YSI Analyser. The use of commercial α -amylase led to higher reducing sugars release (69.21 ± 0.34 g/100 g) and in the combination of enzymes found the maximum efficiency of saccharification i.e. 81.40 ± 0.56 g/100 g (Fig. 17). The results showed that the enzymatic treatment led to higher saccharification efficiency (81.40%) equivalent to 96% of the maximum theoretical. The fermentation process by using various strains of Yeast at different time intervals. The maximum ethanol yield was obtained by *Saccharomyces cerevisiae* MTCC 178 after 72 h was 84.19 g/L.

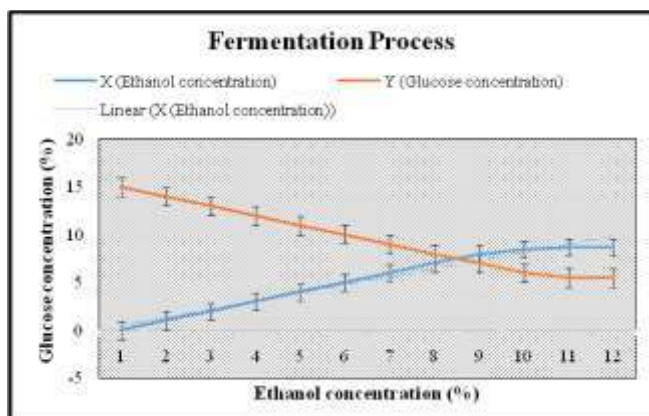


Fig. 17: Bioethanol production of fermentable sugar from enzymatic hydrolysis

Gluten-free potato GulabJamun

No Indian festival is complete without *GulabJamun*, as everyone knows. This delectable delicacy is the lifeblood of all Indian celebrations. Some people prefer hot *GulabJamun* in the winter, while others prefer it with kulfi/ice cream in the summer. This traditional dessert is typically made from khoya kneaded with refined flour. The dough balls are then fried until they turn a golden brown shade. The *GulabJamun* balls become slightly grainy at the crust after the heated oil works its magic, but the centre white heart remains silky smooth. The ball, which is infused with kewra/rose/cardamom-scented sugar syrup, yields to the slightest pressure and literally melts away as one bites into it. This sweet dish is truly delicious and adds soul to any celebration in India. A process for potato-based *GulabJamun* using whole potato flour (Fig.18). Because of the unique formulation, potato *GulabJamun* is high in dietary fibre and gluten-free. The most remarkable aspect of *GulabJamun* is that, unlike other fried potato items such as chips and French fried potatoes, these *GulabJamun* may be made from any shape, size, or variety of potato. Under frozen (-20°C) conditions these *GulabJamun* can be preserved up to 6 months.



Fig. 18: Gluten-free potato GulabJamun

DIVISION OF SOCIAL SCIENCES

PROGRAMME: TRANSFER OF POTATO TECHNOLOGIES TO STAKEHOLDERS AND ASSESSMENT OF THEIR IMPACTS

Farm-Level Adoption of Improved Potato Production Technologies in Bihar

The adoption of improved potato technologies is vital for increasing potato productivity and farmers' income. Thus, this study attempted to analyse the farm level adoption of improved potato technologies during the crop season 2020-21, by interviewing 120 randomly selected potato growers of Bihar (60 each from Patna and Nalanda districts). The survey revealed that technologies like use of improved varieties, pre-sprouting of seed tubers, use of whole

seed tubers, seed retention period, maintenance of spacing, maintenance of irrigation interval, late blight management and earthing up were followed by majority of farmers (Table 1). However, there was very poor adoption of technologies like use of certified/quality potato seeds, FYM application, recommended dose of NPK fertilizers and pre-sowing irrigation. Overall, about 32 percent of farmers applied excess nitrogen fertilizers, 70 percent applied excess phosphatic fertilizers and about 59 percent applied less potash fertilizers.

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

Improved production technologies	Nalanda (n=60)		Patna (n=60)		Overall (N=120)	
	Freq.	%	Freq.	%	Freq.	%
Use of optimum seed rate (25-35 q/ha)	33	55.00	21	35.00	54	45.00
Use of improved varieties	58	96.67	60	100.00	118	98.33
Use of certified quality potato seeds	8	13.3	5	8.3	13	10.8
Pre-sprouting of seed tubers	55	91.7	56	93.3	111	92.5
Use of whole seed tubers	57	95.0	58	96.7	115	95.8
Seed Retention Period (below 4 years)	56	93.3	55	91.7	111	92.5
Maintenance of row to row and plant to plant spacing	53	88.3	54	90.0	107	89.2
FYM application	10	16.7	5	8.3	15	12.5
Balanced dose of fertilizers						
• First dose of Nitrogen fertilizer	23	38.3	18	30.0	41	34.2
• Second dose of Nitrogen fertilizers	27	45.0	21	35.0	48	40.0
• Phosphatic fertilizers dose	10	16.7	16	26.7	26	21.7
• Potash fertilizers dose	18	30.0	16	26.7	34	28.3
Weeding	19	31.7	19	31.7	38	31.7
Optimum irrigation interval (8-15 days)	34	56.7	32	53.3	66	55.0
Pre-irrigation	6	10.0	7	11.7	13	10.8
Late blight management	50	83.3	47	78.3	97	80.8
Earthing up	41	68.3	33	55.0	74	61.7

Incidence and intensity of adoption of improved varieties in Bihar

As quality seeds of improved potato varieties are the basic and crucial determinants of productivity, the 'incidence of adoption' which is the percentage of farmers growing improved varieties and 'intensity of adoption' which is the percentage of area planted to particular varieties at a given time was also analysed and presented in Figure 1. The study revealed that in

Bihar, varieties developed by the institute like Kufri Pukhraj, which was adopted by about 51 percent of potato growers and covered about 60 percent of total potato area and Kufri Sindhuri (about 31% potato growers covered about 31% potato area), were the leading potato varieties in the study area. Local/traditional varieties like *Lal Gulab* and *Bhoora aloo* were still adopted by some farmers.

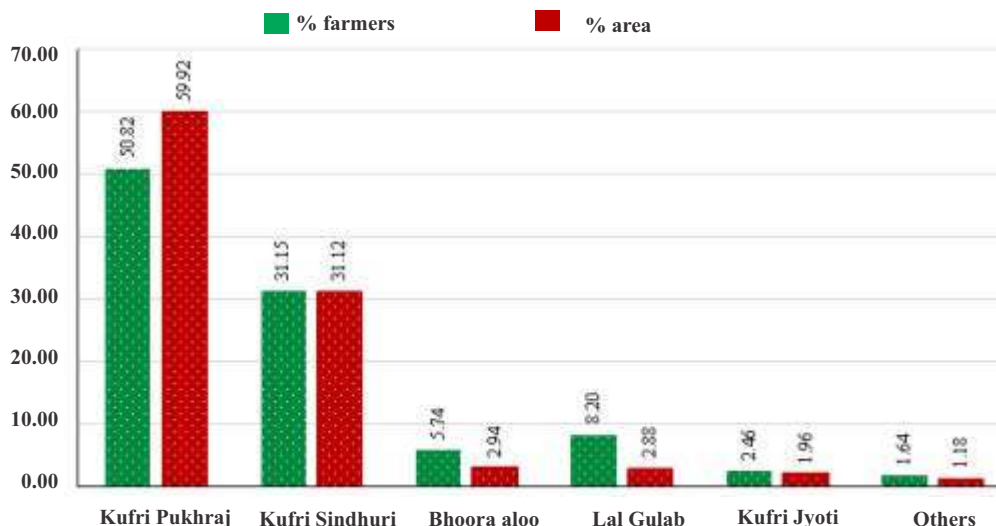


Fig.1. Incidence and intensity of adoption of improved varieties in Bihar

Constraints in adoption of improved potato production technologies in Bihar

The constraints faced by potato growers in adoption of potato technologies in Bihar was analysed and presented in Table 2. The major constraints as perceived by farmers in the study areas were price fluctuation every year and low price of produce, lack

of guidance by extension staffs, good quality seed, region-specific suitable potato varieties, knowledge about improved cultivation practices, storage and processing facilities, training on scientific potato production technologies and production inputs at right time, and high cost of production inputs.

Table 2: Major constraints in adoption of potato production technologies

Constraints	WMS
Price fluctuation every year	2.56
Lack of guidance by extension staffs	2.45
High cost of cultivation	2.43
Lack of good quality seed	2.43
Glut in the market/lower price of produce	2.42
Lack of region-specific suitable potato varieties	2.40
Lack of knowledge about improved cultivation practices	2.37
Lack of storage and processing facilities	2.34
Lack of training on scientific potato production technologies	2.33
Lack/unavailability of inputs at right time	2.28
Higher cost of quality seeds	2.23

WMS=Weighted Mean Score

Survey regarding doubling farmers Income

A survey under “Doubling farmers' Income” was conducted in the adopted area of Fagu, Talai and Cheog. Ten farmers from the said area were interviewed and the comparison of income between 2016-17 and 2020 was drawn to calculate the difference of income they are able to generate form the same area of land.



Transfer of Technologies

Officers training programme on scientific potato cultivation

During the period CPRI conducted a number of trainings for agriculture officers and farmers.

A three day training on **“Improved Potato Cultivation”** was organised by the institute during 7-9 January for 5 officers from agriculture department of Mansa district of Punjab. The training programmes were sponsored by Chief Agriculture Officer Mansa, Punjab (Under ATMA Project). 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. 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.



Farmers training programmes on temperate fruits, vegetables and improved techniques of potato cultivation under TSP

Three 3 days on campus trainings on **“Sheetoshan falon, sabjiyon ttha aloo ki fasal ki unnat taknike”** was organised by the institute in the month of February.

- The first training was organised from 15-17 February for 20 farmers of Ribba village falling under tehsil Bhurang distt. Kinnaur.
- The second training was organised from 22-24 February for 20 farmers of villages falling under tehsil Sangla distt. Kinnaur.
- The third training was organised from 26-28 February for 20 farmers of villages falling under tehsil Nichar distt. Kinnaur.

The highlight of these trainings was a large number of female participants in the trainings. These trainings were undertaken for the Schedule Cast farmers under TSP component. **“Aloo Diwas”** on 15 February was also celebrated during the first training.

The objective of the training was to enhance the knowledge and skill of the trainees regarding cultivation of temperate fruits and vegetables along with production of seed potato and value addition in potato. 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.



Apart from these three trainings one 3 days training on **“Sheetoshan falon, sabjiyon ttha aloo ki fasal ki unnat taknike”** was conducted in collaboration with ICAR-IARI, Regional Station, Dhanda, Shimla from 17 to 19 February for 100 farmers of different villages of Shoghi and Cheog panchayats of district Shimla. This training was also for the Schedule Caste farmers under TSP component and in this training each farmer was provided with inputs like apple, kiwi and pomegranate plants along with pruning scissor. The training was conducted at ICAR-IARI, Regional Station, Dhanda, Shimla and sponsored by CPRI.



International Water Day at celebration at Chamad Bharech, distt. Solan

On the occasion of International Water Day i.e. 22 March, a **“Kisan Goshthi”** was conducted at Chamad

Bharech panchayat, Distt. Solan. The goshti was attended by more than 200 farmers from different villages of Chamad Bharech panchayat of distt. Solan. The farmers were given tips for the cultivation of potato along with a lecture on the importance of water conservation and its judicious use.

The objective of the farmer's trainings was to enhance the knowledge and skill of the participants regarding production of quality potato through new techniques and practices with minimal use of water.



Kisan Melas cum Training under TSP

Two 2 day Kisan Melas cum Training under TSP were organised in the month of March.

- The first one was organised at Narmada, Gujarat during 9-10 March, 2021 and the programme was attended by about 1000 farmers.

The second was at Mandla, Madhya Pradesh during 13-14 March, 2021 and the programme was attended by about 2000 farmers



Farmers Training Programme on Food and Nutrition

A one day training programme on food and nutrition was organised at CPRI for the farmers on 26th August. The motive of the programme was to make the farmer community aware of the nutritional elements present in our daily diet and what should be added or reduced so as to make our diet a balanced diet also they were told about what practice they should follow to grow their crops to make them more healthy for the consumers.



Online training programme on “Making a Secure & Resilient Workplace”

A three day online training programme on “Making a Secure & Resilient Workplace” for Technical/ Administrative staff associated with security of ICAR Institutes and Headquarters was organised by CPRI during 1-3 September. Twenty-four participants from various ICAR institutes joined the training. The training constituted of lectures by the experts who are engaged in safety and security from CPRI and other institutions like ITBP, CIAE on the preventive measures for sensitive data, cyber crimes and also practical demonstrations by Police Department & Fire Department for safety against fire/ violence and other such issues related with security of, staff and infrastructure.



Officers training programme on scientific potato cultivation

Two three day trainings on “Aloo ki unnat Kheti” were organised by the institute. The first batch training was undertaken during 13-15 September for 5 officers/ technologists and the second batch training of 5 officers/ technologists was held during 21-23 September. The trainees were from Banaskantha Jila Sehkari doodh utpadak Sangh Limited, Palanpur (Gujarat).



In the second training a group of 7 progressive farmers mostly ladies from Ayurvet Research Foundation Sonipat, Haryana also joined in. The training programmes were sponsored by them. 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. 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 scientific potato cultivation A three day training programme on “Potato Value Chain: Seed production, Pest management, Post-harvest technology and Value addition in potato”

was organised during 4-6 October for ADOs of Assam. The training was sponsored by Govt. of Assam under RKVY “RAFTAAR” c/o CIP and was attended by 20 ADOs. 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.

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Officers Training Programme

A five day training programme on “Potato Seed Production through In-Vitro, Aeroponics and other Techniques” was organised for 8 officers from Assam and 1 from Uttar Pradesh during 9-13 November. The training was sponsored by APART Project, Govt. of Assam in collaboration with International Potato Centre (CIP).



Officers Training Programme

A three day training on “Potato Value Chain (Seed, Production, Protection and Plant Harvest Management)” was organised for 15 ADOs and 5 Board of directors of Farmer Producer Companies (FPC) during 29th Nov. to 1st Dec. The trainees were from Assam and the training was sponsored by ARIAS Society of Guwahati, Assam. A big number of female participants was the main feature of this training.

Farmers Trainings

Two 3 days trainings cum exposure visits on “Improved Potato Production” during 13-15 Dec. for 26 farmers from Faridkot (Punjab) sponsored by ATMA, Faridkot, Govt. of Punjab and second for 25 farmers during 20-22 Dec. from Firozpur (Punjab) sponsored by ATMA, Firozpur, Govt. of Punjab were conducted by the institute. Both the trainings were facilitated by Development Foundation, Ghaziabad(UP). 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.



Kisan Goshthi A Mahila Kisan Goshthi was organised on 14-15 October for female farmers of Laddakh. A total of 44 persons participated in this goshthi comprising of 42 female farmers and two coordinators. There were lectures, film show and lab visit during this goshthi.



Live Phone-in Programme at Doordarshan

Scientists from ICAR-CPRI, Shimla participated in the live phone-in programmes during January to December, 2021. The details of the topic and the expert is as under:

Month	Topic	Name of the Expert
April, 2021	Potato Varieties and potato Sowing in high hills of Himachal Pradesh	Dr. RK Singh Dr. Ashwani Kumar Sharma
May, 2021	Inter culture operations in potato in higher hills of Himachal Pradesh	Dr. VK Dua Dr. Jagdev Sharma
June, 2021	Potato Storage and marketing in Mid hills of Himachal Pradesh	Dr. Brajesh Singh Dr. NK Pandey
August, 2021	Management of potato disease and pests in high hill regions of Himachal Pradesh	Dr. Ravinder Kumar Dr. Rahul Tiwari
September, 2021	Intercultural operations in potato crop in high hills of Himachal Pradesh	Dr. Ashwani Kumar Sharma Dr. Vinod Kumar
November, 2021	Intercultural operations and weed management in potato crop	Dr. Jagdev Sharma Dr. Anil Kumar Chaudhary
December, 2021	Insect pest and disease management in potato	Dr. Ravinder Kumar Dr. Rahul Kumar Tiwari

Advisory SMSs were sent to various MGMG farmers across state on potato and other vegetable crops.

EXTENSION ACTIVITIES AT ICAR-CPRI, RS, MODIPURAM

Frontline demonstration at farmer's field 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 111 field demonstrations on variety Kufri Chipsona-1, Kufri Chipsona-3, Kufri Frysona, Kufri Surya, Kufri pukhraj and Kufri bahar at 111 Farmer Fields i.e Meerut, Hapur, Lakhimpur Kheeri,

Gautam Buddh Nagar, JP Nagar, Ghaziabad, Baghpat, Etawah, Agra, Bahraich, Bulandshahar, Badaun, Muzafarnagar, Sambhal, Aligarh, Amethi, Moradabad, Shamli and Bijnor districts of Uttar Pradesh and Udham Singh Nagar in Uttarakhand and Sonapat in Haryana in area 0.02 ha. On an average 21.0 % increase in tuber yield recorded under recommended practices as compared to farmers practices.

Frontline demonstration at farmers field on improved

potato varieties and seed production technology in under SCSP: This year 356 quintals breeder seed of improved varieties like Kufri Chipsona-1, Kufri Chipsona-3, Kufri Frysona, Kufri Surya, Kufri Pukhraj and Kufri Bahar was distributed to total 456 schedule caste farmers belong 21 districts of Uttar Pradesh, Haryana and Udham Singh Nagar in Uttarakhand. The average yield of improved varieties were compared with the existing local variety. In Kufri

Chipsona-1, 22.0%, Kufri Bahar 25.5%, Kufri Surya 19.0%, Kufri Frysona 21.0% and in K. Chipsona-3 (18%) and Kufri Pukhraj (28%) increase in average yield was recorded as compared to over yield of local varieties in 356 field demonstrations when crop was harvested after 90 days- 110 days in all 21 districts under recommended practices. On an average 23.0% increase in yield under recommended practices as compared to farmers practices.

Details of Frontline demonstration at farmers field on improved potato varieties and seed production technology in under SCSP

S.N.	District	Quantity of breeder seed distributed(qts)	Number of farmers
1	Meerut	25	25
2	Baghpat	15	15
3	JP Nagar	16	16
4	Ghaziabad	15	15
5	Hapur	15	15
6	Lakhimpurkheri	25	25
7	Etahva	15	15
8	Agra	15	15
9	Bahraich	15	15
10	Shamli	15	15
11	Bijnor	20	20
12	Bulandshahar	25	25
13	Badaun	21	21
14	Hathrus	19	19
15	Muzaffarnagar	15	15
16	Sambhal	15	15
17	Aligarh	16	16
18	Moradabad	20	20
19	Udham Singhnagar(UK)	15	15
20	Sonipat (Haryana)	19	19
	Total	356	356

Training Programme Organized

S.N.	Title of training	Duration	Nos. of trainees	Beneficiaries	Sponsored Agency
1.	गुणवत्तायुक्त आलू उत्पादन की उन्नत तकनीक	23 December, 2021	50 SC category	Farmers of districts Meerut, Hapur, Gautam Buddh Nagar, Shamli and Muzaffarnagar districts of U.P.	ICAR- CPRI under SCSP components
2.	Seed regulations of potato in India	Three days (22-24 March, 2021)	12	KVK Scientists & Progressive farmers	AAU under APART Scheme

Organization of exhibition and participation in Exhibition, Aloo mahotasav and Krishipradarshini

S.N.	Title of exhibition	Duration	Nos. of trainees Beneficiaries	Organize / Sponsored Agency
1	Participation in Krishi Exhibition at Experimental Farm Meerut (U.P.)	One days 23 December, 2021	300 Farmers belong to western districts of U.P.	Deptt. of Agriculture Meerut mandal Meerut

V. Others Extension activities organized at the Campus

Programmes/activities	Duration	Participation	Sponsored Agency	Number of beneficiaries
Parthenium Awareness Week	16-22 August, 2021	Farmers of village Dulhera (Meerut) & Staff Members	ICAR-CPRI	52
भारत के अमृत महोत्सव की शृंखला में किसानों के लिए पोषण प्रशिक्षण कार्यक्रम	26 August, 2021	Farmers & Staff Members	ICAR-CPRI	65
भारत के अमृत महोत्सव की शृंखला में राष्ट्रीय पोषण सप्ताह	13-19 September, 2021	Students, Farmers, Housewives, Scientists	ICAR-CPRI	300
प्रधान मंत्री द्वारा किसानों के साथ वार्ता का सजीव प्रसारण एवं किसान गोष्ठी	28 September, 2021	Farmers & Scientists	ICAR-CPRI	102
फिट इंडिया फ्रीडम रन 2.0 जन भागीदारी से जन आंदोलन (आजादी का अमृत महोत्सव 2021)	16 September to 02 October, 2021	Staff members	ICAR-CPRI	64
सेमिनार "गुणवत्ता युक्त बीज उत्पादन की आधुनिक तकनीक, जलवायु परिवर्तन एवं अद्यतन वैश्विक कृषि परिवेश की चुनौतियाँ"	16 October, 2021	Farmers & Stakeholders	Department of Agriculture, Meerut (UP)	100
कृत्रिम खेती पर प्रधान मंत्री द्वारा किसानों के सम्बोधन का सजीव प्रसारण एवं किसान गोष्ठी	16 December, 2021	Farmers & Staff members	ICAR-CPRI	104
Kisan gosthi evam address by PM to farmers and release PM kisan money	25 December, 2020	Farmers and staff of CPRI	ICAR-CPRI	75
International Women Day	8 March, 2022	Farm women and staff	ICAR-CP	100
Phones attended at Kisan call centre	2021	250 quarries of potato growers on various aspects from various districts of U.P., M.P., Rajasthan, Gujrat, Punjab, Utrakhand Delhi and Haryana states answered through phone	CPRI	350

Details of visits of farmers at the campus sponsored by various organization under different Schemes

Date	District/Place	No. of Farmers visited	Sponsoring authority	Under Scheme
16/9/2021	Mathura and Etah (U.P.)	49	Joint Director, Govt. kkrishi vidhayalay Bulandshahar (U.P.)	Exposure visit of farmers under insitu plan Project
28/10/2021	Moradabad and Bulandshahar (U.P.)	55	Joint Director, Govt. kkrishi vidhayalay Bulandshahar (U.P.)	Exposure visit of farmers under ATMA Project
12/11/2021	Barabanki (U.P.)	100	Programme coordinator, KVK Chittora, Muzafarnagar (U.P.)	Exposure visit of farmers
12/11/2021	Shamli (U.P.)	44	Programme coordinator, KVK, Shamli	Exposure visit of farmers under ATMA PROJECT
19/11/2021	Moradabad (U.P.)	44	Programme coordinator, KVK, Moradabad	Exposure visit of farmers under ATMA Project
24/11/2021	Hapur & Moradabad (U.P.)	63	DY. Director district Basti (U.P.)	Exposure visit of farmers under ATMA PROJECT
06/12/2021	Bulandshahar	45	DY. Director district, Bulandshahar (U.P.)	Exposure visit under in Situ project

Summary of visit

1. Exposure visits of students: Total 220 UG and PG from various colleges and universities of U.P. visited Central Potato Research Institute RS, Modipuram (UP).
2. Exposure visits of farmers: Total 454 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).

EXTENSION ACTIVITIES AT ICAR-CPRI, RS, PATNA

A.	Training	1. One day training on potato to the Arrah farmers on 23.07.21. (27 Nos. farmers)
		2. Exposure visits of ATM/BTM from different district of Bihar on 30 th July, 21. (34 Beneficiary)
		3. A training on Post Harvest Management of Potato was held on 29 th and 30 th July '21 at ICAR-CPRI, RS, Patna sponsored by BAMETI. (65 Beneficiary)
		4. One day farmers training under SCSP were organized at ICAR-CPRI, RS, Patna on 11 th October'2021. 120 farmers from blocks of East Champaran participated in the training. Dr. NK Pandey, Director, ICAR-CPRI, Shimla also present in this occasion.
		5. One day training to prospective inputs dealer of Patna district on "Integrated Nutrient Management" at ICAR-CPRI, RS, Patna on 29 th October'2021. (25 Beneficiary)
		6. 21 one day farmers training s were organized at ICAR-CPRI, RS, Patna from November'21 to March'22. More than 600 farmers from different districts of Bihar participated in the training sponsored by ATMA/BAMETI.
		7. Exposure visits of Saran farmer's on 20 th November, 21. (28 Beneficiary)
B.	Survey	1. Survey on farmer's doubling income in Shivachak, Phulwarisharif, Patna on 6 th September, 21.
		2. Survey on farmer's doubling income in Karmalichak, Patna City, Patna on 10 th September, 21.



EXTENSION ACTIVITIES AT ICAR-CPRI, RS, JALANDHAR

Sl. No.	Title of the training	Date and duration	No. of beneficiaries	Place/ Sponsoring agency
Training imparted under ABI (NAIF)				
1	Technology commercialization and training program on "CPRI - VEGFAST technology for rooftop vegetable production".	20.01.2021	03	Entrepreneurs
2	An Online awareness program with registered VEGFAST service providers.	27.01.2021	17	Entrepreneurs
3	An online technology commercialization and training program on "CPRI -VEGFAST technology for rooftop vegetable production".	28 to 30.01.2021	02	Entrepreneurs

4	Training program on “Net House Technology for Potato Seed Production”.	03.02.2021	18	Farmers
5	Training program was lined up on “Aeroponics Fabrication” for Rajdeep Agri. Products Pvt. Ltd., New delhi.	10.02.2021	01	Entrepreneurs
6	Technology commercialization and training program on “CPRI-VEGFAST technology for rooftop vegetable production”.	11.02.2021	01	Entrepreneurs
7	Technology commercialization and training program on “CPRI-VEGFAST technology for rooftop vegetable production”.	12.02.2021	10	Entrepreneurs
8	Awareness program on the “Smart Seed Production technology of Potato” with farmers from Nakodar, Dist. Jalandhar	16-02-2021	14	Farmers
9	Technology commercialization and training program on “CPRI-VEGFAST technology for rooftop vegetable production”.	20.02.2021	03	Entrepreneurs
10	Technology commercialization and training program on “CPRI - VEGFAST technology for rooftop vegetable production”.	06.03.2021	10	Entrepreneurs
11	An Online VEGFAST technology review program was organized at ICAR-CPRS Jalandhar on 25 -03-2021.	25.03.2021	23	Entrepreneurs
12	Training program on “ICAR - CPRI VEGFAST” technology was conducted at ICAR -CPRS Jalandhar on 09-04-2021.	09.04.2021	04	Entrepreneurs
13	Online VEGFAST technology review program was organized at ICAR-CPRS Jalandhar on	12.05.2021	08	Entrepreneurs
14	Webinar with the help of CCARI, Goa on VEGFAST technology “To increase vegetable production in coastal regions”.	15.06.2021	97	Entrepreneurs/farmers
15	Webinar on “Business opportunities in Hydroponics, Aeroponics and VEGFAST systems in Medicinal Plants”, organized in collaboration with ICAR-DMAPR, Gujrat	03.07.2021	62	Entrepreneurs/ farmers
16	An online Program was organized on “Business Opportunities in VEGFAST, HYDROFAST and Aeroponic system” with ICAR - DMAPR, Anand.	26.07.2021	64	Entrepreneurs
17	Technology commercialization and training program on “Potato minituber counting machine” for manufacturing of the system	22.07.2021	02	Manufacturers

18	An online review meeting was organized for registered service providers on ICAR – CPRI VEGFAST technology for “Upcoming winter season crops”.	17.08.2021	21	VEGFAST stakeholders	
19	Awareness program organized on Hi-tech seed potato production technology at Samrala	19.09.2021	35	Farmers/ Seed growers	
20	EDP and training program organized on VEGFSAT for entrepreneur and scientific staff of CCARI, Goa on 28.09.21.	28.09.2021	04	Entrepreneurs/ scientific staff	
21	EDP organized on Aeroponic facility manufacturing technology at CPRS, Jalandhar	18.10.2021	02	Manufacturers	
22	Awareness program organized on Drone technology in Agriculture on	06.12.2021	30	Farmers	
23.	Awareness Program on “Natural Farming”	16.12.2021	40 participants	ICAR-CPRI (RS), Jalandhar (Pb)	
24.	National Webinar on “World Soil Day” (Virtual)	05.12.2021	110 participants	ICAR-CPRI (RS), Jalandhar (Pb)	
25.	Dr Prince Kumar imparted lectures entitled “Role of essential nutrient elements on potato production” and “Challenges and mitigation strategies for sustainable potato production in the changing climate scenarios” to B.Sc. 3 rd Yr students of Lovely Professional University, Jalandhar	01.12.2021	25 students	ICAR-CPRI (RS), Jalandhar (Pb)	
26.	Dr Prince Kumar imparted lecture entitled “Potato Production: Current Scenario, Challenges, Opportunities and GAPs for Sustainability” organized by APEDA.	11.11.2021	70 progressive farmers	Centre of Excellence on Potato, Dhogri, Jalandhar (Pb)	
27.	Dr Prince Kumar documented “success stories on doubling farmers income” in potato under “Mera Gaon, Mera Gaurav” and Aspirational Distt. programme.	25.09.2021	8 farmers	ICAR-CPRI (RS), Jalandhar (Pb)	
28.	Dr Prince Kumar imparted lecture on “Quality potato production” under the training program organized by APEDA, Chandigarh.	27.05.2021	-	Virtual	
Technologies commercialized					
1	CADAgro, Ahmedabad, Gujrat	CPRI Aeroponics Technology (Minituber production)	CADAgro, 755, Prakruti Farm, Hirapur, Mahemdabad Road, Ahmedabad-382 435, Gujarat, India.		2021 98257-02471

2	Varsha Greenz, Urban state, Jalandhar 1.	CPRI Aeroponics Technology (Manufacturing and installation)	Varsha Greenz, Urban state, Jalandhar, Punjab 144 001	2021	95929-01279
3	Ujjwal Gupta ²	ICAR-CPRI VEGFAST Technology	# 01, Raghav Puram Colony, Saharanpur 247 001, Uttar Pradesh	2021	96908-90468
4	Manavalan Agency (Ranga)	ICAR-CPRI VEGFAST Technology	C2 Ramana Enclave, Mahalingapuram, Chennai 600 034	2021	95661-99990
5	N Gopinathan	ICAR-CPRI VEGFAST Technology	Chennai	2021	96000-22450
6	Rajdeep Agri Products Pvt. Ltd.	ICAR-CPRI VEGFAST Technology	3279/1, Block 9, Ranjeet Nagar, New Delhi, Delhi 110 008	2021	98106-30206
7	Jaswinder Singh	ICAR-CPRI VEGFAST Technology	V.P.O. Chuhan Chak, Teh. Moga, Dist Moga (Punjab)	2021	94174-87823
8	Col Ashok Kumar Sharma (Retd)	ICAR-CPRI VEGFAST Technology	SCO 02, Eagle Enclave Khusropur, Jalandhar Cantt. Bye-pass road, Jalandhar 144 024 (Punjab)	2021	80544-51051
9	Avtar Singh Saini	ICAR-CPRI VEGFAST Technology	V.P.O. Tira, Teh. Kharar, Dist Mohali (Punjab)	2021	98550-09728
10	Paramjit Singh Shahi	ICAR-CPRI VEGFAST Technology	# 125, Narotam Nagar, Khanna 141 401 (Punjab)	2021	98159-48125
11	Bhupinder Singh	ICAR-CPRI VEGFAST Technology	# A-703, Wellington Height, Sector – 117, TDI City, SAS Nagar 160 059, Punjab	2021	98880-79876 90415-51100
12	Jaswinder Singh	ICAR-CPRI VEGFAST Technology	VPO Matti, Dist. Mansa 151 504, Punjab	2021	75891-59643
13	Jaspal Singh	ICAR-CPRI VEGFAST Technology	# 476, Guru Gobind Singh Avenue, Jalandhar, Punjab	2021	94639-95094
14	Umesh Puri	ICAR-CPRI VEGFAST Technology	# 3, Glenmore Farms, Khambra, Jalandhar 144 026, Punjab	2021	98786-10058
15	Tan Vir Pruthi	ICAR-CPRI VEGFAST Technology	# 239/6, St. No. 5, Jagat Pura, Hoshiarpur 146 001, Punjab	2021	92176-66000
16	Jagjit Singh	ICAR-CPRI VEGFAST Technology	V.P.O. Changan, P.O. Chak Kalan, District Ludhiana 141 110, Punjab	2021	97818-37533
17	Harshit Jain	ICAR-CPRI VEGFAST Technology	42, 43 Chandan Nagar, Sodal Road, Jalandhar 144 004, Punjab	2021	98887-34217
18	Ranjodh Singh	ICAR-CPRI VEGFAST Technology	V.P.O. Manki, Teh. Samrala, Dist Ludhiana 141 114, Punjab	2021	98154-22011
19	Lakhwinder Singh	Mini-tuber Counting Machine	Mohali, Punjab	2021	99153-15319 90563-15319

Demonstrations			
Live Demonstration in the field of spray using Drone.	6 th Dec 2021	A group of people.	ICAR-CPRS, Jalandhar
Demonstrated the methods of Hi Tech potato seed production in Aeroponics.	11-03-2022.	A group of 40 M. Sc (Chemistry) students.	DAV College, Jalandhar
Visits/Study trips/Talks			
Arranged an educational tour.	3 rd Dec 2021	A group of 3 rd year students of School of Agriculture	Lovely Professional University
Arranged an educational tour.	11 th March 22	A group of 40 students of MSc Chemistry	DAV College, Jalandhar
A visit arranged	28 th Feb 22	CIP trainees	ICAR-CPRS, Jalandhar

**Training program on “Net House Technology for Potato Seed Production”
was planned for farmers on 03-02-2021**



Training program organized on VEGFAST technology at CPRS, Jalandhar on 28.09.2021



Awareness program organized on Drone technology in Agriculture on 06.12.2021



EXTENSION ACTIVITIES AT ICAR-CPRI, RS, GWALIOR

Sl. No.	Training	From	To	No. of Beneficiaries
1.	Training on potato production technology sponsored by NABARD organized by Atal Woman Awareness and Rural Developme NT Society, Etawah	1/03/2021	3/03/2021	18
2.	Training on Hi-tech potato production technology under SCSP component	13/03/2021	14/03/2021	85
3.	Training on Hi-tech potato production technology sponsored by Deputy director Agriculture, Farukkabad UP Under ATMA	22/09/2021	28/09/2021	22
4. D	Training on Hi-tech Table and seed potato production technology under SCSP component	14/12/2021	16/12/2021	57



Demonstration/exhibition/field day/farmers fair

1. Conducted and monitored 229 FLD's with varieties Kufri Chandramukhi, kufri Mohan and Kufri Bahar different villages of Gwalior, Bhind and Morena districts



1. Field visit of the farmers bought by state department at the station and under ATMA program



EXTENSION ACTIVITIES AT ICAR-CPRI, RS, OOTY

TRANSFER OF TECHNOLOGY/TRAINING IMPARTED

S. No.	Date	Beneficiary	Institution/Organization	No. of participants
Exhibitions				
1.	08.02.2021 to 12.02.2021	Farmers/Researchers	National Horticulture fair 2021 organised by ICAR-IIHR, Bengaluru, Karnataka	>1,00,000
Training imparted				
1.	22.01.2021	Farmers	Govt. of Karnataka, Department of Horticulture, Arkalgodu	50
2.	22.02.2021	Input dealers	ICAR-KVK, Myrada, Erode	40
3.	05.02.2021	Students	AVC College, Mannampandal, Mayiladuthurai, Nagapattanam, Tamil Nadu	49
4.	05.03.2021	Students	AVC College, Mannampandal, Mayiladuthurai, Nagapattinam, Tamil Nadu	47
5.	12.03.2021	Insecticide dealers	Assistant Director of Agriculture, Quality Control, Ooty, The Nilgiris.	40
6.	19.03.2021	Students	AVC College, Mannampandal, Mayiladuthurai, Nagapattanam, Tamil Nadu	54
7.	14.07.2021	Farmers/Officials	Dept. of Horticulture, ATMA, Ooty, The Nilgiris	50
8.	26.07.2021	Farmers	IARI, RS, Wellington organized SCSP programme	30
9.	27.07.2021	Farmers	IARI, RS, Wellington organized SCSP programme	30
10.	1.09.2021	Trainees	Dept. of Horticulture, ATMA, Ooty, The Nilgiris	20
11.	25.09.2021	ATMA Staff	Dept. of Horticulture, Ooty, The Nilgiris	12
12.	25.09.2021	Scientists	Division of Genomic Resources, ICAR - National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka.	3
	9.11.2021	Farmers	Dept. of Horticulture, Ooty, The Nilgiris organized meeting on Organic Farming	100
13.	26.11.2021	Students	University of Agricultural Sciences, Bangalore, College of Agriculture, Karekere, Hassan, Karnataka.	106
14.	30.09.2021	Farmers	Dept. of Horticulture, The Nilgiris, Ooty	10
15.	02.12.2021	Student	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.	1
16.	16.12.2021	Representatives/officials	ICAR-KVK, Myrada, Erode	38
17.	27.12.2021	GSDP Trainees	Institute of Forest Genetics and Tree Breeding, Coimbatore.	40

Training Organized

1. Organized a three days farmers training on "Potato Cultivation in Nilgiri Hills-New Problems and Way Forward" under SCSP component of the institute during 8th to 10th March 2021. The training has benefitted 90 farmers belonging to scheduled caste from nine villages of the Nilgiri district of Tamil Nadu.
2. Organized two workshops on "Advances in Potato Production Technologies" w.e.f. 8th to 9th October 2021 to the farmers of Sangareddy and Viharabad districts of Telangana state. More than 1000 farmers from each district attended these workshops.

Other Extension Activities

- Front line demonstrations (FLDs): FLDs were conducted during Summer season of 2021-2022 in farmer's field at three locations of Nilgiri district viz., Solada, Dhoddani, and Ganagnagar villages for popularization of newly released ICAR-CPRI variety Kufri Sahyadri (with combined resistance to late blight and potato cyst nematode).
- Field Days: Three field days were organized at Solada, Dhoddani and Ganganagar villages on 09.09.2021, 13.09.2021, 14.09.2021 respectively during the harvesting of the FLD trials and farmers of respective areas were educated about the performance of the newly released hybrid and the advantages of growing the same.
- Three villages viz., Kallakorai, Nedugula and Kallati were adopted under "Mera Gaon Mera Gaurav" and all the technical inputs related to potato production have been given during crop season.
- Scientist, ICAR-CPRI, 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 2021-22.

EXTENSION ACTIVITIES AT ICAR-CPRI, RS, SHILLONG

1. Demonstrations

A total of 4 Front line demonstration was conducted during 2021-22. Front Line Demonstration of "Improved potato cultivation method with high yielding varieties" was laid out in two districts of Meghalaya (Jaintia Hills and East Khasi Hills District) during 2021-2022. Improved potato cultivation method with high yielding varieties (K. Himalini and K. Girdhari)

evaluated with conventional organic practices (*nur-bun method* of potato planting) was demonstrated in 4 farmers field.

2. Training conducted

- I. One Day training cum awareness programme on "Advances in potato seed production technology" was conducted in collaboration with KVK, East Khasi Hills, Meghalaya on 06/10/2021. During this program, scientists interacted with the farmers regarding quality seed, varietal selection, nutrient management, and potato storage. 25 numbers of farmers participated in the event.



- I) One day training cum exhibition was conducted in ICAR-CPRI (RS) Shillong to commemorate Mahila Kisan Diwas on 15/10/2021. A total of 21 women from 3 different villages- Mawklot, San Mer and Smit participated in the event. The participants who are actively involved in potato cultivation were honoured and felicitated. The importance of value addition as additional income generation was stressed on the interaction. Different technologies developed by ICAR-CPRI were displayed and shown to the participants. Practical demonstration on value addition in potato was conducted and the participants were involved in Chips and Fries making.





Photo: Kisan Mahila Diwas organised at CPRI(RS) Shillong

Spot lecture/visitor

S.No	Date	Beneficiary	Institution/ organisation	No. of participants
1.	30.11.21	Technical staff	Horticulture and soil conservation, Manipur	58
2.	7.12.21	Students	CAU, Kyrdemkulai, Meghalaya (RAWE programme)	6

Events: ICAR-CPRI RS Shillong celebrated “Hindi Pakhwada” from September 14, 2021 to September 28, 2021. Several competitions were organized like quiz, singing etc., in which all the scientific, administrative, temporary staff of ICAR-CPRI RS Shillong, participated. The winners of the competitions were awarded with participation certificate and cash prizes.

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 122 documents were purchased, procured and added to library resources. The total collection at Shimla stands at 40144 documents comprised of 16599 books, 15780 back volume of journals, 2754 serials, 2266 annual reports, 586 theses, 251 standards, 51 maps/atlasses, 1663 reprints and 198 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 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 CPRIC & CPRS

Regional Stations		Books	Back vols. of Journals	Other Documents (AR/Rpt/Bull)	Total	Current Journals subscribed (Indian)
1	CPRIC, Modipuram	4721	6014	2562	13297	06
2	CPRS, Jalandhar	3357	1591	463	5411	06
3	CPRS, Patna*	2105	1280		3385	09
4	CPRS, Gwalior	1194	4	75	1273	-
5	CPRS, Ooty	1683	580	564	2827	09
6	CPRS, Shillong	1547	-	168	1715	-
7	CPRS, Kufri	144	-	-	144	
	TOTAL	14751	9469	3832	28052	30

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 8 foreign and 93 Indian journals were subscribed on payment basis and rest 20 on exchange or gratis. However this year only 6 Indian journal could be renewed. In all 209 issues of such journals were received, marked and kept in library for use. Besides, 30 titles of different journals were subscribed at CPRS libraries. 122 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. 57 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 411 documents were circulated (borrowed and returned) for home studies and 757 readers consulted 7793 documents within the library. Besides, 4 outside scientists and research scholars of various research organizations consulted the library resources. 6 new members were enrolled and 25 old members withdrew their library membership due to their transfer or retirement. At present 102 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, 270 job requests were received for 92573 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

295 issues of journals were scanned for potato literature and 252 potato articles were found and recorded. Approximately, 122 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. 1,91,280.00 which includes the amount of photocopying charges (Rs. 2981.00), library discount on books (Rs. 1,88,299.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 3,84,334.00 was spent on purchase of library resources like books (Rs. 3,65,518.00), and subscription of journals (Rs. 18,816.00) at HQ library Shimla.



PUBLICATIONS

Research articles published in Journals

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Patent granted/Applied

1. Dipstick for estimation of glucose in potato tubers and method thereof by inventors Bandana, Dutt S, Jeevalatha A, Singh B, Singh BP. Patent No. 376808. Date of grant 09/09/2021.
2. Granted a design patent entitled "Trough for plant production (vertical trough)" by inventors Er Sukhwinder Singh, Er Brajesh Nare, Dr Sugani Devi and Dr A K Jaiswal on 08-03-2021 (Application No. 340331-001).
3. Granted a design patent entitled "Round hydroponic" by inventors Er Sukhwinder Singh, Er Brajesh Nare, Dr Sugani Devi and Dr AK Jaiswal on 09-08-2021 (Application No. 347609-001).
4. Aarti Bairwa, Sundaresha S, Bhawna Dipta, E.P. Venkatasalam and Sanjeev Sharma (2021) Next generation RNA molecule for the management of Potato Cyst Nematode (*Globodera* spp.). Date of Filing: July 17, 2021, Indian Patent Application No.: 202111032262.
5. Vinay Bhardwaj et al. (2021) Soil less potato seed production media free from quarantined pests, nematodes and soil borne diseases. Indian Patent Application No.: 202111033548.



INSTITUTE ACTIVITIES

Important Meetings, Events & Visitors

International Women's Day Celebration

International Women's Day was celebrated in the auditorium of CPRI, Shimla on 8th March 2021 by following the guidelines (MHA) to contain Covid-19. The programme was also hosted in virtual mode so as to ensure maximum participation across the stations of ICAR-CPRI. In the programme, Mrs. Shalini Agnihotri, Superintendent of Police, Mandi, H.P was invited as guest of honor and she graced the occasion with her presence. Dr. Manoj Kumar, Director of the institute joined the celebration through virtual mode and addressed the gathering. He explained about the achievements of the institute and role of women in overall achievements. The awareness on the theme “Women leadership in Agriculture: Entrepreneurship, Equity & Empowerment (3E's)”



which was proposed by ICAR was presented by Dr. N.K. Pandey, Head, Division of Social Sciences, ICAR-CPRI, Shimla and he informed the audience about the role of women in agriculture, right to equality, role in entrepreneurship development and talked about women empowerment. Dr. Pankaj Kumar, Chief Administrative Officer, CPRI, Shimla deliberated in brief about the safety issues at national and international level. Later Dr. Pinky Raigond, Chairman, Internal Complaints Committee made a presentation on 'Roles and responsibilities' of “Internal Complaints Committee” to create awareness among the staff of the Institute. Major components of her presentation were (1) What are Vishakha guidelines, (2) The Sexual Harassment of Women at Workplace Act: 2013, (3) Composition of Internal Complaints' Committee, (4) Who can



complain and where, (5) Complain content, (6) Do's and don'ts for Internal Complaints Committee. Later she presented the achievements of female staff of CPRI through audio-visual presentation. The guest of honor, Mrs. Shalini Agnihotri, congratulated women of CPRI for their achievements. She expressed her views on women empowerment and safety. She encouraged CPRI women's to identify their potential and participate in social works. She honored all the female staff of CPRI with a rose stick and also honoured the female sweepers (*Safai Karamchari*) who look after the cleaning of the institute and residential colonies. The programme was well organized and appreciated by one and all.

An online webinar was organised by the institute on 30th July, 2021 presented by Dr. VK Singh, Director, ICAR-CRIDA, Hyderabad on the topic “Sustainable integrated Cropping System models for enhancing income of farmers”. The said webinar was attended by all the scientists of the institute

Programme under “Azadi ka Amrit Mahotsav”

Under “Azadi ka Amrit Mahotsav” celebrated to commemorate 75th independence year of the nation, patriotic and awareness programmes for residents of CPRI Colony especially children was organised. On 14th August there was celebration with dance and singing for children of the colony on patriotic songs along with recitation of national anthem by all at the end and on 24th August there was an awareness programme on forests and wild animals in which DFO, Shimla range Sh. Anish Sharma and his team elaborated about the importance of forests in human

life and also the wild life that exists in these forests through PowerPoint presentation and a film on wild life. It was attended by all the residents of the colony.



Cereal Year 2023

On the occasion of International Nutritious Cereal Year 2023, in the context of *Azadi ka Amrit Mahotsav* celebrating 75 years of independence and the 71st birthday of the Prime Minister of India, Hon'ble Shri Narendra Modi ji, a one day program "*Poshak Vatika Maha Abhiyan evm Vriksharopan*" was organized at the Institute's headquarters on 17 September 2021. This program was mainly organized in online mode, in which Hon'ble Shri Narendra Tomar Ji, Union Minister of Agriculture and Farmers Welfare (Government of India) and Director General of Indian Council of Agricultural Research, Dr. Trilochan Mohapatra Ji and official from IFFCO India addressed the gathering on the above topic. The programme was conducted on India's proposal to observe an International Year of Millets in 2023. About fifty farmers of Shimla district, mostly women participated on this occasion. A talk on the importance of nutritious cereals in human health and fruits grown in Himachal was also delivered. After this, a tree plantation program was organized in which



the women farmers participated enthusiastically and planted trees in the premises of the institute in the presence of director (A) of the institute. The visiting farmers were also provided with registration material along with one kg of potato and half kg of millet (bajra) flour as a beginning to this movement.



Organization of Fit India Freedom Run 2.0

Under Azadi ka Amrit Mahotsav CPRI organised Fit India Freedom Run 2.0 from 20th September to 2nd 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, hill climbing and trekking for all, volley ball matches of different categories, skipping for students, children of the staff, ladies and gents and yoga sessions for all.



Cleanliness Drive

A cleanliness drive under Swacchta Abhiyan was undertaken at a local school Govt. Senior Secondary School, Lalpani. Nodal Officer for the cause and staff members from CPRI went to the school and briefed the students about the importance and advantages of cleanliness. A brief session on yoga was also undertaken.



International Potato e-Conference

An International Potato e-Conference on “New Paradigms in Food Security and Industrial Application” was organised during 23-26 November. Delegated for all over the world who are working in the potato crop participated virtually in this conference and delivered their talk regarding role of potato in the food security of the world and what are its industrial applications.



Celebration of 73rd Foundation Day

ICAR-CPRI celebrated its 73rd Foundation Day on 26th November. It was a brief celebration due to the ongoing pandemic. Most of the participants joined virtually. During the event Best Worker Awards were given to the staff of all categories of the institute.



Celebration of Constitution Day

On the occasion of constitution day i.e. 26th November the staff of ICAR-CPRI, Shimla joined in virtually the formal function being held in the parliament premises. The said function was presided over by Hon'ble Prime minister of India Sh. Narendra Modi, president Sh. Ram Nath Kovind and other ministers of the government. They addressed the nation about Indian Constitution and its role in maintenance of law and order in the country. On the Occasion the preamble of the constitution was read out by the Director followed by the staff.



National Symposium on Strategic Plant Disease Management for Food Security

ICAR-CPRI, Shimla and Indian Society of Plant Pathologists (INSOPP), Punjab Agricultural University, Ludhiana (Punjab) organised a National Symposium on “Strategic Plant Disease Management for Food Security” during 6-7 December. Plant Pathologists from all over India gathered at the institute to discuss about the management of plant diseases which is very important for the food security of the nation.



Concluding of “*rashtriye krishi evam khadya prasanskran*” programme

The concluding of the nation programme “*rashtriye krishi evm khadya prasanskran*” through virtual mode was conducted on 16th December. The programme was directly telecasted from Anand, Gujarat. The title of this conclave was Natural Farming. The programme was presided over by Sh. Narendra Modi, Hon'ble Prime minister of India. He emphasised on natural methods of farming and appealed to the farmers to turn to natural farming (*prakrit kheti*) and urged the scientists to develop methods suitable for natural farming and to save the soil from deteriorating further due to use of chemical fertilizers and pesticides. On the occasion other than PM, Hon'ble Union Home Minister of India Sh. Amit Shah, Minister of Agriculture & Farmers Welfare Shri Narendra Singh Tomar, Governor of Gujarat Sh. Acharya Devvrat and Chief Minister of Gujarat Sh. Bhupendra Bhai Patel also addressed the audience present in the conclave and joined online. The staff of CPRI also attended the function virtually in the auditorium.



Celebration of *Swaccha Pakhwara*

Under *Swachh Bharat Abhiyan* CPRI celebrated Swaccha Pakhwara during 16-31 December. Various activities were undertaken during this period. The highlight of the programmes undertaken was a cleanliness drive in the MGMG adopted area at Cheog where locals and school children with the staff of CPRI participated in cleaning the area. A cleanliness drive in a new area at Jathai where locals with the staff of CPRI participated in cleaning the area, an awareness programme regarding importance of cleanliness for the farmers specially invited on Kisan Diwas at CPRI and a debate, painting & essay competition for the children of the staff and nearby area. The concluding of the programme was held on 31st where Smt. Satya Kaundal, Mayor, MC Shimla and Sh. Puran Chand, local Councillor were Chief Guest and Guest of Honour.



TRAINING AND CAPACITY BUILDING

Training and capacity building programmes/ conferences/ seminars/ symposium/ workshop etc. attended by Scientific, Technical and Administrative staff of ICAR-CPRI, Shimla in 2021

Sl. No.	Name of Employee	Training Programme	Date & Organised by/ venue
1	Dr. N.K. Pandey, ICAR_CPRI, Shimla	Online "Training Workshop for Vigilance Officers of ICAR Institutes"	Aug 16-18, 2021 ICAR-NAARM, Hyderabad
2	Sh. Kana Singh Chauhan, TO, ICAR-CPRI Shimla	Online Training Programme on "Repair and Maintenance of Office, Residential Building including Guest Houses"	10-12 August, 2021 ICAR-CIAE, Bhopal
3	Dr Raj Kumar, PS & Head, CPRS Jalandhar	Online training programme on Stress Management	July 06-09, 2021 ICAR-NAARM Hyderabad
4	Sh. Vivek Kumar, T-1, CPRI Shimla	Online training on Creating Programming of web & mobile applications using low-code platforms	July 07-11, 2021 ICAR-NAARM
5	Sh. Rahul, T-1, CPRI Shimla Sh. Sumit Kumar, T -1, CPRS Shillong Sh. Vinod Kumar Meena, T -1, CPRS Gwalior	Online training programme on Appropriate Sampling techniques including sample preparation and preservation for soil, water, plant & air samples for various analyses	August 02-07, 2021 ICAR-IARI
6	Dr. Sushil Kumar, ACTO, CPRI Shimla	Online training programme on GAPs for higher productivity, profitability and resource use	August 02-06, 2021 ICAR-IARI
7	Smt. Shashi Bala Thakur, PS and Smt. Tarvinder Kochhar, ACTO	Online training programme on "Gender, Poverty & Employment"	July 12-16, 2021 V.V. Giri National Labour Institute, Noida
8	Dr. Arvind Kumar Jaiswal and Dr. Brajesh Nare	Online Sensitization programme on Entrepreneurship development & Start-up Ecosystem	July 05-09, 2021. NAARM Hyderabad
9	Dr. Aarti Bairwa	Online training programme on Climate Change : Challenges and Response for women scientists	August 09-13, 2021 LBSNAA, Masourie
10	Sh. Ashish Dhangar, AFAO	Online training programme on Budget Utilisation Procedure for administrative and Finance Officers	July 22-24, 2021 ICAR-NAARM
11	Ms. Geeta Devi, UDC	Online Training Programme on "Accrual Accounting" for Administrative and Finance Staff of ICAR Institutes & HQs	20-24 September, 2021. ICAR-NRRI, Cuttack
12	Smt. Meena Verma, AAO, Dr. Ashish Dhangar, AFAO, Sh Sanjib Kumar, AAO Sh. Sandeep Dahiya, AAO and Miss Parwartika Das, AAO	Online Training Programme on "IMPLICATIONS of NEW LABOUR CODES, 2020 FOR ICAR"	September 6-8, 2021 NAARM
13	Dr. Som Dutt, ICAR-CPRI, Shimla	Online training on "Transcriptomic Data Analysis"	28-30 September, 2021 ICAR-IASRI, New Delhi

14	Sh. Krishan Lal, Assistant, ICAR-CPRI, Shimla	Online Training Programme on “Assets Management”	06-08 October, 2021. ICAR-IARI New Delhi
15	Sh. Dharminder Kumar Gupta, TO and Sh. Rakesh Kumar Patyal, TO, ICAR-CPRI, Shimla	Online Training Programme on “Statistical Techniques for Data Analysis in Agriculture”	04-13 October, 2021 ICAR-IASRI New Delhi
16	Dr. Sumita Sharma, STO ICAR-CPRI, Shimla	Online training on “Life skill enhancement and personality development”	16-20 November 2021 ICAR-IARI, New Delhi
17	Dr. Devendra Kumar, PS ICAR-CPRIRS, Modipuram	Online training on “Management of Technology and Innovation”	Dec 13–17, 2021. DST, Govt. of India
18	Smt. Sonia Chauhan,UDC, ICAR-CPRI, Shimla	Online training on “Accrual Accounting”	22-26 November,2021 ICAR-NRRI, Cuttak
19	Sh. Nand Lal, LDC, ICAR-CPRI, Shimla	Online training on “Establishment Matters for LDC and UDC of ICAR”	15-20 November,2021 ICAR-IISR, Lucknow
20	Dr. Sushil Sudhakar Changan, Scientist, ICAR-CPRI, Shimla	Online training on “Protein Structure Modelling and Dynamics”	October 27-29, 2021 ICAR-IASRI, New Delhi
21	Dr. Brajesh Singh, ICAR-CPRI, Shimla	Online training on “Acreditation of ICAR Laboratories”	November, 2021 NABL
22	Sh. Santosh Kumar, ICAR-CPRI, Shimla	Online training on “Science Administration and Research Management”	15-26, November 2021. DST
23	Sh. Joginder Singh Thakur ICAR-CPRI, Shimla	Online training on “Pension and Retirement Benefits”	12-14 January, 2022. ICAR-NRRI, Cuttack
24	Dr. Ngursangzuala Sailo CPRIRS, Shillong	Online training on “Capacity Building Program for Technical Personel ”	6 to 17, December 2021 Department of Science and Technology, New Delhi
25	Ms Parvartika Das, CPRIRS, Jalandhar	“Online Workshop on Public Procurement under GFR- 217”	13th December, 2021 Institute of Secretariat Training and Management
26	Dr. Yogesh Gautam, Pr. Scientist ICAR-CPRI, Shimla	Online training on “Advances on Web and Mobile Application Development ”	6-10 December, 2021 ICAR-NAARM, Hydrabad
27	Sh. Sh. Daljit Singh, ICAR- CPRIRS, Jalandhar Sh. Ramesh Kumar Gupta, ICAR-CPRIRS, Patna	Online training on “Establishment Matters for LDC and UDC of ICAR”	17-22 January, 2022 ICAR-IISR, Lucknow



AWARDS AND HONOURS

Institute Best Worker Award 2021

S.No.	Name of the Person	Category	Year
1.	Dr. Pinky Raigond, ICAR - CPRI, Shimla	Scientific	2021
2	Smt. Shyamlata Beakta & Sh. Gokal Ram,, ICAR-CPRI, Shimla	Administrative	2021
3	Sh. Gyanendra Kumar, ICAR-CPRI, RS, Modipuram	Skilled Supporting Staff	2021

- Awarded best oral presentation award (3rd) to Mehi Lal, Ashwani Kumar, Sorabh Chaudhary, RK Singh, Sanjeev Sharma and Manoj Kumar in National E-Conference Plant Health and Food Security: Challenges and Opportunities during March 25-27, 2021 at ICAR-IARI, Pusa Campus, New Delhi, India.
- Awarded Best oral presentation award to Bhatnagar A. Efficacy and economics of novel insecticides against sucking insect pests of potato (*Solanum tuberosum* Linn.) in Northern India, in TNAU-Golden Jubilee International conference on Global perspective in crop protection for food security-2021” from 08 to 10th December, 2021 organized by the TNAU, Coimbatore.
- Awarded Best Oral Presentation award to Mhatre PH, Thube SH, Navik O, Venkatasalam EP, Sharma S, Patil J, Subhash S, Divya KL, Watpade S, Pandian TP, Shah MA, and Kumar M (2021). Outbreak and management of serpentine leaf miner, *Liriomyza huidobrensis* (Blanchard) on potato crop in Southern Hills of India. *In: Golden Jubilee International Conference - Global Perspectives in Crop Protection for Food Security (GPCP 2021)*, Organized by Center for Plant Protection Studies, TNAU, Coimbatore, during 8th -10th December 2021.
- Awarded Best oral presentation Award to Subhash S, Bhatnagar A, Shah MA, Naga KC, Lal M, Tiwari RK, Sharma S, Kumar M and Kamala Jayanthi P. D. (2021). Essential oils applied on sticky traps increase trapping of aphids in potato under field condition. *In: International Potato e-Conference: New Paradigms in Food Security and Industrial Applications during 23-26 November 2021 at ICAR-CPRI, Shimla, H.P, India.*
- Awarded Best poster presentation (first place) Award to Bansode GM, Subhash, S*, Deshmukh MR and Mhatre PH. (2021). Evaluation of bio-pesticides against Potato tuber moth *Phthorimaea operculella* (Zeller) in stores. *In: Sixth National Conference on Biological Control: Innovative Approaches for Green India during 3-5 March 2021 at ICAR-NBAIR, Bengaluru, Karnataka, India.*
- Awarded Certificate of Merit to Subhash S in 15 days workshop on “ABC of Scientific Writing” from 18 August to 2 September, 2020 conducted by Krishi Vigyan Kendra, Cuttack, Shantapur, ICAR-National Rice Research Institute, Cuttack.
- Awarded Young professional award to Mehi Lal by New Age Mobilization Society, New Delhi in International Conference on Research Initiative for Agriculture, Biotechnology and Allied Sciences (ICRIBAS-2020) held during 24 to 25 April, 2021 at IIMT University Meerut, UP India.
- Awarded Young Scientist Award to Subhash S by Society for Scientific Development in Agriculture and Technology, Meerut, U.P. on July 19-21, 2021 on the occasion of International Web-Conference on Innovative and Current Advances in Agriculture and Allied sciences.

9. Best paper award (1st) oral presentation in the “International Potato e-Conference – New Paradigms in Food Security and Industrial Applications” held on 23-26th November, 2021, Shimla, organized by Indian Potato Association & ICAR-CPRI Shimla for the paper entitled, “Two-decade journey of potato processing in India and future prospects” by VK Gupta, Vinay Bhardwaj, SK Luthra, Sanjay Rawal, Bandna, Salej Sood, Mehi Lal and Arvind Jaiswal.
10. Best poster award (1st) in the “International Potato e-Conference – New Paradigms in Food Security and Industrial Applications” held on 23-26th November, 2021, Shimla, organized by Indian Potato Association & ICAR-CPRI Shimla for the paper entitled, “High throughput Screening for Self-Compatibility and Homozygosity using KASP Markers for Diploid Hybrid TPS” by Salej Sood, Vinay Bhardwaj, Vikas Mangal, Ashwani Kumar, Baljeet Singh, Babita Chaudhary and AK Sharma.
11. Best poster award (1st) in the “International Potato e-Conference – New Paradigms in Food Security and Industrial Applications” held on 23-26th November, 2021, Shimla, organized by Indian Potato Association & ICAR-CPRI Shimla for the paper entitled, “Generation of the DMC1 mutants by using RNA interference (RNAi) approach in Potato” by Ashwani Kumar, Salej Sood, Sundaresha S, Baljeet Singh, Neha Sharma, Vinay Bhardwaj and Umesh Goutam.
12. Best Poster award (Third rank) for the research paper “Studies on production behavior of fresh and one year older aeroponic mini-tubers under protected conditions in high hills” by Ashwani K Sharma, Tanuja Buckseth and Rajesh K. Singh. 2021; presented in technical session “Advances in Potato Breeding and Seed Research” of International Potato e-Conference – New Paradigms in Food Security and Industrial Applications, held at ICAR-Central Potato Research Institute, Shimla, HP during 23rd-26th Nov, 2021.
13. Dr. Dalamu received excellence in Research Award by Society for Scientific Development in Agriculture and Technology (SSDAT) In: International Web Conference on Innovative and current advances in agriculture and allied sciences (ICAAAS 2021) held from 19th-21st July, 2021.
14. Dr Dalamu received Young Scientist Award by e magazine Vigyan Varta.
15. Dr Sanjeev Sharma was awarded the Fellowship of the Indian Society of Plant Pathologists (INSOPP), PAU, Ludhiana for the year 2021.
16. Dr SK Luthra received Aryabhata Scientist Award (2020-21), Samaj Vikas Sansthan, Meerut (14.03.2021)
17. Dr. Anil K Choudhary, Jagdev Sharma, VK Dua, D. Kumar, Name Singh and Sushil Kumar received best oral presentation award (1st) for “Phosphorus economy and yield enhancement in potato through co-inoculation of AM-fungi and PSB in a Himalayan acid Alfisol” in International Potato e-Conference (IPeC-2021) held during 23-26 Nov., 2021 at ICAR-CPRI, Shimla in collaboration with IPA, CPRI, Shimla & CIP, Peru.
18. Dr. Arvind Jaiswal was awarded with 2nd Best Oral Presentation Award for the paper entitled “Sprout suppression in potatoes using an essential oil cocktail: a natural alternative to CIPC” during International Potato e-Conference-New Paradigms in Food Security and Industrial Applications 23-26 November 2021 organized by ICAR-CPRI, IPA and CIP.
19. Dr. Bandana bagged Distinguish Scientist Award for her outstanding contribution in the field of Biochemistry. Registration Link :<https://forms.gle/DUVyzLb6mhoD2AWR7>
20. Dr. Bandana got best oral presentation awards in presentation on “Comparison of different storage methods in Gangetic plains for evaluation of post-harvest losses in potato” (ICAAAS-2021) *w.e.f* 19-21 July 2021.
21. Dr. Brajesh Nare honored with “Jawaharlal Nehru Award for PG Outstanding Doctoral Thesis Research in Agricultural and Allied Sciences-2020” in 93rd ICAR Foundation Day and Award Ceremony held at ICAR New Delhi on July 16, 2021.
22. Dr. Jagdev Sharma, Sharma A., Kumar P., Dua, V.K., Sharma V., Choudhary, A.K. received best poster paper Award (3rd) for “Rice husk ash - a potential source of phosphorus nutrition for potato (Poster presentation)” in International Potato e-Conference (IPeC-2021) held during 23-26 Nov., 2021 at ICAR-CPRI, Shimla in collaboration with IPA, CPRI, Shimla & CIP, Peru.

23. Dr. Jagdev Sharma was awarded as Elected Fellow of IPA award - 2020 during the International Potato e-Conference (IPeC-2021) held w.e.f. 23-26 Nov., 2021 at ICAR-CPRI, Shimla in collaboration with IPA, CPRI, Shimla & CIP, Peru.
24. Dr. Jagesh Kumar Tiwari, Senior Scientist, ICAR-CPRI, Shimla received the Fellow of the Confederation of Horticulture Association of India (CHAI Fellow)-2021.
25. Dr. Jagesh Kumar Tiwari, Senior Scientist, ICAR-CPRI, Shimla received the Fellow of the Indian Society of Vegetable Science (ISVS Fellow)-2019.
26. Dr. Jagesh Kumar Tiwari, Senior Scientist, ICAR-CPRI, Shimla received the D.P. Ghosh Memorial Young Scientist Award-2021 by the Indian Academy of Horticultural Sciences (IAHS), New Delhi.
27. Dr. Kapil K. Sharma (presenting author), Paramjit Singh, VK Dua and Jagdev Sharma received best poster paper award (1st) for "Traceability and certification of seed potato by block chain technology" in International Potato e-Conference (IPeC-2021) held during 23-26 Nov., 2021 at ICAR-CPRI, Shimla in collaboration with IPA, CPRI, Shimla & CIP, Peru.
28. Dr. Milan K Lal: Best Oral Presentation for research topic "Glycemic Response of Starchy Crops: Postharvest factors affecting starch digestibility" presented at International Conference on "Postharvest Disease Management and Value Addition of Horticultural Crops" organized by Division of Plant Pathology, ICAR-IARI, New Delhi during August 18-20, 2021 at ICAR-Indian Agricultural Research Institute, New Delhi, India. Technical session 6: Postharvest quality, value addition, export and entrepreneurship.
29. Dr. Milan K Lal: Best Oral Presentation for research topic on "Effect of Fusarium dry rot on postharvest quality attributes of potato tubers" organized by Division of Plant Pathology, ICAR-IARI, New Delhi during August 18-20, 2021 at ICAR-Indian Agricultural Research Institute, New Delhi, India. Technical session 6: Postharvest quality, value addition, export and entrepreneurship.
30. Dr. Milan K Lal: Best Poster Award on "Morpho-molecular identification and characterization of potato dry rot caused by *Fusarium proliferatum* in India." Presented in International Potato e-Conference 2021, ICAR-Central Potato Research Institute, Shimla, 23-26th November 2021.
31. Dr. Milan K Lal: Best Poster Award on "Standardization of a one-step reverse transcription recombinase polymerase amplification protocol for rapid and sensitive detection of potato virus X in potato." Presented in International Potato e-Conference 2021, ICAR-Central Potato Research Institute, Shimla, 23-26th November 2021.
32. Dr. Milan K Lal: Young Achiever Award (2021), presented by Institute of Scholar, Bengaluru.
33. Dr. Milan Kumar Lal, Scientist, ICAR-CPRI, Shimla and his associates were conferred best poster presentation award for the paper entitled "Effect of Potato Apical Leaf Curl disease on Resistant starch and Glycemic index of Potato (*Solanum tuberosum* L.)" during International Potato e-Conference-2021 held virtually at ICAR-CPRI, Shimla, India from 23-26 November, 2021.
34. Dr. Pooja Mankar, Sanjay Rawal, Manoj Kumar and Vijay Kumar Dua: Best oral presentation Award for Export quality grading of Indian potato varieties using image processing at 5th International Agronomy Congress held during 23-27 November 2021 at PJTSAU, Hyderabad
35. Dr. Prince Kumar, Jagdev Sharma, A Sharma, VK Dua, R. Kumar, Mankaran Singh, B. Nare and M. Kumar received best oral presentation award (3rd) for "Carbon footprint of potato production system of North-West India In: International Potato e-Conference (IPeC-2021) held during 23-26 Nov. 2021 at ICAR-CPRI, Shimla in collaboration with IPA, CPRI, Shimla & CIP, Peru.
36. Dr. Ravinder Kumar was awarded IPA-Chandra Prabha Singh Young Scientist Award for the year 2019-20 in recognition of his outstanding contribution in potato research and development.
37. Dr. Ravinder Kumar and his associates were conferred best poster presentation award for the paper entitled "Standardization of a one-step

- reverse transcription-recombinase polymerase amplification protocol for rapid and sensitive detection of potato virus X in potato” during International Potato e-Conference-2021 held virtually at ICAR-CPRI, Shimla, India from 23-26 November, 2021.
38. Dr. Salej Sood got the Fellowship of Indian Society of Genetics and Plant Breeding in the year 2021
 39. Dr. Sunayan Saha, Name Singh, Bir Pal Singh, RK Arora, Manoj Kumar, Vijay Kumar Dua, Raj Kumar and SBS Parihar received best oral presentation award for “Strategizing Water Productivity Enhancement of Potato in Upper and Trans-Gangetic Plains of India: A Climatological Approach” *In*: International Conference on “Innovative Approaches for Enhancing Water Productivity in Agriculture including Horticulture” held during 16-19 September, 2021, at PJTSAU, Hyderabad, India. pp. 16-17.
 40. Dr. Sunayan Saha, Name Singh, Manoj Kumar, Vijay Kumar Dua, Raj Kumar and NK Pandey received best (2nd) oral presentation award for “Evapo-transpiration and water productivity associations of seed potato in North-Western plains of India over a long-term climate” *In*: International Potato e-Conference during 23-26 November, 2021, held at ICAR-CPRI Shimla (through virtual mode).
 41. Dr. Sushil S Changan was awarded best oral presentation award for “Vacuum Impregnation: A novel tool for development of ascorbic acid fortified potato and its products” during International Potato e-Conference on New Paradigm in Food Security and Industrial Applications at ICAR-CPRI, Shimla, Nov. 23-26, 2021.
 42. Dr. Vinay Bhardwaj got the Fellowship of Indian Society of Genetics and Plant Breeding in the year 2021.
 43. IPA Best paper award for the paper “Efficiency and reliability of marker assisted selection for resistance to major biotic stresses in potato” by Bhardwaj V, Sood S, Kuma A, Vanishree G, Sharma S, Sundaresha S, Raigond B, Kumar R., Bairwa A, Lal M., Chakrabarti, S K.
 44. Dr. Prince Kumar, Sharma J, Sharma A, Dua VK, Kumar R, Singh M, Nare B and Kumar M: Oral Award (Third): Carbon footprint of potato production system of North-west India” during International Potato e-conference – New paradigms in Food Security and Industrial Applications organized by ICAR-CPRI, Shimla (HP), IPA and CIP.



STAFF POSITION

NAME OF STAFF AT ICAR-CPRI, SHIMLA & ITS REGIONAL STATIONS AS ON 31.12.2021

SCIENTIFIC

AICRP (Potato)

1. Dr. Vinod Kumar, PS & Acting Head, Div. of CI&ST

Division of Crop Improvement & Seed Technology

2. Dr. Vinay Bhardwaj, Principal Scientist
3. Dr. Jagesh Kumar Tiwari, Sr. Scientist
4. Dr. Ajay Kumar Thakur, Senior Scientist
5. Dr. Salej Sood, Sr. Scientist
6. Dr. (Mrs.) Tanuja Buckseth, Scientist
7. Sh. Hemant Balasaheb Kardile, Scientist
8. Dr. Vikas Mangal, Scientist

Division of Crop Production

9. Dr. Vijay Kumar Dua, PS & Acting Head
10. Dr. Jagdev Sharma, Principal Scientist
11. Dr. Yogesh Gautam, Principal Scientist
12. Dr. Anil Kumar Choudhary, Sr. Scientist
13. Sh. Paresh Baldeorao Chaukhande, Scientist

Division of Social Sciences

14. Dr. NK Pandey, Principal Scientist & Acting Director
15. Sh. Pynbianglang Kharumunid, Scientist

Division of Plant Protection

16. Dr. Sanjeev Sharma, Principal Scientist and Acting Head
17. Dr. Vinay Sagar, Principal Scientist
18. Dr. Sundaresha S., Senior Scientist
19. Dr. Ravinder Kumar, Senior Scientist
20. Dr. (Ms.) Aarti Bairwa, Scientist
21. Dr. Kailash Chandra Naga, Scientist
22. Dr. Rahul Kumar Tiwari, Scientist
23. Dr. Chandan Maharana, Scientist

Division of CPB & PHT

24. Dr. Brajesh Singh, Principal Scientist & Acting Head
25. Dr. Som Dutt, Principal Scientist
26. Dr. Changan Sushil Sudhakar, Scientist
27. Dr. Dharmendra Kumar, Scientist
28. Dr. Milan Kumar Lal, Scientist

ICAR-CPRI Kufri-Fagu Unit

29. Dr. Ashwani Kumar Sharma, Principal Scientist & Incharge
30. Dr. (Ms.) Dalamu, Senior Scientist

ICAR-CPRI Regional Station, Modipuram

31. Dr. Manoj Kumar, Principal Scientist & Joint Director (A)
32. Dr. Devendra Kumar, Principal Scientist
33. Dr. SK Luthra, Principal Scientist
34. Dr. Name Singh, Principal Scientist
35. Dr. Vinay Singh, Principal Scientist
36. Dr. Anuj Bhatnagar, Principal Scientist
37. Dr. Sanjay Rawal, Principal Scientist
38. Dr. Dhruv Kumar, Principal Scientist
39. Dr. Vijai Kishore Gupta, Principal Scientist
40. Dr. (Mrs.) Babita Chaudhary, Principal Scientist
41. Dr. Mehi Lal, Senior Scientist
42. Dr. (Ms.) Bandna, Senior Scientist
43. Dr. (Ms.) Pooja Praful Mankar, Scientist
44. Dr. Subhash. S, Scientist

ICAR-CPRI, RS, Jalandhar

45. Dr. Raj Kumar, Principal Scientist & Officiating Head
46. Dr. Anil Sharma, Principal Scientist
47. Er. Sukhwinder Singh, Scientist (SG)
48. Dr. (Ms) Ratna Preeti Kaur, Senior Scientist
49. Dr. Prince Kumar, Scientist
50. Dr. (Mrs.) Sugani Devi, Scientist
51. Er. Brajesh Nare, Scientist
52. Dr. Arvind Kumar Jaiswal, Scientist
53. Dr. Sunayan Saha, Scientist

ICAR-CPRI, RS, Gwalior

54. Dr. Shiv Pratap Singh, Principal Scientist & Officiating Head
55. Dr. Murlidhar .J. Sadawarti, Senior Scientist
56. Dr. Subhash Katare, Principal Scientist

ICAR-CPRI, RS, Shillong

57. Dr. Ngursangzuala Sailo, Senior Scientist & Officiating Head
58. Ms. Clarissa Challam, Scientist
59. Sh. Bappi Dass, Scientist
60. Dr. (Mrs.) P Janani, Scientist

ICAR-CPRI, RS, Muthorai (Ooty)

61. Dr. EP Venkatsalam, PS & Incharge
62. Dr. Mhatre Priyank Hanuman, Scientist
63. Mrs. Divya K. Lekshmanan, Scientist

ICAR-CPRI, RS, Patna

64. Dr. Shambhu Kumar, Principal Scientist & Officiating Head
65. Dr. Raj Kumar Singh, Principal Scientist
66. Dr. (Mrs.) Sarala Yadav, Senior Scientist

TECHNICAL STAFF**ICAR-CPRI, Shimla**

1. Sushil Kumar, CTO
2. Yogesh, CTO
3. Tarvinder Kochhar, ACTO
4. Dharminder Verma, ACTO
5. Shelly Chopra, ACTO
6. Kapil Kumar Sharma, ACTO
7. Rajdeep Bux, ACTO
8. Kana Singh Chauhan, ACTO
9. Parvesh Jassal, ACTO
10. Kameshwar Sen, ACTO
11. Avinish Kumar Atrey, ACTO
12. Chander Mohan Singh Bist, ACTO
13. Santosh Kumar, ACTO
14. Sumita Sharma, STO
15. Shruti Gupta, STO
16. Vinod Kumar, STO
17. Tilak Raj, STO
18. Dharam Prakash Gautam, TO
19. Sheesh Ram Thakur, TO
20. Sushil Singh, TO(Driver)
21. Naresh Kumar Sharma, TO
22. Naresh Chand, TO
23. Rajinder Kumar, TO
24. Rakesh Kumar Patyal, TO
25. Asha Thakur, TO
26. Dharminder Kumar Gupta, TO
27. Madhu Bala, STA
28. Hari Kishore, STA
29. Ram Singh, STA
30. Manjeet Syal, STA
31. Roop Lal, STA (Driver)
32. Ravinder Kumar, STA
33. Naresh Kumar, STA
34. Ranjesh Bhardwaj, STA
35. Deep Ram, STA

36. Ashok Kumar, STA (Driver)
37. Rakesh Kumar, STA
38. Jatinder Kaur Arora, STA
39. Jagdish Chand (Welder), TA
40. Jagdish Chand (Carpenter), ST(T-I-3)
41. Dev Raj, STA
42. Ram Dayal, STA
43. Parmesh Dutt, STA
44. Neem Chand, STA
45. Laiq Ram, ST
46. Surinder Pal, ST
47. Mansha Ram, ST
48. Arjun Dass, ST
49. Vivek Kumar, Technician
50. Rahul, Technician
51. Sanjay Kumar, Technician
52. Rakesh Kumar, Technician
53. Sonam, Technician
54. Vandana Parmar, Technician
55. Vineeta Sharma, Technician

ICAR-CPRI, Kufri –Fagu Unit

56. Kedar Singh, TO
57. Ajit Singh, STA
58. Ram jivan, STA
59. Mohan Lal, SA

ICAR-CPRI, RS, Modipuram

60. Mahipal Singh Bharti, CTO
61. Harvir Singh, CTO
62. Ashok Kumar, CTO
63. Krishan Pal Singh, CTO
64. Ompal, ACTO
65. Kusum Singh, ACTO
66. Harvir Singh, ACTO
67. Murari Lal, ACTO
68. Subhash Chand, ACTO
69. Vineet Sharma, ACTO
70. Avinash Chaudhary, ACTO
71. Dinesh Singh, ACTO
72. Pushpendra Kumar, STO
73. Sanat Kumar, ACTO
74. Udai Vir Singh, STO
75. Ved Singh, STO
76. Harvinder Singh, STO
77. Sayed Danish Abbas Rizvi, STA
78. Pawan Kumar Malik, TO
79. Mahesh Pal Singh, TA(T-I-3) Driver
80. Vipin Kumar, TA (Driver)

81. Madan Pal, ST
82. Satpal Singh, ST
83. Siddharth Saroha, Technician
84. Rohit Verma, Technician
85. Ajay Kumar, Technician

ICAR-CPRI, RS, Jalandhar

86. Munna Lal, CTO
87. Jaswinder Singh, ACTO
88. Yogesh Kumar Gupta, ACTO
89. Akhilesh Kumar Singh, ACTO
90. Parveen Kumar, TO
91. Som Dutt Randev, STA (Driver)
92. Narinder Mayer, TO
93. Kulwinder Singh, TO
94. Anil Kumar Chandel, STA
95. Pardeep Kumar Upadhaya, TO
96. Vijay Kumar, STA
97. Pawan Kumar, STA
98. Virender Kumar, Technician
99. Vinod Kumar Meena, Technician

ICAR-CPRI, RS, Gwalior

100. Yogendra Pal Singh, ACTO
101. Sanjay Kumar Sharma, ACTO
102. Shyam Kumar Gupta, STO
103. Rajender Kumar Samadhiya, STO
104. Surender Singh, TO
105. Radha Kishan, TA (T-I-3) Driver
106. Nihal Singh, TA
107. Nisha Verma, Hindi Translator (TA)
108. Tara Chand, ST
109. Sanjeev Kumar Meena, Technician
110. Vinod Kumar Meena, Technician

ICAR-CPRI, RS, Patna

111. Arjun Kumar Sharma, STO
112. Rakesh Srivastava, TO
113. Anil Kumar, TO
114. Alekh Narain, TO
115. Narendra Kumar, TO
116. Lal Babu Das, STA (Driver)
117. Sunil Kumar Singh, ST
118. Rishav Kumar, Technician
119. Pratish Kumar Patel, Technician
120. Akhilesh Singh, Technician

ICAR-CPRI, RS, Shillong

121. Sabarius Nongrum, ST
122. Sumit Kumar, Technician
123. Anubhav Kumar, Technical Trainee

ICAR-CPRI, RS, Muthorai (Ooty)

124. R Lakshmanan, STA
125. B. Suresh, ST

ADMINISTRATIVE

ICAR-CPRI, Shimla

1. Dr. Pankaj Kumar, CAO
2. Sh. Raj Kumar, SFAO
3. Sh. Chander Prakash, FAO
4. Sh. Joginder Singh Thakur, AAO
5. Sh. Chanda Ram, AAO
6. Smt. Poonam Sood, AAO
7. Smt. Meena Verma, AAO
8. Smt. Babli Bhawani, AAO
9. Sh. Gurjeet Singh, PS
10. Sh. Ram Chand, PS
11. Smt. Shashi Bala Thakur, PS
12. Sh. Krishan Lal, Assistant
13. Ms. Rita Walia, Assistant
14. Sh. Amar Chand, Assistant
15. Mrs. Urmila Verma, Assistant
16. Mrs. Sunita Thakur, Assistant
17. Sh. Om Parkash, Assistant
18. Mrs. Shyam Lata Beakta, Assistant
19. Sh. Deep Ram, Assistant
20. Sh. Pawan Kumar, Assistant
21. Sh. Sachin Kanwar, Assistant
22. Sh. Hans Raj, Assistant
23. Smt Chandni Baghta, Assistant
24. Sh. Suresh Kumar, PA
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. Narendra Paul, UDC
35. Sh. Raghubir Singh, UDC
36. Sh. Gokal Ram, UDC
37. Sh. Rakesh Negi, UDC

38. Sh. Kundan Lal, LDC
39. Sh. Nand Lal, LDC
40. Smt. Kiran, LDC

ICAR-CPRI, RS, Jalandhar

41. Miss. Prawartika Das, AAO
42. Sh. Sukhpal Sharma, Assistant
43. Mrs. Sandhya Kapila, Assistant
44. Sh. Rakesh, Assistant
45. Sh. Suresh Kumar Verma, PA
46. Mrs. Daishey Tuli, UDC
47. Sh. Daljit Singh, UDC
48. Sh. Naresh Kumar, UDC

ICAR-CPRI, RS, Modipuram

49. Sh. Sandeep, AAO
50. Sh. Rajesh Kumar, PS
51. Smt. Sneha Lata, UDC
52. Smt. Seema Verma, UDC
53. Sh. Ashok Kumar, UDC
54. Sh. Pradyuman K. Saraswat, UDC
55. Sh. Suraj Singh, LDC
56. Sh. Tejbir Singh, LDC

ICAR-CPRI, RS, Patna

57. Sh. Jagbir Singh, AAO
58. Sh. Pawan Kumar, Steno Gr-III
59. Sh. RK Gupta, UDC
60. Sh. Rajesh Chauhan, LDC

ICAR-CPRI, RS, Gwalior

61. Sh. Sanjib Kumar, AAO
62. Sh. Surender Singh, Assistant
63. Sh. Sunil Kumar, LDC

ICAR-CPRI, RS, Ooty

64. Smt. IC Dharmapaul, AAO
- ICAR-CPRI, RS, Shillong
65. Sh. Ashish Kalyan, UDC

ICAR-CPRI, RS, Shillong

Nil

SKILLED SUPPORTING STAFF

ICAR-CPRI Shimla

1. Sh. Kanhiya Prasad, SSS
2. Sh. Subhash Chand, SSS

3. Sh. Babu Ram, SSS
4. Sh. Rajinder Kumar, SSS
5. Sh. Kulwant Singh, SSS
6. Sh. Sanjeevan Kumar, SSS
7. Sh. Narender Kumar, SSS
8. Smt. Kajal, SSS
9. Sh. Padam Dev, SSS
10. Sh. Roshan Lal, SSS
11. Smt. Manjit, SSS
12. Sh. Amar Nath, SSS
13. Sh. Rajinder Singh, SSS
14. Sh. Padam Chand, SSS

ICAR-CPRI, Kufri-Fagu-Unit

15. Sh. Hira Singh, SSS
16. Sh. Saran, SSS
17. Sh. Roop Singh, SSS
18. Sh. Jia Lal, SSS
19. Smt. Munni Devi
20. Sh. Hira Singh, SSS
21. Sh. Ashok Kumar, SSS

ICAR-CPRI, RS, Modipuram

22. Sh. Amiruddin, SSS
23. Sh. Jagtey, SSS
24. Sh. Som Pal, SSS
25. Sh. Mani Ram, SSS
26. Sh. Rajpal, SSS
27. Sh. Rajbir Singh, SSS
28. Sh. Raj Kumar, SSS
29. Sh. Sudesh Pal, SSS
30. Sh. Gyanendra Kumar, SSS
31. Sh. Ramphal, SSS
32. Sh. Mukesh, SSS
33. Sh. Murari, SSS
34. Sh. Rajpal Singh, SSS

ICAR-CPRI, RS, Jalandhar

35. Mrs. Passo, SSS
36. Smt. Rashpal Devi, SSS
37. Sh. Ram Lubhaya, SSS
38. Sh. Sukhwinder, SSS
39. Sh. Paramjit Singh, SSS
40. Sh. Ram Sarup, SSS
41. Sh. Jagan Nath, SSS

ICAR-CPRI, RS, Patna

42. Sh. Tapan Burman , SSS
43. Sh. Ram Kisun Ram, SSS
44. Sh. Teka Rai, SSS
45. Sh. Jagat Kumar, SSS
46. Sh. Bishun Rai, SSS
- ICAR-CPRI, RS, Gwalior
47. Sh. Niranjan Singh, SSS
48. Sh. Ram Singh, SSS
49. Sh. Jagdish, SSS
50. Sh. Shyam Singh, SSS
51. Sh. Parkash Tomar, SSS
52. Sh. Virendra Singh, SSS
53. Sh. Ranbir Singh, SSS
54. Sh. Kallu, SSS
55. Sh. Ashok Kumar, SSS
56. Smt. Vimla Devi, SSS
57. Sh. Jaswant Singh, SSS
58. Sh. Kedar, SSS
59. Sh. Parasu Ram, SSS

60. Sh. Punjab Singh, SSS
61. Sh. Ram Parkash, SSS
62. Sh. Bharat Singh, SSS
63. Sh. Mannu Singh, SSS
64. Sh. Lala Ram, SSS
65. Sh. Kali Charan, SSS
66. Sh. Tilak Singh, SSS
67. Sh. Net Ram, SSS
68. Sh. Mangal, SSS
69. Sh. Jandel Singh, SSS
70. Sh. Bhagirath, SSS
71. Sh. Ramdin, SSS
72. Sh. Sikander Singh, SSS

ICAR-CPRI, RS Shillong

73. Smt.Theibet Thawmuit, SSS

ICAR-CPRI, RS, Ooty

74. Nil



SANCTIONED, FILLED & VACANT POSITION OF SCIENTIFIC STAFF OF CPRI & ITS REGIONAL STATIONS AS ON 31.12.2021 (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

*Independent to discipline.S-Cadre Strength

F-In position V-Vacancy

**Extension as stop gap arrangement has been given upto April, 2021

SANCTIONED, FILLED & VACANT POSITION OF SCIENTIFIC STAFF OF CPRI & ITS REGIONAL STATIONS AS ON 31.12.2021

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	03	02	07	04	03	30	23	07	42	30	12
2.	CPRIRS, Jalandhar	01	00	01	01	01	00	10	08	02	12	09	03
3.	CPRIRC, Modipuram	01	01	00	04	03	01	10	10	00	15	14	01
4.	CPRIRS, Gwalior	00	00	00	03	01	02	03	02	01	06	03	03
5.	CPRIRS, Patna	00	00	00	01	01	00	04	02	02	05	03	02
6.	CPRIRS, Ooty	00	00	00	00	00	00	03	03	00	03	03	00
7.	CPRIRS, Shillong	00	00	00	00	00	00	04	04	00	04	04	00
	TOTAL	07	04	03	16	10	06	64	52	12	87	66	21

*Excluding RMP

SCIENTIFIC CATEGORY

JOINING

1. Dr. NK Pandey, Principal Scientist & Acting Head, Division of Social Sciences, ICAR-Central Potato Research Institute, Shimla has assumed the acting charge of the post of Director, ICAR-CPRI, Shimla in the forenoon of **23rd August, 2021**.

NEW JOINING

1. Sh. Vikas Mangal, Scientist (Genetics & Plant Breeding) joined at ICAR-Central Potato Research Institute, Shimla on **05.02.2021** (AN).
2. Dr. Ajay Kumar Thakur, Senior Scientist (Agricultural Biotechnology) joined at ICAR-Central Potato Research Institute, Shimla on **01.10.2021** (FN).
3. Dr. Yogesh Gautam, Principal Scientist (Computer Application & IT) joined at ICAR-Central Potato Research Institute, Shimla on **07.10.2021** (FN).
4. Sh. Chandan Maharana, Scientist (Plant Pathology) joined at ICAR-Central Potato Research Institute, Shimla on **21.10.2021** (FN).

TRANSFERS (INTER-INSTITUTE)

1. Dr. Kumar Nishant Chourasia, Scientist (Genetics & Plant Breeding), ICAR-Central Potato Research Institute, Shimla relieved on **23.01.2021** (AN) to join at ICAR-Central Research Institute Jute and Allied Fibres, Barrackpore, Nilgunj, Barrackpore, Kolkata, West Bengal-700121.
2. Sh. VU Patil, Senior Scientist (Agricultural Biotechnology), ICAR-Central Potato Research Institute, Shimla relieved on **08.02.2021** (AN) to join at ICAR-Indian Institute of Horticultural Research, Bengaluru.
3. Dr. Shashi Rawat, Principal Scientist (Computer Application & IT), ICAR-Central Potato Research Institute, Shimla relieved on **09.02.2021** (AN) to join at ICAR-Central Institute of Agricultural Engineering, Bhopal (MP).
4. Dr. Mohd. Abas Shah, Scientist (Agricultural Entomology), ICAR-Central Potato Research Institute, Regional Station, Jalandhar relieved on **10.02.2021** (AN) to join at ICAR-Central Institute of Temperate Horticulture, Srinagar (Jammu & Kashmir).
5. Dr. Baswaraj Raigond, Senior Scientist (Plant

Pathology), ICAR-Central Potato Research Institute, Shimla relieved on **01.10.2021** (AN) to join at ICAR-IIMR, Hyderabad, RS, Solapur.

6. Dr. (Mrs.) Pinky Raigond, Scientist (Plant Physiology), ICAR-Central Potato Research Institute, Shimla relieved on **01.10.2021** (AN) to join at ICAR-National Research Centre on Pomegranate, Solapur.
7. Dr. Gaurav Verma, Scientist (Plant Pathology), ICAR-Central Potato Research Institute, Shimla relieved on **01.10.2021** (AN) to join at ICAR-VPKAS, Almora.
8. Dr. Rajesh Kumar Singh, Principal Scientist (Vegetable Science) & Acting Head, Division of CI & ST, ICAR-CPRI, Shimla relieved on **12.11.2021** (AN) to join at ICAR-Indian Institute of Vegetable Research, Varanasi.

PROMOTIONS

1. Sh. Rahul Ramesh Rao Bakade, Scientist (Plant Pathology, RGP Rs.6000/-), ICAR-Central Potato Research Institute, Regional Station, Patna (**transferred to ICAR-Indian Institute of Natural Resins and Gums, Namkum, Ranchi – 834010, Jharkhand**) promoted to the next higher grade of Scientist (RGP Rs. 7,000/-) under CAS w.e.f. 11.05.2015 vide this Office Order F.No. 02-03/2012/Estt.II/Vol.IV/, dated **22.01.2021**.
2. Sh. Raj Kumar, Scientist (Vegetable Science, RGP Rs.6000/-), ICAR-Central Potato Research Institute, Shimla (**transferred to ICAR-Indian Agricultural Research Institute, New Delhi**) promoted to the next higher grade of Scientist (RGP Rs. 7,000/-) under CAS w.e.f. 01.01.2018 vide this Office Order F.No. 02-03/2012/Estt.II/Vol.IV/, dated **22.01.2021**.
3. Dr. Anil Kumar Chaudhary, Senior Scientist (Agronomy, RGP Rs.8000/-), ICAR-Central Potato Research Institute, Shimla promoted to the next higher grade of Scientist (RGP Rs. 9,000/-) under CAS w.e.f. 16.10.2015 vide ICAR-IARI, New Delhi office order F.No. 2-10/2019-1(CAS) dated **12.10.2021**.
4. Dr. Raj Kumar Singh, Senior Scientist (Seed Technology, RGP Rs.9000/-), ICAR-Central Potato Research Institute, Regional Station, Patna promoted to the next higher grade of Scientist (RGP Rs. 10,000/-) under CAS w.e.f. 23.10.2020 vide ICAR Office Order F.No. Pers.2(Misc.)/2017-AU, dated

03.11.2021.

5. Following scientists of ICAR-CPRI, Shimla have been promoted to the next higher grade of Scientist (i.e. RGP Rs. 7000/-, Rs. 8.000/-

and Rs. 9,000/-) under CAS w.e.f. the date(s) given against their names vide this office order F.No. 02-03/2012/Estt.-II/Vol.-V/877-965, dated **14.10.2021:-**

Sl. No.	Name of Scientist	Level on promotion	Date of promotion
1.	Dr. Gaurav Verma	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.01.2020
2.	Dr. Sundaresha S.	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	01.09.2019
3.	Dr. Ravinder Kumar	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	02.05.2020
4.	Dr. Mehi Lal	Level-13A of 7 th CPC (Pre-revised Pay Band Rs.37,400 – 67,000 + RGP Rs.9,000)	10.02.2021
5.	Sh. Paresh B. Chaukhande	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.01.2020
6.	Mrs. Divya K. Lekshmanan	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.01.2020
7.	Sh. Bapi Das	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.01.2020
8.	Dr. (Mrs.) Sugani Devi	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.07.2019
9.	Dr. (Mrs.) Pooja Praful Mankar	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	02.02.2019
10.	Dr. (Mrs.) P. Janani	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.01.2022
11.	Dr. (Ms.) Dalamu	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	27.04.2020
12.	Dr. Jagesh Kumar Tiwari	Level-13A of 7 th CPC (Pre-revised Pay Band Rs.37,400 – 67,000 + RGP Rs.9,000)	07.01.2020
13.	Dr. Salej Sood	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	14.05.2019
14.	Dr. (Mrs.) Sarala Yadav	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	15.12.2020
15.	Dr. (Mrs.) Ratna Preeti Kaur	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	15.12.2020
16.	Dr. Murlidhar J. Sadawarti	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	26.06.2019
17.	Dr. Priyank Hanuman Mhatre	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.07.2019
18.	Dr. N. Sailo	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	27.04.2020
19.	Dr. (Mrs.) Pinky Raigond	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	28.04.2019
20.	Ms. Clarissa Challam	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.07.2019
21.	Er. Brajesh Nare	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	27.08.2019
22.	Dr. Mohd. Abas Shah	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.07.2019
23.	Dr. (Ms.) Bandana	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	11.05.2019
24.	Sh. Pynbianglang Kharumnuid	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.07.2019

RETIREMENT

1. Er. Sunil Gualti, Scientist (SG), ICAR-Central Potato Research Institute, Regional Station, Jalandhar retired from Council's service w.e.f. 30.06.2021 (AN).

PROBATION / CONFIRMATION

The probation cleared / confirmed of following scientists w.e.f. the date(s) given against their names vide this office order F.No. 02-06/2010/Estt.II/Vol.IV/, dated 22.02.2021:-

Sl.No.	Name of Scientists	Date of appointment	Date on which probation was completed	Date of confirmation
1.	Dr. Kumar Nishant Chourasia, Scientist, ICAR - CPRI, Shimla	02.07.2018	01.07.2020	02.07.2020
2.	Dr. Dharmendra Kumar, Scientist, ICAR-CPRI, Shimla	02.07.2018	01.07.2020	02.07.2020
3.	Sh. Rahul Kumar Tiwari, Scientist, ICAR-CPRI, Shimla	02.07.2018	01.07.2020	02.07.2020
4.	Sh. Milan Kumar Lal, Scientist, ICAR-CPRI, Shimla	02.07.2018	01.07.2020	02.07.2020

SANCTIONED FILLED AND VACANT POSITION OF TECHNICAL CATEGORY AS ON 31.12.2021, BASED ON REVISED CADRE STRENGTH

Functional Group	Hqrs.		Shillong		Jalandhar		Modipuram		Gwalior		Patna		Ooty		Kufri		Total	
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Field Farm Technician (FFT)																		
Cat. I	29	32	5	3	8	7	13	9	4	4	12	8	4	2	8	4	83	69
Jr. Tech. Asstt. / Sr. Field Asstt. / Field Asstt.																		14
Cat. II	9	8	-	-	4	3	13	09	2	1	3	1	-	-	-	-	31	22
Sr. Tech. Asstt. (T-4) / Tech. Asstt. (T-3)																		09
Cat. III	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	2	1
Farm Supdt. T-6																		1
Lab. Technician-																		
Cat. I	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	3	3
Computer (T-2) / Projector Operator, T-2																		0
Cat. II	3	2	-	-	1	-	1	1	1	2	-	-	-	-	-	-	6	5
Lab. Tech. (T-4) / Lab. Tech. (T-3)																		1
Cat. III	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0
Computer programmer T-6																		1
Lib. Information / Documentation																		
Cat. II	1	1	-	-	1	1	1	-	-	-	-	-	-	-	-	-	3	2
Lib. Asstt. (T-3) / Asstt. Librarian (T-5)																		1
Documentalist, T-3 / Tech. Asstt. (Stat.) (T-3)																		1
Functional Group	Hqrs.	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	Total
Photography																		
Cat. I	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0
Photographer /																		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	S	F
Press & Editorial Staff Cat. II																				
Hindi Translator, T-3	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2	2	0	0
Workshop & Engg. Staff																				
Cat. I																				
Blacksmith-cum-Carpenter	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0	0
Sr. Mechanic (T-2)	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	2	2	0	0
Fitter (T-1)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	0	1	1
Welder	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0	0
Mechanic cum Electrician	1	1	-	-	2	-	1	-	-	-	-	-	-	-	-	-	4	1	3	3
Operator Electrical	1	1	-	-	-	-	1	1	-	-	1	-	-	-	-	-	3	2	1	1
Driver	3	2	2	-	2	-	2	2	-	2	1	1	-	-	-	-	13	5	8	8
Tractor Driver	1	1	1	-	1	-	4	-	3	2	1	-	-	-	-	-	12	3	9	9
Cat. II																				
Foreman (T-4)	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1	1	1
Asstt. Foreman (T-3)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1	0	0
Overseer (Civil) T-3	1	-	-	-	-	-	-	01	-	-	-	-	-	-	-	-	1	1	0	0
Cat. III																				
Instrument Engineer, T-7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1
Total	61	54	08	03	22	13	42	26	13	11	19	10	05	02	08	04	178	123	55	55

SANCTIONED, FILLED AND VACANT POSITION OF TECHNICAL CATEGORY AS ON 31.12.2021

Category	Sanctioned	Filled	Vacant
Category-I	125	88	37
Category-II	49	34	15
Category-III	04	01	03
Total	178	123	55

Appointment

1. Sh. Anubhav Kumar, Technical Trainee appointed on compassionate ground at CPRIRS, Shillong and joined on 22.11.2021(FN)

Promotions

1. Sh. Akhilesh Singh, SSS, CPRIRS, Patna promoted to Technician from 15.6.2021
2. Sh. Rajdeep Bux, Sr. TO, CPRI, Shimla promoted to ACTO from 14.10.2019
3. Sh. Kana Singh Chauhan, Sr. TO, CPRI, Shimla promoted to ACTO from 27.3.2020
4. Dr. Sanjay Kumar Sharma, Sr. TO, CPRIRS, Gwalior promoted to ACTO from 14.5.2019
5. Dr. Sanat Kumar, Sr. TO, CPRIRS, Modipuram promoted to ACTO from 16.5.2016
6. Sh. Munna Lal, ACTO, CPRIRS, Jalandhar promoted to CTO from 22.4.2020
7. Dr. Sushil Kumar, ACTO, CPRI, Shimla promoted to CTO from 1.1.2020
8. Sh. Harvir Singh, Sr. TO, CPRIRS Modipuram promoted to ACTO from 30.9.2019

Probation/confirmation

1. Sh. Sanjeev Kumar Meena, Technician, CPRIRS, Gwalior from 17.12.2020
2. Sh. Rahul, Technician, CPRI, Shimla from 18.12.2020
3. Sh. Rohit Verma, Technician, CPRIRS, Modipuram from 18.12.2020
4. Sh. Sanjay Kumar, Technician, CPRI, Shimla from 20.12.2020
5. Sh. Vivek Kumar, Technician, CPRI, Shimla from 23.12.2020
6. Sh. Rishav Kumar, Technician, CPRIRS,

Patna from 25.12.2020

7. Sh. Virender Kumar, Technician, CPRIRS, Jalandhar from 27.12.2020
8. Sh. Rakesh Kumar, Technician, CPRI, Shimla from 28.12.2020
9. Sh. Siddharth Saroha, Technician, CPRIRS, Modipuram from 28.12.2020
10. Sh. Sumit Kumar, Technician, CPRIRS Shillong probation clear on 28.12.2020
11. Smt. Sonam, Technician, CPRI, Shimla from 7.1.2021
12. Miss Vandana Parmar, Technician, CPRI, Shimla from 28.1.2021
13. Sh. Pratish Kumar Patel, Technician, CPRIRS Patna from 31.1.2021
14. Sh. Ajaya Kumar, Technician, CPRIRS, Modipuram from 5.2.2021
15. Miss Vineeta Sharma, Technician, CPRI, Shimla from 21.2.2021
16. Smt. Nisha Verma, Hindi Translator, CPRIRS, Gwalior from 24.6.2021
17. Sh. Vinod Kumar Meena, CPRIRS, Gwalior from 29.9.2021

Retirements/VRS

1. Sh. Parvesh Kumar Yadav, Sr. Technician, CPRIRS Patna retired on 28.2.2021
2. Sh. Ram Dass Rai, T-I-3 (Driver), CPRIRS, Shillong retired on 30.4.2021
3. Sh. Omvir Singh, Sr. TO, CPRIRS, Modipuram retired on 30.6.2021
4. Sh. V. Rajenderan, TO, CPRIRS, Ooty VRS on 31.7.2021
5. Sh. Arun Kumar Singh, CTO, CPRIRS, Patna retired on 31.8.2021
6. Sh. Anil Kumar Dube, Sr. Technician, CPRI, Shimla retired on 31.10.2021

7. Sh. UP Paudal, Driver, CPRIRS, Modipuram VRS on 31.10.2021
8. Resignation of Dr. Rakesh Mani Sharma, CTO, CPRI, Shimla accepted by Council from 31.8.2019 and absorbed in Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar on the post of University Librarian from 02.9.2019.
9. Sh. Krishan Pal Singh, Tech. Asstt, CPRIRS Modipuram compulsory retired on 18.12.2021
10. Smt. Shelly Chopra, ACTO, CPRI, Shimla retired on 31.12.2021
11. Sh. Chet Ram, Sr. Technician, CPRIRS, Gwalior retired on 31.12.2021

Death

1. Sh. PR Khongbuh, Ex-TA, CPRIRS, Shillong expired on 15.6.2021

Transfer

1. Sh. Harvinder Singh, Sr. Tech. Officer, CPRI, Shimla transferred to CPRIRS, Modipuram on 12.2.2021
2. Sh. Santosh Kumar, ACTO, CPRI Kufri –Fagu Unit to CPRI, Shimla on 21.1.2021
3. Sh. Sanjeev Kumar Meena, Technician, CPRS, Patna to CPRIRS, Gwalior on 3.2.2021
4. Dr. Kapil Kumar Sharma, ACTO, CPRI Kufri- Fagu Unit to Crop Production Division, CPRI, Shimla on 16.4.2021
5. Sh. Mansha Ram, Sr. Technician, Crop Production Division to Library Section, CPRI, Shimla 20.4.2021
6. Sh. Arjun Dass, Sr. Technician, Crop Improvement and Seed Technology Division to Plant Pathology Division on 26.4.2021

SANCTIONED, FILLED AND VACANT POSITION OF ADMINISTRATIVE CATEGORY AS ON 31.12.2021

Designation	As per Old Sanctioned Strength			As per New Sanctioned Strength			Excess
	S	F	V	S	F	V	
CAO	1	1	0	1	1	0	—
AO	2	0	2	2	0	2	—
AAO	10	10	0	8	10	-2	—
Asstt.	30	20*	10	24	20*	4	—
UDC	17	17	0	9	17	-8	—
LDC	24	7	17	9	7	2	—
Principal Private Secretary (Level-11)	0	0	0	1	0	1	—
PS	4	4	0	4	4	0	—
PA	10	3	7	4	3	1	—
Steno Grade-III	0	2	2**	0	2	2**	—
Deputy Director (OL) Level-11	0	0	0	1	0	1	—
AD(OL)	1	0	1	0	0	0	—
Dy. Dirct./Comptroller (Level-12)	0	0	0	1	0	1	—
SF&AO	1	1	0	0	1	-1	—
F&AO (Level-10)	0	1	-1	1	1	0	—
AF&AO	2	0	2	2	0	2	—
Total	102	66	36	67***	66	1	—

*Downgraded and filled as UDC

**One Steno relieved to join at CGST, Delhi Zone, New Delhi and requested for Lien which is under process with council.

***Cadre Sanctioned Strength of Admn. Cat, has been reduced from 102 to 67 vide Council letter No.14-1/2019-R&P dated 18.6.2021.

Appointment/Promotion/Retirement/Transfers/ Deaths

Administrative Staff. Promotions

1. Sh. Sanjib Kumar, Assistant, CPRIRS, Patna promoted to Asstt. Admn. Officer, CPRIRS, Gwalior w.e.f. 01.01.2021 (FN)
2. Sh. Hans Raj, UDC, CPRI Shimla promoted to Assistant w.e.f. 11.03.2021.
3. Sh. Sachin Kanwar, UDC, CPRI Shimla promoted to Assistant w.e.f. 11.03.2021.
4. Sh. Chander Prakash, AF&AO, CPRI, Shimla promoted to Finance & Accounts Officer w.e.f. 5.11.2021.

Expired

1. Sh. Jaspal Singh, AO., CPRIRS, Modipuram expired on 8.05.2021.

Transfers on selection basis

1. Sh. Sandeep Singh Dudi AO, CPRI Shimla relieved w.e.f. 30.06.2021 (AN) to join as

Under Secretary at ICAR, KB, New Delhi.

2. Dr. Ashish Dhangar, Asstt. Finance & Accounts Officer, CPRI, Shimla relieved w.e.f. 06.11.2021(AN) to join as Finance & Accounts Officer at DMR Solan.
3. Sh. Mohit Oberoi, Steno Gr.3, CPRI, Shimla relieved w.e.f. 27.12.2021(AN) to join as Steno Grade-1 at CGST, Delhi Zone, New Delhi.

Transfer within Institute

- 1 Sh. Ashish Kalyan, UDC, CPRI, Shimla Temporary transferred to CPRIRS, Shillong w.e.f. 24.06.2021 and permanently transferred to CPRIRS, Shillong w.e.f. 30.09.2021.

Clearance of Probation Period

- 1 Sh Mohit Oberoi, Steno Gr.-III, CPRI, Shimla, probation cleared w.e.f. 22.03.2021.
- 2 Sh. Pawan Kumar, Steno Gr.-III, CPRIRS, Patna, probation cleared w.e.f. 27.03.2021.

SANCTIONED, FILLED AND VACANT POSITION OF SKILLED SUPPORT STAFF CATEGORY AS ON 31.12.2021

Name	Sanctioned	Filled	Vacant
Shimla/Kufri	30	20	10
Modipuram	21	13	08
Jalandhar	14	07	07
Gwalior	26	26	-
Patna	07	05	02
Shillong	04	01	03
Ooty	03	-	03
Total:	105	72	33

Promotion:

- 1 Smt. Kiran, SSS, CPRI, Shimla promoted to the post of LDC w.e.f. 13.1.2021 (AN).
- 2 Sh. Akhilesh Singh, SSS, CPRIRS, Patna promoted to the post of T-1 w.e.f. 15.6.2021.

Transfer:

1. Sh. Rajender Singh, SSS, CPRI, Shimla transferred on 15.2.2021 (AN) to CPRI-Kufri-Fagu Unit.
2. Sh. Ashok Kumar, SSS, CPRI, Shimla transferred on 23.10.2021 (AN) to CPRI-Kufri-Fagu Unit.

Retirements:

1. Sh. Ram Babu, SSS, CPRIRS, Gwalior retired on 31.1.2021.

2. Sh. Charan Dass, SSS, CPRI, Shimla retired on 30.4.2021.
3. Sh. Mansa Ram, SSS, CPRI, Shimla retired on 30.4.2021.
4. Sh. Komal, SSS, CPRIRS, Jalandhar retired on 31.7.2021.
5. Sh. Jagai Ram, SSS, CPRIRS, Jalandhar retired on 31.7.2021.
6. Smt. Muni Devi, SSS, CPRI-Kufri-Fagu unit retired on 31.12.2021.

Death:

1. Smt. Tellinora Kurkalang, SSS, CPRIRS, Shillong expired on 23.5.2021.
2. Sh. Joginder Pal, SSS, CPRIRS, Jalandhar expired on 13.10.2021.

INSTITUTE BUDGET (2021-22)

ANNEXURE- 'A'

ICAR-CPRI ANNUAL ACCOUNT 2021-22 ABSTRACT OF 'OTHER RECEIPTS' FOR THE YEAR 2021-22

(Amount in Rs.)

S.NO	HEAD OF ACCOUNT	AMOUNT
1	Sale of farm produce	5716115
2	Sale of fish & poultry	0
3	Sale of land	0
4	Sale of building	0
5	Sale of vehicle, other machine tools	429779
6	Sale of livestock	0
7	Sale of publication and advertisement	0
8	Licence fee	1576364
9	Interest earned on loans & advances	625981
10	Leave salary and pension contribution	811895
11	Receipts from schemes	0
12	Analytical and testing fee	0
13	Pre-Shipment fee	0
14	Application fee from candidates	1250
15	Diploma Charges	0
16	Receipts from services rendered	0
17	Unspent balance of Grants of previous years	0
18	Interest earned on short term deposits	2306618
19	Income generated from Internal Resource Generation Schemes	0
	a) Training	523190
	b) Consulancy	0
	c) Contract Research	0
	d) Sale of technology	0
	e) Other (Specify the source)	0
20	Revolving funds	112308545
21	Recoveries of Loans & Advances	795960
22	Miscellaneous Receipts	991900
	TOTAL : OTHER RECEIPTS	126087597

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)	NEH	TSP	SCSP	Other than NEH & TSP	7	8 (6 + 7)
1	Works									
	A. Land									
	B. Building									
	i. Office building	3800000.00	0.00	3800000.00	2800000.00	0.00	0.00	1017820.00	0.00	3817820.00
	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	0.00	0.00	0.00	0.00	0.00	0.00
2	Equipments	15420000.00	0.00	15420000.00	2335589.00	42861.00	19315.00	12946723.00	0.00	15344488.00
3	Information Technology	2900000.00	0.00	2900000.00	239922.00	106879.00	79000.00	2525958.00	0.00	2951759.00
4	Library Books and Journals	390000.00	0.00	390000.00	0.00	0.00	0.00	384334.00	0.00	384334.00
5	Vehicles & Vessels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Furniture & fixtures	1490000.00	0.00	1490000.00	619628.00	0.00	0.00	868525.00	0.00	1488153.00
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)	24000000.00	0.00	24000000.00	5995139.00	149740.00	98315.00	17743360.00	0.00	23986554.00
1	Establishment Expenses(Salaries)									
	i. Establishment Charges	392500000.00	0.00	392500000.00	0.00	0.00	0.00	392448312.00	0.00	392448312.00
	ii. Wages									0.00
	iii. Overtime Allowance									0.00
	Total – Establishment Expenses (Grant in Aid - Salaries)	392500000.00	0.00	392500000.00	0.00	0.00	0.00	392448312.00	0.00	392448312.00
1	Pension & Other Retirement Benefits	291600000.00	0.00	291600000.00	0.00	0.00	0.00	291598731.00	0.00	291598731.00
2	T.A.									0.00
	A. Domestic TA / Transfer TA	1800000.00	0.00	1800000.00	0.00	0.00	0.00	1752994.00	0.00	1752994.00
	B. Foreign TA									0.00
	Total – Traveling Allowance	1800000.00	0.00	1800000.00	0.00	0.00	0.00	1752994.00	0.00	1752994.00

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)
3	Research & Operational Expenses									
	A. Research Expenses	19900000.00	0.00	19900000.00	10496446.00	125700.00	2386126.00	7067114.00	0.00	20075386.00
	B. Operational Expenses	900000.00		900000.00	0.00	0.00	0.00	816692.00	0.00	816692.00
	Total - Research & Operational Expenses	20800000.00	0.00	20800000.00	10496446.00	125700.00	2386126.00	7883806.00	0.00	20892078.00
4	Administrative Expenses									
	A. Infrastructure	19200000.00	0.00	19200000.00	167677.00	0.00	0.00	18950053.00	0.00	19117730.00
	B. Communication	650000.00	0.00	650000.00	111553.00	0.00	0.00	532757.00	0.00	644310.00
	C. Repair & Maintenance									
	i. Equipments, Vehicles & Others	4600000.00	0.00	4600000.00	2151160.00	0.00	0.00	2470284.00	0.00	4621444.00
	ii. Office building	1180000.00	0.00	1180000.00	199000.00	0.00	0.00	978547.00	0.00	1177547.00
	iii. Residential building	1325000.00	0.00	1325000.00	0.00	0.00	0.00	1325685.00	0.00	1325685.00
	iv. Minor Works	450000.00	0.00	450000.00	231849.00	0.00	0.00	217838.00	0.00	449687.00
	D. Others (excluding TA)	36500000.00	0.00	36500000.00	4357502.00	274000.00	313020.00	31464433.00	0.00	36408955.00
	Total - Administrative Expenses	63905000.00	0.00	63905000.00	7218741.00	274000.00	313020.00	55939597.00	0.00	63745358.00
5	Miscellaneous Expenses									
	A. HRD	1500000.00	0.00	1500000.00	892087.00	0.00	290469.00	339499.00	0.00	1522055.00
	B. Other Items (Fellowships, Scholarships etc.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C. Publicity & Exhibitions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D. Guest House - Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E. Other Miscellaneous	125000.00	0.00	125000.00	102448.00	0.00	0.00	0.00	0.00	102448.00
	Total - Miscellaneous Expenses	1625000.00	0.00	1625000.00	994535.00	0.00	290469.00	339499.00	0.00	1624503.00
	Total -- Grants in Aid - General	379730000.00	0.00	379730000.00	18709722.00	399700.00	2989615.00	357514627.00	0.00	379613664.00
	Grand Total (Capital + Establishment+General) Loans and Advances	796230000.00	0.00	796230000.00	24704861.00	549440.00	3087930.00	767706299.00	0.00	796048530.00
6	Swachh Bharat Mission	0.00	0.00	0.00	0.00	0.00			0.00	0.00

