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Supervision and Guidance
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PREFACE

Climate change, environmental degradation and over exploitation of natural resources are the key challenges for sustainability of the Indian Agriculture. The progress on meeting the targets of Sustainable Development Goals (SDGs) by 2030 has been rather slow. However, the Indian Agricultural Research Institute did not let its zeal and enthusiasm wane during these turbulent times of Covid and remained resolved in its pursuit to empower the farming community for the prosperity of the nation. The institute sharpened its focus on broader 2030 agenda and strived for the development of cutting-edge technologies to achieve more efficient, inclusive, resilient and sustainable agro-ecosystem.

In the year 2021, the institute released 32 varieties and hybrids with improved yield, quality and resilience including 16 in field crops, 08 in vegetables and 08 in fruit crops. Two biofortified wheat varieties (one bread and one durum) with enhanced iron, zinc and protein contents and improved resistance to stem and leaf rusts were released. This year, three blast- and bacterial blight-resistant basmati rice varieties *viz*. PB 1847, PB 1885 and PB 1886 and two herbicide-tolerant varieties namely, PB 1979 and PB 1985 suitable for direct seeded rice cultivation were released, with an aim to enhance the income of farmers by economizing the cost of cultivation. A provitamin-A rich Quality Protein Maize (QPM) hybrid, developed through marker assisted stacking of genes, has been released across the country; it possesses 7.02 ppm provitamin-A against the 1-2 ppm found in traditional hybrids. A MAS-derived drought-tolerant variety of chickpea (BG 4005) with 11% yield superiority over recurrent parent was also released during this year. It was one of the 35 crop varieties dedicated to the nation by Honorable Prime Minister of India on September 28, 2021. Besides, Pusa Double Zero Mustard 33 (PDZ-11) having low erucic acid (<2%) and glucosinolate (<30 ppm) levels and an in-built resistance against white rust disease was released for the North Western Plain Zone. A MYMV-resistant mungbean variety (Pusa 1641), which matures in 62-64 days was also released and notified. Furthermore, two varieties of tomato *viz*. Pusa Tomato protected-1 and Pusa Golden Cherry Tomato No. 2 and one variety of Pakchoi were released for protected cultivation in NCT of Delhi.

An Internet of Things (IoT) based automatic basin irrigation system was developed that improved the irrigation application efficiency to 86.6 per cent. Similarly, an IoT based monitoring and alert system was designed and installed for greenhouse aeroponics. The institute also upscaled Pusa farm Sun-Fridge (Pusa-FSF), a solar stand-alone cold store developed for reducing spoilage of the perishable horticultural produce. Large scale multi-location trials of our breakthrough technology "Pusa Decomposer" were conducted for its further optimization and improvement for providing sustainable solution to the intractable problem of residue burning.

ICAR-IARI continued its mission to reshape the future of the country by educating and training young students as per the needs of an agrarian society and preparing them for a wide spectrum of roles in the government and private sector. The Covid-19 pandemic impacted our teaching activities; however, online teaching helped us in coping with teaching activities very well. A total of 252 candidates (138 M.Sc., 9 M.Tech. and 105 Ph.D.) including

9 International students received their hard-earned degrees during 59^{th} convocation of the Post-Graduate School of IARI. Furthermore, a road map was prepared and strategic steps were taken for the successful implementation of the new National Education Policy-2020.

Pusa Krishi Vigyan Mela 2021 was organized on the theme "*Atma Nirbhar Kisan*" by IARI during February 25-27, 2021 wherein five farmers were recognized as IARI Fellow Farmer and 35 farmers were honoured as Innovative Farmers. The institute played a pivotal role in capacity building of all the stakeholders including farmers and laid immense emphasis upon transfer of technologies through its vibrant extension and outreach programmes including *Mera Gaon Mera Gaurav* (MGMG), NEH Scheduled Caste Sub Plan (SCSP), and Tribal Sub Plan (TSP) for their accelerated adoption, diffusion and penetration.

Under '*Lab to Land*' initiative, a total of 73 technologies of ICAR-IARI were transferred to 64 industry partners resulting in total revenue generation of ₹ 63 lakhs. Under the IP Management vertical, three patents were granted to the institute and two copyrights were registered. Besides, nine varieties were registered with PPV & FRA. Being a knowledge partner in the RKVY-RAFTAAR Scheme of Ministry of Agriculture & Farmers' Welfare, GoI, the institute organized a wide array of programs and events such as ARISE, UPJA, ABIC and BEEJ etc. to support the agribusiness startup community of the country. A well-curated mentor-driven two-month intensive incubation program namely COHORT 2021 was also successfully organized to provide 360° mentoring to startups for their empowerment.

This year, the scientists of IARI published 956 research papers in peer reviewed journals with international impact factor. I warmly acknowledge and thank the staff of ICAR-IARI for their time, commitment and leadership during challenging 2021. My thanks are also due to the guidance provided by the members of various expert committees including Research Advisory Committee, Institute Management Committee etc.

I would like to thank Dr. D.K. Yadava, ADG (Seed) and Dr. T.R. Sharma, DDG (Crop Science), ICAR for their constant support and guidance. I also thank Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for being the guiding light for the institute and for providing generous financial support to the institute that enabled us to discharge our mandate more effectively and efficiently.

I acknowledge the funding agencies such as NASF (ICAR), NAHEP (ICAR), DBT, DST and other national & international agencies, who supported 228 externally funded projects for the financial year 2021 that not only helped us immensely in meeting our research, teaching, and service goals but enabled us to optimize our output as well.

I express my sincere admiration to the annual report editorial team for bringing out the annual report in time.

I look forward to more productive years ahead.

(Ashok K. Singh)

Director, ICAR-IARI

Contents

IARI: An Introduction

Originally established in 1905 at Pusa (Bihar) with the financial assistance of an American Philanthropist, Mr. Henry Phipps, the Indian Agricultural Research Institute (IARI) started functioning from New Delhi since 1936 when it was shifted to its present site after a major earthquake damaged the Institute's building at Pusa (Bihar). The Institute's popular name 'Pusa Institute' traces its origin to the establishment of the Institute at Pusa.

The Indian Agricultural Research Institute is the country's premier national Institute for agricultural research, education and extension. It has the status of a 'Deemed-to-be-University' under the UGC Act of 1956, and awards M.Sc./ M. Tech. and Ph.D. degrees in various agricultural disciplines.

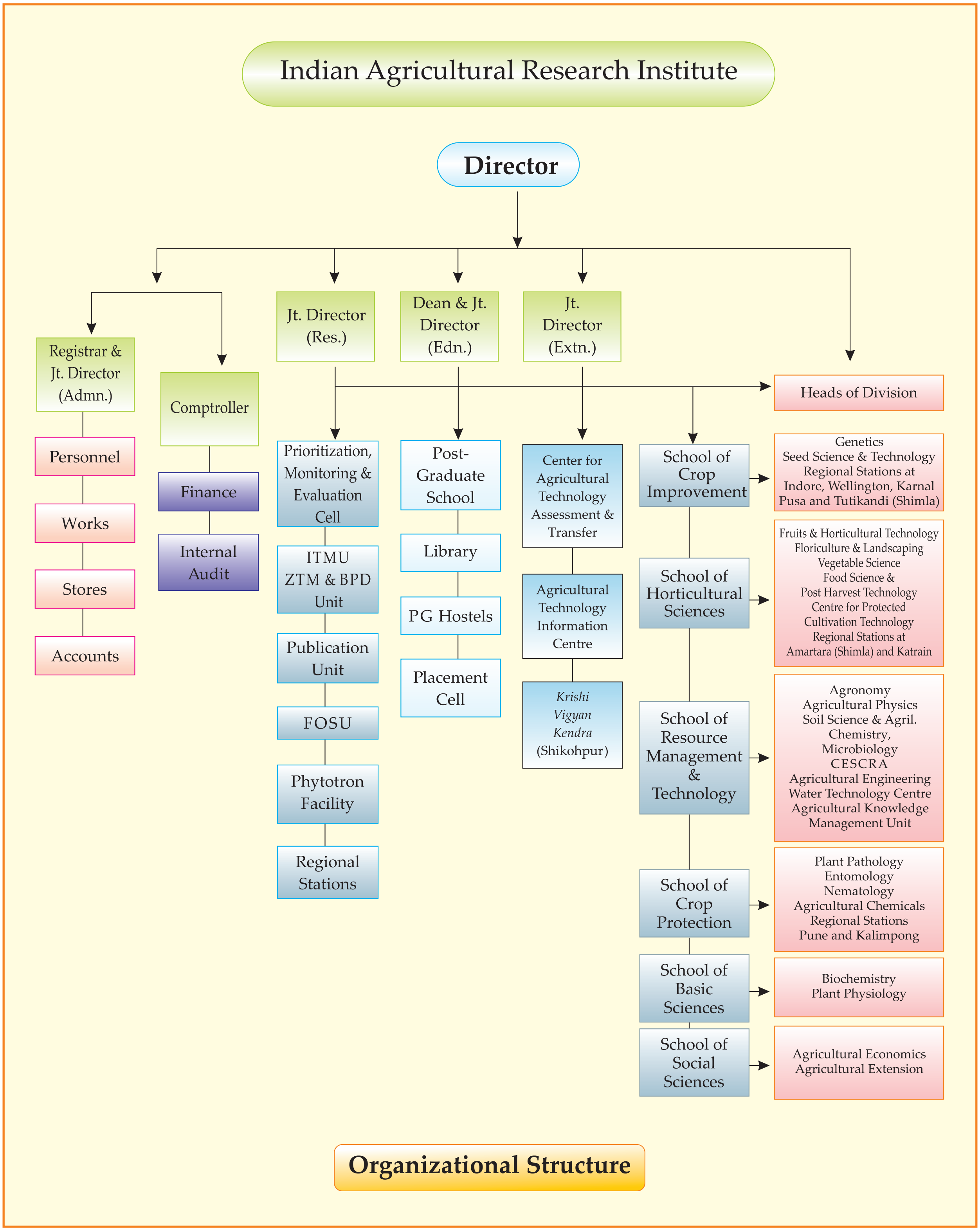
The growth of India's agriculture during the past more than 100 years, is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout the country, generation and standardization of their production techniques, integrated pest management and integrated soil-water-nutrient management have been the hallmarks of the Institute's research. The Institute has researched and developed a large number of agrochemicals which have been patented and licensed and are being widely used in the country. Over the years, IARI has excelled as a centre of higher education and training in agricultural sciences at national and international levels.

The mandates of the Institute are as follows:

- To conduct basic and strategic research with a view to understanding the processes, in all their complexity, and to undertake need based research, that lead to crop improvement and sustained agricultural productivity in harmony with the environment
- To serve as a centre for academic excellence in the area of post-graduate and human resources development in agricultural sciences
- To provide national leadership in agricultural research, extension, and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards
- To develop information systems, add value to information, share the information nationally and internationally, and serve as a national agricultural library and database

The present campus of the Institute is a self-contained sylvan complex spread over an area of about 500 hectares. It is located about 8 km west of New Delhi Railway Station, about 7 km west of Krishi Bhavan, which houses the Indian Council of Agricultural Research (ICAR), and about 16 km east of Indira Gandhi International Airport at Palam. The location stands at 28.38′23′′ N and 77.09′27′′ E with altitude of 228.6 meter above mean sea level. The climate is sub-tropical and semi-arid with warm and dry summer and cold winters. The daily maximum temperature during the hot period (April 2021-Sepember 2021) ranges from 28.0°C to 43.8°C and the daily minimum temperature ranges from 10.2°C to 32.5°C. June to September are rainy months during which 1349 mm of rainfall received. Winter sets in from mid-November and is delightful. The daily maximum temperature during winter (November - March 2021) ranges from 14.4°C to 40.0°C and the mean minimum temperature from -0.8°C to 20.6°C. During winter 84.3 mm rainfall is received.

The Institute has 19 divisions, 2 multi-disciplinary centres situated in Delhi, 8 regional stations, 2 off-season nurseries, one krishi vigyan kendra at Shikohpur, 3 all India coordinated research projects with headquarters at IARI, and 21 National centres functioning under the all India coordinated research projects. It has sanctioned staff strength of 2304 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹62059.94 lakh (Unified Budget) for the year 2021-22.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Agronomy
Agricultural Physics
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Agricultural Knowledge Management Unit
School of Crop Protection
Plant Pathology
Entomology
Nematology
Agricultural Chemicals
Regional Stations Pune and Kalimpong
School of Basic Sciences
Biochemistry
Plant Physiology
School of Social Sciences
Agricultural Economics
Agricultural Extension
Organizational Structure

EXECUTIVE SUMMARY

In 2021, the onslaught of COVID-19 pandemic continued to cause large scale loss of lives and livelihoods. Its ripple effects plunged the global economy into deeper contraction and resulted in unprecedented increase in hunger and malnutrition worldwide. Responding to these pandemic-induced challenges, the Indian Agricultural Research Institute worked tirelessly to provide innovative technologies to maintain food security. The institute released new varieties/hybrids with improved yield, quality and climate resilience in food and horticultural crops, and developed several technologies for enhancing input use efficiency and profitability of farmers. The silient achievements of IARI in research, extension and education during 2021 are summarized here.

The School of Crop Improvement has developed and released sixteen (16) improved crop varieties with higher yield, better nutritional quality, resistance/ tolerance to biotic and abiotic stresses and higher adaptability to different agro-ecological conditions during the year 2021. On September 28, 2021 the Honorable Prime Minister of India dedicated 35 crop varieties to the Nation, of which 12 varieties were developed by IARI. A biofortified bread wheat variety HI 1636 with high iron content (44.4 ppm), resistance to diseases such as stem and leaf rusts, Karnal bunt and flag smut, was released for timely sown, irrigated conditions of Central Zone. This variety has an average and potential yield of 5.66 t/ha and 7.88 t/ha, respectively. A biofortified durum wheat variety HI 8823 with good levels of protein (12.1%), iron (37.9 ppm) and zinc (40.1 ppm) has been released for timely sown, restricted irrigation conditions of Central Zone. This variety showed high levels of resistance to stem and leaf rusts and has average and potential yield of 3.85 t/ha and 6.56 t/ha, respectively.

Three new basmati rice varieties namely Pusa Basmati 1847, Pusa Basmati 1885 and Pusa Basmati 1886 with inbuilt resistant to bacterial leaf blight and blast disease were developed through marker assisted-improvement of popular rice varieties *viz*. Pusa Basmati 1509, Pusa Basmati 1121 and Pusa Basmati 6, respectively. The Pusa Basmati 1847 has been released for commercial cultivation in the Basmati GI area of the Western Uttar Pradesh, National Capital Region of Delhi and Punjab. It is a short duration (120 days) variety with an average yield of 5.7 t/ha. The Pusa Basmati 1885 (average yield 4.68 t/ha) and Pusa Basmati 1886 (average yield 4.49 t/ha) have a duration of 135-140 days and has been released for the states of Delhi, Punjab and Haryana and for Basmati GI area in Haryana and Uttarakhand. The institute has also developed Country's first non-GM imazethapyr herbicide-tolerant rice varieties namely Pusa Basmati 1979 and Pusa Basmati 1985, which are near-isogenic lines of "PB 1121" and "PB 1509", respectively. The Pusa Basmati 1979 takes 130-133 days for maturity with an average yield of 4.577 t/ ha under irrigated transplanted conditions. The Pusa Basmati 1985 (average yield of 5.2 t/ha) has a maturity duration of 115-120 days under irrigated transplanted conditions. These varieties, being tolerant to the broad-spectrum herbicide-imazethapyr, would help in effective control of weeds in DSR, thus economizing cost of Basmati rice cultivation.

Pusa HQPM-1 Improved, a provitamin-A rich QPM hybrid developed through marker-assisted stacking of *crtRB1*, *lcyE* and *opaque2* genes, has been identified for release across the Country. It has 7.02 ppm of provitamin-A against 1-2 ppm in traditional hybrids along with high lysine (4.59%) and tryptophan (0.85%). Similarly, Pusa Biofortified Maize Hybrid-1, a provitamin-A rich QPM hybrid (6.60 ppm) has been identified for release in NHZ and NEPZ. It matures in about 86 days in NEPZ and 107 days in NHZ. It contains high lysine (3.37%) and tryptophan (0.72%) content. Pusa HM4, a Male Sterile Baby Corn, was developed which is country's first from the public sector and has a yield of 7.07 t/ha (with husk) and 2.27 t/ha (without husk). It saves around ₹ 8,000-10,000/ ha of labour cost in detasseling.

A MAS derived drought tolerant chickpea variety Pusa Chickpea 4005 (BG4005), with 11% yield superiority over recurrent parent Pusa 362, was released for commercial cultivation in North Western Plain Zone comprising of Punjab, Haryana, western UP and Rajasthan. It has a yield potential of 1.94 t/ha under drought conditions in North Western Plain Zone. Also, a desi line of chickpea *viz*. Pusa Chickpea Vijay (BGM 10217) with a potential yield of 2.36 t/ha was identified during 2021 for release in Uttar Pradesh by UPSVRC. It is highly resistant to *Fusarium* wilt and carries a QTL introgressed from ICC 4958 for drought tolerance. Mungbean variety Pusa 1641 with improved yield and resistance to MYMV was released and notified for NCR region.

Mustard variety Pusa Double Zero Mustard 33 (PDZ-11) with <2% erucic acid in the oil and <30ppm total glucosinolates content in defatted seed meal cake, and suitable for timely sown irrigated conditions was released for North Western Plain Zone including Rajasthan, Punjab, Haryana, Delhi, Western Uttar Pradesh and Plains of Jammu & Kashmir and Himachal Pradesh. It also possesses inbuilt resistance against white rust disease. Soybean variety *viz*. Pusa Soybean 6 with improved yield and resistance against yellow mosaic virus (YMV), *Rhizoctonia* Arial Blight (RAB) and Bacterial Pustule (BP) was released and notified for Delhi NCR region. A large number of promising genotypes in several crops are under various stages of evaluation in All India Coordinated trials.

The institute has a good collection of genetic resources comprising wild relatives of crops, land races, indigenous and exotic collections and introgression lines. Several genetic stocks with specific traits in wheat, barley, rice, maize and Indian mustard were registered with ICAR-NBPGR, New Delhi. These include wheat genotypes HD3304 (INGR 21124) and HD 3241 (INGR 21186) were registered for highest sedimentation value (75 and 73 ml respectively) that makes them a valuable resource for improving gluten strength in wheat varieties. Wheat genotypes QBI20-14 (INGR 21183) and QBP17-7 (INGR 21185) were registered for greater grain micronutrient concentration. A new barley (*Hordeum vulgare* L.) line BHS 481(INGR 21125) was registered as genetic stock resistant to stripe, leaf and stem rust. Pusa Rice Restorer 402 (PRR402), a tropical *japonica*-based NPT line, which is a restorer of wild abortive (WA) cytoplasm possessing the restorer gene *Rf4*, developed in the background of a popular *indica* rice variety Pusa 44 has been registered with INGR No. 21012 at NBPGR, New Delhi. Also, Nerica-L 44 (EC67488), a reproductive stage heat stress tolerant rice genotype has also been registered with NBPGR (INGR 21011). Karuppunel, a high grain zinc rice landrace with a higher Zn content (46.2 ppm in brown rice and 40.9 ppm in polished rice) than the target 28 ppm for biofortification programmes by HarvestPlus was collected from Tamil Nadu state, characterized and registered with a registration No. INGR 21006. A maize inbred line PML-35 with improved adaptability and performance at higher plant density was registered (INGR 21032). Furthermore, *Teosinte branched-1*(*Tb1*) gene from teosinte (*Zea mays* ssp. *parviglumis*), a novel genetic stock in the maize breeding programmes responsible for prolificacy character, was introgressed into seven elite inbreds. Besides, Indian mustard genotypes NPJ 149 (INGR20093; possessing high temperature tolerance) and RDV 29 (INGR20041, possessing powdery mildew resistance) were also registered with NBPGR, New Delhi.

The School of Horticultural Sciences developed and released vegetable crop varieties *viz*. Dolichos bean, DB-5; Carrot, Pusa Prateek (IPC-3); Muskmelon, Pusa Kazri (DMM-148); Muskmelon, Pusa Sunehari; Tomato, Pusa Rakshit (DTPH-60) through CVRC. In addition, Pusa Golden Cherry Tomato-2 and Pusa Tomato (Protected)-1 were released for commercial cultivation by the SVRC. Several other varieties *viz*. Brinjal, Pusa Hara Baingan 2, Pusa Safed Baingan, parthenocarpic gynoecious Pusa Pickling Cucumber-8 (DG-8), and Bitter gourd, Pusa Hybrid-5 (DBGH-159) suitable for spring-summer season for open field conditions having higher female to male flower ratio (2:1); Pusa Sponge Gourd-29 (DSG-29), Satputia Pusa Tripti (D Sat-4); and summer squash Pusa Shreyash (DS-17) suitable for growing during winter season (off-season) under naturally ventilated polyhouse (under North Indian plains) were also notified by CVRC.

In tomato, eight parental lines with improved ToLCD tolerance (<5% incidence) and processing trait with TSS>5.0°Brix and a yield potential of >60 t/ha were identified. Besides, 58 F_1s for ToLCD tolerance (35) and improved processing traits (23) and a sweet-fruited line (Sel. -11) with indeterminate growth, high TSS (6.9-8.5ºBrix) and enhanced processability were developed. Cherry Sel. 3 having orange colour fruits with average yield of 8 q/100 m^2 area and moderate TSS (8.5^{0}Brix) was developed. Promising brinjal hybrids having inbuilt *fusarium* wilt resistance, DBHR-175 with yield of 645 q/ha and DBHR-326 with yield of 600 q/ha. In chilli, DChV 39, DChV 63 and DChV 42 varieties were found to be resistant to leaf curl disease. Intergeneric hybrids between *Solanum pseudocapsicum* and *Capsicum annuum* were found to be resistant to leaf curl disease both under natural epiphytotic and controlled conditions. In capsicum, F_1 hybrids like KTC-130 × YW, KTC-142 × YW and KTC-152 × KTC-131 were found promising for fruit set at high temperature. Two orange fruited lines (KTC-130 and KTC-145-1) were found most promising for yield.

Pusa Red Cabbage Hybrid-1 developed using cytoplasmic male sterility (CMS) was released for commercial cultivation. In tropical broccoli, Purple Broccoli-1 (purple) and DC-Brocco-13 (green) were advanced to AVT-II in AICRP (VC) trials. In snowball cauliflower, Pusa Snowball Hybrid-2 has been released, while F_1 hybrid, Pusa Hybrid-301 has been released and notified by the Central Sub-Committee. Pusa Purple cauliflower-1 has been released by the Delhi State Seed Sub-Committee. Five CMS and inbred parental lines-based hybrids of snowball cauliflower were identified. Introgression of β-carotene (*Or* gene) and anthocyanin (*Pr* gene) genes into snowball cauliflower was achieved and the lines were advanced. In cole crops, promising F_1 hybrids with high marketable curd yield were identified for October (#08; 20 t/ha yield) and November (#05; 25 t/ha yield) month maturity. Two CMS based F_1 hybrids DCEH-15419 and DCEH 529819 of orange cauliflower with a yield potential of >18 t/ha yield were found to be promising.

In okra, DOH-3, DOH-7, and DOH-9 were found highly resistant to *Bhendi Yellow Vein Mosaic Virus* (*YVMV*) and *Enation Leaf Curl Virus* (ELCV) under field conditions. In muskmelon, small fruited (900 g) type, DM-31 having dark orange flesh and high TSS (12^{0}Brix) was identified. In bottle gourd, genotypes IC0319838, IC337078, IC296733, EC800995 and EC750696 were found resistant to powdery mildew disease. In carrot, based on the quality for root shape, surface, external & internal colour, DCat-13, DCat-36, DCat-6, DCat-48 and DCat-1 were identified as most promising hybrids with higher yields. A unique shaped radish, Sel.-14, attaining marketable maturity in 50-55 days after sowing during *rabi* season has been identified.

In onion, two promising *kharif* genotypes (2020ENTO and 2020HORT) were identified having superior survival and bulb formation. Three accessions (BR021, BR111, and BR119) were recorded as bolting tolerant (5-10%) genotypes. Genotypes, PKO 2009 (30.65 t/ha), PKO 2010 (29.81 t/ha) and PKO 1964 (29.35 t/ha) were found promising genotypes for *kharif* season. Three lettuce lines, DLS 127 (green leafy type), DLS 134 (green leafy type) and DLS 110 (butterhead red type) were found most promising with high yields. In garden pea, advance breeding lines *viz*. GP2165, GP2179, GP2178, GP2174 and GP2113 were identified for early maturity and resistance to *Fusarium* wilt. Genotype DB 41 (dark purple pod), DB 42 (dark red flat), DB 43 (green) and DB 44 (yellow flat with purple suture) were identified as semi-dwarf type with profuse bearing habit.

In fruit crops, four mango hybrid varieties, namely, Pusa Pratibha, Pusa Shreshth, Pusa Lalima and Pusa Peetamber were released by the Central Sub-Committee. Two grape varieties namely Pusa

Aditi and Pusa Urvashi suitable for table and juice making purposes were released by the CVRC, while Pusa Purple Seedless and Pusa Swarnika were released by the SVRC. Pusa purple seedless with extra-early ripening behaviour and bunches are ready for harvest between 75-80 days after full bloom. In guava, a red pulped, soft-seeded hybrid, GH-2016-8F (Thai x Punjab Pink) was found to be having excellent nutritional quality with desirable flavour characteristics. Two acid citrus hybrids (ACSH-3-2/18 and ACSH-9-13/18) were noted to be highly precocious and having immunity to citrus canker. Three Sequence Characterized Amplified regions (SCAR) *viz*., PKBT5, SDP and PMSM 2 linked to sex determination were developed and can be commercially utilized for identification of male and hermaphrodite plants among dioecious and gynodioecious genotypes.

In floriculture crops, rose var. "Pusa Alpana", gladiolus var. "Pusa Shanti" and chrysanthemum var. "Pusa Sundari" were released for the Delhi State by State Seed-Sub-committee. Two new pink coloured rose hybrids *viz*. RH-19-2017 (BRRS-1) and RS-03-2017 were identified, respectively, for loose flower and garden display purpose. In marigold, two selections, namely, Fr./R-5-1 and Fr./R-5-2 were identified for loose flower production and bedding purposes. Pusa Lily-1 entered in the AICRP (Floriculture) and other promising lilium germplasm *viz*. Buzzer was found suitable for pot conditions and it showed high number of flowers per plant (10.07) as well as improved duration of flowering (27.33 days). Doubled-haploid plants of ornamental kale were developed through microspore culture and maintained for further field evaluation. In gladiolus open cultivation, the silver/black mulch was found best with regard to plant growth, spike andrachis length, and number of florets which was followed by yellow/ black mulch.

The School of Crop Protection focused it research on diagnostics, diversity analysis, identification of resistant sources and integrated management of important pests and pathogens of national importance. *Tilletia indica* isolates, causing Karnal bunt of wheat, were genotyped using a ddRADseq genotyping by sequencing approach to detect genetic variation(s). Association mapping revealed 13 SNPs associated with *T. indica* virulence. Thirty-eight polymorphic SSR markers were developed from the whole genome of *B. sorokiniana* isolate BS 112. *Magnaporthe grisea* isolates were genotyped by exploiting sequence variations in six selected housekeeping (*Pgk, Pfk, Cal*) and effect or coding (*Mpg1, Slp1, and Mlc1*) genes. Morphological and cultural characterizations coupled with molecular characterization with species specific markers were carried out to identify the *Fusarium* species associated with the head blight of wheat. Full genome of *Bipolaris oryzae* was sequenced using PacBio Sequel II platform. Citrus Tristeza Virus (CTV) isolates were collected from different citrus orchards of Assam and characterized based on sequence analysis of 5'ORF1a gene fragments of CTV genome. The bacterial pathogen causing stalk rot disease of maize was identified as *Dickeyazeae*, after comprehensive biochemical characterization and carbon utilization tests of the isolates. Occurrence of an emerging *polerovirus*, Cucurbit Aphid Borne Yellow Virus (CABYV), infecting bitter gourd and cucumber plants in India was reported for the first time. Occurrence of 16SrII-C phytoplasma in papaya was reported first time. A graphene oxide based electrochemical immuno-sensor for rapid and sensitive detection of groundnut bud necrosis orthotospovirus was developed. A nano-biosensor for the detection of chili leaf curl virus was developed. A multiplex RT-PCR was standardized to detect four viruses *viz*. apple mosaic virus-ApMV (*ilarvirus*), apple stem pitting virus-ASPV (*fovea virus*) and apple stem grooving virus-ASGV (*capillo virus*), simultaneously. The isolate Xcc-C7 race 4 of *Xanthomonas campestris* pv. *Campestris* causing black rot of cabbage was isolated from cabbage from Bengaluru and whole genome sequence data was generated, which revealed its close similarity with Chile Xcc isolate. Role of crude toxin in the pathogenicity and virulence of *Rhizoctonia solani* for rice sheath blight was established. Cocktail dsRNA of multiple suppressor genes of chili leaf curl virus reduced the virus infection in *Nicotiana benthamiana.* Long-fragment circular-efficient PCR for viral genome construct was invented for the restriction and ligation free manipulation of virus-genome construct. To inhibit PRSV, viral genome linked protein (VPg) was targeted. Transovarial transmission and propagation of a bipartite begomo virus in whitefly progenies was reported first time. Management of different diseases with different biocontrol agents, microbiome formulations and IDM modules was studied. One phyllosphere microbiome formation (PMF2) developed for biotic stress management in rice showed exceptional performance; better than the existing formulation BioCure (T-Stanes Co. Ltd.) in trials conducted at 12 different geographical locations in Punjab, Haryana, Uttar Pradesh and Tamil Nadu.

Weather based prediction models developed for thrips and GBNV disease incidence in tomato. A tinged bug, *Urentius euonymus* was first time recorded as pigeon pea pest from Delhi. Fumigation toxicity of 12 different monoterpenes was evaluated against storage insect pests *viz*., rice weevil, *Sitophilus oryzae*, pulse beetle *Callosobruchus maculatus* and red flour beetle, *Tribolium castaneum*. The studies signified the species specificity of monoterpenes toxicity against storage insect pests. Characterization of *Chilopartellus from* different agro-ecological *regions* concluded that *C. partellus* populations from Hisar, Hyderabad, Parbhani and Coimbatore were distinct from each other, indicating that there are four biotypes of *C. partellus* in India. Heat stress influenced population dynamics through its detrimental effects on reproductive output of *S. frugiperda* especially through paternal effects. Studies on virus vector dynamics showed *significant* differences in the rate of transmission between *B. tabaci* genetic groups, Asia I and Asia II-1. Orientation response of whitefly adults to synthetic volatiles was studied using a Y-tube olfactometer and Olfactometric preference index (OPI) was estimated. Among various treatments, the OPI value was significantly low for ocimene (0.64) indicating possible repellent activity of this volatile compound to whitefly, *B. tabaci*.

The genome of Indian entomopathogenic nematode *Heterorhabditis indica* was sequenced to create a genomic resource to facilitate comparative and functional genomics. RNA-sequencing was used to understand the *Heterorhabditis bacteriophora* nematode factors involved in symbiosis with *Photorhabdus luminescens*. Loop-mediated isothermal amplification (LAMP) assay was developed for rapid detection of potato cyst nematodes (PCN) *Globoderarosto chiensis*, and entomopathogenic nematodes *Heterorhabditis* spp. and *Steinernema* spp. from total soil DNA. In an attempt to identify nematode antagonistic microbes suitable for use as biocontrol agents in polyhouses, three isolates of *Bacillus subtilis* and one isolate of *B. licheniformis* (associated with uninfected tomato roots in root-knot infested polyhouses) exhibited significant juvenile mortality and disruption of nematode embryogenesis in *M. incognita* in lab assays. The bioefficacy trial conducted in polyhouse on tomato cv Abhilash by soil application of an *B. subtilis* isolate not only caused significant reduction in nematode reproduction, but also showed significant enhancement in plant growth characters, compared to untreated control.

To remove three most commonly used pesticides namely azoxystrobin (AZX), nitenpyram (NIT), and thiamethoxam (TMX) from water, a magnetite-activated charcoal composite was synthesized and characterized using FT-IR, SEM, and TEM. Chemo and bioprospecting for agrochemicals through design, discovery and development of novel processes was undertaken. Synthesized compounds were found active against different fungal pathogens and nematodes. Concomitant data generation, fine-tuning of composition and field performance evaluation of EPN biogel formulations was accomplished. Pusa Hydrogel and SPG-1118 hydrogels were evaluated for their water productivity enhancement potential under field conditions in cauliflower. The curd yields were higher in hydrogel treated plots as compared to the control plots. A modified QuEChERS extraction and cleanup method was optimized for trace level quantification of 100 pesticides using UPLC-MS/MS and validated on coriander leaves, curry leaves (representative crops in crop group 027 *i.e*., Herbs). An analytical method was developed for the trace level analysis of sulfamethoxy pyridazine in soil using modified QuEChERS extraction and clean-up technique followed by HPLC-

VWD or LC-MS/MS analysis. Degradation of crude oil hydrocarbons was studied using microbes isolated from a contaminated soil. Among 17 bacteria and 3 fungi isolated from a crude oil contaminated soil, *Pseudomonas* sp. and *Bacillus amyloliquefaciens* (bacteria) and fungus *Aspergillus sydowii* were identified as best degraders of crude oil aliphatic hydrocarbons in medium.

The School of Basic Sciences made significant progress in genome editing of rice. Genome editing technology was employed to successfully developed SDN1 type mutant alleles of drought and salt tolerance (*DST*) gene in rice mega variety MTU1010. These rice mutant lines showed enhanced tolerance to salt and drought stresses at reproductive stage, and also enhanced yield under non-stress conditions. Towards unraveling the role of farnesyl transferase A (*FTA*) gene in rice, SDN1 type knockout mutants were generated in rice using genome editing. These mutants showed very early flowering (about one month) as compared with WT MTU1010 genotypes. For the functional validation of *IPT 9* gene (involved in cytokinin biosynthesis), *IPT9*-overexpressing transgenic plants were generated in rice cv MUTU 1010 and further characterized for its role in drought and salt stress tolerance.

Deep Learning based approach (Web-SpikeSegNet) was developed for automated spike detection and counting from RGB images in wheat in a collaborative work between ICAR-IASRI and Nanaji Deshmukh Plant Phenomics Centre. This method will be useful for automated phenology detection and yield prediction in wheat. Phenomics studies led to the identification of QTLs and superior RILs for diurnal and nocturnal transpiration and Water Use Efficiency (WUE) under irrigated and moisture deficit stress were identified in rice. Four rice genotypes (BAM3690, CAUVERY, SUWEON and Eypo) were identified as Nitrogen Use Efficiency (NUE) donors. Also, two major QTLs associated with nitrogen uptake efficiency (qNUpE2.1 and qNUpE12) and nitrogen utilization efficiency (qNUtE2.1 and qNUtE9.1) were identified.

A space planting method as a surrogate for identification of high [CO_2] responsiveness genotypes of rice was validated and superior genotypes were identified. A three year study showed that high [CO_2] responsiveness trait could help minimize the adverse effect of high night temperature (HNT)-induced losses quality and yield of rice. On the basis of changes in spikelet fertility, panicle grain yield and heat susceptibility index under high temperature stress, three Indian rice accessions were identified as tolerant to high temperature stress. Genome wide association analysis for identification of genes for phosphorous-related indices in 82 diverse bread wheat accessions revealed 78 marker-trait associations and total of 294 candidate genes.

Epigenetic regulation of phosphorous-starvation genes was studied in a pair of contrasting rice genotypes *viz*. Pusa 94 (P-deficiency sensitive) and NIL-23 (P-deficiency tolerant). The P-starvation responsive genes were observed to be downregulated due to hypermethylation in Pusa 44 while they were upregulated due to hypomethylation in NIL-23. Whole transcriptome sequencing (WTS) of developing grains of diverse genotypes of pearlmillet was performed and a BioProject based on WTS was submitted to NCBI (Acc # PRJNA625418). A putative starch synthase-IV gene,which showed significantly lower in pearlmillet hybrids than in landraces, was cloned and characterized from pearlmillet landrace Damodhar (Acc.#MW505986). In wheat, High night temperature significantly reduced the proportion of α-gliadin in gluten fraction of different wheat genotypes.

A technology of vital wheat gluten (VWG) reconstitution in bajra and makka flour was developed for superior dough and chapatti making quality, and two products Hallur: soft bajra atta and Makai: soft makka atta were developed and commercialized. An economically viable production methodology was standardized for the production of microgreens from six crops (Brassica, mungbean, lentil, pearlmillet, red radish and red cabbage), their nutritional profiling done and a NutriGreens kit was developed and commercialized.

Interactions of proteins and lipids with the starch matrix were studied in basmati and non-basmati rice varieties and compared between 6 and 12-months aged rice samples to understand the biochemical changes associated with aging of rice. The quality of proteins from chickpea (both Desi and Kabuli type) and pigeonpea genotypes was analysed in terms of their Protein Digestibility Corrected Amino Acid Score (PDCAAS). A method was standardized for extraction of carotenoids from carrot using five green solvents, wherein Cyclopentyl methyl ether (CPME)-based extraction resulted in maximum yield of the carotenoids. Furthermore, the nutritional, functional and sensory properties of soymilk after its single- and mixed- culture probiotic fermentation were compared, which revealed mixed-culture probiotic fermentation to be more rewarding.

In rice, a dCAPS marker, HB-LOX3 was designed to differentiate the rice accessions carrying *LOX3*-null and *LOX3*-functional alleles as well as to identify heterozygotes carrying one copy each of null and functional allele at the *LOX3* locus associated with rapid rancidity of rice bran. This marker can be effectively utilized in the marker assisted breeding programs aiming for the development of improved rice varieties with better storability. In maize, a major QTL, having tremendous potential for development of highly prolific baby corn hybrids, was identified and designated as 'qProl-SP-8.05'. A single dominant gene for foliar blast resistance in pearlmillet was identified and mapped on the chromosome #4 using the SSR marker. In lentil, transcriptomics studies led to the identification of key genes and metabolic pathways involved in alkalinity and aluminum stress tolerance. Furthermore, molecular aspects of plant pathogen interactions manifested in 'dry root rot disease', caused by *Rhizoctonia bataticola,* were also studied using RNA-seq approach. Mapping of the QTLs/genes was done for heat tolerance, oil content and seed size in *Brassica*. Inheritance of seed coat color, early maturity trait and resistance against MYMV was studied in soybean. In addition, QTL mapping of genes governing anthocyanin content was done in brinjal. Efforts to develop doubled haploids in *Capsicum annuum* were initiated with an aim to achieve rapid homozygosity and a method was standardized for direct plant regeneration from microspores. Haploidy was also induced in cucumber through gynogenesis. In Drosophila, the SNPs in *DWnt4* gene that are responsible for embryonic lethality were identified and germline clones of *DWnt4*^{AL7}stained to study the underlying mechanism of arrest of these cones in stage 6 of oogenesis.

The School of Natural Resource Management focuses on the use of non-invasive sensors, remote sensing, machine learning and arificial intelligence approaches were developed to characterize soil and plant health. Forewarning models for predicting various characters of powdery mildew disease in grapes were developed and validated. Multispectral indices were identified for distinguishing between paddy harvested and paddy burnt. Hyperspectral vegetation indices *viz*. normalized different red edge (NDRE) and normalized pigment chlorophyll index (NPCI) were developed to predict rice yield. A satellite-based ensemble model for surface soil moisture (SSM) monitoring was developed, using an ensemble modelling approach combining optical-thermal-microwave based predictive models, which can be effectively used for SSM retrieval, covering an entire cropping season, with reasonable and consistent accuracy and thus can aid in irrigation planning. Models were also developed by using stepwise multiple linear regression (SMLR) and artificial neural network (ANN), support vector machine (SVM), random forest (RF), and principal component analysis (PCA) techniques for predicting mustard yield from long term weather data and yield data. Among all the six models, PCA-SVM performed best for the study area.

Nanosensors for rapid, portable and highly sensitive detection of soil nitrate was fabricated using various organic and metal oxide based nanomaterials. In soybean, a comparative study of application of nano particles revealed that ZnO and Fe_3O_4 are more effective in enhancing the grain yield as compared to coventional fertilizers *i.e.* $ZnSO_4$ and $FeSO_4$. A Normalized Sunlit Shaded Index (NSSI) was developed to characterize the status of the wheat crop grown under moisture-stress conditions. Weather-based agromet advisory bulletin were prepared based on past weather, real time weather and weather forecast for next five days. During 2021, 105 agromet advisory bulletins were prepared in Hindi as well as in English and SMS regarding agromet advisory were sent through the m-Kisan portal. Farmers who followed the agromet advisories are able to reduce the input cost by reducing the irrigation, number of sprays, seed rate and timely management practices based on agromet advisories.

Conservation agriculture (CA)-based permanent raised bed + residue retention (3 t/ha) led to highest seed yield of pigeonpea. Similarly, CA-based cotton-wheat cropping system was found to be a superior crop diversification option in north-western Indo-Gangetic plains and thus could prove to be an important adaptation and mitigation strategy to climate change. CA-based rice-wheat-mungbean proved to be an alternative to conventional puddled transplanted rice-wheat system. Conservation agriculture practices improved yield of maize-wheat system in both north-western and north-eastern plain zones of India. Long-term conservation agriculture increased soil organic carbon sequestration (37 to 50%) in rice-wheat cropping system and improved overall soil health.

Soil and nutrient management research revealed long term fertilization and manuring application enhanced humus stability. Non-rice-based systems sequestrated more soil organic carbon in Indo-Gangetic Plains. Silicon application improved P availability and positively impacted the wheat growth parameters. Experiment involving mica application revealed that waste mica serves as source of K. Nano clay polymer composites (NCPCs)-based fertilizer products showed a great potential towards s enhancement in N-use efficiency in crops. The NCPC loaded with urea ammonium nitrate performed better and gave higher wheat yield. Biodegradable clay-polymer blended coating film was synthesized, leading to significant reduction in N and P losses from fertilizers. Developed portable Pusa Soil Test and Fertilizer Recommendation (STFR) Meter, which can analyze 14 important soil parameters, *viz.* pH, EC, OC, available nutrients [P, K, S, Zn, B, Fe, Mn, Cu and N (based on OC)], gypsum requirement and lime requirement and give crop-specific fertilizer recommendations.

Precision nutrient management based on NutrientExpert tool improved soybean–wheat system productivity. Leaf colour chart-based N management reduced N-use by 33.3 and 50% for direct-seeded and transplanted rice, respectively. Summer green manuring and nano zinc oxide coated urea improved basmati rice productivity. Urea-S could be an alternative to regular S fertilizers, enhancing productivity of Durum wheat–soybean system. Integrated farming system models having multiple enterprises (crops, livestock, poultry, duckery, fishery, mushroom production, beekeeping, agri-horti system, etc.) was developed to ensure round the year livelihood, income and employment of small and marginal farmers.

Water management research has led to significant improvements in crop water productivity and profitability. Near real time soil moisture criteria-based irrigation could save 44-50% water in green pea. An Internet of Things (IoT) based automatic basin irrigation system increased irrigation efficiency by 86.6%. CERES-wheat model indicated substantial decline in phenology, yield and water productivity under RCP 4.5 and RCP 8.5 at baseline CO_2 concentration. Quantified irrigation efficiencies (48.4% head, 54% middle and 61% tail reaches) of Amarpur minor of Bhagawatipur distributary of Eastern Sone High Level Canal Command of Bihar, India. Trend analysis and spatio-temporal variability mapping of ground water table depth was done for past 20 years (1999-2019) for Moga, Barnala, Patiala, Sangrur and Ludhiana districts of Punjab. Scientific protocol developed for revival of village ponds in Nuh Block of Mewat.

Research on protected cultivation brought out promising agro-techniques for highly profitable crop cultivation. Centre has developed two varieties of tomato (Pusa Tomato Protected-1 & Pusa Golden Cherry Tomato 2), which are the first indigenous open-pollinated varieties suitable for naturally ventilated polyhouse/protected cultivation in NCR. One variety of Pakchoi (Pusa Pakchoi-1) developed, which is the first indigenous variety developed for North Indian Plains. Also, new promising capsicum germplasm No 32 identified for protected cultivation. IOT based monitoring and alert system for greenhouse aeroponics and vertical hydroponic prototype with and without artificial light were developed. Besides, a plastic low-tunnels technology was developed for summer squash varieties during winter season and integrated nematode management under protected cultivation.

Three units of Pusa-Farm SunFridge for cold storage of perishable agricultural produce were established at Picholiya Ajmer (Rajsthan), Chamrara (Haryana), and Palla (Delhi) villages and one unit at IARI, New Delhi. Developed smart device for on-field crop cutting energy measurement and two-wheel battery-assisted (electric) weeding cum intercultural machine for pigeon pea, chrysanthemum, and marigold. Sensor-based control volume sprayer for grape clusters could reduce use of chemicals by 30%. Sensor-based spraying system for microbial inoculum and customized aqueous fertilizer metering system for aqua-ferti seed drill were also developed. A battery-powered, manually operated pineapple harvester was developed for faster harvesting. Tractor operated microbial inoculum sprayer was developed with a field capacity of 0.52 ha/h and a discharge rate of 1072 l/ha. Braking system for fodder cutter machines and a green pea sheller with separation efficiency of 83.6% developed. Solar-powered air-inflated grain dryer, portable hybrid dryer, and infrared dryer for apple slices were developed.

Research on food science highlighted that ascorbic acid at 1% could effectively inhibit the extent of browning in fresh-cut beans and cauliflower mix, and calcium lactate could maintain quality and extend storage life of bitter gourd fruits. Protein and flavonoid rich baked products were developed using okara (by-product of soymilk industry) and citrus peel from citrus juice industry. Another interesting study revealed that mixing of pea pod powder in buckwheat flour not only enhances it dough quality, appearance and overall acceptability but also improves the shelf-life of buckwheat bread prepared from the mixture. Also, an ultrasound assisted extraction method for extraction of phenolics from potato peels was optimized using response surface methodology. Furthermore, it was found that addition of salt at lower concentration (<3.0%) in beetroot extracts imparts stability to beta lain pigments and helps them to retain their antioxidant activity. Steam blanching capsicum samples retain more total antioxidants (96.5 mM Trolox), ascorbic acid (56.3 mg/100g) and total phenol (73.4 mg GAE/g). Canola oleogel was found to be a good agent to replace 40% hydrogenated fat during cookies preparation, as it does not affect visual, textural and sensory attributes of cookies. *Pseudomonas putida* BP25 volatiles were identified as very good post-harvest fumigants to suppress mango anthracnose. An edible coating formulation was developed using a combination of carnuba and shellac wax for enhancing the shelf life of strawberries.

Two endophytic actinobacteria with PGP traits and antifungal activity against different fungal pathogens including *F. graminarium* were isolated and identified as *Streptomyces rochei* and *S. sampsonii*. Inoculation of these isolates improved wheat seed germination by 35-43% compared to fungal control. Furthermore, two actinobacterial strains with great promise for agro-residue and biomass management (on the basis of their ability to produce lignocellulolytic enzymes) were isolated from compost samples and identified as *Streptomyces thermoviolaceous* and *S. thermophilus*. Pusa Decomposer-an eco-friendly and environmentally useful technology having potential to contribute significantly towards Swachh Bharat Mission by curbing stubble burning pollution- was demonstrated and validated on large scale (3000 acres in Delhi, 500 acres in Punjab, 500 acres in Haryana by IARI while 200 acres in Uttar Pradesh by KVK and About 17 lakh acres by private companies) at multiple locations.

An estimation of carbon storage in trees growing at IARI campus ecosystem revealed that a total of 119.31 tons of carbon is stored by 64 diverse tree species present at IARI campus, which is 436.83 tons in terms of CO_2 equivalence. Another study showed that avenue trees like *Morus alba* are capable of efficiently taking up atmospheric heavy metals like Zn, Fe, Pb, Ni etc. and can thus play a crucial role in improving the air quality. It was found that the use of methane utilizing bacteria (*Methylobacterium oryzae* MNL7 & *Paenibacillus polymyxa* MaAL 70) could be a viable option to minimize methane emission from rice-rice system. Another study showed that alteration of soil chemical properties and enzymatic activities influence emission of greenhouse gases (GHG) significantly. Inoculation of *Azospirillum* with *Pseudomonas fluorescens*, *B. subtilis*, *B. licheniformis* increased N-use efficiency of maize inbred lines. Application of limus (urease inhibitor) coated NCU increased wheat yield by 9.5% and decreased nitrous oxide and ammonia emissions by 8.9% and 36%, respectively. Furthermore, our studies showed that conservation agriculture-based cotton-wheat system can be a good alternative to rice-wheat system when it comes to profitability and reducing GHG emission. The application of ZnO-nano particles improved the plant growth and reduced toxic effects of Cd by reducing the concentration of bioavailable Cd in rhizosphere soil.

The School of Social Sciences undertook studies on government schemes, assessment of technologies, extension approaches, climate change adaptation, nutrition and livelihoods system for the welfare of the farmers. A comprehensive assessment of the e-NAMschemeshowed that the major commodities traded through e- NAM are cereals which account for nearly 40 per cent of total volume and 25 per cent of the value of trade in e-NAM in 2020-21. A study was carried out for deciphering the effect of covid-19 pandemic on export from India, in quantitative terms. It was found that agriculture exports saved the GDP_{fc} fall, output demand fall and labour demand fall to the extent of ₹ 1.37 lakh crore, ₹ 4.3 lakh crore and ₹ 0.3 lakh crore respectively. It was estimated that Wayanad paddy ecosystem generated ₹ 6,26,919 per ha worth of ecosystem services annually. The average ecosystem services delivered by the Eastern Yamuna Canal (EYC) in its command area were estimated to be ₹ 1123 million, which is quite higher than working expenses (₹ 757 million) of this canal irrigation system.

Analysis of total economic surplus generated from the adoption of the varieties of basmati rice, showed that Pusa Basmati 1121 generated ₹ 39250 crores and Pusa Basmati 1509 generated ₹ 2941 crores (at 2019-20 prices).

The 'Pusa Samachar'-IARI's innovation for dissemination of information and knowledge through YouTube Channel - made great strides during 2021 as the subscribership of the you tube channel increased to 17700 with a total viewership of 4.5 lakhs. A micro-processing unit was established at KVK Chitrakoot under DBT Biotech KISAN Hub Project and all the necessary equipments for value addition were provided in the hub for use by the local farmers for processing at community level. Ten women SHGs were formed in Manjhawali and Swamika and two Farmer Interest Groups (FIGs) were mobilized in Fatehpur Bilochin collaboration with NABARD. Furthermore, two Farmer Producer Companies with 100 members eachwere established in Fatehpur Biloch and Tigipur village. Social learning-based adoption of climate resilient technologies (direct seeded rice, zero-till wheat, IPM in cotton) was analysed in Gaya district of Bihar. It was found that cconvergence based extension led to increase in water security, technology accessibility, capacity development, and income generation. Under ICAR NICRA project, interventions were made for capacity building of farmers in utilization of Climate Resilient Technologies at NICRA villages in Gurgaon (Haryana), Chandauli (Uttar Pradesh), Gaya (Bihar), and Sundarbans (West Bengal). The food consumption pattern and dietary diversity were measured and found that majority of the respondents from female group were under underweight having medium Diet Diversity Score (DDS) was majorly noticed.

Agricultural Technology Information Centre (ATIC) of IARI continued its excellence in providing products, services, technologies and information services to the different stakeholders through a 'Single Window Delivery System'. It attended a total number of 9,870 visitors as well as 7,522 telephone calls on various aspects of agriculture through Pusa *Agricom*, Pusa Help-line and *Kisan Call Centre* from 18 states.

Pusa seeds and biofertilizers of worth ₹ 15,36,836/- and farm publications of ₹ 19,090/- were sold to the farmers even during the covid-19 affected year. Under NEP collaborative programme with ICAR institutes and SAUs, 197 demonstrations involving 22 varieties of 9 crops were conducted during *Rabi* 2020-21 and 281 demonstrations on 9 crops with 18 varieties were conducted at 12 locations of ICAR Institutes/ SAUs during *Kharif* 2020-21. KVK Gurugram organized several FLDs, OFTs, on-campus as well as off-campus trainings besides 9 vocational training programmes in areas of value addition, apiary, mushroom cultivation, motor binding and dress designing. The institute is implementing Mera Gaon Mera Gaurav, a flagship programme of ICAR, along with adjoining ICAR institutes IASRI and NBPGR in 120 clusters comprising of 600 villages through 480 scientists of the Institute. Under MGMG 1922 filed interventions were made benefitting 13668 farmers. Through different KVKs of NEH region 1650 quintals of potato seed and 2599 kg of vegetable seed (marigold, carrot, radish and vegetable kits) were provided to the farmers of NEH region. Under SC-SP programme. 10615 SC farmers were covered in 23 districts of 3 states during *Kharif* 2021-22, Pusa *Krishi Vigyan Mela* 2021, themed "*Atmanirbhar kisan*" was organised at the IARI mela ground from February 25-27, 2021. During this year, three patents were granted, two copyrights were registered, nine genotypes were registered in PPV & FRA and two copyright applications were filed. Under 'Lab to land' Initiative, a total of 73 technologies of ICAR-IARI were transferred to 62 industry partners resulting in total revenue generation of ₹ 63 lakhs. During this year IARI has produced and supplied 175.03 tonnes of breeder seeds, and 591.86 tonnes of truthfully labelled seeds in different crops.

The post Graduate School of IARI continued to provide national and international leadership in human resource development. So far, 4444 M.Sc., 72 M.Tech. and 5079 Ph.D. students have been awarded degrees including 487 international students. The institute also received accreditation from National Agricultural Education Accreditation Board of ICAR (2020-2025 with 'A' Grade). The 59th Convocation of the Post Graduate School of the IARI was held on February 12, 2021 in hybrid mode. The Hon'ble Union Minister of State for Agriculture and Farmers' Welfare, GoI graced this function as Chief Guest. During this convocation, 252 students (138 M.Sc., 9 M. Tech. and 105 Ph.D.) including 9 international students (3 M.Sc. and 6 Ph.D.) received their degrees. In addition, the degree of Doctorate of Science (*Honoris causa*) was conferred upon two eminent IARI alumni namely Prof. Sanjaya Rajaram, the recipient of World Food Prize 2014 and Prof. Rattan Lal, the recipient of World Food Prize 2020.

IARI is playing a key role in establishing Afgan National University of Agricultural Sciences and Technology (ANASTU), Kandhar, Afganistan and Advanced Centre for Agricultural Research and Education (ACARE) at Yezin Agricultural University (YAU), Myanmar in collaboration with Ministry of External affairs (MEA), GoI. Under ANASTU programme, the students of the 3rd batch were provided online guidance by IARI faculty for completion of their thesis writing. Under the ACARE programme, short term (2 weeks) training programmes for the benefit of stakeholders of Myanmar Agriculture were conducted by IARI in collaboration with YAU, Myanmar.

The scientists of the institute published 956 research papers in scientific peer-reviewed journals with international impact factor. In addition, several other publications in the form of symposia papers, books/book chapters, popular articles, technical bulletins, regular and *ad-hoc* publications, both in English and Hindi, were brought out for the timely dissemination of the technical know-how and other important information to the respective stakeholders. Several national and international training courses and other capacity building programmes were conducted for the benefit of farmers, academicians, researchers, extension workers and other professionals. New linkages and collaborations with several national and international institutions/organizations were fostered. Many scientists, students and faculty of the institute received several prestigious awards and recognitions and brought laurels to the institute.

1. CROP IMPROVEMENT

The crop improvement programme of the institute is primarily aimed at enhancement of the productivity and nutritional quality of various field crops. Modern tools of molecular breeding are increasingly used to complement the conventional methods of crop improvement. Improved varieties with higher productivity, enhanced nutritional quality and tolerance to biotic and abiotic stresses suited to different agro-ecological conditions have been developed and released during the reporting period. Besides, a large number of promising genotypes in several crops are under various stages of evaluation in ICAR-All India Coordinated trials. The crop improvement programme was complemented by quality seed production and progress in other relevant areas of seed science.

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released

HI 1636 (Pusa Vakula): A biofortified bread wheat variety with high iron content (44.4 ppm) has been released for timely sown, irrigated conditions of Central Zone. The average yield of HI 1636 is 5.66 t/ha and potential yield is 7.88 t/ha. It has high levels of resistance to stem and leaf rusts. It showed good levels of resistance to Karnal bunt and flag smut.

Field view of HI 1636

HI 8823 (Pusa Prabhat): A biofortified durum wheat variety with good levels of protein (12.1%), iron (37.9 ppm) and zinc (40.1 ppm) has been released for timely sown, restricted irrigation conditions of Central Zone. The average yield is 3.85 t/ha and potential yield is 6.56 t/ha. It has high levels of resistance to stem and leaf rusts.

Field view of HI 8823

1.1.1.2 Promotion and new genotypes contributed to AICRP trials

During the year under report, 25 genotypes have been promoted to AVT on the basis of yield superiority and disease resistance. Thirty-two new high yielding genotypes were contributed for evaluation in NIVT under various AICRP trials of all the wheat growing zones of the country. The details are given below:

AVT	HD 3388, HD 3392, HD 3400, HD 3402, HD 3406, HD 3407, HD 3415, HD 3418, HD3436, HD3437, HD3438, HD3439, HD3440, HI 1650, HI 1653, HI 1654, HI 1655, HI 1665, HI 1666, HI 8826 (d), HI 8830 (d), HI 8839 (d), HI 8840 (d), HI 8846 (d), HI 8847 (d)
NIVT	HD 3419, HD 3420, HD 3421, HD 3422, HD 3424, HD 3426, HD 3433, HD 3435, HP 1974, HP 1975, HP 1976, HP 1977, HI 1668, HI 1669, HI 1670, HI 1671, HI 1672, HI 1673, HI 1674, HI 1675, HI 1676, HI 1677, HI 1678, HI 1679, HI 1682, HI 1680, HI 1681, HI 8841(d), HI 8842(d), HI 8843 (d), HI 8844(d), HI 8845(d)

1.1.1.3 Promising genotypes under IARI Common Varietal Trials

Different breeding groups engaged in the development of condition specific genotypes contributed a total of 168 promising genotypes for yield and disease resistance evaluation in Common Varietal Trials conducted at Delhi, Indore, Pusa, Shimla and Wellington under targeted production conditions.

1.1.1.4 Development of CMS(A) lines in the background of high yielding varieties:

Recently released varieties like HD3226, HD3293 and DBW 187 are being converted to CMS lines, and the lines are in the BC_1F_1 stage.

1.1.1.5 Marker-assisted transfer of genes for rust resistance

Two MABB lines, *i.e.*, HD 3406 (HD 2967+*LrTrk/YrTrk*) in the background of HD 2967 and HD 3407 (HD 2932+*Lr19/Sr25+Lr24/Sr24+Yr10*) in HD 2932 background, were promoted to the final year of testing in AICRP trials. In addition, five new MABB entries were nominated to MABB trials of AICRP. These are HD 3436 (HD 2967+*Lr19/Sr25+Yr10*) and HD 3437 (HD 2967+*Lr34+Yr10*) for both NWPZ & NEPZ; HD 3438 (HD 2932+*Lr24/Sr24*) and HD 3439 (HD 2932+*Lr19/Sr25+Yr10*) for CZ & PZ and HD 3440 (HD2733+*Lr34+Yr10*) for NEPZ. Further, five additional MABB lines *i.e.*, HD 2733+*LrTrk*, HD 2932+*LrTrk*, HD 2967+*Lr19+Lr34+Yr10*, HD 2733+*Lr34+Lr46*, and HD 3059+*Lr34+Lr46* carrying seedling and adult plant resistance genes are being tested in IPPSN nurseries for rust resistance. Besides, HD 3086 and HD 3059 were used as the recurrent parent in marker-assisted backcross breeding to transfer linked rust resistance genes, *Lr52/Yr47* and *Lr53/Yr35*.

Rust response in parental lines and NILs

1.1.1.6 Performance of doubled haploid (DH) lines and imparting resistance to multiple rusts

DH progenies carrying *Sr26*, a gene resistant to stem rust race Ug99 (TTKSK), and stripe rust resistance gene *Yr57* were evaluated for the field resistance and yield performance. Among the tested entries DH-455 (Av. yield: 6.965 t/ha) outperformed most of the test entries and nominated into common varietal trials. As per the IPPSN data, this line showed an ACI of 0.8 for stem rust and 3.1 for yellow rust confirming the effectiveness of these genes in controlling the rust disease.

1.1.1.7 Development and characterization of mutant line of HD 3086 for abiotic stress tolerance

Mutant lines of HD 3086 were analysed for genes governing glaucousness; a trait important in abiotic stress tolerance. Expression of the three genes which constitute W1 locus, *viz*., *carboxylesterase* (*DMH*), *polyketide synthase* (*DMP*) and *cytochrome P450* (*DMC*) on 2B chromosome did not show significant differential gene expression, however a rise in expression of inhibitor gene was observed in non-glaucous lines.

1.1.1.8 Yield consolidation through adapted and sustainable agronomy

To explore the possibilities of yield consolidation by modulating lodging, a concept of green cut is introduced. Number of lines with higher yield after cut in comparison to uncut were found. Significant genetic variation has been found for green biomass production, regeneration capacity after cutting and yield consolidation capacity by managing lodging and, therefore, provides a scope for dual purpose wheat particularly under early seeding.

1.1.1.9 Development of wheat strains with reduced celiac immunogenicity

Celiac disease is caused due to gluten intolerance and consequent immunogenic reaction in genetically susceptible human beings. Crosses between durum wheat (HI 8663) and bread wheat cytostocks Null 1A, Nulld 6A, Ditelosomic 1A and Ditelosomic 6A were made. The F_1s were backcrossed with HI 8663 and BC_1F_2 single plants selected with the EST markers for the respective chromosomes. The single plants were advanced to BC_1F_5 progenies and unstable plants rejected. A set of lines for each of the cytogenetic conditions (single chromosome knock out lines) has been obtained and further crosses between single knockout lines have been made to produce lines lacking both 1A and 6A chromosomes.

1.1.2 Rice

1.1.2.1 Varieties released

Pusa Basmati 1847: A MAS derived near-isogenic line of a popular Basmati rice variety, Pusa Basmati 1509, possessing two genes for bacterial blight resistance *Xa13* and *Xa21*; and two genes for blast resistance, *Pi54* and *Pi2*, with seed-to-seed maturity of 120 days and average yield of 5.7 t/ ha has been released for commercial cultivation in the Basmati GI area of the Western Uttar Pradesh, National Capital Region of Delhi and Punjab. It is highly resistant to blast with a score of 2.5 as against highly susceptible score of 7.0 in Pusa Basmati 1509. Further, Pusa Basmati 1847 is also highly resistant to bacterial blight disease (SI: 3.0) as compared to its recurrent parent, Pusa Basmati 1509 (SI: 8.3).

Field view of Pusa Basmati 1847

Pusa Basmati 1885: A MAS derived near-isogenic line of a popular Basmati rice variety, Pusa Basmati 1121, possessing two genes for bacterial blight resistance *Xa13* and *Xa21*; and two genes for blast resistance, *Pi54* and *Pi2*, with seed-to-seed maturity of 135-140 days and average yield of 4.68 t/ha has been released for Basmati GI area of the states of Delhi, Punjab and Haryana. It is highly resistant to blast (SI: 2.3) It is also highly resistant to bacterial blight with an SI of 3.3 against SI of 6.3 in Pusa Basmati 1121.

Field view of Pusa Basmati 1885

Pusa Basmati 1886: A MAS derived near-isogenic line of a popular Basmati rice variety, Pusa Basmati 6, possessing two genes for bacterial blight resistance *xa13* and *Xa21*; and two genes for blast resistance, *Pi54* and *Pi2*, with seed-to-seed maturity of 135-140 days and average yield of 4.49 t/ ha has been released for Basmati GI area in Haryana and Uttarakhand. It is highly resistant (SI: 2.5) to blast as well as to bacterial blight (SI: 3.3).

Field view of Pusa Basmati 1886

Pusa Basmati 1979: A MAS derived herbicide tolerant near-isogenic line of Basmati rice variety "PB

1121" possessing mutated *AHAS* allele governing Imazethapyr tolerance with seed to seed maturity of 130-133 days and average yield of 4.577 t/ ha under irrigated transplanted condition has been released for GI area of Delhi, Punjab and Haryana. Due to labour and water shortage, there is a shift in the rice cultivation from transplanted condition to the direct seeded rice (DSR) cultivation in which weeds are of major concern. Pusa 1979 (IET 28812) variety being tolerant to the broad-spectrum herbicide, Imazethapyr will help in effective control of weeds in DSR, thus economizing the cost of Basmati rice cultivation. Moreover, this herbicide has added advantage over the conventional herbicides as it is required in minimal doses and is also environmentally safe.

Field view of Pusa Basmati 1979

Pusa Basmati 1985: A MAS derived herbicide tolerant near-isogenic line of Basmati rice variety "PB 1509" possessing mutated *AHAS* allele governing Imazethapyr tolerance with seed to seed maturity of 115-120 days and average yield of 5.2 t/ha under irrigated transplanted condition has been released for GI area of Delhi, Haryana and Western Uttar Pradesh. In direct seeded rice (DSR) cultivation weeds are of major concern. Pusa 1985 (IET 28814) variety being tolerant to the broad-spectrum herbicide, Imazethapyr will help in effective control of weeds in DSR, thus economizing cost of Basmati rice cultivation. Moreover, this herbicide has added advantage over the conventional herbicides as it is required in minimal doses and is also environmentally safe.

Field view of Pusa Basmati 1985

1.1.2.2 Entries in AICRP trials

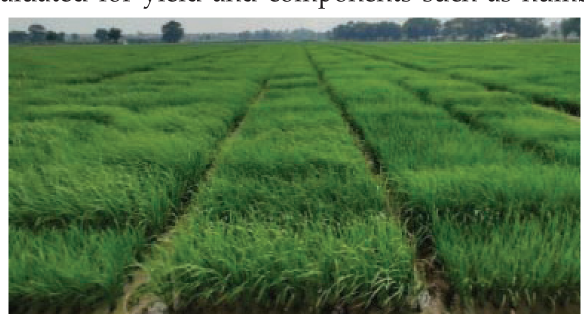
A total of 15 genotypes [IVT-L (2), IVT-IM (4), IVT-IME (1), IVT-LPT (2), AVT1-E-TP (1), AVT1-IME (1), AVT1-IM (1), AVT1-MS (1) and AVT2-BT (2)] are in different stages of testing in the AICRIP trials during *kharif* 2021. This includes six promotions to AVT and 9 new entries.

1.1.2.3 Pre-breeding-evaluation of wild rice accessions

A set of 100 different accessions of wild rice collections of *O. rufipogon*, *O. nivara*, *O. longistaminata etc.* were evaluated for various agronomic traits including resistance against different isolates of *Xanthomonas oryzae* pv. *oryzae* (*Xoo*), causal organism of bacterial blight. These lines were crossed with cultivated rice for introgression of useful traits and also inoculated for screening.

1.1.2.4 Evaluation of rice landraces for yield and other components

Two thousand one hundred and two rice landraces collected from different parts of the country were evaluated for yield and components such as number



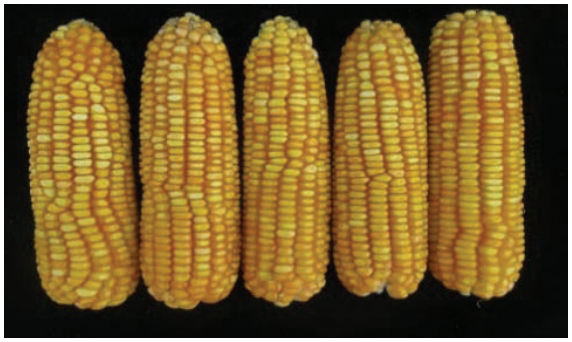
Field evaluation of rice landraces during *Kharif* 2021

of tillers per plant, plant height, panicle length, days to 50% flowering, days to maturity and number of grains per panicle during *kharif* 2021.

1.1.3 Maize

1.1.3.1 Hybrids released

Pusa HQPM-1 Improved: A provitamin-A rich QPM hybrid developed through marker-assisted stacking of *crtRB1*, *lcyE* and *opaque2* genes has been identified for release across the country. It has 7.02 ppm of provitamin-A against 1-2 ppm in traditional hybrids along with high lysine (4.59%) and tryptophan (0.85%) in protein. With an average grain yield of 8.19 t/ha in NHZ, 6.97 t/ha in NWPZ, 5.95 t/ha in NEPZ, 7.93 t/ha in PZ, 5.09 t/ha in CWZ and with an average grain yield of 6.96 t/ha in 96.6 days (NHZ: 110.5 days, NWPZ: 94.0 days, NEPZ: 90.0 days, PZ: 96.0 days, and CWZ: 92.0 days), has been released nationally.



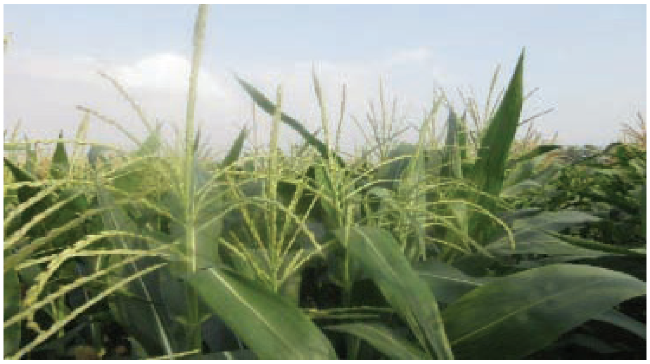
Ear and grain characteristics of 'Pusa HQPM-1 Imrpoved'

Pusa Biofortified Maize Hybrid-1: A provitamin-A rich QPM hybrid developed through marker-assisted selection of *crtRB1* gene has been identified for release

Grain characteristics of 'Pusa Biofortified Maize Hybrid-1'

in NHZ and NEPZ. It has 6.60 ppm of provitamin-A compared against 1-2 ppm in traditional hybrids along with high lysine (3.37%) and tryptophan (0.72%) in protein. It has an average grain yield of 7.62 t/ha in NHZ and 5.44 t/ha in NEPZ. Its potential grain yield is 13.32 t/ha (NHZ) and 7.84 t/ha (NEPZ). It matures in average of 86.3 days (NEPZ) and 107.4 days (NHZ).

Pusa HM4 Male Sterile Baby Corn: It is a male sterile baby corn hybrid possessing T-cytoplasm. It has baby corn yield of 7.07 t/ha with husk and 2.27 t/ha without husk. It produces fodder yield of 2.71 t//ha. It is country's first male sterile baby corn hybrid developed from the public sector. Male sterile baby corn hybrid saves around ₹ 8,000-10,000/ha of labour cost in detasseling.



Tassels showing no anther exsertion in 'Pusa HM4 Male Sterile Baby Corn'

1.1.3.2 Variety approved for commercialization

Pusa Baby Corn Hybrid (AH 7043) released for cultivation in NHZ, NEPZ and PZ by CVRC during the year 2020 has been approved for commercialization by ZTM & BPD Unit, ICAR-IARI.

1.1.3.3 Entries in AICRP trials

Biofortified hybrids, *viz.*, APH-2 and APH-3 in AVT-II; APH-4 and APTQH-5 in AVT-I were evaluated in AICRP *kharif* trials. Among specialty corn, male sterile baby corn hybrid (ABHS4-2 in BC-II) and male fertile baby corn hybrids (AH-7204 and AH-7188 in BC-II) were evaluated. Pop corn hybrids, *viz.*, APCH-2 and APCH-3 were evaluated in PC-II trial. Field corn entries in medium maturity group (AH-1625, AH 8452 and AH 8245 in AVT-I, and AH 4142 in AVT-II) were tested in different zones under AICRP *kharif* trials. Besides, the entries AH 4152, AH 4158, AH 4651, AH 4653, AH 8741, AH 8178 & AH 8727 (NIVT medium maturity); and AH 1634 & AH 1645 (NIVT late maturity) are under AICRP *rabi* and spring season trials.

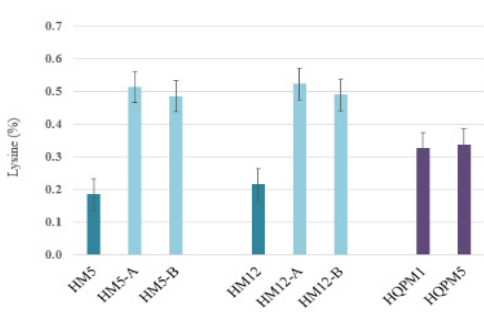
1.1.3.4 Accelerating the breeding cycle

Development of locally adapted haploid inducer lines: A set of elite inbreds were crossed with donor(s) for maternal haploid inducer gene. The markers developed and standardized in the lab were used to screen F_2 populations segregating for both *mtl* and *dmp* genes. Progenies with *mtl* + *dmp* genes were selected, and these inbreds possessed purple colour (*R-nj* gene) in the endosperm. More than 8.0% haploid induction rate (HIR) was observed among these newly developed locally adapted inducer lines.

Development of improved HI inbreds with higher expression of purple colour in seed and plant: Higher intensity of anthocyanin in seed and plant parts are desirable for easy and unambiguous identification of haploids. Inbreds with (i) *mtl* gene and higher anthocyanin, and (ii) *dmp* gene with higher anthocyanin, were crossed and F_2 populations were generated. Segregants with both *mtl* and *dmp* and higher anthocyanin in seed and plant parts were selected.

1.1.3.5 Nutritional quality

Development of white maize with *opaque2* and *opaque16* genes: White maize is a preferred option as human food. Parental lines of white grained hybrids *viz*., HM 5 (HKI 1344 × HK 1348-6-2) and HM 12 (HKI 1344 × HKI 1378) were improved by marker-assisted introgression of *opaque2* and *opaque16*. The average lysine (0.50%) and tryptophan (0.13%) in reconstituted hybrids (*o2o2/o16o16*) amounted to 152% and 332% enhancement over the original hybrids.



Lysine levels in improved (A- and B-) and original (HM-5 and HM-12) and check (HQPM-1 and HQPM-5) hybrids.

Biofortified maize hybrid with higher oil: High oil exotic donors were crossed with elite inbreds (HKI161PVA+PVE, HKI163PVA+PVE and HKI193-1PVA+PVE) for introgression of *dgat1* and *fatB* genes. Marker polymorphism was validated for candidate genes between recurrent and donor parents. BC_2F_2 populations were genotyped and homozygotes were advanced to generate BC_2F_3 generation. The homozygous lines were crossed to reconstitute the experimental hybrids which were evaluated at multilocation. Hybrids with >8.0 t/ha of grain yield have been selected for quality analysis.

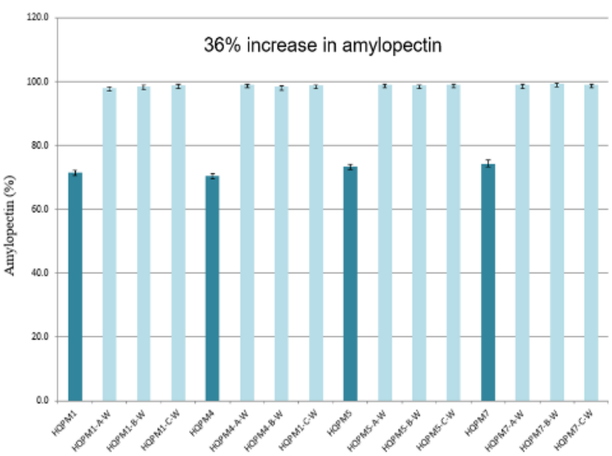
Hybrids with low phytate: Three elite QPM inbreds, *viz*., HKI323Q, HKI1105Q, HKI1128Q; and four elite QPM + provitamin-A inbreds, HKI161-PV, HKI163-PV, HKI193-1-PV and HKI193-2-PV which are the parents of nine hybrids (HM4, HM8, HM9, HM10, HM11, HQPM1, HQPM4, HQPM5 and HQPM7) were targeted for introgression of *lpa1-1* and *lpa2-1* alleles separately through MAS. Station trial for the *lpa1*- and *lpa2*- based hybrids were conducted using the original hybrids as checks and the agronomically superior low phytate experimental hybrids have been selected. The MAS-derived hybrids possessed ~30-40% less phytate than the traditional hybrids.

1.1.3.6 Specialty corn

Selection of *waxy1* gene in segregating generations through pollen staining: Rapid pollen staining technique has been used for identifying the segregating genotypes (*Wx1Wx1*, *Wx1wx1* and *wx1wx1*) in seven BC_2F_2 populations. Pollens from wild type (*Wx1Wx1*) genotypes were in dark purple colour, while waxy pollens (*wx1wx1*) exhibited red colour. Pollens from heterozygotes (*Wx1wx1*) showed mix of both dark purple and red colour. The genotypic status was confirmed by *wx1*-based markers, *viz*., *phi022* and *wx2507F/RG*.

Development of sticky maize: High amylopectin maize or 'sticky' maize is popular as food in North-Eastern states. Recessive *wx1* allele has been introgressed in three elite inbreds (HKI323, HKI1105 and HKI1128) that are the parents of two popular hybrids. The reconstituted waxy hybrids also recorded significantly higher amylopectin (mean: 98.0%) compared to original hybrids (mean: 69.7%).

Development of sticky maize with higher lysine and tryptophan: Recessive *wx1* allele has been introgressed in four elite QPM inbreds (HKI161, HKI163, HKI193-1 and HKI193-2) that are the parents of four popular hybrids. The reconstituted hybrids showed 1.4-fold increase in amylopectin (mean: 98.8%) compared to the original hybrids (mean: 72.5%). The reconstituted hybrids also showed 14.3% and 14.6% increase in lysine (mean: 0.384%) and tryptophan (mean: 0.102%), respectively compared to the original hybrids (lysine: 0.336%, tryptophan: 0.089%).



Enhanced level of amylopectin among waxy hybrids compared to normal maize

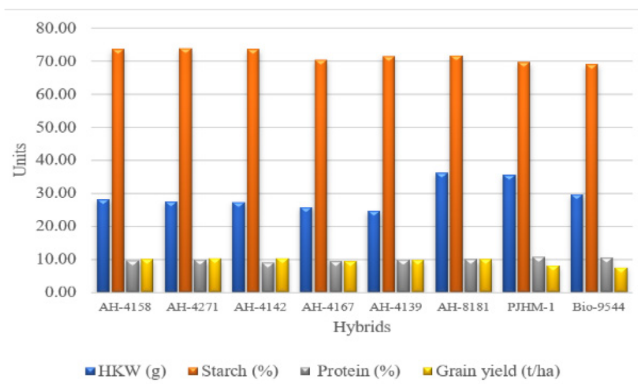
Genetic variation for amylose in diverse inbreds: Maize grains possess 25-30% amylose and high glycemic index (GI: 80-90). However, *amylose extender1* (*ae1*) enhances amylose to the extent of 50-70% depending upon the genetic background, and reduces GI to <50. A set of 48 diverse inbreds including the *ae1*-based mutant lines were evaluated for amylose at three locations. Amylose varied from 0.86-66.16% with a mean of 29.77% of the starch. Three inbred lines (MGU-ae-145, MGU-ae-146 and MGU-ae-147) with >50% amylose were identified.

Pyramiding of *silkless1* (*sk1*), *tasselseed1* (*ts1*) and *tasselseed2* (*ts2*): HM4 - a popular baby corn hybrid was targeted for introgression of *sk1*, *ts1* and *ts2* alleles for converting into silkless version. The required mutants carrying genes were crossed with parental inbreds. The BC_2F_2 populations were genotyped and mutant plants possessing desirable phenotypes were identified. The mutant plants were crossed among themselves to develop the inbreds with combination of *sk1+ts1* and *sk1+ts2* in genetic background of HKI1105 and HKI323. True F_1s (*Sk1sk1/Ts1ts1* or/and *Sk1sk1/Ts2ts2*) were raised and selfed to generate F_2 seeds.

Development of baby corn hybrid suitable for high density planting: The parental inbreds of the HM4 were crossed with a donor with low leaf angle. Foreground selection for the target gene was undertaken in BC_1F_1 and BC_2F_1 and promising BC_2F_2 progenies with desirable phenotypes and high genome recovery were selected.

1.1.3.7 Selection for high grain yield

Identification of field corn for its high yield per se with kernel parameter and nutritional value: A total of six medium maturing hybrids along with one each local (PJHM-1) and national check (Bio-9544) were

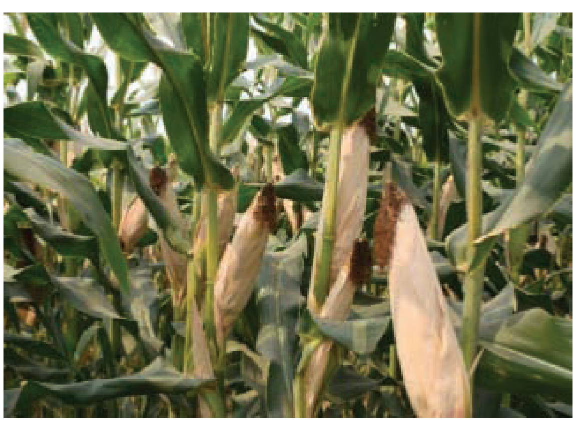


Performance of high yielding hybrids for starch, protein and kernel weight

evaluated in two seasons (*kharif* 2020 and 2021) for its yield per se and nutritional value of the same was profiled across the years. Among the tested hybrid, three hybrids *viz*., AH-4158, AH-4271, and AH-4142 recorded per se grain yield of ≥10 t/ha and a good amount of starch content (>73%). The hybrid PJHM-1 and AH-8181 had high kernel weight (100-kernel weight) compared to the others.

Introgression of the late-flowering trait in breeding lines: Field corn can be categorized into early, medium, and late-maturing hybrids based on their time to flowering. Late maturing hybrids have an advantage over the other two for their yielding ability. Late maturing hybrid is a preferred option for many of the maize growing ecology *viz*., North Eastern Plain Zone, Peninsular Zone, and Central Western Zone. A tropicalized white line CML 442 was used as a donor for late-ness and crossed with elite inbred lines with high yield *per se*. A BC_1F_1 population was obtained and promising segregants were selected.

Characterization of PJHM-1 for fodder quality parameters: Maize is one of the good sources of fodder. Characterization of available hybrids for fodder quality traits may be the indirect way to identify hybrids for desirable traits. PJHM-1 showed a stay-green characteristic; hence it was characterized for fodder quality parameters. It was found that PJHM-1 had better green fodder yield (25.39 t/ha), dry matter yield (6.31 t/ha), quality silage yield (20.15 t/ha), ^{0}brix (9.07), and pH (4.13) compared to J-1006.



Stay green characteristics of PJHM-1.

Popularization of PJHM-1 in Madhya Pradesh: Seed production activity of PJHM-1 was undertaken in around 90 ha area at different locations of Madhya Pradesh, in collaboration with Zonal Agricultural Research Station, Chhindawara, and Madhya Pradesh State Seed Corporation. A total of 139.0 t of hybrid PJHM-1 seed was produced.

1.1.3.8 Resistance to biotic stress

Identification of biotic stress tolerant genotypes: A set of 150 newly developed inbreds against Turcicum Leaf Blight (TLB) and 100 inbreds against Maydis Leaf Blight (MLB) and Curvularia Leaf Spot (CLS) were screened under artificial epiphytotic condition.C-153, HSW-1 A, JBc-8-1, C-11, C-119, C-141, C-150, C-154, C-79, C-90, D-2273-2, TC-19, C-82, DDM-2207 and PDIM-639 were resistant to TLB. C-11, DMS-4-B, HSW-5-2, PDIM-639, DMS-7-B, DMS-9-B, C-82, C-79, C-81, DDM-2207, PDM-112, C-78 and PML-62 showed resistance to MLB. While, C-11, DMS-4B, HSW-5-2, C-82, C-142, DMS-4A, JBc-8-1, C-79, C-81, PDM-112, C-78, PML-62, D-2445 and DMS-3A possessed resistance to CLS. Besides, C-11, DMS-4-B, C-82, C-142, JBc-8-1, C-79 and PDIM-639 were resistant to all the three diseases.

MLB and CLS symptoms in the maize leaf

Development and evaluation of new inbred lines: Seventy-two inbreds were evaluated for yield, TLB and MLB. The inbreds *viz*., C-79, CML-582, PDM-6554, PML-25, BGD-48y, C-25, C-78, CDM-105 were promising with a grain yield of more than 3.5 t/ha and TLB and MLB score of less than 3 under artificial epiphytotic conditions.

Development and evaluation of single cross hybrids: Of the 450 plus single cross hybrids developed and evaluated for yield superiority and biotic stress resistance, H-2055, H-2006, H-2091, H-2011, H-2137, H-2010, H-2053, H-2078, H-2126 had more than 10% standard heterosis coupled with TLB resistance (score less than 3.0/10) under artificial epiphytotics and resistant to CLS and MLB under natural epiphytotics.

Identification of inbreds for tolerance to Fall Army Worm (FAW): A set of 50 biofortified and specialty type inbreds were screened for tolerance to FAW infestation under natural field conditions. Seven inbreds, MGU-FAW-101, MGU-FAW-109, MGU-FAW-121, MGU-FAW-125, MGU-FAW-136, MGU-FAW-141 and MGU-FAW-149 were found to be tolerant. Further, 180 field corn inbreds were also screened under natural conditions in field for tolerance to FAW infestation. Eleven inbreds *viz*., AI-501, AI-542, AI-544, PML-105, DIM-204, CM-213, C-70, DDM-2207, PDIM-639, C-11 and C-79 recorded tolerance to FAW. These inbreds will be used in hybrid breeding programme.

1.1.3.9 Tolerance to abiotic stress

Screening maize geneotypes under excess soil moisture: Six hundred accessions (ICs and ECs), 27 elite lines and 10 released hybrids (along with their parentals) were screened under pot conditions for ESM at seedling stage. Based on survival and growth attributes, 153 accessions (including 5 released hybrids, 10 parental lines and 138 germplasm accessions) were evaluated under managed waterlogging conditions in field. Based on comparative performance of germplasm under stress and control conditions most promising included Pusa HQPM-7 Improved, PusaVivek-27 Improved, PMI-PV-5, PMI-PV2, PMI-Q3; and 12 diverse germplasm accessions were selected.

Screening of maize genotypes under excess soil moisture conditions

1.1.3.10 Germplasm management

Screening of germplasm accessions for desirable yield components: Five hundred and fifteen NGB-germplasm accessions were characterized for agro-morphology, phenology, yield and its component traits. The data on maturity indicated 24% of the accessions to be of short duration, while 41% were of intermediate duration and 35% of long duration types. IC-983810, IC-985520, IC-9975599, IC-612474, IC-48958735 recorded grain yield >3.0 t/ha. Likewise, >70% accessions displayed harvest index (HI) between 2.1 and 3.0, while only two accessions (IC-816407 and IC-744112) had HI of >4.0.

1.1.4 Barley

1.1.4.1 Genotype entries in coordinated trials

Among 34 barley entries, 5 genotypes *viz*., BHS 488, BHS 489, BHS 490, BHS 491 and BHS 492 were entered for testing in AVT-TS-RF-Dual/Grain Purpose of Northern Hills Zone under All India Co-ordinated Wheat and Barley Improvement Programme (AICW&BIP).

1.1.4.2 Barley segregating material handled

Sixty nine advanced F_{10} lines were evaluated, out of which 34 lines were entered for testing under station trial. One hundred and seventy F_2 plant progenies were evaluated for agronomic performance and advanced to next generation. Also, 628 segregating lines were evaluated in different generations for agronomic score and advanced to next generation.

1.1.4.3 Co-ordinated and station trials conducted

One AVT-RF-NHZ-Grain Co-ordinated trial was conducted comprising 23 entries with four replications. Eighteen entries were evaluated in Station trial-I and sixteen entries in Station trial-II with three replications and submitted elite lines for testing in IBDSN under AICRP on barley. Besides, one NBGSN nursery (20 entries) and one EIBGN nursery (75 entries) were also conducted.

1.2 MILLETS

1.2.1 Pearl millet

1.2.1.1 Hybrid Development

Station Hybrid Trial (Early): In Station Trial for short duration, thirty-eight hybrids were tested in randomized block design with two replications at Delhi during *Kharif* 2021. Three hybrids appearing at plot no. 4403 (411A x CHI 19/26), 4406 (411A x ICMR 08888) and 4420 (411A x RIB 155076) were found promising on the basis of yield and related traits.

Station Hybrid Trial (Medium): In station trial for medium duration, 135 hybrids of medium maturity group were tested in alpha lattice design with two replications at Delhi during *kharif* 2021. Thirteen hybrids, *viz*., 4631 (ICMA 11222 x CHI 19/38), 4632 (ICMA 11222 x CHI 19/44), 4633 (ICMA 11222 x CRPB-PLT 19/16), 4635 (ICMA 11222A x CTPRLT 17/14), 4667 (ICMA 11222A x HP-B-460), 4698 (ICMA 13222 x DHLBHI 1603), 4711 (ICMA 13222 x HP-B-460), 4717 (ICMA 13222 x PPMI 1272), 5030 (ICMA 11222 x ICFD-14-R-16), 5052 (ICMA 11222 x PMBVN-20-11), 5066 (ICMA 11222 x PPMI 1094), 5081 (ICMA 13222 x ICFD-14-R-16) and 5082 (ICMA 13222 x PMBVN-20-11) were found promising on the basis of yield and related traits.

Composite and Synthetics: Pusa Composite 725 (MP 609) was promoted for second year of testing in B zone in AICRP. It recorded an average grain yield of 3.07 t/ha over the best check Pusa Composite 612 (2.822 t/ha). Three new populations, namely, Pusa Composite 726, Pusa Composite 727 and Pusa Composite 728 were nominated for Population Trial.

1.2.1.2 Nominations in AICRIP trials

Three hybrids *viz*., Pusa 2101 (ICMA 11222 x PPMI 1239), Pusa 2102 (ICMA 13222 x PPMI 1239-1) and Pusa 2103 (ICMA 08666 x PPMI 1239-1) based on yield superiority were nominated to AICRP during *kharif*, 2021.

1.2.1.3 Maintenance breeding of cytoplasmic male sterile lines

Thirty six CMS lines were maintained by attempting 3327 paired crosses. Pure seed of 17 promising CMS lines (411A/411B, 431A/431B, ICMA 843-22/ICMB 843-22, ICMA 841A/B, ICMA 92777A/B, 576A/B, ICMA 96222/B, ICMA 96666 /B, ICMA 97111/B, ICMA 99111/B, ICMA 01222/B, ICMA 01555/B, ICMA 04111/B, ICMA 04999/B, ICMA 08666/B, ICMA 11222/B, and ICMA 13222/B) was produced by crossing of 6123 panicles.

1.2.1.4 Maintenance breeding of restores/inbreds

Five hundred forty-nine elite inbred lines were maintained by selfing. These inbred lines possessed desirable traits like early maturity, thick spike, compact spike, disease resistance, good tillering and overall agronomic superiority and are to be tested for combining ability. Some of them are also having high lysine, tryptophan, Fe and Zn content.

1.2.1.5 Maintenance and utilization of germplasm

A total of 562 germplasm lines including association mapping panel (260), *P. glaucum* core-collection (234), landrace collections (14), mapping populations (8), *P. violaceum* (32), *P. mollissium* (11), *P. purpureum* (2) and *P pedicellatum* (2) were maintained by selfing and utilized in breeding programme.

1.2.1.6 Screening of germplasm for seedling thermo-tolerance

A total of 253 germplasm accessions including inbreds, landraces, new and extant cutivars were screened for seedling thermo-tolerance. Heat stress of 40, 44 and 46^{0}C was imposed on 10-days-old seedling in a growth chamber. Most of the entries (235/253) were classified as susceptible and genotypes such as PRPT 18/28, DTRLT 17/17, WSBLT-15/5, Raj LR-1, Raj LR-2, P 7-3 and PPMI 1002 were found to have better tolerance towards heat stress.

1.2.1.7 Screening lines against foliar blast disease

A total of 52 elite lines were screened for foliar blast resistance under natural epiphytotic conditions. Six genotypes namely ICMR 08444, IP 12374-1-1-2, ICMR-11666, 17613, CCSHAU Blast-11 and ICMR 06444 were found to have resistance with mean blast score of less than 3.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Varieties released

Pusa Chickpea 4005 (BG 4005): It was released by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, Government of India for commercial cultivation in North Western Plain Zone comprising of Punjab, Haryana, western UP and Rajasthan. The MAS derived near-isogenic line, BG 4005, has drought tolerance with 11% yield superiority over recurrent parent Pusa 362. BG 4005 gave an overall weighted mean yield of 1.618 t/ha and has a yield potential of 1.94 t/ha under drought conditions in North Western Plain Zone. Pusa Chickpea 4005 was one of the 35 crop varieties dedicated to the nation on September 28, 2021 by the Honourable Prime Minister of India.

Grain Characteristics of Pusa Chickpea 4005 (BG 4005)

Pusa Chickpea 20211 (Manav): It is a *Fusarium* wilt resistant chickpea introgression line developed through molecular breeding and notified by CVRC for commercial cultivation in central India comprising states of MP, Maharashtra, Gujarat, Chhattisgarh, and parts of Rajasthan and Bundelkhand region of UP. It has been developed through introgression of "QTL region" for wilt resistance on LG 2 having QTLs 1, 2, 3 & 4 from WR 315. Its average yield is 2.39 t/ha with a potential yield of 3.92 t/ha. It matures in 108 days and its 100-seed weight is 19.5 g.

Grain Characteristics of Pusa Chickpea 20211 (Manav)

1.3.1.2 Variety identified

Pusa Chickpea Vijay (BGM 10217): It is a desi line identified during 2021 for release in Uttar Pradesh by UPSVRC. It has a yield advantage of 8 % over the check with an average yield of 1.85 t/ha and potential yield of 2.36 t/ha. It flowers in about 83 days and its maturity duration is about 131 days. It has an excellent

Grain Characteristics Pusa Chickpea Vijay (BGM 10217)

grain color, size and shape. Its average 100-seed weight is 16.6 g. Its grain protein content is 18.1%. It is highly resistant to *Fusarium* wilt and carries the drought tolerance QTLs from ICC 4958.

1.3.1.3 Promising chickpea entries in All India Coordinated programme and State Varietal Trials

BG 4027, a tall and erect genotype has been promoted to AVT 1 (Mechanical Harvesting) in North Eastern Plains Zone for further testing. Seven desi entries (BG4029, BG4030, BG4031, BG4032, BG4033, BG4036 and BG4037) and two large seeded kabuli types (BG4034 and BG 4035) were entered in five different IVTs during 2021-22. From Dharwad Centre, BGD 166 has been nominated for testing in IVT (rainfed) in different zones. BGM 10222 and BGM 20215 have been nominated for testing in AVT (Drought Tolerant Introgression Lines) and AVT (Wilt Resistant Introgression Lines), respectively for testing in different zones. The large seeded kabuli entry, BG 3057 has been promoted to third year of testing in UP.

1.3.1.4 Breeding for resistance to soil borne diseases

One hundred and ninety-two F_6 lines were screened for soil borne diseases. Thirty-five F_6 lines were identified as resistant to both dry root rot (DRR) and *Fusarium* wilt. The yield performance of resistant breeding lines was assessed in a replicated trial. Six entries (BG 618-11, BG 618-30, BG 618-2, BG 618-12, BG 718-154 and BG 718-231) recorded high grain yield with less than 10% of disease incidence. A mapping population of 167 lines for dry root rot was also advanced to F_5 generation.

1.3.1.5 Screening of Pre-breeding lines against rust disease

One hundred and seventy-three pre-breeding lines were screened for rust disease under artificial epiphytotic condition. One of the exotic accessions, EC 556270R and one pre-breeding line (ICC-29/Cr-31) showed high degree of resistance to rust, while 21 pre-breeding lines (7225, 7244, 7246, 7254, 7294, 7302, 7303, 7304, 7307, 7309, ICC-29/Cr-1, ICC-29/Cr-13, ICC-29/Cr-16, ICC-29/Cr-21, ICC-29/Cr-36, ICC-29/Cr-41, ICC-29/Cr-43, ICC-29/Cr-44, ICC-29/Cr-47, ICC-29/Cr-48 and ICC-29/Cr-49) were moderately resistant.

1.3.1.6 Selection of kabuli chickpea genotypes for extra-large seed size and high yield

Development of kabuli chickpea combining large to extra-large seeds and greater yield potential is needed to enhance the profitability of chickpea cultivation in India. Efforts were made to develop higher yielding kabuli genotypes with better plant type and resistance to *Fusarium* wilt. During 2020-21 season, evaluation of 18 large and extra-large seeded improved breeding lines derived from diverse crosses resulted in the identification of genotypes having 100-seed weight of 45-60 g that produced 15-20% greater yield than the national check Phule G 0517 (1.46 t/ha).

1.3.1.7 Genotypes with early flowering

Time of flowering is highly sensitive to photoperiod and temperature. As a result, early flowering genotypes remain in flowering stage without any pod formation till the photoperiod and temperature become favourable, particularly in the cool and long duration environments of northern Indian plains. Early flowering has no advantage unless they are early podding also. BG 1044, BG 1054, BGD 9617, BGD 9722, BGD 9976, BGD 2608 and BGD 200104 are some of the genetic stocks that flower in 65-70 days of sowing, complete 80-90% of podding in 95-100 days and mature

Field view of early maturing chickpea genotype

in 120-125 days in Delhi. Some of these early flowering and maturing breeding lines have higher seed yield potential than the popular varieties in the region.

1.3.2 Pigeaonpea

1.3.2.1 Evaluation of determinate type pigeonpea lines

One hundred and fourty-nine advanced generation determinate Pigeonpea lines with semi-erect compact and semi-dwarf plant type have been developed and were evaluated during *kharif* 2020-21 in Augmented design (in multi row plots) for grain yield related traits and high yielding lines were selected.

Field view of PAE 1-51 line

1.3.3 Lentil and mungbean

1.3.3.1 Variety released and notified

Mungbean variety Pusa 1641: Pusa 1641 was released and notified for NCR region. Pusa 1641 outyielded Pusa 9531 (1.147 t/ha) by 13.8%, Pusa Vishal (1.160 t/ha) by 12.5%, Pant M5 (1.170 t/ha) by 11.53% and IPM 02-3 (1.172t/ha) by 11.3%. The variety was developed through single seed decent method. It showed resistance to MYMV in Northern parts of India. Pusa 1641 has an average protein content of 25.4%, which is on par with the checks. Pusa 1641 exhibited 50% flowering 36 days after sowing, it matures in 62-64 days and 100 seed weight is 4.1-4.2 g.

Grain view of Pusa 1641

1.3.3.2 Entries contributed in coordinated trials (AICRP and State trials)

Mungbean: Pusa M 1971, Pusa M 19111, Pusa M 2131, Pusa M 2132, Pusa M 214, Pusa 2171, Pusa 2172, Pusa 0871, Pusa 1501, Pusa 1571, Pusa 1572, Pusa M 1771, Pusa M 1831, Pusa M 1871, Pusa M 1931, Pusa M 1932, Pusa M 1941, Pusa M 1972, Pusa M 2071, Pusa M 2072, Pusa M 19111, Pusa M 1872 and Pusa M 2131.

Lentil: PLL 2020-1, PLL 2020-2, PLS 2020-1, PLS 2020-2, PLRF 2020-1, PLRF 2020-2, PLEE 1901, PLEE 1902, PLLS 1901, PLLS 1902, PLSS1901, PLSS1902, L 4730, L 4731, L 4772, L 4774 and L 4777.

1.3.3.3 Breeding materials evaluated and advanced

Mungbean: Thirty seven crosses were made involving trait specific donors. Fifty nine F_1s were raised. Two thousand six hundred and forty SPS in different generations were raised and evaluated.

Lentil: Forty five crosses were made involving trait specific donors. Forty four F_1s were raised. Two thousand and forty SPS in different generations were raised and evaluated.

1.3.3.4 Maintenance/ evaluation of germplasm

Mungbean: Two hundred and ten germplasm lines were raised/multiplied.

Lentil: Three hundred and ten germplasm lines were raised/multiplied. Two ICARDA nurseries LIEN Global 21 with 35 entries and LIEN SA with 36 entries were evaluated. The entries were low in biomass.

1.3.3.5 Trials conducted

Mungbean: Two station trials were conducted. In Station Trial-I, P 20-03, P 20-07, P 20-13, P 20-15, P 20-17, P 20-21, P 20-23, P 20-25, P 20-26, P 20-33 and P 20-34 outyielded check varieties MH 421, IPM 02-3, MH 02-15 and ML 818 by more than 10%. In Station Trial-II, P 20-40, P 20-46, P 20-49, P 20-51, P 20-59, P 20-60, P 20-65 and P 20-69 outyielded check varieties MH 421, IPM 02-3, MH 02-15 and ML 818 by more than 10%.

Lentil: Two station trials were conducted. In Station Trial-I, PLS 20-7, PLS 20-15, PLS 20-18 and PLS 20-23 outyielded the check varieties L 4717 and L 4147 by more than 10%. In Station Trial-II, PLL 20-7, PLL 19-11, PLL 19-34 and PLL 19-39 outyielded the check varieties L 4727 and L 4076 by more than 10%.

1.3.3.6 MYMIV resistance in mungbean

The resistance to MYMIV was found to be involving a very complicated gene network, which begins with the production of general PAMPs, then activation of various kinase-signaling cascades, and finally an expression of specific genes (like PR-proteins, defence related proteins, *etc*.) leading to resistance response.

1.3.3.7 Development of RIL (lentil and mungbean) populations for mapping of economic traits

A mungbean RIL population (PMR-1 x Pusa Baisakhi; ~350 plants) is in F_5 generation. This population (in F_7) will be used for the mapping of various QTLs through GBS approach. Two lentil RIL populations which are derived from L830 x LC300; 319 Nos and L 830 x L 4602; 212 Nos and differing for the seed size, seed coat color, maturity duration, etc. are now in F_6 generation.

1.3.3.8 Screening of lentil germplasm for nutritional quality traits

One hundred and forty- seven lentil germplasm lines were screened at 3 locations for grain Fe and Zn, phytic acid, protein content and total sugar content. Significant variation was recorded for nutritional quality traits. The association mapping will be used for these traits.

1.3.3.9 Multi-flowering in lentil

A novel multi-flowering (MF) lentil genotype, *viz*., IC 241473 was identified having up to 15 flowers per peduncle. This genotype is a ‘fasciated mutant’ line having fasciation for the stem and peduncle. The F_2 of MF based crosses *viz*., (i) PMF3 × ILL7663, (ii) PMF4 × ILL-7663 and (iii) ILL7663 (2FPP) × MFX (5FPP) showed 13:3 (χ^2 = 2.12, 0.12, 2.19; respectively) for MF: 2FPP; while for the cross ILL7663 (2FPP) x Globe (3FPP) we observed 9:7 (χ^2 = 2.69) and for ILL7663 (2FPP) × L82224 (3FPP) we found 15:1 (χ^2 = 0.78) segregation for MF: 2FPP. However, the MF × MF cross, *viz*., PMF4 (4FPP) × MFX (5FPP) showed only MF plants in the F_2 generation.

1.3.3.10 Microgreens

Twenty diverse genotypes each of mungbean and lentil were grown as microgreens under plain-altitude (Delhi) and high-altitude (Leh) conditions, which showed significant genotypic variations for ascorbic acid, tocopherol, carotenoids, flavonoids, total phenolics, DPPH, FRAP *etc*. The lentil and mungbean genotypes L830 and MH810, respectively were found superior over other genotypes. Interestingly, Leh grown microgreens were found superior to the Delhi grown microgreens, which could be due to unique environmental conditions of Leh, especially wide temperature amplitude, PAR, and UV-B content. The most abundant elements recorded were in the order of K, P, and Ca in mungbean microgreens; and K, Ca, and P in the lentil microgreens. Also, developed a microgreens kit named *TinyFields*, with the aim to popularise this innovative technology among the masses with nutritional facts.

1.4 OILSEEDS CROPS

1.4.1 Mustard

1.4.1.1 Variety released

Pusa Double Zero Mustard 33 (PDZ-11): A double low variety, possessing <2% erucic acid in the oil and <30 ppm total glucosinolates content in defatted seed meal cake was released for North Western Plain Zone including Rajasthan (Northern and Western Parts), Punjab, Haryana, Delhi, Western Uttar Pradesh and Plains of Jammu & Kashmir and Himachal Pradesh under timely sown irrigated conditions. Average seed yield of this variety is 2.644 t/ha with 38% oil content in its seeds. Average 1000-seed weight of this variety is 3.9 g. It also possesses inbuilt resistance against white rust disease.

Field view of Pusa Double Zero Mustard 33 (PDZ-11)

1.4.1.2 Entries in AICRP trials

Six entries were contributed for testing in different advance varietal trials under AICRP RM *viz*., PDZ 11 & PDZ 12 ('00' low erucic acid and total glucosinolates; promoted to AVT II Q in Zone II), LES 60 ('0' low erucic acid; promoted to AVT-I in Zone II & III), NPJ 231 (promoted to AVT-I TS Irrigated Trial in Zone IV) and NPJ 229 and NPJ 230 (promoted to AVT (E) in Zone III). Furthermore, sixteen new entries were contributed for testing in initial varietal trials (IVTs), *viz*., IVT-TS Irrigated (NPJ 241 & NPJ 242), IVT TS Rainfed (NPJ 243 & NPJ 244); IVT-Early Sown (NPJ-239 & NPJ-240); IVT-Late Sown (NPJ-245 & NPJ-246); IVT-Quality [PDZ-14 (00), PDZ-15 (00), LES 62 (0), LES 61(0)] trials. This also includes two hybrids in IHT (Pusa MH 57 and Pusa MH 61) and two entries in Uniform Disease Nursery (NPJ 247 & PMW 18).

1.4.1.3 Entries evaluated in different trials

A total of 111 pure lines (25 quality mustard, 11 under early sown, 28 under Timely Sown Irrigated, 28 under Timely Sown Rainfed and 19 under Late Sown conditions) and 29 (22 normal duration and 7 short duration) CGMS based hybrids along with the check entries were evaluated in seven mustard station trials. Sixty-nine hybrids, four CMS lines (A & B lines) and two fertility restorers were contributed for multi-location evaluation in CRP Hybrid Common Trials. A total of 236 hybrids, 45 parental lines (A/B/R) and 70 genotypes were evaluated in six trials constituted for identification of high yielding hybrids and crosses, good general and specific combiners and superior parental lines.

1.4.1.4 Breeding materials generated and evaluated

To develop conventional and better oil and seed meal quality varieties suitable for early, timely and late sown conditions, large number (436) of crosses were made, segregating populations/ progenies (1644) were raised, desirable recombinants were selected (1455) and entries were bulked for testing (154) in different trials. Direct and indirect selection approaches facilitated by conventional, biochemical and molecular methods are being used for genetic enhancement and screening of segregants/ recombinants. For low erucic acid, 2367 single plants/ bulks were analysed, of which 2187 were identified with <2% erucic acid. Single plants/ bulks, 1670 in number, from double low quality material/ progenies were also analyzed for total glucosinolates content of which 885 plants/ bulks were possessing <30 ppm glucosinolates. High oil content and bold seed size were considered for selecting the recombinants.

1.4.1.5 Wide hybridization

To create selectable genetic variability, re-synthesis of *B. juncea* was attempted by crossing *B. rapa* with *B. nigra*. Amphihaploids, thus, recovered were treated with colchicine to obtain amphidiploid *B. juncea*. Out of 48 S_2 progenies of synthetic *B. juncea*, S_3 seed from 36 selected single plants were retained. Further, resynthesized *B. juncea* lines were crossed with improved *B. juncea* lines and a total of 21 progenies were raised from these populations and nine single plants were selected for raising next generation. In addition to this, 43 progenies from multiple/ three-way interspecific crosses involving *D. erucoides/B. rapa//B. juncea* derived introgression lines were evaluated and 36 single plants were selected from these F_4/MCF_3 generations. *B. carinata* derived *B. juncea* introgression lines (191 ILs) in BC_1F_6 generations were evaluated under both irrigated and rainfed conditions at IARI, New Delhi and DRMR Bharatpur. Two BC_2F_5 progenies from *B. juncea* x Turnip (*Brassica rapa* var. *rapa* L.) crosses were raised and two single plants were selected for further evaluation. Six new crosses were also attempted between *B. juncea* and *B. rapa/ B. napus*.

1.4.1.6 Hybrid breeding

Concerted efforts were made for the development, maintenance and use of parental lines in hybrid breeding. To transfer nuclear genome from 8 genetic backgrounds to *Ogu* cytoplasm crosses (BC_1/BC_3) were attempted. Twenty-eight nuclear backgrounds in different sterility inducing cytoplasms, *viz.*, *Moricandia arvensis* (*mori*), *Diplotaxis erucoides* (*eru*) and *Diplotaxis berthautii* (*ber*) were maintained by attempting three paired crosses each with the pollen tested plants. A total of 56 CMS lines were maintained and used in hybrid seed production. To convert maintainers into fertility restorers BC_5F_2 and BC_6F_2 generations were raised and homozygous dominant plants from 28 nuclear backgrounds were identified through microscopic examination and selfed. Sixty-eight fertility restorers were used and maintained by raising 215 progenies. Single plants from the selected progenies were selfed for their maintenance. Furthermore, 329 test crosses were also generated through hand pollination to identify heterotic combinations and good combiners.

1.4.1.7 Shuttle breeding for incorporating disease resistance

The segregating material is being shuttled between IARI, New Delhi (favourable environment) and IARI, Regional Station, Wellington (hot spot) to develop white rust and powdery mildew resistant *B. juncea* genotypes. A total of 13 and 6 crosses were attempted to incorporate white rust and powdery mildew resistance into improved genetic background, respectively, and 6 populations were generated to combine resistance in improved backgrounds. Furthermore, three crosses (9 SPS) were advanced from BC_2F_2 to BC_2F_3; four crosses (16 SPS) from BC_3F_2 to BC_3F_3 and nine crosses (22 SPS) from BC_1F_2 to BC_1F_3 for transferring powdery mildew resistance from PMW 18 to popular Indian mustard cultivars, *viz*. Pusa Mustard 25, Pusa Mustard 28, Pusa Mustard 29, Pusa Mustard 30, Pusa Mustard 31, NRCDR 02, NRCHB 101 and Giriraj. For conducting test of allelism a set of 32 F_1s was made by crossing five white rust resistant Indian mustard accessions (WRW 28, WRW 29, WRW 41, WRW 206 and Ooty collection) suspected to contain "new" genes with known donors (Heera, Donskaja and PDZM 31). Their F_1s and F_2s will be raised at Wellington, Tamil Nadu.

1.4.1.8 MAS for white rust and quality traits

Molecular markers linked to white rust and oil quality traits were screened in 57 backcross populations generated for introgression of white rust resistance, low erucic acid and/ or glucosinolate traits in different promising Indian mustard varieties/ genotypes, *viz*., Pusa Mustard 21, Pusa Mustard 22 and Pusa Jagannath. Based on genotyped data for the three traits *viz*., white rust, erucic acid and glucosinolates, 12 backcrosses were also attempted with the respective recipient parents. Fresh F_1s were also generated to introgress white rust resistance, low erucic acid and/ or glucosinolates traits in high yielding varieties, namely Pusa Mustard 25, Pusa Mustard 26 and Pusa Mustard 32.

1.4.1.9 Germplasm maintenance and evaluation

A total of 766 germplasm lines including 718 *B. juncea*, 18 accessions of related species [*B. nigra* (11), *B. rapa* (1), *Eruca sativa* (1), *B. napus* (2) and *B. carinata* (3)], and 30 accessions of wild relatives were evalauated and maintained through selfing/sibmating.

1.4.2 Soybean

1.4.2.1 Variety released

Pusa Soybean 6 (DS 3106): It has been released and notified for Delhi NCR region. It has shown higher and stable yields over all the three checks, *viz*., SL 688

(23.73%), PS 1347 (5.4%) and Pusa 9712 (20.21%). DS 3106 has resistance against yellow mosaic virus (YMV), *Rhizoctonia* Arial Blight (RAB) and Bacterial Pustule (BP). It has high oil content (20.08%) and matures in 120-125 days with an average yield of 2.1 t/ha.

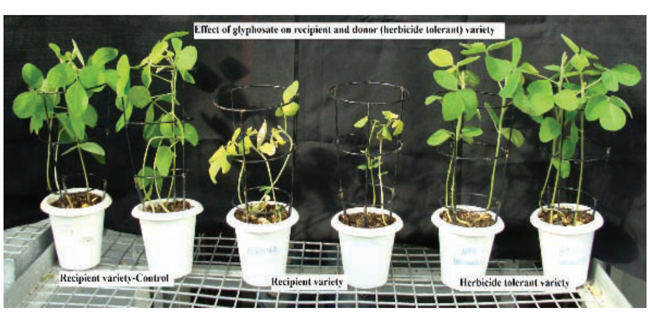
Grain view of Pusa Soybean 6 (DS 3106)

1.4.2.2 Entries in AICRP trials

DS1312, DS3124, DS3163, DS3168 (NIVT), DS9421 and DS9422 (AVT-I) were evaluated in AICRP trials.

1.4.2.3 Development of herbicide (glyphosate) tolerant soybean genotypes

Weed causes significant loss of yield in soybean. Glyphosate, a broad-spectrum herbicide, can effectively control the weeds. A massive programme has been initiated to introgress herbicide tolerance in seven Indian soybean varieties *viz*., JS20-34, JS335, JS9560, JS20-69, JS 20-29, JS20-98 and DS9712 through marker-assisted backcross breeding approach. The S14-9017GT, an American soybean variety, has been used as the donor of herbicide tolerance gene *EPSPS*. During *kharif* 2021, crosses were attempted and F_1 seeds have been harvested from all the seven cross combinations. While sprayed with herbicide glyphosate, the F_1 plants and the donor variety S14-9017 survived, while the recipient Indian varieties turned yellow with herbicide injury. The development of BC_1F_1 seeds is in progress.



Effect of herbicide (glyphosate) on the recipient and herbicide tolerant (donor) variety of soybean

1.4.2.4 Development of KTI-free soybean genotype

Two specialty-soybean genotypes, *viz*., DS9421 and DS 9422 have been developed through marker-assisted backcross breeding (MABB) programme. The genotypes are being tested in Advanced Varietal Trial-I under AICRP-Soybean during *kharif* 2021 in the North Plain Zone of India.

1.4.2.5 Development of KTI and lipoxygenase-free soybean genotype

The development of soybean genotypes free from KTI and lipoxygenase are in progress. The NILs in BC_2F_4 generation were tested during *kharif* 2021. Selected lines have been sent for generation advancement during off-season at IARI RS, Dharwad centre.

1.4.2.6 Screening for rust resistance and tolerance to pod borer

Forty soybean germplasm lines were screened for rust resistance and tolerance to pod borer (*Cydia pytchora*) under natural epihytotic conditions during

Rust resistant line identified in screening under natural epiphytotic conditions at the hot spot

kharif 2021 at IARI regional centre, Dharwad. One line (GP 38) was identified as moderately resistant to rust (rust score 20.33%) and three lines (GP 14, 18 and 19) recorded very low pod borer damage (<1% pod damage).

1.4.2.7 Screening advanced breeding lines to identify MYMV resistant genotypes

The data was recorded on MYMV incidence on 92 genotypes and 5 check genotypes. Out of 92 genotypes screened for incidence of MYMV ten *Glycine soja* derived lines (GSDL) were found to be resistant to MYMV while seven *G. max* (L.) Merrill lines (DS1565, DS1567, DS1568, DS1569, DS1571, DS1572 and DS153) were completely immune to MYMV. All the checks were resistant to MYMV.

1.4.2.8 Genetic improvement of vegetable soybean

A set of 15 vegetable soybean genotypes has been obtained from the World Vegetable Centre, Taiwan. A few vegetable genotypes have been used in breeding program to improve its quality by making it free from off-flavour. The F_1 plants of the cross involving PI496540, donor of null-allele of lipoxygenase (*lx2*) and the vegetable soybean have been tested for hybridity and the backcrossed to develop BC_1F_1 seeds. The programme is being carried out under controlled condition following the techniques of speed breeding. Further, genetics of seed size and seed coat color has also been studied with the vegetable soybean genotypes.

1.5 SEED SCIENCE AND TECHNOLOGY

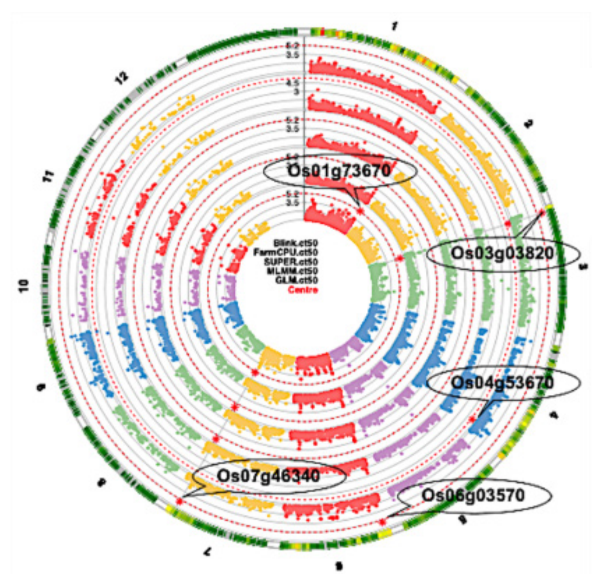
1.5.1 Seed quality traits

1.5.1.1 Seed dormancy in rice

Seed dormancy in rice varieties is a required trait in case of unfavourable weather conditions during seed maturation and harvesting. It has been studied in the F_5 generation in 3 crosses involving varieties with fresh seed dormancy (Basmati 370) and relatively non-dormant varieties (Annada, IR 64 and Jaya). Fresh seed dormancy was observed in some of the F_5 plant progenies. Selected F_5 seeds with fresh seed dormancy were grown in 4 lines for each F_4 plant. After harvesting the seeds were evaluated for fresh seed dormancy and at 3 months after harvesting keeping the seeds at ambient conditions. Most of the selected F_5 derived F_6 progenies showed fresh seed dormancy (more than 70%) indicating the transfer of dormancy trait from the donor parent to the recipient parents and the positive effect of selection for the trait. A total of 15 plants selected for fresh seed dormancy will be studied in the next generation.

1.5.1.2 Identification of QTLs/ genes associated with early seedling vigour characters in rice

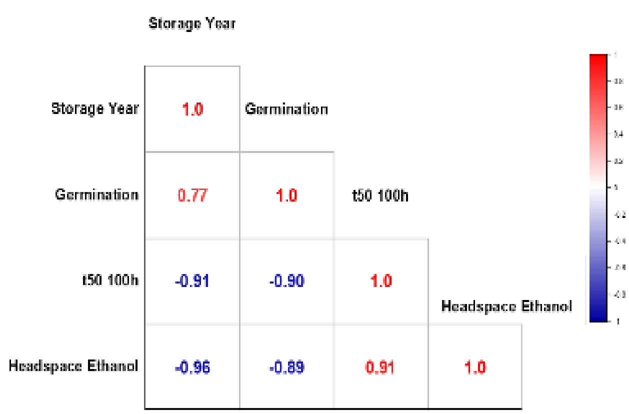
Genome Wide Association analysis for the time to 50% lemma rupture in rice using the SNPs established the association of three genes on chromosome 3 (LOC_Os03g03820), chromosome 6 (LOC_Os06g03570) and chromosome 7 (LOC_Os07g46340). The allelic effect of LOC_Os03g03820 was found to be 20.09 and that of other two genes LOC_Os06g03570 and LOC_Os07g46340 was found to be -6.39 and 13.71, respectively. The identified genes were further subjected to confirmational studies through in-silico transcriptome analysis using the data available in the public domain and found that LOC_Os03g03820 was associated with lemma rupture in rice during seed germination.



GWAS analyses for time to 50% lemma rupture in rice

1.5.1.3 Headspace Ethanol Assay: Biomarker for early vigour loss in rice seeds

A simple assay to measure head-space ethanol using modified breath analyser for early seed vigour loss in fresh and aged seed lots of rice was validated. Nine different seed lots harvested under different years and subsequently stored under laboratory conditions were used to correlate the vigour loss by recording seed germination parameters (total germination and speed of germination) and headspace ethanol accumulation. The result showed that aged low vigour seed lots had highest headspace ethanol accumulation with significant high negative correlation for storage year and total germination and high positive correlation for t50 (in h) values.



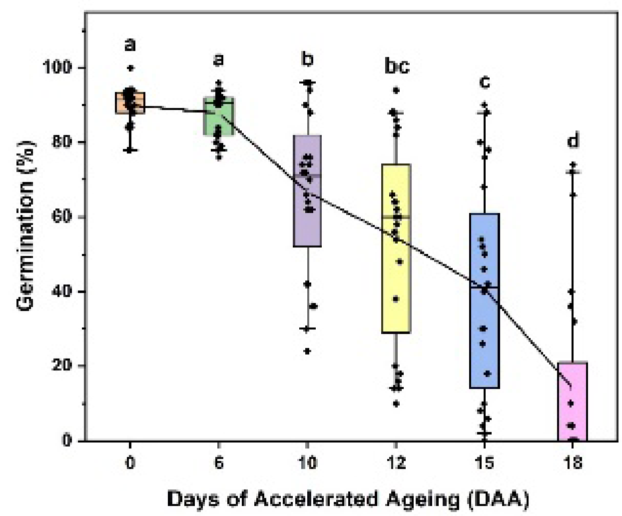
Pearson's pairwise correlation plots for seed germination parameters and headspace ethanol accumulation from 9 different rice seeds lots.

1.5.1.4 Screening of maize QPM lines for better germination and vigour

Twenty-eight QPM inbred lines having distinguishable seed morphological characters were screened for germination and vigour using 29 vigour related parameters. The PCA followed by Hierarchical Clustering on Principal Components helped in the identification of seven genotypes with high vigour. Further analysis resulted in the identification of six genotypes with no significant difference for vigour. These genotypes can be used in developing QPM hybrids with good seed vigour.

1.5.1.5 Variability for seed longevity among field corn inbred lines

Eight field corn inbred lines were subjected to accelerated ageing at 42°C and 75% RH up to 18 days. The results indicated large variation among inbred lines for percentage seed germination over the ageing period. The mean seed germination value declined to 54% at 12 DAA (days of accelerated ageing). From among the inbred lines, AI 501 showing medium initial seed vigour (Seedling Vigour Index-II of 4043) maintained high germination (71%) even after 18 DAA, while PML 105 exhibiting high initial seed vigour (SVI-II of 5136) completely lost germination at 18 DAA.



Variability for seed longevity among field corn inbred lines

1.5.1.6 Seed quality in double zero *B. juncea* genotypes differing in seed coat colour

Seed germination and vigour were significantly affected by seed coat colour in *B. juncea* genotypes. Seed germination percent in black seeded genotypes was 92%, while 89% in yellow seeded genotypes. Similarly, genotypes with darker seed coat colour were more vigorous when compared to genotypes with lighter seed coat as revealed by seedling vigour index and electrical conductivity. Differential response to seed imbibition to water was observed in different compositional groups. Quality mustard genotypes imbibed more water than conventional genotypes. Imbibitional behavior was also influenced by seed coat colour. Darker the testa colour, less is the imbibitional damage and this decreased imbibitional injury may cause less stress on the membrane integrity, which ultimately increases the seed vigour.

1.5.1.7 Reserve mobilization during seed germination in Indian mustard

Starch mobilization starts earlier than lipid mobilization. The percent of starch and protein utilized during the period of germination was highest in conventional mustard and they showed a positive correlation with various seed quality traits including Seedling Vigour Index-I. While, percent lipid utilized was highest in double zero mustard and it showed a negative correlation with Seedling Vigour Index-II. Maximum percentage of lipid was utilized during 7 days period of germination followed by starch and protein.

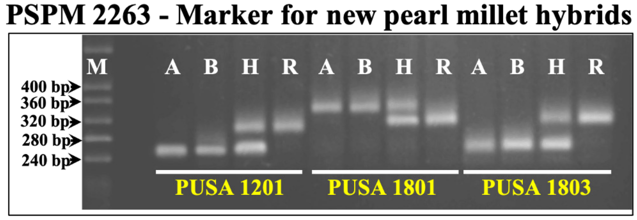
1.5.1.8 Basis of phenol colour variation in wheat seeds

In order to understand biochemical basis of phenol colour reaction in wheat, experiments were conducted to evaluate 57 wheat varieties and 15 wild species accessions belonging to different genomic constitution using rapid chemical test. Majority of varieties showed 80-90% grains with colour reaction in dark brown and light brown groups, in others it was above 90%. Phenol colour reaction in the growing grains was observed a week after anthesis. No significant difference in phenol colour in seeds within a plant *i.e.,* inter-earhead and intra-earhead in a variety was observed. The phenol content in different ear-heads in a plant and seeds at different positions of an ear-head in a variety indicated non-significant differences. Further, polyphenol oxidase activity in the seed coat governed by tyrosinase enzyme and other substrates like pyro-catechol and L-DOPA were studied. The polyphenol activity and phenol content along with phenol colour per cent have shown higher values in old seed lots of varieties than that in fresh seed lots. A significant difference in phenol content, L-DOPA, tyrosinase and pyrocatechol activity was found among the varieties and species belonging to different phenol colour groups. Diploid species showed higher values of PPO and phenol content in all the colour groups. The results of the study indicated that wheat varieties showed a very high level of phenol colour reaction to its seeds corresponding to the phenol content and polyphenol oxidase activity. This information would be useful in clearly characterizing a wheat variety for phenol colour reaction and in determining varietal admixture.

1.5.2. Application of DNA markers for ensuring the seed purity

Developed and validated the SSR based DNA marker (PSPM 2263) for establishing the identity and to ensure the purity of pearl millet hybrids (Pusa 1201, Pusa 1801 and Pusa 1803) and respective parental lines.

PSPM 2263 - Marker for new pearl millet hybrids



1.5.3 Seed priming

1.5.3.1 Effect of thermo-priming on seed quality and yield in pigeonpea under heat stress conditions

Thermo-priming significantly increased field emergence in pigeonpea var. Pusa 991 (20.2%) and Pusa 992 (52%) over the respective controls. The plant stand establishment was also increased due to thermo-priming to the extent of 8.9 and 7.8% in Pusa 991 and Pusa 992, respectively over control. While, thermo-priming enhanced seed yield to the tune of 19.7% in Pusa 991 and 5.2% in Pusa 992 over respective controls.

1.5.3.2 Use of nano-particles in enhancing seed quality and storability of soybean seeds

Two soybean varieties namely DSb21 and DSb23 were treated with both nano and bulk form of three different nano-particles, *viz.,* zinc oxide, titanium and silicon dioxide at five different concentrations, *viz.,* 100, 250, 500, 750 and 1000 ppm. Seeds treated with nano ZnO @ 500 ppm showed higher primary root length and better lateral root growth development as compared to other treatments.

1.5.4 Seed production technology

1.5.4.1 Standardization of hybrid seed production technology in Sponge gourd

Planting ratio of 4: 1 (female: male) was found to be optimum for hybrid seed production of Pusa Shreshta under Delhi conditions. Pollination should be undertaken between 6:00 to 10:00 am for higher fruit set and seed yield. Further, foliar spray of GA_3 @ 150 ppm at 2-3 leaf stage and 4-5 leaf stage improved vegetative growth, flowering behaviour, sex ratio, fruit traits, seed yield and quality traits.

1.5.4.2 Synchronization of flowering in parental lines of Pusa Cauliflower hybrid 3

In the mid-maturity hybrid, Pusa Cauliflower Hybrid 3 has been identified and released for cultivation. The parental lines of Pusa Cauliflower Hybrid 3 showed non-synchronization of flowering for 10-12 days (male parent is late) that can be bridged by application of growth regulators. GA_3 @100 ppm and IAA @ 50 ppm sprayed thrice at 7-day interval starting bolting stage to the late parent of the cauliflower hybrid synchronized flowering between the parental lines.

1.5.4.3 Effect of planting geometry and micronutrient application on seed yield and quality of Pusa Parthenocarpic Cucumber-6

Planting geometry of 100 cm x 45 cm, along with foliar spray of nano formulation zinc + boron @ 1 ml/l at two stages [vegetative stage @ 15 DAT) and reproductive stage @ 22-25 DAT)] was effective in optimizing seed yield and quality in this hybrid.

1.5.5 Effect of abiotic stress on seed yield and quality

1.5.5.1 Seed water and temperature relations with germination in rice

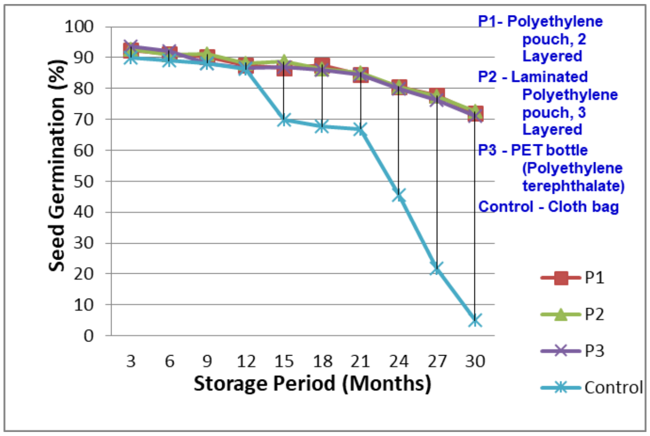
Two contrasting rice genotypes, N22 and IR64 (tolerant and susceptible for drought and heat tolerance, respectively), were subjected to five different temperatures (T) and six different water potentials (WP). The germination capacity decreased with a reduction in water potential. The N22 and IR64 genotypes behaved differently at -0.8 MPa, and lower water potentials under the studied temperatures. The FPHF model helped to distinguish the varietal response to T and WP combination based on the area under the germination rate curve (AUC). The time at maximum germination rate was lower at 35°C than other tested temperatures. Thus, the combination of 35°C and -0.8 MPa could be used to screen the abiotic stress tolerance at the germination stage in rice.

1.5.5.2 Effect of high temperature on seed yield and quality in wheat varieties

Lower seed germination per cent as well as reduced seedling vigour was recorded under heat stress condition as compared to normal sown conditions. Based on the results of morphological traits, yield and its contributing traits, physiological, biochemical and seed quality parameters, it was found that varieties, namely, HD 3086, HD 3171, HD 3117, HD 3118 and HD 3090 were heat tolerant. Therefore, these varieties can be grown for quality seed production of wheat under heat stress condition.

1.5.5.3 Effect of packaging material and seed moisture content on seed longevity in onion cv. Pusa Riddhi under ambient conditions

Three-year study on improving storability of onion seed under ambient storage conditions was concluded. Processed seed (*rabi* 2016-17) of onion cv. Pusa Riddhi at three different moisture contents (m.c.) 3.4, 5.1, 7.4% were packed in three different packing materials, i.e. two layered polyethylene bags, three layered polyethylene bags, PET bottles and in cloth bags. Seed with initial moisture content of 7.4% and packed in cloth bags served as control. Samples were drawn at every three months interval to study seed moisture and standard germination. The results of this study indicate that onion seed stored in cloth bags retained germination above IMSC limits only up to 12-month of ambient storage. However, onion seed packed in polyethylene bags and PET bottles can be safely stored for 30 months under ambient storage conditions. There was no significant difference on seed germination in three different initial seed moisture levels.



Effect of packaging material on storability of onion seed under ambient conditions

1.5.5.4 Standardization of sieve size for mechanical seed processing of *Palak*

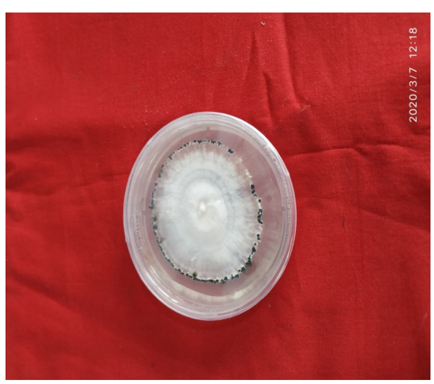
Six treatment combinations of two upper (4.00 and 5.00r) and three lower (2.50, 2.60 and 2.75r) sieve sizes including recommended ones (upper –5.00r and lower – 2.50r for sharp seed) were tried at seed cleaner cum grader for getting the maximum recovery of pure live seed of *palak* cv. All Green. Treatment combination of 4.00r upper and 2.75r lower sieve size was found most effective with 84.3% seed recovery and processed seed met the physical purity IMSC standard of 96.0% as against 87.3% of raw seed. The processed seed also met the Indian Minimum Seed Certification Standards of germination (60.0%).

1.5.6 Seed health

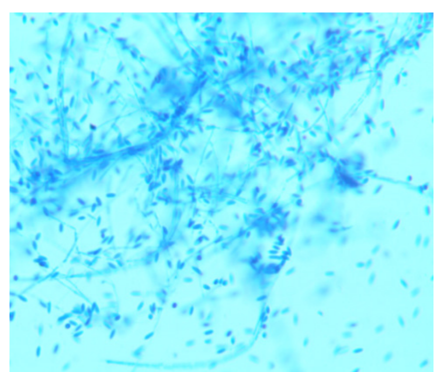
1.5.6.1 Pathogenic association of *Albifimbria terrestris* with rice seeds

A peculiar black coloured spore mass was observed attached to the seeds in seed samples of popularly cultivated short duration variety PR 126. White coloured fungal cultures with dark green to black stroma/sporodochia were obtained in the culture plates. Black stroma/sporodochia appeared in concentric rings. The cultures obtained were identified as *Myrothecium sp* based on microscopic observations. For the molecular identification, ITS region between rDNA of chromosomes was amplified by using ITS 1 (5′-TCCGTAGGTGAACCTGCGG-3′) and ITS 4 (5′-TCCTCCGCTTATTGATATGC-3′) primers and has been sequenced by Sanger's sequencing technique. The first nine alignments for ITS regions had 98.92% similarity to *Albifimbria teresstris* (NR 153549.1) by using Blast, NCBI and deposited in NCBI gene bank (Accession number MT 549897). Various species of *Albifimbria* have pathogenic potential as they are associated with the diversity of crops causing severe losses that can be transmitted through soil and seeds. Pathogenic association of *Albifimbria terrestris* with rice seeds has been reported and this work has been carried out in association with PAU Ludhiana.

Inoculated panicles showing sheath rot like symptoms in rice panicles



Culture obtained from infected panicles



Sporulation of *Albifimbria*

2. HORTICULTURAL SCIENCES

Horticultural production in India has shown phenomenal increase both in cultivated area and production since 2013-2014 and is maintaining the annual growth of about 4%. Due to this, changing trends has begun in the country towards sustainable nutritional security, besides creating opportunities for livelihood security as outlined in SDGs. The School of Horticultural Sciences was created in 2013 by reorganizing the School of Crop Improvement. Presently, focused attention is being made on genetic improvement; developing technologies for efficient and cost saving production and resource management strategies and diverse value addition. A number of improved varieties/ rootstocks in different horticultural crops having been identified and notified at State and Central levels for different agro-ecological zones. These improved genotypes have high yields, besides better biotic and or abiotic stress tolerance, high nutraceautical properties and processing attributes have been developed. Emphasis is also on use of wild and related species in pre-breeding for evolving desired genotypes. New genotypes have been identified in several crops for their release by the AICRP, Delhi State and Institute levels. Technologies for quality planting material and seed production and efficient production technologies have also been developed. Efforts have been made to integrate conventional strategies along with molecular technologies in achieving precision in breeding.

2.1 VEGETABLE CROPS

Varieties notified for vegetable Crops

***Dolichos* bean: DB-5**: It is a pole type medium maturing variety identified for release in Zone-V (Odisha, Andhra Pradesh and Chhattisgarh). It possessed field resistance to anthracnose, *Cercospora* leaf spot and moderately resistant to golden mosaic virus. Pods are dark red, thick, flat, soft, smooth, pod length 10-11 cm, width 2.5-2.8 cm having 5 seeds/ pod with 10-pod weight ranging from 90-100 g. It gave the zonal average pod yield of 15-20 t/ha.

Carrot: Pusa Prateek (IPC-3): It has been released for Zone VI (Rajasthan, Gujarat, Haryana and Delhi) and Zone VIII (Karnataka, Tamil Nadu, Kerala and Puducherry) with an average root yield of 30 t/ha. It is ready for harvesting after 85-90 days after sowing. The average root length is 20-22 cm and root weight ranges from 100-120 g. The external & internal root colour is red with small self-coloured core.

Carrot Pusa Prateek (IPC-3)

Muskmelon Pusa Kazri (DMM-148): It is an early maturing muskmelon variety with average yield of 22.73 tonnes/ha and having tolerance to *Fusarium* wilt.

Muskmelon Pusa Sunehari: It is a specialty melon (*C. melo* var. *inodorous*) variety suitable for protected cultivation with an average yield of 5.5 tonnes/1000 square meter having very long shelf-life.

Varieties identified by AICRP (VC)

Muskmelon DMH-5 (F_1): It was identified by XXXIX Group meeting of AICRP VC for release in Zone VII.

Bittergourd DBGH 542 (F_1): The hybrid was identified for cultivation in Zone I (Humid Western Himalayan Region, *i.e.* Jammu & Kashmir, Himachal Pradesh and Uttarakhand). It is suitable for spring-summer season in open field conditions with higher female to male flower ratio. Fruits have desirable marketable attributes and are attractive green with average fruit length of 16.5 cm and diameter 5.0-5.5 cm with smooth surface. First fruit harvesting starts in 45-50 days after sowing with average fruit weight of 75 g. Average fruit yield is 25.5 t/h.

Field view of DBGH 542

Varieties Identified by IARI Variety Identification Committee

Tomato: (Pusa Rakshit (DTPH-60) and Pusa Golden Cherry Tomato-2 & Pusa Tomato (Protected)-1: These varieties were identified for cultivation under protected environments for growing in Delhi & NCR.

Brinjal: Pusa Hara Baingan 2: Fruits are long (25 cm) and green in colour. Average fruit weight is 100 g, while average yield is 385 q/ha. It is very rich in total phenols (97.72 mg GAE/100 g) and antioxidant (CUPRAC-131.83 mg GAE/100 g, and FRAP-160.47 mg GAE/100 g).

Fruits of Pusa Hara Baingan 2

Brinjal: Pusa Safed Baingan 2: Fruits are white and long (15-20 cm). Average fruit weight is 80-100 g. Average yield is 400 q/ha. It is rich in total phenols (97.72 mg GAE/100 g) and antioxidant activities (CUPRAC-94.20 mg GAE/100 g, and FRAP-100.93 mg GAE/100 g).

Fruits of Pusa Safed Baingan 2

Parthenocarpic gynoceious Pusa Pickling Cucumber-8 (DG-8): Fruits have desirable marketable attributes and are attractive, uniform, dark green, glossy, cylindrical, straight, ribbed, and warty with prickles, thus is highly acceptable to the growers. Average fruit length is 8.5 cm and width of 2.0 cm. Average fruit weight is 18-20 g. Average fruit yield 84.9 t/ha (849 kg/ 100 m^2) during winter season (off-season, November-March) under low-cost polyhouse, which is 19.2% superior over Annaxo.

Pusa Pickling Cucumber 8

Bitter gourd: Pusa Hybrid-5 (DBGH-159): It is suitable for spring-summer season in open field conditions with higher female to male flower ratio (2:1). The fruits have desirable marketable attributes and are attractive green with average fruit length of 15.5 cm and diameter 6.0-6.5 cm with 5-6 discontinuous narrow ridges. First fruit harvest is achieved in 44-48 days after sowing with average fruit weight of 70 g. Average fruit yield is 24.5 t/h, which is higher (22%) than the national checks (Pusa Hybrid-2 and NBGH-167). The notification is under process by CVRC.

Pusa Hybrid-5

Sponge gourd: Pusa Sponge Gourd-29 (DSG-29): It is the first *ToLCNDV* resistant sponge gourd variety for *kharif* cultivation under North Indian plains. Fruits have desirable marketable attributes and are attractive, uniform, dark green, elongated, cylindrical, 22-24 cm long, average fruit weight is 105-110 g, with superficial ribs, thick skin, smooth texture and white flesh, which is highly acceptable to consumers. Average fruit yield is 17.8 t/ha. It is highly resistant under natural field condition with vulnerability index of 8.5.

Pusa Sponge Gourd-29

Satputia: Pusa Tripti (D Sat-4): It is suitable for summer and *kharif* season under North Indian plains. The fruits are ready for first harvesting in 48-50 days and 42-45 days after sowing during spring summer and *kharif* seasons, respectively. The fruits are elliptical elongated, 9-10 cm, dark green with intermediate skin lustre, superficial ribs and have soft flesh at edible maturity stage. Number of fruits per cluster ranged from 5 to 6 with average fruit weight of 20-22 g. The average fruit yield was recorded as 15.0 t/ha.

Pusa Tripti

Summer squash Pusa Shreyash (DS-17): It is suitable for growing during winter season (off-season) under naturally ventilated polyhouse (Mid-October to Mid-February) and early spring summer season under insect proof net house (February to April) under North Indian plains. Fruits are flattish-round, weighing 370-420 g, green skin colour and mottles like pumpkin,

Pusa Shreyash

grooves & warts absent, weak ribs, size of flower scar is medium to large and has tender flesh at edible maturity stage. Average fruit yield is 21.0 t/ha.

2.1.1 Solanaceous crops

2.1.1.1 Tomato

Screening and evaluation of ToLCD tolerant genetic stocks: Under genetic enhancement of released varieties using *Solanum habrochaites* (LA1777), F_4 progenies (35) were screened for ToLCD tolerance during *kharif* 2021. The plants promising for ToLCD tolerance (<5.0 %), yield (>55 t/ha) and quality traits (brix-yield: >25 q/ha) during spring-summer 2020-21 and autumn-winter 2021, were selected for further station trials and utilization in F_1 development. The progenies were genotyped and found to carry *Ty-3* gene, which is effective for tolerance to ToLCD caused by bipartite begomo-viruses including ToLCNDV. These genetic stocks will be screened for tolerance to late blight, *Fusarium* wilt, red spider mites, fruiting at high temperature (> 35^{0}C) and low-temperature (<8.0^{0}C).

Two entries identified as promising for ToLCD resistance were promoted to AICRP (VC) IET-1 trials, while two were promoted to AVT-II trials. A total of 58 F_1s including 35 for ToLCD and 23 with improved processing traits were developed. Further, eight parental lines with improved processing traits including ToLCD tolerance (<5% incidence, yield: >60 t/ha, TSS >5.0^{0}Brix) were identified. Among these two lines, MAS TOLCV-2, a short duration line (<90 DAS), short plant height suitable for growing without stacking (<70 cm), high temperaturefruit set (35^{0}C), was found suitable for kitchen gardening as well as open field cultivation.

Tomato hybrids for Protected Environment: About 21 tomato hybrids alongwith commercial hybrid GS-600 were evaluated under protected conditions. Hybrid DTPH-60 recorded the total yield of 16.5 q from 100 m^{2}area, high TSS (5.1^{o}Brix) and desirable lycopene (6.0 mg/100 g) content with average fruit weight of 105 g under protected conditions. Hybrid DTPH-60 was also evaluated at farmer's field/ research stations of various institutes and the performance was superior. Five cherry tomato selections and three hybrids were also evaluated. Sel.1 recorded prolific bearing with average fruit yield of 10.5 q/100 m^{2}area along with high TSS 10^{0}Brix. Cherry Sel. 3 had orange colour fruits with average yield of 8 q/100 m^2 area and TSS 8.5^{0}Brix.

Selection of promising tomato lines

Selection-29: A natural virus tolerant line Sel. 29 was identified and stabilized through single plant selection from a segregating population germplasm line EC-538421. The plants of Sel. 29 showed indeterminate growth habit (around 200 cm) with slightly serrated leaves. The fruits are large (73.5 g) and "desi type" with groves. The plants show heavy fruiting with an average number of 80 fruits/plant and TSS of 5.67 ^{o}Brix.

Selection-25: A dwarf line with large size fruits isolated from Pusa Gaurav. It is indeterminate (55-60 cm) with heavy fruit bearing with field tolerance to leaf curl virus disease. Fruit weight varies from 70-75 g with moderate TSS 4.3-4.5ºBrix.

Selection-11: Isolated from line EC-538421, it is very sweet fruited line having high TSS (6.9-8.5 ^{o}Brix), useful for processing with indeterminate growth (height around 150 cm) and heavy fruiting.

2.1.1.2. Brinjal

Promising lines: Two lines, DBR-160-32-4-5 (450 q/ ha) and DBPiL-186-3-13-3 (390 q/ha) were found

DBR-160-32-4-5

very promising. A white fruited line, DBWR-190-44-3-2-5 was found superior for yield and quality (total phenolics of 45.23 mg GAE per 100 g FW). Three lines, namely, DBL-21, DBL-08 and DBL-175-5-1 were found to be heat tolerant.

Promising hybrids: Among the hybrids, DBHR-175 (round fruited; 645 q/ha) and DBHR-326 (round fruited; 600 q/ha) were found superior.

Screening for *Fusarium* wilt resistance and genetic analysis: A total of 180 F_2 plants from a cross of DBL-186 (susceptible) and DBR-40-7-10-5 (resistant) were phenotyped, which segregated in 3: 1 ratio, suggesting the control of single dominant gene. Among the lines, DBR-160-2-3-1-3 was found highly resistant with DI of 0. Among the wild accessions, *S. sysimbrifolium* (EC-390352), *S. macrocarpum* (EC-874750022 and EC-790354), *S. aethiopicum*, and *S. torvum* were found to be highly wilt resistant.

Screening for Phomopsis blight and nematode resistance: Among the evaluated lines, BR-40-7-3-2-1, DB-175 and DBR-112-14 were found to be *Phomopsis* blight resistant after artificial inoculation. F_1s also showed resistance reaction. The wild accessions, namely, *S. torvum* and *S. sysimbrifolium* were found to be nematode resistant.

Biochemical estimation of hybrids and parental lines: Among 45 hybrids, maximum anthocyanin content was estimated in DBHR-25407 (168.85 mg/ 100 g), total phenolics was highest (182.79 mg GAE/ 100 g) in DBHR-25, CUPRAC and FRAP assays were highest in DBHL-1407 (82.24 and 75.72 mg GAE/100 g, respectively).Among the parental lines evaluated, NDB-25 was found to be highest for all the biochemical traits evaluated, *viz.*, total monomeric anthocyanins (96.6 mg/100 g), total phenolics (86.72 mg GAE/100 g), and antioxidant activities (CUPRAC: 73.63 and FRAP: 81.40 mg GAE /100 g).

Promising genotypes for desired biochemical contents: Twenty five genotypes were evaluated for biochemical content. The highest total phenolics were observed in DBR-03 (224.32 mg/100 g GAE FW). Among the antioxidant assay,DB-10 recorded the highest FRAP value (160.92 mg/100 g GAE FW). The ascorbic acid content was highest in G-164 (2.77 mg/100 g GAE FW), while the total flavonoids was highest (45.90 mg/100 g GAE FW) in DBOR-94, respectively.

Anthocyanin profiling of parental lines: Anthocyanin profiling of the 10 parental lines of used for the development of hybrids, showed high predominance of the anthocyanin fraction Nasunin [Delphinidine-3-(p-coumaroylrutinoside)-5-glucoside)].

2.1.1.3 Chilli

Promising Varieties/ Hybrids: One promising line, DChV-92 was promoted to IET trials ofAICRP (VC). About 46 hybrids were evaluated for yield traits. Two hybrids, DChH-56 and DChH-10 gave a yield of 10.2 and 9.8 t/ha, respectively. Six genotypes, DChV 39, DChV 42, DChV 47, DChV 74, DChV 69 and DChV60 gave a yield of 650, 670, 625, 600, 595 and 590 g/plant, respectively, during *kharif*, 2021. The National check -Kashi Anmol produced a yield of 590 g/plant.

Phenotypic screening of advanced lines for resistance to leaf curl disease under natural epiphytotic conditions: Advanced breeding lines, namely, DChV 39, DChV63 and DChV 42 were found to be resistant to leaf curl disease with a disease severity score of 21.2, 36.7 and 40%, respectively, whereas the susceptible lines Phule Mukta and Chilli Kashmir Long showed the disease score of 100%.

Development of intergeneric crosses between *Solanum pseudocapsicum* and *Capsicum annuum*: *Solanum pseudocapsicum* was found to be resistant to leaf curl disease both under natural epiphytotic conditions and through challenge inoculation. Attempts were underway to develop intergeneric crosses with *C. annuum*. Successful F_1s could be generated with one genotype (AS-15), and the hybridity of it could be confirmed with the molecular markers.

Phenotypic evaluation of cold tolerant lines: The cold tolerant genotypes, namely, DLS-CT-IR2-1, DLS-P-1R-3, DLS-L-2R-5 and DLS-CT-IR2-2 were identified during 2020 were further evaluated for their performance during December, 2020 to January 2021. These lines had good chlorophyll retention capacity where as other lines showed severe yellowing, normal flowering and some fruit set compared to susceptible genotypes under low temperature conditions. However, the fruit size reduced and developed purple pigmentation under low temperatures. The reduction in fruit size was 31%, 43%, 40% and 45% for CT-IR2-1, DLS-P-1R-3, DLS-L-2R-5, and DLS-CT-IR2-2 I, respectively.

Selection of promising chilli line: Selection-1 (Seln-1) was identified as a variant from EC783760 for bright attractive colored fruits, which is unique from the parental line. Seln.1 bears dark red colored fruits with less pungency, which makes it better utility for colouring purpose in culinary. The light purplish unripe fruits of Seln 1 turn orange initially and then change to dark red upon complete ripening.

2.1.1.4 Capsicum

Identification of high temperature tolerant lines: Lines, KTC-152, KTC-120 and KTC-130 were promising for high fruit set with good quality traits. The F_1 hybrids like KTC-130 × YW, KTC-142 × YW and KTC-152 × KTC-131 were also promising for fruit set at high temperature. The line KTC-144 (850 g/plant) followed by KTC-130 (810 g/plant) and CW (check) 790 g/plant were good yielder. Out of 37 hybrids evaluated, hybrid KTC-130 × CW (950 g/plant) followed by KTC-142 × KTC-145 (910 g/plant) and KTC-130 × YW (890 g/plant) were promising for yield per plant. Lines KTC-152, KTC-120 and KTC-130 were found promising for fruit setting at high temperature (40°C day and 28°C night).

Development of coloured capsicum: Two lines, KTC-130 and KTC-145-1 were found promising for production of orange colour fruits. Maximum fruit size (8.33 cm length and 5.5 cm width) was obtained in KTC-152 followed by Yellow Wonder (7.0 × 5.5 cm) and Hybrid 6-3 (6.16 × 6.23 cm). The maximum average fruit weight was observed in Hybrid-6-3 (105 g) followed by KTC-145 (92.66 g) and KTC- 130 (90.66 g). Lines, KTC-145 (1100 g/plant), KTC- 142 (850 g/plant) and KTC- 130 (800 g/plant) were found promising for fruit yield.

Development of CMS lines and disease resistant lines: Three CMS lines, namely, KCS-1A, KCS-2A and KCS-3A of sweet pepper along with their maintainer lines are being maintained, while KTC-152 is being maintained for *Phytopthora* resistance.

Evaluation of coloured capsicum germplasm under protected conditions: Six genotypes along with two check cultivars being maintained at ICAR-IARI Regional Station, Katrain were evaluated for different quantitative traits. Genotypes, KTGC-1 (green) (29.50 t/ha) followed by KTOC-1 (orange) (29.00 t/ha) and KTYC-4 (yellow) (26.10 t/ha) performed better over the check cultivars, *viz.*, Pusa Capsicum-1 (green) (25.98 t/ha) and California Wonder (green) (17.20 t/ha).

KTGC-1 KTOC-1 KTYC-4

Pusa Capsicum-1 California Wonder

Promising genotypes of coloured capsicum

Hybrid's evaluation: Thirty hybrids including one standard check cultivar (Asha) were evaluated for yield and its attributing traits. Among them, KTCH-8 (36.29 t/ha), KTCH-14 (36.13 t/ha), KTCH-13 (35.76 t/ha), KTCH-9 (34.31 t/ha) and KTCH-7 (33.46 t/ha) performed better over the check var. Asha (30.86 t/ha).

Assessment and utilization of yellow gypsum in agriculture under variable environment: During summer/*kharif*, 2021, the effect of application of yellow gypsum was studied on yield and quality traits of capsicum var. California Wonder. In first experiment, treatment T5 (T1+ 60 kg/ha sulphur through yellow gypsum) was found best based on yield and its contributing traits. While, in second experiment, treatment T6 (T3 + yellow gypsum @ 30 kg/ha) was found best based on yield and its contributing traits. Besides this, incidence of blossom end rot was reported nil with the application of gypsum.

Entries contributed in AICRP (VC) trials: Two open-pollinated genotypes (KTOC-1 and KTYC-17) were contributed to IET.

2.1.2 Cole Crops

2.1.2.1 Cauliflower

Development of new promising materials: In total, 135 CMS based F_1 hybrids of early group cauliflower were evaluated during September-November maturity period. Eight F_1 hybrids were found promising for October maturity with marketable curd yield (20 t/ha) and five for November month (25 t/ha). The most promising new F_1 hybrids for October maturity were DCEH-9867, DCEH-7567, DCEH-7598, DCEH-4198 and DCEH-988. DCEH-6741, DCEH-2171, DCEH-4158 and DCEH-9903 for November maturity. In mid-early group, out of 21 CMS based F_1 hybrids, the promising hybrids (>30 t/ha) were DCMEH-8405, DCMEH-910, DCMEH 8425, DCMEH 8461 and DCMEH 993 for mid-November to mid-December. In mid-late group, 16 F_1 hybrids were DCMLH-4902, DCMEH-8405, DCMEH 5161, DCMEH 9202 and DCMEH 8411 for mid-December to mid-January harvesting. Furthermore, four F_1 hybrids (DCH 312397, DCH 1527 of early group; DCMH 1544, DCMH 8405 of mid-group) were advanced to AVT-II, two F_1 hybrids of early (DCEH 31503, DCEH 7523) and two of mid-group (DCMH-8404 and DCMH-8476) advanced to AVT-I in AICRP (VC). Two CMS based F_1 hybrids DCEH-15419 and DCEH 529819 of orange cauliflower were found to be promising in the initial evaluation for orange curd and with high yield (>18 t/ha). Two pyramided lines (DC-MAS-7-33-10-5 and DC-MAS-7-9-15-10) in Pusa Meghna background were found superior along with resistance to black rot and downy mildew disease.

DCEH-15419

DCEH 529819

DCEH 2171

Development of pre-breeding genetic stock(s) for black rot resistance in cauliflower: The plants of BC_3F_3 stage of ('Pusa Sharad' × *B. carinata* 'NPC-9') and BC_3F_3stage of ('DC 401' × *B. juncea* 'Pusa Vijaya') and ('DC 401' × *B. nigra*) were inoculated with *Xcc* race 1, 4 and 6 and resistant plants were selected for backcrossing to the recipient cauliflower parent. Three genetic stocks were identified to be resistant, namely, BRS04, BRS08, BRS09 of *B. napus* (AACC) and one genetic stock (BRS11) of *B. carinata* (BBCC) from segregating population (BC_1F_3) derived from inter-specific hybridization between cauliflower (CC) × *B. juncea* (AABB). Selfed seeds were harvested for achieving stability of the genetic stock and backcrossed with cauliflower for the recovery of C genome-specific traits along with *Xcc* resistance. Chromosome pairing frequently at metaphase I in pollen mother cells (PMCs) of cauliflower × *B. juncea* derived BC_3F_2 black rot resistant line(s) was recorded in selected lines. However, frequent univalent were observed in rest of the alien introgression lines.

2.1.2.2 Tropical broccoli

Out of five broccoli genotypes, DPB-1 (22.7 t/ha) and DC-Brocco-13 (20.7 t/ha) were recorded with December maturity. Purple Broccoli-1 (purple) and DC-Brocco-13 (green) were advanced to AVT-II in AICRP(VC) trials.

Purple Broccoli-1

2.1.2.3 Cabbage

Varieties released

Pusa Red Cabbage Hybrid-1: This is the first hybrid of red cabbage from public sector in India, developed by using cytoplasmic male sterility (CMS) system. It was released by the Delhi State Seed Sub Committee for NCT of Delhi during February, 2021. The average head weight and yield under multi-location evaluation trials is 1.10 kg and 43.63 t/ha, respectively, which is 10.50 and 21.40% higher over the commercial hybrids, Pusa Cabbage-1 and Primero, respectively. It matures in 70-75 days after transplanting and has an excellent field staying capacity (25-30 days). The anthocyanin concentration in the edible portion is 7.94 mg/100 g (7.5 times higher than that in the white cabbage, 1.05 mg).

Pusa Red Cabbage Hybrid-1

Evaluation of CMS based F_1 hybrids of white cabbage: Four CMS lines of white cabbage were crossed with different male lines to produce 57 hybrids. These hybrids were subjected to evaluation against three public sector and four private sector checks. Hybrid 5A × EC-686707 recorded the highest head yield of 74.35 t/ha followed by 5A × 686715 (68.66 t/ha), 6A × CH-6 (67.31 t/ha), 6A × CH-5 (65.44 t/ha), 2A × 83-6-MR-1 (62.77 t/ha) and 2A × CH-5 (60.35 t/ha).

5A × EC-686707 5A × EC-686715

2A × 83-6-MR-1 2d A × CH-5

Promising CMS based F_1 hybrids of white cabbage

Evaluation of F_1 hybrids of red cabbage: Seven CMS based red cabbage hybrids were evaluated against a private hybrid as check. Hybrids PRA × RJ gave the highest yield of 59.84 t/ha followed by PRA × ZH (58.56 t/ha).

PRA x RJ PRA x ZH

Promising CMS based F_1 hybrids of red cabbage

Diversification of CMS system: BC_6 and BC_7 generations with *Diplotaxi scatholica* and *Trachystom aballii* male sterile cytoplasms are being further backcrossed with variety Golden Acre as recurrent parent. Besides this, *Erucastrum canariense* male sterile cytoplasm was also introgressed from Indian cauliflower to cabbage genotypes.

Introgression of β-carotene rich '*Or*' gene into cabbage and broccoli: BC_3 populations of the introgressed β-carotene rich gene (*Or*) in cabbage and broccoli genotypes were evaluated. The plants carrying β-carotene rich '*Or*' gene will be advanced to next generation based on the biochemical profile.

Cabbage (BC_3)

Broccoli (BC_3)

Introgression of β-carotene rich 'Or' gene into cabbage and broccoli

Assessment and utilization of yellow gypsum in agriculture under variable environment: The effect of application of yellow gypsum was studied on yield and its contributing traits of cabbage var. Golden Acre during winter, 2020-21. In first experiment, treatment T_4 (T_1 + 45 kg/ha sulphur through yellow gypsum) followed by T_5 (T_1+ 60 kg/ha sulphur through yellow gypsum) and T_3 (T_1 + 30 kg/ha sulphur through yellow gypsum) were found best based on yield and its contributing traits. On the other hand, in second experiment, treatment T_6 (T_3 + yellow gypsum @ 30 kg/ha) was found best based on different horticultural traits under study.

Entries contributed in AICRP (VC) trials: During the year two open-pollinated varieties (KTCB-24 & KTCB-30) and three CMS based hybrids (KTCBH-225, KTCBH-625 & KTCBH-619) of white cabbage were contributed to IET, while two open-pollinated varieties of red cabbage (KTCBR-3 & KTCBR-5) were advanced to AVT-II.

2.1.2.4 Snowball cauliflower

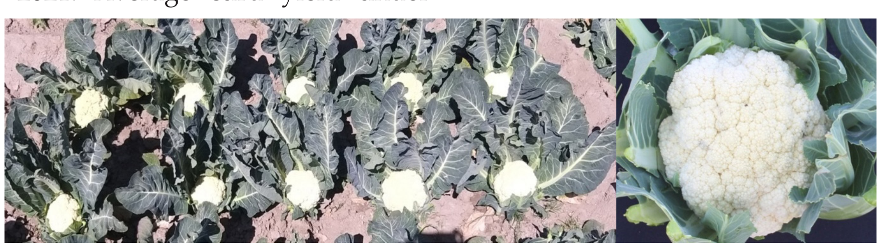
Varieties released

Pusa Snowball Hybrid-2: It is the first doubled haploid based hybrid in vegetable crops. It has been released by Delhi State Seed Sub Committee for NCT of Delhi during February, 2021. Average curd yield under NCR is 60.19 t/ha. Average curd weight is 1.41 kg and it has 5-12% more yield compared to Pusa Snowball Hybrid-1. Curds are attractive snow white in colour and retain it even after few days exposure to sunlight.

Pusa Hybrid-301: One cauliflower F_1 hybrid, Pusa Hybrid-301 has been released and notified by Central Sub-Committee during 2021. This is the first CMS based F_1 hybrid in the mid-late group of cauliflower developed by Indian public sector. It has been recommended for cultivation in the Zone I [Humid Western Himalayan Region, *i.e.* Jammu & Kashmir (J&K), Himachal Pradesh and Uttarakhand] and Zone-VI (Arid Western Plains: Rajasthan, Gujarat, Haryana and Delhi). This hybrid is suitable for cultivation in the mid-season with the harvesting of curd in the month of December and onwards. It has very compact white curd with average curd weight of 1.04 kg and average yield of 39.5 t/ha.

Pusa Hybrid-301

Pusa Purple cauliflower-1: This is the first true purple cauliflower variety developed by Indian public sector. It has been released by Delhi State Seed Sub Committee for NCT of Delhi during February, 2021. Suitable for growing in NCR Delhi under mid (November maturity) and late (December onwards maturity) conditions. Its average marketable curd weight is 765 g and average curd yield is 32.12 t/ha under NCR. The crop matures in 85-90 days after transplanting. It is a bio-fortified



Pusa Snowball Hybrid-2

variety which has 43.70 mg/100 g anthocyanins content in edible part.

Pusa Purple Cauliflower-1

Evaluation of CMS and inbred parental lines-based hybrids of snowball cauliflower: In snowball cauliflower, 170 F_1 hybrids were evaluated at Baragran Farm of ICAR-IARI Regional Station, Katrain during winter season. The marketable yield of top five hybrids *viz*., KTCF-53A_4 × KTCF-4B (49.38 t/ha), KTCF-51A_2 × KTCF-68B (49.11 t/ha), KTCF-60A_3 × KTCF-37B (43.85 t/ha), KTCF-60A_3 × KTCF-38B (43.69 t/ha) and KTCF-53A_3 × KTCF-3B (43.39 t/ha) were found higher than both check cultivars, *viz*., 'Pusa Snowball Hybrid-1 (36.93 t/ha) and Casper (39.11 t/ha) with a heterosis range of 17.47-33.69 and 10.94-26.26%, respectively. These promising hybrids need to be tested at multi-locations for stability analysis.

KTCF-53A_4 × KTCF-4 B; KTCF-51A_2 × KTCF-68B; KTCF-60A_3 × KTCF-37B; Casper, Pusa Snowball Hybrid-1

Promising CMS and inbred parental lines-based hybrids of snowball cauliflower

Evaluation of CMS and DH parental lines-based hybrids of snowball cauliflower: Newly developed 60 CMS and DH parental lines based F_1 hybrids were evaluated at Baragran Farm of ICAR-IARI, Regional Station, Katrain during winter season of 2020-21. The marketable yield of top five hybrids, *viz*., KTCF60A_3 × KTCF-DH-5B (41.28 t/ha), KTCF-54A_1 × KTCF-DH-4B (38.91 t/ha), KTCF63A_4 × KTCF-DH-5B (38.58 t/ha), KTCF60A_4 × KTCF-DH-8B (36.67 t/ha) and KTCF-65A_2 × KTCF-DH-4B (35.88 t/ha) were found higher than the check cultivar 'Pusa Snowball Hybrid-2 (34.70 t/ha) with a heterosis range of 3.42-18.98 %. These promising hybrids need to be tested at multi-locations for stability analysis.

KTCF60A_3 × KTCF-DH-5B; KTCF-54A_1 × KTCF-DH-4B; KTCF-63A_4 × KTCF-DH-5B and Pusa Snowball Hybrid-2

Promising CMS and DH parental lines-based hybrids of snowball cauliflower

Introgression of β-carotene (*Or* gene) and anthocyanin (*Pr* gene) rich genes into snowball cauliflower: BC_3 population of the introgressed β-carotene (*Or* gene) & anthocyanin (*Pr* gene) rich genes into different genotypes of snowball cauliflower (Pusa Snowball K-1 & Pusa Snowball K-25) was evaluated during winter, 2020-21. The plants carrying β-carotene rich '*Or*' and anthocyanin rich '*Pr*' genes will be advanced to next generation through marker-assisted backcross selection.

Orange cauliflower (BC_3) Purple cauliflower (BC_3)

Introgression of β-carotene (*Or* gene) and anthocyanin (*Pr* gene) rich genes into snowball cauliflower

Diversification of male sterile cytoplasm in snowball cauliflower: During summer season of 2021, BC_6 and BC_7 populations of the introgressed *Diplotaxis catholica* and *Trachys tomaballii* male sterile cytoplasms, respectively into cauliflower background through embryo rescue and backcrossing. Besides, this *Erucastrum canariense* male sterile cytoplasm was also introgressed from Indian cauliflower to snowball genotypes.

Consortia Research Platform on hybrid technology-cauliflower

Evaluation of promising snowball cauliflower hybrids under multi-location yield trials: Twenty-five promising F_1 hybrids developed and already tested by ICAR-IARI Regional Station, Katrain were evaluated at three different locations, *viz*., ICAR-IARI Regional Station, Katrain, ICAR-IARI, New Delhi and Dr YS Parmar UHF, Nauni, Solan. At ICAR-IARI Regional Station, Katrain, 14 hybrids were found superior over two check cultivars, *viz*., Pusa Snowball Hybrid-1

KTCFH-13; KTCFH-2; KTCFH-6; Pusa Snowball Hybrid-1; Pusa Snowball Hybrid-2; Pusa Hybrid-301

Promising snowball cauliflower hybrids in multi-location yield trials

(PSBH-1) and Pusa Snowball Hybrid-2 (PSBH-2), with a heterosis range of 3.82-39.31 and 2.18-37.11 per cent, respectively. In the mean, while 15 hybrids performed better than the check cultivar, Pusa Hybrid-301 with a heterosis range of 1.04-45.92 per cent. These hybrids performed well during last year and their performance in this year was also promising. Therefore, these hybrids could be carried forward for multi-location trials throughout India and their identification at national level.

Evaluation of CMS based hybrids received from Dr YS Parmar UHF, Nauni, Solan: Twenty CMS based hybrids of snowball cauliflower received from Dr YS Parmar UHF, Nauni, Solan, HP were evaluated at ICAR-IARI Regional Station, Katrain, of which the marketable yield of two hybrids, *viz*.,UHFCAU-45 (35.16 t/ha) and UHFCAU-21 (34.51 t/ha) were found superior than the check cultivar Pusa Snowball Hybrid-1 (33.38 t/ha). These hybrids resulted in 5.33 and 3.38 per cent, respective increase in yield over the standard check cultivar.

UHFCAU-45 **UHFCAU-21**

Pusa Snowball Hybrid-1

Promising snowball cauliflower hybrids received from Dr YS Parmar UHF, Nauni, Solan, HP

Assessment and utilization of yellow gypsum in agriculture under variable environment:

Cauliflower: The effect of application of yellow gypsum was also studied on yield and quality traits of snowball cauliflower var. Pusa Snowball K-1 during Winter, 2020-21. In first experiment, treatment T_3 (T_1 + 30 kg/ha sulphur through yellow gypsum) was found best based on yield and its contributing traits. Whereas, in second experiment, treatment T_6 (T_3 + yellow gypsum @ 30 kg/ha) was found best based on yield and its contributing traits.

Entries contributed in AICRP (VC) trials: During the year 2021, two open-pollinated genotypes (KTCF-36 and KTCF-37) and two CMS based hybrids (KTCFH-534 and KTCFH-6270) of late-season cauliflower along with two CMS based hybrids (KTCFH-514 and KTCFH-8470) of mid-season cauliflower were contributed in AICRP (VC) IET. Besides this, two open- pollinated genotypes (KTCF-14 and KTCF-25) and two CMS based hybrids of mid-season cauliflower (KTCF-11 and KTCF-22) were advanced to AVT-I. In the meanwhile, two entries of open-pollinated late-season cauliflower (KTCF-30 and KTCF-33) and two CMS based hybrids of mid-season cauliflower (KTCF-23 and KTCF-40) were advanced to AVT-II under AICRP (VC).

2.1.2.5 Broccoli

Evaluation of CMS based F_1 hybrids of broccoli: Fifteen CMS based hybrids of broccoli were evaluated for yield and horticultural traits against two private sector hybrids, *viz*., Saki and Fantasy. Hybrid VCHA × Sel-3 recorded the highest head yield (27.89 t/ha) followed by VCHA × SMD (26.91 t/ha), Aish A × VCH (24.78 t/ha), KTSA × VCH (22.43 t/ha) and VCHA × B-31 (22.21 t/ha), which were significantly higher than best check Saki (13.65 t/ha).

VCHA × Sel-3 **VCHA × B-31**

Promising CMS based F_1 hybrids of broccoli

Entries contributed in AICRP (VC) trials: Four hybrids (KTHB-303, KTHB-304, KTHB-3111 & KTHB-3411) of broccoli were contributed to IET, while two open-pollinated varieties (KTB-3 & KTB-10) were advanced to AVT-II.

2.1.2.6 Other *Brassica* crops

Identification of novel gene and development of recombinant inbred lines (RILs) in *Brassica napus*: Identified single dominant genes in *B. napus* breeding line 'BN-2-1 against black rot (R1, R4 and R6) those were inherited together to each other during linkage analysis in their respective test cross against *Xcc* 1, 4 and 6, respectively. Being single dominant gene and linked to each other, it is feasible to transfer strong resistance from *B. napus* breeding line 'BN-2-1' into *B. oleracea via* distant hybridization due to close relationship at sub genomic level (AC/C)that will enable to develop strong resistant pre-breeding genetic stock(s) with black rot resistance in *B. oleracea* group. 190 RILs (stage F_4) were developed advancing GSL-1 (susceptible) × BN-2-1 (resistant) in *Brassica napus.* One hundred fifteen BC_1 inter-specific plants (*Brassica napus* 'BN-2-1' × cauliflower 'Pusa Meghna') were raised, characterized on the basis of morphology and floral traits. Resistant plants were backcrossed with Cauliflower variety "Pusa Meghna" to produce second back cross generation to enhance recovery of the C genome.

(RILs) in *B. napus*

2.1.3 Cucurbitaceous crops

2.1.3.1 Bitter gourd

Promising hybrids: Two hybrids, namely, DBGH-5201, DBGH-4863, DBGH 246 and DBGH 163 were prompted to AVT-I and AVT-II trials of AICRP (VC), respectively. Thirty eight hybrids were evaluated for yield and related traits andthe two best performing hybrids were Pusa Aushadhi × NEH-4 (DBGH-14; 30.25 t/ha), and G-21 × Pusa Vishesh (DBGH-2163; 29.45 t/ha), which were entered in IET trials of AICRP (VC).

Identification of virus resistance genotype: The long-fruited genotype, Sel-2 (DBGS-2) was found resistant to virus complex including ToLCNDV with the vulnerability index of 17.55% under 5th August sowing (*kharif* season). It was also promising for yield (24.55 t/ha). Fruits are green, 21-26 cm long, 4.0-4.5 cm diameter with broken ridges. Individual fruit weight is 85-95 g. The genotype, DBGS-2 was usedto develop F_1 hybrids with three susceptible genotypes (Pusa Purvi, Pusa Rasdar and Pusa Vishesh). The presence of ToLCNDV was confirmed in all the infected leaf samples through ToLCNDV specific primers.

Promising genotypes: About 32 genotypes were under station trial and two genotypes, namely, DBGS 21-06 and DBGS 48-00 were recorded higher yield of 25.50 and 24.38 t/ha under open field conditions. The fruits of DBGS 21-06 are light green, 20.25 cm long, 6.0-6.5 cm fruit diameter with pointed tubercles, discontinuous ridges with individual fruit weight of 120 g.

DBGS 21-06

Promising selections for protected cultivation: Two selections (DBGS-32 and DBGS-57) were found promising under polyhouse and net house growing conditions. The yield of 4.10 and 3.85 q/100 m^2 polyhouse was recorded with individual fruit weight of 95 and 120 g, respectively. The yield of DBGS-32 was 4.72q/100m^2area with average fruit weight of 133 g, whereas DBGS-57 produced 4.04q/100m^2 yields with an average fruit weight of 141g under insect proof net house. Three private company hybrids were used as check for total yield. The yield of 3.34, 3.19 and 3.54 q/100 m^2 net house was recorded for Nandita (VNR seeds), KSP1198 (Kalash Seeds) and Prachi (East West Seeds).

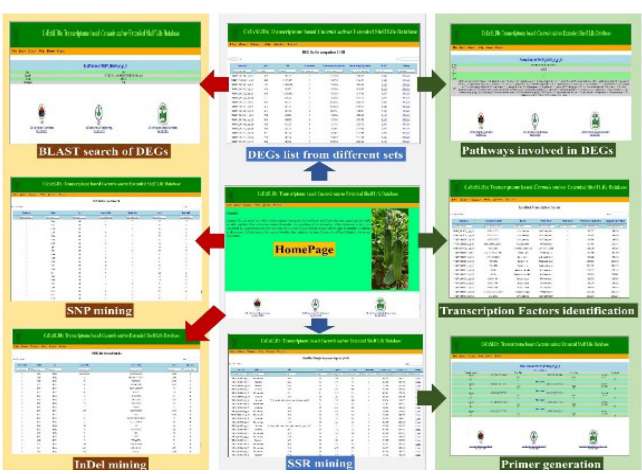
DBGS-32

Unique germplasm: Among 32 genotypes evaluated one medium fruited genotype (DBGS-54-18) was identified with white flower colour, which can be used as a morphological marker. Fruits are medium (12-14 cm long, 5.0-5.5 cm fruit diameter with discontinuous narrow ridges). The genotype DBGS-54-18 was crossed with dark-yellow flowered genotypes, DBGS-2 and Pusa Do Mausami for genetic study of white flower.

DBGS-54-18

2.1.3.2 Cucumber

Studies on inheritance, molecular mechanisms and molecular mapping of extended shelf-life in cucumber: In cucumber, one natural variant (DC-48) with extended shelf-life was isolated and maintained. This genotype was crossed with a contrasting genotype, Pusa Long Green (DC-83) to develop F_1, F_2 and back-cross progenies. Based on the phenotyping of the F_1, F_2, BC progenies along with the parental line, it was revealed that the trait is governed by single recessive gene. Comparative transcriptomics was performed in the contrasting genotype, DC-48 and DC-83 at two fruit developmental stages (5 and 10 DAP) to reveal the key molecular pathways and networks determining the extended shelf-life. A total of 1364 DEGs were identified and cell wall degradation, chlorophyll and ethylene metabolism related genes played key role. Polygalacturunase (PG), Expansin (EXP) and xyloglucan were down regulated determining fruit firmness and retention of fresh green colour was mainly attributed to the low expression level of the chlorophyll catalytic enzymes (CCEs). Gene regulatory networks revealed the hub genes and cross-talk associated with wide variety of the biological processes. Large number of SSRs (21524), SNPs (545173) and InDels (126252) identified will be instrumental in cucumber improvement. A web genomic resource, CsExSLDb developed (http://backlin.cabgrid.res.in/csexsldb/) will provide a platform for future investigation on cucumber post-harvest biology. QTL-seq was performed for identification of the genomic region(s) for extended shelf-life using the two contrasting parents and F_2 bulk of 20 each representing the parental lines. Based on the QTL-seq analysis, only one major QTL on the Chr-4 was identified.



QTL-sequence analysis

Development of mapping population for extended shelf-life, high carotenoids and downy mildew resistance: To develop recombinant inbred lines (RILs), $F_{2:3/4}$ progenies were developed which will be used for advancement of progenies through single plant selection to develop RILs. One orange fleshed genotype (AZMC-1) with high carotenoid content was crossed with green fleshed genotype (DC-48) and F_3 progenies were developed for further advancement. For development of mapping population for downy mildew resistance, one resistant genotype, DC-77 was crossed with DC-773. F_1, F_2, F_3 and BC progenies were developed for studies on inheritance and development of mapping population.

Development and evaluation of gynoecy based F_1 hybrids: Out of 51 F_1 hybrids evaluated under replicated trial,gynoecious hybrids DGCH-31 and DGCH-40 yielded 22.8 and 24.2 t/ha, respectively as compared to National check -Pant Sankar Khira (17.8 t/ha). Another hybrid DGCH-56 having large size fruit and desirable horticultural traits yielding 25.0 t/ha was concluded in AVT-II of AICRP (VC) trial. Another 67 F_1 hybrids were developed using five gynoecious lines.

Identification of wild *Cucumis* species and accessions with resistance to leaf curl disease: A selected set of *Cucumis* genotypes including 112 *C. sativus* and 23 wild accessions (*C. sativus* var. *hardwickii* and *C. callosus*) were evaluated for resistance against leaf curl disease in cucumber predominantly caused by *ToLCNDV* both under natural field conditions and forced white fly inoculation. Majority of the accessions were found to be highly susceptible, while two genotypes of *C. hardwickii* (H-06 and H-16) and one genotype of cultivated type (DC-61) showed effective resistance against leaf curl disease with a score of less than 2.0 on a scale of 0-9. F_1, F_2 and back-cross progenies were developed involving DC-749 × DC-61. These populations will be used in inheritance study and for molecular mapping of lead curl resistance.

2.1.3.3 Sponge gourd

Out of 60 sponge gourd F_1 hybrids evaluated, DSGH-38 (17.8 t/ha) and DSGH-95 (17.2 t/ha) were found to be very promising as compared to National Check Kalyanpur Hari Chikni (12.3 t/ha). Hybrid DSGH-38 was entered in AVT-1 and DSGH-95 was advanced to AVT-II of AICRP (VC) trial. Two new genotypes (DSGH-132 and DSGH-134) were entered in IET of AICRP (VC) trial.

2.1.3.4 Muskmelon

Development of Novel monoecious line: Monoecious line DMM-31 with round fruit and excellent fruit quality was developed, which will be utilized for easy and economical hybrid seed production. The yield potential of DM-31 is 5.8 tonnes/1000 sq. m. area in net house. It has fruit weight of 900 g with dark orange flesh and 12^0Brix.

DM-31

Identification of promising genotypes: Out of 14 genotypes evaluated, the promising genotypes for open field cultivation from station trial conducted in summer 2021 were DM-154 (22.6 t/ha, green flesh, TSS 11.8^0Brix) followed by DM-156 (21.9 t/ha, TSS 11.7^0Brix) and DM 193 (21.4 t/ha, TSS 11.9 ^{0}Brix).

The new selection of specialty melon (C. *melo* var. *inodorous)* DHM-39 (5.6 tonne/1000 m^2 with orange flesh & TSS 13.9^0Brix) and DHM-162 (5.3 t/1000 m^2 with green flesh & TSS 13.6^0Brix) were found most promising for protected cultivation and shelf-life of these two genotypes was 15 days which was better than muskmelon genotypes from *cantalupensis* group.

Promising hybrids: Two hybrids from C. *melo* var. *cantaloupensis* group DMH-18 (25.7 t/ha, TSS 11.9^0Brix) and DMH-23 (24.2 t/ha, TSS 11.8^0Brix) were found most promising in station trial. Specialty melon hybrid DMH- 112 was found to be most promising recording yield of 5.8 tonne/1000 m^2 followed by DMH-119 (5.6 tonne/1000 m^2) under nethouse during off-season cultivation from September to November.

Screening for WBNV resistance: Forty three genotypes of watermelon from *Citrullus lanatus* var. *lanatus*, var. *citroides* and *C. colocynthis* were evaluated in open field and net house conditions. *C. colocynthis* lines DWM-210 and DWM-222 were identified as highly resistant. A new accession DWM-45 from *C. lanatus* var. *citroides* type could also be identified as highly resistant to watermelon bud necrosis virus after four seasons of continuous screening.

2.1.3.5 Pumpkin

Evaluation of breeding lines for yield and quality: Fifty genotypes/ breeding lines were evaluated for yield and yield related traits, out of which five genotypes, namely, DPU-150, DPU-136, DPU-129, DPU-14 and DPU-165 were found promising. The fruits of DPU-150 are spherical with light ribs and orange flesh. The fruits of DPU-136, DPU-129, DPU-14 and DPU-165 are flattish-round with orange flesh.

Screening for virus resistance: Out of fifty genotypes/ advanced breeding lines, DPU-41 and DPU-43 showed field resistance against *Squash Leaf Curl China Virus* (*SLCCV*) and *Tomato Leaf Curl New Delhi Virus* (*ToLCNDV*) causing leaf curl disease. The occurrence of *Cucurbit Chlorotic Yellows Virus* (*CCYV*) association with pumpkin was reported for the first time from India.

Identification of unique genotype: Pumpkin DPU-84 having lemon yellow flower colour, which can be used as a morphological marker was identified and maintained. Fruits of DPU-84 are flattish-round with average weight of 5.5 kg and yellow orange thick flesh.

Evaluation of hybrids for yield and quality: Sixty F_1 hybrids along with check Pusa Hybrid-1 were developed and evaluated for yield and related traits in the spring-summer season. The best performing F_1 hybrids on the basis of fruit yield, shape and flesh colour in small fruit segment were DPUH-101-15 (avg. fruit weight 2.6 kg, flesh thickness 3.1 cm) and DPUH-U-10 (avg. fruit weight 2.7 kg, flesh thickness 3.6 cm). In the medium fruit size segment, DPUH-150-01 (avg. fruit weight 3.6 kg, flesh thickness 3.7 cm), DPUH-U-01 (avg. fruit weight 4.1 kg, flesh thickness 3.9 cm), DPUH-U-15 (average fruit weight 3.5 kg, flesh thickness 3.7 cm) were found promising. All the five promising hybrids had orange flesh colour.

DPUH-101-15

2.1.3.6 Bottle gourd

Screening of genotypes against powdery mildew: A total of 44 genotypes (which included indigenous collections, exotic collections and cultivated varieties) were screened for resistance to powdery mildew in collaboration with ICAR-NBPGR, New Delhi. Scoring at 0–9 rating scale (Jenkins and Wehner, 1983) was done at 7 day intervals. Genotypes IC0319838, IC337078, IC296733, EC800995 and EC750696 were found resistant with disease reaction 0-10%, while genotypes Pusa Naveen, Pusa Samridhi, IC0418258, IC0092447, IC0092384, IC0092455, IC0418249, IC274035, IC279630, IC279634, IC297583 and IC315971 were found highly susceptible (>60%).

Pusa Naveen (Susceptible)

IC337078 (Resistant)

2.1.4 Malvaceae crop

2.1.4.1 Okra

Development of hybrids: About 48 F_1 hybrids were evaluated along with 26 private sector hybrids for yield, quality and disease resistance. DOH-3, DOH-7 and DOH-9 were found highly resistant to *Bhendi Yellow Vein Mosaic Virus* (*YVMV*) and *Enation Leaf Curl Virus* (ELCV) Resistance both under field condition and PCR reaction. DOH-3 recorded the maximum yield 275 q/ha followed by DOH-9 (273 q/ha) and DOH-7 (270 q/ha).

DOH-3

Advancing of lines: A total of 44 parental lines and 17 advance lines (F4-F9) were evaluated and DOV-92 was found most promising for yield (231q/ha), resistant to YVMV and ELCV diseases. DOV-69 recorded 203 q/ha fruit yield, YVMV and ELCV resistance under field conditions.

Breeding for YVMV and ELCV: Individual plant selection was made from advance lines, namely, DOV-6490, DOV-6126, DOV-6128 and DOV-6496 (>25 long fruits), which were found high yielding, dark-green fruited with resistance to YVMV and ELCV diseases. Among genotypes evaluated, private hybrid Shakti and US-8063 recorded 100% ELCV incidence and IC-685583 and Pusa Sawani recorded 92 and 88% YVMV incidence. Among red fruited okra lines and hybrids evaluated, hybrid DOH-68 also found resistant to both the diseases under field conditions and recorded 243 q/ha fruit yield with fruit anthocyanin content of 415 ppm. More than 25 fruits/plant were recorded in DOV-69 and DOV-92. Fruiting at shorter internodes were recorded in DOV-69 (3.5 cm), DOV-6490 (4.0 cm), DOV-6126 (4.2 cm) and DOV-6492 (4.5 cm). Among 15 genotypes evaluated for insect resistance, DOV-92 was found extremely resistant, 4 genotypes (IC-090491, DOV-17, Pusa Sawani and DOV-69) moderately resistant, while wild genotype *Abelmoschus caillei* was found extremely susceptible to red spider mites.

DOV-92

Development of pre-breeding lines: About 59 selected wild okra accessions representing different species, namely, *Abelmoschus angulosus*, *A. tetraphyllus*, *A. moschatus*, *A. caillei*, *A. ficulneus*, *A. mizoramensis* and *A. tuberculatus* were screened for YVMV and ELCV resistance. The F_1 and back cross populations of wild with cultivated species in the background of Pusa A4, Pusa Bhindi-5 and DOV-92 were evaluated. Advance population of *A. moschatus* and *A. angulosus*, namely, Am66-2, Am92-1 in the background of DOV-66 and DOV-92 had desirable fruit set with improved fruit type. The resistant plants were selected for further generation advancement.

2.1.5 Root crops

2.1.5.1 Carrot

Evaluation of breeding lines for yield and quality: Under normal season, 50 genotypes/ breeding lines were assessed for quantitative and quality traits. Based on the quality for root shape, surface, external & internal colour and external appearance, the promising high yielding genotypes identified were DCat-13, DCat-36, DCat-6, DCat-48 and DCat-1.

CMS based F_1 hybrids

Evaluation of hybrids for yield and quality: Twenty eight CMS based F_1 hybrids of tropical-subtropical type were assessed for quantitative and quality traits. Based on the quality for root shape, surface, external & internal colour, self-core and external appearance, the promising high yielding F_1 hybrids were DCatH 713, DCatH 913, DCatH 785, DCatH 71 and DCatH 716. Forty eight CMS based F_1 hybrids were assessed for TSS, invert sugar, fructose, juice recovery and total sugars. The promising hybrids were DCatH 5316 for TSS (8.57°Brix), DCatH 788 for invert sugar (7.87% mass), DCatH 5316 for fructose (8.17% mass), DCatH 5330 for juice recovery (65.37%) and DCatH 9813 for total sugars content (11.49%).

2.1.5.2 Temperate carrot

Evaluation of CMS based F_1 hybrids: Sixty F_1 hybrids developed by using 10 CMS lines were evaluated for yield and its contributing traits against PusaNayanJyoti

KT-48 A × KS-73 | KT-48 A × New Kuroda | KT-95 A × KS-21 | KT-7A × New Kuroda | KT-80A × KS-20

Promising CMS based hybrids of temperate carrot

as check. A total of 5 hybrids, *viz*. KT-48 A × KS-73 (37.50 t/ha), KT-48 A × New Kuroda (34.40 t/ha), KT-95 A × KS-21 (33.71 t/ha), KT-7A × New Kuroda (32.47 t/ha) and KT-80A × KS-20 (31.89 t/ha) were found superior than the check cultivar (25.60 t/ha).

Entries contributed in AICRP (VC) trials: Four CMS based hybrids (KTTCH-804, KTTCH-954, KTTCH-2859 and KTTCH-9659) were contributed to IET and two open-pollinated varieties, *viz*; KTTC-50 and KTTC-59 were advanced to AVT-II testing under AICRP (VC) trials.

2.1.5.3 Radish

Promising genotype: Selection-14 attains marketable maturity in 50-55 days after sowing during *rabi* season. The roots are 7-8 cm long, 3.5 cm in diameter and the average root weight is 75 g. The colour of petiole and root skin is pink. The average root yieldis 18-21 t/ha.

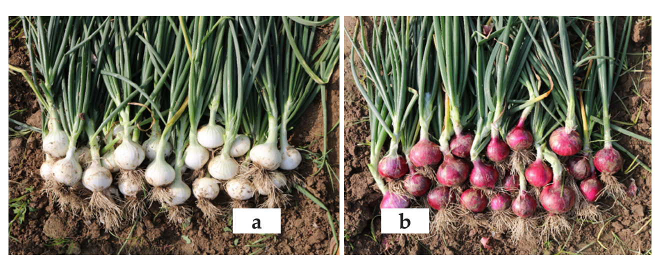
Selection-14

Advancing the male sterile backcross populations: Ten backcross populations (BC_3 generation) were raised for maintenance of male sterility in ten different genetic backgrounds having the traits of economic importance such as leaf morphology, root colour, root shape and adaptability. All the backcross progenies were 100% male sterile indicating the maintenance of sterility. In all the 10 backcross populations, individual plants having similarity to their maintainer parent were selected and were backcrossed with respective maintainer parents to advance the generation.

2.1.6 Bulbous crops

2.1.5.1 Onion

Breeding for superior varieties/ hybrids during *kharif* season: A total of 160 breeding lines for *kharif* season were planted out of which 55 were planted as seedlings. About 10% of the accessions developed bulbs, which were planted again for seed production. Eight elite lines were evaluated for adaptability and bulb formation along with the recommended varieties. It was observed that two advanced lines 2020ENTO and 2020HORT performed superior in terms of survival



Performance of promising onion accessions (a) 2020ENTO and (b) 2020HORT during *kharif* 2020-21

(33.4 and 35.8%) and bulb formation (15.85 and 19.68%) as compared to the recommended varieties, *i.e.*, Bhima Light Red, Bhima Raj, and Bhima Super.

Breeding for bolting tolerance during *late kharif* season: Fifty-five breeding materials were evaluated for bolting resistance during late *kharif* season. Four accessions (BR061, BR001, BR002, and BR036) were found to be bolting resistant, whereas three accessions (BR021, BR111, BR119) were recorded as bolting tolerant with bolting between 5-10%.

Promising selections: In *kharif* onion, for set raised material PKO 2009 (30.65 t/ha), PKO 2010 (29.81 t/ha) and PKO 1964 (29.35 t/ha) were found promising. For seedling raised type, KP-41 (25.08 t/ha), KP-62 (23.20 t/ha) and KP-420 (23.08 t/ha) were found superior. The study of different morphological traits, total sugars and reducing sugar and mineral content (N, P, K, Ca, Mg, S, Fe and Zn) at 60, 90 and 120 DAP planting revealed greater vegetative growth at high temperature and humid condition upto 60 DAP had significant positive association with marketable bulb yield in *kharif* onion. Sulphur content at 60 DAP had significant positive correlation with *kharif* onion yield. The expression of six *ACFT* genes suggested the role of *AcFT6*, *AcFT1* and *AcFT2* genes for bulb differentiation traits in *kharif* onion.

KP 41

KP 62

Screening of onion genotypes against *Alternaria alternata:* Twenty nine genotypes of late *kharif* onion along with three allied species were screened against *A. alternata* isolated from *kharif* onion leaves. Disease infection was observed in all the genotypes. Pusa Soumya was found resistant and VPB-20-78 was found moderately resistant.

Quality Estimation of *kharif* onion: The storage study of *kharif* onion genotypes revealed high storability of KP-41. The TSS of *kharif* onion genotypes ranged from 12.5-15.6°Brix. The mineral content in onion genotypes were ranged from 561.08-850.77 mg/kg DW for calcium, 818.3-1353.8 mg/kg DW for sulphur, 5.89-8.7 mg/kg DW for iron and 1.38-3.28 mg/kg DW for zinc.

Garlic: Over 135 germplasms were evaluated for yield and yield-related traits. Twenty-nine accessions were analysed for development of black garlic based on their biochemical composition. Black garlic (BG) was produced by aging of garlic cloves at constant temperature and relative humidity. Seven biochemical traits, *viz.*, total phenolics content, total flavonoids content, total antioxidant capacity (CUPRAC, FRAP&DPPH assays), allicin content (mg/100 g) and pyruvic acid (µMol/ ml) were recorded. All the biochemicals exhibited increase or decrease at various stages of aging. Total phenolics, CUPRAC and DPPH increased till 40 days of ageing, whereas FRAP and allicin exhibited an increase till 20 days of aging. Total flavonoids content continued to increase throughout the aging process (60 days), whereas pyruvic acid did not increase after aging. This is the first report on development of black garlic from Indian genotypes.

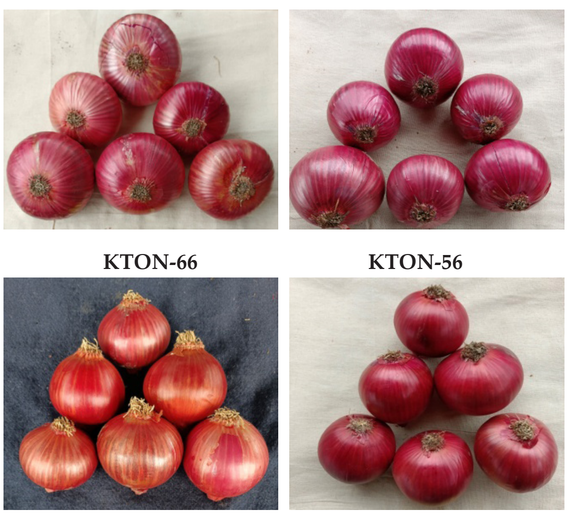
Fresh garlic (a) and black garlic after 60 days of aging (b).

Breeding for Stemphylium blight resistance: One hundred and sixty one genotypes were screened against *Stemphylium* blight. Leek (*Allium porrum*) was found to be immune. Based on the artificial inoculation, 16 onion accessions, *viz.*, JNDWO85 × P. Saumya 10-1 (SO01); L28-Self1 (SO02); PM-16-2 (SO03); Sel383 × BS#27-14 (SO04); Sel383 × BS#27-17 (SO05); AVON 1021-2(OP) (SO06); B-780 (SO07); EGRN-1 × PRDN-2-1 (SO08); Sel 153-N-1 × AKON083(P-3) (SO09); Hisar-2 (Waxy) (SO10); JWDW085 × P. Saumya-10-2 (SO11); PR × BS(II)-4-3 (SO12); NHRDF Red 4 (SO13); Arka Bheem-Sel (SO14); T-821-Sel (SO16); Hisar-2 (Self-2)

(SO15) were found to be moderately tolerant, while AKON068 was most susceptible genotype.

Screening against Stemphylium blight (a) moderately tolerant (SO01) and (b) Highly susceptible (AKON068) genotypes

Development and evaluation of long day red onion inbred lines: Ten advanced breeding lines with red colour have been developed at IARI RS, Katrain. These lines along with the check cultivar (Brown Spanish) were evaluated for different horticultural traits. Out of these, seven genotypes, *viz*., KTON-66 (44.51 t/ha), KTON-56 (41.63 t/ha), KTON-55 (40.57 t/ha), KTON-64 (37.33 t/ha), KTON-51 (36.92 t/ha), KTON-52 (35.46 t/ha) and KTON-65 (34.86 t/ha) yielded higher than Brown Spanish (32.13 t/ha).



KTON-66 **KTON-56**

KTON-51 **KTON-52**

Promising genotypes of long day red onion

2.1.7. Luguminous crops

2.1.7.1 Garden Pea

New genetic material developed for high yield and disease resistance: Evaluated 30 new bulks derived from F_6 generations breeding materials against three checks (Pusa Shree, VRP 6 & Arkel). Among these, 16 lines were grouped as early maturity and 14 were medium maturity. The promising genotypes in early group were GP 1501 (10.83 t/ha), GP 1502 (11.25 t/ha), GP 1504 (12.70 t/ha), GP 1802 (12.08 t/ha) and GP 1803 and in medium maturity group, genotypes having high degree of powdery mildew resistance were GP 1503, GP 1505, GP 1804.The genotypes, GP 1101, GP 1504, GP 1505 and GP 1802 are under multi-location trials of AICRP.

Development of lines for wilt resistance: Twenty five germplasm and 92 F_4 crosses were evaluated in wilt sick plot for screening and advancing the selected lines. Based on last 10 years evaluation in sick plot, the genotypes GP17 (Pusa Shree), GP6, GP48, GP55 and GP473 (Pusa Prabal) have been found highly resistant to *Fusarium* wilt. Besides, EC 677214, EC 927771, the F_4 crosses of GP 48 × GP473-1-2, GP 48 × 2011/ PEV-3, PP × GP55, 2011/PEV-3-1-1 × GP48, AP-3 × GP55, GP17 × 2011/PEV-2, GP55 × 2011/PEV-2, and 2017/ PEV-5 × GP-17 were identified as highly wilt resistant with good horticultural traits.

Development of powdery mildew resistance lines: The genotypes found highly resistant to powdery mildew were GP6, GP 473, GP 1001, GP 1101, GP 1102, GP 1501 GP 1502, GP 1505 and GP 1804. Two genotypes, i.e. GP6 and GP 473 (Pusa Prabal) have been screened for 10 years consecutively and found multiple disease resistant especially for *Fusarium* wilt and powdery mildew. GP6 is an afila type genotype, while Pusa Prabal is a cultivated type.

Screening of lines for heat tolerance and disease resistance: Ninety two genotypes were screened for high temperature tolerance to extend the fresh pod availability beyond mid-March in north Indian plains. Out of 92 genotypes, GP 55, GP 57, EC 598638, GP916, GP473, GP 912-II, VP 233, VP438-2 and EC 598646 were found promising for pod setting at high temperature.

Development of RIL$_S$ for *Fusarium* wilt resistance using inter-specific hybridization: The RILs population at the stage of F_4 *viz.*, PSM-3 × *Pisum sativum* ssp. *elatius* 'N-8', Pusa Pragati × *P. sativum* ssp. *elatius* 'N-14', VRP-6 × *P. sativum* ssp. *elatius* 'N-8', PB-89 × *P. sativum* ssp. *elatius* 'N-14', MA-7 × M-1, PB-

89 × *P. sativum* ssp. *elatius* 'N-8' were developed using single seed descent method for mapping *Fw* gene in *P. sativum* ssp. *elatius*.

Identification of host plant resistance against *Fusarium* wilt: Total 120 *Pisum* accessions including alien species, *viz*., *P. fulvum*, *P. elatius*, *P. sativum* var. *elatius*, *P. sativum* and commercial susceptible garden pea varieties were grown in the artificial sick pots, those were developed by inoculating four virulent *Fop* isolates. Total 15 accessions *viz*., were found highly resistant against *Fop-1* Delhi isolates in which two of *P. fulvum* (N-3, N13), one of *P. elatius* (M2), four of *P. sativum* var. *elatius* (N-6, N8, N11, N14) and eight of *P. sativum* (M13, Hyd32-sel-2, Hyd26, Hyd51-sel-1, Hyd42 sel-1, GP2230, GP2308 and GP2239).

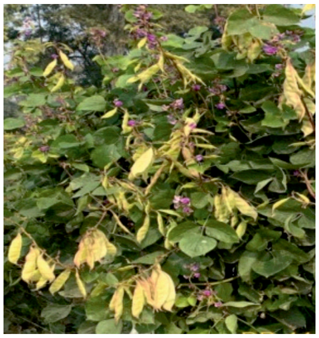
Development of breeding population for *Fusarium* wilt resistance: Advance breeding lines developed for *Fusarium* wilt resistance with earliness, *viz*., GP2165, GP2179, GP2178, GP2174 and GP2113 were evaluated and advanced for seed production stage. Fifty single plant selections (SPS) were made among twenty two F_2 populations, namely, Arkel × N-8, VRP-5 × N-8, VRP-6 × N-8, MA-7 × N-8, Pusa Pragati × N-8, PB-89 × N-8, Arkel × N-14, VRP-5 × N-14, VRP-6 × N-14), MA-7 × N-14, Pusa Pragati × N-14, PB-89 × N-14, MA-7 × NB-4, Pusa Pragati × M1, Arkel × M2 VRP-5 × M1 Pusa Pragati × M5, VRP-5 × NB3, Arkel × NB-5, Arkel × NB4, VRP-6 × NB3, MA-7 × M1 and 15 backcross introgression populations (BC_1F_1/ BC_2F_2) were raised and advanced. Single plant selections were also made for early maturity with *Fusarium* wilt resistance along with desirable horticultural traits.

Single plant selection with *Fusarium* resistance with early maturing pods BC_1F_1 (Pusa Pragati × N-8)

2.1.7.2 Other legumes

Cowpea: Two bush/dwarf type entries were entered under testing in AICRP trials, namely, CP 29 in IET and CP-60 (Red pod) in AVT-II. The newly released variety Pusa Dharni through CVRC is being used as national check in different AICRP trials.

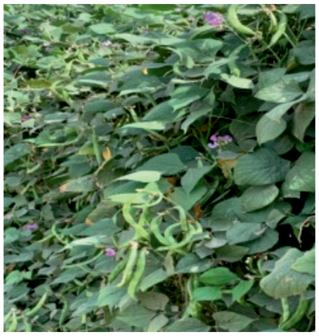
***Dolichos* bean:** Four entries of *Dolichos* bean (pole type) are under testing in AICRP trials, namely, DB 24, DB 27 (AVT-II) and DB 32 (AVT-I) and DB 13-2 (IET).



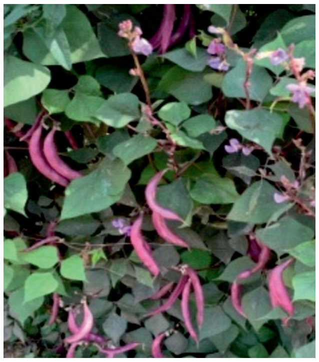
DB 30 semi-dwarf HR to GMV

DB 44 semi-dwarf HR to GMV

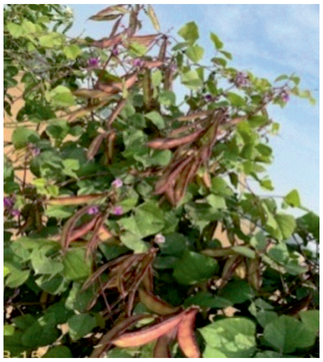
DB 41 HR to GMV& extra early semi-dwarf



DB 32 pole type HR to GMV



DB 24 pole type HR to GMV



DB 15 HR to GMV & Early pole type

New genetic material developed for high yield in *Dolichos* bean

From F_4-F_5 crosses, evaluated many dwarf/ semi-dwarf lines, which have been developed with different pod colours and pod shape as novelty alongwith resistant mosaic virus (DYMV, GMV *etc.*). Among these, DB 41 (dark purple long narrow pods), DB 42 (Dark red flat), DB 43 (Green) and DB 44 (Yellow flat with purple suture) have been selected based on semi-dwarf plant type with profuse bearing & highly attractive pods. Besides, DB 32 is a late variety with long narrow plumpy pods coupled with high resistance to DYMV, GMV, anthracnose and *Cercospora*. Another genotype, DB 37, is highly resistant to GMV, and other mosaic virus with peculiar pubescent glabrous leaves.

2.1.8 Lettuce

2.1.8.1 Promising genotypes

Twenty five germplasm/ advanced breeding lines were evaluated and promising lines were maintained. Three lines, DLS 127 (green leafy type), DLS 134 (green leafy type) and DLS 110 (butterhead red type) showed good performance and yielded 42.5, 38.6 and 34.8 t/ha yield, respectively, over check, Chinese Yellow (32.1 t/ ha). One heading selection DLS-1-52 was found to be promising with an average yield of 31.6 t/ha having uniform reddish colour head.

2.1.8.2 New disease report on lettuce germplasms caused by *Sclerotinia sclerotiorum*

The symptoms which appeared initially was wilting of the outermost layer of leaves and as the infection progresses the crown region became brown, soft, watery, decayed followed by a snowy white mycelium and presence of sclerotial bodies on the affected portion. Leaf samples were collected from two varieties (one heading and one leafy type) and the pathogen was identified as *Sclerotinia sclerotiorum* from Indian Type Culture Collection, Division of Plant Pathology, ICAR-IARI, New Delhi. The healthy plants of heading type which was giving a yield of 702.25 g/ plant reduced drastically to 275.5 g/plant. Similarly in leafy types the yield was 862.75 g/plant was reduced to 303.5 g/plant.

2.2 FRUIT CROPS

2.2.1 Mango

Release of varieties by CVRC

Four mango hybrid varieties, namely, Pusa Pratibha, Pusa Shreshth, Pusa Lalima and Pusa Peetamber have been released in 28th Meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops and notified in the Gazette of India CG-DL-E-08042021-226407 dated 07.04.2021.

Release of varieties by SVRC

Mango hybrids, namely, H-11-2 (Pusa Deepshikha) and H-8-11 (Pusa Manohari) have been released in the 9th State Seed Sub-Committee for Agricultural & Horticultural Crop, Govt. of NCT of Delhi and notified No. F.10(1)2/SI/TA/Sub-Committee/2017-18/2 332-2373 dated 12.02.2021.

Pusa Deepshikha (H-11-2): It is a unique hybrid (Amrapali x Sensation) having regularity in bearing, attractive fruit shape, bright red peel and orange-yellow pulp. The red peel colour on deep yellow background makes it very appealing to the buyers. Trees are semi-dwarf and about 278 plants of this hybrid can be accommodated in a hectare (6 m x 6 m). It has oblong shape and uniform sized fruits with moderate TSS (18.67^0Brix), moderate acidity (0.33%), high pulp content (70%) and good ascorbic acid content (35.34 mg/100 g pulp). It has 7 to 8 days shelf-life at room temperature after ripening.

Hybrid 11-2 (Pusa Deepshikha)

Pusa Manohari (H-8-11): It is a unique hybrid (Amrapali x Lal Sundari) has regular bearing habit, attractive fruit shape, peel greenish-yellow with red tinge on shoulders with yellow orange pulp. It has elongated oblong in shape and uniform sized fruits. Average fruit weight is 223.4 g. It has moderate sweetness, pleasant aroma and good sugar: acid blend. Fruits are fibreless having moderate TSS (20.38^{0}Brix), acidity (0.27%), ascorbic acid (39.78 mg/100 g pulp) and β-carotene (9,738 μg per 100 g pulp) contents. Suitable for table as well as processing purposes (68.76% pulp content). Trees are semi-vigorous and about 278 plants of this hybrid may be accommodated in a hectare (6 m x 6 m). Pusa Manohari showed field tolerance to mango malformation disease and is moderately tolerant to powdery mildew.

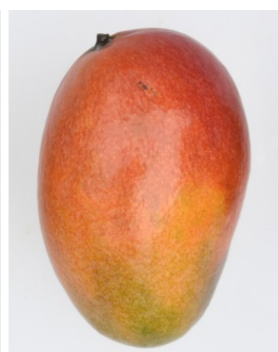
Hybrid H-8-11 (Pusa Manohari)

Hybridization: In scion breeding, 10 cross combinations were attempted on 772 panicles having 6,217 flowers employing Amrapali, Mallika, Neelum, Totapari and Dashehari as female parents and Dashehari, Neelum, Vanraj, Tommy Atkins, Elaichi, Pusa Arunima, Eldon, Maya as male donor parents during March 2021. Total 191 hybrid stones have been obtained, of which 165 germinated and 152 hybrids are surviving in nursery. In rootstock breeding, 91 panicles (275 flowers) were crossed in different combinations employing polyembryonic genotypes, namely, Olour, Kurukkan, Bappakai and M 13-1. Out of total crossed flowers, fruit set was observed in 41 (Olour x Kurukkan), 21 (Olour x Bappakai), 17 (Bappakai x 13-1), and 14 (Bappakai x Olour). Subsequently, 11 seedlings [3 (Olour x Kuruk an), 5 (Bappakai x 13-1), and 3 (Bappakai x Olour)] were recovered for further evaluation from the 15 harvested fruits.

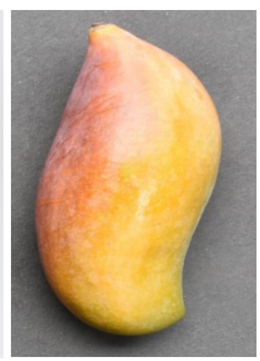
Evaluation of hybrids: Total 58 mango hybrids from different crosses have been have been evaluated physico-chemical traits. Maximum fruit weight was observed in H-14-8 (440.25 g) and minimum fruit weight was noted in H-15-5 (76.25 g). Maximum peel thickness was noted in H-4-10 (2.4 mm) and minimum in H-15-5 (0.29 mm). Stone weight was found to be maximum in H-14-2 (57.6 g) and minimum was in H-11-5 (16.49 g). Significant variation has also been

Coloured mango hybrids

Hyb. H-20-2



Hyb. H-18-4



Hyb. H-19-2

Hyb. H-18-4

Hyb. H-20-2

Hyb. H-19-2

observed for fruit shape index, TSS, stone weight, pulp percentage and peel colour. Fruits of hybrids,namely, H-11-2, H-12-5, H-3-2, NH-16-2, NH-17-1, NH 18-4, NH -19-2 , NH-20-2 *etc*. had attractive bright red peel colour, while H-18-4, H-20-2, and H-3-2 had more than 200 g fruit weight with attractive red peel colour.

Evaluation of maternal Amrapali half-sib population: Total 126 maternal half-sibs of Amrapali were observed for growth and vigour parameters. Out of 109 plants which flowered, fruit yield and quality parameters have been observed in 75 half-sibs. Plant (No. 17/8) had maximum number of fruits (93), plant (No. 39/7) had maximum fruit weight (392.5 g). The maximum TSS (29.5^{o}Brix) was observed in plant (30/9). Nine half-sibs, namely, 19/2, 28/7, 30/9, 31/2, 34/2, 23/7, 21, 8, 33/9 and 24/1 had higher TSS than the seed parent Amrapali.

Evaluation of progeny population of polyembryonic cv. Olour: Progenies of Olour (28) were characterized based on physiological and biochemical traits. A significant level of variability was observed among 28 hybrids. The minimum stomatal density was observed in OP-17-15 (518.67 stomata/ mm^2) in comparison with Olour sapling (617.30 stomata/ mm^2) and the maximum stomatal density was observed in OP-17-56 (746.67 stomata/ mm^2). The minimum photosynthetic rate (4.490 µmol CO_2 m^{-2} s^{-1}) was observed in OP-17-47 in comparison with Olour sapling (6.293 µmol CO_2 m^{-2} s^{-1}) and maximum photosynthesis rate was observed in OP-17-39 (14.483 µmol CO_2 m^{-2} s^{-1}) followed by OP-17-34 (11.517 µmol CO_2 m^{-2} s^{-1}). The minimum transpiration rate was recorded in OP-17-90 (0.520 mmol H_2O m^{-2} s^{-1}) and maximum transpiration rate was recorded in OP-17-39 (4.553 mmol H_2O $m^{-2}s^{-1}$). Lower stomatal density, less photosynthetic and transpiration rate indicates dwarfism in the plant. Furthermore, the maximum total leaf phenolics was recorded in OP-17-11 (3660 mg/100 g FW) followed by OP-17-58 (3650 mg/100 g FW), whereas minimum total leaf phenolic compounds were recorded in OP-17-41 (2040 mg/100 g FW) as compared with Olour (3063.33 mg/100 g FW). The maximum leaf flavonoids content was in OP-17-58 (256.56 mg/100 g FW) followed by OP-17-57 (248.68 mg/100 g FW) and minimum leaf flavonoids content was recorded in OP-17-41(123.86 mg/100 g FW) as compared with Olour (206.167 mg/100 g FW). The high content of phenolics and flavonoids indicate about dwarfness and biotic stress resistance.

***In-silico* mining of ripening related genes for shelf-life:** *In-silico* mining of 95 nucleotide ripening gene sequences of *Mangifera indica* L. was carried out and 35 shelf-life specific primers were designed. Of these, 27 were found polymorphic, which showed substantial genetic diversity among the 20 mango genotypes. The average number of alleles per locus (An), gene diversity (GD), major allele frequency (Maf), expected heterozygosity (Ho) and polymorphic information content (PIC) of the 27 markers were 2.25, 0.40, 0.77, 0.20 and 0.61, respectively. Loci MSL-1, NMSLC-12, NMSLC-14 and EXPM-2 gave specific allelic pattern with good PIC values. Detailed cluster analysis revealed that the 20 mango genotypes grouped according to their shelf-life duration (long, medium and short). Association analysis revealed that a total of 12 markers were associated with 6 traits and had strong association between MSL-8 with PLW and MSL-13 with titratable acidity (%) with a phenotypic variance of 30 and 67%, respectively. Therefore, these gene-specific SSRs loci could be utilized in designing of marker-assisted breeding for achieving longer shelf-life genotypes.

2.2.2 Citrus

Development of sweet scion hybrids: Seven sweet citrus scion hybrids (pummelo x sweet orange) were examined for growth, yield and fruit quality. Hybrids SCSH-5/2016, SCSH-7-2/12, SCSH-11-15/12 and SCSH-19-5/14 produced encouraging results with respect to moderate fruit weight (282.83-620.67 g), higher juice content (45.16 to 48.86%) as compared to PS-2 (female parent) (23.41%). These orangelo also had moderate acidity (1.60 to 1.96%) but much higher than both the parents. All the hybrids had much lower seeds (<34 seeds/fruit) than pummelo (female parent) but higher than male parent.

Development of acid citrus scion hybrids: Yield and fruit quality of eight acid citrus scion hybrids (acid lime x lemon) were assessed during 2021. Two acid citrus hybrids (ACSH-3.2/18 and ACSH-9-13/18) appeared to be highly precocious and having immunity to citrus canker. These hybrids also exhibited moderate fruit size (67.07 and 73.77 g, respectively). Compared to check (Pusa Abhinav), > 74 g and 90% bigger fruits were found in ASCH-3-2/2018 and ASCH-9-13/18. Both hybrids were found to bear fruits twice a year but had lower juice content (19.08 and 18.12%).

Isolation of grapefruit limb sports: Three different types of grapefruit variants were noticed in cv. Redblush. These sports were assessed for fruit quality traits and time of ripening with the parent cv. Redblush. It was observed that all these limb sports were different with original Redblush with regard to quality traits (colour of juice vesicles, acidity, fruit weight, vit. C content) as well as time of ripening. Limb sport RBLS-1 had deep red juice colour than Redblsuh but much higher peel thickness (7.09 mm as compared to 4.64 mm in Redblush) and lesser juice content (34.32%). Another two limb sports (RBLS-2 and RBLS-3) has moderate sized fruit (315.18 and 329.79 g), deep pigmentation on peel as well deep red juice colour, thin peel thickness (3.29 and 4.26 mm), higher ascorbic acid content (50.57 and 39.27 mg/100 ml juice) than Redblush. These sports mature by first week of October compared to the original Redblush.

Variation in size, peel thickness and aril colour in grapefruit limb sports

Clonal selection in lemon: During 2020-21, the performance of seven lemon accessions was evaluated in comparison to cvs. Pusa Lemon-1 and Kagzi Kalan. The highest fruit weight (86.52 g) was recorded in LS-3, which was statistically at par with Pusa Lemon-1. The fruits of LS-10 had the thinnest peel (0.89 mm) compared to Pusa Lemon-1, LS-7 and Kagzi Kalan. The fruits of LS-8 were most juicy (52.08%). The juice TSS (7.96°Brix) was highest in Pusa Lemon-1 which was statistically similar with LS-7, LS-8, LS-9, LS-10 and Kagzi Kalan (7.56°-7.86°B). The fruits of LS-8 had the highest juice acidity (5.61%) comparable to Pusa Lemon-1 and LS-9 fruits.

Evaluation of new cultivars of citrus fruits: The performance of Dancy and W. Murcott tangerines, and Minneola tangelo was assessed with Kinnow mandarin. Minneola yielded the heaviest fruits (287.66 g) with lowest number of seeds (11.00 seeds/ fruit). The fruits of W. Murcott had the thinnest peel (2.15 mm) statistically. W. Murcott and Kinnow proved equally good for juice content (46.10-51.80%), while it was lowest in Dancy (23.72%). The fruits of Dancy and W. Murcott proved similar statistically in respect of low acid content (0.63-0.70%). The highest content of ascorbic acid was recorded in the juice of Minneola (53.86 mg/100 ml), closely followed by W. Murcott and Kinnow.

Evaluation of citrus rootstock hybrids for drought: A hydroponic experiment was conducted with newly developed citrus rootstock hybrids [(CRH-21-13, CRH-21-14, CRH-23-9, CRH-23-5 and *Jatti khatti* (check)] under PEG induced drought. Among studied hybrids, CRH 21-13/14 sustained higher relative water content in the leaves and showed excellent chlorophyll stability index, therefore was able to preserve chlorophyll content and had minimal cell membrane injury triggered by PEG induced drought stress. Furthermore, superior root architecture of this in terms of higher root length, area, volume, tips, forks and crossings could possibly contributed in better uptake of nutrients and water from nutrient solution having negative osmatic potential, therefore negating adverse impact of PEG induced drought stress. The superiority of hydroponic drought screening technique was noted compared to *in vitro* and *in vivo* screening, as it is simple, rapid, efficient and also cost effective.

Evaluation of citrus hybrids against salinity & polyembryony: Of the nineteen citrus rootstocks hybrids (Sunkokan × Kinnow, Sunkokan × Pummelo, Sunkokan × Mosambi, Pummelo × Sacaton, Pummelo × Troyer) screened against 50 mM NaCl induced salinity, only 14 hybrids have shown tolerance. Of the 20 hybrids tested, only 09 (CRH 21-9, CRH 21-13, SCHS 9-19, SCHS 15-7, CSH 17-12, CSH 17-19, SCSH 3-14, SCSH 3-15 and CRH 7-4) have polyembryony. CRH-7-4/18 rootstock has been found quite hardy, bearing fruits 2-3 times higher along with dwarf and compact growth.

Hybridization: In scion, 122 flowers were crossed for development of citrus canker tolerant hybrids in acid citrus using crosses of lemon x lime and lime x lemon (Konkan SL, Pusa Abhinav, Pusa Udit, Pusa Lemon-1). In sweet citrus scion improvement, back cross was attempted in SCSH-11-15/12 (Pummelo x Mosambi) and total 13 flowers were hybridized. In addition back cross as well crosses with limequat were also attempted in acid citrus scion hybrid (ACSH-3-2/18 and ACSH-9-13/18).

Ploidy manipulation in Kinnow mandarin and sweet orange: Sixty-six 2nd generation colchiploids of Kinnow and 47 of Mosambi were characterized using fruit, flower, plant growth and leaf characteristics. A large variation was recorded for all the traits in the colchiploids, but very little variation within colchiploids, indicating the stability of the colchiploids in first and second generations. The fruit rind roughness/ smoothness and thickness exhibited differences among colchiploids, indicating towards their hyperploidy. All the colchiploids had lower stomata number, but minimum stomatal length and width in wild type compared to colchiploids. The colchiploids, K-1, K-2, K-3, K-5, K-6, K-7, K-11, K-16, K-19 and K-20 in Kinnow and M-8, M-1, M-2, M-13, M-16, M-18, M-21 and M-22 in Mosambi sweet orange were identified as putative tetraploids. The stomatal characteristics can be used as markers for identification of Kinnow and sweet orange putative tetraploids. Cytological investigations were carried out on 22 second generation colchiploids of Kinnow and 21 of Mosambi. Observations clearly indicated hyperploidy. On the basis of comparative visual observations, 10 putative tetraploids of Kinnow and 8 of Mosambi were detected.

Kinnow mandarin tetraploids with fruits having rough rind

Hybridization in Kinnow and Mosambi tetraploids: For the production of triploids in Kinnow and Mosambi, 430 flowers of putative second-generation tetraploids of Kinnow and 433 of Mosambi were pollinated. Comparatively, a better fruit set was noted in Mosambi than Kinnow. Retention of fruits in Kinnow colchiploids (12.01%) was better compared to Mosambi colchiploids (6.74%) after one 30 days of hybridization.

Mutagenesis studies on Kinnow and sweet orange: Six putative mutants identified for dwarfing trait, *viz*., G-20-5, EMS-M-3, Col-1 and Col-2 and low seeded mutants G-6-1, G-9-4 and G-39-3 (<10 seeds/ fruit) were multiplied *in-situ* on *Jatii khatti* rootstock for further evaluation and testing. Four plants of each mutant were raised. Cent per cent survival was recorded in all the multiplied mutants except G-39-3.

***In vitro* mutagenesis in Kinnow and validation of mutants using molecular markers:** Hardwood stage was observed as a proficient explant maturity stage to boost the vigorous early shoot emergence on MS (Murashige and Skoog) and MT (Murashige and Tucker) media added with GA_3 10 mg L^{-1} which also delayed leaf abscission in cultures. Although BAP 2.5 mg L^{-1} induced multiple shoots, severe abscission of micro-shoots was noticed. Further reduction in abscission rate and healthy shoot growth were observed when sub-culturing the micro-shoots on MS + BAP 2.5 mg L^{-1} + GA_3 10 mg L^{-1} + silver thiosulfate (5 mg L^{-1}) medium.

2.2.3 Grape

Hybridization: Hybridization work was attempted for achieving extra early maturity, seedless berries, bold berries and improved fruit quality. A total of 14 cross combination having 179 panicles (12,060 flowers) crossed. In rootstock breeding, crossing among the *Vitis* sp. genotypes, namely, *V. parviflora* × Dogridge (*V. champini*), and *V. parviflora* × Salt Creek (*V. champini*) were attempted.

2.2.3.1. Hybrids released and notified

Pusa Aditi (Hybrid 75-32, Banqui Abyad x Perlette): This hybrid wasidentified for release in 28th Meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops. It has been released for sub-tropical part of north-western plains of North India. It has potential yield of 18.77 t/ha with large bunch size (440 g) and uniform round, juicy, seedless and bold berries (2.77 g). Its early maturing grape hybrid, matures after 82-85 days after full bloom. Total soluble solids of juice is 19.31°Brix with mild titratable acidity (0.56%). It is suitable for table and juice purposes.

Pusa Aditi

Pusa Urvashi (Hybrid 76-64, Hur x Beauty Seedless): It was released in 28th Meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops. It is a hybrid released for sub-tropical part of north-western plains of North India. It has potential yield of 20.60 t/ha with large bunch size (323 g), semi-loose, firm, seedless and bold berries (2.68 g). Its mid-season maturing, which matures after 97 days after full bloom. Total soluble solids of juice is 17.34°Brix and mild titratable acidity (0.70%). It is suitable for table and juice making purposes.

Pusa Urvashi

Pusa Purple Seedless: It was identified by the State Seed Sub-Committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi No. F.10(1) (2)/S1/TA/Sub-Committee/2017-18/2332-2373 vide dated 12.02.2021. Average yield is 8.6 kg per vine from 5-year-old vines trained on Kniffin system. Average yield is 14 t/ha if planted at 2 m x 3 m spacing. It has purple elongated bunch (350 g) with seedless berries suitable for table purpose which have 20-23°Brix TSS. Veraison starts after 50-55 days from pruning and requires another 25-30 days for harvest. It has extra-early ripening behaviour and bunches are ready for harvest between 75-80 days after full bloom (3rd week of May).

Pusa Purple Seedless

Pusa Swarnika: It is identified by State Seed Sub-Committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi. The average fruit yield is 16.71 t/ha, which is 15.2% higher than check variety Perlette.

It is a unique hybrid having early berry ripening habit, loose bunch, golden-yellow coloured bold berries and suitable for sub-tropical climate. Bunches are loose and medium to large in size (317 g). Berries are bold, large in size (4.14 g), round golden-yellow colour, seeded with fírm pulp. High TSS (20.71°Brix), mild acidity and ideal TSS: acid ratio. It is moderately rich in nutraceutical properties like total phenolics (91.29 mg/100 g) total flavonoids (91.80 mg/100 g), and antioxidant properties as estimated by DPPH, FRAP and CUPRAC assays. Suitable for table purpose, juice making and *Munnakka* preparation.

2.2.3.2 Hybrids identified with loose bunch, bold berry and early maturity

Three grape hybrids (Hyb. 16/2A-R1-P9, Banqui Abyad x Perlette; Hyb. 16/2A-R1-P14, Cardinal x Beauty Seedless; Pusa Swarnika, Hur x Cardinal) have been found promising against the check variety 'Black Muscat'. These hybrids showed superiority for economic traits like loose bunch, bold berry, early maturity and high TSS with regard to check Black Muscat. The seeded hybrids, namely, Hyb. 16/2A- $R_{1-}P_9$ (BA x Per) had big sized bunch (363.0 g), with berry weight of 3.93 g, 20.0^{0}Brix TSS, and 0.87% acidity, while Hyb. 16/2A-$R_{1-}P_{14}$ (Card x BS) had bunch weight of 332.25 g, high TSS (23.10 ^{0}Brix), and acidity of 0.91%. Both matured in the first week of June.

2.2.3.3 Hybrids for juice making with better nutraceutical properties

Four grape hybrids (Hyb. 16/2A-R4-P7, Pusa Navrang x Hyb. 76-1; Hyb. 16/2A-R2P7, Pusa Navrang x Hyb. 76-1; Hyb. 16/2A-R3-P3, Pusa Navrang x Banqui Abyad; Hyb. 16/2A-R4-P9, Pusa Navrang x Black Muscat) are rich in total anthocyanins, phenolics, flavonoids and other berry quality traits. These hybrids were found superior in terms of bold berries, higher juice recovery, yield, and early maturity.

2.2.3.4 Identification of berry cracking tolerant genotypes

Twenty-nine diverse grape genotypes were assessed for their berry cracking tolerance based on morpho-physical, physiological, biochemical, mechanical and nutrient element properties. Genotypes 'Black Muscat', 'Black Prince' and 'Hur' were found more tolerant against the berry cracking as compared to commercial varieties like Flame Seedless, Perlette, Beauty Seedless and Cardinal. *In vitro* berry cracking ratio and water uptake by berries were found associated with traits related to the berry cracking. Based on the berry cracking ratio, genotypes 'Black Muscat', 'Black Prince' and 'Hur' were found more tolerant and 'Hy. 72-151', 'Flame Seedless', 'Cardinal' and 'Beauty Seedless' were most susceptible under *in vitro* conditions.

2.2.4 Guava

Hybridization: Hybridization was attempted as per diallel mating design by involving ten best combiner genotypes with superior desirable traits. Thirty cross compatible desirable combinations were used and a total of 760 flowers were crossed during this period. Out of the different cross combinations, final fruit set was noticed in 21 cross combinations resulting in 1270 F_1 population.

Characterization of genotypes: Genotypes and hybrids were evaluated based on morphological, biochemical and physiological parameters and nutrient profiling. Among the various biochemical traits studied, *viz.*, the highest content of TSS was recorded in GH-2017-1F (12.54°Brix), highest total titratable acidity was recorded in GH-2017-8B(R) (0.66%), while the highest ascorbic acid content (285.03 mg/100 g of pulp)was recorded in GH-2017-4F. Similarly, phenolic content was recorded highest in Lalit (283.67 mg/100 g GAE of FW), while hybrid GH-2017-6C exhibited the highest total flavonoids content (92.53 mg/100 g FW). The total carotenoids content in pulp varied and was recorded in maximum in Lalit (0.68 mg/100 g of FW). Total sugars content was registered to be the highest in GH-2017-1F (9.09%), while total soluble proteins were highest in GH-2017-2A (16.65 mg/ml).

Among the crosses resulting from Kashipur Collection x Black guava, hybrids showed pigmentation on leaves and stem in vegetative growth stage. Three promising F_1 hybrids were identified with pink pulp having less numbers of seeds and more pulp thickness. Among all the red pulped hybrids, hybrid GH-2016-8F (Thai x Punjab Pink) was found potential with excellent nutritional quality and soft seeded. Fruit quality traits like fruit weight (160-175 g), antioxidant activity (6.4-7.5 mg/100 g of FW), total flavonoids (84.53-110.22 μM TE/g FW), ascorbic acid (157.22-190.16 mg/100 g of pulp), total soluble solids (11.25°Brix) 12.50 to 13.6, phenolic content (121.57- 142.00 mg/100 g GAE of FW) and titrable acidity ranging from 0.41-0.45%, with average yield of 40 t/ha.

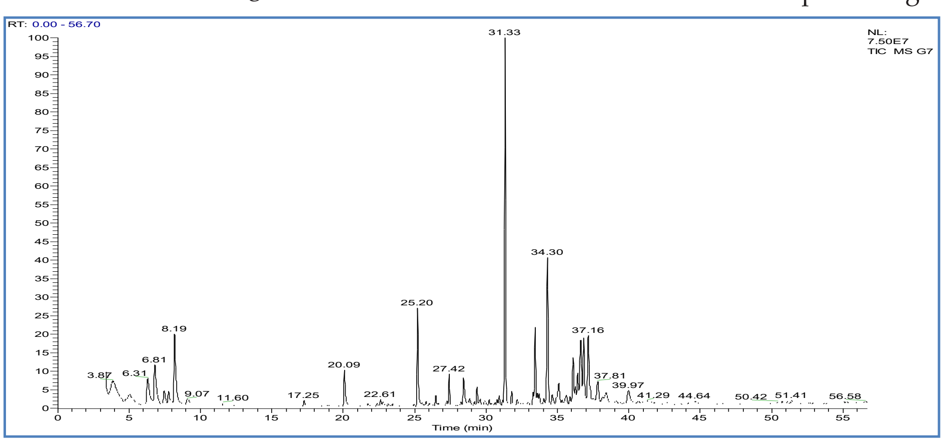
GH-2016-8F

Flavour compounds fraction analysis: Thirty two genotypes including hybrids were also analysed using GC-MS for flavouring compounds. The major compounds identified were hexenol, ethyl acetate, benzldehydes, 3Z-hexenyl acetate 3-phenylpropyl acetate, butylated hydroxytoluene, β-caryophyllene, caryophyllene oxide, nerolidol and globulol, besides several compoundswere present in minor and trace amounts. Guava genotype 'Black guava' has been analysed using LC-MS and HPLC to understand the basis of pulp colour. The results showed that the three anthocyanins delphinidin-3-glucoside, petunidn-3-glucoside and cyanidin-3-glucoside are present in Black guava, which are responsible for its purplish peel and pulp colour.

To dissect the complex process of pulp colour development in guava a comparative transcriptome analysis between red pulp and soft seeded and white pulp hard seeded genotypes was done. For each genotype samples from three different developmental stages,*viz.*, early ripening stage, mid ripening stage and late ripening stage were taken for expression profiling. The contrasting pulp colour was clearly visible in mid and late fruit developmental stage. A total of 18 samples were sent for RNA-seq, which include three stages of the contrasting genotype with 3 biological replicates for each stage. After quality check *de-novo* transcriptome assembly using Trinity pipeline. A total of 251,345 transcripts were assembled with a N50 value of 1,530. The annotation of transcripts and comparative transcriptomic analysis is in progress.

2.2.5 Papaya

Hybrid evaluation: Five hybrids, namely, P-7-15 x Pune Selection 3, P-7-15 x P-7-2, P-7-15 x P-9-12, P-7-15 x Pusa Nanha and Red Lady were evaluated for different horticultural parameters under insect proof net-house. The minimum plant height (69.5 cm) at first

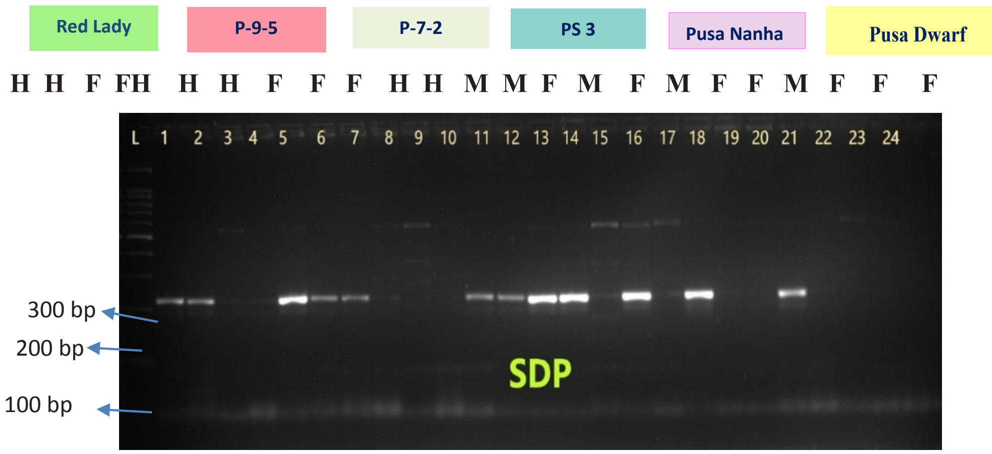


GC-MS analysis for flavour

flower initiation was noticed in hybrid P-7-15 x Pusa Nanha, followed by (71.25 cm) P-7-15 x P-7-2, (73.33 cm) P-7-15 x Pune Sel. 3 and maximum (85.15 cm) in P-7-15 x P-9-12. The highest fruiting zone (167.25 cm) was recorded in hybrid P-7-15 x Pune Sel. 3 followed by P-7-15 x P9-12 (147.25 cm), and Red Lady (143.25 cm), while the lowest fruiting zone (127.33 cm) was observed in P-7-15 x Pusa Nanha. The minimum days to fruit maturity (132 days) was recorded in P-7-15 x Pune Sel. 3, closely followed by the hybrid P-7-15 x P-7-2 (133.5 days), while it was most delayed (147.25 days) in Red Lady. The number of fruits per plant was maximum (45.67) in the hybrid P-7-15 x P-7-2 followed by P-7-15 x P-9-12 (41.33) with minimum in P-7-15 x Pusa Nanha (29.33). The maximum average fruit weight (1588 g) was recorded in P-7-15 x Pusa Nanha followed by (1495 g) in P-7-15 x P-9-12, whereas it was lowest (1175 g) in the hybrid P-7-15 x P-7-2. The hybrid Red Lady had maximum TSS (13.6ºBrix), which was statistically similar to the P-7-15 x Pune Sel. 3. However, minimum TSS (9.8ºBrix) was recorded in P-7-15 x Pusa Nanha. The total phenolic content and total flavonoids content in fruits were highest for the hybrid Red Lady followed by P-7-15 x Pune Sel. 3. The highest amount of CUPRAC activity was in the P-9-5 (4.37 μmol/g), while maximum DPPH activity was in Red Lady (36.22 μmol/ g) followed by P-7-15 x Pune Sel. 3 (28.26 μmol/g) through it was minimum in P-7-15 x P-7-2 (16.42 μmol/g). Based on above findings, genotype P-7-15 as maternal female parent holds immense potential towards development of a commercial hybrids. Hybrid P-7-15 x Pune Sel. 3 had longer fruiting zone, av. fruit weight, early fruit maturity and higher per plant fruit yield with better antioxidant activities.

P-7-15 x Pusa Sel 3 in fruiting

Identification of sex form using molecular markers: Total 10 SCAR and RAPD markers, namely, 71E, SDP, SMY 1, PKBT4, PKBT5, PMSM2, OPO-08, SCO-08, PVF 1, PVR 2 and SMY 1 were used in 48 papaya plants in 6 genotypes, namely, 3 gynodioecious (Red Lady, P-9-5, P-7-2) and 3 dioecious (Pune Sel. 3, Pusa Nanha, Pusa Dwarf) for the sex identification at early stage. Among 10 markers, only four, *viz.*, PKBT4, PKBT5, SDP, and PMSM2 were amplified for that particular sex loci and another one marker 71E showed amplification in all the 48 tested samples. Among the amplified SCAR markers, PKBT5, SDP and PMSM2 showed higher level of accuracy. The marker 71E amplified all the three sex types, namely, male, female and hermaphrodite and can be taken as a control. This particular marker produced amplicons for all the three sex types at 1000 bp since the sequence was present on autosomes but they were not polymorphic. The marker SDP amplified a fragment length of ~ 220 bp and it indicated the presence of *SEX1* gene. In this marker the desired bands were present in both male and hermaphrodite plants but absent for female plants in both types of genotypes. Among the SCAR markers that produced sex polymorphism, PKBT 5 showed the 100% reliability in sex identification. This marker amplified at ~ 350 bp for both male and hermaphrodite plants and no bands were obtained for female plants. A robust male specific marker PMSM 2 (Papaya male specific marker 2) was precisely designed to detect the male-specific regions. For RAPD-SCAR marker PMSM 2 amplification occurred at ~ 500 bp only in male but not in female and hermaphrodite plants may due to



PCR amplification for the SCAR marker SDP for different papaya sex types. The genotypes names are depicted in the coloured boxes, H-Hermaphrodite, F-female, L- 100 bp ladder

probable location of this marker on the male specific region on Y chromosome. Molecular marker PKBT 5, SDP and PMSM 2 can be commercially utilized for identification of male and hermaphrodite plants among dioecious and gynodioecious genotypes.

Mutation breeding: The seeds of the papaya line P-7-2 were treated with gamma rays 0.1, 0.15, 0.2, 0.25 and 0.3 kGy. Two mutants, *viz*., PM 04 and PM 28 were selected from the two lower doses (0.10 and 0.15 kGy), which were particularly having dwarf stature and low bearing height in M6 population andwere selected and advanced in M7 generation. Minimum plant height (102.44 cm), plant height at flower initiation (70.34 cm), plant girth at first fruiting (64.25 mm), nodes to first flowering (52.44), days to flower initiation (84.52), length of middle internode (4.6 cm), petiole length (74.24 cm) and minimum plant spread in east-west direction (132.4 cm) was noted in PM 04 and minimum plant spread in north-south direction (135.6 cm) was recorded in PM 28 followed by PM4 (146.4 cm). However, maximum height (132.64 cm), plant height at flower initiation (92.24 cm), plant girth (74.36 mm), nodes to first flowering (64.2), days to flower initiation (98.44), length of middle internode (7.2 cm), petiole length (94.25 cm) and plant spread in east-west direction (148.2 cm) and north-south direction (152.2 cm) was found in control (P 7-2). Maximum number of fruits (42.4) and width of fruit (12.22 cm) were recorded in PM 04, while maximum fruiting length (96.4 cm), fruit weight (0.980 kg) and fruit length (21.84 cm) were recorded in control (P 7-2). Minimum fruit cavity length (14.24 cm) and width (4.22 cm), maximum pulp thickness (3.44 cm) and TSS (10.22^{o} Brix) were recorded in PM 04, while minimum pulp thickness (2.52 cm) and TSS (8.44^{o} Brix) were recorded in control (P-7-2).

2.2.6 Temperate fruits

Pusa Khor: One branch of "Pusa Khor" variety of walnut of four-years of age showed cluster bearing habit having more than 25 pistillate flowers, which is not reported. This was found in research farm Dhanda

One four-years of age branch of "Pusa Khor" walnut showing cluster bearing

of ICAR-IARI, RS, Shimla. This tree and branches were tagged for future observation.

Rootstock trial on temperate fruit crops: Evaluations of different rootstocks (*Prunus japonica*, wild peaches, Chuli, Behmi, Bitter almond, Paja) for different stone fruits were studied with different spacings. *Prunus japonica* exhibited the best results under high density planting. Newly introduced plum varieties Fariar, Red Beaute, Black Amber and prune variety Green Gauge were evaluated after top working on *P. japonica*. Fruit weight of plum varieties varied from 43.82-50.17 g with maximum in Red Beaute (50.17), while TSS varied from 11.9-14.8^{0}Brix. Fruit weight of Green Gauge (prune) was 37.82 g.

Performance of spur varieties of plum: Of the different varieties evaluated, fruit weight varied from 175.88-255.12 g, TSS from 10.4-14.6^{0}Brix, total sugars 8.05-10.44%, and vitamin-C 25.98-41.24 mg/100 g. Performance of plum cultivars were evaluated on Behmi rootstock for yield, quality and shelf-life. Highest average fruit weight was recorded in Black Amber (69.65 g), Vitamin-C in different cultivars varied from 7.81-10.74 mg/ 100 g, total sugars was maximum in Santa Rosa (11.59%), longest shelf-life was recorded in Black Amber (28 days) with lowest (4 days) in Satsuma on room temperature.

Evaluation of temperate fruit genotypes: Out of 25 Russian type accessions of pomegranates 18 genotypes have started flowering and fruiting. Fruit weight varied from 115-211 g, TSS varied from 13.9-21.2%, vitamin-C 7.99-11.12 mg/100 g in different genotypes. New strawberry genotypes were evaluated in polyhouse conditions; fruit weight varied from 16.32-23.57 g, Capri variety had the highest vitamin-C content (35.12 mg/100 g). Evaluation of new peaches on different rootstocks for yield and quality. Total sugars varied from 10.8-14.6% TSS varied from 11.5-16.2 ^{0}Brix, dry matter varied from 18.45- 21.51 g. Studies on application of B+Zn+Ca and different mulches in pomegranate was conducted. The spray of 0.4% B+Zn+Ca with grass mulch gave better results in Kandhari Kabuli variety with respect to fruit weight (295.88 g), minimum fruit cracking (12.31%), and good Vitamin-C (16.5 mg/100 g).

2.2.7 Production Technologies of Fruit Crops

2.2.7.1 Mango

Effect polyembryonic rootstocks on semi-vigorous mango varieties: Both rootstock and scion genotypes as well their combined effect impacted tree growth in terms of canopy diameter, tree volume and height significantly. Concerning variety only, 'Pusa Arunima' showed highest tree growth, while lower values were found in 'Pusa Surya'. Considering rootstock individually, 'K-5' and 'K-2' inhibited tree growth. Combined influence of both scion and rootstock exhibited that rootstock K-5 or 'K-2' produced smaller tree growth in all three cultivars. However, Olour and K-3 rootstocks were found vigorous for 'Pusa Arunima' and 'Pusa Surya' but variable results were obtained for dwarf cultivar 'Amrapali'. Yield per tree, yield efficiency and yield/meter canopy cover also influenced significantly by rootstock individually and jointly, though cultivar did not have significant difference. Excluding the effect of cultivar, fruits/tree and yield/tree were found higher either on 'K-2', Kurakkan' or 'Olour' rootstock, while it was 'K-2' which produced higher yield efficiency (YE) and yield per meter canopy diameter (YPCD). Furthermore, for 'Pusa Arunima', Kurakkan (27.13 kg) and 'K-2' rootstock (29.50 kg) had higher yield/tree, while YE (0.25 kg/m^3 CV) and YPCD (1.66 kg/ m canopy diameter) was found highest on 'K-2' and 'Kurakkan' rootstocks.'Pusa Surya' exhibited higher fruits/tree and yield/tree on K-3 (65.00 fruits/tree) and K-2 (68.0 fruits/tree) rootstocks, except rootstock K-5, all other excelled for yield/tree. Both YE and YPCD were found highest on 'K-2' (0.54 kg/m^3 CV; 1.88 kg/ m canopy diameter) for 'Pusa Surya'.

Fruit quality traits also influenced significantly by rootstock and scion varieties individually and jointly. Combined effect witnessed superiority of 'K-2' and Kurakkan for 'Pusa Arunima for fruit weight', but rootstock failed to influence fruit weight in case of 'Amrapali' and 'Pusa Surya'. Acidity, TSS and ascorbic acid contents were also affected by scion cultivars, rootstocks and their interactions. The highest TSS in

Pusa Surya was obtained on K-5, while Olour, K-3 and K-2 produced fruit with higher TSS in Amrapali. Pulp TSS was not influenced in Pusa Arunima by rootstocks.

Effect of polyembryonic rootstocks on vigorous mango varieties: Canopy diameter (CD) was not affected significantly by rootstocks, while rootstock impacted tree volume (TV) and height was significantly affected in Mallika and Dushehari. Vigorous trees were observed in case of Mallika/ Kurakkan, while reverse was noticed for Dushehari. Olour promoted tree height in Dushehari, while inhibitory effect was observed for Mallika. Almost similar trend was noticed for tree volume. Varieties, rootstock alone or jointly impacted fruits/tree, yield efficiency (YE), yield/tree and yield per meter canopy diameter (YPCD). Overall, Dushehari- 'Olour' and Mallika-Kurakkan had highest fruits/tree and YPCD but not significantly different with Mallika-K-5. Moreover, YE was found to be the highest in Mallika-Olour which was not significantly different from Mallika-K-5. However, Dushehari-K-5 and Dushehari-Kurkkan had higher YE. 'Mallika' had higher fruit weight on Kurakkan which showed parity with trees on Olour rootstock. Both Kurakkan and Olour induced higher pulp: stone ratio superiority with others. In Dushehari, pulp content was found highest on Kurakkan (61.47%), while it was K-5 (3.82) on which the highest pulp: stone ratio was noticed.

Evaluation of newly developed mango hybrids under INM schedule: The 100% recommended dose of fertilizers (RDF) alone and alongwith AMF (250 g) and *Azotobacter* (250 g), 75% RDF alongwith AMF (250 g) and *Azotobacter* (250 g) and 50% RDF alongwith AMF (250 g) and *Azotobacter* (250 g) were applied to new mango hybrids. There was significant effect of INM treatments, mango cultivars and interaction effect on plant height and canopy volume. Maximum tree height (4.85 m) was recorded in treatment NPK 100% + AMF (250 g)+ *Azotobacter* (250 g) followed by 4.32 m in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g), while minimum (3.60 m) in treatment T8. Among cultivars, maximum tree height (4.34 m) was found in Pusa Arunima and minimum (3.91 m) in Pusa Pratibha. Maximum canopy volume (71.60 m^3) was recorded in treatment NPK 100% + AMF (250 g) + *Azotobacter* (250 g) followed by 47.38 m^3 in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g). Among cultivars, maximum canopy volume (68.35 m^3) was found in Pusa Arunima and minimum (24.81 m^3) in Pusa Pratibha. The maximum number of fruit (31.01) was recorded in treatment NPK 100% + AMF (250 g) + *Azotobacter* (250 g) followed by 29.50 in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g). Among varieties maximum number of fruits (36.77) was counted in Pusa Arunima, while minimum (23.16) in Pusa Pratibha. Maximum weight of fruit (245.50 g) was recorded in the treatment NPK 100% + AMF (250 g) + *Azotobacter* (250 g) followed by 216.71 g in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g). Among varieties, maximum fruit weight (245.46 g) was found in Pusa Arunima followed by Pusa Lalima (200.00 g), while minimum (170.55 g) was recorded in Pusa Pratibha. Maximum fruit yield (20.04 kg) was recorded in treatment NPK 100% + AMF (250 g) + *Azotobacter* (250 g) followed by 18.09 kg in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g). Among varieties, maximum fruit yield (20.79 kg) was found in Pusa Arunima followed by Pusa Lalima (17.185 kg) and minimum (11.298 kg) in Pusa Pratibha. Maximum TSS of fruit (21.0^{0}Brix) was recorded in treatment NPK 100% + AMF (250 g) + *Azotobacter* (250 g) followed by 20.0^{0}Brix in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g). Among varieties, maximum TSS (21 ^{0}Brix) was found in Pusa Arunima and Pusa Lalima followed by Pusa Shreshth and Pusa Pratibha (20.5^{0}Brix). Among varieties minimum acidity (0.14%) was found in Pusa Lalima followed by Pusa Pratibha (0.16%) and maximum (0.24%) was in Pusa Shreshth and Pusa Arunima.Treatment T-7 comprising of NPK 75% + AMF (250 g) + *Azotobacter* (250 g) recorded higher leaf macro-nutrients and Zn contents in mango hybrids compared to other INM treatments.

Effect of organic nutrient sources: The Effect of organic nutrient sources and microbial consortium on bearing Amrapali were evaluated under high density. Twelve treatments of different organic nutrient sources were investigated using standard methodologies. The treatment T8 (vermicompost (40 kg $tree^{-1}$) + microbial consortia) improved growth, soil physical, chemical and biological properties. Significantly higher leaf macro and micronutrients such as nitrogen (1.18%) and potassium (1.45%), copper (22.18 ppm), iron (278.46 ppm), and zinc (58.98 ppm) as well as total microbial biomass carbon (78.41 µg g^{-1} soil) activities of acid phosphatase (78.36 µg p-nitrophenol g^{-1} soil h^{-1}) and dehydrogenase (42.68 TPF g^{-1} h^{-1}), were observed in T8. The highest fruit yield was also recorded with the application of treatment T8 (13.14 t/ha), which was on par with the application of treatment T2 (12.68 t/ha). The recommended dose of NPK had shown higher cost: benefit ratio compared to all other treatments.

2.2.7.2 Citrus

Performance of sweet orange cultivars on different rootstocks: The tree vigour, fruit yield and quality of two newly released cultivars of sweet orange (Pusa Sharad and Pusa Round) were significantly influenced, while budded on different rootstocks. Over all, RLC-6 and Yama Mikan proved most vigorous rootstocks for Pusa Sharad (72.87 m^3 canopy volume) and Pusa Round (68.12 m^3 CV), respectively. The lowest tree vigour of Pusa Sharad (23.93 m^3 CV) was recorded on Yama Mikan. In Pusa Round, the similar vigour was recorded on RLC-6 and X-639 rootstocks. RLC-6 rootstock proved to be the most productive rootstock for Pusa Sharad (58.69 kg/tree) and Pusa Round (40.93 kg/tree) cultivars.

The lowest peel thickness in the fruits of Pusa Sharad (3.96 mm) was recorded on X-639 rootstock, which proved similar with rest of the rootstocks except C-35 and Soh Sarkar. However, in Pusa Round, the lowest peel thickness was observed on RLC-7 (3.75 mm). The content of juice in the fruits of Pusa Sharad (44.29%) was recorded, while grown on Yama Mikan without any significant difference with RLC-6, X-639 and RLC-7 rootstocks, however, in Pusa Round, the highest juice content (50.50%) was recorded on X-639 rootstock. Yama Mikan also tended to show the highest TSS content (7.72°Brix) in Pusa Sharad with no significant difference with RLC-6 and X-639, while C-35 and Yama Mikan proved equally effective to produce the fruits of Pusa Round with high content of TSS (7.12 -7.60°Brix). *Soh Sarkar*, *Jatti khatti* and X-639 rootstocks contributed the low acid content in the fruits of Pusa Sharad (0.51-0.60%), while the similar response in Pusa Round (0.53-0.62%) was noticed while grown on *Soh Sarkar*, *Jatti khatti* and RLC-7 rootstocks. Yama Mikan proved best rootstock to improve the ascorbic acid in Pusa Sharad (40.44 mg/100 ml) and Pusa Round (40.96 mg/100 ml) cultivars.

2.2.7.3 Grape

Evaluation of bio-regulators for quality production: During the year, four different varieties of grape, namely, Flame Seedless; Beauty Seedless (seedless, coloured), Pusa Aditi (seedless, white) and Pusa Swarnika (seeded, golden yellow) were subjected to treatment of bio-regulators for berry quality improvement. Ethephon (400 ppm) was found to be found the best for Flame Seedless and Beauty Seedless in improving colour of the berries and berry quality, while ethephon (300 ppm) for Pusa Aditi and boric acid (0.4%) for Pusa Swarnika were found better compared to other treatments.

2.2.7.4 Guava

Management of Guava wilt through bio-control agents: Guava genotypes were multiplied through air-layering (Allahabad Safeda) were treated with bio-agents for the management of guava wilt with initial inoculation of *Fusarium oxysporum* in the previous year (both in pots and under field conditions). The plants inoculated with *Trichoderma viride* and *Aspergillus niger* treated plants were observed to be vigorous and green in colour when compared to untreated plants. The genotypes were inoculated with bio-agents *A. niger* of IARI strains were found more vigorous and green compared to *Trichoderma* sp. at farmer's field at Rewari, Sonipat.

2.3 ORNAMENTAL CROPS

New varieties released

Rose var. "Pusa Alpana", gladiolus var. "Pusa Shanti"and chrysanthemum var. "Pusa Sundari" were released for Delhi State by State Seed-Sub-committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2021.

Pusa Alpana

Pusa Shanti

Pusa Sundari

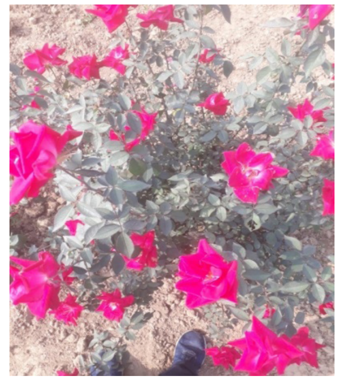
2.3.1 Rose

2.3.1.1 Newly identified rose hybrids for loose flower purpose and garden display purpose

RH-19-2017 (BRRS-1): It is a hybrid between cv. Dr. Bharat Ram × Rose Sherbet and belongs to Floribunda group. It produces pink coloured medium sized blooms. The plants are short and narrow bushy. It has fragrant flowers, less petal shedding, compact and better flower anchorage.

RH-19-2017 (BRRS-1)

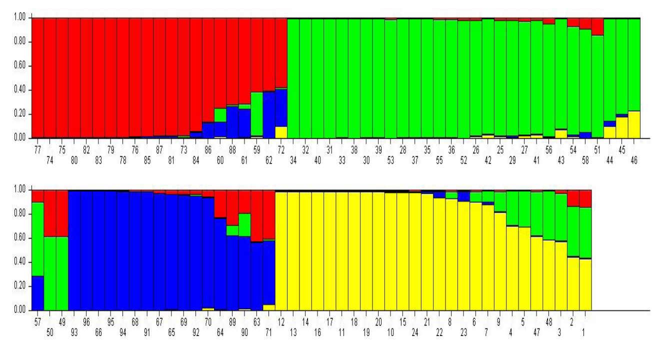
RS-03-2017: It is a selection from open-pollinated population of cv. Pink Parfait. It produces dark pink coloured medium sized blooms. The plants have bushy growth habit. The promising selection is suitable for garden display purpose.



RS-03-2017

2.3.1.2 Genotyping and population structure of rose association mapping

Genotyping of rose using SSR markers was done for 96 varieties. A total of 200 SSR markers were procured, out of which 140 gave amplification. Out of 140 SSR markers tested, amplified products obtained from 53 markers showed clear cut polymorphism. Genotypic data were analyzed for presence of population structure using the software STRUCTURE. Four types of populations were found in the rose association mapping panel.



Model based population structure plot for rose association mapping panel

2.3.1.3 Hybridization in *Rosa × hybrida* L. for loose and fragrant flower purposes

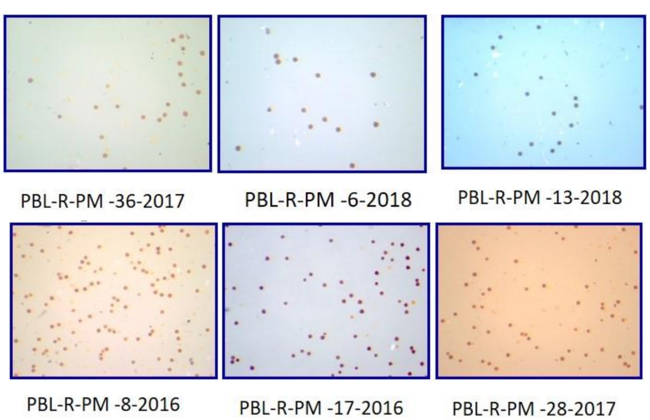
Crosses were made among promising varieties of rose in 45 cross combinations to develop varieties for loose and fragrant flower production. The varieties utilized in the crossing programme were *Rosa chinensis*, Rose Sherbet, Pusa Mahak, Jantar-Mantar, Krishina, Surabhi, Pusa Virangana, Shola, Pusa Baramasi, Pink Queen Elizabeth, Delhi Princess, Pusa Urmil, Surdas, Oklahoma, Jadis and Midas Touch. The cross combinations of different varieties exhibited good hip set.

2.3.1.4 Screening of rose pre-breeding lines for powdery mildew tolerance

During second year of screening, pre -breeding lines such as PBL-R-PM -1-2016, PBL-R-PM -5-2016, PBL-R-PM -11-2016, PBL-R-PM -12-2016, PBL-R-PM -15-2016, PBL-R-PM -21-2017, PBL-R-PM -25-2017, PBL-R-PM -32-2017, PBL-R-PM -35-2017,PBL-R-PM -8-2016, PBL-R-PM -17-2016, PBL-R-PM -36-2017, PBL-R-PM -13-2018, PBL-R-PM -28-2017, PBL-R-PM -6-2018, and PBL-R-PM-3-2019, of rose were screened against powdery mildew. Among these, PBL-R-PM -28-2017, PBL-R-PM -6-2018, PBL-R-PM-3-2019, pre-breeding lines were found highly resistant and PBL-R-PM -8-2016, PBL-R-PM -17-2016, PBL-R-PM -36-2017 and PBL-R-PM -13-2018 pre -breeding lines were found moderately resistant.

2.3.1.5 Pollen viability of promising rose pre-breeding lines

Pollen viability was studied in promising pre -breeding lines such as PBL-R-PM -8-2016, PBL-R-PM -28-2017, PBL-R-PM -36-2017, PBL-R-PM -17-2016, PBL-R-PM -6-2018, PBL-R-PM -13-2018, PBL-R-PM-3-2019, *etc.* Lines such as PBL-R-PM -8-2016, PBL-R-PM -17-2016 and PBL-R-PM -28-2017 exhibited high percentage of viable pollens.



2.3.1.6 Self-incompatibility in rose pre-breeding lines resistant to powdery mildew

Self-incompatibility was studied in different rose pre-breeding lines tolerant to powdery mildew and only four lines including PBL-R-PM-3-2019, PBL-R-PM -32-2017, PBL-R-PM -13-2018 and PBL-R-PM -15-2016 exhibited hip set and other lines exhibited self-incompatibility.

2.3.2 Marigold

2.3.2.1 Newly identified marigold selections for loose flower production and bedding purposes

Fr./R-5-1: This selection belongs to French marigold group and has bush type of growth habit. The plant height is 60-70 cm and produces orange medium size flowers. Its flowering time is October - November. It is suitable for loose flower production and bedding purposes.

Promising Selection Fr./R-5-1of French marigold

Fr./R-5-2: This selection belongs to French marigold group and has bush type of plant growth habit. The plant height is 70-80 cm and it produces dark red colour medium size compact flowers. The flowering time is festive season *i.e.* October - November end. This selection is suitable for loose flower production and bedding purposes.

Promising SelectionFr./R-5-2 of French marigold

2.3.2.2 Evaluation and maintenance of germplasm

Five new collections were done in French marigold, *viz*. Durango Red, Bonanza Bolero, Bonanza Orange

Deep Improved, Bonanza Gold and Bonanza Bee and were evaluated during *kharif* season for various vegetative and flowering traits. The maximum plant height was recorded in variety Durango Red (22.75 cm) followed by Bonanza Gold (21.25 cm). The maximum plant spread was recorded in variety Bonanza Bolero (24.44 cm) followed by Bonanza Gold (22.94 cm). The earliest flowering (50%) was obtained in variety Bonanza Bolero (68.50 days) followed by Durango Red (71.50 days). The maximum flower diameter was recorded in variety Bonanza Orange Deep Improved (4.50 cm) followed by Bonanza Bolero (4.40 cm). The variety Bonanza Gold produced maximum number of flowers per plant (37.50) as compared to other varieties evaluated which also gave maximum flower yield (0.06 kg/plant). In total 85 genotypes were maintained in germplasm including varieties, selections and male sterile lines belonging to *Tagetes erecta*, *T. patula* and *T. minuta* species.

2.3.2.3 Development of *in vitro* regeneration protocols

For rapid callusing/regeneration in anther derived cultures, experiments on pre-treatments of anthers with cold temperature, anther starvation with mannitol and modification of culture media with alteration in copper sulphate quantity werecarried out to refine *in vitro* protocol for rapid regeneration from anthers. Under experiment of pre-treatment with cold temperature, pre-treatment at 4^0C for 6 days gave the best results *i.e.* highest explant survival (72.00%), highest percent of responding anthers (82.40%), lowest number of days taken to callusing (11.00 days), highest percent caulogenesis (82.40%) and highest percent rhizogenesis (82.4%), lowest days to shoot bud induction (3.50 days), highest number of shoot buds per anther (5.50), highest number of regenerated plants (green + albino) (9.50) and highest number of green plants (5.00), while inanther starvation experiment, 0.3 M mannitol solution used for 4 days gave highest explant survival (62.00 %), highest percent of responding anthers (85.70%), lowest number of days taken to callusing (9.00 days), highest caulogenesis (88.40%) and highest percent rhizogenesis (81.4%), lowest duration to shoot bud induction (2.70 days) highest number of shoot buds per anther (7.00), highest number of regenerated plants (green + albino) (11.00) and highest number of green plants (7.00). Modification of copper sulphate in the culture medium (standardized by Ravindra *et al.*, 2019) with $CuSO_4$. $5H_2O$ @ 25 µM gave highest explant survival (85.00%), highest of responding anthers (88.70%), lowest number of days taken to callusing (10.00 days), highest caulogenesis (86.40%) and highest rhizogenesis (88.40%), lowest days to shoot bud induction (4.50 days) highest number of shoot buds per anther (10.00), highest number of regenerated plants (green + albino) (13.00) and highest number of green plants (5.00).

Protocol was also standardized for high through put *in vitro* maintenance of genetic male sterile lines (GMS) of marigold. Three male sterile lines of marigold namely, 'MS-5', 'MS-7' and 'MS-8' were compared for their *in vitro* regeneration abilities using two different explants, *viz.*, shoot tips and nodal segments. Among the three genotypes best *in vitro* establishment was recorded in 'MS- 5' line using nodal explants followed by MS-8 with the same explant. Among the different media tested, best *in vitro* establishment was obtained on MS medium supplanted with 1.5 mgl^{-1} Thidiazuron (TDZ), 0.1 mgl^{-1} GA_3 and 0.5 mgl^{-1} NAA and 250 mgl^{-1} polyvinyl pyrrolidine (PVP). The maximum proliferation of *in vitro* shoots was obtained on MS medium supplemented with 1.0 mgl^{-1} KIN, 0.1 mgl^{-1} GA_3, 0.1 mgl^{-1} NAA and 250 mgl^{-1} PVP.

2.3.2.4 Induction of double haploids (DHs)

Local strain of *Tagetes patula* L. was used for *in vitro* and organogenesis. One haploid from anther derived regenerants was isolated multiplied further under *in vitro* conditions by using shoot tips and nodal segments on MS mediaum, sucrose (3%), agar-agar (0.8%), $AgNO_3$ (2.5 ml/l), Adenine sulphate (0.016 g/l.). For doubling of chromosome, the *in vitro* multiplied plantlets of haploid were subjected to colchicine treatment (0.005, 0.01, 0.02 for 36 and 48 h) using nodal segment explants. The results revealed that treatment T_1- Colchicine (0.005%) for 36 hexposure was good for parameters like survival (81.22%), percent diploidization (48.00), leaf length (3.77 cm), leaf width (2.49 cm), number of shoots per plant (9.89) followed by treatment T_2- colchicine (0.005%) for 48 h exposure for parameters like percent survival (69.67%), diploidization (37.22%), leaf length (3.56 cm), leaf width (1.97 cm), number of shoots per plant (8.67). Cytological analysis and chloroplast counting in stomatal guard cells was one for determination of ploidy level in colchicine treated haploid plantlets. The results revealedthat in cytological analysis out of 38 plants screened, 26 plants (68.4%) were tetraploids and 12 plants (31.57%) were polyploids. Whereas, through chloroplast counting, 38 plants screened out of which 26 plants (68.4%) were tetraploids with mean of 16 chloroplasts in the guard cells and 12 plants (31.57%) were polyploids with mean of 18 to 22 chloroplasts in the guard cells.

2.3.2.5 Evaluation of promising lines and hybrids

In *kharif* season, forty-five selections/ lines of marigold of *Tagetes patula* and *T. erecta* species were evaluated for various vegetative and flowering traits. Among the selections belonging to *T. patula*, the selections numbered as Fr./R-5-1, Fr./R-5-2, Fr./R-2, Fr./R-5 and Fr./R-14-6 performed better as compared to others, while among the selections of *T. erecta* group, the selections numbered as Af./SR-12, Af./SR-15-1, Af./SR-53, Af./SR-16-1 and Af./SR- 16-2 were found very promising for loose flower production and bedding purposes. All these selections flower profusely during festive season, *i.e.* October-November. In *rabi* season, 22 selections/ lines of *T. patula*and *T. erecta* species were evaluated for various vegetative and flowering traits. Among them, the selections Fr./R-20 and Fr./R-20-1 in *T. patula* and Af./w-1, Af./w-2, Af./w-3-2, Af./w-4, Af./w-7 and Af./w-8 in *T. erecta* were found very promising for loose flower production and bedding purposes. In addition, during *rabi* season, 20 genotypes (10 each of *T. patula* and *T. erecta*) were subjected for cold tolerance studies. Marigold germplasm was also evaluated for total carotenoids. In rainy season, selection namely Sel. Af./SR-12 was found rich in total carotenoids on fresh weight basis, while in winter season, Sel. Af./W-1 was reported high in total carotenoid.

Thirty hybrid combinations involving two genetic male sterile line and 15 advanced inbred lines were evaluated for various vegetative and flowering traits. Most of the F_1 hybrids produced semi-double type of flower forms. The earliest flowering was observed in MS7 × M23 followed by MS7 × M24. The maximum plant height and flower size was recorded with MS5 × M21. Among the three male sterile lines, early flowering was observed in the cross combination involving MS7 as female parent.

2.3.3 Gladiolus

2.3.3.1 Hybridization

During this year 2020-21, more than six hundred crosses were made in 20 genotypes with different cross combinations according to their colour, spike/corm and flowering traits. Out of 20 cross combinations, 10 had set the seeds, The mature seeds had been collected including open pollinated genotypes for further evaluation and multiplication of cormels. In this study results also indicated that the maximum seed set 70% were found in Pusa Sinduri x Creamy Green and Dhanvantri x RTS, whereas maximum seeds per capsule were found in cross combination of Chandni x Oscar and Suchitra x Mayur, respectively.

2.3.3.2 Performance evaluation of promising hybrids

During the year 2020-21, twenty six most promising hybrids with standard check variety White Prosperity were planted for evaluation for different traits. The hybrids such as Smokey Lady x Mayur, High Hopes Open, P-16-1 x Eurovision, Chandni x Snow Princess and Melody Open Seedling have shown continuously earliness in flowering and took 79.66-85.00 days range after planting, whereas hybrids such as Pearl Beauty x Lucky Shemrock took 110.00 days followed by Vidushi (Mutant) 109.33 days, Bindiya x Creamy Green 108.66 days, Pink Parasol Open 108.33 days, Swarnima x Viola and Canada x Green Willow each 108.00 days as compared to remaining hybrids and check variety. The maximum plant height 142.00 cm, rachis length 84.00 cm and number of florets per spike 20.66 was recorded in Bindiya x Creamy Green hybrid. The remaining hybrids such as Green Pasture x Regency, Smokey Lady x Oscar, Vidushi (mutant) and S. Lady x Headywine and Melody open seedling have also showed excellent performance in terms of plant height, spike length, rachis length, number of shoots and number of florets per spike, respectively. Moreover, hybrids such as Bindiya x Creamy Green, Green Pasture x Regency, S. Lady x Oscar, AVE x Mayur, Salmon Queen Open Seedling, High Hopes Open and Vidushi (mutant) have shown more florets (7.00 -7.66) remain open at a time as compared to check variety and other hybrids, most of them also produced three or more than three shoots per plant.

Gladiolus hybrids evalution

2.3.3.3 Studies on drip fertigation and mulching

In this experiment, there were four fertigation levels, *i.e.* 100 % RDF (200:100:100 kg/ha NPK), 80, 60, and 120% and three levels of mulching as Silver/Black, Yellow/Black and one without mulch as control. Five varieties suchas Bindiya, Jyotsna, Anjali, Shubham and Smokey Lady were tested in split-split plot design with three replications keeping fertigation levels as main plot. The experiment showed that most of the characters were found significant with the application of drip fertigation, mulching on gladiolus varieties. The results indicated that maximum plant height (118.60 cm), spike length (112.86 cm), rachis length (58.73 cm) and number of florets per spike (19.44) was recorded with 80% NPK fertigation followed by 60% RDF/NPK application. The Silver/Black mulch was best for plant height (109.85 cm), spike length (100.86 cm), rachis length (57.08 cm) and number of florets (19.35) followed by Yellow/Black. Among the varieties, Anjali recorded maximum plant height (119.16 cm), spike length (100.50 cm), number of florets (19.30) and number of shoots (3.38) followed by Bindiya, Smokey Lady, Jyotsna and Shubham, respectively.

Black mulch with 80% NPK fertigation in cv. Anjali

2.3.4 Lilium

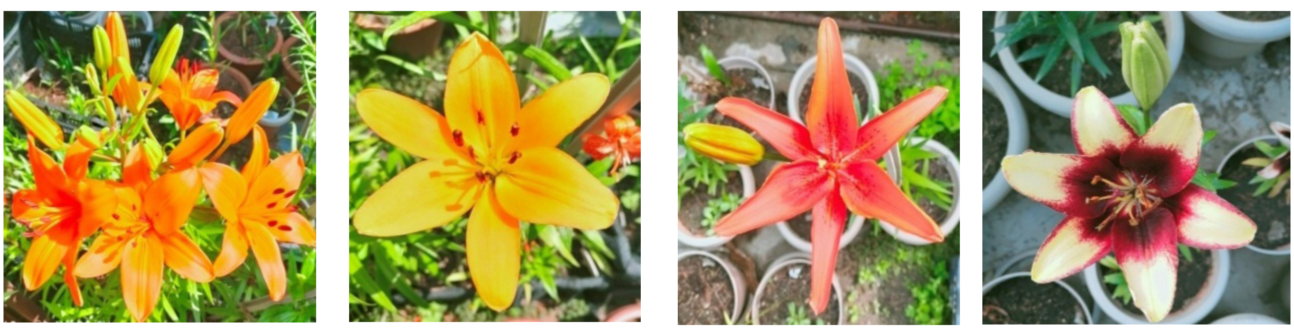
2.3.4.1 Response of organic manure and inorganic fertilizer on flower and bulb production

The present investigation was conducted on LA hybrid lilium cv. Masai using 5 levels of organic manure (FYM) 0, 10, 15, 20 and 25 t/ha and 5 levels of inorganic fertilizers ($N:P_2O_5:K_2O$) 160:120:100, 120:90:75, 80:60:50 and 40:30:25 and their combinations. The findings revealed that among various concentrations of FYM @ 25 t/ha performed better in most of the vegetative growth parameter, better quality flower, bulb & bulblet production and total phosphorous content in leaves. Whereas, plants applied with FYM @ 20 t/ha showed Early flower opening and early bud initiation. Among different concentration of inorganic fertilizer, plants applied with $N:P_2O_5:K_2O$

@ 160:120:100 kg/ha performed better over control in most of the parameters,*viz*., plant height, leaf length, leaf width, stalk length, stalk diameter, bulb & bulblet production, chlorophyll, total nitrogen, phosphorous and potassium content in leaves and partitioning rate. Plant applied with $N:P_2O_5:K_2O$ @ 120:90:75 kg/ha found early colour shown and early flower opening. Whereas, plant applied with $N:P_2O_5:K_2O$ @ 80:60:50 kg/ha found early bud initiation. Among different concentration of combination of both organic manure and inorganic fertilizer, plants applied with FYM @ 25 t/ha + $N:P_2O_5:K_2O$ @ 160:120:100 kg/ha performed better over control in most of the parameters, *viz*., plant height, leaf length, early flowering, stalk length, stalk diameter, bulb & bulblet production and total nitrogen content in leaves.

Evaluation of inter-ploidy hybrids: Three interploidy crosses and one self-pollinated seedling progenies were evaluated for growth and flowering traits. Among different cross combinations, earliest flowering (142.5 days), average number of flower/plant (4.3) and leaves (77.5) were found in 'Eyeliner x Brunello'. Average plant height of 78.0 cm, flower size (17.3 cm) and leaf length (11.2 cm) were noticed in 'Eyeliner x Blackout' cross combination. On the other hand, self-pollinated seedling progeny of 'Curitiba' took minimum number of days to flowering and exhibited minimum plant height of 36.5 cm and found suitable for pot culture.

Evaluation of lilium germplasm: Six cultivars were evaluated for different growth and flowering traits. Earliest bud initiation was noted in cv. Buzzer (30.15 days). Cultivar Buzzer was earliest to flower (61.25 days), whereas it was most delayed cv. Tresser took maximum number of days to flowering (259.20 days). As regards length of buds, longest buds were found in cv. Provecho (15.21 cm), whereas, shortest buds were observed in cv. Buzzer (6.49 cm). Cultivar Provecho showed maximum flower size (28.53 cm). Cultivar 'Fangio' attained maximum plant height (105.22 cm). Number of flowers per plant was observed maximum in cv. Buzzer (10.07). Cultivar Buzzer showed the maximum duration of flowering (27.33 days). Pavia



Eyeliner x Brunello **Yellow Tycon x Prato** **Eyeliner x Blackout** **Curitiba (Selfed seedling)**

Promising interploidy hybrids of lilium

Buzzer **Fangio** **Provecho** **Frontera**

Evaluation of promising lilium germplasm under protected conditions

produced more number of bulbs per plant (2.0), while bulb size was maximum in cv. Provecho (19.10 cm^2). Bulb weight was found maximum (120.14 g). Cultivars Provecho, Frontera, Fangio and Buzzer most were found ideal field cultivation while 'Buzzer' found suitable for pot cultivation.

Entries contributed in AICRP (F) trials: One variety, Pusa Lily-1 was entered in the ICAR-AICRP (Floriculture).

Standardisation of light requirement of Licoris for growth and flowering: Growing of Licoris in 100% irradiance improved leaf biomass(0.34 g/leaf); Leaves-(8/bulb); above ground biomass(2.8 g); Below ground level biomass-20.5 g; Chlorophyll (a+b) 115 µ/cm^2 and flowers (6/clump) and spike length (30.25 cm) as compared to 70, 50 and 30% irradiance.

Effect of organic manure and inorganic fertilizers on Easter Lily production: The application of 50% RDF (100:100:75 NPK kg ha^{-1}) along with 50% farm yard manure (15 t FYM ha^{-1}) gave significant effect on plant growth, flower yield and flower quality of Asiatic lily.

2.3.5 Bulbous plants

Collection and evaluation of indigenous bulbous flowering plants: Indigenous bulbous flowering species *Amaryllis Asparagus racemosum Berginia ciliate Dioscorea bulbifera Hemarocallis* and *Hedychium* were collected at the centre.

2.3.6 Ornamental kale

In ornamental kale, 2 CMS lines were advanced to BC_1 and BC_4 stage by crossing them with their respective maintainers. Besides this, six doubled haploid (DH) and five other elite inbred lines were selected for CMS conversion. The CMS system was introgressed into these lines by crossing them with two other CMS lines. The new CMS system (*Erucastrum canariense*) from Indian cauliflower was also introgressed in to five DH lines. Twenty one DH plants of ornamental kales were developed through microspore culture and planted for their maintenance. Four open-pollinated genotypes, *viz.*, KtOk-2, KtOk-39, KtDH-57 and KtDH-19 were contributed for AICRP (Floriculture) trials.

3. GENETIC RESOURCES AND BIOSYSTEMATICS

Plant genetic resources have a pivotal role in crop improvement programmes. The institute has a vibrant programme for collection, maintenance, evaluation and utilization of germplasm in various crops. A large number of germplasm lines including some wild relatives of crops were maintained, evaluated, characterized and utilized in pre-breeding and genetic enhancement in various crops.

3.1 CROP GENETIC RESOURCES

3.1.1 Wheat

3.1.1.1 Germplasm registration

Wheat accessions, IC 128565 (INGR21030), IC 128638 (INGR21031), IC 252458 (INGR21097), IC 279875 (INGR21099), IC 290150 (INGR21098) and Hango2 (INGR21180) were registered for stem, leaf and stripe rust resistance genes at NBPGR, New Delhi. Wheat genotypes HD 3304 (3HPAN54/Zincol) and HD 3241 Danphe#1*2/Solala/3/TacupetoF2001/Brambling *2// Kachu) were registered at NBPGR with INGR Nos. 21124 and 21186, respectively for highest sedimentation value (75 and 73 ml respectively) and are valuable resources for improving gluten strength in wheat varieties. Genotypes QBP18-8 and QBP18-10 were registered at NBPGR with INGR Nos. 21182 and 21184 respectively for their highest Test (hectoliter) weight. These two genotypes have recorded more than 80 kg/hl in multilocation trials for three years. QBI20-14 (Francolin #1/3/IWA 8600211//2* PBW343*2/Croc_1/Aesquarrosa//Kulin/3/ Westonia/6/ Kachu//Wbill1*2/Brambling) and QBP17-7 (Kvz/PPR47.89C//Francolin #1/3/ 2* Pauraq/4/PBW343*2/Kukuna*2//Frtl/Pifed) were registered at NBPGR with INGR Nos. 21183 and 21185, respectively, for greater grain micronutrient concentration. QBI20-14 has shown higher levels of mean grain zinc concentration (51 mg/kg). The genotype QBI20-14 had higher yield (4.56 t/ha) and in protein content (13.6%). QBP17-7 recorded higher mean value zone wise as well overall higher mean (48.1 ppm) of grain iron concentration. The line also had the protein content of 13.1% similar to WB02 (13.3%).

3.1.1.2 Germplasm conservation

More than 6000 wheat, barley, oats, triticale lines, synthetic wheats, CIMMYT advance lines, RILs carrying different leaf, stem, head scab, blight resistance genes, PHS sources and 1900 accessions of wild species are continuously maintained in both net house and field, evaluated and utilized at IARI, RS, Wellington. The harvested seeds are conserved. Gene sources for *Lr19*/*Sr25*, *Sr36*/*Pm6*, *Lr24*/*Sr24*, *Lr24*/*Sr24*/*Sr26 Sr27 Lr28 Lr32 Lr37*/*Sr38*/*Yr17 Lr45 Lr47 Lr34 Lr46 Lr67 Lr68 Yr10* and *Yr15* are maintained.

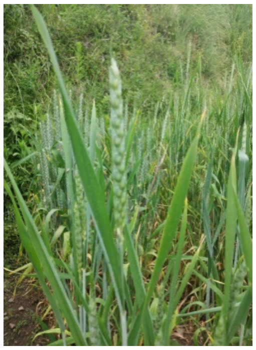
3.1.1.3 Evaluation of germplasm for seedling resistance to stripe rust

Two hundred and twenty wheat germplasm were evaluated for stripe rust resistance at seedling stage. Thirty-two genotypes (FLW3 FLW10 FLW13 FLW16 HS580 HS591 HS594 HS628 HS645 HSB2801 WBM3468 WBM3682-1 WBM3721 WR3008 PBW703 H81 H83 H86 H101 H103 H105 HS661 JINGDONG MORO *Triticum spelta album*, ZANDER33, Avocet *Yr5* Avocet *Yr10* Avocet *Yr15*, Avocet-R, Avocet *YrSP*, China84-40022) exhibited seedling resistance to virulent stripe rust pathotypes (110S119 238S119 110S247 110S84 and 47S103). All the 32 genotypes except HS580 HS591 HS594 HS645 JINGDONG and ZANDER33 are postulated to carry either of the stripe rust resistance genes *Yr5 Yr10 Yr15 YrSp* and China84-40022 as predicted from their pedigree lineage. All the 32 genotypes are carrying good agronomic background and would be useful as potent donors for breeding wheat varieties for all stage stripe rust resistance.

3.1.1.4 Development of disease-resistant genetic stocks

Aegilops speltoides derived leaf rust resistance gene *LrS2427* in an alien introgression line Sel. 2427 was found to be effective against 25 leaf rust pathotypes. However, its association with gametocidal genes reducing fertility limits its utilization in breeding programmes. To break the undesirable association through mutation, gamma-ray was utilized. F_1 (Agra Local x Selection 2427) seeds were exposed to 250 Gy and 300 Gy of gamma radiation. Irradiated M_0F_1 plants were observed for fertility parameters, and only desirable plants were carried forward. Subsequently screening for leaf rust resistance was undertaken to identify homozygous resistant plants. Leaf rust-resistant plants with ineffective gametocidal alleles were identified. This will facilitate the utilization of *LrS2427* in the wheat improvement programme. Besides this, other alien introgression lines showing multiple resistances to leaf rust, yellow rust, stem rust, Karnal bunt, head scab and spot blotch were also identified.

Genetic stock DH-1: A wheat (*Triticum aestivum* L.) doubled haploid line (DH-1) is developed following *Imperata cylindrica* mediated chromosomal elimination technique by crossing wheat F_1s (developed by crossing spring wheat variety HS542 with winter wheat genotype China 84-40022) with *Imperata cylindrica*. DH -1 has been recorded as resistant against all the prevailing pathotypes of stripe and leaf rust at seedling stage (except Pt 77-5). This wheat genetic stock is developed *via I. cylindrica* mediated chromosomal elimination technique and have characteristic features of both winter and spring wheat genotypes, thereby increasing the variability.

Field view of genetic stock DH1

3.1.2 Barley

3.1.2.1 Germplasm registration

BHS 481 (Reg. No. INGR 21125): A new barley (*Hordeum vulgare* L.) line BHS 481 is registered with NBPGR, New Delhi as resistant genetic stock against stripe, leaf and stem rust. It has shown highest degree of resistance against all the prevailing pathotypes of stripe, leaf and stem rust at seedling stage, except moderate resistance to 117-6 race of stem rust. BHS 481 is also recorded as resistant to all the three rusts at adult plant stage.

Field and grain view of BHS 481

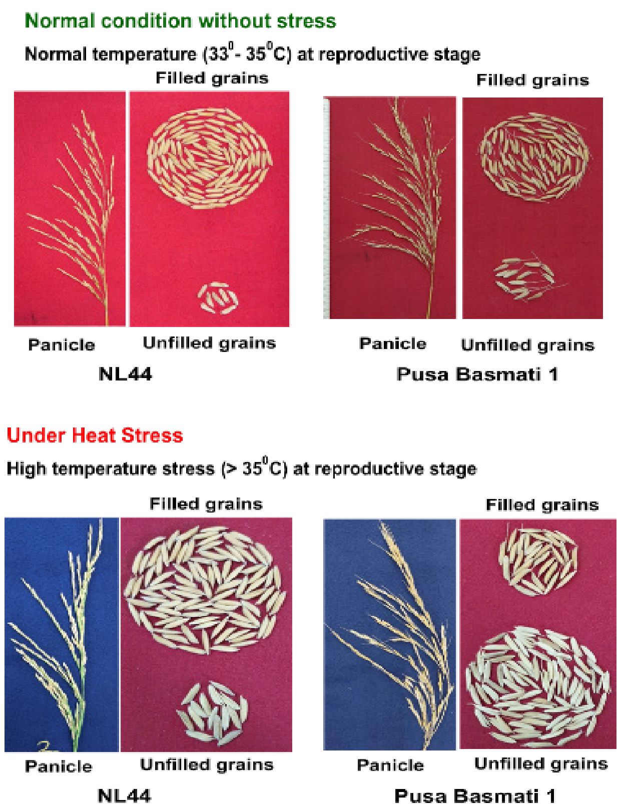
3.1.3 Rice

3.1.3.1 Germplasm registration

Pusa Rice Restorer 402: A New Plant Type (NPT) based rice restorer line (Registration No. INGR 21012): Pusa Rice Restorer 402 (PRR402), a tropical *japonica* based NPT line, which is a restorer of WA cytoplasm possessing the restorer gene *Rf4*, developed in the background of a popular *indica* rice variety Pusa

44 has been identified as one of the promising line. It has all NPT characters such as plant height of 85–92 cm, 10 to 13 productive tillers, sparse unproductive tillers, sturdy culm, heavy panicles having 200 to 250 grains, dark green leaves, and growth duration of 110 to 130 days. It produced fertile hybrid (pollen fertility- 91.44 to 96.46% and spikelet fertility- 80.07 to 85.32%) when crossed with a male sterile line, Pusa 6A.

NL 44 (EC67488): A reproductive stage heat stress tolerant rice genotype (Registration No. INGR 21011): NL 44 is tolerant to high temperature stress (> 35^{0}C) at reproductive stage with very high spikelet fertility particularly under high temperature stress. Molecular validation with previously reported QTL linked SSR markers have demonstrated NL44 as a novel source of heat stress tolerance in rice.



Karuppunel –High grain zinc rice genotype (Registration No. INGR 21006): Karuppunel is one such landrace which has huge potential for enriching the endosperm zinc content of popular rice varieties. The accession was collected from Tamil Nadu, purified and being maintained as part of breeders' collection in the Division of Genetics, ICAR-IARI, New Delhi. Upon evaluation of a set of 192 rice accessions for grain iron and zinc concentrations, Karuppunel recorded as high as 46.2 ppm in brown rice and 40.9 ppm in polished rice, the values were significantly higher than the recommended target of 28 ppm for biofortication programmes as per the HarvestPlus guidelines. The accession was further nominated for testing at multiple locations under a biofortification donor trial conducted under the consortium research project (CRP) on biofortication and it out-performed all the promising donors in the trial with a range of 29.1 to 49.67 ppm across the environments. It has also recorded considerably high mean concentration of 4.3 ppm iron in polished rice as against to 2 ppm in popular cultivars.

3.1.4 Maize

3.1.4.1 Germplasm registration

A maize inbred line (PML-35) with specific feature of adaptability and better performing at higher plant density was registered (INGR 21032) at NBPGR. PML-35 under high-density planting (83,333 plants/ha) produces 4.07 t/ha of grain yield.

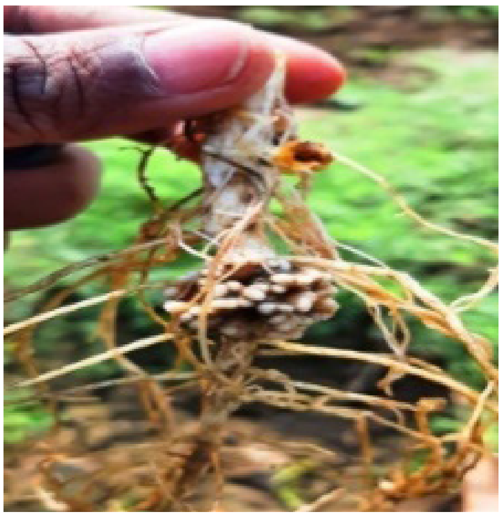
3.1.4.2 Teosinte derived genetic stocks

Teosinte branched-1 (*tb1*) gene of teosinte is responsible for prolificacy in maize. Gene *tb1* from teosinte (*Zea mays* spp. *parviglumis*) was introgressed into seven elite inbreds. Backcross populations were genotyped using *tb1*-specific marker, and foreground positive plants with phenotypic similarity were selected. The *tb1*-based genotypes possess up to five ears per plant, thus serve as novel genetic stocks in the breeding programme.

3.1.5 Chickpea

3.1.5.1 Genotype with large number of bigger size root nodules

An association panel consisting of 300 genotypes containing 224 desi and 76 kabuli types was evaluated at multi-locations. Further, a sub-set of eighteen contrasting genotypes for nodulation were selected from the association panel and grown along with two control varieties in a RBD with three replications under 6 environments/ treatments (control, NP, AMF, *Rhizobium*, AMF + NP, *Rhizobium* + NP) for assessing their response to nodulation and nitrogenase activity. The genotype ICC8095 was identified with highest number of large sized nodules and also with maximum nitrogenase activity.



Nodulation in ICC 8095 genotype

3.1.6 Mustard

3.1.6.1 Germplasm registration

Indian mustard genotypes NPJ 149 (INGR20093; possessing high temperature tolerance) and RDV 29 (INGR20041, possessing powdery mildew resistance) were registered with NBPGR, New Delhi.

3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.2.1 Biosystematics

Maintenance and preservation of fungal cultures at ITCC and fungal specimens at HCIO: About 4,100 fungal cultures at ITCC were maintained under different preservative methods. A total of 365 fungal and 26 bacterial cultures were supplied to the indenters, while 157 fungal and 19 bacterial cultures were identified.

3.2.2 Insect biosystematics

3.2.2.1 Entomological identification service

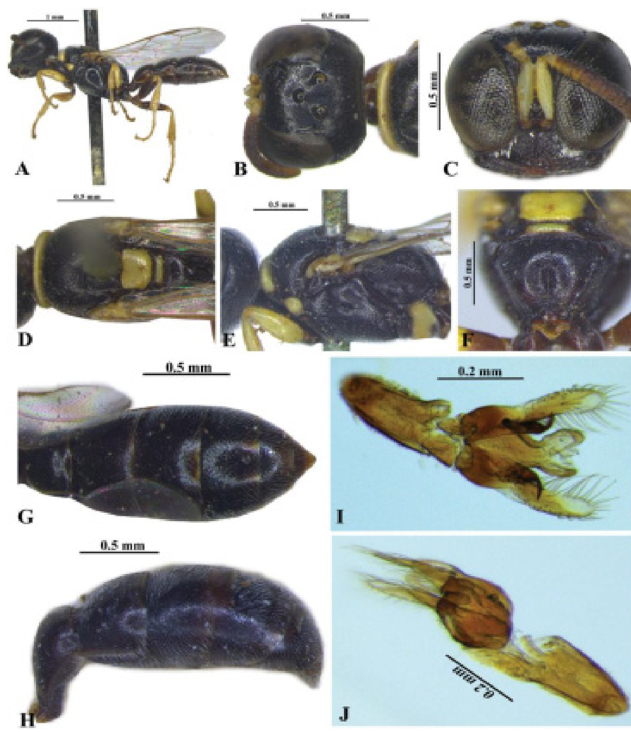
A total of 624 specimens were registered/ identified for various correspondents from all over India. The details are as Coleoptera: 31; Hymenoptera: 323; Diptera: 144; Hemiptera: 48; Lepidoptera: 91 and Others: 2.

3.2.2.2 Collection and suitable processing of the collected material for further studies

Collections were made from 10 states of India. Almost all the different groups of crops both their vegetative as well as their reproductive phases were covered during the surveys. Around 8,000 specimens could be collected and more than 500 field visuals on the various life stages and adults could be captured and documented.

3.2.2.3 Biosystematic studies

Hymenoptera: Studies on sand wasps or mustache wasps belonging to family Crabronidae was undertaken. An up-to-date annotated checklist of the



A–J. *Piyuma chapraensis* **Saini and Dey, 2022: A, habitus in lateral view; B, head dorsally; C, head in front view; D, thorax dorsally; E, thorax laterally; F, propodeum; G, gaster dorsally; H, gaster laterally; I, male genitalia dorsally; J, male genitalia laterally**

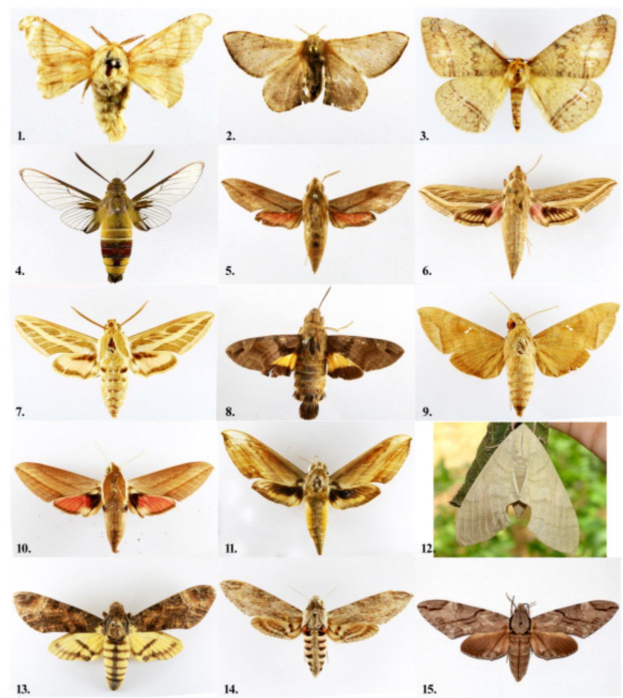
Indian species complied indicated a total of 88 species under 13 genera *viz*., *Crabro Crossocerus Dasyproctus Ectemnius Encopognathus Entomognathus Hingstoniola Isorhopalum Lindenius Lestica Piyuma Rhopalum* and *Vechtia*. All synonyms and distribution records were included along with 19 new locality records in the checklist. The genus *Piyuma* Pate from India is reviewed, and a new species, *Piyuma chapraensis* (Bihar: Chapra), was described and illustrated. Furthermore, two sub-species of *P. prosopoides viz*., *makilingi* and *iwatai* are redescribed with illustrations. A checklist is provided for all *Piyuma* species reported from the Indian sub continent.

Hemiptera: The genus *Parasogata* Zhou, Yang & Chen, 2018 was reported first time from India represented by the new species *P. sexpartita* sp. nov. collected in a recent exploration and survey of delphacids from Nagaland in northeastern India. A second species of *Eoeurysa* Muir, 1913 from India, the new species *Eoeurysa sagittaria* sp. nov., (registration id: urn:lsid:zoobank.org: act: EA1BE8CB-8138-4643-A8B9-DE75946E422D) was found in Rampur, Una, Himachal Pradesh. Both the new species were described with illustrations, and a molecular identification is given with the mtCOI gene sequence. A modified key to species of the genera is also provided.

A new leafhopper species, *Anagonalia lapnanensis* sp. nov., is described from Arunachal Pradesh, India. A morphological variant is also described. Morphological variant is interpreted as belonging to the same species due to pair wise Distance matrix genetic distance between mophovariant and a new species 0.2%, which is negligible according to the 3.5% divergence rule. Thus, it is inferred that the differences found in topotypical specimens are deemed to be variations of the new species rather than being of a different species. This variation may be attributed to seasonal climatic differences, *i.e.*, the rainy season in July, and winter in November. Further confirmation of these findings will require breeding experiments and or acoustic recordings.

Lepidoptera

Moths (Insecta: Lepidoptera) of Delhi: A comprehensive checklist of 338 moths species using 8 years of light trapping data (2012-2020) and examining about 2000 specimens from historical collections at the National Pusa Collection of ICAR-IARI, New Delhi (NPCIARI) spanning over 100 years (1907-2020) was compiled. The checklist comprises moths from 32 families spanning 14 super-families with Noctuoidea (48.5%) and Pyraloidea (20.4%) being the two most dominant super-families. This is the first comprehensive annotated checklist of the moths of Delhi. The present study adds 234 species to the biodiversity of moths from Delhi that were not reported previously, along with illustrations for 195 species.



1. *Bombyx mori* 2. *Trilocha varians* 3. *Eupterote undata* 4. *Cephonodes hylas* 5. *Hippotion boerhaviae* 6. *Hippotion celerio* 7. *Hyles lineata* 8. *Macroglossum neotroglodytus* 9. *Nephele hespera* 10. *Theretra alecto* 11. *Theretra nessus* 12. *Clanis sp.* 13. *Acherontia styx* 14. *Agrius convolvuli* 15. *Psilogramma increta*

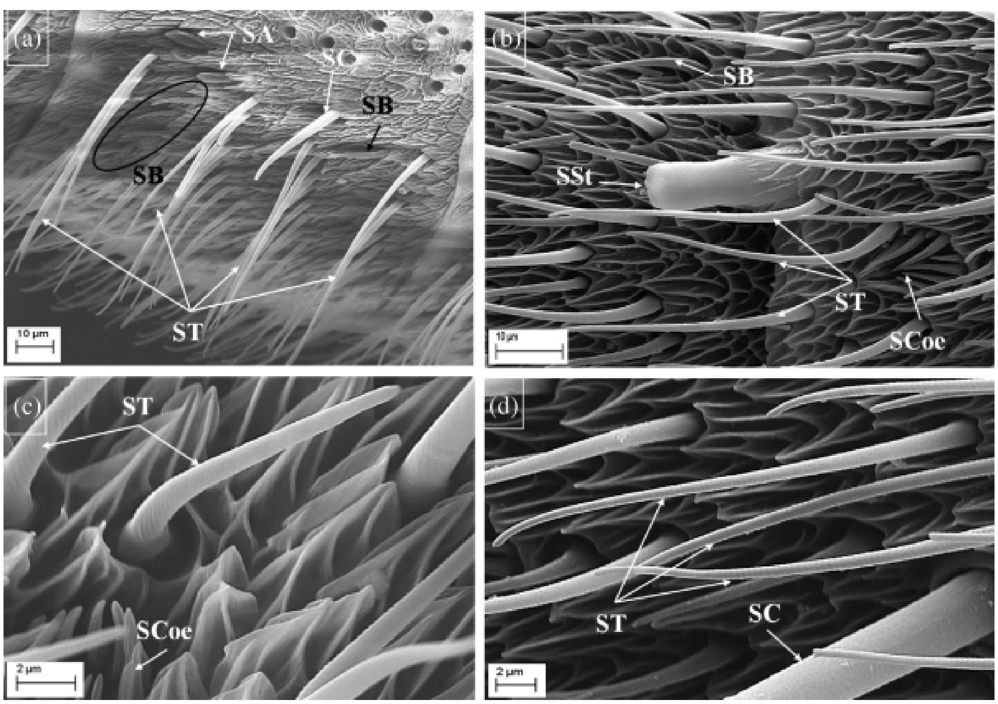
3.2.2.4 Morphological characterization and distribution of antennal sensilla of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae)

Helicoverpa armigera (Hübner) is a serious polyphagous pest of various field and horticultural crops. A complete knowledge on the morphological features of antennal sensory structures is essential for efficient semio chemical-based control methods.

The external structure and distribution of antennal sensilla in male and female adults of *H. armigera* were investigated using scanning electron microscopy. Eight distinct morphological types of sensilla were identified in both sexes: sensilla trichodea, sensilla basiconica, sensilla auricillica, sensilla coeloconica (multiporous), sensilla chaetica (uniporous), sensilla styloconica, sensilla squamiformia, and Böhm sensilla (aporous) in varying numbers and distribution along the length of the antennae. Of these, the most widespread are sensilla trichodea and sensilla basiconica on the antennae of both sexes. Female antennae have comparatively greater number of sensilla trichodea than male antennae. Among eight types of sensilla, sensilla basiconica, auricillica, styloconica type II, squamiformia, and Böhm sensilla were identified and reported for the first time in H. armigera. Sexual dimorphism in *H. armigera* was mainly detected as the variations in sensilla shape, numbers, and distribution of each type of sensilla. The sexual difference was observed in the numbers of sensilla coeloconica, chaetica, styloconica, and squamiformia per flagellomere. The possible functions of these sensilla were discussed in view of previously reported lepidopteran insects. The findings provide fundamental information on the morphology and distribution of antennal sensory structures in *H. armigera*. It would be useful for further detailed studies on physiological and behavioral function of each sensillum type and helpful for formulating related pest control methods.

Coleoptera

A check list of family Lymexylidae (Coleoptera: Tenebrionoidea) a rare family of beetles from India was compiled. The common names of these beetles are ship-timber beetle and pinhole borer relating to their nature of the damage cause to wood. In India, *Atractocerus reverses* Walker, 1858 was a serious pest of standing trees, felled logs, billets and plancks of the *salai*. Family Lymexylidae in India is represented by two sub families Atractocerinae Laporte, 1840 and Melittommatinae, Wheeler, 1986. Atractocerinae with four genera *viz*.,



Scanning electron microscopy images showing sensilla trichodea on male (a) and female (b) flagellum of *Helicoverpa armigera*. (a) Lateral view of male flagellomere showing uniform and parallel arrangement of the numerous sensilla trichodea on ventro-lateral surface alongwith other sensilla; (b) Ventral view of female flagellomere, showing sensilla trichodea (ST) along with other types of sensilla; (c) Higher magnification of short sensilla trichodea; (d) Higher magnification of long sensilla trichodea. ST, sensilla trichodea; SB, sensilla basiconica; SC,sensilla chaetica; SA, sensilla auricillica; SSt, sensilla styloconica; SCoe, sensilla coeloconica

Atractocerus de Beauvois, 1801, *Arractocetus* Kurosawa, 1985, *Hymaloxylon* Kurosawa, 1985, each with two species, and *Raractocetus* Kurasawa, 1985 with three species. Melittommatinae is represented by a single species *Melittomma albitarsis* Blair, 1936.

Heavy infestation of long horned beetle *Xylotrechus smei* on red sanders *Pterocarpus santalinus* L.f. was reported for the first time from Eastern Ghats, India. This is the first report of this pest on red sanders which is relatively resistant to pests and diseases. As many as 15-20 larvae were found in completely damaged trees. As a result of damage there was complete drying of 5-6-year-old trees. Bore holes on the bark, presence of galleries and complete drying of the trees were observed in *X. smei* infested trees. Supplementary description including the morphometrics, description of terminal abdominal segments and genitalia of both sexes, immatures with illustrations. Both sexes can be readily differentiated based on the shape and size of terminal abdominal tergites and sternites.

***Xylotrechus smei*, Female**

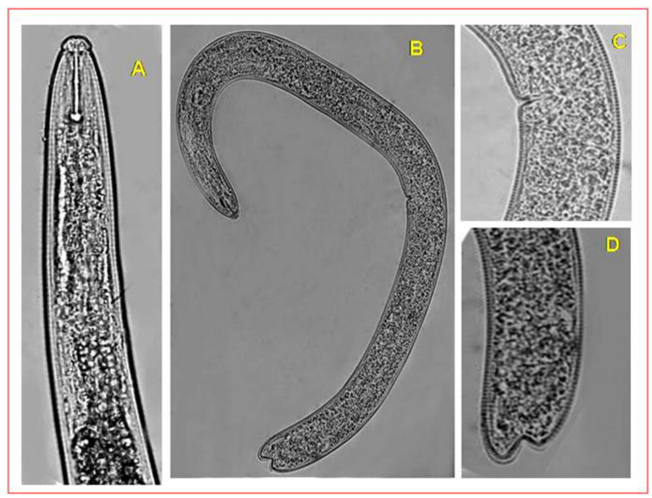
Maintenance of the National Pusa Collection in terms of curation, augmentation, deposition, loan of material etc. was looked after. Depositions: 10 holotypes and 75 paratypes and Loans:14 pinned specimens.

Augmentation to National Pusa Collection: Over 2,000 specimens belonging to 50 species were augmented.

3.2.3 Nematode Biosystematics

3.2.3.1 New species of a plant parasitic nematode *Hoplolaimus* sp. n.

A new species of a plant parasitic nematode *Hoplolaimus* sp. n. (Nematoda: Hoplplaimida) is identified based on morphological characterization. This new species was encountered from rhizosphere of okra (*Abelmoschus esculentus*), which was grown under polyhouse in Kharkhoda tehsil of district Sonepat, Haryana.



***Hoplolaimus* sp. n.: A – Anterior region; B – Female body; C – Vulval opening; D –Tail**

4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

The school of crop and natural resource management has endeavoured to make significant achievement/progress towards developing agro-techniques to conserve natural resources, enhance input-use efficiency, reduce environmental pollution, and improve productivity, profitability and sustainability of crops and cropping systems. Need-based scale-appropriate integrated farming systems, precision and nano-formulation based nutrient management strategies, and conservation agriculture-based crop and cropping systems diversification options/alternatives were developed for improved soil health, crop yield and farm income. Nano-clay polymer composites-based fertilizer products led to enhance N-use efficiency in crops. Developed portable Pusa Soil Test and Fertilizer Recommendation (STFR) meter for analyzing 14 important soil parameters. Near real time soil moisture criteria-based irrigation and an Internet of Things (IoT) based automatic basin irrigation system were developed for higher water use efficiency and labour reduction. New varieties of tomato, pakchoi, and chrysanthemum were developed for protected cultivation. Pusa-Farm SunFridge cold store, two-wheel battery-assisted (electric) weeding cum intercultural machine, a battery-powered, manually operated pineapple harvester, tractor operated microbial inoculum sprayer, and solar-powered air-inflated grain dryer was developed and validated. Innovative and cost-effective technologies have been developed for enhancing storage life and value addition of fruit and vegetable crops. Various bio-inoculants were identified for nutrient use efficiency and stress tolerance for various crops. Pusa Decomposer a viable technology for biomass degradation and preventing environmental pollution was demonstrated in large scale. Greenhouse gas emission has been estimated under various farm management practices.

4.1 AGRONOMY

4.1.1 Precision nutrient and water management

4.1.1.1 Precision nutrient management improved soybean–wheat system productivity

Highest soybean grain yield was obtained in sprinkler irrigation at 80% ET_C (2.45 t/ha). The point-placement of fertilizers with SPA-guided nutrient management resulted in a higher soybean grain yield (2.45 t/ha) compared to other precision nutrient management treatments. In combination, sprinkler irrigation with 80% ET_C, and 50% RDF point placed and rest N top dressed using chlorophyll meter was the best treatment combination for soybean. For wheat crop, sprinkler irrigation at 80% ET_C treatment led to significantly higher yield (5.22 t/ha) than check basin irrigation at 25% DASM (4.48 t/ha). The NutrientExpert tool based nutrient application (50% N + full doses of P + K) as basal dose point placed and remaining 50% N top dressed based on GreenSeeker resulted in highest yield of wheat under system of wheat intensification (SWI).

4.1.1.2 Nitrogen management options for rice-wheat system

Highest grain yield of rice (5.47 t/ha) was recorded under TPR, followed by *vattar*-direct seeded rice, dry DSR and wet DSR. Compared to recommended N application (RDN), leaf colour chart (LCC)-based N scheduling in TPR resulted in 26.3% increase in grain yield. The modified N application in TPR (No-basal, 33% N each at 25, 45 and 65 DAS) also resulted in 20.1% increase in grain yield over RDN. The highest agronomic efficiency of N (44.5 kg grain/kg N applied) was also recorded with TPR, followed by DDSR (32.5 kg grain/ N applied). The result indicated that a 33.3 and 50% saving of N fertilizers can be achieved under DSR methods and TPR, respectively by using LCC-based N scheduling over conventional RDN.

4.1.1.3 Performance of new wheat genotypes across dates of sowing

Genotype HI 1636 resulted in the highest grain (5.14 t/ha) and biological (13.49 t/ha) yield but it was on par with the check variety HI 8713 although there was no statistical difference among timely and late sown wheat varieties.

4.1.1.4 New wheat genotypes performance under different irrigation levels

Maximum grain (4.18 t/ha) and biological (9.66 t/ha) yield of wheat were recorded with two irrigations compared to one irrigation and without irrigation. The highest grain (3.80 t/ha) and biological (9.05 t/ha) yields were recorded for genotype HI 8823 and it was statistically on par with DBW 110 for grain yield and HI 8627 for biological yield.

4.1.2 Crop establishment methods

4.1.2.1 Land configuration and weed management on pigeonpea–wheat system

In pigeon pea, broad-leaved weeds account for 52 and grasses 39%, whereas in wheat, 68 and 29%, respectively. The highest weed control efficiency of 71.8 and 82.9% was noted in broad bed and furrow treatment in pigeon pea and wheat, respectively. The wheat equivalent yield (9.77 t/ha) and net returns (₹1,27,500/ha) were also recorded for broadbed and furrow method followed by ridge and furrow method. Two hand weeding recorded a highest weed control efficiency, system productivity (10.5 t/ha) and net returns (₹1,28,600/ha) followed by pre-emergence application of metribuzin 0.25 kg/ha and one hand weeding at 30 days after sowing.

4.1.2.2 Land configuration for improving yield and profitability of cowpea varieties

Cowpea grown in ridge and furrow method with residue retention (3 t/ha) was produced significantly higher green pod yield (6.17 ton/ha) and fodder yield (18.5 ton/ha), net returns (₹ 38250/ha), B: C ratio (1.91) and economic efficiency (₹ 478/ha/day) compared to other treatments. The nodules per plant (19.7/plant) and nodules weight per plant (262 mg), moisture-use efficiency (11.93 kg/ha-mm), and production efficiency (77.12 kg/ha/day) were also highest in ridge and furrow + residue (3 t/ha). The variety Pusa Dharni gave maximum green pod yield (6.2 t/ha) and green fodder yield (13.7 t/ha) compared to other varieties.

Yield and economics of cowpea influenced by different varieties and land configurations

Treatment	Green pod yield (t/ha)	Net returns (₹/ha)	B: C ratio
Pusa Dharni	6.20	42311	2.10
Pusa Sukomal	5.52	31161	1.81
Kashi Kanchan	5.80	36971	1.96
P=0.05	0.16	-	-
Flatbed	5.55	35560	2.01
Flatbed + residue (3 t/ha)	5.87	36070	1.92
Ridge-and-furrow (R&F)	5.79	37295	1.99
R&F + residue (3 t/ha)	6.17	38250	1.91
P=0.05	0.24	-	-

4.1.2.3 Planting geometry and crop management technique for system of soybean intensification

Maximum dry matter accumulation and seed yield (2.3 t/ha) was obtained with the application of system of crop intensification (SCI); full protocol + SCI- seed treatment at 30 × 30 cm manual sowing. However, the highest number of pods plant^{-1} (>100) and seeds pod^{-1} were recorded in SCI - full protocol + SCI- seed treatment through 40 × 40 cm spacing.

4.1.3 Nutrient management

4.1.3.1 Summer green manuring and nano-zinc-oxide coated urea can improve basmati rice productivity

A study conducted on Pusa Basmati 6 rice variety after green manurin grevealed that an additional grain yield of 0.42 and 0.23 t/ha can be obtained by incorporating *Sesbania* and cowpea green manuring, respectively compared to no green manuring. Further, 1% bulk ZnO coated urea (BZCU) application produced more grain, straw, biological yields and higher harvest index than combined application of bulk ZnO with prilled urea (without coating), suggesting that coating of ZnO along with prilled urea is more effective than their separate application. However, nano zinc oxide coated urea applied at 0.1% also resulted in similar yield and harvest index of basmati rice, indicating that nano Zn oxide is more efficient than BZCU.

4.1.3.2 Urea-S and other S fertilizer sources as an alternative to regular S fertilizers

Urea–S was evaluated with other S sources in pearl millet-mustard, maize-wheat and maize-potato systems. Urea-S was found superior with a high residual effect on the succeeding crop. The application of 50% urea-S (15 kg/ha) as basal and 50% (15 kg/ha) as top dressing resulted in significantly higher maize grain yield (5.34 t/ha) and was comparable with S application (60 kg/ha). Furthermore, 46.8 and 20.1% increase in maize yield was recorded compared to recommended PK + S through SSP and recommended NPK.

4.1.3.3 Growth regulators improved the yield of wheat

Application of higher dose of NPK (100, 125 and 150% of the recommended) with growth regulators [(tank mix-at 0.2% chlormequat chloride (Lihocin) + 0.1% tebuconazole (Folicur 430 SC)] at jointing and boot leaf stage to wheat variety HI 1531 considerably reduced the plant height, increased more tillers and protected crop from lodging but not much improvement on grain yield due to significant reduction in number of grains per spike and thousand grain weight. Maximum grain yield (4.40 t/ha) was recorded with 100% recommended doses of NPK without growth regulators.

4.1.3.4 Urea-S can improve the productivity of Durum wheat–soybean cropping system

Maximum grain (6.16 t/ha) and biological (14.65 t/ha) yield of durum wheat HI 8759 (Pusa Tejas) were observed under recommended NPK + 60 kg S through urea-S2. However, the recommended NPK + 30 kg S through urea-S1 recorded the highest grain (1.77 t/ha) and biological (3.66 t/ha) yields of succeeding soybean crop. The range of increase in soybean grain yield was 6.9 to 10.8% when applied to both the crops and 2.31 to 8.31% to only wheat compared to recommend NPK to both crops.

4.1.3.5 Use of yellow gypsum under inorganic and partial organic production systems

Yellow gypsum application in both bread and durum wheat species has been found useful at 45 kg S/ha alongwith 100% recommended doses of NPK, which could give higher wheat yield with improved quality of grains in Vertisols of Central India. In another study, comparative efficacy of S sources (yellow gypsum, common gypsum and elemental S) under farmers' and recommended nutrient management practices could reveal that yellow gypsum application was found equally effective as other S sources like elemental sulphur and common gypsum, which may be applied as substitute for getting higher durum wheat yields in Vertisols of Central India.

4.1.4 Crop diversification, agroforestry and integrated farming system

4.1.4.1 Cropping systems and moisture conservation practices for agri-horti systems

The highest water-use efficiency (15.7 kg/ha-mm), chickpea equivalent system productivity (4760 kg/ha)

A view of crop diversification experiment

and highest net returns (₹ 156, 590/ha) with net B: C ratio (1.83) was obtained from babycorn-chickpea cropping systems followed by maize (cob)–chickpea cropping system. Moisture conservation practice, *i.e.*, ridge and furrow system with residue mulch at 3 t/ha resulted in maximum system productivity (4450 kg/ha), net returns (₹ 140420/ha) and B: C ratio (1.62). Sole crop resulted in higher system productivity (4.41%) compared to agri-horti system (crops + *Kinnow*). The net returns (₹ 1, 00, 056 /ha) and B: C ratio (1.22) were also higher with crops compared to agri-horti system (₹ 93,400/ha with B: C ratio 1.09).

4.1.4.2 Bio-intensive resource efficient cropping systems for profit maximization

The maize + blackgram (raised bed) + soybean (furrow) - chickpea (raised bed) + wheat (furrow) (3:2) - green gram (raised bed) + sunflower (furrow) (5:1) recorded significantly higher system productivity, production efficiency, and the lowest greenhouse gasses intensity (GHGI).

4.1.4.3 Effect of different integrated farming system models for small farmers (area 1 ha)

Integration of crop, dairy, fishery, poultry, duckery, apiary, boundary plantation and biogas unit gave maximum net return (₹ 4,05,460/ha) followed by crop + dairy + fishery + poultry + duckery + apiary + boundary plantation + biogas unit + vermi-compost (₹ 4,04,960/ha). The minimum net returns (₹ 1,15,080/ha) was obtained with rice-wheat cropping system. Similarly, the maximum net profit (₹ 1,70,058) and employment (365-man days in a year) was obtained from dairy enterprises followed by crops cultivation (₹ 1,08,874 net returns and 150-man days employment) for small landholder farmers.

Economics of different integrated farming system of small farmers (area – 1.0 ha) in North India

Enterprise	Area	Cost of cultivation (₹)	Net Returns (₹)	Employment generation (man days)
Crops	0.70 ha	92,115	108,874	150
Dairy	3 cows	355,646	170,058	365
Duckery	35 birds	32,330	31,431	26
Fishery	0.1 ha	60,691	32,294	26
Poultry	50 birds	27,270	25,379	26
Fruit production	0.05 ha	9,418	8,840	15
Agroforestry	120	1,504	3,290	3
Biogas	2 m^3	4,090	4,715	12
Fencing area-country bean	---	2,223	9,307	5
Total	**1.0**	**585,288**	**394,188**	**628**

4.1.5 Integrated crop management

4.1.5.1 Integrated crop management for maize–wheat rotation

Conservation agriculture (CA) based ZT raised bed maize and wheat with the residues produced 7.8-21.3% greater maize grain yield than the other ICM treatments. Notably, all the CA-based ICM treatments gave statistically similar wheat grain yield and was 8.4-11.5% greater than the conventional technique based ICM treatments. Moreover, CA-based ICM treatments recorded 9.5-14.3% highest system yields in terms of maize grain equivalents over the residue removed CT-based ICM. System water productivity was also highest with CA-based ICM treatments (10.3-17.8%). At 0-15 cm soil profile, residue retained CA-based treatments registered a 10.2-17.3% greater SMBC than the conventional treatments.

4.1.5.2 Integrated crop management on maize + black gram – wheat cropping system

The conservation agriculture (CA) with residue retention (3 t/ha) on a permanent raised-beds, glyphosate pre-plant *fb* pendimethalin as pre-emergence with 3 irrigations and need based plant protections (ICM module) resulted in significantly higher grain (6.20 t/ha), stover yield (8.25 t/ha), energy output (19.4 × 10^4 MJ/ha) over conventional tilled (CT) and organic input based ICM modules. CA practices improved maize grain yield by 9% over CT; while organic input based ICM module produced 22% less maize grain yield than CT. Blackgram intercropping significantly improved maize yield (6% increases) over sole maize and provided 2.5 to 3 q/ha of blackgram yield from intercropped plots.

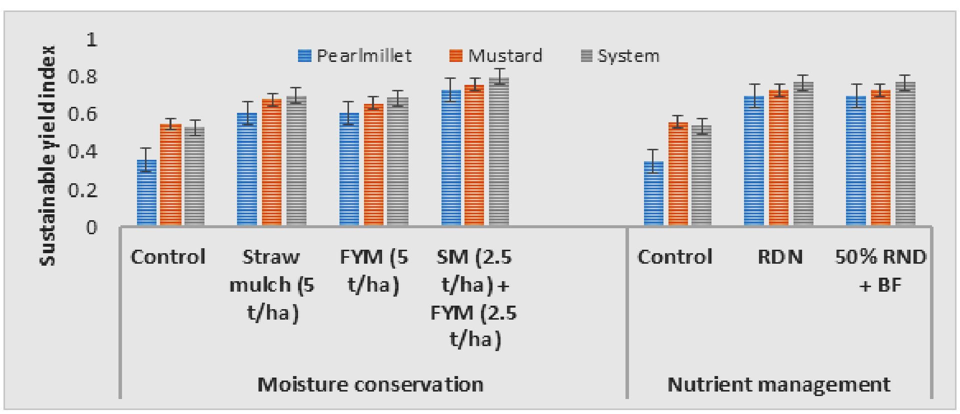
4.1.6 Production technologies for rainfed/ dryland /limited moisture condition

4.1.6.1 Conservation agriculture and pulse integration technologies for North west rainfed systems of India

Application of crop residue as mulch at 4 t/ha in pearlmillet-chickpea cropping system significantly improved soil properties like physical (bulk density, water holding capacity, soil temperature and soil moisture), chemical properties (organic carbon, soil pH, N, P and K availability) and biological properties (MBC, DHA and ALP) of the soil compared to conventional tillage and standing residue retention in zero tillage (ZT) than the rest of the cropping systems. The highest system productivity in terms of chickpea equivalent yield (2.13 t/ha), net returns (₹ 37,875/ha) and B: C ratio (1.53) was obtained with ZT + residue mulch followed by 2.04 t/ha with ZT + residue retention.

4.1.6.2 Moisture conservation and nutrient management for pearlmillet–mustard cropping system

Straw mulch (2.5 t/ha) + farmyard manure (2.5 t/ha) soil moisture conservation practices resulted in higher pearlmillet grain yield, mustard seed yield, pearlmillet-



Sustainable yield index in pearlmillet-mustard cropping systems

mustard system productivity, N uptake, rainfall-use efficiency, monetary returns, sustainable yield index, soil organic carbon compared to rest of the moisture conservation treatments. The recommended dose of nitrogen (RDN) resulted in maximum pearlmillet grain yield, mustard seed yield, pearlmillet-mustard system productivity, N uptake, rainfall use efficiency, sustainable yield index and soil organic carbon however was at par with 50% RDN + biofertilizer (BF). Net monetary returns were also greater under the treatment of 50% RDN + biofertilizer over RDN and control.

4.1.6.3 Moisture conservation practice can improve production of maize, pearl-millet and cowpea based intercropping systems

Moisture conservation-based tillage establishment and intercropping with legumes reduced weed density and biomass by 25-30% through smothering effect. Moisture conservation-based furrow planting and residue retention recorded the highest yield of all crops followed by ridge planting. Both maize and pearlmillet based intercropping systems followed by mustard resulted higher productivity compared to the sole crop-based chickpea cropping system. Cowpea followed by barley was comparable with pearlmillet + cowpea followed by mustard in terms of productivity. Ridge planting is beneficial during kharif season while in *rabi* season furrow planting was found better in terms of productivity and WUE. Overall, water use efficiency was higher under maize + cowpea – mustard cropping system.

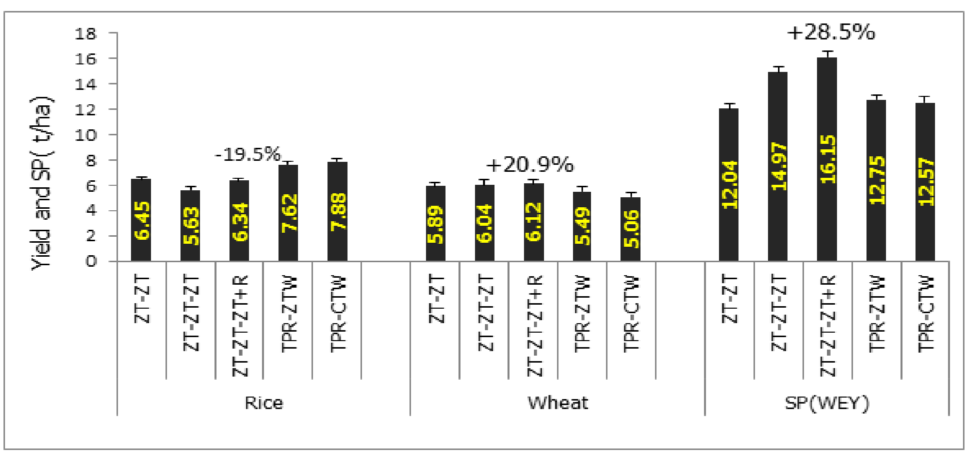
4.1.6.4 Tillage, leaf defoliator and deficit irrigation can be profitable for pigeon pea-wheat cropping system

CA-based permanent raised bed + residue retention (3 t/ha) recorded the highest seed yield of pigeonpea. Urea spray (10%) at physiological maturity on pigeonpea resulted in seed yield reduction but there was increase in wheat yield. On an average defoliation of pigeonpea leaves added around 15 kg N /ha to the wheat crop.

4.1.7 Conservation agriculture

4.1.7.1 Conservation agriculture-based rice-wheat system can be a superior crop diversification option in north-western Indo-Gangetic plains

A long-term CA experiment (11 years) revealed that a triple cropping system involving ZT DSR with summer mungbean (SMB) residue (MBR)- ZT wheat (ZTW) with rice residue (RR)– ZT summer mungbean (ZTSMB) with wheat residue (WR) was consistently superior to other CA systems and puddled transplanted rice (PTR) - conventional till wheat (CTW) system on system productivity and net returns. Moreover, recorded a 20.9% higher wheat yield, 28.5% higher system productivity and 35.3% higher net returns than TPR-CTW system, although it had a 19.5% lower rice yield. This triple ZT system could save almost 60 kg N/ ha in rice-wheat system per year. Also obtained 35% and 7% higher net returns with and without mungbean, respectively. Thus, it can be a superior alternative to



CA in triple croping system

rice-wheat system and an important adaptation and mitigation strategy to climate change.

4.1.7.2 Conservation agriculture effects on productivity and profitability in cotton-wheat cropping system

A 11-year-long CA-based cotton-wheat system revealed that CA-based ZT permanent broad, narrow, and flat beds with residue resulted in significantly higher yields of cotton, wheat and system productivity than CT. However, in contrast to previous years where ZT permanent broad bed was superior, this year the ZT flat bed with residue with 100% N led to significantly higher cotton yield by 51.3%, wheat yield by 25.6% and system productivity by 51.4% than CT system. This practice with 75% N was comparable with it, leading to a saving of 25% N. The cotton-wheat system under PFB+R led to 65% increase in net returns compared to CT. This CA-based cotton-wheat system could be a promising crop diversification option for rice-wheat system and an important adaptation and mitigation strategy to climate change.

Cotton and wheat crops under CA-based production system

4.1.7.3 Conservation agriculture based technologies can improve the yield of maize-wheat cropping system in North Eastern Plain Zone of India

A study reported that zero tillage-flat bed systems resulted in highest number of effective tillers/m^2 (246.3), straw yield (61.33 q /ha) and grain yield (43.54 q /ha) than zero tillage-raised bed. Application of residue 3 t/ha + RDF recorded highest growth, yield attributes and yields (45.36 q /ha) compared to no residue + RDF (44.91 q /ha).

4.1.7.4 Sustainable Intensifications through CA Technologies and Pulse Integration in rainfed regions of Eastern India

A study conducted at IARI regional station PUSA, Samastipur, Bihar revealed that zero tillage with residue mulch (ZT+RM) system was found to be best to retain maximum soil moisture (by 7-14% at 0-15 and 15-30 cm soil depth at 30 DAS) compared to conventional tillage (CT). Application of 4 t/ha residue retained maximum soil moisture and lowered soil profile temperature. Significantly higher chickpea grain equivalent yield was recorded in ZT + RM, which was higher than CT and zero tillage with standing residue retention (ZT + RSR). The net returns and net B:C was influenced by tillage, residue rate and crops. The net returns and net B: C was observed maximum with ZT + RM followed by ZT+RSR. Among the residue rates, maximum net returns and net B: C ratio were obtained due to application of 4 t/ha.

4.1.7.5 Evaluation of different *rabi* crop genotypes under varied management practices for higher productivity and profitability under rainfed condition of Eastern India (IARI-ICARDA Collaborative project)

Higher chickpea grain equivalent yield was recorded due to ZT+RM compared to CT. Growing of chickpea after rice recorded maximum chickpea grain equivalent yieldthan lentil and grasspea after rice. Growing of high yielding varieties such as Ujjwala of chickpea, Rajendra Khesari 1 of grasspea and Pusa Shivalik of lentil recorded significantly higher chickpea grain equivalent yield, which was higher than local variety. The highest net returns and net B: C were recorded with zero tillage along with residue mulch (ZT+RM) applied at 3 t/ha. Among the crops, chickpea resulted in maximum net returns and B: C followed by lentil.

4.2 SOIL MANAGEMENT

4.2.1. Stability of soil organic carbon

4.2.1.1 Humus stability enhanced by long term fertilization and manuring application

The FTIR spectroscopy absorption peakat 1300-1100 cm^{-1} representing in-plane bending of the aromatic ring C-H bonds in soil organic matter (SOM) were significantly higher in 50% N treatment supplemented with green manuring (GM) in both Vertisol and Alfisol. The same treatment also had a higher carbon sequestration potential. This finding was also supported by the FTIR spectra of the fulvic acid. An increase in intensity and broadening of the adsorption bands at 1720-1725 cm^{-1} (C=O stretching of COOH and ketonic C=O), and 1040 cm^{-1} (O-CH_3 vibrations) when 50% N is supplemented through organic inputs. The SOM accumulated in Vertisol showed higher aromaticity indicating more stabilization of carbon followed by Mollisol, Alfisol and Inceptisol. This observation was supported by the data on NaOCl resistant C and thermal resistant C.

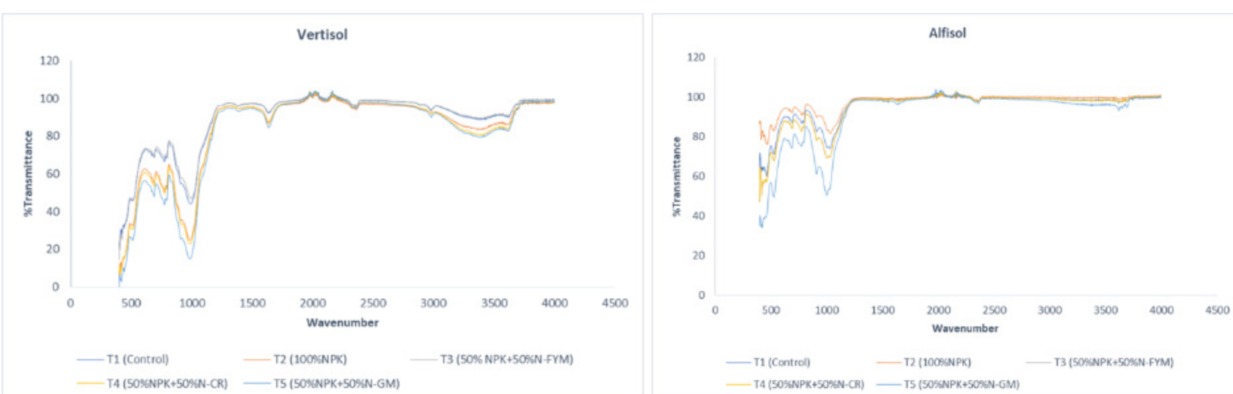
4.2.1.2 Non-rice based systems can sequestrate more soil organic carbon in Indo-Gangetic Plain (IGP)

The study showed that the recalcitrant carbon stock was higher in non-rice based cropping system than rice based cropping system. Further, non-rice based system had a higher carbon stability in clay-humus complex. Both the labile and recalcitrant soil carbon stocks were higher at 0-30 cm layer as compared to 30-60 cm in both the cropping systems and the carbon stability decreased with increasing depth. Thus shifting from rice to non-rice based cropping system in IGP can have more carbon sequestration potential.

4.2.2. Soil organic carbon, nitrogen, phosphorus, soil biological health improvement in conservation agriculture

4.2.2.1 Conservation agriculture for enhancing soil organic carbon sequestration in rice-wheat cropping system

Nine years of conservation agriculture under direct seeded rice + mungbean residue – zero tilled wheat + rice residue – zero tilled summer mungbean with wheat residue had ~44, 37%, and more than 50% higher total soil organic carbon (SOC) concentration in the 0-5, 5-15, and 15-30 cm soil depths, respectively, than transplanted rice (TPR)-conventionally tilled wheat (CTW) plots in Indo-Gangetic alluvial plains. In another experiment, five years of maize-wheat

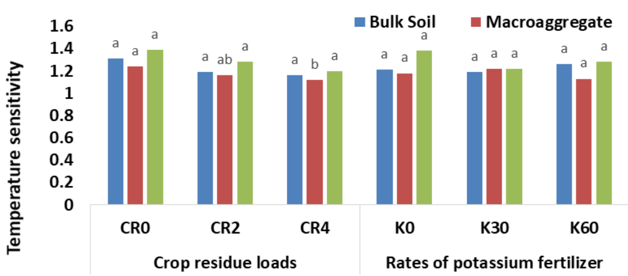


FTIR spectra of soil organic matter in Vertisol (Jabalpur) and Alfisol (Ranchi) as influenced by long-term manuring and fertilization

cropping system under different tillage, residues and nitrogen management recorded a significant increase in carbon management index (CMI) under no-tillage than that of conventional tillage by 34.5 and 6.8% in 0-5 and 5-15 cm soil depths, respectively. Crop residue retention significantly increased CMI at 0-5 and 5-15 cm depth by 19.5 and 22.8%, respectively.

4.2.2.2 Temperature can enhance aggregate carbon oxidation

Total SOC and its pools of varying oxidizability significantly increased with increase in CR retention. Accumulation of C-rich macro-aggregates were noticed under high CR retention plots with concomitant decrease in micro-aggregates contents in soil. Micro-aggregate showed higher mineralization carbon with higher decay rate constant (Kc) and therefore this fraction of carbon had higher temperature sensitivity (Q_{10}) as compared to either bulk soil or macro-aggregates. However, the decay rate of carbon mineralization was drastically reduced due to increase in CR loads, indicating higher stability of carbon by physical protection within soil aggregates.



Temperature sensitivity of soil organic carbon mineralization from different aggregate size fractions (0-5 cm); (CR_0: No retention of crop residue, CR_2: Retention of crop residue at 2t /ha, CR_4: Retention of crop residue at 4t/ha, K_0: No Potassium fertilizer application, K_{30}: Potassium fertilizer application at 30 kg K_2O /ha, K_{60}: Potassium fertilizer application at 60 kg K_2O /ha). The bars with different lower case letters under crop residue loads and rates of potassium fertilizer in a column are significantly different according to LSD at 5% level of significance

4.2.2.3 Soil nitrogen transformation and microbial function under conservation agriculture based cotton system

A 10-year-old cotton-wheat cropping system under conservation agriculture showed that total N was the highest in flat bed with residues retained plots (FB+R) (1.41 mg kg^{-1}) followed by permanent narrow bed residues retained plots (PNB+R) (1.39 mg kg^{-1}). The hydrolysable amino acid N (HAAN) constituted 44.2 (PNB) to 54.9 % (PNB+R) of total hydrolysable N (THN). The minimum HAAN was recorded in permanent broad bed (PBB) plots. Residue retention decreased hydrolysable amino sugar N (HASN) concentration in the soil. Unidentified hydrolysable N (UHN) varied from 0.09 mg kg^{-1} (PBB+R) to 0.24 mg kg^{-1} (FB). Non hydrolysable N (NHN) constitutes 12.4 (FB+R) to 22.7% (PBB) of total-N concentration present in soil among different treatment.

4.2.2.4 Conservation agriculture can improve soil phosphorous fractions

The zero tillage with residue retention practices significantly increased the water-soluble P (WSP), $NaHCO_3$ extractable fraction (labile P) in both 0-5 cm and 5-15 cm soil layer, whereas it did not significantly affect NaOH extractable fraction as well as HCl extractable fraction. Total P as well as microbial biomass P were the highest in triple zero-till system with residue retention, whereas the lowest values of the same were observed in conventional systems. In another experiment, it was found that labile pool of P was significantly increased in narrow bed + residues and broad bed + residues treatments in comparison to other treatments, which indicates that residue retention has significantly increased the available P content in the soil.

4.2.2.5 Conservation agriculture can boost soil health

The soil health index (SHI) was higher in 0-5 cm (0.67 to 0.98) than 5-15 cm (0.66 to 0.82) soil depth under eleven years old triple zero tillage with residue (ZTDSR+MR-ZTW+RR–ZTMB+WR) treatment in conservation agriculture under rice-wheat cropping system. Therefore, conservation agriculture with the above treatment may be advocated in rice-wheat cropping system of IGP for enhancing soil health.

4.2.2.6 Impact of organic farming on soil health

Long-term impact of organic farming practices involving five treatments comprising of absolute control, biofertilizer consortia at 3.5 kg/ha, compost at 5.0 t/ha, compost at 5.0 t/ha + biofertilizer consortia at 3.5 kg/ha, enriched compost at 2.5 t/ha, enriched compost at 5.0 t/ha and azolla at 0.5 t/ha+ biofertilizer consortia at 3.5 kg/ha on soil organic carbon pools and available nutrients were studied under rice in an acid soil. Results indicated that the long-term use of enriched compost at 5 t/ha had a higher acid phosphatase, alkaline phosphatase, dehydrogenase and beta-glucosidase activities compared to application of compost @ 5.0 t/ha.

4.2.3. Nutrient management

4.2.3.1 Silicon application improved phosphorus availability

Experiments were conducted to assess the influence of various doses and sources of Si on the availability of P in two different soils namely, alkaline I soil (pH 8.30 and available P content 12.4 kg/ha) from IARI and calcareous soil (pH 8.6 and Olsen-P content 13.6 kg /ha) from Bihar. Two Si rich crop residues, *i.e.*, rice straw (6.76% Si) and sugarcane leaf (2.65% Si) and one water soluble Si salt, *i.e.*, sodium silicate were used as sources of Si. The Si sources i.e., rice straw (6.76% Si) and sugarcane leaf (2.65% Si) and one water soluble Si salt resulted in higher 0.01 M $CaCl_2$ extractable P in both the soils. All the three Si sources also positively impacted the wheat growth parameters.

4.2.3.2 Potassium depletion under varying soil potassium supplying capacity

In low K soil, 50% RDK was not adequate to preserve the K-bearing clay mineral *i.e.,* illite; whereas in high K soil the same dose appeared more or less adequate in preventing accelerated weathering of illite. The changes in NH_4OAc- K and non-exchangeable K based on HNO_3 could not account for the total soil contribution. However, the 24 h or the 7 days extraction with sodium tetraphenylborate (NaTPB) could account for almost entire soil contribution of K towards plant uptake.

4.2.3.3 Waste mica as a potassium source

Mica application at 50 and 100 mg kg^{-1} soil significantly improved the yield and K uptake by wheat as compared to treatments without mica application. Isolated strains of potassium solubilizing bacteria (KSB) and standard strain *Bacillus* sp. were found equally effective in improving K availability from mica to the wheat crop. Mica, bio-activated *via.* rice residue and KSB was able to improve relative efficiency and per cent K recovery from soil but it was comparable with muriate of potash (MOP).

4.2.3.4 Identification of zinc efficient and inefficient rice genotypes

A study conducted in a pot culture to confirm the Zn deficiency tolerance response of 20 genetically diverse rice genotypes under Zn deficient (Zn-) and Zn sufficient (Zn+) soil condition. The study identified that Jaya, Paung, Lal Japani, Pusa-33, Arupathaam Kuruvai, GR-8 and GR-12 were the most Zn efficient genotypes.

4.2.4. Development and evaluation of novel fertilizers

4.2.4.1 Novel fertilizer products can enhance nitrogen use efficiency

N-loaded nano-clay polymer and bio-polymer composites were effective in enhancing nitrogen use efficiency in maize crop. The NCBPC-II product showed promising results in terms of yield when applied at the rate of 75% N as compared to application of 100% N through urea. Similarly, 75% N applied through NCPC was also effective in terms of yield, uptake and nutrient use efficiency by maize crop besides maintaining available nutrients in soil.

N-loaded nano-clay polymer and bio-polymer composites on yield and N use efficiency of maize

Treatment	Grain yield (t /ha)	AUE (kg kg^{-1})	ANR (%)
Control	3.33^{c}	-	-
100% N through urea	5.30^{ab}	13.1^{d}	41.5^{de}
100% N through UAN	5.37^{ab}	13.6^{d}	44.6^{cd}
100% N through NCPC	5.56^{a}	14.9^{bcd}	54.8^{a}
75% N through NCPC	5.29^{ab}	17.4^{a}	52.5^{ab}
100% N through NCBPC-I	5.49^{a}	14.4^{cd}	48.1^{bc}
75% N through NCBPC-I	5.15^{b}	16.2^{abc}	36.9^{e}
100% N through NCBPC-II	5.51^{a}	14.5^{bcd}	50.6^{abc}
75% N through NCBPC-II	5.24^{ab}	16.9^{ab}	41.5^{de}
LSD at 5%	0.33	2.45	6.19

NCPC – Nano clay polymer composite, NCBPC - Nano clay bio-polymer composite, UAN – Urea ammonium nitrate, AUE – Agronomic use efficiency, ANR – Apparent nitrogen recovery; The data followed by different uppercase letters in a particular column are significant according to LSD at P = 0.05

4.2.4.2 Novel fertilizer products improved phosphorus use efficiency

Biodegradable clay-polymeric (starch/PVA) blended coating films (CPSBs) were synthesized from wheat starch, PVA and bentonite for CPSB-encapsulated DAP. The relative crystallinity index and density of CPSBs were increased with increasing bentonite content.Formulated oil-based formulations using double-boiled linseed and mustard oils were used for coating DAP. Nutrient release from oil-based formulations coated DAP significantly reduced in comparison with uncoated DAP, indicating that double-boiled linseed and mustard oil-based formulations of coated DAP could be an alternative option to produce cost effective controlled release fertilizers.

4.2.4.3 Novel Zn fertilizers enhanced zinc use efficiency

The maize grain yield in NPK+1.0 kg Zn /ha through Zn-NCPC was significantly higher than NPK + 2.5 kg Zn/ha through $ZnSO_4$, NPK+ 0.5 kg Zn /ha through Zn-NCPC and NPK + seed coating Zn- NCPC treatments, but on par with the yield of NPK+ 5 kg Zn /ha through $ZnSO_4$, NPK+ 5 kg Zn /ha through Zn- NCPC and NPK+ 2.5 kg Zn /ha through Zn-NCPC treatments. In case of chickpea grain yield in NPK + 1.0 kg Zn /ha through Zn-NCPC was significantly higher than NPK + 2.5 kg Zn / ha through $ZnSO_4$ and NPK + 0.5 kg Zn /ha through Zn-NCPC treatments, but on par with the yield as obtained in the rest of the treatments. Hence, application of Zn through NCPC is five times more efficient than that of the conventional source, *i.e.* $ZnSO_4$.

4.2.5. Management of metalloid and heavy metals in soil

4.2.5.1 Arsenic contamination level in Nadia district of West Bengal

Solubility-FIAM model could successfully be used for predicting uptake of As by rice grown in Nadia district of West Bengal. Model parameters were optimized for calibration yielded R^2 value of 0.82, whereas for validation, 71% variation in As content in rice grain could be successfully predicted by solubility-FIAM model.

4.2.5.2 Adsorption-desorption of Arsenic (As) on soil and clay sized fractions

The As adsorption was higher in Alfisol, however, the percentage of As desorption was higher in Inceptisol. Among the clay-sized fraction, As adsorption and cumulative desorption was higher in clay-oxides and clay organic complex (COC) of Alfisol and Inceptisol, respectively. However, the percentage of As desorbed over the adsorption was higher in clay for both the soil orders. The organic matter and Al-Fe-oxides greatly influence the As adsorption and desorption processes in soil.

4.2.5.3 Different chemical pools of Pb in sludge amended soil

The application of chemical fertilizers (N, P and K) and sludge alone as well as in combination compared to the control (no fertilizer application) significantly decreased the DTPA extractable Pb. The dominant Pb fraction was residual fraction (39-46% of total metal) followed by organically bound (28-53%) in all the treatments.

4.2.6. Soil test based fertilizer recommendation

4.2.6.1 Pusa soil test fertilizer recommendation (STFR) meter

The Pusa Soil Test and Fertilizer Recommendation (STFR) Meter is highly useful for the areas where soil testing facility is not available. It consists of a meter, a mini-shaker, a reagent-kit (for 50 soil samples) and other important accessories needed for soil testing. This portable soil testing kit now analyzes as many as 14 important soil parameters, *viz.* pH, EC, OC, available nutrients [P, K, S, Zn, B, Fe, Mn, Cu and N (based on OC)], and gypsum requirement and lime requirement. It gives crop-specific fertilizer recommendations.

4.3 WATER MANAGEMENT

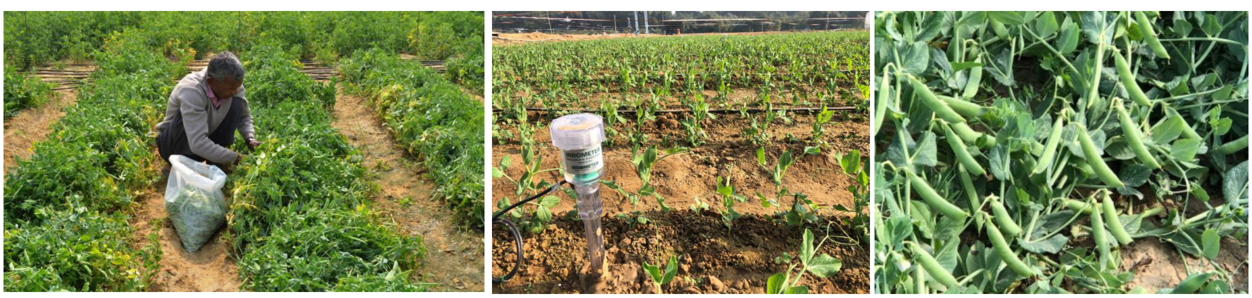
4.3.1 Irrigation Water Management

4.3.1.1 Near real time soil moisture criteria based irrigation scheduling for green pea

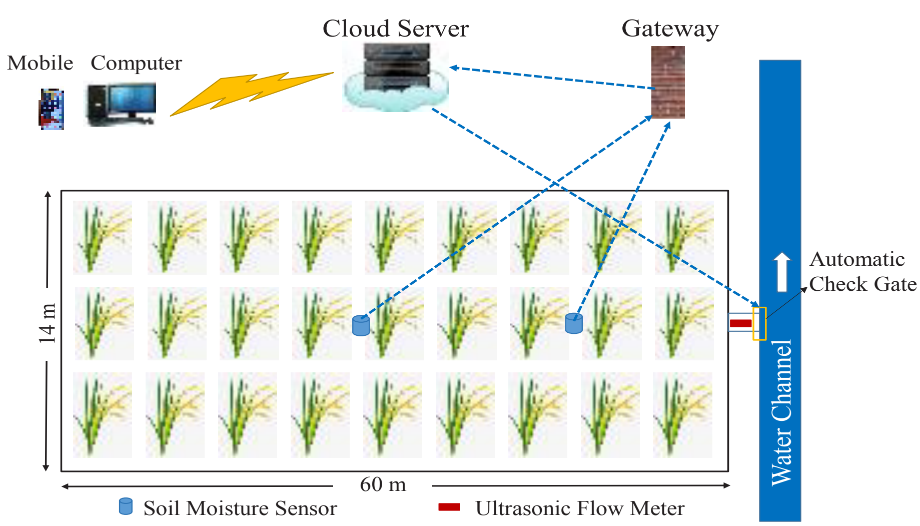
Higher green pea yield (17.9 t/ha) was observed in -30 kPa SMP threshold with 120% of recommended dose of fertilizer treatment. Lower yield was observed in -40 kPa SMP treatment with 80% RDF through fertigation. Water saving of 44-50% was recorded in real time soil moisture based irrigation schedule than the surface irrigation practice.

4.3.1.2 Automation of soil moisture sensor-based basin irrigation system

An Internet of Things (IoT) based automatic basin irrigation system was developed through a wireless connection between the automatic check gate and soil moisture sensors. The results suggested that the best



Near real time irrigation scheduling in green pea using Tensiometer



Schematic diagram of the experimental evaluation of automatic basin irrigation system

location of sensors for closing the system would be at 37.5 cm depth placed at 25% length from the inlet in higher soil moisture deficit condition and at 7.5 cm depth placed at 75% length in low moisture deficit condition. Overall, the irrigation application efficiency was improved to 86.6% with automation.

4.3.1.3 Canopy temperature-based indices (DANS and DACT) for assessing crop water stress estimating potential

A study was conducted to assess the crop water stress estimating potential of two canopy temperature-based indices, namely, Degree above Non-Stressed (DANS) and Degree Above Critical Temperature (DACT) for the wheat crop. The analysis showed a linear relationship between soil water deficit (SWD) and two computed indices. However, the coefficient of determination (R^2) value for SWD versus DACT index was observed to be significantly higher ($R^2 = 0.60$) than that for the DANS ($R^2 = 0.25$), thereby indicating DACT as a better indicator of soil moisture stress.

4.3.1.4. Integrated water footprint of different crops of Bahraich district, UP

Water footprints of major 10 crops for 30 years for all 14 blocks were estimated for Bahraich of Uttar Pradesh. Highest green water use was observed for sugarcane in Huzoorpur block followed by paddy in Jarwal block, whereas corresponding blue water use in Bisheswarganj and Shivpur, respectively. Economic water productivity was found to be medium except Chittaur block. Integrated water footprint was highest for Mahsi block (947 m^3/t).

4.3.1.5 CERES-wheat model can assess climate change

The CERES-wheat model indicated that substantial decline in phenology, grain yield, biomass yield and crop water productivity (CWP) observed under RCP4.5 and RCP8.5 at baseline CO_2 concentration. The decline was more under RCP 8.5 than under RCP 4.5. But the CO_2 concentration effect could minimize the loss in grain yield and CWP but not influenced crop phenology (days to anthesis and physiological maturity). The days to anthesis and physiological maturity were declined by 2-7 and 4-7 days, respectively under RCP 4.5 and 2-11 and 5-10 days, respectively under RCP 8.5. The grain yield of wheat will decline by 10.2, 15.7 and 14.9% during 2030's, 2050's and 2070's, respectively under RCP 4.5 and 7, 12.6 and 8.9%, respectively under RCP 8.5 at future elevated CO_2 concentration. However, positive effect of CO_2 concentration on CWP was noticed under both RCPs and the reduction will be only 5.4 and 2.2% during 2050's and 2070's, respectively under RCP 8.5.

4.3.1.6 Irrigation efficiencies of Amarpur minor of Bhagawatipur distributary of ESHLC

The field application efficiencies (Ea) for the first and second runs of irrigation of the selected fields varied from 48-61% of eastern sone high level canal command (ESHLC) of Bihar, India. Ea for the head, middle and tail reaches were 48.4, 54 and 61% respectively, for the first run of irrigation. However, for the second run of irrigation; Ea for the head, middle and tail reaches varied from 51, 53 and 59%; respectively. The storage efficiency for the first run of irrigation for the three fields varied between 87-91%. However, the storage efficiencies for second run of irrigation was ranged of 82.5-94%. From this study it was recommended that instead of a constant supply the canal discharge should be changed with variable one.

4.3.1.7 Spatio-temporal crop water demand (ETc), crop water surplus deficit index (CWSDI) for mustard and maize

The crop water demand (ETc), CWSDI and coupling degree of ETc and Pe of mustard ranged from 367 to 487 mm, -94 to -74%, and 0.06 to 0.25, respectively during 1985-2018. The average ETc during 2007-18 was relatively high compared with that of 1985-95 and 1996-2006, which led to the increase of both CWSDI and the coupling degree of ETc and Pe. The highest CWR was observed in Faridabad, Palwal and Mewat districts, whereas the lowest was observed in Panchkula and Yamunanagar districts. In case of Maize, ETc, CWSDI and coupling degree of ETc and Pe ranged from 571 to 766 mm, -74% to -29%, and 0.26 to 0.71%, respectively during 1985-2018. Highest CWR of maize was found in the districts of Sirsa, Hisar and Bhiwani, whereas the lowest was observed in the districts of Ambala, Yamunanagar and Panchkula.

4.3.1.8 On-farm irrigation efficiency and water productivity of Ghazipur district

On-farm irrigation efficiencies at farmers' fields in selected villages of JakhnianBlock in Ghazipur district of Uttar Pradesh were determined for paddy and wheat to assess the performance of surface and groundwater irrigation. The application efficiency was found to be 53.4, 72.7, 65.92, and 76.68% for paddy and 55.5, 72.7, 67.8, and 77.95% for wheat in case of canal irrigation, diesel operated pumps, electric operated pumps, and hired tubewell water, respectively. The highest water productivity was with electric operated pumps (0.5 kg/m^3 for paddy and 1.2 kg/m^3 for wheat) and lowest for canal irrigated farmers (0.43 kg/m^3 for paddy and 0.83 kg/m^3 for wheat).

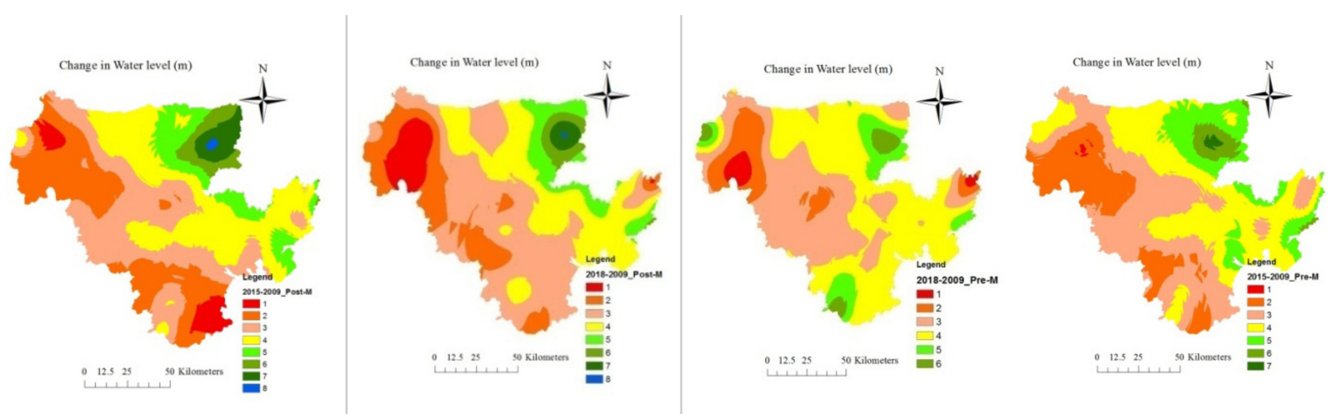
4.3.2 Water conservation for Rainfed Agriculture

4.3.2.1 Trend analysis and spatio-temporal variability mapping of ground water table depth for Central Punjab

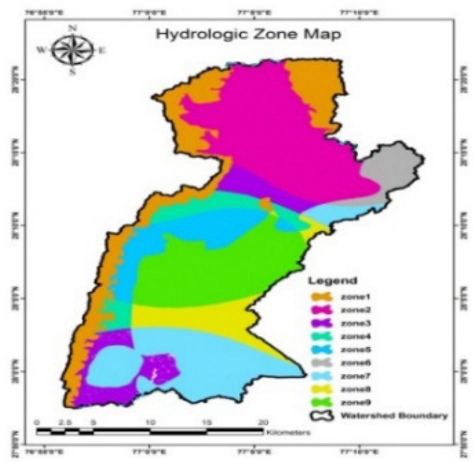
Trend analysis and spatio-temporal variability mapping of ground water table depth (GWTD) was undertaken for past 20 years (1999-2019) for Moga, Barnala, Patiala, Sangrur and Ludhiana districts of Punjab, India. Both the Modified Mann-Kendall (MMK) trend test and Innovative Trend Analysis (ITA) indicated a decreasing trend of water table depth for all Districts at P<0.01. The MMK test indicated the highest rate of decline in GWTD for the Sangrur district (≥1.3 m/year) followed by Barnala (≥1.1 m/year), Patiala (≥0.9 m/year), Moga (≥0.8 m/year) and Ludhiana (≥0.4 m/year) for both the pre monsoon and post monsoon periods, respectively. Moreover, 26, 39.3, 15.9% and 6.3% area showed a decline in ground water table by 10 m, 10 m to 20, 20 m to 30 m and >30 m, respectively, whereas, a rise of water table by ≤10 m, 10-20 m, 20 to 30 m and >30 m were observed for about 7.8, 2.9, 1.7 and 0.1% area, respectively.

4.3.2.2. Hydrological zone for upscaling water harvesting structures of Nuh watershed

Scientific protocol was developed for revival of village ponds in Nuh Block of Mewat. A Nuh watershed of area 633.63 km^2 was delineated using RS, GIS and DEM, and different thematic maps including spatial variability maps of different soil parameters and groundwater table were also developed. It was observed that 43% area is under agricultural land. Soil texture found to be loam, clay, sandy loam and clay loam. Runoff was estimated for 30 years data and found to be 18.9% of total rainfall. Hydrological zone was developed and potential water harvesting sites were identified using AHP which will be used to develop protocol to redesign the WHSs through ecohydrological approach under changing climate.



Changes in groundwater table in 2018 and 2015 from base year 2009. Pre-M refers to pre-monsoon and Post-M refers to post monsoon



Hydrological zone map of Nuh watershed (Note: zone 1 to 9 indicates higher to lower runoff potential)

4.3.3. Waste water use in agriculture

4.3.3.1. Calcium alginate based biopolymer can reduce heavy metal contamination

Gram +ve bacterial isolates (*i.e.*, 47/59 and 71/92) were observed in Ni, Cr and Pb reduction with the efficiency of 27.06 to 47.54%, 39.96 to 42.47% and 52.97 to 61.14%, respectively. The strain Nos. 71 and 92 were associated with Ni, Cr and Pb reduction efficiencies of 40.96 to 55.47%, 36.50 to 43.41% and 51.14 to 51.92%, respectively. However, under immobilized conditions, the same appeared to be associated with just about 11 to 16% increased Ni and 15 to 19% increased Pb reduction efficiencies with respect to the control (with no bacterial isolates).

4.3.3.2 Organic (rice straw and sawdust) and inorganic (bentonite) amendments can effectively remediate heavy metal (Ni) in wastewater-irrigated soil

The wastewater usage study showed that potato and maize yields were significantly higher with wastewater irrigation (41.5 and 7.5 t/ha, respectively) as compared to groundwater-irrigation. Heavy metal analysis of tuber and cob indicated that amendments applied plots recorded 50-60% and 25-45% reduction in Ni and lesser risk values (<1.0) compared to the control plots.

4.4 CENTRE FOR PROTECTED CULTIVATION TECHNOLOGY (CPCT)

4.4.1. Newly released varieties

Centre has developed two varieties of tomato *i.e.*, Pusa Tomato Protected-1, Pusa Golden Cherry Tomato No. 2 and one variety of Pakchoi *i.e.*, Pusa Pakchoi-1.Notified vide No. F.10(1)2/SI/TA/Sub-Committee/2017-18/2 332-2373 for NCT of Delhi.

4.4.2. Design and installation of IoT based monitoring and alert system for greenhouse aeroponics

The IoT based aeroponics monitoring and alert system was designed and developed inside the climate-controlled greenhouse based on parameters like EC, pH, temperature and level of nutrient solution, temperature and humidity of air around the plant. The IoT based monitoring and alert system consisting of five sensors, ESP-32 microcontroller and other accessories developed to monitor mentioned parameters on user smartphone using Thing speak online platform and it can be operated from anywhere in the world. Also, alert system was integrated with monitoring system using IFTTT software platform which send an alert notification to user smartphone when any of the parameter were not in its predefined range.

IoT based Greenhouse Aeroponic Monitoring System

4.4.3. Design and installation of vertical hydroponic prototype with and without artificial light

Vertical hydroponic technology-based prototypes for 50 plants with 3 vertical layers was designed and installed with and without artificial light. Automatic fertigation with 35 watt submersible pump was used to supply water and nutrients as per the plant requirement. The total cost of the vertical hydroponic system is ₹ 32,650 and ₹ 19,330, respectively for 50 plants system with and without artificial light, respectively.

Vertical Hydroponic System 3 layers with artificial light

4.4.4. Tomato

4.4.4.1 Pusa Tomato Protected-1

This is the first indigenous open pollinated variety of tomato suitable for naturally ventilated polyhouse/ protected cultivation in NCR. It has indeterminate growth habit and attains average vine length varying from 8-12 m. It has 9-10 average flower truss per plant. Fruits are round, deep red in colour with average fruit weight of 80-85 g. The ripe red fruits have TSS 5.60^{o}Brix and lycopene content 8.0 mg/100 g. It gives an average yield of 12-14 kg/m^2 in 9–10 month crop duration. Fruits has thick flesh and suitable for long distance transportation. Average yield potential is 120-140 q / 1000 m^2.

Pusa Tomato Protected-1

4.4.4.2 Pusa Golden Cherry Tomato No. 2

This is the first indigenous golden yellow cherry tomato variety suitable for naturally ventilated polyhouse/protected cultivation. It is characterized by indeterminate growth habit and attains average vine length varying from 8-12 m. It has 9-10 average flower truss per plant. The average fruit weight is about 7-8 g with approximately average fruit yield 3.5-4.0 kg/plant with yield potential of 9-10 t/1000 m^2. The fruits get ready for first harvest is about 75-80 days and crop last for about 9-10 months. The fruits contain 13.02 mg /100 g fresh weight-carotene, 18.3 mg/100 g fresh weight ascorbic acid, 0.33% acidity and TSS 9.0 ^{0}brix.

Pusa Golden Cherry Tomato No. 2 (Cherry No. 214)

4.4.4.3 Pakchoi: Pusa Pakchoi-1

This is first indigenous Pakchoi variety developed for cultivation in North Indian Plains. It gets ready for harvest in 45-50 days after transplanting. It has

Pusa Pakchoi-1

attractive light green color. Average Pakchoi weight is 500-650 g and yields around 50-55 t/ha. Terrace gardeners will be benefited with this variety because of its yielding ability and seed production can also be done under the North Indian plains.

4.4.5 Evaluation and demonstration of PakChoi varieties/ hybrids for precision farming

Evaluation of Pak Choi genotype PakChoi-1 under Manipur and Wellington conditions

Genotype	No. of leaves /plant	Plant height (cm)	Plant fresh weight (g)	Yield/ kg m^2
Pak Choi-1	13-17	29.5	620	5.58
Check var. Choko	14-18	30	670	6.0

4.4.6 Promising capsicum germplasms

A 62 imported capsicum genotypes were grown and characterized for their suitability to protected cultivation system. Of these, 16 advanced genotypes of capsicum were evaluated for various horticultural and yield attributes. No. 32 is one of the promising genotype with red in fruit colour, medium in size (80-90 g), profuse fruiting, average yield (2.75 kg/plant). The No. 30-1 is an another promising genotype with yellow colored fruits, small in size (20-25 g), conical in shape and a yield of 2.15 kg/plant.

4.4.7 Tomato germplasms for protected cultivation

A total of 36 genotypes of tomato were evaluated for various morphological, biochemical and molecular attributes. The promising genotypes are No. 220 (for plant height), No. 305 (more No. of fruits/ cluster), No. 68 (more No. of fruit clusters after internode), 178 (for average fruit weight), No. 68 (for maximum No. of locules), Nos. 271, 284, and 189 (for pericarp thickness), Nos. T-42, 115 and 178 (for equatorial dia. of fruit), 178 (for fruit weight uniformity within cluster) and 178 (avg. fruit weight/ plant at each harvest), 305 (for number of fruits/plant), 305 and 220 (for T.S.S.), 191 (for ascorbic acid), 264 (for acidity, total carotenoids & *β-carotene*). Among the 36 genotypes, genotype 169 showed resistant to Mi gene while all were susceptible.

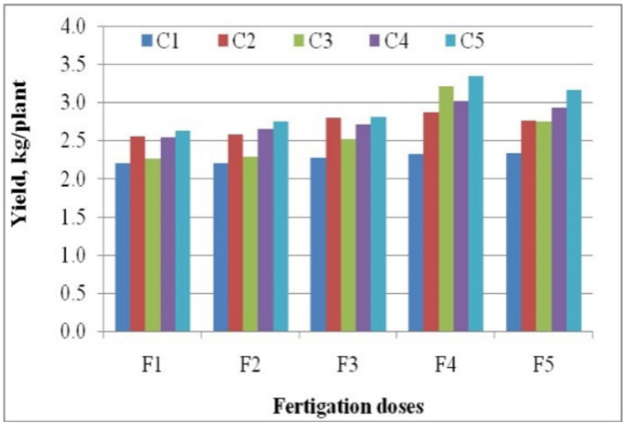
Pusa Pakchoi-1

4.4.8 Evaluation of winged bean accessions as alternate crop

A total of 13 accessions of winged bean along with two check varieties were evaluated. The genotype DWB-5-1 was found promising in yield and other horticultural traits. A white flowered plant was also isolated from the germplasm which is designated as DWBWh-1.

4.4.9 Fertigation schedule for growing off-season cucumber in NV polyhouse

Five cucumber varieties (C_1= Aviva; C_2= Mini Sri Ram; C_3= Terminator; C_4= Sania and C_5 = Oscar) along with five doses of fertilizers (F_1=100:75:125; F_2= 150: 112: 188; F_3= 200: 150: 250; F_4= 250: 188: 312 and F_5= 300: 225: 375 kg/ha) were evaluated. A 25-day-old cucumber nursery was transplanted using crop geometry of 60 cm x 30 cm with drip fertigation in naturally ventilated polyhouse on October 30. Total 8 pickings were done and crop cycle completed on March 28. Maximum



Cucumber varieties evalution with fertilizer doges

yield 3.34 kg/plant, *i.e.* 92.5 t/ha was obtained from the var. Oscar by applying N: P: K: 250: 188: 312 kg/ha.

4.4.10 Pusa tomato vs private tomato varieties under polyhouse

Indeterminate type big tomato var. Pusa Rakshit under optimum NPK dose (45: 22: 49 kg/1000 m^2) was comparable with private varieties Himsona, Himshikhr, NS-4266 and GS-600 under polyhouse condition in terms of fruit yield and income. Yield gap of Pusa Rrakshit was 270 g/m^2 and 340g/m^2 less from Private NS-4266 and GS-600, respectively.

4.4.11 Coloured capsicum with different methods of branch pruning under polyhouse structure

Capsicum var. Swarna (in Yellow group) gave maximum fruit yield and income compared to Red group var. 'Bomby' under Fan-pad polyhouse and found yield difference between yellow v/s red capsicum by about 2 kg/m^2. Canopy management with two branch pruning method exhibited maximum quality yield and income as compared to signal, triple and four branch pruning methods.

4.4.12 Pusa bitter gourd gave higher yield under protected cultivation

The variety Pusa Rasdar gave maximum marketable yield and profit during September, October, and January month planting under Polyhouse and Net house condition as compared to S-57, and S-32 new lines of Pusa bittergourd. However, private bittergourd var. Unnat CT-208, Prachi, and Altaf-Raja exhibited low yield and profit compared to Pusa Rasdar and new lines. Polyhouse Vs IP-net house both are the best structures for bittergourd production. However, September and January planting were found beneficial in the net house and October planting in polyhouse structure.

4.4.13 Pusa cucumber superior to private cucumber varieties

Maximum fruits yield was recorded from the new 7 lines of Pusa cucumbers. Pusa cucumber line DPACH-7 and DPACH-4 exhibited more yield than private variety Hilton and Infinity. The yield gap was 300 g/m^2 between Pusa line DPACH-7 and private var. Hilton, and 400 g/ m^2 between Pusa cumber line DPACH-4 and private var. Infinity. Maximum yield was found in September and January planting in polyhouse as compared net house.

4.4.14 Pusa musk melon superior to private muskmelon

Experiments were conducted during August 2020 to March 2021 at CPCT farm under IP-net-house conditions for off-season production. Maximum fruits yield and income were recorded from PusaSunaheri followed by MM-228 line Pusa Sarda variety as compared to private muskmelon var. Toko-10 under IP-net-house structure.

4.4.15 Plastic low-tunnels technology for summer squash varieties during winter season

Experiments were conducted during August 2020 to March 2021 under low-tunnel conditions for off and early season squash production. After and before transplanting, with recommended package of practices for realizing full yield potential. Long fruited var. Pusa Alankar was exhibited maximum yield and income than Australian Green and Pusa Pasand varieties during early season under poly-low-tunnel technology in an open field conditions.

4.4.16 Brassinosteroid and GA_3 can enhance yield of chrysanthemum under greenhouse

Application of 2 ppm of brassinosteroid + 100 ppm of GA_3 application resulted in early (56 days) harvest (by 12 days) compared to without hormonal sprays. However, no difference in plant height was observed. The plants of cv. Autumn White sprayed with GA_3 alone at 100 ppm could yield maimum flowers/plant (67) followed by 2 ppm brassinosteroid + 100 ppm GA_3 (61) than that of without PGR spray (27).

4.4.17 Performance of chrysanthemum varieties under the artificial light

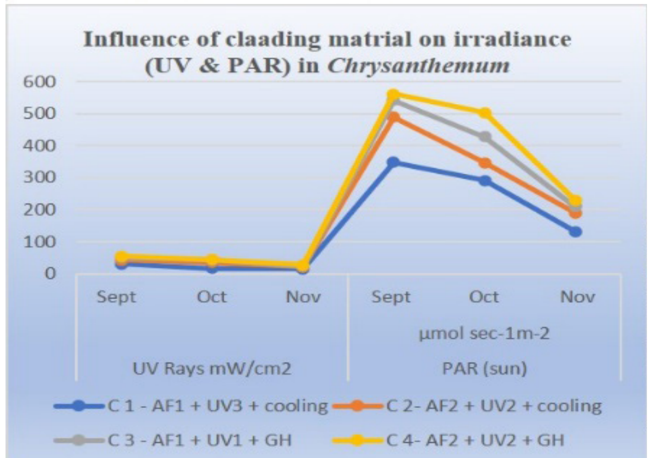
Two single flowering (pompon /star) (White Bridge and Yellow Stone) and two spray varieties

(Diana Orange and Autumn White) were evaluated under an artificial long day length (4^{th} supplementary, photoperiodic lighting) provided with 130 ± 5µ mol $m^{-2}sec^{-1}$ for 12 days. It was found that Diana Orange could be harvested at the earliest (78 days) followed by White Bridge (86 days), Yellow Stone (90 days) and Autumn White (93 days) to produce grade-A flower stems (> 80 cm). However, the plant beds raised with no photoperiods control could produce only grade-C stems (< 55 cm).

4.4.18 Cladding material for growing cucumber, capsicum and tomato under naturally ventilated low-cost structures

Five varieties of *Chrysanthemum* namely Autumn White, Diana Orange, White Bridge, Yellow Stone and Zembla were grown under four different low-cost polyhouse designs with anti-thermal cladding material (Table). It revealed that the structure 4 (C4-AF2 + GH) was highly suitable for chrysanthemum, as it allowed more irradiance during the vegetative growth stage compared with the structures 1 and 2 (having cooling effect againt UV rays). The strucures 3 and 4 have been found effecient during summer-winter months providing maximum PAR infiltration resulting in higher vegetative growth.

Polyhouse structure 4, C4 : AF2+UV2+GH



4.4.19 Integrated nematode management in greenhouse tomato

Management of root knot nematode and soil substrate input use efficiency was studied in greenhouse tomato cv NS-4622 (last year GS-600) using

Cladding material response on solar radiation components

Structure No.	Structures and type of cladding material	UV rays (mW/cm^2)			PAR (sun) µmol m^{-2} sec^{-1}		
		Sept	Oct	Nov	Sept	Oct	Nov
1	C 1 - AF1 + UV3 + cooling	29.5	16.5	14.7	348	291	131
2	C 2- AF2 + UV2 + cooling	42.6	35.2	21.1	489	346	190
3	C 3 - AF1 + UV1 + GH	49.8	42.6	23.2	541	428	210
4	C 4- AF2 + UV2 + GH	54.6	43.5	27.0	561	502	230

fortified organic inputs such as farm yard manure and vermi-compost in combination with bioagents *viz.*, *Purpureocilium lilacinum* ($2x10^6$), *Pseudomonas fluorescens* ($2x10^{11}$ – commercial strain) and *Trichoderma harzianum* ($2x10^7$ commercial strain). Gall index (GI) of tomato was reduced to 2.3 in treated plots compared to 4.0 in untreated plots on a scale of 0–5. Two nematicides, *viz.*, fluopyram (1.2 ml/m^2) and fluensulfon (1.2 g/m^2) decreased root-gall indice to 2.3 and 2.7, respectively. *P. lilacinum* resulted in better control (GI 2.3) than *P. fluorescens* and *T. harzianum* (GI of 2.7).

4.5 AGRICULTURAL ENGINEERING

4.5.1 Upscaled pusa farm Sunfridge

Three units of Pusa-Farm SunFridge (Pusa-FSF) – an off-grid, batteryless stand-alone green-energy (solar-refrigerated) cold storewere established one each in villages of Picholiya Ajmer (Rajasthan), Chamrara (Haryana) and Palla (Delhi). In addition, one unit was established at Mela ground IARI for the purpose of demonstration to farmers, government officials, policy makers and different visitors to IARI. The unit was inaugurated by Sh. Narendra Singh Tomar (Union Minister of Agriculture and Farmers Welfare, Government of India and Sh. Kailash Chaudhary (Minister of State for Agriculture and Farmers Welfare) on February 25, 2021 during Pusa *Krishi Vigyan Mela* – 2021. The FSF is of size 3 x 3 x 3 m, uses 12 solar panels (425 W each), in the series-parallel circuit, to power 1.5 tons refrigeration capacity. Pusa-FSF can achieve daytime temperatures as low as ~4-6°C and night time

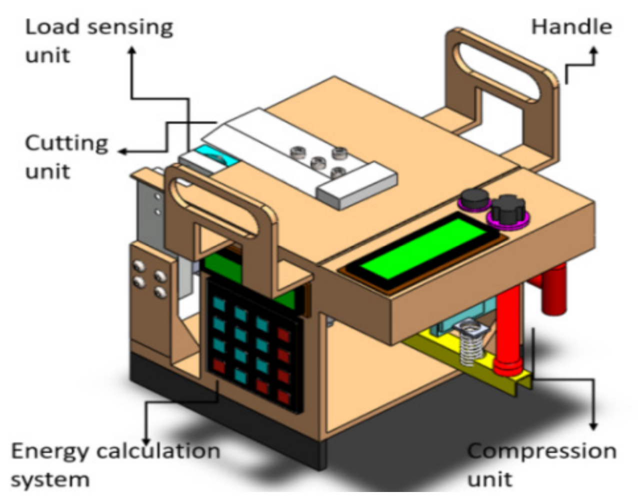
Inside view of Pusa-Farm SunFridge

temperatures ~10°C, when the daily ambient maximum temperature reaches approximately 35-45°C. The vegetables stored in Pusa FST stayed fresh and marketable after 10 days of storage with physiological loss in weight < 10%.

Inauguration of Pusa-Farm SunFridge

4.5.2 Smart device for on-field crop cutting energy measurement

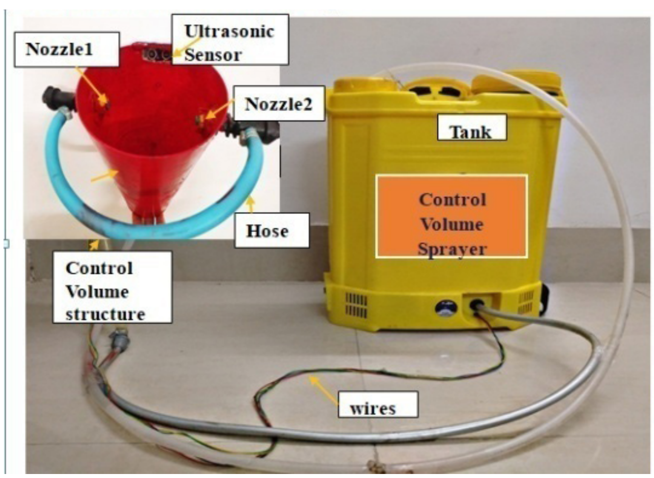
Studied the physical (internode length, stem diameter and stem wall thickness), engineering properties (shear force, shear energy and shear strength), anatomical properties (cellular components) and chemical composition (cellulose, hemicellulose and lignin) of prominent Indian rice cultivars (PB-1509, PB-44, Jaya, PB-1121, Swarna and BPT-5204). Based on optimum design values, a protype device was developed for crop cutting energy measurement



On-field crop cutting energy measuement device at field level. The developed smart device consisted of different functional units like compression system, crop holding system, crop cutting system and sensor system for measurement of force, speed and height of cut. Speed measurement and force measurement with less error was achieved with an incremental rotary encoder and 5 kg force sensor. Ultrasonic and Gyroscope sensor MPU 6050 for distance and angle measurement performed better with low drift in output values. The developed device could measure the cutting force, cutting speed, cutting stem height and cutting angle under field conditions with accuracy of 98.88, 97.6, 97.5 and 94.29 %, respectively.

4.5.3 Sensor-based control volume sprayer for grape

The grape bunch/ detection unit, two different types of sensors *i.e.*, ultrasonic sensor (HC SR-04) and infrared proximity sensor (B0115NCT4U) were evaluated for their performance using a customized experimental set-up. The data on physical properties of grape bunch revealed that the maximum bunch length was 24.00±0.91 cm and maximum bunch width was 18.80±0.15 cm. Hence, control volume unit of length 25 cm and width 20 cm was fabricated using 3D printing system. Three different growth regulator application methods revealed that, with the use developed sensor-based control volume sprayer there can be 30% saving in chemical use and 35.48% saving in operational time compared to conventional dipping method.



Sensor-based Sprayer

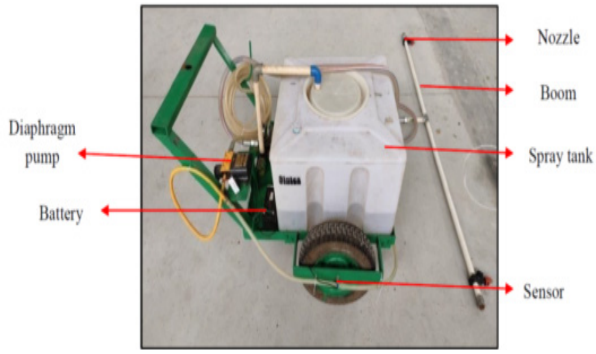
4.5.4 Two-wheel battery-assisted (electric) power unit

A two-wheel electric power unit was developed to increase the operator's working efficiency in weeding-cum intercultural operations in wide-row (≥40 cm) sown crops. The effective field capacity of the two-wheel electric power unit for weeding-cum-intercultural operation in pigeon pea, chrysanthemum, and marigold was 0.039, 0.0251, and 0.0293 ha/h at an operational speed of 1.6, 1.5, and 1.5 km/h, respectively. The energy consumption with this power unit was 8-9 MJ/ha for weeding-cum-intercultural operations. A fully charged pack of batteries was suitable for 0.23-0.25 ha with a cost of operation per ha was ₹ 1280-1330/-.

Battery-assisted power unit

4.5.5 Sensor-based spraying system for microbial inoculum

A sensor-based spraying system was evaluated in terms of application rate at recommended combine harvester speeds. The accuracy in the change of



Sensor-based spraying for microbial inoculum

application rate for change in combine harvester speed was observed in the range of 87.9 to 99.5%. The average response time of the developed sensor-based spraying system was 3.25 s.

4.5.6 Customized aqueous fertilizer metering system for aqua ferti seed drill (AFSD)

A centralized stainless steel tank of capacity 127 l was used for metering purpose, which takes aqueous fertilizer from two PVC storage tanks of capacity 225 litres. Two pipes were connected at the bottom of the centralized tank in which nine nozzles were fitted to deliver aqueous fertilizer to the furrow openers. Two valves were for controlling the discharge rate. The discharge rate was uniform for the 90º valve opening.

Aqua ferti seed drill

4.5.7 Semi-automatic pineapple harvester

A battery-powered, manually operated harvester consisting of a grabbing unit, cutting unit, handle, and linear actuator. The cutting unit consisted of a circular

Semi-automatic pineapple harvester

cutting blade, DC motor, connector, and battery (12 V, 7 Ah). The power source also operated the scissor mechanism of the grabbing unit with a linear actuator with a loading rate of 7 mm/s. The harvesting time for semi-automatic pineapple harvester was 3-10 s with a mean value of 5.85 s for the Queen cultivar and 5-15 s with a mean value of 10.1 s for the Kew cultivar.

4.5.8 Tractor operated microbial inoculum sprayer

Two microbial inoculum delivery systems, *i.e.*, a hand-operated spray gun and a rear-mounted spraying system. The major components of the spraying system are a storage tank of capacity 300 L, piston pump of 36 Lpm and a flat fan type nozzle with spray width of 3.0 m operated by the PTO of the tractor. The effect of spray deposition on rice residue decomposition by flat fan type nozzle was determined through simulation in the laboratory for selected operational parameters (pressure and speed). The field capacity of the spraying system was 0.52 ha/h with a discharge rate of 1072 L/ha.

Tractor operated sprayer

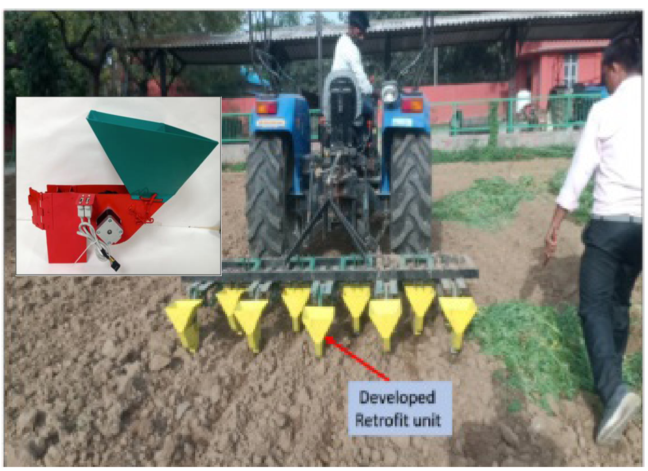
4.5.9 Braking system for fodder cutter machine

A disc brake was integrated with the fodder cutter machine axle of manual chaff cutter. The disc brake was fixed firmly on the extended length of the axle. The brake connected with wire actuated with a foot pedal placed at 330 mm height and could be easily applied with a leg force.

Fodder cutter machine

4.5.10 Electronic seed metering mechanism (ESMM) retrofitting module

The developed ESMM is a low-cost retrofit integrated with the most commonly available secondary tillage tool (cultivator). It will cater to the needs of multi-crop precision planting machines. It can be installed and removed very easily with a developed retrofit mechanism.



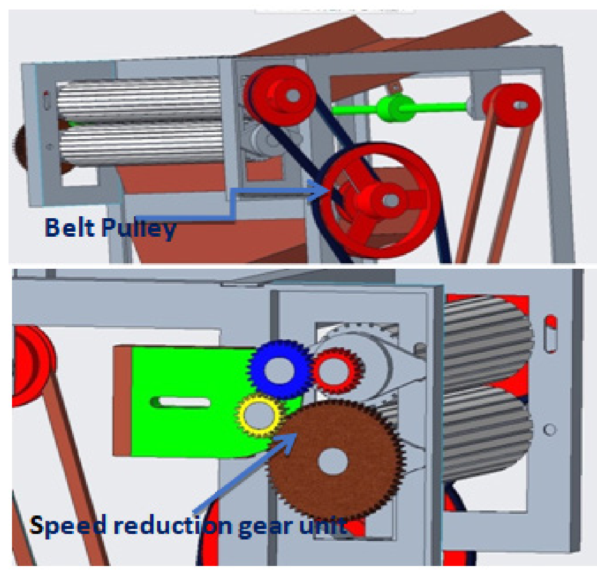
Cultivator with retrofit mechanism

4.5.11 Tractor-trailer vibration studied for health limit

The measurement of vibration on the tractor's seat in the tractor-trailer system gave a maximum value of a_v as 1.11 m/s^2 for a farm road with loaded trailer at the speed of 7 km/h. The upper and lower health limit of 4.85 and 1.21 h, respectively, whereas the minimum value of acceleration was observed as 0.63 m/s^2 at 10 km/h speed on asphalt road with empty trailer with upper and lower health limits of 14.99 and 3.75 h respectively.

4.5.12 Green pea sheller

The developed green pea sheller consists of two nylon rollers (diameter 75 mm, length 450 mm), one AC motor (0.5 hp, 1400 rpm, phase 1, 220 V), and a power transmission system. The shear forces separated green peas between the lower and upper nylon rollers. Speed of AC motor was reduced from 1400 to 270 rpm through belt pulley and gear reduction arrangement. The speed of the upper roller was 270 and 78 rpm for the lower roller. The speed of camshaft of the feeding tray was 1212 rpm. Green pea pods slide/moved on the feeding tray and reached the rollers. Slots were provided in the tray to align the green pea pods in a lateral direction. The separation efficiency of prototype green Pea Sheller observed was 83.6%.



Green pea sheller

4.5.13 Solar-powered air-inflated grain dryer

The developed dryer was found to have a significant difference in temperature of the drying air (P <0.0001) and drying rate (P=0.0019) compared to sun drying. The time required for drying paddy up to milling moisture content of 14% in the developed dryer ranged from 7.5-9 and 11-12.8 h in sun-drying respectively. The developed solar-powered air-inflated dryer provides a promising alternative for on-farm drying of grains because of its low construction cost, easy operation, green energy utilization and portability.

4.5.14 Single/double glasses cover performance in hybrid solar dryer

During experimental testing, the difference between the ambient temperature and the temperature inside the dryer was 15.1 and 18°C for the use of single and double glass covers, respectively. The heat loss by conduction through the glass cover was reduced using a double glass cover. The collector efficiency for single glass cover was found to be 28.56% and for double glass cover was 33.35%. It was observed that the use of a double glass cover reduced the drying time also.

4.5.15 Low-cost storage structure for rural areas

Outdoor metal (single and double layer) and plastic storage structures of 500 kg capacity was installed. Mean temperature and humidity differences of about 9°C and 38% were observed among tested structures. Grain moisture was observed to increase from 10.35 to 13.68% (single wall silo; SWS), 12.91% (triple-wall silo; TPS), and 12.06 (double-wall silo; DWS). About 8% damage in terms of broken was observed in SWS. A significant drop in germination percentage was noticed in SWS (24.83%) compared to initial germination (84%). At the end of the 8^{th} month, wheat stored in DWS had a germination ability of 59.09%. Kernel hardness decreased from 146.9 to 98.7, 104.53, and 114.4 N in SWS, TPS, and DWS, respectively. These results demonstrate that the use of double-wall insulated storage has resulted in a safe and sustainable storage method with advantages over the continuous fluctuation of seasonal temperature in long-term grain storage.

Single wall Double wall insulated Triple-layer plastic structure

Storage structure

4.5.16 Portable hybrid dryer

The dimension of the dryer is 1500 x 460 x 600 mm and weight 22 kg. It is a battery-operated dryer and portable. Operated by 12V battery, the dryer is fitted with a 12 W DC motor-driven blower (203 x 77 mm) for air circulation and a steam-to-air heat exchanger for air heating. It has 12 perforated drying trays (400 x 400 x 30 mm) arranged vertically with a tray to tray spacing of 60 mm. Preliminary temperature profiling of the dryer showed that, on a low solar intensity partly cloudy day, the temperature difference of about 10°C was observed between the outside and inside of the dryer within 30 min. of operation. However, inside temperature of about 60-65°C can be maintained using a steam-to-air heat exchanger when the dryer is connected to biomass-fired boiler.

Portable dryer

4.5.17 Infrared dryer for apple slices

Influence of IR wattage (450-650 W) on drying and colour kinetics of pretreated (KMS 1500 ppm) apple slices (2-3 mm thick) were studied in comparison with conventional hot air drying. At identical temperatures, IR drying showed a higher rate of drying and the overall process takes nearly 45% less time as compared to hot air drying. Colour parameters, *L** and b* values increased with drying time for both the drying methods while *a** values reduced. The IR dried samples had lower changes in ΔE and BI values compared with hot air drying. Apple slices dried using IR dryer at 550W had better colour and texture besides the higher rate of drying in comparison to conventional hot-air drying.

4.6 FOOD SCIENCE AND POSTHARVEST TECHNOLOGY

4.6.1 Pre-storage calcium lactate (CL) treatment can maintain quality and extend storage life of bitter gourd fruit

Immature fruit were dipped in the aqueous solution of CL (50, 75, and 100 mM) and stored at 10°C and 85-95% relative humidity (RH). The results showed that physiological loss in weight (PLW) and decay incidence were minimized for fruits treated in CL at 100 mM. Furthermore, their firmness, total phenolics, antioxidants and total chlorophyll retained at higher side. Shelf life also increased to 20 days compared to untreated fruit (15 days).

Appearance of whole and longitudinally cut section of (a) control, (b) CL 50mM, (c) CL 75 mM and (d) CL 100 mM treated bitter gourd fruit on 20th day of storage at 10°C (85-95% RH)

4.6.2 Ready-to-use mix of fresh-cut cauliflower and beans

Application of ascorbic acid at 1% could effectively inhibit the extent of browning in the fresh-cut beans and cauliflower mix. The minimally processed cauliflower and beans mix retained colour and overall acceptability upto six days under low temperature. The product was microbiologically safe under shrink wrap conditions.

Ascorbic acid treatec vegetables

4.6.3 Ultrasound assisted extraction of phenolics from potato peels

Microwave drying proved to be the best drying procedure for maximum retention of phenolics in dried product. Response surface methodology (RSM) was used as an optimization tool to achieve maximum yield of phenolics by ultasonication. Ultrasound extraction for 22 min in absolute ethanol gave maximum yield of phenolics. The extract can be commercially exploited for the development of functional foods, supplements, and natural preservatives.

4.6.4 Protein and flavonoid rich baked products

Soy okara from soymilk industry and citrus peel from citrus juice industry were utilized to develop protein and flavonoids rich functional muffins. Citrus peel was candied peel and incorporated in the muffins to improve the flavonoid content. Okara addition

Protein and flavonoid rich baked products

resulted in ~22% increase in protein and ~45% increase in dietary fiber content of the muffins. Approximately, 146% increase in flavonoids and 68.83% increase in phenolic content established functional potential of the developed muffins. Moreover, the naturally coloured candied peel can serve as an alternate to the synthetically coloured tutti fruitti.

4.6.5 Development, packaging and storage of tomato powder

The tomato powder could be stored upto 4 months at room temperature (15-33.5^{o}C) and six months at low temperature (7^{0}C) for better retention of lycopene, rehydration ratio, sensory score and less non-enzymatic browning after packing in 200 g HDPE or 400 g LDPE pouches.

Tomato powder

4.6.6 Dehydration process for coloured capsicum

Steam blanched samples retained more amount of total antioxidants (96.49 mM Trolox), ascorbic acid (56.34 mg/100 g) and total phenol (73.42 mg GAE/g), respectively. HDPE packaging retained better functional qualities than LDPE in terms of moisture

content (6.13%), ascorbic acid (52.10 mg/100g), total carotenes (4.88 mg/100 g) total phenols (64.78 mg GAE/100 g), and rehydration ratio (5.58) during 4 month storage period.

4.6.7 Food additives for stability of beetroot betalains

A lower concentration of salt (<3.0%) was the best to impart stability of betalains pigments and antioxidant activity in beetroot extract. Almost in all incubations, betalains and colour degradation followed a similar trend, however, antioxidant activity was not related with betalains content.

4.6.8 Use of canola oleogel for saturated fat replacement in cookies

Canola oil oleogel was prepared using ethyl cellulose at 4 to 10% level. The prepared oleogel were used to replace 20, 40 and 60% of hydrogenated fat for preparing cookies. These cookies were compared with the ones prepared with commercial shortening and hydrogenated fat for textural attributes and physical parameters. Oleogel was used to replace 40% hydrogenated fat in cookies preparation, the visual, textural and sensory attributes of cookies were found statistically similar to those prepared from commercial shortening.

Ethyl cellulose oleogel and cookies prepared with substitution of hydrogenated fat by oleogel

4.6.9 Pea pod powder can enhance shelf-life of buckwheat bread

Mixing of pea pod powder (PPP) made up for the hardness of dough which increased by 0.64,1.42 and 1.88 times at 10, 15 and 20% levels, respectively, thus

Bread slices with pea pod powder

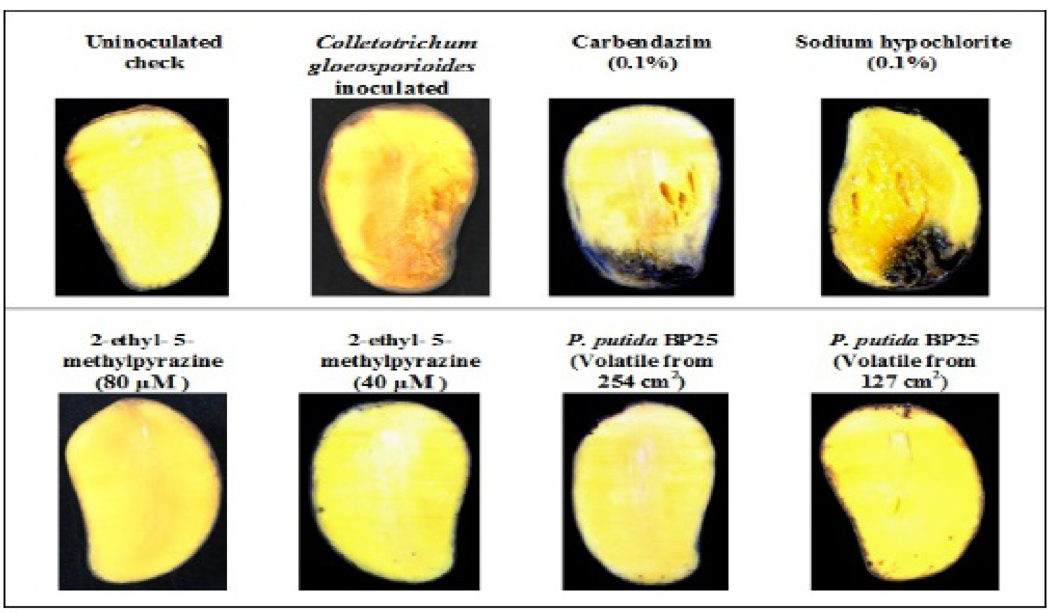
attaining values close to refined flour dough hardness at intermediate levels between 10 and 15% PPP. Similarly, adhesiveness, gumminess, chewiness and resilience attributes of the dough were brought closer to that of refined flour dough upon incorporation of PPP at levels between 10 and 15%. 15% PPP bread was rated best in terms of appearance and overall acceptability.

4.6.10 *Pseudomonas* as post-harvest fumigant for mango anthracnose

Significant reduction of anthracnose severity on mangoes by native *Pseudomonas putida* BP25 volatiles was achieved. The anthracnose reduction/ suppression (98.3%) was pronounced when the fruit was fumigated using the synthetic 2-ethyl-5-methylpyrazine and 2, 5-dimethyl pyrazine, the prime chemical ingredients of *Pseudomonas putida* BP25 volatilome.

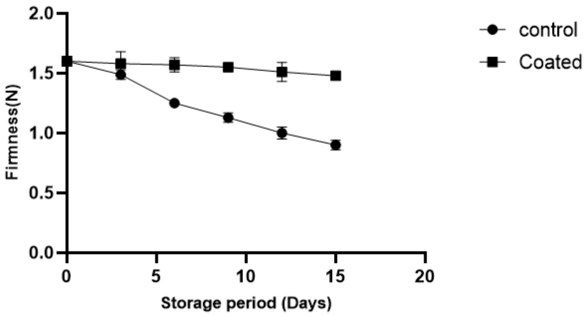
4.6.11 Development of functionalized edible coating for enhancement of strawberry shelf-life

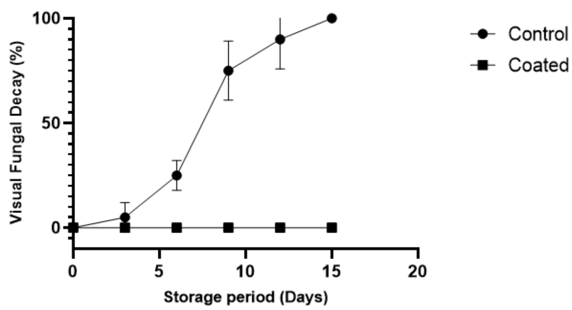
Strawberry fruit has very short shelf life (~3-4 days) and subjected to post-harvest losses due to moisture loss and fungal infestation with *Botrytis cinerea* and *Rhizophus stolanifer*. In order to enhance the shelf life of strawberries an edible coating formulation was prepared using a combination of carnuba and shellac wax. The edible coating matrix was functionalized



The effect of native and synthetic (2-ethyl-5-methylpyrazine) volatile organic compounds of *Pseudomons putida* **BP25 on the expression of postharvest anthracnose in pulp of mango cv. Amrapali**

using encapsulated clove bud oil with jackfruit seed starch to inhibit postharvest fungal infestation. Efficacy of the developed coating matrix was evaluated during storage of strawberry at a temperature of 5°C and 90% RH. Thoroughly washed and uncoated fruits were taken as control. The control fruits were infested with fungus within 5 days of storage period compared to 15 days in case of coated strawberries.



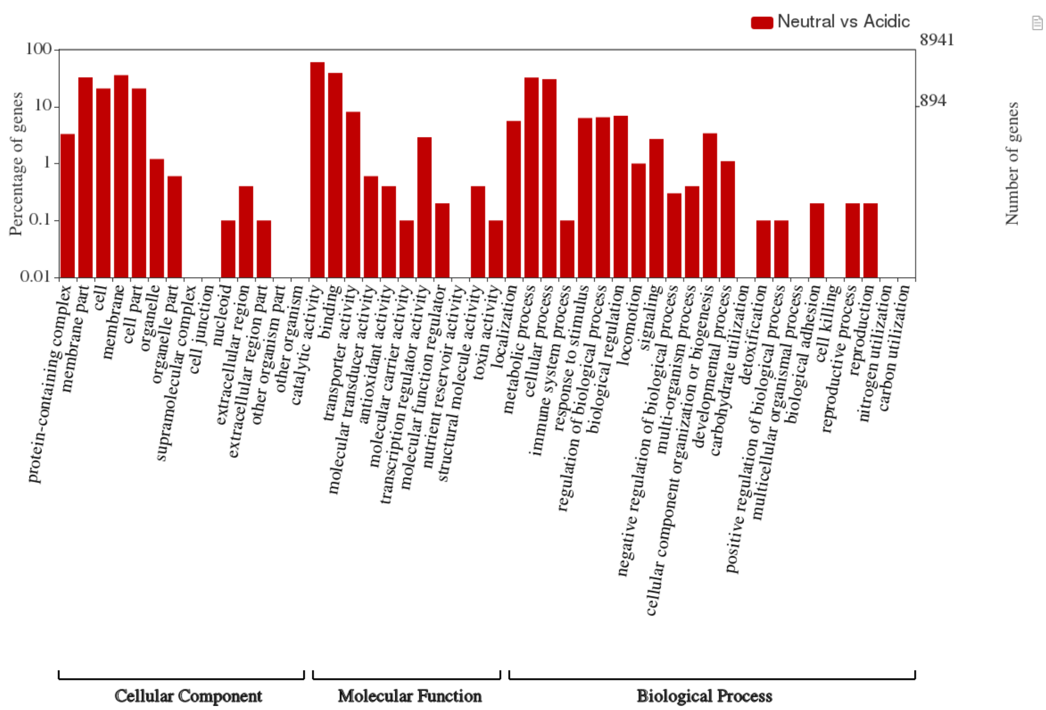


4.7 MICROBIOLOGY

4.7.1 Restoration and improvement of soil health

4.7.1.1 Metatranscriptomics analysis of rice rhizosphere

The analysis of differentially expressed genes demonstrated high expression of transcripts related to membrane, catalytic activity, binding, metabolic- and cellular processes in neutral (alluvial, ICAR-IARI)-compared to acidic soil (acidic, Kuttanad, Kerala). Several transcripts related to regulation of biological processes, locomotion and signaling were highly expressed in neutral rice rhizosphere.



Transcripts (either as percentage of genes or number of genes) which were up-regulated in the rhizosphere of rice planted to neutral-, compared to those of acidic soil. The rhizosphere soils were sampled from rice plants grown after 30 days in pots at the National Phytotron Facility, ICAR-IARI, New Delhi

4.7.1.2 Microbe-mediated nutrient cycling under aerobic and anaerobic conditions

Compared to the gene copies of *Alphaproteo* bacteria, the gene copies of 16S rRNA *Betaproteo* bacteria were higher in the ranges of 10^7 to 10^9 g^{-1} soil. The order of their abundances was Kuttanad> IARI ≥ Karnal > Rajasthan >Umiam >Aduthurai (LSD of 5.3 × 10^4; *p=0.05*) under flooded conditions. The gene copies of 16S rRNA of *Geobacter,* involved in the iron reduction processes, quantified in different soil types (both under the flooded and non-flooded conditions) were more in the soils of Karnal, Rajasthan, and IARI under both flooded and non-flooded conditions with highest abundance of these gene copies (1.4 × 10^6 g^{-1} soil) was in the soil sampled from the rice fields of Karnal under flooded condition. Abundances of *narG*, *nirS* and *nirK* which encode the key enzymes of denitrification (nitrate reductase, and two different nitrite reductases *nirS* and *nirK*, respectively), were found to be more in soils under non-flooded than under flooded conditions. The soils under non-flooded condition and flooded condition recorded about 10^8 to 10^9 and10^6 to 10^8 gene copies of *nirK* g^{-1} soil respectively. The abundances of *nirK* under non-flooded condition followed the order: Rajasthan (RAJ) > Karnal (KAR) > IARI >Umiam (UMI) >Kuttanad (KUT) >Aduthurai (ADU).

4.7.1.3 Priming nursery soil-less media with cyanobacteria to enhance plant growth and productivity

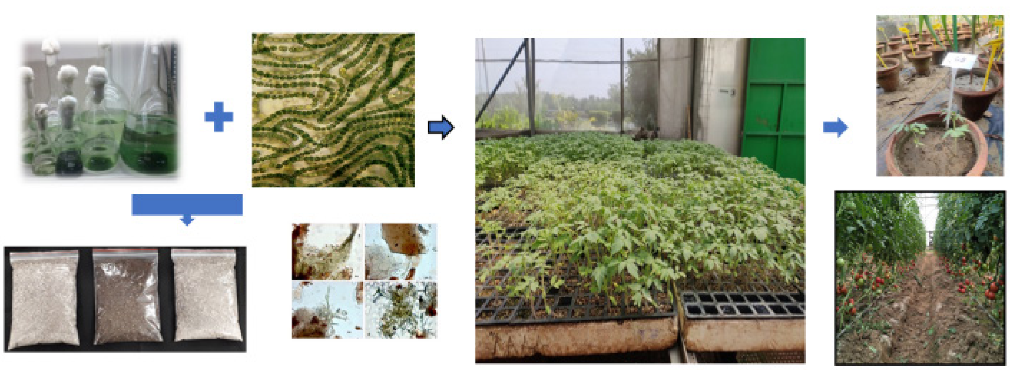
Beneficial cyanobacterial cultures such as *Anabaena laxa*, *Calothrix elenkinii*, and biofilm-*Anabaena torulosa-Trichoderma viride* (An-Tr), when augmented with different soil-less media combinations involving perlite, cocopeat and vermiculite (P, C, V) in different combinations, using Protrays revealed significant differences in terms of plant and media parameters of tomato from seed to fruiting stage. The performance of PM (Potting mix; C: V: P, 3: 1: 1) + *A. laxa*in terms of leaf, soil and nutrient data suggested its superiority among all other treatments with an enhancement of 14.7 and 36.6% in fruit and flower count over control.

4.7.1.4 Chemical and bio-inoculants enhance diversity of soil microbial groups in soybean-wheat cropping system

Paenibacillus polymyxa (HKA-15) and *Bacillus* sp. (W1-2) inoculation significantly increased biomass based on the PLFA (phospholipid fatty acids) profile of rhizosphere soil samples collected at vegetative (35 DAS) and flowering stage (65 DAS). Increased level of branched fatty acids (FA) types was observed at 35 DAS and 65 DAS, except the AMF mix inoculation treatment with more straight FA types at 35 DAS and the *Burkholderia arboris* treatment with MUFA (monounsaturated fatty acids) types at 65 DAS. Overall G+ve groups were more prevalent at both stages.

4.7.1.5 Bio-inoculants treatments increased PLFA profile of wheat soil

Increase in biomass was noticed with *Bacillus* sp. (W1-2) and *Pseudomonas* sp. (PSD) inoculation followed by *Bacillus* sp. and *Rhizobium* sp. (CP-11) at 75 DAS based on the PLFA profile of rhizosphere soil samples collected at anthesis (50 DAS) and milking stage (75 DAS). There was a slight increase in the level of



Sequence of activities undertaken, from preparation of formulations and their evaluation in Protrays, pot and field experiments

branched FA types in all inoculated treatments at both stages, except uninoculated control treatment with less straight FA types and higher branched FA at 75 DAS, and the RDF with 250 g N/12 m^2 plot with an increase in straight and PUFA at 75 DAS. Over all G+ve groups were observed higher at 50 DAS and 75 DAS, and G-ve increased at 75DAS. The RDF with 250g N/12 m^2 plot increased fungi with low G+ve and G-ve bacteria.

4.7.1.6 Arbuscular mycorrhiza (AM) fungal infection in wheat and chickpea varieties

In chickpea, percent root colonisation and spores count were found maximum with inoculation of *Bacillus* sp. (Wi-2) followed by *Bacillus* sp. (Wi-9) and *Paenibacillus polymyxa* (HKA15), which emphasised that these organisms support the improved AMF colonisation. In wheat, HD-2932 established to be a better host for AMF with high spore count (54 spores/g soil) and percent colonization (68.2%) in comparison to HD 2967 (39 spores/g soil and 50.3%) and HD-2851 (29 spores / g soil and 41.9%). Glomalin content was maximum when treated with *Bacillus sp*(Wi-2) but did not vary among the wheat varieties. Higher root colonisation in chickpea varieties (67 to 77%) in comparison to wheat (45.4 to 52.1%) indicates that chickpea is the better host for AMF colonisation than wheat.

4.7.2 Microbe mediated water stress alleviation in crops

4.7.2.1 Prospecting wheat microbiome for heat stress tolerance

Wheat seeds, plant tissue (leaves, roots, spikes) at two growth stages (flowering and milking) and rhizosphere soil from one heat susceptible (GW 322) and two heat tolerant wheat (HD 3271 & HD 3298) were investigated for microbiome analysis. A total of 56 isolates were obtained from seeds, 144 and 173 isolates from leaf, spike, root and rhizospheric soil at flowering and milking stages, respectively. These also included 23 actinobacteria isolated from three varieties. A82 isolates were found to be thermotolerant growing at 60°C and 47 isolates were showing maximum number of qualitative characteristics for plant growth promoting traits such as P, K and Zn solubilisation, IAA and siderophore production. The metagenomic analysis revealed the dominant phyla from families *Alcaligenaceae, Bacillaceae, Bradyrhizobiacea, Burkholderiacea, Lactobacillaceae, Pseudomonadaceae* and others.

4.7.2.2 Exploring wheat seed vectored endophytic actinobacteria for PGP traits and biocontrol of major fungal pathogens

Among 44 endophytic actinobacterial strains isolated from seeds of six different wheat genotypes collected from five major agro-ecological zones representing three species of wheat *T. aestivum*, T. dicoccum and *T. durum*, 90.9% isolates were positive for nitrogen fixation (n = 40), 77.3, 36.4, 20.5 and 9.1% produced ammonia (n = 34), IAA (n = 16), siderophore (n = 09) and HCN (n = 04), respectively, while 9.1% isolates solubilised phosphate (n = 09). In case of production of hydrolytic enzymes, 93.2% isolates produced amylase (n = 41), 61.39 and 49.8% produced cellulase (n = 27) and proteinase (n = 21) respectively. The IAA production ranged from 8.74-84.43 µg/mg protein/day with maximum in NEPZ-WSA 40 isolate, while phosphate solubilisation was in the range of 3.8-24.1 µg/mg protein/day, with maximum by PZ-WSA 35. Maximum number (n = 30) of isolates displayed antifungal activity against *F. graminarium* (68.2%), followed by 52.3, 43.2 and 40.9% isolates were active against *T. indica* (n = 23), *Alternaria* sp. (n = 19) and *B. sorokiniana* (n = 18) respectively. Fourteen isolates (31.81%) displayed antagonistic activity against all the fungal pathogens and the isolates exhibited 45.2-73.8% of inhibition against *F. graminarium*, while 54.2-72.9%, 42.5-75.0% and 57.7-78.9% of inhibition against *B. sorokiniana*, *T. indica*, and *Alternaria* sp. respectively. On the basis of their PGP traits and bio-control potential, two isolates, namely PZ-WSA 35 and NWPZ-WSA 20, were selected and identified as *Streptomyces rochei* and *S. sampsonii*, respectively based on 16S rDNA gene sequencing. Inoculation of these isolates improved wheat seed germination by 35-43% compared to fungal control where germination was less than 40%.

4.7.2.3 Culturable microbiome profiling of pedigree-hybrid of maize

For studying inheritance pattern of endophytic bacterial species, parental pedigree PML105 (M) x

PML93 (F) and hybrid PJ-HM1, seed and plant parts of maize at flowering stage were taken for isolating predominant bacterial morphotypes. Overall, 36 seed vectored endophytes and 55 from plant parts were purified as predominant morphotypes. Male parent PML105 possessed 14, 11, 3 and 3 in its seed, stalk, root and leaves, respectively. Of 17 plant endophytes, 14 could grow up to 42^0C, 10 at 5%NaCl conc., 15 at pH 5 and 14 at pH 10, 14 at 5% PEG. Among PGP traits, 2 isolates were P solubilizers, 1 was K mobilizer and 7 were producing siderophores for Fe chelation. Similarly female parent PML93 possessed 14, 8, 4, and 4 in its seed, stalk, root and leaves, respectively. Of 16 plant endophytes, 14 could grow up to 42^0C, 7 at 5% NaCl conc., 14 at pH 5.0 and 9.0 at pH 10.0 and 14 at pH 10, 9 at 10% PEG. Among PGP traits, 5 isolates were P solubilizers, 3 were K mobilizer and 6 were producing siderophores for Fe chelation. Likewise, hybrid PJ-HM1 possessed 8, 4, 11, and 7 in its seed, stalk, root and leaves, respectively. Of 22 plant endophytes, 17 could grow up to 42^0C, 13 at 5% NaCl conc., 16 at pH 5.0 and 15 at pH 10.0 and 14 at 10% PEG. Among PGP traits, 2 isolates were P solubilizers, 4 were K mobilizer and 9 were producing siderophores for Fe chelation.

4.7.2.4 Stress tolerant fungal–bacterial formulations for better crop nutrient and moisture availability and soil health

Under optimum irrigation, *Bacillus megaterium* inoculation caused an increase in the plant chlorophyll A and B content by 45.1 and 39.2% respectively. However, the corresponding values in the moisture stress condition were 54.8 and 10.2 % respectively. Positive impact of the bacterial inoculation on the plant hormone IAA content was recorded with an increase of 40.7 and 60.1% under optimum and moisture stressed conditions.

Influence of *Bacillus megaterium* on IAA production in cowpea under moisture stress

Irrigation / bacterial inoculation)	Indole acetic acid (µg/g) in (uninoculated)	Indole acetic acid (µg/g) in inoculated	Per cent change
Optimum irrigation	45.2[b]	63.6[b]	40.7
Moisture stress	53.4[a]	87.6[a]	64.1

4.7.2.5 Microbial mediated biofortification of Zn and Fe in chickpea (*rabi* 2020-21)

The nodule dry weight of chickpea was significantly higher with *Mesorhizobium*+ Zn and Fe solubilizers + RDF + 25 kg $ZnSO_4$ / ha (soil application) in cv. BG 372 (61 mg/plant) treatments. Whereas, *Mesorhizobium* + RDF + 25 Kg $ZnSO_4$ /ha recorded highest nodule dry weight (116.48 mg/plant) of PUSA3022. The chlorophyll content and leghemoglobin content recorded at 50% flowering stage was non-significant however the genotype PUSA 3022 recorded significantly higher value than BG 372.

4.7.3 Agri-residue and biomass management

4.7.3.1 Biomass fractionation and production of value-added products from all components (cellulose, hemicellulose and lignin)

Of the thirteen actinobacterial strains isolated from compost samples after enrichment on rice straw at 40ºC and pH 8, two strains were identified based on their potential to produce lignocellulolytic enzymes *Streptomyces thermoviolaceous* (S1) and *S. thermophilus* (S2). Rice straw was better carbon substrate for production of lignocellulolytic enzymes (CMCase, FPase, β-glucosidase, xylanase, laccase, lignin peroxidase) under submerged fermentation than cellulose. Except β-glucosidase, all enzyme activities were found to be produced at higher level upon prolonged incubation (21 days). Under solid state fermentation, *S. thermophilus* (S2) showed higher lignin degradation and higher enzymatic activities compared to *S. thermoviolaceus* (S1). Structural and compositional analysis using electron microscope, XRD and FTIR also provided the evidence for disintegration of lignin-carbohydrate complex and lignin removal from *Streptomyces* treated rice straw compared to uninoculated rice straw.

4.7.3.2 Pusa decomposer: Design and development of mechanical and biological techniques for *in- situ*/ *ex-situ* biomass degradation

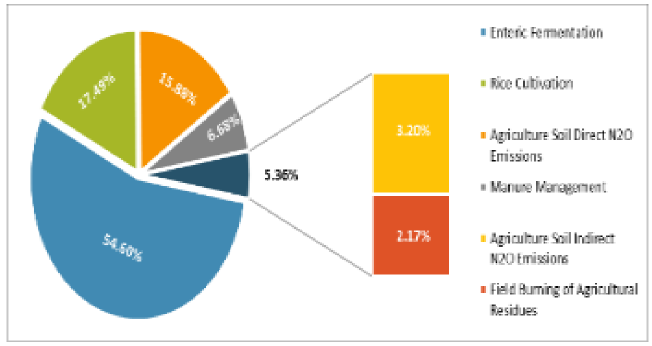
Pusa decomposer trial was initiated at four locations in IARI fields where after harvesting of paddy, Pusa decomposer was sprayed at 10 l/acre and whole straw was incorporated into soil using rotavator and the field was irrigated. Soil samples collected periodically from initial to 25 days showed rapid increase in both fungal and bacterial populations compared to uninoculated control. The initial fungal and bacterial counts were 32.5 x 10^2 cfu/g and 14 x 10^5cfu/g, which increased to 233 x 10^2 cfu/g and 24 x 10^5cfu/g. Soil dehydrogenase activity also increased from 11.3 μgTPF/g to 42.83 μgTPF/g while alkaline phosphatase activity increased from 53.16 to 91.66 μg PNP/g. The microbial biomass carbon showed an increase from 25.66 to 266.29 μg/ g of soil in 25 days.

Pusa decomposer spraying in field

4.8. ENVIRONMENTAL SCIENCE AND CLIMATE RESILIENT AGRICULTURE

4.8.1 Methane and nitrous oxide emission from agriculture sector and crop residue burning

The main sources of CH_4 are enteric fermentation and rice cultivation, whereas the main sources of N_2O emission are agricultural soils in India. Enteric fermentation was the largest source of carbon equivalent emissions followed by 19.07% from agricultural soils (15.88% from direct N_2O and 3.20 per cent from indirect N_2O), 17.49% from rice cultivation in 2016. Emission inventory of GHGs from crop residue burning for the year 2016 was developed. During the year 2016, 112.71 million tonnes of crop residue was burnt on farm leading to the global warming potential of 8834 Gg CO_2 equivalent 79.8% of the total crop biomass burnt was contributed by rice, wheat and sugarcane crops.



Contribution to CH_4 and N_2O emission

4.8.2 Microbial interventions to mitigate methane emission in rice-rice system

Methane utilizing bacteria (MUB) (*Methylobacterium oryzae* MNL7 and *Paenibacillus polymyxa* MaAL 70) applied as seedling root dipped and spayed at maximum tillering stage could reduce methane by 20-31% in two varieties ADT-53 (short duration) and ADT-54 (medium duration) compared to control (100% N). Methane emission was further reduced by 9-15% under the 75% N + MUB treatment compared to 100% N + MUB. MUB was found to have plant growth promoting traits as higher number of tillers were observed in both the microbial treatments. Rice yield was increased under the microbial treatments, but the increase was significant only in ADT-53.

Methane emission (kg/ha) in rice on application of methane utilizing bacteria (MUB)

Variety	Treatment	Methane (g/m^2)	Grain yield (g/m^2)
ADT-53	100% N	9.12a	545a
	100% N + MUB	7.18b	585b
	75% N + MUB	6.08c	572ab
ADT-54	100% N	8.62a	598b
	100% N + MUB	5.93c	605bc
	75% N + MUB	5.37d	610bc

4.8.3 Soil chemical properties and enzymatic activities could influence GHG emission

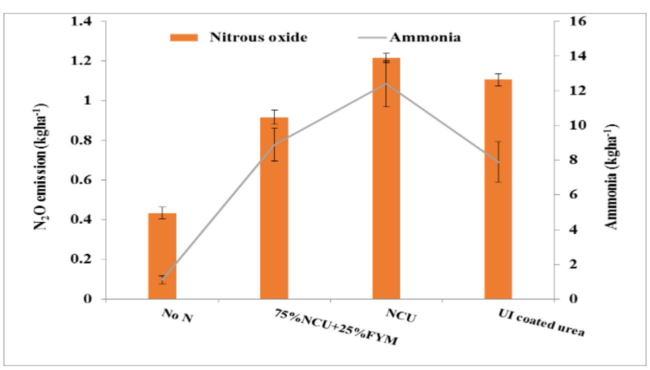
Among physico-chemical parameters of soil, EC and SOC had significant correlation with CO_2 and CH_4 emission, while total N, NO_3^--N, and NH_4^+-N were significantly correlated with N_2O emission. Furthermore, soil enzymes like β-glucosidase and α-glucosidase were positively correlated with CO_2 and CH_4 emission, while phosphatase did not show any correlation with the GHG emission.

4.8.4 PGPR for enhanced nitrogen use efficiency of maize inbred lines: a strategy to reduce GHG emission

Field scale assessment of the inoculation of *Azospirillum* with three other organisms *Pseudomonas fluorescens*, *B. subtilis* and *B. licheniformis* in maize inbred lines resulted in highest increase in grain N uptake (31.57%), nitrogen use efficiency in grain (8.12%), partial factor productivity of fertilizer N (30.12%) and nitrogen uptake efficiency (31.57%) in PML36 compared to other inbred lines of maize. This will help to reduce the N-losses (nitrous oxide and ammonia) from soil.

4.8.5 Urease inhibitors can reduce reactive N fluxes in wheat

Limus was used as urease inhibitor (UI) and treatments were neem-coated urea (NCU), Limus coated NCU, 75% Neem coated urea +25% FYM and control. Application of Limus coated NCU increased yield by 9.5% and decreased nitrous oxide and ammonia emissions by 8.9 and 36%, respectively. By replacing 25% NCU with FYM, the nitrous oxide and ammonia emissions were reduced by 24 and 28% compared to NCU. The peak flux of nitrous oxide flux was delayed by 5-7 days under the UI treatment

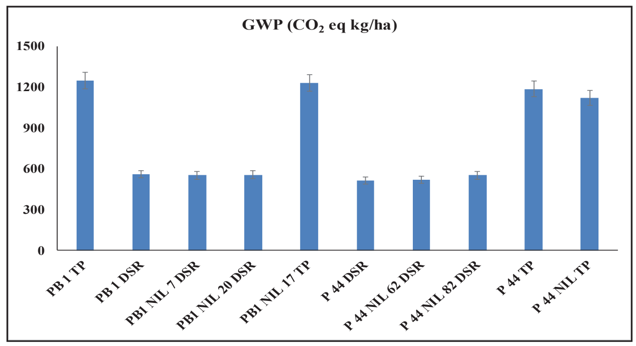


Nitrous oxide and ammonia emissions under different treatments in wheat

compared to NCU alone. Also, significantly higher N uptake was observed in UI treatment.

4.8.6 GHG mitigation potential of new varieties of rice for direct-seeded situation

In DSR, CH_4 emission was reduced by 77.5- 82.4%, but N_2O emission increased by 8.4-22.6%. GWP was reduced by 54.9-58.7% in P44 and 56-57.6% in PB-1. There was ~38-40% water saving in DSR method with new varieties compared to transplanted rice. In Punjab State, 18.87% of the total area under transplanted rice was converted to DSR in 2021. CH_4 emission will be reduced by 5.6 to 30.4%, while N_2O emission will be increased by 1.4 to 8.0% with DSR across the districts. Total GHG mitigation potential was 10.23% in the state with 5.6 lakh ha of area under DSR (18.87% total rice area) with approximately 28-32% water saving.



Global warming potential (GWP) of rice varieties under DSR when compared with transplanted system of rice cultivation

4.8.7 Cotton-wheat system as an alternative system to mitigate GHG emission

The emissions of carbon dioxide and nitrous oxide were measured under different tillage practices with and without residue under two dose of N fertilizer application (75 and 100% N). The CO_2 emission reduced by 13.7% in cotton compared to 7.5% in wheat under ZT compared to CT. Lower CO_2 emissions were observed in all the non-residue retained plots. The GWP of cotton-wheat system was the lowest in the ZT-BB plots and reduced by 7.6% compared to CT. The highest system GWP was observed in the ZTFB + R treatment with 100% N application. It increased by 5.6% compared to CT.

4.8.8 Interactive effect of elevated ozone and carbon dioxide in maize

A field experiment was conducted under the free air O_3 and CO_2 enrichment (FAOCE) growing HQPM-1 and PMH-1 maize cultivars under two levels of CO_2: ambient and elevated (550 ppm) along with ambient and elevated O_3 (70 ppb). Elevated CO_2 significantly increased the leaf area index by 7.7-20.5%, chlorophyll by 7.9-17.6% and photosynthetic rate by 10.5-26.4% in two cultivars across the growing seasons, The grain yield increased significantly (p<0.01) in HQPM-1 and PMH-1 by 16.7 and 13.6%, respectively over the ambient. However, 27 ppm hr^{-1} of O_3 exposure under elevated O_3 treatment led to a significant yield loss (p<0.01) of 9.2% in HQPM-1 and 10.3% in PMH-1. Interaction between elevated CO_2 and O_3 increased grain yield in HQPM-1 by 8% and PMH-1 by 2.7%.

4.8.9 Future climate scenario on soil carbon dynamics

The cumulative C mineralization (Ct) from the surface soil (0-15 cm depth) was 27% higher under elevated CO_2 than ambient condition in 52 days. However, elevated O_3 had similar Ct to ambient condition. Soils under elevated O_3 + elevated CO_2 had 13% more Ct than elevated O_3 only in that layer. Similar trend was obtained in the sub-surface soil layer (15-30 cm depth). Despite Q_{10} values of all plots were similar, both in surface and sub-surface soils, activation energy of surface and subsurface soils under elevated CO_2 was higher than ambient condition. Soils under both elevated O_3 and elevated O_3 + elevated CO_2 also had significantly (P<0.05) less activation energies compared with ambient condition.

4.8.10 Reducing ammonia volatilization using organic and inorganic amendments in wheat

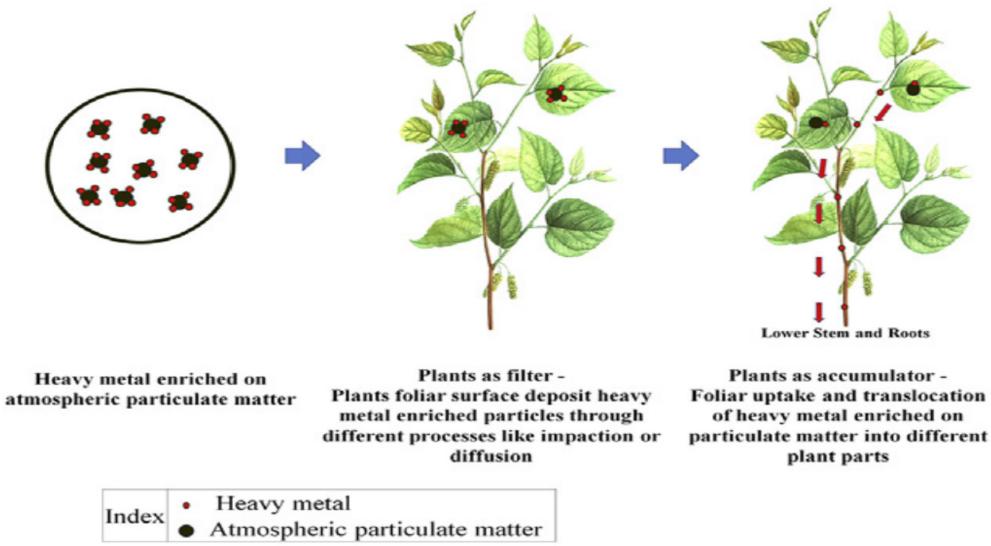
Both organic and inorganic amendments reduced the NH_3 losses and increased soil available nutrients and soil quality. Some of the organic amendment treatments have been found to increase microbial activity. However, in reducing NH_3 volatilization inorganic amendments performed much better than organic amendments but inorganic amendments showed some negative effect on soil microorganism's activity.

4.8.11 Microbes for mitigating N_2O and CH_4 emission in rice field

Azolla (*Azolla microphylla*) alone was found to have significant methane mitigation potential. While the treatment comprising of both N_2O reducing bacterial consortia and Azolla was found to have negative effect on mitigation of both methane and nitrous oxide. The treatment with N_2O reducing bacterial consortia found to reduce N_2O emission significantly.

4.8.12 Carbon storage in standing trees on IARI campus ecosystem

A total of 5,368 individual native trees belonging to 27 different families were present in different avenues and streets of IARI campus. *Heterophragma astinophylla b*elonging to family Bigoniaceae was the most dominant tree species with 794 trees (14.79% of total) while *Acaiapycnantha* belonging to family Fabaceae was the least represented tree species. Carbon storage in standing trees was determined based on tree heights, DBH, BGB and AGB. The maximum AGB was recorded in *T. arjuna* (25760.85 kg), while the minimum AGB was recorded in *B. glabra* (55.82 kg). The maximum BGB was recorded in *T. arjuna* (3864.12 kg) while minimum BGB was recorded in *B. glabra* (8.37 kg).The maximum total biomass was recorded in *T. arjuna* (29624.97 kg), while minimum biomass was recorded in *B. glabra* (64.19 kg). *T. arjuna* was recorded to store the greatest amount of carbon (14.18 t) in the campus followed by *Ficus religiosa* (11.62 t), *Eucalyptus tereticornis* (9.18 t), *Syzygiumcumini* (7.14 t), *Azadirachta indica* (6.80 t), *Ficus virens* (5.72 t), *Dalbergia sissoo* (4.04 t) while the lowest amount of carbon is stored by *B. glabra* (0.032 t). Total 119.31 t carbon is stored by 64 diverse tree species of IARI campus, which is 436.83 t in terms of CO_2 equivalence.



4.8.13 Urban green can capture heavy metal from suspended particulate matter

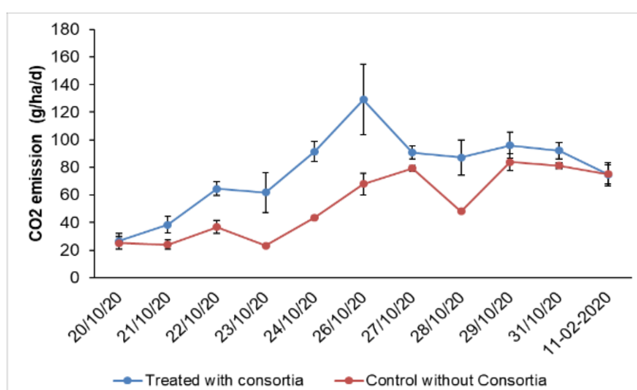
Atmospheric particulate matter (PM) is rich carriers of heavy metals like Zn, Fe, Pb, Ni *etc*. Morphological feature like trichomes and grooves on the foliage of plants may enhance PM-metal capture and absorption by the road side tree species. Radiotracer studies support that avenue trees like *Morus alba* not only efficiently trap atmospheric PM but also exhibit foliar uptake and translocation. Thus, avenue trees are capable of taking up atmospheric heavy metals and can play a crucial role in improving air quality.

4.8.14 Emission of air pollutants from crop residue burning

Emission of GHG and air pollutants due to burning of rice residues in districts of Punjab and Haryana was quantified based on real time monitoring of rice area burned. In 2020, 12.84 Mt of rice stubble was burned in different districts of Punjab. Rice stubble burning increased by 49.3% compared to that in 2019. Approximately 2.9–67.5% of biomass generated in districts of Punjab is burned on farm resulting in emission of 1711 Gg of air pollutants and 21 Tg of GHG (CO_2 eq). In Haryana 1.42 Mt of rice stubbles were burned though burning was reduced by 11.7% compared to that in 2019. 0.0-27.74% of biomass generated in different districts of Haryana is burned on farm resulting in emission of air pollutants (189.4 Gg) and GHG (2.33 Tg of CO_2 eq).

4.8.15 GHG emission following PUSA decomposer application

PUSA bio-decomposer increased CO_2 emission by 39.8% compared to control where no consortia was applied indicating the increased rate of degradation of rice stubble and residue. No significant change in N_2O emission. The study is presently being further validated.



GHG emission during bio-decompsoition of rice residue treated with PUSA decomposer

4.8.16 Health Risk Assessment of heavy metals in PM_{10} and $PM_{2.5}$ through ingestion (ing), dermal (der) contact and inhalation (inh) exposure

Sampling for different PM fractions ($PM_{2.5}$ [<2.5 µm], PM_{10} [<10 µm], and total suspended particulate) was conducted using air sampler. The concentrations of PM10 and PM2.5 varied from 136.3 to 176.7 µg/m^3 and 56 to 162 µg/m^3, respectively. The average PM2.5 concentrations for Zn, Pb and Cd found as 0.25 µg/m^3 0.11 µg/m^3 and 0.007 µg/m^3, respectively and for PM10 the values were 0.04 µg/m^3 for Zn, 0.002 µg/m^3 for Pb and 0.76 µg/m^3 for Cd. The average hazard quotient (HQ) values for adult population in PM2.5 through exposure roots (inh, ing, and der) was observed for Zn as 5.93345E-08, Pb as 2.24694E-06 and Cd as 5.20048E-07, whereas in PM10 the values resulted as 1.01936E-08 for Zn, 4.3137E-08 for Pb, 5.45518E-06 for Cd respectively. In case of children the values for Hazard Quotient (HQ) were found for Zn, Pb and Cd in PM2.5 as 2.18597E-06, 8.27807E-05, 1.95241E-05 while in PM10 the values were 3.75548E-07, 1.58923E-06, 2.01E-04 *via*., three different pathways (inh, ing, and der), respectively.

4.8.17 Nano particles effects on plant growth and cadmium (Cd) dynamics in soil and plant system

Plant growth was retarded at 50 mg Zn L^{-1} concentration in ZnO-NP (ZnO nano particle) treatment. ZnO-NP significantly increased super oxide dismutase, guaiacol peroxidase, ascorbate peroxidase activity and lipid peroxidation (measured as malondialdehyde) activity in rice plants. Further the inhibition of rice plant growth was found to be source and concentration-dependent. It may be concluded that, plant enzymes activities may be used as sensitive tools for assessing the environmental toxicity of ZnO-NP in plant system. In another experiment pot culture studies found that reductions in plant height and biomass under Cd stress were recovered and improved after the addition of ZnO-NP. The addition of ZnO-NP increased wheat biomass by 10 to 25% in the cadmium contaminated soil with that of the respective control treatment. ZnO-NP could decrease the concentration of bioavailable Cd in rhizosphere soil. This work revealed that ZnO-NP could improve plant growth and reduce toxic effects of Cd.

5. CROP PROTECTION

Pests and pathogens scenario in different crops is affected by changing climatic conditions. The school of Crop Protection develops and employs innovative management options to minimize the losses in field and horticultural crops due to pests and pathogens. During the year under report, studies on diversity, host-pathogen interaction, epidemiology, new disease reports and development of new diagnostic tools were undertaken. Besides biological control agents, novel chemicals molecules were identified to form a part of integrated management. Identification of resistant sources will certainly help the breeders in developing insect pest and disease resistant varieties.

5.1 PLANT PATHOLOGY

5.1.1 Pathogen diagnostics and genetic variability

5.1.1.1 Genotyping of *Tilletia indica* isolates causing Karnal bunt of wheat

Thirty-nine isolates of *Tilletia indica* collected from different locations in India were genotyped using a ddRADseq genotyping by sequencing approach to detect genetic variation. An association study was performed to identify single nucleotide polymorphisms (SNPs) associated with virulence genes using 41,473 SNPs. Per cent heterozygosity varied from 0.1 to 16.23% in 39 *T. indica* isolates. Based on population structure analysis, *T. indica* isolates were grouped in three sub populations. All groups contained genetic mixing of more than one sub population. Association mapping revealed 13 SNPs associated with *T. indica* virulence.

5.1.1.2 SSRs, SNPs and InDel identification and characterization from whole genome of *Bipolaris sorokiniana*

Molecular markers were developed from the whole genome of *B. sorokiniana* isolate BS112. On the basis of localization, a total of 5996 SSRs were identified, of which 37.49% were tetra nucleotide followed by 21.8% mono nucleotide and 20.6% tri nucleotide repeats. Out of 41 SSR markers which amplified 39 isolates of *B. sorokiniana*, 38 were polymorphic. Heterozygosity and PIC across all the isolates varied from 0.404-0.991 and 0.336-0.978, respectively, from which SSR10 showed the highest, while SSR57 showed the lowest heterozygosity and PIC.

5.1.1.3 Genotyping of *Magnaporthe grisea* infecting pearl millet

Magnaporthe grisea isolates were genotyped by exploiting sequence variations in six selected house keeping (*Pgk, Pfk, Cal*) and effector coding (*Mpg1, Slp1, and Mlc1*) genes. Sequence analysis revealed ACTC deletion polymorphism in the 36-39th nucleotide sequence position in the genetic locus, *pfk* (coding for 6-phosphofructo-2-kinase 1) only in the pearl millet isolates.

5.1.1.4 Morpho-molecular characterization of *Ganoderma* spp. collected from arecanut

Twelve samples of *Ganoderma* spp. were collected from different locations of Assam and West Bengal. One sample was also collected from Delhi from a dead ornamental tree. The isolates JPG3WB19, JPG8WB19, KRG16AS20, KRG20AS20 and NDG1DL20 were clustered into stipitate group. On the basis of basidiospore size, two groups namely larger spore group and medium spore group were identified. Isolates JPG3WB19 and KRG17AS20 were found to have large spore which are closer to *G. boninense* and isolates JPG2WB19, JPG5WB19, JPG6WB19, JPG8WB19,

JPG9WB19, JPG10WB19, KRG14AS19, KRG16AS20, KRG18AS20, KRG20AS20 and NDG1DL20 were medium spore group that are closer to *G. orbiforme*. ITS sequence based molecular characterization confirmed that isolates JPG2WB19, JPG5WB19, JPG8WB19, JPG9WB19 KRG14AS19, KRG17AS20, KRG20AS20 as *G. orbiforme* and JPG3WB19, JPG6WB19, JPG10WB19, KRG16AS20, KRG18AS20 as *G. boninense.*

5.1.1.5 Genotyping of *Fusarium graminearum* isolates for trichothecene

Twenty-seven pure cultures of *Fusarium graminearum* were established from the 120 diseased wheat spikes collected from the Wellington (Tamilnadu). Morphological and cultural characterizations coupled with molecular characterization with species specific markers were carried out to identify the *Fusarium* species associated with the disease. Twenty-four isolates were tested positive for the genes responsible for the production of DON toxin, whereas all 27 isolates showed positive results for genes responsible for 15-ADON toxin. The isolates Fg-W20-8 and Fg-W20-18 were found more aggressive as compared to other isolates. Isolate Fg-W20-6 was found least virulent after 14 days of inoculation.

5.1.1.6 Genetic diversity among *Citrus tristeza* virus in citrus growing areas of North-east India

Twenty-one isolates of *Citrus Tristeza Virus* (CTV), designated as CTV-Asm 1 to CTV-Asm 21 were collected from different citrus orchards of Assam and characterized based on sequence analysis of 5'ORF1a gene fragments of CTV genome. Phylogenetic analysis segregated the isolates into two genogroups; of which 16 isolates clustered into one genogroup along with the decline CTV strain VT/Kpg3, and the remaining isolates into another genogroup along with Indian CTV isolate AR-1.

5.1.1.7 Identification of bacterial pathogen causing stalk rot of maize

A survey was conducted in 16 districts of five maize growing states of India during *kharif* 2019 to 2021. The natural incidence of the bacterial stalk rot disease was observed with a range of 13.30-37.93%. Biochemical characterization and carbon utilization tests of these isolates were done using sets of 25 biochemical kit and carbon utilization tests specific to *Enterobacteriaceae.* A pair of *fliC* gene based primer, specific to *Dickeyazeae* was designed to identify the pathogen and these isolates were amplified at 230 bp. The bacterium associated with stalk rot of maize was confirmed as *Dickeyazeae*.

5.1.1.8 Occurrence of an emerging polerovirus, cucurbit aphid borne virus (CABYV), infecting bitter gourd and cucumber plants in India

Symptoms like bright yellowing, puckering of the leaf and vein thickening were observed on bitter gourd (*Momordica charantia*) and cucumber (*Cucumis sativus*) plants in IARI, New Delhi during *kharif* 2019. Leaf-dip electron microscopy of the symptomatic leaves revealed the association of isometric virus particles measuring ~25 nm. The RT-PCR assay using polerovirus generic primers covering the partial RdRp, intergenic region, and partial CP region resulted the amplicons of ~ 1.1 kb. Subsequent cloning, sequencing, and sequence analysis revealed the association of *cucurbit aphid-borne yellows virus* (*CABYV*) with bitter gourd and cucumber plants. This is the first report of CABYV infection on cucumber plants from India.

5.1.1.9 Identification and characterization of peanut witches' broom phytoplasma associated with witches' broom disease with bamboo

Suspected phytoplasma like symptoms of witches' broom and leaf yellows were observed in the bamboo species, *Dendrocalamus strictus*, in Karnataka and Delhi. Preliminary test for detection of phytoplasma was conducted by PCR amplification of the phytoplasma specific universal primer pairs P1/P7 followed by nested primer pair R16mF2/R16mR1. The expected amplicons of 1.4 kb were obtained from all the symptomatic samples and were sequenced. Pairwise sequence comparison of the *16S rRNA* gene sequences showed 100% similarity with that of peanut witches' broom (16SrII-D) phytoplasma strain. Phylogenetic analysis by neighbour-joining method based on *16S rRNA* gene sequences clustered the bamboo phytoplasma strains from Karnataka and Delhi with strains of 16SrII-D subgroup. Virtual RFLP conducted using *i*PhyClassifier online tool with 17 restriction enzymes confirmed the identity of 16SrII-D subgroup of phytoplasma associated with the bamboo samples.

5.1.1.10 A graphene oxide based electrochemical immuno-sensor for rapid & sensitive detection of groundnut bud necrosis orthotospovirus

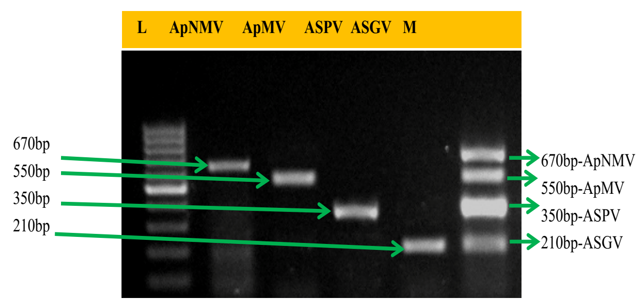
A graphene oxide (GO) based electrochemical immune-sensor for the rapid and sensitive detection of groundnut bud necrosis orthotospovirus (GBNV) was used. The immune electrode was prepared by depositing GO onto indium-tin oxide (ITO) coated glass substrates and functionalized by anti-GBNV antibodies using N-ethyl-N′ - (3-dimethylaminopropyl) carbodiimide hydrochloride and N-hydroxysuccinimide (EDC-NHS) conjugation chemistry. The response measurements of the immune electrodes revealed a sensitivity of 221 ± 1 μA μg^{-1} mL^{-1} (n = 3) and limit of detection (LOD) of 5.7 ± 0.7 ng mL^{-1} (n = 3) for the standard concentrations of GBNVantigen. Further, the usefulness of developed immuno-sensor was validated through GBNV detection in the infected leaf extracts of three different host plants, *i.e.* tomato, cowpea, and *N. benthamiana* and the results were compared with DAC-ELISA technique. There is immense potential of GO based immunosensor to overcome the limitations of traditional methods of virus detection under field conditions.

5.1.1.11 Development of a nano-biosensor for the detection of chili leaf curl virus

An attenuated total reflection (ATR)-mediated localized surface-plasmon-resonance-based optical platform was established, where a segment of ssDNA of the chili leaf curl virus was bound as a receptor sequence on the surface of gold nano-particle. The virus specific nano-biosensor successfully detected ChiLCV in chili sample with detection limit of 1.0 μg/ml.

5.1.1.12 Development of multiplex RT-PCR for simultaneous detection and distribution of novel virus ApNMV along with APMV, ASPV and ASGV

As apple was found infected with ApNMV along with apple mosaic virus-APMV (ilarvirus), apple stem pitting virus-ASPV (foveavirus) and apple stem grooving virus-ASGV (capillovirus), a multiplex RT-PCR has been standardized to detect these four viruses simultaneously. Four primer pairs produced amplicons of 670, 550, 350, and 210 bp corresponding to ApNMV, ApMV, ASPV and ASGV, respectively. The m-RT-PCR protocol developed was further validated on seven symptomatic or asymptomatic apple cultivars, which revealed the presence of 1 to 4 viruses in these cultivars. The ApNMV and APMV were found associated in 6 symptomatic apple cultivars either alone or together. However, ASPV was more common as it was present in 6 out of 7 cultivars tested. The presence of ASGV was variable in symptomatic plants showing presence of ApNMV or APMV. As this multiplex RT-PCR has included ApNMV, a new virus infecting apple along with three more common viruses, it has potential for routine application in indexing of mother plants for production of virus free planting material in apple.



m-PCR showing amplicons of 4 viruses, L-100 bp Ladder, ApNMV-Apple necrotic mosaic virus, ApMV-Apple mosaic virus, ASPV-Apple stem pitting virus, ASGV-Apple stem grooving virus, M: All 4 viruses

5.1.1.13 Molecular detection of phytoplasma associated with rose

Improvement in standardization for PCR assay for phytoplasma detection was established with rose samples by selection of various combinations of nested primer pairs of 16S ribosomal gene and *secA* gene.

CTAB DNA extraction method was slightly modified by adding 2% polyvinyl pyrrolidone and increased the isopropanol volume and better-quality DNA was obtained. Best amplification results were achieved in nested PCR assay employing P1/P7, R16mF2/R16mR2 and R16F2n/R16R2, P1/P7 and R16mF2/R16mR2, and R16mF2/R16mR2 and fU5/rU3 primer pairs. Besides, a multiplex PCR assay was also developed and optimized for consistent identification of phytoplasma in rose samples by employing primer pairs of *16S rRNA* and *secA* genes together in a single PCR reaction by optimizing annealing temperature at 55°C.

5.1.1.14 First report of occurrence of 16SrII-C phytoplasma in papaya worldwide and 16SrII-D phytoplasma in Pune

Molecular identification of 16SrII-C and 16SrII-D phytoplasma strains associated with phyllody and axillary shoot proliferation in papaya was undertaken. The presence of phytoplasma in the infected plants was confirmed by nested PCR amplifying the 16SrRNA gene and sequence analysis. Amplicon sequences obtained from samples showing phyllody (MW404675) and axillary shoot proliferation (MW450863) were deposited in NCBI GenBank.

5.1.1.15 First report of occurrence of Zucchini yellow mosaic virus (ZYMV) in sponge gourd

Occurrence of ZYMV in sponge gourd (*L. aegyptiaca*) was reported for the first time from Pune, India. *L. aegyptiaca* plants exhibiting mosaic, blistering and deformation of leaves were observed in Pune. Presence of ZYMV was confirmed through DAS-ELISA and RT-PCR. Amplification product was sequenced and deposited in GenBank (Acc. No. MT070964).

5.1.1.16 Identification of new phytoplasma diseases belonging to 'clover proliferation' (16SrVI) subgroup D in cucurbits in India

Phyllody symptoms were recorded in bottle gourd crops in fields at Pune. Association of phytoplasma was confirmed by nested PCR. The consensus sequences were deposited in GenBank (Acc. No. MW664325 and MW672511) and they shared 99-100% identity with phytoplasmas belonging to 16SrVI group ('*Candidatus* Phytoplasma *trifolii*' -related strain). Virtual RFLP analysis of 16SrDNA sequences classified the phytoplasmas in 16SrVI-D subgroup.

5.1.2 Host-pathogen interaction and genomics

5.1.2.1 Genome sequencing of *Bipolaris oryzae* infecting rice

Full genome of *Bipolaris oryzae* sequenced using PacBio Sequel II platform. A total of ~171 Gb (1,962,945 raw reads) of data was generated using PacBio Sequel II. In which ~22 Gb data of unique single molecules were sequenced. A high quality of genome of 34.918311 Mb was assembled in 18 contigs with N_{50} of 2268570 bp. BUSCO analyses showed 98.9% of assembly.

5.1.2.2 *Colletotrichum aenigma* mitochondrial genome

The complete mitochondrial genome of *C. aenigma* was studied which was circular molecules with sequence with 62,588 bp length containing 14 protein-coding conserved genes and 22 tRNA genes (trn) that recognize codons for all amino acids. However, the ATP-synthase gene atp 8 was not found in *C. aenigma*. The GC content was found approximately 53%.

5.1.2.3 Whole genome sequence of *Xanthomonas campestris* pv. *campestris* race 4 the causal agent of black rot of cabbage

The isolate Xcc-C7 race 4 of *Xanthomonas campestris* pv. *campestris* was isolated from cabbage (*B. oleracea* var. *capitata*) from Bangaluru. Whole genome sequence data was generated by the illumina. The comparative analysis elucidated the Indian race 4, closely related to the Chile Xcc isolate. However, the genome size and non-coding RNAs of Indian race 4 were ~5.1 Mb and 86 as compared to Chile Xcc isolate ~4.9 Mb and 4, respectively. The assembled complete genome sequence of Xcc-C7 strain of *Xanthomonas campestris* pv. *campestris* has been deposited in the GenBank database under accession number CP077958.

5.1.2.4 High throughput sequencing of apple cultivars for characterization of viruses

In the present study, the next generation sequencing of rRNA depleted total RNA (RNA-Sequencing) was applied to two apple cultivars, Oregon Spur and Golden Delicious with symptoms of mosaic and necrosis using Illumina Hiseq2500. The RNA-Seq.detected four viruses, *viz.*, apple necrotic mosaic virus (ApNMV), apple mosaic virus (ApMV), apple stem grooving virus (ASGV) and apple stem pitting virus (ASPV) and viroid *viz.*, apple hammerhead viroid (AHVd). The new virus ApNMV was present in both the cultivars, but in Golden Delicious, it was found in mixed infection with ApMV. All the viruses and viroids present in symptomatic cultivars were further confirmed through RT-PCR amplification. The complete genomes were reconstructed from sequencing data for all four viruses (ApMV-9kb, ApNMV-8.5kb, ASGV-7.6kb, ASPV-7kb) and a viroid (AHVd-434bp). The phylogenetic analysis revealed the presence of genetic diversity among our isolates by forming sub clusters with other isolates from different countries. Recombination analyses also showed the occurrence of various recombinant events among the viruses identified, whereas SNVs were detected in ApMV and ApNMV only.

5.1.2.5 Draft genome sequence of 'Ca. Phytoplasma australasia', strain SS02 associated with sesame phyllody disease

'Among the group of phytoplasmas, the Peanut Witches' Broom (PWB) or 16SrII group of phytoplasmas associated with various diseases in economically important crops cause serious losses every year in India. The strain SS02 belonging to '*Ca.* Phytoplasma australasia' (Peanut Witches' Broom or 16SrII-D group) was identified associated with sesame phyllody disease. To understand better the genome structure of this pathogen, the genome of strain SS02 was obtained using its genomic DNA enrichment and hybrid assembly of sequences generated on Illumina and Oxford Nanopore Technologies (ONT) platforms. The hybrid assembly generated a draft genome with 47 contigs totalling to 536,153 bp chromosomes with more than 400x depth coverage and 92.47 % of the estimated genome size. The SS02 genome draft sequence contains 432 protein-coding genes, 16 tRNA genes and three rRNA genes.

5.1.2.6 Understanding hormone signaling network of systemic resistance induced by *Chaetomium globosum* through transcriptomics

Inhibition of early blight disease by 30% in tomato plants when pre-treated with C. *globosum* was observed. The temporal expression analysis of marker genes (*PR1, PiII, PS, PAL, Le4* and *GluB*) of hormone signaling pathways in tomato plants after root inoculation with potential strain Cg-2 revealed the maximum expression of genes at 12 hpCi. Therefore, the RNA sequencing was performed for control tomato plants (mock inoculated with water) and biocontrol treated plants at 12 h post root inoculation with Cg-2. The transcriptome data revealed that 22473 DEGs were expressed in tomato at 12 h post Cg-2 inoculation as compared to control plants and among these 922 DEGS had a fold change of -2 to +2 with $p<0.05$. The KEGG pathway analysis revealed that most of the DEGs belonged to metabolic pathways, biosynthesis of secondary metabolites, plant-pathogen interaction, chlorophyll metabolism and plant hormone signal transduction. The transcriptomic data revealed that systemic resistance involves the active participation of SA and JA hormone signaling networks that indicates the involvement of SAR and ISR.

5.1.2.7 Virulence factors annotated from rice and pearl millet

Time course (0-120 hpi) real time PCR assisted expression analysis of putative virulence factors such as *MBSD02000619.1.g3349*, *MBSD02000495.1.g5524* and *MBSD02000009.1.g8852* (annotated in the genome of rice infecting RMg_Dl) revealed nearly identical expression pattern in all tested plants such as rice, finger millet and pearl millet. However, the expression of the virulence locus MBSD02000495.1.g5524 was moderately high (15-fold) in susceptible rice lines.

Time course (0-120 hpi) real-time PCR guided expression analysis of putative virulence factors such as *20007- Mg.00g31250-v1.0.a, 20007- Mg.00g080210-v1.0.a, 20007- Mg.00g080580-v1.0.a, 20007- Mg.00g034390-*

v1.0.a, 20007- Mg.00g016130-v1.0.a and *PWL2* (annotated in the genome of pearl millet infecting, PMg_Dl) was performed both *in vitro* on mycelium and *in planta* on symptomatic leaf tissues of pearl millet, rice and finger millet. Here, the expression of the virulence loci was high in pearl millet host as compared with rice. Expression was higher in susceptible lines however in rice some contradictory results were obtained where gene *20007-Mg.00g080210-v1.0.a, 20007-Mg.00g080580-v1.0.a, 20007-Mg.00g034390-v1.0.a, 20007-Mg.00g016130-v1.0.a* showed higher fold expression in resistant line rather than susceptible.

5.1.2.8 Role of differentially expressed genes during *Magnaporthe oryzae* interaction

In blast susceptible rice genotype, ABC transporter G, Sugar transporter SWEET11, BZIP protein, Cytochrome P450, Elongation factor EF-G, Expansin-B3, NAC protein, Early nodule-specific protein ENOD8, SOUL heme-binding protein, PDZ domain-containing protein, chloroplastic stress tolerance OsCEST protein, RING zinc finger protein-like and WAT1-related protein were found up-regulated during early pathogenesis events. Heat shock protein HSP, SNF1-related protein kinase, bZIP transcription factor RISBZ2, NFACT-R_1 protein, Nodulin family protein NIN, RSH disease resistance-related protein, SWIM-type protein, Uridine kinase, VPS9 domain-containing protein, and Zinc finger protein were found down-regulated. In blast-resistant genotype, ABC1 domain-containing protein, BZIP protein, CAAD protein, CMV1a interacting protein, Cytochrome P450, DYW_deaminase domain-containing protein, Elongation factor EF-G, HABP4_PAI-RBP1 domain-containing protein, Myb transcription factor, PAP_fibrillin domain-containing protein, PDZ domain-containing protein, PPR-repeat protein-like, RING-CH-type domain-containing protein, Superoxide dismutase, Transcription factor PCL1, and V-type proton were among the up-regulated transcripts. Auxin-responsive protein ARF, bZIP transcription factor RISBZ2, Calcium uniporter protein, Cytochrome P450, Nuclear transcription factor NF-Y, Heat shock protein HSP, Helix-loop-helix DNA-binding domain, NAC domain-containing protein, Zinc finger transcription factor ZF1, WRKY transcription factor, and Zinc finger CCCH domain protein were found down-regulated during early pathogenesis events.

5.1.2.9 Improved artificial inoculation method for the false smut disease of rice

False smut disease caused by *Ustilaginoidea virens* is an emerging problem. Very less success is observed till now for the artificial inoculation of the pathogen in host plants. Here, we developed an improved methodology for the disease development. For which mycelium from actively growing culture was transferred into a 100 ml flask containing 50 ml of Potato Sucrose Broth (PSB). The culture was incubated in a rotatory shaker (120 rpm) at 28°C for 7 days. The hyphae and conidia were collected by filtration and centrifugation, respectively. The spore suspension of respective fungal isolates was prepared at approximately 1×10^6 conidial/ml and 0.5% gelatin was added prior to use to prevent spore desiccation. Spore suspension (2 ml) was used for injection at booting stage. The temperature and relative humidity were maintained by covering the plants with green net and frequently spraying water. False smut disease symptoms were visible after 21 days of inoculation with the incidence of 8-30% depending on the isolate.

5.1.2.10 New phytotoxic compound isolated from *Rhizoctonia solani* AG 1A inciting rice sheath blight

Role of crude toxin in the pathogenicity and virulence of *R. solani* for rice sheath blight was first established by artificial inoculation assay under controlled conditions. Toxic fraction was purified by bioassay-guided fractionation. The most bioactive fraction was analysed by GC-MS analysis and 3-butylpyridine (3-BP) was identified as a major compound in the active fraction by comparing its mass spectrum with the NIST library as well as with its standard. The toxicity of purified bioactive fraction and standard (3-BP) was further validated and compared at 1000 ppm. The result showed that both the bioactive fraction and the 3-BP have caused necrosis, similar to the one incited by *R.*

solani. This study showed that 3-BP is one of the major compounds responsible for the necrosis development in the rice plant during sheath blight disease.

5.1.2.11 Role of candidate hypothetical pathogenicity genes in sheath blight development

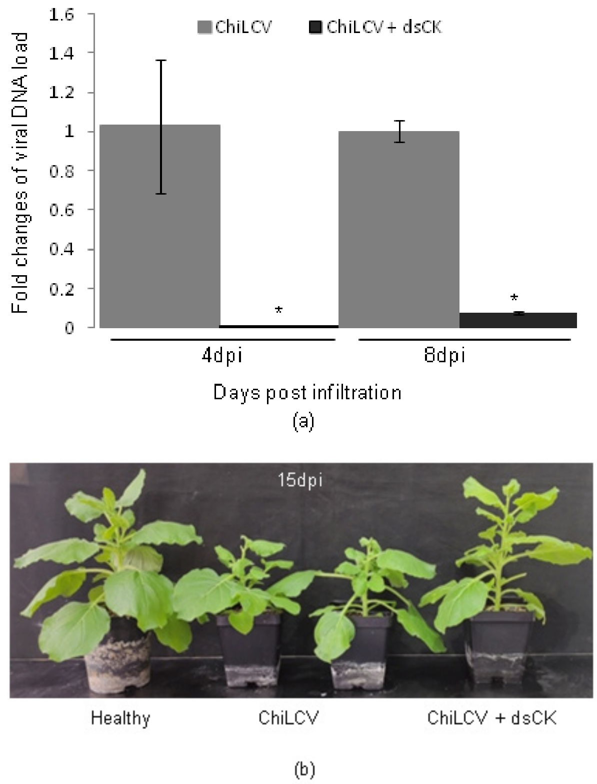
In ascertaining the role of four candidates in plant induced genes, AG1IA_06195, AG02692, AG04508 and AG05730 in sheath blight development based on disease scoring and gene expression studies, the down regulation of the candidate genes in the fungus upon infection of a ShB susceptible rice cultivar, PB-1 pre-colonised by a potent biocontrol consortium comprising of *Bacillus subtilis* (S17TH), *Pseudomonas putida* (TEPF-Sungal-1) and *Trichoderma harzianum* (S17TH) was identified. The possible role of these genes in *R. solani* pathogenesis was elucidated by studying their responses to ferulic acid (1 mM to 5 mM), the main phenolic compound of rice. At rice phenolic acid concentration (1 mM), despite the down-regulation of other putative pathogenicity genes, a strong expression (3-fold) was observed for the AG02692 gene indicating its role in fungal pathogenesis.

5.1.2.12 Biotechnology-based mild strain cross protection of citrus decline caused by *Citrus tristeza virus*

Effort has been made to identify mild cross protecting strain (MCPS) of *Citrus tristeza virus* (CTV) using 12 Indian CTV isolates based on *in silico* analysis using nucleotide sequences of CP and ORF1a gene fragments of CTV genome. Analyses of pair-wise nucleotide identity matrix, phylogenetic relationships and codon usage biasness (CUB) three Indian CTV isolates, K10, Mnp1 and MB3 were identified as mild CTV isolates. However, the CTV isolate B3 may be a strong MCPS as it is genetically more related to the severe and decline Israel CTV isolate VT and Indian decline CTV isolate Kpg3.

5.1.2.13 Cocktail dsRNA of multiple suppressor genes of *chili leaf curl virus* (ChiLCV) reduces the virus infection in *Nicotiana benthamiana*

In the present study, a novel approach is attempted to prevent ChiLCV infection by spray application of cocktail dsRNA (ds-CK) of three suppressor genes, C2, V2 and C4 of ChiLCV. A single spray application of ds-CK reducedChiLCV infection significantly in *Nicotiana benthamiana* plants up to 8 days. Semi quantitative PCR and real time PCR showed significant reduction of the viral load up to 99.9% compared to control. This is the first report of inhibition of a monopartite begomovirus by spray application of cocktail dsRNA to multiple viral genes.



Reduction of viral load and delayed in symptom development. a) Real time PCR of CP gene of ChiLCV at 4 dpi. Actin was taken as internal control gene(*Fold changes reduction of viral DNA load in dsCK treatment as compared to the plants treated onlywith the virus); b) Morphological differences and delay in symptom development of ChiLCV in *N. benthamiana* plants treated with dsCK as compare to the plants inoculated only with the virus at 15 dpi

5.1.2.14 Long-fragment circular-efficient PCR (LC-PCR) for viral genomeconstruct

LC-PCR was invented for the restriction and ligation free manipulation of virus-genomeconstruct. Innovation was made in designing an additional primer while conducting over lapping circular PCR that helped in self-recircularization of the PCR molecule. We show that the LC-PCR is highly useful for creating insertion, deletion and point mutation in the large plasmid of 16.4 kb of CGMMV infection clone.

5.1.2.15 Genome editing initiative to inhibit papaya ringspot virus (PRSV)

To inhibit PRSV, viral genome linked protein (VPg) was targeted. Cas13a (LshC2c2) has been cloned in pGWB402, a binary vector using Gateway™ LR Clonase™ Enzyme mix (Invitrogen). For systemic transient assays, guide RNAs targeting VPg gene have been cloned in SPDK3876, a TRV2 vector with PEBV promoter.

5.1.2.16 Nuclear localization of GBNV-N protein in cells of *T. palmi in vitro*

A primary cell culture of *T. palmi* was established previous year. Embryonic tissue of 60-70 h old was implanted in a modified Kimura's medium. Round-shaped cells of varying sizes and tissue clumps were observed immediately after implanting. Fibroblast-like cells started generating within 3 h of tissue implantation. The fibroblast grew in size and number with time and networking of fibroblast was observed post 5 days of implantation. Fresh media was supplemented at 2-3 days intervals. A 48-hour-old primary cell culture of *T. palmi* was transfected with semi-purified groundnut bud necrosis virus (GBNV). The virus localization in cells was visualized using GNBV-N protein antibody and FITC conjugated secondary antibody. The N-protein of GBNV was localized in the nucleus of *T. palmi* cells 24 h post transfection.

5.1.2.17 First evidence of transovarial transmission and propagation of a bipartite begomovirus in whitefly progenies

We have tested the transovarial transmission of dolichos yellow mosaic virus (DoYMV) in progenies of its vector, *Bemisia tabaci* Asia II 1 by PCR, real-time PCR, Southern blot hybridization, and biological transmission. Eggs laid by DoYMV-exposed *B. tabaci* carry the virus in a unique fashion. Only the eggs laid in between 3-6 days post virus acquisition by parent were DoYMV positive. When tested individually in real-time PCR, around 31-53% of eggs carried the viral DNA. Presence of the DoYMV in ovaries and F_1 eggs was further substantiated by hybridization of a Cy3-conjugated nucleic acid probe complementary to DoYMV. DoYMV DNA was also detected in F_1 adults and F_2 eggs. *B. tabaci* not only carries the DoYMV DNA but also the infectivity. The F_1 adults could transmit DoYMV to all test plants and produced strong symptoms. An increase in viral copies from egg to 3rd instar nymph indicated propagation of DoYMV in *B. tabaci*. However, the increase was for a short period and decreased thereafter. The transovarial transmission and replication of DoYMV in *B. tabaci* have epidemiological relevance as *B. tabaci* can serve as a major host of the virus to bridge the gap between cropping seasons.

5.1.3 Disease epidemiology

5.1.3.1 Simulation of leaf curl epidemics in terms of migrant viruliferous vectors

Epidemiological modeling on population of infectious host and viruliferous white flies indicated migrant viruliferous vector is the most influential epidemic parameter in leaf curl epidemic in chili. Change in the level of migrant vectors (rate) in the model has resulted in a change in the number of infectious host and viruliferous vectors. Low levels of migrant viruliferous vector population are shown to correspond with low epidemic and higher levels with high epidemic level as indicated by number of infectious and viruliferous vector population.

5.1.3.2 Interception of migrant vectors and survival analysis and plant health probability

To check migrant population from transplantation is expected to check leaf curl epidemic. Field experiment with plant cover for two, three and four weeks followed by one insecticidal spraying (imidacloprid 0.1%) checked the growth of infectious host population. Median survival time for plants to remain uninfected by the leaf curl virus was observed to be significantly higher in covered plots in comparison to the plots kept uncovered and regular insecticidal spraying.

5.1.3.3 Prediction of sheath rot distribution in rice based on weather and satellite data

Sheath rot in rice is now a well-established disease especially in *kharif* rice. Spatiotemporal distribution is an important input needed for developing strategic management policy. Sheath rot development index based on threshold temperature estimated was used for mapping sheath rot infection in Indian region. Temperature profile based on ground record as well as remote sensing data as LST and ground truth proofing in selected locations indicated disease is prevalent in all rice regions except in hilly ecosystems where it is comparatively less prevalent.

5.1.4 Host resistance

5.1.4.1 Wheat

A total of 36 isogenic lines containing different powdery mildew resistant genes were evaluated for two years against stem and leaf rust resistance. A total of 16 entries were found to be resistant to stem and leaf rusts.A total of 1813 entries were evaluated for field resistance to stem and leaf rusts under artificial inoculations using mixtures of important pathotypes. Of these, 844 entries (~46% of the total) showed resistance (Coefficient of Infection value up to 10.0) to both stem and leaf rusts at Indore. In addition, the AVT entries (52) were evaluated in isolation for adult-plant resistance to stem rust pathotypes 40A and 117-6 (race-specific APR Nursery). Around 73% entries were resistant to both stem pathotypes. A total of 587 genotypes of preliminary disease screening nursery (PDSN) were evaluated for field resistance to stem and leaf rusts under artificial inoculations using mixtures of important pathotypes. Of these, 292 entries (49.7% of the total) showed resistance (Coefficient of Infection value up to 10.0) to both stem and leaf rusts at Indore.

Three hundred forty-four wheat genotypes including released cultivars, advance lines and indigenous germplasm were evaluated for resistance against head scab. Out of all the genotypes under evaluation, one genotype DBW 302 and nine indigenous germplasm lines IC 335992, IC079040, IC 266978, IC 585643, IC 585659, IC 35611, IC 145983, IC 138554 and IC 0111868 were found moderately resistant based on percent spikelet infection. The rAUDPC values revealed that one genotype DBW 302 and nine indigenous germplasm lines were having the rAUDPC values of less than 20% as compared to most susceptible genotype IC 252354. Such genotypes which have shown slow development of disease can be utilized for incorporating resistance in released cultivars of wheat which are high yielding. Ninety six genotypes were evaluated for Karnal bunt resistance. Among wheat genotypes, the disease incidence varied from 0.92 to 58.82% and coefficient of infection (COI) ranged from 0.23 to 67 %.

5.1.4.2 Rice

Out of 706 rice genotypes evaluated against sheath blight disease of rice genotypes KNM12509, WGL1119, JGL37180, RP-Bio Patho-11, HR-12, VP-R294, VP-R295, Tetep and Vikramarya were moderately susceptible.

5.1.4.3 Maize

A total of 287 maize genotypes were evaluated in 14 different trials against maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf and sheath blight (BLSB, *Rhizoctonia solani*) diseases. Of which, 263 and 84 genotypes were moderately resistant to MLB and BLSB, respectively. None of the genotypes showed resistance to these diseases. In the case of 15 sweet corn genotypes, 11 genotypes were moderately resistant to MLB and only one genotype was moderately resistant to BLSB disease while in the case of 15 baby corn genotypes, 10 were moderately resistant to MLB. In the case of 39 genotypes of QPM (QPM I, II, III), 35 and 24 genotypes showed moderate resistance to MLB and BLSB, respectively.

5.1.4.4 *Brassica* spp.

The field screening of 35 cultivars/varieties of *Brassica* spp. was done against artificially inoculated *Xanthomonas campestris* pv. *campestris* (*Xcc*) races 1, 4 and 6. *Brassica napus* (GSL-2) showed partial resistance against Xcc race 4 and resistance against race 1 and

4. *Brassica napus* (PAC-401) showed partial resistance against race 1 and resistance against race 4 and 6; *B. carinata* (Pusa Aditya- NPC-9) showed partial resistance against race 4 and resistance against race 1 and 6.

5.1.4.5 Development of a disease scoring scale for estimating leaf curl disease in *Ty* gene containing donor lines of tomato

In order to evaluate the resistance behavior of these genotypes, a quantitative scoring system for analyzing disease severity was developed based on different grades of symptom phenotypes and their impact in disease development. Such deduced disease severity score was used to develop a disease scoring scale based on the co-efficient of infection that includes both percent disease incidence and severity grade. Based on such disease scoring scale, a high resistance response was observed in five genotypes (ToLCD Tol-5, ToLCD Tol-8, ToLCD Tol-12, ToLCD Tol-14, ToLCD Tol-15) containing both *Ty-2* and *Ty-3* genes. Further evaluation of three highly resistant genotypes under challenged viruliferous whitefly inoculation with a well characterized isolate of tomato leaf curl New Delhi virus, the most prevalent begomovirus in tomato causing leaf curl disease in India, confirmed their resistance behavior.

5.1.4.6 Indexing of begomoviruses in *Ty* gene containing donor lines of tomato

Indexing of the begomoviruses in all these genotypes through PCR based detection using seven begomovirus species specific primers and one genus specific primer followed by their confirmation through representative sequencing revealed presence of a number of begomovirus speciesin these tomato genotypes indicating the probable occurrence of mixed infection of two to six different begomoviruses under field condition. While tomato leaf curl New Delhi virus was detected in seven samples, the majority of the samples (13) showed association of a *Croton yellow vein mosaic virus* (CYVMV), alone or in combination with other begomovirus species.

5.1.5 Disease Management

5.1.5.1 Physiological and growth responses of tomato plants to different delivery methods of biocontrol agent *Chaetomium globosum*

Seed treatment supplemented with single drenching with suspension showed the highest increase in plant growth (36.70%), showing 65 and 53% increase in plant height and root length, respectively. The physiological parameters like photosynthesis, stomatal conductance and transpiration increased in Cg-2 treated plants were found highest in seed treatment supplemented with double drenching with suspension which was 9.72 µmol m^{-2} s^{-1}, 0.216 mol m^{-2} s^{-1} and 0.03 mol m^{-2} s^{-1}, respectively, whereas internal CO_2 concentration decreased in Cg-2 treated plants.

5.1.5.2 *Chryseobacterium-* a new biocontrol agents with volatile mode of action

Diverse flavobacterial *Chryseobacterium* species were found on the rice phyllosphere. *Chryseobacterium* emitted antifungal 2-Ethylhexanol against *Magnaporthe oryzae*, which altered the transcription of innate immune genes causing suppressed blast incidence upon seed or foliar application.

5.1.5.3 Microbiome formulations

Two microbiome formulations named as PMF1 and PMF2 were developed based on growth kinetics and time of the bacterial isolates. PMF1 is consisted of *Brevundimonas vesicularis*-T1R; *Microbacterium oleivorans*-L15R; *Microbacterium testaceum*-30B1R; *Pantoea ananatis*-30B17R; *Pantoea deleyi*-VPA1aR; *Pantoea dispersa*-VSA76R; *Pantoea vagans*-30B3R; *Pantoea vagans*-VPA3aR; *Pseudomonas fulva*-VPA22R; *Pseudomonas parafulva*-PPA1R; *Pseudomonas parafulva*- PPA3R; and *Stenotrophomonas maltophilia*-L7R as a consortium active ingredient. PMF2 is consisted of *Microbacterium oleivorans*-L15R; *Pantoea ananatis*-30B17R; *Pantoea deleyi*-VPA1aR; *Pantoea dispersa*-VSA76R; *Pantoea vagans*-30B3R; *Pantoea vagans*-VPA3aR; *Pseudomonas fulva*-VPA22R; *Pseudomonas parafulva*- PPA1R; *Pseudomonas parafulva*-PPA3R; and *Stenotrophomonas maltophilia*- L7R as a consortium active ingredient. Investigation on shelf-life of bacterial isolates in the microbiome formulations (PMF1 and PMF2) revealed the cells viability upto 10 months of storage at 30^{o}C.

Evaluation of phyllosphere microbiome formulations PMF1 and PMF2 for biotic stress management was conducted in 12 different geographical locations in Punjab, Haryana, Uttar Pradesh and Tamil Nadu. Two rounds of microbiome formulation spray on 30 and 60th day post transplantation commensurating with active tillering stage in rice was performed in the trial locations. Superior performance of formulation PMF2 for disease control, plant growth promotion and grain yield parameters over other formulations BioCure (T- Stanes Co. Ltd.) was observed in the majority of the trials.

5.1.5.4 Management of bakanae disease of rice

Twelve fungicides (single and in combination) were evaluated against the bakanae disease as seedling treatments during the *kharif* season of years 2019 and 2020. Minimum disease incidence was observed with the fungicides Carbendazim 50% WP (19.47%), and Tebuconazole 50% + Trifloxystrobin 25% w/w 75 WG (25.71%) during the years of evaluation with maximum yield. Area under disease progress curve was minimum (621.58) with the treatment of Tebuconazole 50% + Trifloxystrobin 25% w/w 75 WG followed by Carbendazim 50% WP (671.30). Differences in bakanae disease symptoms were observed in different treatments. Among treatments, elongated tillers as major symptoms were observed in Mancozeb 75% WP, Zineb 68% + Hexaconazole 4% and Azoxystrobin 23% SC treated plants. Whereas, tiller elongation with rotting was prominent in Kitazin 48% EC treated and inoculated control plants. In the case of Carbendazim50% WP, Tebuconazole 8% + Captan 32% SC treatments, detachment of tillers was prominent. Therefore, seedling treatment with fungicides was observed to be effective in reducing bakanae disease incidence with low AUDPC and high yield compared to inoculated control.

5.1.5.5 IDM modules for managing maize diseases

Three modules *viz.*, organic, chemical and IDM were evaluated for the third season for MLB disease management. Of these, the IDM module comprising seed treatment with *Trichoderma harzianum* (10 g/kg of seed), foliar spray of *Pseudomonas fluorescens* (10 g/L of water) at 45 DAS, foliar spray Azoxystrobin 18.2% + Difenconazole 11.4% w/w SC (Amistar Top 325 SC) 1ml/L of water at 50 DAS, foliar spray of cow urine (20%) at 60 DAS was best that provided 21% disease control and 6 % (16 q/ha) increase in grain yield. For the management of BLSB, four modules namely one chemical module, two organic modules and one IDM module were evaluated. The IDM module comprising soil amendment with *Trichoderma* formulation [@ 6t/acre FYM] + seed treatment with salicylic acid [100 ppm]+ foliar spray with Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.1% using 500 l water/ha [at 3 DAI] and Neem leaf extract [@ 1%, at 15 DAI] was the best with 25% disease control and 42 % increase in yield.

5.2 ENTOMOLOGY

5.2.1 Integrated pest management

5.2.1.1 Cereals

Evaluation of rice germplasm against brown plant hopper (BPH): Out of 21 rice germplasm screened for BPH, only two germplasm were found to be moderately resistant with 3.23 and 3.73 damage score under greenhouse conditions on 0-9 damage scale.

Validation of forewarning model of BPH: A forewarning model developed earlier for BPH was validated during 2021. The BPH incidence pattern over long period of time had indicated that a greater number of rainy days (>30) during June to September played an important in the flare-up of BPH population.

5.2.1.2 Vegetables and fruits

Evaluation of okra lines against sucking pests: Out of 12 okra lines evaluated against leaf hoppers and mites, only one line was found to be highly resistant while four lines were moderately resistant.

Ecological engineering for insect pest management in cole crops: The role of crop diversification on insect pest and their natural enemies in cole crops was assessed. Soybean crop attracted a greater number of cabbage aphids per plant on cabbage; whereas, coriander, tomato and berseem were found at par with control. It was also noticed that radish as a border crop could attract more numbers of cabbage aphid and coccinelid beetles compared to other crops like soybean, fenugreek, sunflower, marigold, tomato, coriander, rijka, and *berseem*.

Pollination studies in grape: The efforts were made to document the diversity and diurnal abundance (at peak flowering) of pollinators visiting the grapes (Pusa Navrang) flower during peak flowering stage of grapes during 2021. With help of video graphic recordings, the number of flower visits, average time spent, and numbers of visitors/ 5 min. were determined. An un-identified dipteran spent highest time (sec/ flower) followed by little bee, *Apis florea* for the nectar and pollen collection.

Seasonal incidence of chilli thrips: Thrips infestation was observed higher during reproductive stage of the crop (flowering and fruit set stage) and gradually decreased to maturity stage. Weather based prediction models developed for thrips and GBNV disease incidence in tomato crop at IARI. Current week- Thrips Y = 2.422- 0.011(RF)-0.109 (SS); GBNV disease Y = 331.586-6.037(Max T)-1.588 (RH I); Spiders Y = -2.555+0.084 (RH II); One Lag Week - Thrips Y = 9.515-0.378(RF) - 0.0080(Min T); GBNV disease Y = 264.364-5.644 (Max T)-0.193(RF) - 1.052(RHI) + 3.181(SS); Spiders Y = - 2.157+0.079(RH II).

5.2.1.3 Oilseeds

Evaluation of bio-intensive IPM modules for management of mustard aphid: Among six bio-intensive IPM modules evaluated for management of mustard aphid, the module with two sprays of Dimethoate 30 EC@ 1 ml/L witnessed maximum reduction in aphid population (78.8 and 45.0% respectively after 1st and 2nd spray) and also recorded higher seed yield and IBCR.

Assessment of yield loss due to mustard aphid *Lipaphis erysimi* in mustard varieties *viz.*, PDZM 31 and RH 725: The significantly higher seed yield and lower aphid population in these genotypes recorded under protected condition (two insecticide sprays of Dimethoate 30EC @ 1 ml/l followed by Imidacloprid 17.8SL @ 0.25 ml/l) as compared to unprotected conditions. Need based insecticide application resulted in 41.3 and 62.8% increase in seed yields of PDZM 31 and RH 725, respectively.

5.2.1.4 Pulses

Monitoring of pod borer, *Helicoverpa armigera* and *Spodoptera exigua* moths using pheromone traps in chickpea: Studies were conducted to monitor the adult population of chickpea pod borer, *H. armigera* and *S. exigua* using pheromone traps in chickpea from 2015-16 to 2020-21 in *H. armigera* and from 2016-17 to 2020-21 in *S. exigua.* Data revealed that the activity of *H. armigera* started from 3rd standard meteorological week (SMW) with highest activity during 8th to 15th SMW during the crop season in all six years. The peak activity was observed to be during 12th, 10th, 15th, 15th, 10th and 13rd SMW during 2015-16, 2016-17, 2017-18, 2018-19, 2019-20 and 2020-21, respectively. In case of *S. exigua* the moth activity was observed from 50th SMW with maximum activity during 9th to 15th SMW. The peak *S. exigua* population was observed during 14th, 15th, 12th, 12th and 13th SMW during 2016-17, 2017-18, 2018-19, 2019-20 and 2020-21, respectively.

Incidence and seasonal dynamics of insect pests of pigeon pea: Atinged bug, *Urentius euonymus* was first time recorded as pigeon pea pest from Delhi.Incidence of spotted pod borer, *Maruca vitrata* and blister beetle, *Mylabris pustulata* were commenced on 35th SMW (Standard meteorological week). *Maruca vitrata* population was reached to its peak in the 39rd SMW (0.56 webs/plant) whereas blister beetle population was at peak in 39th SMW. The pheromone trap catches of *H. armigera* were started in 33rd SMW and maximum catches (7.6 adults/ trap) were obtained during 35th SMW.

Evaluation of pigeon pea germplasms against insect pests: One test entry along with three checks was evaluated for its performance against different pests. There was no significant difference in number of

Maruca webs/plant among different entries except in all SMW. Total pod damage due to *Maruca* and pod fly was found to be higher in PUSA 992 (15.41%). whereas PUSA 2018-4 was found to be less susceptible (6.00%). Four hybrid pigeonpea Early (131-150 days) test entries were evaluated wherein no significant difference in number of *Maruca* webs/plant were observed. Total pod damage due to *Maruca* and pod fly was found to be higher in PAH 13 (6.17%) and PAH 11 (6.16%) whereas PAH 10 (2.87%) and PAH 5 (2.94%) was found to be less susceptible.

5.2.2 Storage entomology

5.2.2.1 Evaluation of fumigants

Fumigation toxicity of 12 different monoterpenes was evaluated for their fumigation toxicity against storage insect pests *viz*., rice weevil, *Sitophilus oryzae*, pulse beetle *Callosobruchus maculatus* and red flour beetle, *Tribolium castaneum.* It was found that against *S. oryzae* allylanisole was most toxic with LC_{50} 6.12 µl/L air and LC_{90} 9.04 µl/L air, whereas thymol was found to be most toxic against *T. castaneum* (LC_{50}=6.12 µl/L air and LC_{90} = 25.88 µl/L air) and carvacrol against *C. maculatus* (LC_{50} 1.81 µl/L air and LC_{90}= 4.26 µl/L air). The studies signify the species specificity of monoterpenes toxicity against storage insect pests.

5.2.2.2 Development of a olfactometer for post-harvest varietal screening against insects

Circular acrylic prototype (20 cm diameter with 24 wells, each well is 1cm (h×w) along with insect releasing chamber (5 cm w × 1cm h) was developed for post-harvest varietal screening of stored pests. This olfactometer was used for screening of 130 cowpea germplasms of which 43 were found moderately resistant.

5.2.3 Biological control

5.2.3.1 Feeding potential and life table studies of six spotted ladybird beetle, *Cheilo menessexmaculata* (F.) on cotton aphid, *Aphis gossypii* Glover

Grub stages showed significant difference for predation rate with each other by displaying increase in consumption with advancement of stage and attaining maximum consumption (101.43 ± 3.04) at fourth instar grub. Adult beetles exhibited high consumption rate over grub because of long duration of adult life with significant high consumption by female compared to male. Mean daily consumption analysed for all the stages of grub and adults showed significant superiority of female with the consumption of 43.13 ± 0.54 aphids/day, followed by fourth instar grub and male. Under life table studies, age-specific survival rate (lx) ranged from 0.03 to 0.91. The age-specific fecundity (mx), age-specific maternity (lxmx) and age-stage-specific fecundity (fx) of *C. sexmaculata* preyed on *A. gossypii* was maximum at 27 days age with the values of 14.63, 13.3 and 27.44, respectively. Life table studies showed intrinsic rate of increase (r) of 0.22, net reproductive rate of 383.6, mean fecundity of 790.19 and the mean generation time of 27.29 days.

5.2.3.2 Functional and numerical response of *C. sexmaculata* against the cotton aphid, *A. gossypii*

Polynomial logistic regression analysis of proportion of prey consumed (N_e/N_0) to the initial prey density (N_0) is resulted in significant negative linear parameters (P1< 0) and confirmed the type-II response for all the predatory stages. Female beetle has shown the highest coefficient of attack (a′) followed by male, fourth and other instar grubs. However, the fourth instar recorded lowest handling time (0.01 day) followed by female, male and other instar grubs. Pair-wise comparison of different stages of predator for the functional response parameters *viz*., coefficient of attack (a′) and handling time (T_h) revealed the significant difference among each other except for fourth instar grub which is non-significant with male for attack rate (a′), and female for handling time (T_h).

5.2.3.3 Screening of behavior modifying cues for attracting *C. sexmaculata*

Screening of selected attractive semiochemicals at different dosage *viz*., 10, 100, 300 and 1000 µg revealed highest attraction to n-heptane @100 µg followed by (E)-β-farnesene @ 10 µg with 550 and 400% response, respectively.

5.2.4 Insect physiology

5.2.4.1 Biochemical and hormonal regulation in diapause and nondiapause *Chilo partellus*

There was no significant difference in protein content at initiation of hibernation and aestivation, while during diapause it was significantly higher in aestivation as compared to hibernation. Protein content was significantly higher in aestivation followed by hibernation and nondiapause larvae, while no significant differences were observed in the pupae of these strains. The lipid content both at initiation and during diapause was significantly higher in hibernation as compared to aestivation. Among the diapause strains lipid content was significantly higher in the larvae of hibernation and pupae of aestivation as compared to their respective counterparts, while it was higher in the larvae and pupae of nondiapause as compared to diapause strains. The ecdysone titre was significantly higher in hibernation than aestivation larvae both at initiation and during diapause. However, the ecdysone titre was significantly higher in the larvae of hibernation and pupae of aestivation as compared to other strains. The ecdysteroidtitre was significantly higher in hibernation at diapause initiation, and during diapause it was higher in aestivation as compared to their respective counterparts. Further, the ecdysteroid titre was significantly higher in the larvae and pupae of aestivation as compared to respective stages of hibernation and non-diapause strains. The juvenile hormone was higher in aestivation both at initiation and during diapause. Further, the juvenile hormone was higher in the larvae of aestivation and pupae of non-diapause as compared to respective stages of other strains.

5.2.4.2 Characterization of *Chilo partellus* from different agro-ecological *regions* for establishing population guilds/biotypes

There was a significant variation in biological attributes and biochemical profiles of *C. partellus* populations from different geographical regions. Based on virulence and biological attributes, similarity index placed the *C. partellus* populations in five groups. Likewise, lipophilic and amino acid profiling also placed the *C. partellus* populations in five groups. However, the different clusters based on biological and biochemical attributes did not include populations from the same regions. Similarity index based on virulence, biological attributes, and amino acids and lipophilic profiles placed the *C. partellus* populations in six groups. The *C. partellus* populations from Hisar, Hyderabad, Parbhani and Coimbatore were distinct from each other, indicating that there are four biotypes of *C. partellus* in India.

5.2.4.3 Dynamics of eupyrene sperm descent/ movement in *Spodoptera frugiperda*

In virgin males, the eupyrene sperm bundles was maximum in 0-1day old and as the day progressed the sperm count reduced, the sperm bundles were noticed in seminal vesicle and ductus ejaculatory duplex only on 4th day old male. In case of mated males, the sperm bundles were visible on 2-3rd day only in seminal vesicle and duplex, it has increased progressively with the age of adult moth.

5.2.4.4 Development of meridic diet and standardized rearing procedure for fall armyworm, *Spodoptera frugiperda*

One chickpea based meridic diet was developed for mass rearing under laboratory conditions (27±1^{0}C, 65±5%RH and photoperiod of 14:10(L:D)h). The biological parameters of insects reared on meridic diet were found to be as good as natural host without any significant change in their biology and behaviour.

5.2.4.5 Impact of heat shock on reproductive physiology of fall army worm, *S. frugiperda*

The studies revealed that thermal stress did not have detrimental effect on immediate mortality and mating success. The fecundity of adults exposed to 42^{0}C at different durations differed significantly with highest egg production at 4 h followed by 6 h of exposure as compared to insects maintained under control conditions and 2 h exposure at 42^{0}C.

Stressed males' combination resulted in declined egg production irrespective of durations. Stressed female and stressed male combination had highest mating frequency with lower longevity indicating stressed males are in rush for dumping of spermatophores in female genital tract. Furthermore, high temperature exposure for longer duration (6 h) negatively affected the fertility percentage to a greater extent followed by 4 h and 2 h. Thus, it indicates that heat stress had detrimental effects on reproductive output of *S. frugiperda* especially through paternal effects thereby influencing its population dynamics.

5.2.4.6 Characterization of midgut bacterial community of *Pectinophora gossypiella* larvae

Proteobacteria, Firmicutes, and Actinobacteria were the predominant phyla in the midgut of pink bollworm. The alpha diversity analysis showed that the gut bacteria of males were diverse and rich as compared to that of females. Further, beta diversity analysis indicated that the gut bacterial communities of both larval groups were unique from each other. These findings are the maiden report on sex-based variation in gut bacteria in *P. gossypiella* larvae. Further studies on influence of midgut bacteria on toxicity of *Bacillus thuringiensis* revealed that DiPel® as well as *Cry1Ac* and *Cry2Ab* toxins along with antibiotics were less toxic to larvae of *P. gossypiella.*

5.2.4.7 Temporal and spatial dynamics of endosymbionts of *B.tabaci*

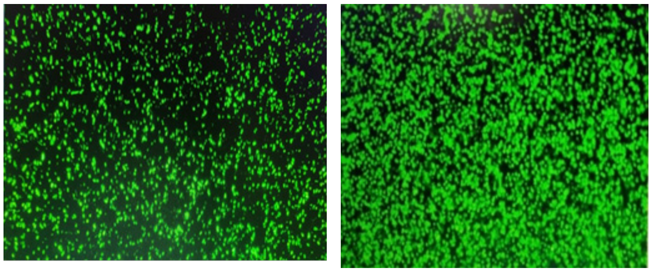
Studies on Temporal and spatial dynamics of endosymbionts of *B. tabaci*-Asia II-1 revealed significant variation in profile of key facultative endosymbionts of *B. tabaci* over seasons, across locations and host plants. Analysis of whitefly populations in Delhi over a period of 44 months (August 2017 to March 2021) revealed dynamic changes in infection frequency of endosymbionts as influenced by host, season and weather parameters. While, *Porteira* and *Arsenophonus* have shown to be stable while, drastic changes in *wolbachia* and *Rickettsia* were noticed with respect of infection frequencies. Low infections of *Wolbachia* were observed when compared to *Arsenophonus* and *Rickettsia* in the *B.tabaci* populations screened.

5.2.4.8 Host shift *vis a vis* endosymbiont frequency associated with whitefly, *B.tabaci*

Dynamic changes in infection frequency of endosymbionts in whitefly populations were triggered with respect to the changes in their host from cotton to tomato or cotton to brinjal. While, shift to Tomato was not favourable for *Wolbachia* but it supported the *Rickettsia*. Whereas, brinjal did not support for *Rickettsia;* However, *Rickettsia* reappeared when whiteflies are shifted from brinjal to tomato. Cotton, brinjal and tomato foster the infections by *Arsenophonus.* Interestingly, none of these favors *Cardinium* species.

5.2.4.9 Dynamic interaction of endophytes and endosymbionts in whitefly

Studies using Fluorescent in situ hybridization (FISH) techniques with two strains of GFP- tagged *Pseudomonas putida* revealed that whiefly *B.tabaci* aquire endophytes from plants and these endophytes could localise inside the bacteriocytes of *B.tabaci*. A combination of FISH, confocal microscopy and species-specific primers for GFP- tagged *Pseudomonas putida* established the uptake of the tagged bacterial strains by whitefly from previously inoculated cotton and tomato plant.



Transformation of plant endophyte strains with GFP Tomato endophytes:WF23 and WF 27

5.2.5 Insect toxicology

5.2.5.1 Insecticide resistance in *B. tabaci* populations

Adults of *B. tabaci* preconditioned at different temperatures *viz*., 27, 31 and 35 were then exposed to the LC_{50} dose of imidacloprid (103 ppm). The Specific activity of esterase and glutathione S-transferase (GST) was found significantly higher at 31 and 35^{0}C, whereas that of cytochrome was significantly reduced.

5.2.5.2 Baseline susceptibility of *S. frugiperda* against *Adhoc* insecticides

Larval mortality observed in all the tested insecticide treatments but lower level of tolerance observed in carbofuran 3G, phorate 10G and chlorantraniliprole. Field efficacy study on fall army worm revealed that, Spinetoram and chlorantraniliprole 18.5 SC. Whereas other insecticides Spinetoram, Spinosad 45 SC and Emamectin Benzoate 5 SG and found more toxic. Similarly, these insecticides found effective with higher per cent reduction (92.5 to 98.60%) of larval reduction as compared to other insecticides under study.

5.2.5.3 Semiochemical studies on whitefly, *Bemicia tabaci*

Orientation response of whitefly adults to synthetic volatiles was studied using a Y-tube olfactometer and Olfactometric preference index (OPI) was estimated. Among various treatments, the OPI value was significantly low for ocimene (0.64) indicating possible repellent activity of this volatile compound to whitefly, *B. tabaci*. Conversely, significantly higher OPI values were observed for (+)-α-pinene (1.71), γ-Terpinene (1.65), α-guaiene (1.59) and 4- Hydroxy-4 methyl-2- pentanone (1.56) suggesting the positive orientation of whitefly, *B. tabaci* to these compounds. Influence of these volatiles on oviposition was studied and significantly lower mean number of eggs (35.0±8.1 to 7.7 ± 2.3) was recorded on cotton plants treated with ocimene whereas higher numbers of eggs were recorded in γ – Terpinene treated plants.

5.2.5.4 Efficacy of newer insecticides against *Bemisia tabaci* in soybean

Three insecticides namely, spiromesifen 20 EC, diafenthiuron 50 WP and thiamethoxam 25 WG were evaluated and It was observed that all the insecticidal treatments were significantly superior to the control treatment in field conditions. The percentage reduction in the whitefly population was higher in spiromesifen followed by diafenthiuron and thiamethoxam.

5.3 NEMATOLOGY

5.3.1 Nematode and host-plant genomics

In the previous year, we generated a high-quality 36.86 million base pairs (Mbp) draft genome assembly of *M. graminicola. M. graminicola* which contained 17.83% repeat elements and showed 14,062 protein-coding gene models, 4,974 conserved orthologous genes, 561 putative secreted proteins, 49 RNAi pathway genes, 1,853 proteins involved in pathogen-host interactions, 1,575 carbohydrate-active enzymes, and 32,138 microsatellites. Five of the carbohydrate-active enzymes were found only in *M. graminicola* genome and were not present in any other analysed root-knot nematode genome. This improved genome assembly would facilitate comparative and functional genomics for *M. graminicola*.

Genetic resistance is the most viable and economical method to manage *M. graminicola* nematode. To find new management solutions, previously, activation tagging in rice was utilized to identify candidate gene(s) conferring resistance against *M. graminicola*. T-DNA insertional mutants were developed in a rice landrace (Acc. No. JBT 36/14), and four mutant lines showed nematode resistance. Whole-genome sequencing of JBT 36/14 was done along with the four nematode resistance mutant lines to identify the structural genetic variations that might be contributing to the incompatible interaction with *M. graminicola*. Sequencing on Illumina Novaseq 6000 platform identified 482,234 genetic variations in JBT 36/14 including 448,989 SNPs and 33,245 InDels. In addition, 293,238 to 553,648 unique SNPs and 32,395 to 65,572 unique InDels were found in the four mutant lines, of which 93,224 SNPs and 8,170 InDels were common between all the mutant line. Functional annotation of genes containing these structural variations showed that the majority of them were involved in metabolism and growth. Trait analysis revealed that most of these genes were involved in morphological traits, physiological traits and stress resistance. Additionally, several families of transcription factors such as FAR1, bHLH, and NAC, and putative susceptibility (S) genes showed the presence of SNPs and InDels.

5.3.2 Entomopathogenic nematodes

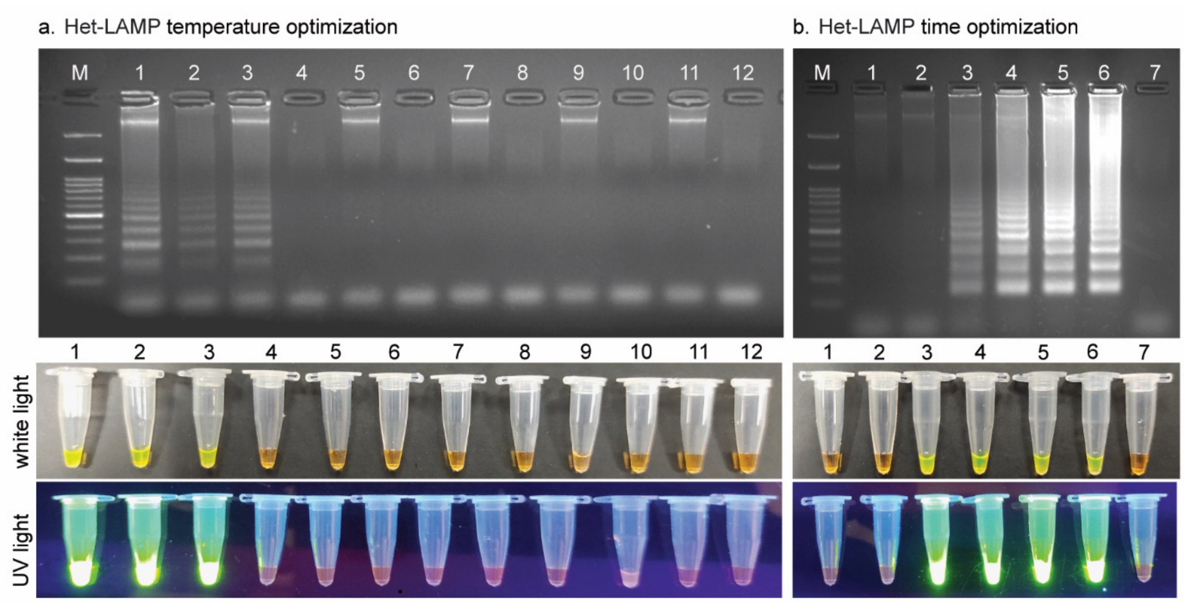
The genome of Indian entomopathogenic nematode *Heterorhabditis indica* was sequenced to create a genomic resource to facilitate comparative and functional genomics. The final *H. indica* genome assembly was 91.26 Mb size, comprising of 3,538 scaffolds with the N_{50} value of 217 Kb. Functional annotation resulted in the annotation of 9,596 genes. Identification of orthologous genes present in *H. indica* Hms1-i20 genome compared to four other nematode genomes revealed that *H. indica* shared 2,848 groups with *H. bacteriophora*, 4,526 with *C. elegans*, 4,059 with *S. carpocapsae* and 3,396 with *Oscheiustipulae*. This genomic resource will facilitate functional and comparative genomic studies and genetic exploration in *Heterorhabditis* nematodes.

RNA-sequencing was used to understand the *Heterorhabditis bacteriophora* nematode factors involved in symbiosis with *Photorhabdus luminescens*. A total of 754 differentially regulated transcripts were identified in symbiotic nematodes, and additional 12,151 transcripts expressed only in symbiotic nematodes. The symbionts of these EPNs, *Photorhabdus* bacteria are known to produce numerous protein toxins. Injection of the *Photorhabdus* bacteria and toxin into the haemocoel of *G. mellonella* produced different cadaver colours.

5.3.3 Nematode taxonomy, detection and diagnosis

Loop-mediated isothermal amplification (LAMP) assay was developed for rapid detection of potato cyst nematodes (PCN) *Globodera rostochiensis*, and entomopathogenic nematodes *Heterorhabditis* spp. and *Steinernema* spp. from total soil DNA. The LAMP assays were highly sensitive and specific for the target species and could be completed within 90 minutes.

In addition, populations of *Xiphinema* and *Longidorus* recovered from around the roots of hedge plant (*Euphorbia* sp.) and citrus grown at the IARI, New Delhi were characterized morphologically and



Optimization of *Heterorhabditis* (Het)-LAMP reactions for incubation temperature and time, 2a Optimization of reaction temperature at six different temperatures (65 to70 °C) with negative control for each temperature- Lane M, 100bp ladder; Lane 1, 65°C; Lane 2, No template control; Lane 3, 66°C; Lane 4, No template control; Lane 5, 67 °C; Lane 6, No template control; Lane 7, 68 °C; Lane 8, No template control; Lane 9, 69 °C; Lane 10, No template control;Lane 11, 70 °C; Lane 12, No template control; The bottom panel shows the visualization of amplified Het-LAMP products under normal light and UV lights, respectively treated with SYBR-Green I dye, 2b Optimization of time of reaction, Lane1 to 6-15 min, 30 min, 45 min, 60 min, 75 min, 90 min respectively; Lane-7, No template control. The bottom panel shows the visualization of amplified Het-LAMP products under normal light and UV lights, respectively treated with SYBR-Green I dye

molecularly for identification of the species. *Xiphinema basiri* Siddiqi, 1959 was identified based on morphology and gene sequences of ITS rRNA (accession number MZ566842), D2-D3 expansion segment of 28S rRNA (MZ568465), and *COI* of mtDNA (MZ562890) from the roots of hedge plant. Similarly, *Longidorus pisi was* identified from the rhizosphere of citrus grown in the horticultural farm. Nematode diversity in drip vs surface irrigation under protected and open cultivation system are being analysed at four sites of IARI farm. Results showed nematode abundance varied significantly both crops ($F_{3, 152}$ = 4.9, p< 0.05) and irrigation type ($F_{1, 152}$ = 33.4, p< 0.05). Higher nematode abundance was observed in drip irrigation system across all crops, *viz*., pomegranate, citrus, lettuce and chrysanthemum. Shannon diversity index varied significantly both across crops ($F_{3, 152}$ = 5.5, *p*< 0.05) and irrigation type ($F_{1, 152}$ = 6.4, *p*< 0.05) and their interaction ($F_{3, 152}$ = 6.2, *p*< 0.05). Nematode diversity was higher in drip irrigation system except in citrus. No significant differences were observed in terms of maturity index (t = -0.64, *p* = NS) or plant parasitic index (t = 0.70, *p*=NS) over irrigation types.

5.3.4 Nematode management

Root-knot nematode, *Meloidogyne incognita* is a severe problem in polyhouse cultivated tomato. In an attempt to identify nematode antagonistic microbes suitable for use as biocontrol agents in polyhouses, three isolates of *Bacillus subtilis*, and one isolate of *B. licheniformis*, (associated with uninfected tomato roots in root-knot infested polyhouses) exhibited significant juvenile mortality and disruption of nematode embryogenesis in *M. incognita* in lab assays. The bioefficacy trial conducted in polyhouse on tomato cv. Abhilash by soil application of an *B. subtilis* isolate not only caused significant reduction in nematode reproduction, but also showed significant enhancement in plant growth characters, compared to untreated control.

Likewise, two nematophagous fungal species isolated from Indian soils were identified as *Arthrobotrys thaumasia* and *Tolypocladium cylindrosporum* based on morphological characteristics and further confirmed using molecular markers. *In vitro* evaluation of *A. thaumasia* against *M. incognita* and *Caenorhabditis elegans* showed 82 and 73% parasitism respectively, whereas *T. cylindrosporum* gave 65.2 and 57.7% parasitism, respectively. Similarly, culture filtrates of *A. thaumasia* caused 57.7 and 53.7% mortality of *M. incognita* and *C. elegans*, respectively, whereas *T. cylindrosporum* caused higher mortality of 87.3 and 64%, respectively. Besides, greenhouse evaluation of both fungi against *M. incognita* infecting tomato significantly reduced nematode disease burden reflecting parasitic success measured as the total number of galls, egg masses, eggs per egg mass, and derived nematode multiplication factor. Application of *A. thaumasia* and *T. cylindrosporum* reduced nematode multiplication factor by 80 and 95%, respectively, compared with control.

General metabolite profiling of tested fungi using gas chromatography–mass spectrometry and ultra-performance liquid chromatography–quadrupole/time of flight mass spectrometry reported for the first time here showed presence of various volatile and non-volatile compounds with nematicidal activity, *viz*., trimethyl-heptadiene, methyl-hexadecanol, dodecadienal, decane, terpendole E, dodecane, acetamido-6-anthraquinone, and hexadecanol. Also, other compounds such as undecane, dibutyl-disulfide, octadecenal, paganin, talathermophilin, dactylarin, tolypyridone A, tolypyridone B, pyridoxatin, and destruxin were identified that are reported in the literature to possess antibacterial, antifungal, and insecticidal properties. This is the first report of the occurrence of both fungi from India and pioneer demonstration of *T. cylindrosporum* for root-knot nematode management.

5.4 AGRICULTURAL CHEMICALS

5.4.1. Development of active molecules for crop protection

5.4.1.1. Synthesis and bio efficacy evaluation of azole derivatives and azole based nano fungicides

Based on earlier *in vitro* studies, potent Isoxazole and Pyrazole derivatives were synthesized for field evaluation. Bio-efficacy evaluation against *Rhizoctonia* *solani* in field of rice cv. 1509 revealed that application of P-5F {3-(5-Fluoro-2-hydroxy phenyl)-1H-pyrazole} and P-14{3-(2-chloro phenyl)-1H-pyrazole exhibited lowest % disease incidence (PDI) as compared to control @ 1000 ppm at 30 DAI.

Azole (tebuconazole, fluconazole, bifonazole, isoconazole nitrate, ketoconazole, and itraconazole) based nano fungicides were prepared using polyethylene glycol (particle size in the range of 1–100 nm). *In vivo* bio-efficacy evaluation against *Rhizoctonia solani* in maize revealed that all of the nano fungicides were effective in controlling the Banded leaf and sheath blight disease with percent disease index values of 33.33 - 48.14% at 100 ppm as compared to inoculated control having disease index value of 77.77%.

5.4.1.2 Synthesis, characterization and bio efficacy evaluation of benzimidazolyl and triazolyl chromones

Two series of 2-(1-Pyrrolyl) chromones and 2-(1-Pyrazolyl) chromones were synthesized and characterized by ^{1}HNMR and ^{13}CNMR.

5.4.2. Bioprospecting of natural resources

5.4.2.1 Essential oil of *Kaempferia galanga* rhizomes for antifungal activity against *Aspergillus flavus*

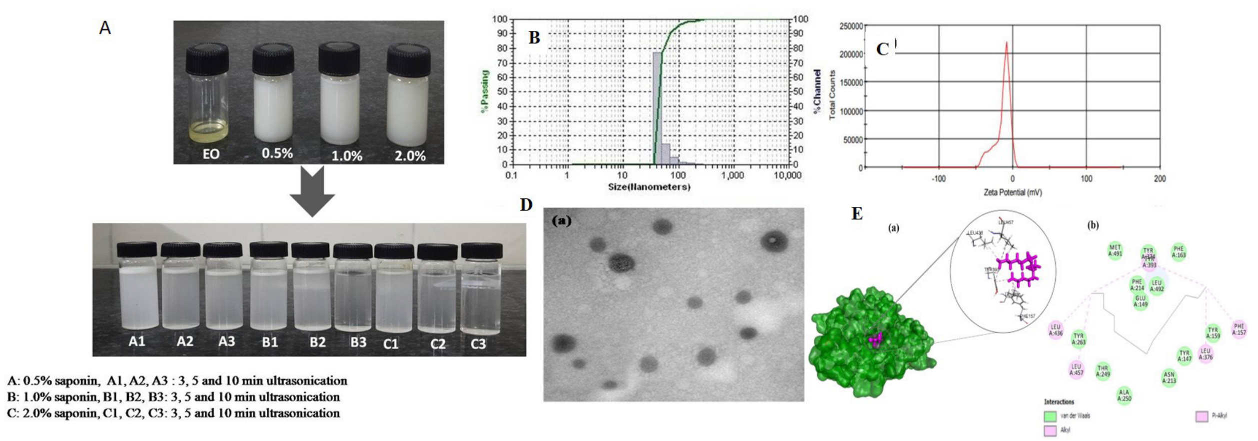
GC-MS analysis revealed that the essential oil primarily comprised of ethyl-*p*-methoxycinnamate (59.4±0.8%) and *trans*-ethylcinnamate (17.1±0.5%). Further nano emulsion of the oil prepared with saponin and characterized to determine intrinsic emulsion stability, mean droplet diameter, polydispersity index, zeta potential. NEs exhibited excellent efficacy against *A. flavus* 2547 (32.3 µg/mL) followed by *A. flavus* 2838 (45.6 µg/mL), *A. flavus* 8601 (56.2 µg/mL). *In silico* modelling revealed most promising binding complexes of 6IV7-ethyl-*p*-methoxycinnamate (-56.22 kcal/mol), 4QBJ-pentadecane (-50.15 kcal/mol) and 6JOH-ethyl-*p*-methoxycinnamate (-45.91 kcal/mol).

5.4.2.2 Identification of isolated compounds and pot experiment of nematicidal extract/oils/ compounds

Three pure compounds isolated from the fruits of *Syzygium aromaticum* were identified as eugenol, oleanolic acid and biflorin. Pot experiments of citronella oil, geranium oil and different extracts of *Anonna squamosa*, together with two pure compounds namely citronellol and citronellal found previously promising in *in-vitro* bioassay was carried out and results showed promising nematicidal activity at 500 to 1000 ppm against *Meloidogyne incognita* and *M. graminicola*.

5.4.2.3 Behaviour of anthocyanin in inclusion complex

In order to delineate the behaviour of anthocyanin in β-cyclodextrin during the development of



Development and characterization of nano emulsion of essential oil of *K. galanga* rhizomes Aa) Standardization of nano emulsion with saponin B) Average droplet diameter of nano emulsion C) zeta potential of the nano emulsion D)TEM image of the spherical nanodroplets E) Molecular docking analysis

inclusion complex, molecular docking study was conducted. Source of anthocyanin used for the study was *Berberis* sp. While predicting the role of non-bonding forces between the selected anthocyanins and β-CD, molecular docking study revealed that delphinidin-3-glucoside (d3g) and β-CD complex was thermodynamically more stable than cyanidin-3-glucoside (c3g) complex. Further, no significant changes in the bio accessibility of anthocyanin from inclusion complex was observed, but stability has been greatly improved by inclusion complex formation.

5.4.2.4 Screening of alkaloids against *Thrips palmi* by *in silico* and *in vitro* approaches

A study was conducted to understand the effects of alkaloids against thrips, and to develop a safe and effective controlled release formulation for its management. Seven alkaloids namely, atropine, cinchonine, noscapine, piperine, reserpine, strychnine and tropinone were screened against *Thrips palmi* by both *in silico* and *in vitro* approaches. Molecular docking studies of the alkaloids against four target proteins of *T. palmi*, namely, HSP70, EnoPh, CathB and CysP established tropinone as the best putative inhibitor. Bioassay of tropinone by leaf dip method revealed its LC_{50} values as 1262.6 and 734.9 µg/mL at 24 and 48 h, respectively.

5.4.3. Development of formulations for smart delivery of crop protection inputs

5.4.3.1 Bioinsecticidal EPN formulations

Performance of newly developed lipid metabolism arrestant enriched EPN powder formulation for termites' management in wheat and chickpea at IARI field confirmed biocontrol potential of developed product at par with the synthetic pesticide (chlorpyriphos). Molecular validation study of effect of lipid metabolism arrestant compound (LMA) on beta oxidation of fatty acids revealed that in *Steinernema abbasi* (= *thermophilum*), as compared to fresh nematode IJs, most genes involved in Beta oxidation showed a higher down-regulation at 24 and 168 h (7 days), suggesting the inhibitory role of the LMA compound in beta oxidation in IJs.

5.4.3.2 Enrichment and field evaluation of Premix suspension concentrate (Tebuconazole and cycocoel) PGR formulation

Multilocational field evaluation of SC product at three locations (IARI New Delhi, RS Karnal, RS Indore), in C-306 tester wheat variety confirmed significant height reduction of tester variety C-306 (20-25%), as compared to control, besides registering yield increase due to application of formulation at two growth stages (first internode and flag leaf stage). Expression analysis revealed that the combination inhibits kaurene oxidase and kaurenoic acid oxidase proteins in GA pathway.

Performance of SC (TBZ+CCC) ready to use product in C-306 and HD 3226

5.4.3.3 Ready to use Sachet product for stored grain pests of mustard

Sustained vapour release sachet product (VP) formulation and dispenser system were developed utilizing the indigenously available carriers and plant-based bio actives having insect fumigant and/or killing properties. Bio-efficacy of prepared VP sachet formulation assessed under closed container storage conditions demonstrated 100% mortality of insect populations and no population build-up was observed in any of the formulation treated container up to 6 months of study.

5.4.3.4 Bio-efficacy evaluation of *Rhynchosia minima* essential oil on white fly

The essential oil was extracted from the aerial parts of the plant *Rhynchosia minima*. The extracted essential oil was then formulated as nano emulsion and tested for its bio-efficacy on white fly. For bio-efficacy evaluation essential oil concentration ranged between 312.5-5000 ppm. Maximum mortality of around 80% was observed at 5000 ppm, whereas no mortality was observed under controlled conditions.

5.4.3.5 Evaluation of Pusa Hydrogel and SPG-1118 on Cauliflower under field conditions

Pusa Hydrogel and SPG-1118 hydrogels were evaluated for their water productivity enhancement potential under field conditions in cauliflower. In this experiment, the effect of hydrogels for enhanced water productivity potential was observed under mulch and non-mulch conditions using drip irrigation system. The curd yields were higher in hydrogel treated plots as compared to the control plots.

Cauliflower in control and SPG-1118 treated plots

5.4.4. Analytical methods and protocols for detection/quantification of contaminants

5.4.4.1 Evaluation of matrix effect on pesticide residue estimation in representative crop and member crops under crop group 27 (Herbs)

Crop grouping is a step forward in the direction to enable processes to expand label claims to those crops where the given pesticide has effective role in pest management. The crop groups are established when residue data for certain representative crops are used to establish pesticide tolerances for a group of crops that are botanically or taxonomically related. A modified QuEChERS extraction and cleanup method was optimized for trace level quantification of 100 pesticides using UPLC-MS/MS and validated on coriander leaves, curry leaves (representative crops in crop group 027 *i.e.*, Herbs). The performance of the developed method evaluated in their respective member crops (mint leaves, tejpata leaves. The dilution of extracting solvent (acetonitrile) was much effective in reduction of matrix effect in coriander leaf and curry leaf. Use of anhy. $MgSO_4$, PSA and GCB was found most effective as clean up agent for coriander matrix and anhy. $MgSO_4$, PSA and C-18 for curry leaf matrix. The optimized method for coriander and curry leaves performed equally good or even better in mint leaves, tejpata leaves, respectively and thus can be utilized effectively for member crops.

5.4.4.2 High affinity molecularly imprinted polymers (MIPs @ MAA-EGDMA) for selective recognition of tricyclazole in rice and water

Tricyclazole selective MIPs have been synthesized by precipitation polymerization technique using three different functional monomers. Sorption kinetics followed second pseudo-order model (R^2 = 0.999) and the data fitted better to Freundlich isotherm (R^2 = 0.991). High values of α (19.43-24.90) and β (23.88-35.03) indicate selectivity of MIPs over NIPs toward tricyclazole in presence of other structural analogues. The MIPs were successfully applied to separate tricyclazole from fortified samples of rice and water, with recovery percentage of 91.64 and 88.04%, respectively.

5.4.4.3 Analytical method for the trace level analysis of sulfamethoxy pyridazine

An analytical method was developed for the trace level analysis of sulfamethoxypyridazine in soil using modified QuEChERS extraction and clean-up technique followed by HPLC-VWD or LC-MS/MS analysis. Method LOQ was found to be 0.05 µg/g.

5.4.4.4 Removal of pesticides from water using magnetite-activated charcoal

To remove three most commonly used pesticides namely azoxystrobin (AZX), nitenpyram (NIT), and thiamethoxam (TMX) from water, a magnetite-activated charcoal composite was synthesized and characterized using FT-IR, SEM, and TEM. Maximum sorption was observed for nitenpyram (K_F= 3706.8) followed by azoxystrobin (K_F= 3288.51) and thiamethoxam (K_F= 3250.87). After three reusability cycles only 8-9% decline in sorption was observed. Such magnetite-activated charcoal composites are cost-effective, eco-friendly alternatives for removal of pesticides from wastewater.

5.4.4.5 Computational chemistry assisted synthesis of metal organic framework(s)

Molecular simulation of metal organic frameworks (MOFs), ZIF-8 and MIL-53, followed by their laboratory synthesis and characterization (using SEM, TEM and FT-IR) were undertaken. The yields for the ZIF-8 and MIL-53 were 73 and 71%, respectively.

5.4.4.6 Bioremediation of petroleum hydrocarbons

Accidental contamination of agricultural field by crude oil due to broken pipe lines/ explosions make these field unfit for growing crops. Bioremediation is considered to be safe and economical approach. Therefore, degradation of crude oil hydrocarbons was studied using microbes isolated from a contaminated soil. Among 17 bacteria and 3 fungi isolated from a crude oil contaminated soil, *Pseudomonas* sp. and *Bacillus amyloliquefaciens* (bacteria) and fungus *Aspergillus sydowii* were identified as best degraders of crude oil aliphatic hydrocarbons in medium. Bio-formulations (3 types) of these microbes were as effective as free cultures in degrading total petroleum hydrocarbons in fortified sandy loam soil and naturally contaminated loamy soil. The half-life values were decreased by 70-80% (fortified soil) and 57-65% (naturally contaminated soil).

5.5 WEED MANAGEMENT

5.5.1 Chemical weed management options in conservation agriculture-based rice-wheat system

The CA-based triple cropping system involving zero-tillage direct seeded rice (ZTDSR) with mungbean residue (MBR)-zero tillage wheat (ZTW) with rice residue (RR)-zero-tillage mungbean (ZTMB) with wheat residue (WR) combined with weed control option such as pyrazosulfuron at 0.025 kg/ha as pre-emergence (PRE) followed by cyhalofop at 0.100 kg/ha as early post-emergence (EPOST) followed by bispyribac at 0.025 kg/ha as post emergence gave comparable rice yield with transplanted puddled rice (TPR) and could be a viable substitute to TPR. This combination led to significant reductions in weeds interference and parasitic nematodes infestation in rice crop over the years. Similarly, in wheat, the above CA-based triple cropping system with zero tillage combined with tank-mixture applications of clodinafop-propargyl 0.060 kg/ha + metsulfuron-methyl 0.004 kg/ha at 30 days after sowing (DAS) was more effective than others in controlling diverse weeds, resulting in higher wheat grain yield. Therefore, pyrazosulfuron (PRE) followed by cyhalofop (EPOST) followed by bispyribac (POST) in rice and tank-mixture application of clodinafop-propargyl 0.060 kg/ha + metsulfuron-methyl 0.004 kg/ha at 30 DAS in wheat may be recommended for better control of weeds in both rice and wheat and their system productivity.

5.5.2 Weed dynamics and management in CA-based cropping systems

Direct-seeded rice (DSR) witnessed insurgence of weed species such as *Dactyloctenium aegyptium*, *Dinebraretro flexa*, *Leptochloa chinensis*, and *Eleusine indica*, which were not found in PTR, whereas *C. difformis*, *C. iria* were found only in PTR. The application of pyrazosulfuron at 0.025 kg/ha PE followed by (*fb*) cyhalofop-butyl at 0.100 kg/ha at 20 DAS *fb*bispyribac-Na at 0.025 kg/ha at 25 DAS could control grassy (by 72%), broad-leaved (by 60%) and sedge (by 43%) weeds and increase rice yield by 125%. *Medicago denticulata* an annual weed occurred in very high density in mustard under maize-mustard system, and another annual weed, *Malva parviflora* was seen first time in wheat under the maize-wheat-mungbean system in sandy loam soil. *Medicago denticulata* was controlled by pendimethalin @ 1.0 kg/ha and *Malva parviflora* was controlled by pre-mix carfentrazone+metsulfuron.

5.5.3 Effective weed management in wheat under a CA-based maize-wheat system

Weed management was studied in wheat under zero-till residue-laden conditions in a 10-year-old conservation agriculture (CA) based maize-wheat cropping system. The wheat crop in the experiment was dominated with *Malva parviflora* weeds. To manage this *M. parviflora* four weed control treatments were planned and adopted in wheat. Results revealed that the tank mix application of carfentrazone 0.020 kg/ha + metsulfuron-methyl 0.004 kg/ha at 30 DAS was highly effective towards reducing weed dry weight of *M. parviflora* and achieved highest weed control efficiency. This herbicide treatment resulted in ~31% higher wheat yield over un-weeded control.

5.5.4 Bio-efficacy and selectivity of New Low dose herbicides in Maize and their residual effects in succeeding wheat crop

An investigation was carried out during 2020-21 to evaluate the bio efficacy and selectivity of new low dose herbicides applied at 15-30 days after sowing of *kharif* maize and their residual effects in succeeding wheat crop. The experimental field of maize crop was heavily infested with, *Trianthemapor tulacastrum, Commelina benghalensis, Digera arvensis, Cyperus rotundus, Dactyloctenium aegyptium, Echinochloa colona* and *Cynodon dactylon*. Results revealed that tank mix pre-emergence application of atrazine and pendimethalin (0.5 + 0.75 kg/ha) and early post-emergence application (15 DAS) of tembotrione at 120 g/ha were found superior treatments in reducing weeds infestation and in increasing grain yield of maize.The succeeding crop of wheat was found full of *Avena ludovician* and *Phalaris minor* amongst grass weeds but amongst broad leaved weeds *Rumex dentatus, Malva parviflora, Chenopodium album* and *Chenopodium murale* were found in majority The residues of atrazine (1.0 kg/ha) and tembotrione (120 g/ha) applied in maize resulted significant reduction in weeds population in succeeding wheat crop. Direct effect of post-emergence application of tank mix combination of sulfosulfuron + metsulfuron (20 + 4 g/ha) in wheat resulted the highest increase in grain yield of wheat over weedy check.

6. BASIC AND STRATEGIC RESEARCH

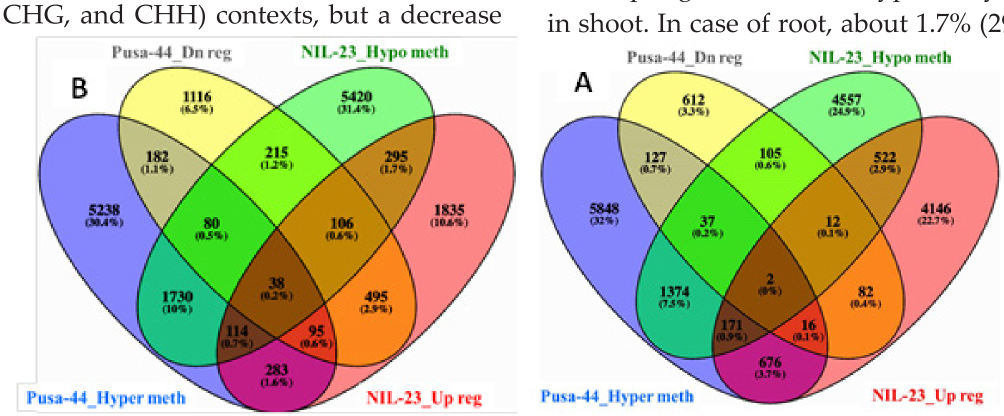
The basic and strategic research at IARI was focused on phenomics and high throughput phenotyping for identification of superior donors and breeding lines, development of CRISPR-Cas9 genome editing platform in rice nutritional quality of pearl millet, rice, wheat and soybean functional validation of genes and mapping QTLs for biotic and abiotic stress tolerance, the physiological basis of crop yield, mitigation studies on climate change, development of remote sensing and GIS techniques for assessment and management of crops and natural resources. This section briefly covers some of the significant achievements in these areas.

6.1 PLANT MOLECULAR BIOLOGY

6.1.1 Epigenomics of phosphorus use-efficiency in rice

Whole methylome analysis of a pair of contrasting rice genotypes viz. Pusa 44 (P- deficiency sensitive) and NIL-23 (P-deficiency tolerant) in different contexts indicated that CG methylation comprised the highest percentage (54%) of differentially methylated cytosines (DmCs) in both leaf and root tissues, followed by methylation at CHG (~24%) and CHH (~6%) contexts. Allocation of DmCs to genomic regions revealed ~77% of DmCs in upstream, ~6% in gene body and ~17% mapped to downstream region. Context-specific analysis of methylome data revealed a major change in methylation to occur in leaf tissue of NIL-23 in CG context. In root of the P-deficiency tolerant (NIL-23) genotype, no significant change was observed in any of the (CG, CHG, and CHH) contexts, but a decrease in methylation was observed in all three contexts in P deficiency sensitive genotype (Pusa-44).

To assess the effect of methylation on gene expression, methylome and transcriptome data were analyzed and it was observed that hypermethylation of promoter, particularly proximal-promoter region, down-regulates its expression. While, hypomethylation results in its up-regulation. Moreover, in shoot, about 3% (522) of the DEGs in NIL-23 but 0.7% (127) DEGs in Pusa-44 were regulated through epigenetic changes via DNA (de) methylation. However, only two genes showed varietal differences under P-starvation with respect to the epigenetic regulation of P-starvation responsive genes in the shoot. These two genes were observed to be down-regulated due to hypermethylation in the promoter region, particularly in CHH context, in Pusa-44, while they were up-regulated due to hypomethylation in NIL-23 in shoot. In case of root, about 1.7% (295) of the DEGs

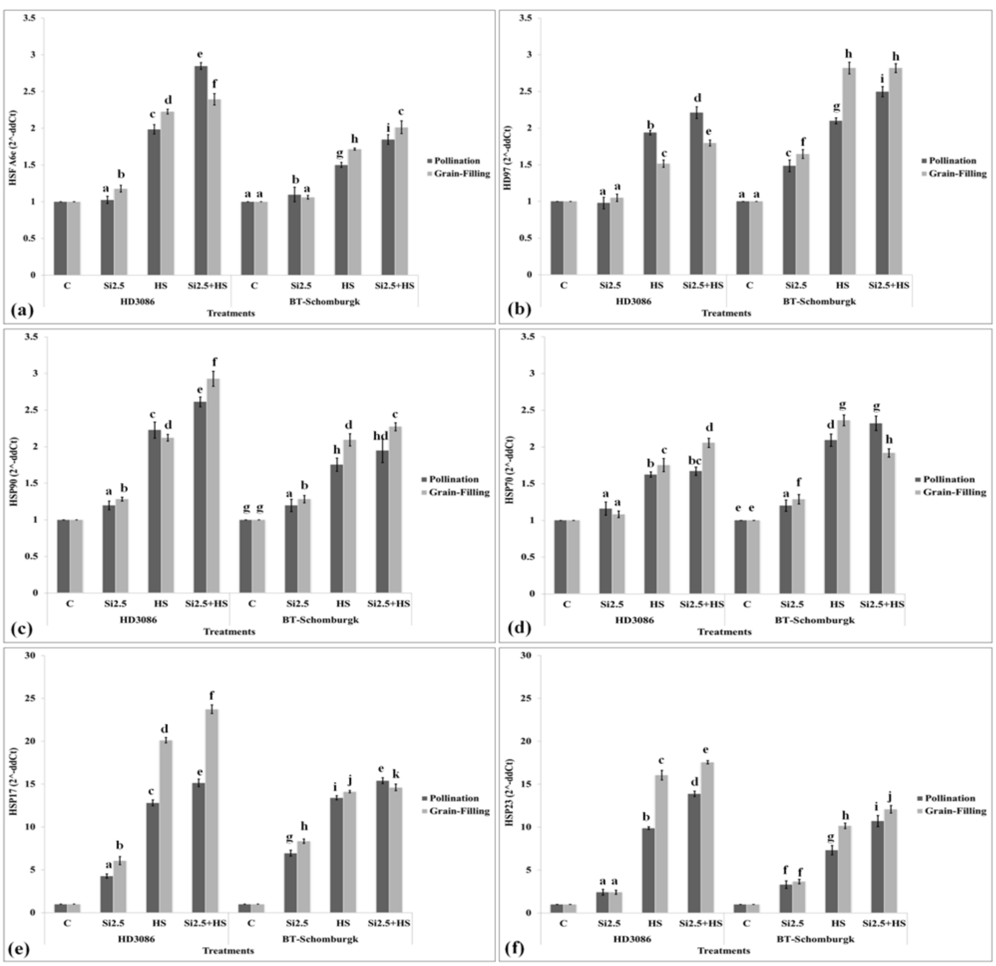


Correlation between DNA methylation (in CHH context) and gene expression at variety level in the contrasting rice genotypes, (A) in shoot, and (B) in root. Plants were grown hydroponically with 0 ppm Pi or 16 ppm Pi for 45 days.

in NIL-23 and 1.1% (182) in Pusa-44 were regulated through epigenetic changes via DNA (de)methylation in the promoter region, particularly in CHH context. Moreover, 38 genes were observed to show varietal differences under P-starvation with respect to epigenetic regulation of P-starvation responsive genes. These genes were observed to be down-regulated due to hypermethylation in Pusa-44, while they were up-regulated due to hypomethylation in NIL-23 in shoot.

6.1.2 Effect of exogenous silicon on alleviating the effect of terminal heat stress in wheat

Exogenous application of 2.5 mM Si was observed to be very effective in modulating the thermotolerance and quality of the grains. The application of Si induced the expression of heat-responsive TFs, and HSPs. The maximum expression of HSF A6e was observed in response to Si2.5+HS during pollination stage in thermotolerant cvHD3086.The maximum expression of HD97 TF was observed in response to Si+HS during grain-filling in susceptible cvBT-Schomburgk. The HSP17 (sHSPs) showed maximum fold-increase in the expression in response to Si treatment under HS in both the cultivars.The starch biosynthesis pathway associated genes were downregulated under HS; the percent decrease was lower under Si treatment. The biochemical traits linked with grain quality were also induced by Si treatment under HS; the effect was observed more pronounced in wheat cv. HD3086, as compared to BT-Schomburgk. The Si application was observed to have negative effect on the activity of catabolic enzyme like amylase, though HS enhanced



Application of exogenous Si alleviate the effect of heat stress in wheat cvs. at pollination and grain filling stage of growth and development

the activity of the enzyme. The exogenous application of Si can be effectively deployed as a technology for mitigating the effect of terminal HS in wheat.

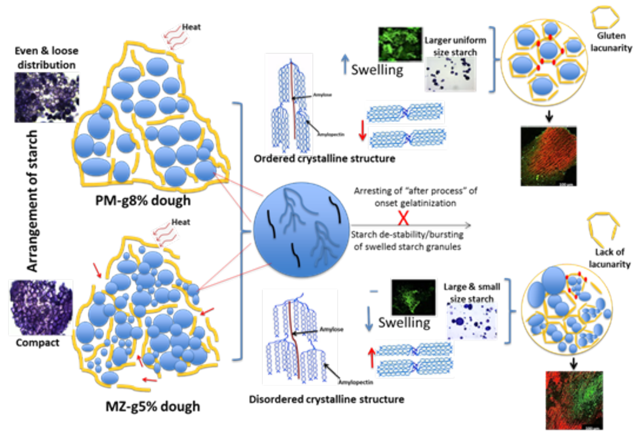
6.1.3 De novo transcriptome sequencing to dissect candidate genes associated with pearl millet grain quality

Whole transcriptome sequencing (WTS) of developing grains of diverse genotypes of pearl millet – Chadi Bajri, Damodar Bajri, Pusa-1201 and Pusa composite-701 was performed. A BioProject based on the WTS was submitted to NCBI with accession no. PRJNA625418. Based on the annotation of rice database, 42,355 CDS were identified. Ninteen transcripts identified were annotated to be polyphenol oxidase (PPO), 52 transcripts of lipase, 47 transcripts of lipoxygenase and 75 transcripts of peroxidase. Sixteen transcripts showing homology with starch synthase, 23 showing homology with SBE, 8 transcripts of SDE, and 17 transcripts of AGPase were identified. Three putative lipase genes from pearl millet - Lip-1 from *cv.* Pusa 1201 [acc. no. MW424395], Putative Lipase-3 gene from Chadhi Bajri [acc. no. MW424396], Lipase variant-1 from pearl millet *cv.* Pusa1201 were cloned and sequence submitted to NCBI Genbank. A putative starch synthase-IV gene from pearl millet landrace Damodhar, Bajri (acc. no. MW505986) was cloned and characterized. Comparative analysis showed significant variation (~3%) in the amino acid sequences of SS-IV in landraces and hybrids. Significant increase in the expression of SS-IV in developing grains of landrace Damodhar Bajri was observed till seed hardening stage, and thereafter a decrease was observed.The expression of SS-IV was relatively lower in hybrids, as compared to landraces.

6.2 BIOCHEMISTRY

6.2.1 Optimization of onset of gelatinization to enhance the dough and chapatti quality of gluten reconstituted pearl millet and corn flour

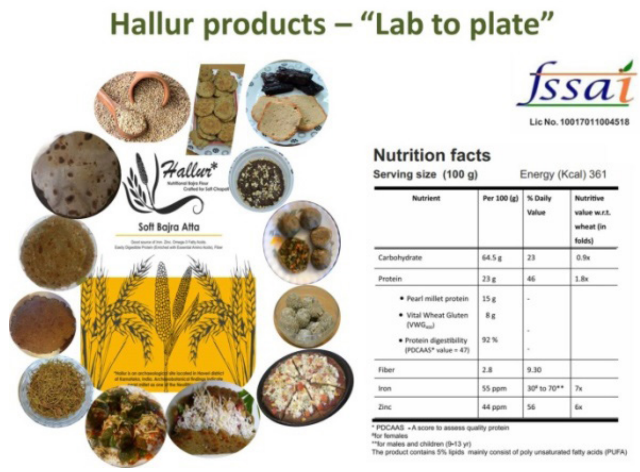
The aim of this study was to utilize most nutritious pearl millet and maize flour as routinely as wheat flour by improving the dough quality through gluten reconstitution wherein onset of gelatinization process (OGP) is promoted. Both the dough systems *viz.*, gluten reconstituted pearl millet (PM-g) and maize (MZ-g) at 8% and 5% respectively showed a dominance of elastic behaviour (G′) over the viscous one, a typical behaviour of wheat flour dough. Compared to MZ-g dough at 5%, higher G′ was observed in PM-g dough. This behaviour could be explained by higher concentration of gluten that is reconstituted in pearl millet flour and higher swelling power of starch at prevalent gelatinization temperature during dough making process.



Heat induced onset of gelatinization during the process of dough kneading enhanced dough quality, however size of the starch, its distribution and molecular structural arrangement in dough matrix affected the dough stability

6.2.2 Development of wheat gluten based "Soft Nutri-cereal Atta"

To address poor dough and chapatti making quality of pearl millet and maize flour and its utilization in bakery industry, a technology of vital wheat gluten (VWG) reconstitution in bajra and makka flour was developed and products namely "Hallur: 'Soft Bajra Atta" and Makai: Soft Makka Atta" were as good as wheat in viscoelastic properties for superior dough and chapatti making quality**.** The different proportion of VWG regeneration was optimized in bajra flour and tested for several dough quality parameters. The 7-10% VWG was optimized for bajra flour, depending on the purity and water absorption capacity of the extracted VWG. Similarly, different percentage of VWG were optimized and further tested for dough



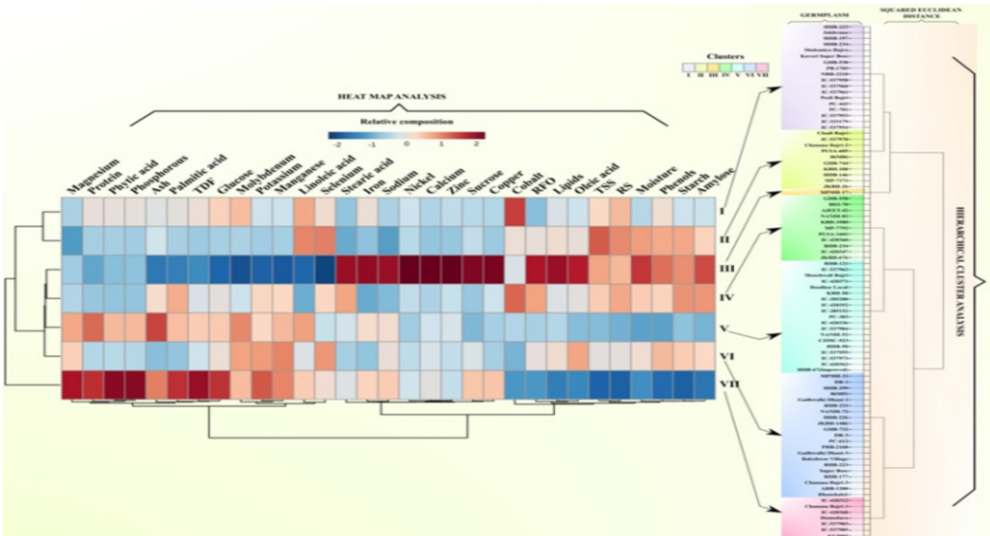
Nutrient	Per 100 (g)	% Daily Value	Nutritive value w.r.t. wheat (in folds)
Carbohydrate	64.5 g	23	0.9x
Protein	23 g	46	1.8x
• Pearl millet protein	15 g	-	
• Vital Wheat Gluten (VWG)	8 g	-	
• Protein digestibility (PDCAAS* value = 47)	92 %	-	
Fiber	2.8	9.30	
Iron	55 ppm	30# to 70**	7x
Zinc	44 ppm	56	6x

Regeneration of VWG viscoelasticity property in gluten free flour and Nutritional facts of Hallur: Soft Bajra Atta

Nutrient	Per 100 (g)	% Daily Value
Carbohydrate	74.30 g	27
Protein	13.84 g	28
Maize protein	8.84 g	-
Vital Wheat Gluten (VWG)	5.00 g	-
Fiber	7.30 g	29
Phosphorous	348.0 mg	28
Magnesium	139.0 mg	33
Potassium	325.0 mg	9
Thiamine (Vit. B1)	0.42 mg	40
Riboflavin (Vit. B2)	0.20 mg	15
Pyridoxin (Vit. B6)	0.62 mg	31
ß-carotene	1.30 mg	13

Nutritional facts of Makai: Soft Makka Atta

quality parameters in makka flour to make it as superior as wheat flour. Here 5 to 10% VWG reconstitution was optimized. Both "Hallur: 'Soft Bajra Atta" and Makai: Soft Makka Atta" with all the bestowed nutrition, can now be consumed with variety of recipes. The product was commercialized by signing MOU with a private company.



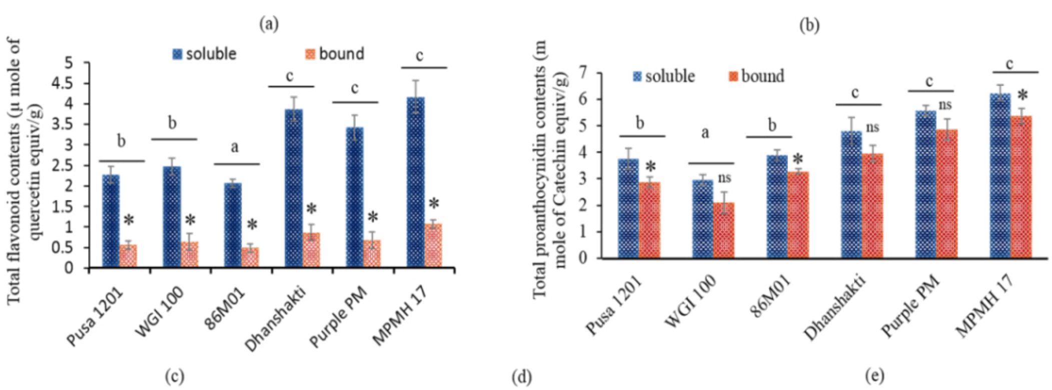
The germplasm grouped into 7 clusters using hierarchical cluster analysis along with the mean value of their nutritional attributes as indicated through a heat map

6.2.3 Analysis of nutritional composition of pearl millet genotypes

The nutritional composition of 87 diverse Pearl millet (*Pennisetum glaucum* (L.) R. Br.) genotypes including landraces and commercial varieties were assessed. The results indicated a substantial variability in total carbohydrates, protein, lipids, anti- nutritional factors and minerals. Multivariate analysis using hierarchical clustering analysis (HCA), and principal component analysis (PCA) was used to decipher the diversity of these attributes across germplasm. The germplasm displayed distinct region specific variations in their nutritional content. The analysis can form the basis for the commercialization and utilization of pearl millet using efficacious breeding strategies.

6.2.4 Profiling of phenols (µg/g flour) in differently coloured pearl millet genotypes

Estimation of total phenolics in terms of their different fractions like bound, soluble (free and esterified) were carried out in differently coloured pearl millet genotypes. MPMH 17 had maximum phenolic content followed by purple PM, Dhanshakti, 86M01, Pusa 1201 and WGI 100. The distribution and contents of ferulic, p-coumaric, and gallic acids of soluble (free and esterified) and insoluble bound phenolic fractions of pearl millet. In all the varieties analyzed, the following order of distribution, ferulic acid > p-coumaric acid >gallic acid and insoluble bound > esterified >free fractions was prevalent. Profiling of phenolic acids in pearl millet genotypes revealed that



Characterization of phenolic content and composition of bound and soluble (free and esterified) fractions in pearl millet genotypes (A) Quantification of total flavonoid content (TFC) (B) Quantification of total pro-anthocyanidin content (TPAC)

the insoluble bound fraction of MPMH 17 had the highest ferulic acid content(1690 µg/gof flour) which was about 3 times higher ($p<0.05$)than that of white colored pearl millet WGI 100 (576.2 µg/gof flour). The esterified and free ferulic acid content ranged from 257.6 to 543.9 µg/g of flour and 74.9 to187.1 µg/g of flour, respectively.

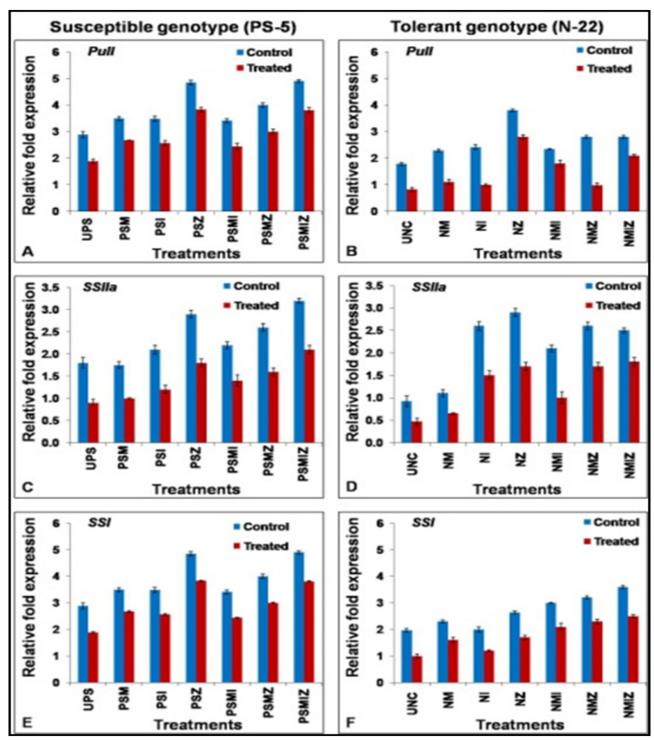
6.2.5 Microgreens: A nutraceutical food for better health and wellness

Microgreens are the emerging crop-based nutraceutical foods of the 21st century, produced from seedlings of edible vegetables and herbs. An economically viable production methodology was standardized for the production of microgreens (MGs) from six crops (Brassica, Mungbean, Lentil, Pearlmillet, Red radish and Red cabbage) and parameters temperature, humidity and light/dark cycle for the optimum growth of microgreens were standardized. The nutritional evaluation of microgreens revealed that their mineral and antioxidant potential is 2-3 & 4-8 fold higher respectively than their seeds/mature counter parts and they are 4-6 times richer in vitamins as well. A "NutriGreens kit" named 'TinyFields' having the seeds of different Brassica family (Mustard, red cabbage and red radish) was also developed and commercialized.

Tiny Field Nutri Green Kit Developed at Division of Biochemistry

6.2.6 Effect of seed priming on expression analysis of the key genes involved in starch metabolism under drought stress in the contrasting rice genotypes

A study was conducted to study the ameliorative effect of seed priming on starch biosynthesis in two contrasting rice genotypes viz. PS-5 (drought susceptible) and N-22 (drought tolerant). Pullulanase (Pull) gene expression was found to be more in control samples of primed and unprimed as compared to their drought treated samples in both the genotypes. Pull gene expression was found to be increased in all the primed samples under both control and drought stress condition as compared to the unprimed samples. Under drought stress condition, maximum increase in Pull gene expression was observed in Zn primed samples of PS-5 (2.1-fold) and N-22 (3.5-fold) as compared to their unprimed drought treated sample. Expression of starch synthase IIa (*SSIIa*)and starch

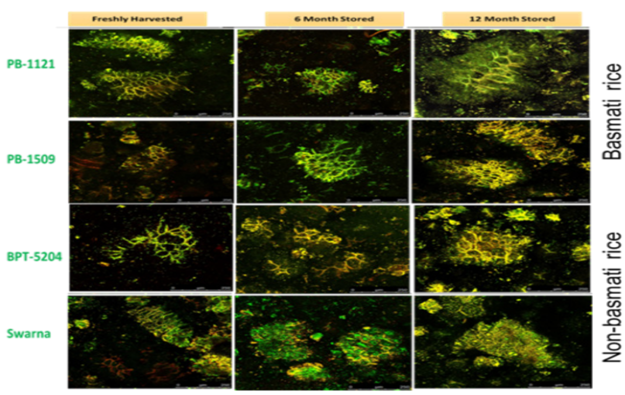


Expression analysis of genes involved in starch biosynthesis at reproductive stage in contrasting rice genotypes- N-22 (drought-tolerant) and PS-5 (drought-susceptible) after drought stress imposition against priming with 100µM of methyl jasmonate (MJ), and 1.5% each of Zinc sulphate and Iron sulphate.

synthase I (*SSI*) was found to be increased in primed samples under control and drought stress condition in both the genotypes as compared to their unprimed samples. In PS-5, after drought stress imposition the maximum increase in SSIIa expression was observed in MJ+Fe+Zn primed samples (2.3-fold) and SSI was found to be more in Zn primed samples (2.1-fold) while in case of N-22, 4.3-fold and 2.5-fold increase in both SSIIa and SSI gene expression was observed in MJ+Fe+Zn primed samples as compared to their unprimed drought treated sample.

6.2.7 Physico-chemical analysis of aged rice for improved quality traits

Viscosity profiling, texture analysis and matrix interaction analysis of freshly harvested Basmati (PB-1121 & PB-1509) and Non-basmati (BPT-5204 & Swarna) rice varieties were compared with one year aged (06 & 12 months stored) rice grain. Further, the confocal laser scanning microscopy (CLSM) images of the cooked rice slurry revealed that matrix component interaction was more in 6 and 12 month aged samples of all the rice varieties (PB-1121, PB-1509, BPT-5204 and Swarna) as compared to freshly harvested rice. Protein and lipid interact with starch by being embedded within the internal starch matrix.



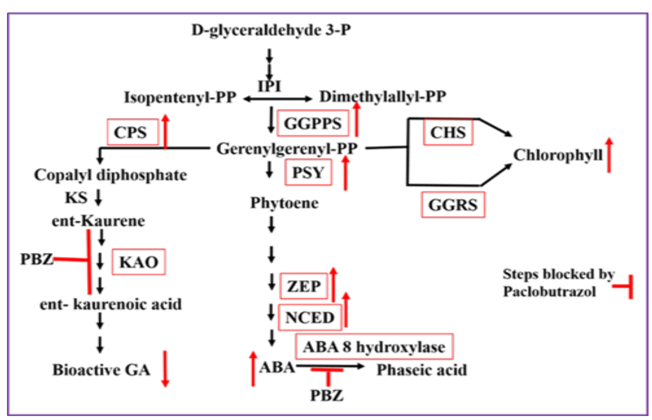
CLSM images of the cooked rice slurry stained with FITC (green), Rhodamine B (yellow) and Nile blue (red). Starch is labeled by FITC in green, protein labeled by Rhodamine B and lipids are labeled with Nile blue dye

6.2.8 Profiling of seed protein quality in chickpea and pigeonpea genotypes

In general, Desi chickpea genotypes were found to have lowest Amino Acid Score (AAS) for lysine (35.98% to 71.79% with an average score of 59.29) whereas Kabuli genotypes had lowest AAS for threonine (17.69% to 118.48% with an average of 49.45%). The AAS for essential amino acids in the studied pigeonpea genotypes showed a wide variation, wherein the AAS of the S-containing amino acids and lysine was found to be less in most of the varieties with a mean value of 78.15% and 89.43% respectively. In Desi chickpea genotypes, the Protein Digestibility Corrected Amino Acid Score (PDCAAS) ranged from the 0.42 to 0.86 while the lowest and highest value of PDCAAS in Kabuli chickpea were 0.18 and 0.74 respectively. The analysed pigeonpea genotypes were found to have a PDCAAS (%) in the range of 0.39 to 0.85 with BSMR 736 and ICP 87 showing the lowest and highest value respectively.

6.2.9 Ameliorative effect of paclobutrazol (PBZ) application on under drought stress in rice

The effect of PBZ application (100 ppm), at anthesis stage, on mitigating water-deficit stress (WDS) in rice was studied. The PBZ application helped the plant to maintain RWC, MSI, total chlorophyll, CSI, GA and total antioxidant activity at higher level under WDS. Besides, the PBZ application decreased hypermethylation and increased drought tolerance efficiency (DTE) and decreased drought susceptibility index (DSI). The Geranylgeranyl pyrophosphate synthase (GGPPS) was induced by PBZ leading to enrichment of GGPP pool under WDS. Also, PBZ upregulated phytoene

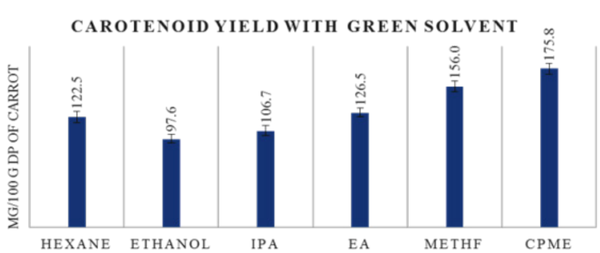


Effect of optimized dose on genes involved in diversification of GGPPS under WDS

synthase (PSY), zeaxanthin epoxidase (ZEP) and 9-cisepoxycarotenoid dioxygenase (NCED) and downregulated ABA-8'-hydroxylase (ABA8OX) thereby increasing ABA. PBZ upregulated both CHS and GGR, and increased both Chl content and stability.

6.2.10 Development of protocol for extraction of pro-vitamin A carotenoids using green solvents

A method was standardized for the extraction of carotenoids from carrot sample using five green solvents *viz.* Cyclopentyl methyl ether (CPME), 2-methyltetrahydrofuran (2-MeTHF), isopropyl alcohol (IPA), ethanol and ethyl acetate (EA) than n-hexane. After optimization of all the parameters- highest carotenoid content (286.6 mg/100g DP) was observed in CPME. After screening of 15 elite lines/ hybrid/ cultivars it was found that among screened carrot- Rasna (Private sector hybrid) is richest in total carotenoid content (248.8 mg/100 g DP) followed by Ashwini (private sector hybrid – 245.2 mg/100 g DP) and Nantes (241.5 mg/100 g DP). Lowest contents of carotenoid were found in Pusa Meghali (121.4 mg/100 g DP). The results support the potential of green solvents as an alternative for extraction of carotenoids.



Efficacy of different green solvents for extraction of carotenoids

6.2.11. Enhancing the nutritional, functional and sensory quality of soymilk using probiotic fermentation approach

Five novel strains of *Weissella* sp. were procured and soymilk fermentation was done using individual cultures. In addition, mixed fermentation with selected strains *viz., Weissella confusa* 30082b and *Lactobacillus rhamnosus*, having functional similarity, was also carried out and the effect of probiotic fermentation with single and mixed cultures (1% (v/v) single *Weissella* sp. and 1% (v/v) of *L. rhamnosus* and *W. confusa* 30082b) showed an increase in total antioxidant activity, reduction in phytic acid levels, increase in free mineral content, bioconversion of isoflavone glycosides into more bioavailable aglycones (daidzein, glycitein, genistein), and reduction in hexanal- a major compound responsible for low sensory quality of soymilk. The magnitude of enhancement being higher in mixed culture than single culture. The scanning electron microscopy (SEM) and rheological analysis showed the improvement in textural properties- measured in terms of rigidity- smoothness and pore size of the product, especially in co-culture fermented soymilk. The results of the study suggest that the mixed culture fermentation could be an ideal strategy for improving the health benefits of soymilk.

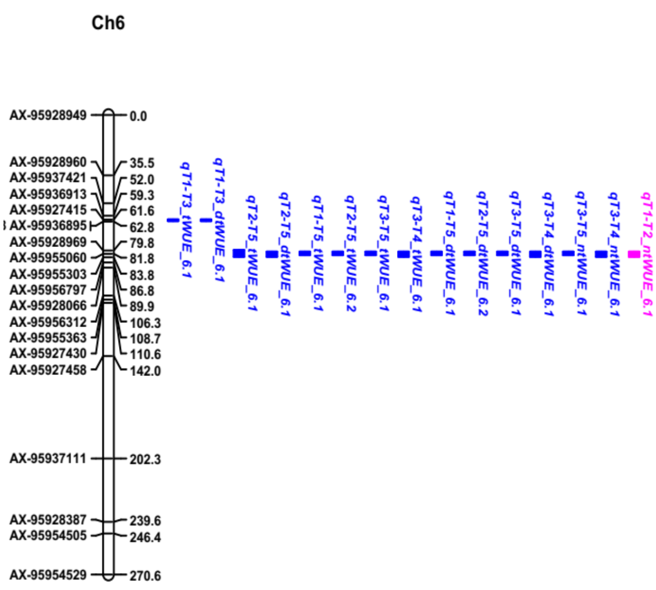
6.3 PLANT PHYSIOLOGY

6.3.1 Development high throughput phenotyping protocols

"Web-SpikeSegNet": Deep Learning based approach was developed for automated spike detection and counting from RGB images in wheat at Phenomics facility. A software was developed & applied for copy right. This method will be useful for automated phenology detection and yield prediction in wheat. Drone based phenotyping for identifying wheat RILs for N-deficiency and drought stress was standardized in a field experiment with wheat crop during *rabi* 2020-21. Two hundred seventy eight (278) RILs of Raj3765*HD2329 were grown in field under control, N-deficiency and drought stress, and phenotyped with RGB, thermal, multispectral and hyperspectral sensors placed in a drone. Based in the spectral similarity of RIL with parents, JM Spectral Distance was calculated to identify RILs similar to either parent.

6.3.2 Phenomics of water use efficiency (WUE) in rice

An experiment was conducted at Nanaji Deshmukh Plant Phenomics Centre with 170 RILs of BVD109 x IR20 of rice to identify QTLs and superior RILs for diurnal and nocturnal transpiration and WUE under irrigated and moisture deficit stress. Two hundred forty (240) traits were extracted. Parents showed contrast for WUE traits, and transgressive segregants were identified. The RILs and parents were genotyped with 50K genotype Chip. About 1859 SNPs were used for linkage map construction and Inclusive composite interval mapping (IciM) method was used for QTL mapping. Totally, 112 QTLs were detected for 240 traits and the phenotypic variation explained (PVE %) under the influence of these QTLs was in the range of 3.06 to 42.38%. Transpiration Efficiency (TE) and WUE QTLs were derived from BVD 109. Under drought conditions, 36 QTLs were mapped with a phenotypic variation of 6-43%. Candidate genes in the region of MTA were identified.



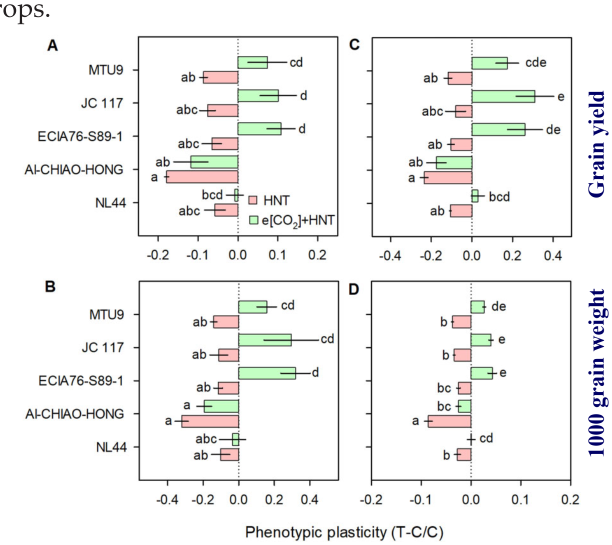
Water use efficiency (WUE) in rice though Phenomics

6.3.3 Phenomics of nitrogen use efficiency (NUE) in rice

Three hundred (300) diverse rice genotypes were phenotyped with and without recommended N fertilizer at Nanaji Deshmukh Plant Phenomics Centre and 2.88 TB phenome image data acquired using RGB, IR & NIR sensor. Sixty eight (68) i-traits associated with NUE were identified. Four rice genotypes (BAM3690, CAUVERY, Suweon and Eypo) were identified as elite NUE donors on the basis of multi-trait index which in turn is based on factor analysis and genotype-ideotype distance (MGIDI). Genome-wide association study with three models (GLM, MLM, FarmCPU) across first subset with 150 diverse rice genotypes collected from the 3,000 rice genomes project have identified two major QTLs associated with nitrogen uptake efficiency (qNUpE2.1 and qNUpE12.1) and nitrogen utilization efficiency (qNUtE2.1, qNUtE9.1).

6.3.4 Carbon dioxide responsiveness mitigates rice yield loss under high night temperature (HNT)

Earlier, a field experiments to identify [CO_2] responsiveness from a diverse indica panel comprising 194 genotypes under different planting geometries, 23 different genotypes were tested under different planting geometries and e[CO_2] using a free-air [CO_2] enrichment facility and the most promising genotypes and positive and negative controls were tested under HNT and e[CO_2] + HNT. The [CO_2] genotypes revealed significantly lower ($P < 0.001$) impact of HNT in high [CO_2] responsive (HCR) genotypes compared to the least [CO_2] responsive genotype. A systematic investigation highlighted that active selection and breeding for [CO_2] responsiveness can help to maintain carbon balance which may counter balance HNT-induced yield losses in rice and potentially other C3 crops.

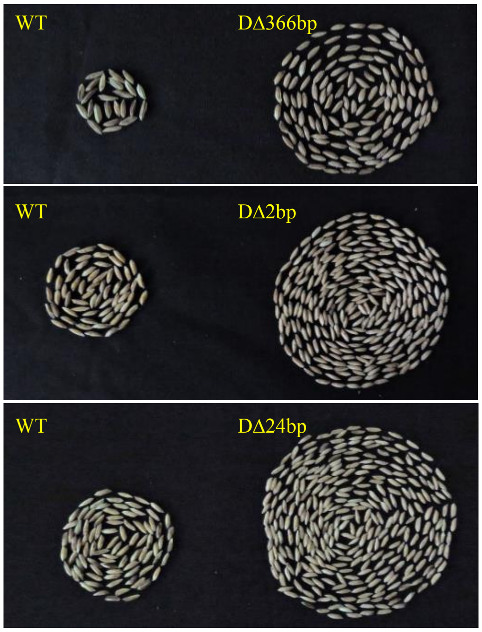


6.3.5 Functional validation of Isopentenyl transferase 9 (IPT9) gene for stress tolerance in rice

Genome-wide analysis of Isopentenyl transferase gene was carried out in rice cv. Nagina 22 and IPT9 gene cloned from and overexpressed by using stress inducible RD29A promoter in rice cv. MUT1010. Transgenic plants showed enhanced tolerance to drought and salt stresses at both seedling stage and reproductive stage. IPT9 overexpressing plants showed reduced dark induced senescence in planta. Transgenic lines maintained better plant water status, photosynthesis, spikelet fertility and yield under drought and salt stresses.

6.3.6 CRISPR-Cas9 genome editing in rice

Genome editing in rice was carried out to create mutants of DROUGHT AND SALT TOLERANCE (DST) gene, Protein Phosphatase 2C Clade A, miRNA169a, Farnesyl transferase and putative Phytomelatonin Receptor 1 (PMTR1) genes in rice cv. MTU1010. Previously, a genome edited deletion mutant (deletion of amino acid residues from 184 to 305 in frame, dst184-305) of DST gene was developed, which showed reduced stomatal density and enhanced salt tolerance at seedling stage. Additional mutants with one base insertion, and 2 and 24 bp deletion alleles of DST were also developed. Mutants and WT plants grown in the same pot were subjected to salt (200mM) and drought (-90KPa) stress at reproductive stage. All mutant alleles showed higher tolerance than that of WT plants to both salt and drought stresses under pot culture conditions, and showed reduced whole plant transpiration.



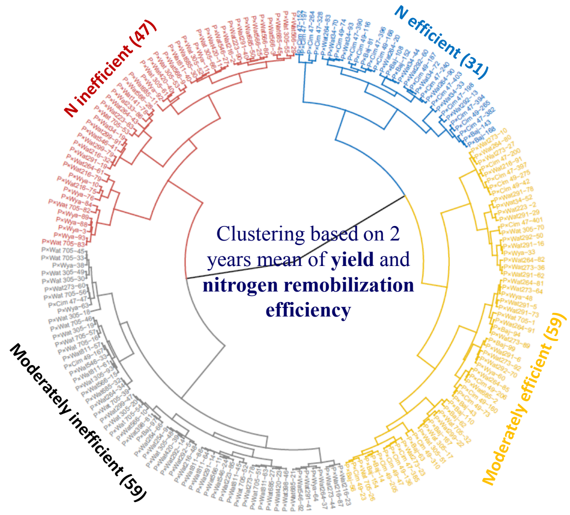
Yield of WT and genome edited mutants under salt stress

6.3.7 Heat labile gluten protein fractions in wheat under high night temperature

An experiment was conducted to evaluate the impact of high night-time temperature (HNT; +3 °C over the ambient), from heading to maturity, on seed storage protein fractions in wheat flour especially gluten which consists of gliadin and glutenin fractions that determine the bread making quality of flour. High night-time temperature decreased the proportion of α-gliadin in both the inferior and superior grains of all genotypes. However, Low molecular weight (LMW) glutenin decreased only in superior grains under high night-time temperature conditions.

6.3.8 Genome wide association studies for identification of genes for phosphorus related indices in diverse bread wheat genotypes

Marker-trait association study on 82 diverse bread wheat accessions which were phenotyped at low and sufficient P earlier was carried out using 35K Wheat Breeder's Affymetrix array. Traits such as total biomass per plant, grain weight per plant, and phosphorus (P) related indices were considered. The high-quality



Genome wide association studies in diverse bread wheat genotypes

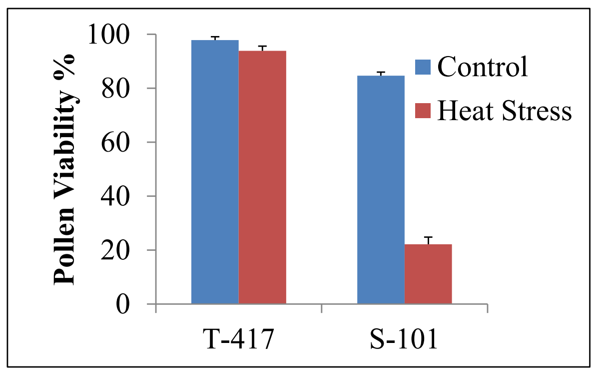
single nucleotide polymorphisms across the genomes were evenly distributed. Structure analysis revealed three subpopulations. Genome wide association analysis revealed 78 marker-trait associations, but only 35 of them passed Bonferroni correction, and a total of 294 candidate genes. These genomic regions could be utilized for improving bread wheat to tolerate low P stress through marker-assisted selection.

6.3.9 Phenotyping of Indian rice accessions for reproductive stage high temperature stress tolerance

A set of 281 Indian rice accessions were planted in pots during kharif season (2020-21) and raised under natural environment. At booting stage, one set of accessions was exposed to high temperature stress (38.4±1.1°**C) inside** controlled greenhouses to identify tolerant donors. Based upon earlier findings, eight contrasting accessions were characterized for pollen viability, anther microscopic visualization and spikelet fertility. Tolerant genotypes showed marginal reductions in pollen viability and spikelet fertility as compared with sensitive types. Box plot analysis of all 281 accessions showed 78 and 10 per cent spikelet fertility under control and high temperatures stress conditions. Large number of accessions showed zero spikelet fertility under high temperature stress as compared with control. Similar response was observed for panicle yield, membrane stability and canopy temperature. On the basis of changes in spikelet fertility, panicle grain yield and heat susceptibility index under high temperature stress, three accessions were identified as tolerant to high temperature stress.

6.3.10 Evaluation of rice N22 mutants for higher leaf photosynthesis rate

Leaf photosynthesis rate (Pn) was measured in 74 rice N22 mutants during anthesis to early grain filling stage. It ranged from 9.88 µmole m^{-2} s^{-1} (mutant MG273) to 23.6 µmole m^{-2} s^{-1} (mutant MG463) as compared to the wild type N22 (16.54 µmole m^{-2} s^{-1}). Further, investigation on the CO_2 response, expressed in terms of ACi curve, of WT and mutant showed that there appeared no difference in CO_2 compensation point but significant difference in the *in vivo* rate of carboxylation of Rubisco was observed . The study indicated that a highly efficient Rubisco may not be present in the mutant but the difference observed may be due to the higherSpecific leaf weight (SLW) of mutant as compared to the WT. At gene expression level also, this was associated with a higher expression of Rubisco small subunit gene (*rbcS*) compared to the WT. The high Pn mutant also showed a lower expression of Rubisco activase gene (*rca*) as a compensatory mechanism to higher expression of rubisco. A higher expression of Fructose-1,6-bis-phosphatase gene (fbp) involved in sucrose synthesis was observed in the high Pn mutant. This was also associated a high leaf vein density and narrow leaves in high Pn mutants. Further studies on photosynthesis and source-sink relations in the high Pn rice N22 mutants and WT will be undertaken.



Evaluation of rice N22 mutants for photosynthesis rate

6.4 GENETICS

6.4.1Wheat

6.4.1.1 Mapping QTLs for component traits of drought tolerance

In a RIL derived from a cross SYNTHETIC 46 x HD 2932, two major QTLs *viz.*, *Q.Gy.iari-4B* and *Q.Tgw.iari-7A* for grain yield and thousand grain weight have been reported.

6.4.1.2 GWAS Studies yield and grain parameters

The genomic regions associated with the yield, thousand grain weight (TGW) and grain length were identified through association mapping of a panel comprising 192 and 236 genotypes and using 35k genotypic data information. The studies revealed significant QTLs and QTNs which were identified in previous studies and also few of the new regions.

6.4.1.3 Evaluation of advance breeding lines of wheat for yellow rust resistance

Among 175 CVT entries of wheat evaluated against different stripe rust pathotypes, 40 were found to possess seedling resistance to 110S84 pathotype, 37 entries possessed resistance to 110S119, whereas 25 were recorded resistant to 238S119. The data revealed 238S119 pathotype of stripe rust as the most virulent.

6.4.1.4 Response of breeding lines for adult plant rust resistance under PDSN

Among 767 breeding lines evaluated under PDSN at rust hot spot Dhaulakuan and Katrain, 69% have shown resistance, whereas 1% moderately resistant to stripe rust under natural condition. The incidence of stripe rust ranged 5MS-20MS in 28% of the lines. Only six lines have shown high incidence of stripe rust (≥20S) at adult plant stage.

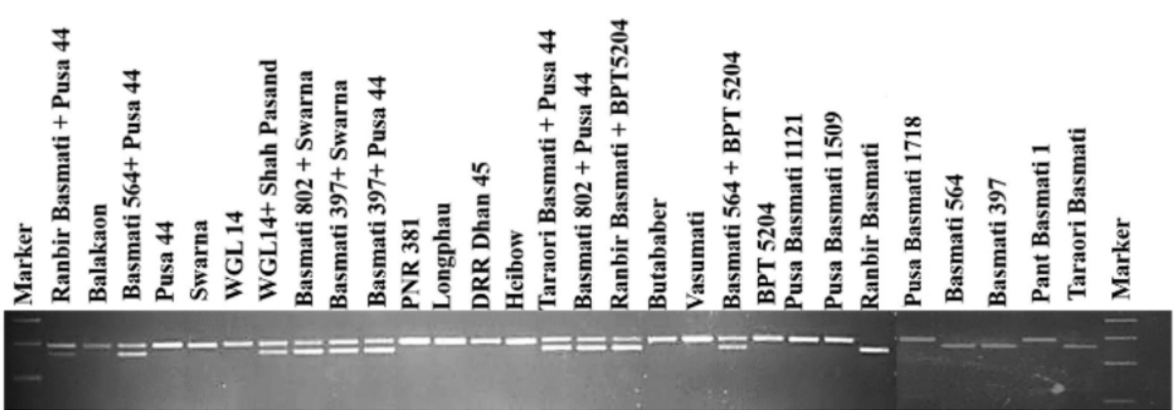
6.4.1.5 Doubled haploid (DH) wheat lines developed

Nineteen DH lines of wheat, developed through *Imperata cylindrica* mediated chromosome elimination technique, were evaluated for different traits. Wide character variability was obtained in the DH lines with respect to plant height, spike length and yield. All the lines showed high uniformity. Also, new crossing of F_1's with *Imperata cylindrica* resulted into the development of 121 haploid plants. These plants were hardened and subsequently 52 haploid plants survived but after doubling with colchicine only six doubled haploid plants were produced.

6.4.2 Rice

6.4.2.1 Development and validation of PCR based in dCAPS marker for novel *lox3-b* null allele

A dCAPS marker, HB-LOX3 was designed based on the C deletion which is a functional nucleotide polymorphism (FNP) in the *LOX3* gene associated with rapid rancidity of rice bran. The forward primer (5′ GAACCACCACAGCAACGAGTTCTTCtT3′) contained a mismatch at 26 bp position that introduced a restriction site, TTAA for SaqAI enzyme while the sequence of reverse primer of dCAPS marker was 5′CGCCTACCAAACGACGTGAA3′. The primer pair amplified a 291bp fragment which was cleaved into two fragments of sizes 265 bp and 26 bp in *LOX3*-null individuals harbouring the C deletion while in those accessions lacking the deletion, the 291 bp fragment remained undigested. A set of 70 basmati rice accessions was assayed using the dCAPS marker for its validation. From the dCAPS assay, it was observed that two traditional Basmati accessions *viz*.



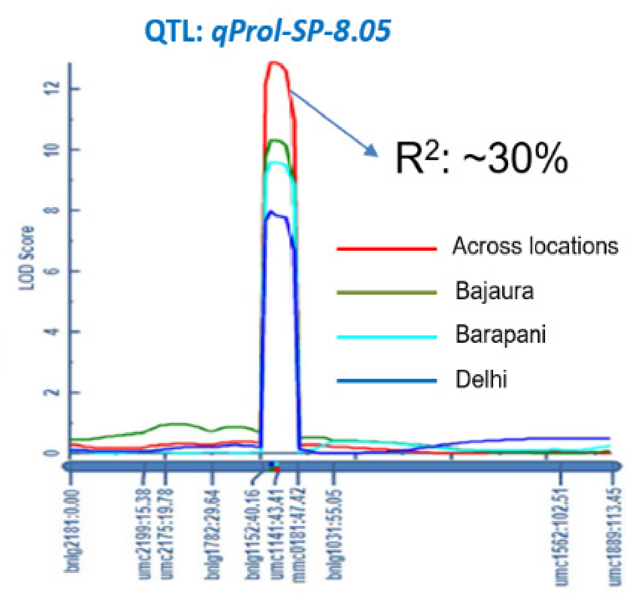
Gel picture depicting the efficiency of dCAPS marker in differentiating C deletion based *LOX3* null and functional alleles

Taraori Basmati and Haryana Basmati 2 carried the C deletion in addition to the nine previously known accessions. This validates the functionality of dCAPS marker designed in this study to differentiate the rice accessions carrying *LOX3*-null and *LOX3*-functional alleles as well as to identify heterozygotes carrying one copy each of null and functional allele at the *LOX3* locus. Hence the marker can be effectively utilized in the marker assisted breeding programs aiming at the development of improved rice varieties with better storability.

6.4.3 Maize

6.4.3.1 Identification of novel QTL for prolificacy in 'Sikkim Primitive'

'Sikkim Primitive' a prolific maize landrace with 5-9 ears per plant was discovered in 1960s, however, the loci governing the prolificacy were not identified. A major QTL (bin: 8.05) explaining 31.7% phenotypic variation in 145 F2:3 of MGUSP101 × HKI1128 and 29.2% of phenotypic variance in 138 F2:3 individuals of MGUSP101 × UMI1200 was identified and was designated as 'qProl-SP-8.05'. This new QTL would pave the way for development of highly prolific baby corn hybrids.



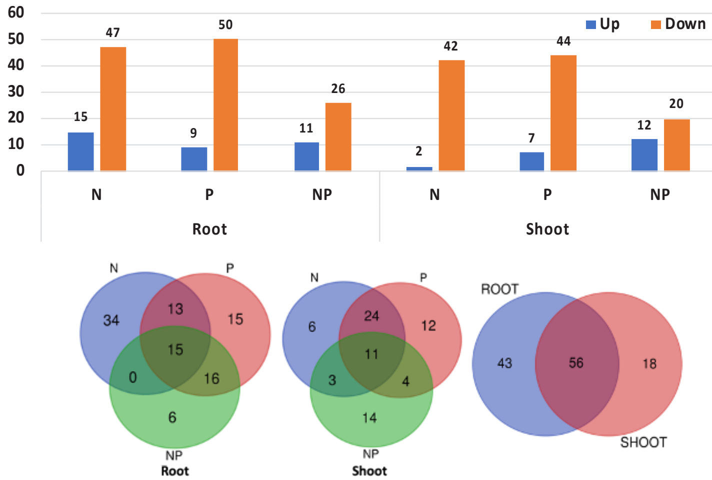
Detection of QTL (qProl-SP-8.05) for prolificacy in 'Sikkim Primitive'

6.4.3.2 Development of allele-specific marker of fea2 governing kernel row number (KRN) in maize

A next-generation sequence-based approach was followed to sequence the *fea2* gene in AI 535 and AI 536 having contrast KRN. Allelic variation for KRN was detected and at nucleotide position 1311 that bears transversion (A-T) in comparison with reference gene (B73), resulted in amino acid changes (serine to cysteine) in low (AI 535) vis-a-vis high KRN genotypes (AI 536). An allele-specific marker (1311fea2.1) was designed and validated to differentiate the genotype having A/T transversion that leads from the high KRN genotype to the low. After validation, the primer was designated as an allele-specific primer to high and low KRN genotype in maize.

6.4.3.3 miRNA profiling for low N and low P stress interactions in maize

The high-quality genome-wide small RNA-seq data is generated for nitrogen (N), phosphorous (P) and combined nitrogen phosphorous (NP) starvation and uploaded in the NCBI GEO database linked to GEO ID of GSE186592. A total of 797.44 million reads of small RNA-Seq data was generated with an alignment of 95.92-98.47% with the reference genome. The genome-wide miRNA-Seq profiling for N, P, and NP deficiencies showed 62, 59 and 37 miRNAs, respectively in root and 44, 51 and 32 miRNAs, respectively in the shoot. The differential expression of miRNAs across all the stress treatments resulted in 43 and 18 miRNAs expressing specifically in root and shoot, respectively; whereas 56 miRNAs were differentially expressed under both root and shoot tissues. The study revealed that members of miRNA families, zma-miR166, zma-miR169, zma-miR395 and zma-miR827 were differentially expressed in both root and shoot tissues across N, P and NP starvation. In comparison, the zma-miR399 family showed differential expression in P-deficiency specific manner in both root and shoot tissues. Most importantly, the investigation in toto revealed 21 novel mRNAs which are otherwise not reported previously



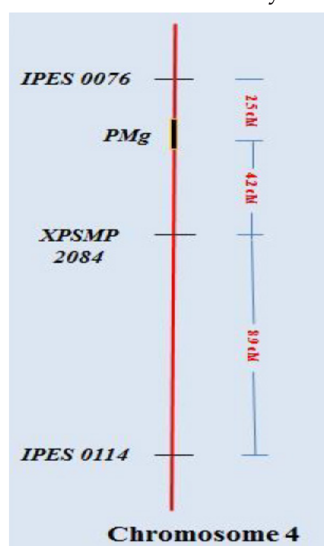
miRNA	Chromosome	Start	End
Low N (Root)			
new-miR319_2	3	2020814	2020922
new-mir-novel6	7	132641621	132641694
new-mir-novel1	B73V4_ctg121	20816	20885
Low N (Shoot)			
new-miR9774	B73V4_ctg121	20819	20883
new-mir-novel4	2	98025936	98026000
new-mir-novel6	2	16789331	16789436
Low P (Root)			
new-mir-novel1_1	B73V4_ctg121	20817	20885
new-mir-novel1_2	2	9670098	9670163
new-mir-novel2	7	142286589	142286751
new-miR171bA	9	100082908	100083011
Low P (Shoot)			
new-miR171b	9	100082908	100083011
new-miR1861h	9	145888832	145888972
new-miR6027	4	49669801	49669882
new-miR9774	B73V4_ctg121	20819	20883
new-mir-novel5	6	7404503	7404604
new-mir-novel6	3	156033862	156033952
new-mir-novel8	8	7722199	7722273
Low N&P (Root)			
new-mir-novel2	2	176912961	176913031
Low N&P (Shoot)			
new-mir-novel1	5	94725826	94725984
new-mir-novel5	5	158822618	158822695
new-mir-novel7	1	288423362	288423498

The genome-wide expression snapshot of differentially expressed miRNAs and novel miRNAs in response to N, P and N and P stresses. Bar diagram depicts up- and down-regulated miRNAs, Venn diagram depicts the distribution of differentially expressed miRNAs in root and shoot tissues and N, P and N and P stresses. The table shows the list of novel miRNAs identified in the genome-wide miRNA-Seq analysis under N and/or P starvation.

6.4.4 Pearl millet

6.4.4.1 QTL mapping for seed yield per plant and 1000-seed weight

An experiment was designed for QTL mapping of important traits seed yield per plant and1000-seed weight in 210 recombinant inbred lines (RIL) derived from the cross PPMI 683 × PPMI 627. These RILs were evaluated at three pearl millet growing agro-climatic zones of India. QTL analysis revealed a total of three significant common QTL for TSW flanked by the markers namely *Xpsmp2273- Xipes0203; Xpsmp2077-Xpsmp2059; ICMP3058- Xipes0147* which explained the total phenotypic variance of 27.57%, 22.61% and 7.59% for QTL 1 on LG 1; 21.38%, 24.13% and 12.14% for QTL 2 on LG 2; 7.34%, 15.26% and 9.6% for QTL 3 on LG 6 across three consecutive years at Delhi (E1), Dharwad (E2) and Jodhpur (E3), respectively. Two constitutive expressing QTLs for seed yield per plant (SYPP) were found at a significant threshold LOD value of 3.5 and were flanked by the markers *viz.Xpsmp2273- Xipes0203* and *Xpsmp2077- Xpsmp2059* with a total phenotypic variance of 28.24%, 19.95% and 6.31% for QTL 1 on LG 1; 19.78%, 21.38%, 7.17% for QTL 2 on LG 2 across three years at E1, E2 and E3, respectively. A total of 34 (9 for E1, 11 for E2 and 14 for E3) digenic interactions were detected showing a significant effect on the TSW. A total of 29 (8 for E1, 7 for E2 and 14 for E3) digenic interactions were detected for seed yield per plant.



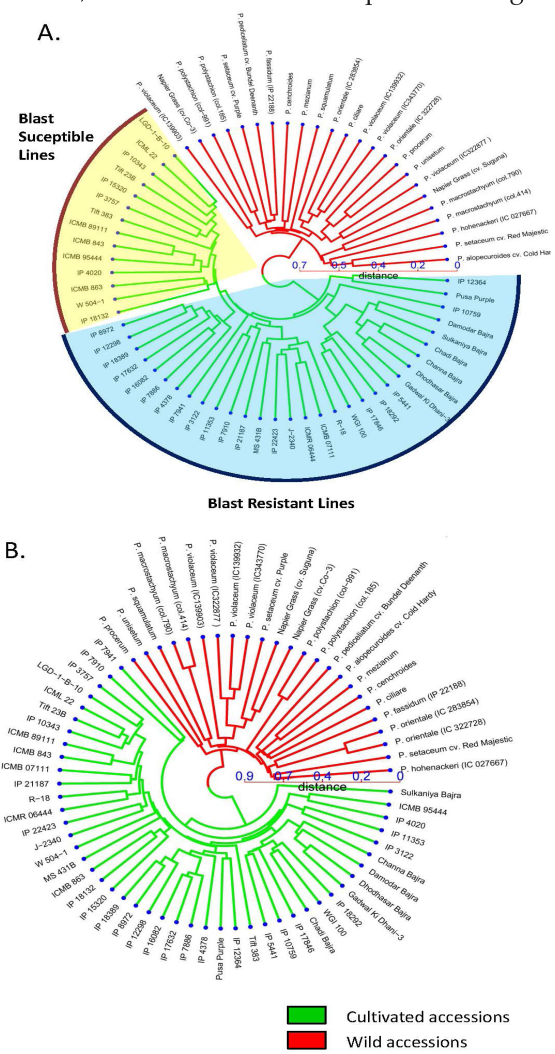
QTL mapping for seed yield and weight

6.4.4.2 Mapping of foliar blast resistance gene in pearl millet

Recently, foliar blast in pearl millet has become the major disease in pearl millet. Hence, the efforts are undertaken to identify the genomic regions responsible for the resistance against the disease. Two F_2 population derived from ICMB 95444 (susceptible parent) with resistant lines (PPMI 2464 and PPMI 10018) were used and genetic analysis showed a single dominant gene for foliar blast resistance. The resistance gene PMg was mapped on the chromosome#4 using the SSR markers namely IPES 0076, IPES 0114 and XPSPMP 2084.

6.4.4.3 Assessment of genetic diversity in wild and cultivated lines using molecular markers

Genetic diversity in 69 accessions of 17 species of genus *Pennisetum* was assessed using 25 CBDP and 38 SCoT markers. CBDP markers exhibited higher polymorphism in comparison to SCoT markers. CBDP 4, CBDP 15, CBDP11 and CBDP 24 produced high PIC values >0.37. Both the marker system could clearly distinguish the wild types and relatives from cultivated species. However, the CBDP marker system could clearly discriminate the blast susceptible genotypes from resistant ones present in cultivated group. The Prichard's structure of 69 accessions revealed a few instincts of introgression of cultivated types from wild which indicated the greater scope of future pre-breeding activities in pearl millet.



Dendrograms obtained using (A) CBDP markers (B) SCoT markers

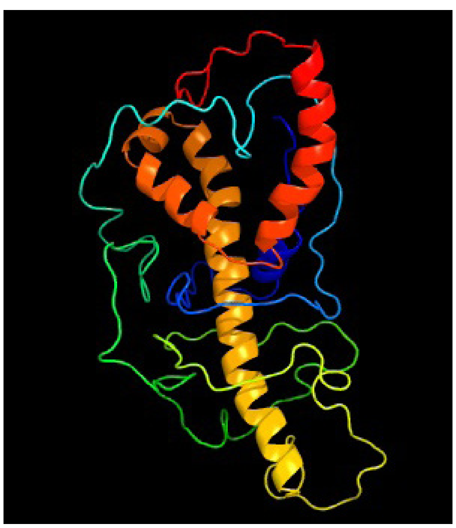
6.4.5 Chickpea

6.4.5.1 Genetics and interrelationships of time of flowering and stem growth habits in chickpea

Time of flowering and stem growth habit are the two important plant architectural traits desirable for improving adaptation of chickpea and its grain yield potential under cool long-duration environments of northern Indo-Gangetic plains. Three parents namely BGD72 (IDT, Late, Desi), BG1054 (SDT, Early, Kabuli) and BG1044 (SDT, Early, Desi) their F_{1S}, F_2s and $F_{2:3}$ of three crosses (BGD72 x BG1054; BGD72 x BG1044 and BG1044 x BG1054 were evaluated for flowering time (Late and Early), stem growth habit (IDT &SDT) and productivity related traits during rabi 2019-20 and 2020-21. The study of F_1s and segregation pattern in F_2s and $F_{2:3}$ progenies of BGD72 (Late) x BG1054 (Early) and BGD72 (Late) x BG1044 (Early) showed that late flowering was dominant and followed 3 Late: 1 early suggesting early flowering in BG1044 and BG1054 was governed by a single recessive gene each. The F_1 plants of BG1044 (Early) x BG1054 (Early) were early and showed no segregation for flowering time in F_2 and $F_{2:3}$ demonstrating that BG1044 and BG1054 might be carrying the same gene for early flowering. The study of F_1s and segregation pattern in F_2 s and F_3 progenies of BGD72 (IDT) x BG1054 (SDT), BGD72 (IDT) x BG1044 (SDT) suggested that indeterminate growth (IDT) was dominant and followed 3IDT: 1SDT indicating semi-determinacy (SDT) in BG1044 and BG1054 was controlled by a single gene in each. The F_1 plants of BG1044 (SDT) x BG1054 (SDT) was semi-determinate and showed no segregation for stem growth habit in F_2 and $F_{2:3}$ suggesting that BG1044 and BG1054 carried the same gene for semi-determinacy. Time of flowering showed significant negative correlation with seed yield per plant in the F_2 of BGD72 (IDT Desi Late) x BG1044 (SDT Desi Early) suggesting the possibility of combining earliness and greater seed yield through selection. The study also showed that hybridization between indeterminate desi and semi-determinate kabuli parents followed by careful selection of semi-determinate recombinants with more number of pods in F_2 is expected to result in simultaneous improvement of earliness (early flowering and podding) as well as seed yield in chickpea.

6.4.5.2 Dissection of ASR and DHN genes controlling drought tolerance in chickpea

ASR and DHN genes play a key role in regulating different plant stresses. Molecular characterization and functional role of abscissic acid and stress ripening (ASR) gene established the role of hypothetical ASR protein NP_001351739.1 in mediating drought response in chickpea. The gene sequence identified is submitted to NCBI Gene bank (MK937569). Sequence similarity of ASR gene to chickpea putative ABA/WDS induced protein mRNA clearly indicated its potential involvement in drought tolerance. The in silico analysis of NP_001351739.1revealed that it might have enhanced the ASR gene activity as a transcription factor regulating drought stress tolerance in chickpea. This study could be useful in identification of new ASR genes that play a major role in drought tolerance and also develop functional markers for chickpea improvement.Pusa1103, Pusa362, and ICC4958 were selected as drought tolerant based on higher RWC and MSI under drought stress. These genotypes were utilized for validation of candidate genes and identification of allelic variation in the drought responsive *DHN* gene based on sequence similarity approach. homozygous indels and SNPs in the *DHN* gene of Pusa1103 and Pusa 362 genotypes were identified suggesting that such changes can be highly associated with drought tolerance response.



Structure modeling of the hypothetical protein NP_001351739.1. (a) Structure prediction of ABA/WDS domain containing protein constructed by using Phyre2 (www.sbg.bio.ic.ac.ukphyre2)

6.4.6 Lentil & mungeban

6.4.6.1 Genetic dissection of phosphorous uptake and utilization efficiency traits using GWAS in mungbean

A genotyping-by-sequencing (GBS) based genome-wide association study (GWAS) approach was employed to dissect the complexity of PUpE and PUtE traits at the genetic level in mungbean. This has identified 116 SNPs in 61 protein-coding genes and of these, 16 have been found to enhance phosphorous uptake and utilization efficiency in mungbean. We identified six genes with a high expression (VRADI01G04370, VRADI05G20860, VRADI06G12490, VRADI08G20910, VRADI08G00070 and VRADI09G09030) in root, shoot apical meristem and leaf, indicating their role in the regulation of P uptake and utilization efficiency in mungbean. The SNPs present in three genes have also been validated using a Sanger sequencing approach.

6.4.6.2 Linking genome wide RNA sequencing with physio-biochemical and cytological responses to catalogue key genes and metabolic pathways for alkalinity stress tolerance in lentil (*Lens culinaris*Medikus)

PDL-1 exhibited lesser salt injury and performed better as compared to L-4076.Later showed severe wilting symptoms and higher accumulation of Na^+ and lower K^+ in roots and shoots. PDL-1 performed better under high alkalinity stress which can be attributed to its higher mitotic index, more accumulation of K^+ in roots and shoots and less aberrantly dividing cells. Significantly up-regulated differentially expressed genes were found to be involved in abscisic acid (ABA) signalling and secondary metabolites synthesis. ABA responsive genes *viz.*dehydrin 1, 9-cis-epoxycarotenoid dioxygenase, ABA-responsive protein 18 and BEL1-like homeodomain protein 1 had log_2fold change above 4.0. A total of 12,836 simple sequence repeats (SSRs) were found. Present study has laid the foundation for designing breeding strategies, carrying out genetic manipulations or genomic editing interventions for improving lentil production under alkalinity stress.

6.4.6.3 Comparative inter and intra species transcriptomics revealed key differential pathways associated with aluminium stress tolerance in lentil

Transcriptome analysis under Al3+ stress revealed 30,158 specifically up regulated genes in different comparison groups showing contigs between 15,305 to 18,861 bp. In tolerant genotypes, top up-regulated Differentially Expressed Genes (DEGs) were found to be involved in organic acid synthesis and exudation, production of antioxidants, callose synthesis, protein degradation along with phytohormone and calcium mediated signalling under stress condition. DEGs associated with epigenetic regulation and lAl3+ sequestration inside vacuole were specifically upregulated in wild and cultivars, respectively. Based on assembled unigenes, average of 6645.7 using quantitative Real Time- Polymerase Chain Reaction, twelve selected genes were validated.

6.4.6.4 Comparative RNA sequencing elucidates common pathways for multiple abiotic stress tolerance in lentil

The study was conducted to dissect transcriptomes of contrasting lentil genotypes under different stresses *viz*. drought, heat, salinity and alkalinity. Majority of differentially expressed genes (DEGs) which were up-regulated under drought and heat stresses were involved in organic acid synthesis and translational regulation. Similarly, DEGs which were co-upregulated under salinity and alkalinity stresses belonged to ABA signaling, epigenetic regulation, sucrose transport, vesicular trafficking and regulation of cation transport. Data generated in this study can be used to elucidate converging tolerance pathways under multiple abiotic stresses together with identification of associated markers. The information can be utilized in molecular breeding and gene pyramiding programmes of lentil.

6.4.6.5 Dry-root rot transcriptome in lentil

Dry root rot caused by the *Rhizoctonia bataticola* (Taub.) is a major emerging seedling disease in lentils especially under dry and humid climatic conditions. To gain insight into the molecular aspects of dry root rot fungus invasion and plant pathogen interactions, RNA-seq approach was used to identify differentially expressed genes (DEGs) in a highly susceptible lentil genotype. Gene expression profiling identified DEGs associated with changes in phenolic compounds, carbohydrate metabolism, transcription factors, antioxidants, Ca+2 binding proteins, receptor kinases and hormone signals. Moreover, these genes are corresponded to cell wall modification enzymes, transcriptional regulations (e.g., AP2/ERF, WRKY, NAC, MYB, BZIP, bHLH), defense-related metabolites including PR genes, phenylpropanoid precursors and jasmonic acid/ ethylene pathway related genes.

6.4.7 Mustard

6.4.7.1 Development of resources for molecular mapping

- Mapping population derived from crossing *B. juncea* genotypes (Pusa Mustard 28 and Pusa Karishma; in F_3 generation)is being advanced for mapping genes/QTLs for heat tolerance, oil content and seed size were advanced for developing RILs.
- For mapping of Powdery Mildew Resistance in RDV 29, Recombinant Inbred Lines (246 families) from involving powdery mildew resistant and susceptible genotypes (PMW 25 x RDV 29) were

advanced from F_6 to F_7 generation following Single Seed Descent method.

- To conduct Genome wide Association Study (GWAS) for drought tolerance a total of 171 genotypes including released varieties and advanced breeding lines were raised under rainfed conditions in augmented block design with seven checks and data were recorded for 15 agro-morphological traits.
- To map QTLs for high temperature stress tolerance, a set of 164 genotypes including 96 diverse genotypes from diversity panel and 68 genotypes including popular varieties were subjected to heat stress screen at the reproductive stage and data were generated on agro-morphological traits.

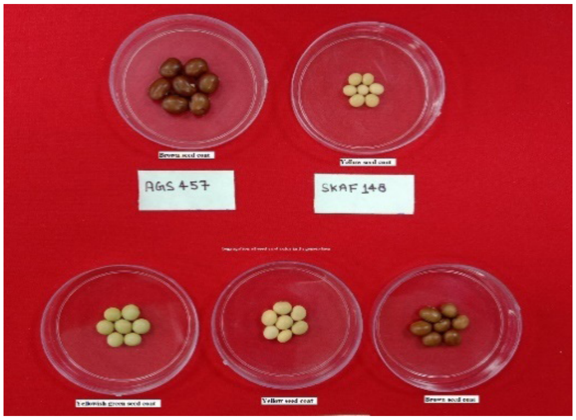
6.4.8 Soybean

6.4.8.1 Inheritance of resistance against MYMV in soybean

In the F_2 population derived from the cross SL 958 X VLS 59 a total of 104 plants were subjected to infection by MYMV by whitefly feeding (the vector). Healthy white flies were collected from the soybean field and released on the plants at seedling stage. Out of the 104 plants subjected to white fly feeding, 71plants exhibited resistant reaction and 33 plants showed susceptibility. The segregation for resistance to MYMV in F_2 population showed a goodness of fit to 3:1 susceptible ratio with probability of 0.28 at X2 (3:1) as 2.51 in the cross SL 958 x VLS 59.

6.4.8.2 Inheritance of seed coat colour

To understand the genetics of seed coat colour, soybean genotype with brown seed coat (AGS457) was crossed with a genotype with yellow seed coat (SKAF148). The seed coat in the F_1 generation was green, which indicated gene interaction in expression of seed coat colour. In the F_2 generation, the colour segregated with Yellowish Green: Yellow: Brown in the ratio of 9:3:4. It indicated involvement of two genes with recessive epistasis. Involvement of two genes with supplementary gene interaction for expression of seed coat colour has also been confirmed in its reverse cross and some other cross combinations involving genotypes having yellowish green and yellow seed coat.



Segregation of seed coat color in F_2 generation

6.4.8.3 Inheritance of early maturity trait in soybean

An extra early soybean genotype SKAF148 (68-70 days to maturity) was crossed with DS9712 (115-120 days to maturity). About 453 seeds from the hybridity tested F_1 plants were grown during *kharif* 2020 and segregation in days to maturity was noted. Confirmation of the segregation was done in F_3 plants during 2021. Mapping of the QTL for early maturity trait is in progress.

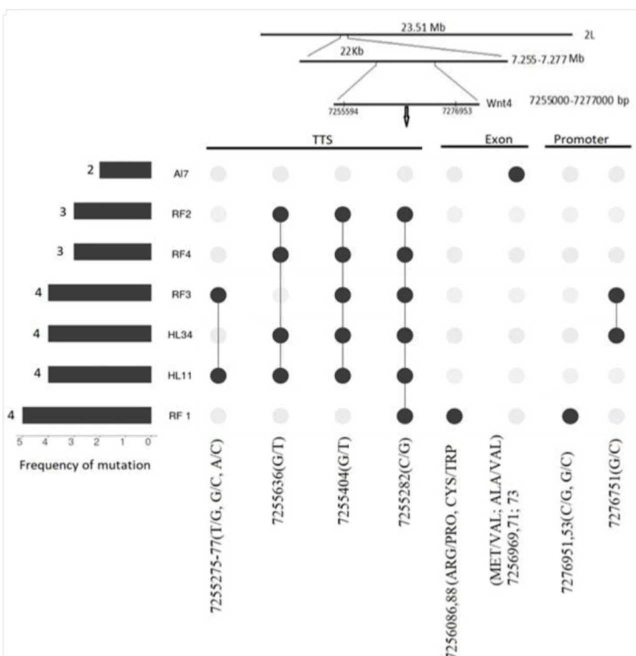
6.4.8.4 Doubled haploidy as a tool in pre-breeding approach

The induction of soybean Androgenesis and Gynogenesis were examined using the modified Gamborg's medium (B5) and B5 long media supplemented with different concentrations of plant growth regulators (PGRs). Four genotypes namely JS335, SL1074, Pusa12-13 and SL958 were cultured on a B5 medium provided with different PGRs, sucrose and organic compounds for callus initiation and organogenesis. Simultaneously, different temperature conditions were also provided. A combination of 10 mg/L2,4-D, 1mg/L IBA and1mg/L BAP supplemented with 30 g/L sucrose and 200 mg/L myo-inositol and temperature around 26°C showed the best callus induction for Gynogenesis, whereas Androgenesis showed no response so far.

6.4.9 Drosophila

6.4.9.1 Identification of SNP responsible for embryonic lethality in DWnt4 IARI mutations

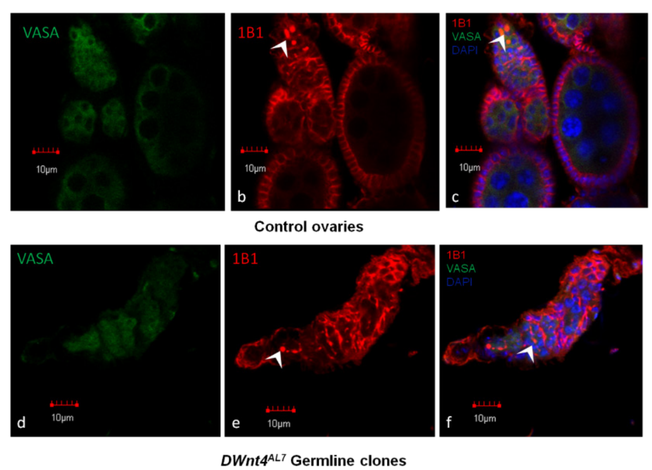
In the 22Kb area of the 2L chromosome corresponding to *DWnt4* position, a total of 342 mutations (SNPs) were identified from all seven mutant lines. Most mutations were found in the intron, followed by promoter and Transcription Termination Site (TTS) regions (Fig), when extracted through genomic annotation. Functional annotation of identified mutations localized 341, 117 and 43 mutations within three genes, namely, *Wnt4*-Wnt oncogene analogue4, *CG31909* and CG13786, respectively. CG31909 and CG13786 are nested within intronicregion of *DWnt4* (www.flybase.org). The mutation *AL7* has *Met* to *Val* and *Ala*to *Val* substitution at positions 313 and 314 in 539 amino acid long *DWnt4* protein. *RF1* has *Arg* to *Pro* and *Cys* to *Trp* substitution at positions 513 and 512 and substitutions in the *TTS* and *promoter* region. Wnt signals are secretory proteins, and their function is abolished if they are not secreted in the cytoplasm. The presence of 24 cysteine residues characterizes all Wnt genes. The mutation RF1 has a substitution for *Cysteine*, which can abolish the Wnt signal. The substitutions in AL7 may be affecting the folding of *DWnt4* protein as the region where substitution is present falls near the region involved in disulfide bond formation (www.uniprot.org). The rest of the mutations has mutation causing SNP located in the promoter or TTS region.



Mutations in exons, promoter and TTS regions of DWnt4 gene identified using WGRSFour mis-sense mutations were identified causing ARG to PRO, CYS to TRP, MET to VAL, ALA to VAL at amino acids 513, 512, 314 and 313 respectively. The substitution at positions 314 and 313 are present in mutation AL7 and substitutions 513 and 512 are present in mutation RF1 Three non-synonymous mutations were identified at 7276751, 7276951 and 72769753 positions in promoter region and six non-synonymous mutations were identified at 7255275-77, 7255282, 7255404 and 7255636 positions in TTS region

6.4.9.2 *DWnt4*germline clones: a novel phenotype

The mutant alleles we are reporting here are null alleles of *DWnt4* and the germline clones of *DWnt4*^{AL7} are arrested in stage 6 of oogenesis., Functions of *DWnt4* in the development of escort cells and follicular stem cells is well established. We stained the germline clones *DWnt4*^{AL7} to study the differentiation defects with *1B1* (to mark spectrosomes). The germline clones have accumulation of spectrosomes as compared to control ovaries (arrowhead in figure 2) which indicates that escort cell function is affected. We stained the germline clones *DWnt4*^{AL7} to study the differentiation defects through the protein vasa (marks germ line). The arrest in oogenesis at stage 6 to 8 in case of *DWnt4*^{AL7} may be due to defects in formation of escort cells and



Expression of Vasa, 1B1 in control and ovaries of germline clones.(a,b,c) control ovaries showing expression of 1B1(red and arrowhead in b) a marker for spectrosome and vasa (green) a marker for germline. (d,e,f) DWnt4AL7 germline clone ovaries, showing loss of vasa (d) and increased number of sprctrosomes (arrowhead in e and f).

it is not related to germline cell differentiation. These results are in accordance with the previous reports of Motier-pavie, 2016and Upadhyay et al 2018.

6.4.10 Brinjal

6.4.10.1 Mapping of *Fusarium* wilt resistance gene

A total of 90 $BC_1F_1P_1$ plants from the cross of DBL-186 and DBR-40-7-10-5 were used for mapping of the fusarium wilt resistant gene. Polymorphism survey was carried out among the parents using 350 brinjal specific SSR markers. Among these 15 markers were found to be polymorphic which will be used to genotype backcross plants.

6.4.10.2 QTL mapping of genes governing anthocyanin pigment

Through QTL-seq approach, leaf samples of bulked purple, green and white fruited plants were sent for sequencing by Illumina Hi-seq platform technology. The anthocyanin content was found to be very high in Pusa Shyamla parent and there were variation in anthocyanin content F_2 population.

6.4.11 Cauliflower

6.4.11.1 Screening wild *Brassicas* against *Alternaria brassicicola*

134 inbred lines were screened against *A. brassicicola* and identified four lines DC-315-5, DC 303-7, DC-300-1-2-2 and DC-73-7-3as moderate resistant at seedling stage. Out of 38 wild *Brassica* species, complete resistance was observed in *Capsella* while strong resistance in *Lepidium*, *Camelina* and *Biscutella*. *Capsella bursa pastoris* (L.) Medik. (early) and *C. bursa pastoris*(L.) Medik. (late) were symptomless resistant. *Camelina sativa* (L.) Crantz, *Diplotaxiserucoides* (L.) DC and *Diplotaxisgomez-campoi*Mart.-Laborde were found to be resistant against *A. brassicicola*.

6.4.11.2 Determination of glucosinolates in cauliflower

Significant variation were observed in glucosinolates (sinigrin, glucoerucin and progoitrin) content in cauliflower hybrids tested in line × tester mating design (CMS lines: 10 early, 5 mid; testers: 5 early, 4 mid; F_1 crosses: 50 early; 20 mid). Significant positive and negative heterosis were observed for glucosinolates. Best general combiners were CMS 8441-5, CMS N-2-121 and CMS 8410 in CMS lines and DC 71, DC-98-2 and DC 309 in testers for glucoerucin. For sinigrin content, CMS 8441-5, CMS 175-8, CMS 8401 and CMS 1944-309 in CMS lines and DC-41-5, DC-71, DC-309 and DC-401 were most promising.

6.4.11.3 Tropicalization of cabbage & broccoli

The F_2 population from Pusa Ageti (no chill type) × Golden Acre (chill type) generated with the help of IARI RS, Katrain were evaluated in Delhi condition and segregation pattern indicated polygenic dominant nature of tropical/annual flowering trait in Pusa Ageti. The plants were advanced to $F_{2:3}$ for further evaluation and development of tropical flowering lines.

6.4.11.4 Mineral content in cauliflower

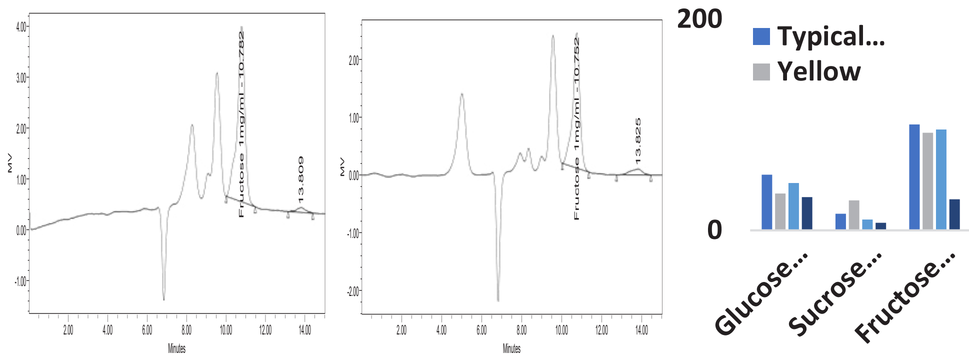
Ten minerals were analysed in leaves and curds of 150 genotypes of cauliflower. Genotypes had wide variation in iron (6.64 – 160.3 ppm), zinc (10.2-172.8 ppm), Mn (16.6 – 28.2 ppm), in K (3654.2 - 9088.0 ppm) Ca (18.9 to 154.0 ppm), Cu (66.0-175.3 ppm) and in Mg (243.3-1469.6 ppm). Similarly, 38 wild *Brassicas* also showed wide variation for these minerals in leaf samples.

6.4.11.5 Segregation of anthocyanin trait in tropical cauliflower

Two sets of F_{2s} namely 238 plants of DC-23 (early group) × PPCF-1 (snowball group) and 356 plants of DC-67 (early group) × PPCF-1 (snowball group) were raised and observed for curd colour. In both sets, the segregation ratios were fitting well with Mendelian ratio of 3:1 (purple: white). Early maturing and flowering type plants from F_2 and BC_1 were advanced.

6.4.11.6 Sugar analysis in orange cauliflower

Glucose, sucrose and fructose content were analysed using HPLC in orange cauliflower and observed that the fructose (58.4 – 104.19 mg/100 g



a. b. c.

HPLC analysis of sugar in different orange cauliflower samples. Chromatogram of sucrose in homozygous orange (a), white curd (b) and comparison graph (c)

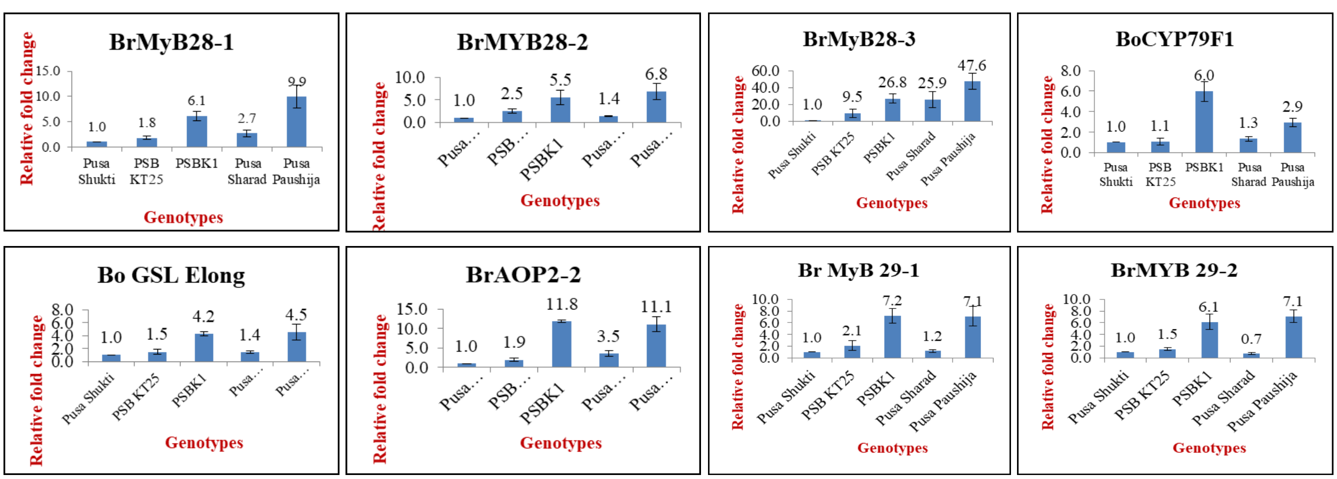
FW) is major sugar followed by glucose (31.6-49.9 mg/100 g FW) and sucrose (10.0 – 15.0 mg/100g FW). In homozygous curds, the sucrose (15.15 mg/100 g FW) and glucose (49.95 mg/g FW) content was higher than heterozygous orange (10.08, 43.20 mg/100 gFW) and homozygous white curds (11.28, 31.6 mg/100 gFW) .

6.4.11.7 Glucosinolates content and expression anaylysis of GSL pathway genes in cauliflower

Expression of eight different genes involved in glucosinolate pathway *viz.* BoGSL-Elong, BrAOP-2-2, BrMYB 28-1, BrMYB 28-2, BrMYB 28-3, BrMYB 29-1, BrMYB 29-2 and BoCYP79F1 was analysed in Pusa Shukti, Pusa Snow ball Kt25, Pusa Snowball K-1, Pusa Sharad and Pusa Paushja. 18S was used as a house keeping gene and PusaShukti was used Callibrator. As is evident from the figure there were differences in the expression of different glucosinolate pathway genes in different varieties. Highest expression of all the genes except, BrMYB 29-2, BoCYP79F1 was observed in Pusa Shukti. On the basis of expression pattern of GSL pathway genes the genotypes under study could be divided into two distinct classes one comprising Pusa Shukti, PSB KT25 and Pusa Sharad which had high expression of all the genes studied while the second class comprising PSBK-1 and Pusa Sharad which had low expression of all the genes studied.

6.4.11.8 Marker assisted pyramiding for black rot and downy mildew resistance

The pyramided black rot and downy mildew resistant lines in the background of Pusa Meghna and



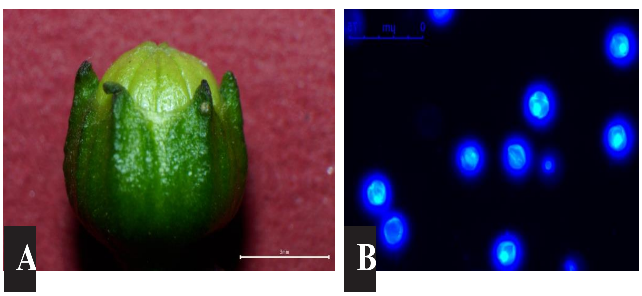
Expression profile Glucosinolate pathway genes in different cauliflower varies at two different time points (Error bars indicate SE)

Pusa Sharad were advanced and seeds were produced for BC_2F_5 generation.

6.4.12 Chilli

6.4.12.1 Development of doubled halpoids

Efforts to develop doubled haploids in *Capsicum annuum* were initiated with an aim to achieve rapid homozygosity. We have started this with bell peppers as these are more amenable for tissue culture. In this endeavor the stage of bud development at which the microspores are in uninucleate has been found where it was observed that unopened flower buds with corolla slightly bigger than calyx contained uninucleate pollen. This was done using fluorescence microscopy after staining the anthers with DAPI (4′,6-diamidino-2-phenylindole), a blue-fluorescent stain.



A Capsicum bud (corolla slightly bigger that calyx) having uninucleate pollen (A), Uninucleate pollen under fluorescencemicroscope (B).

Efforts have also been directed to standardise the media for direct plant regeneration from microspore as well as through intervening callus phase. Direct embryo formation was achieved from the cultured anthers on MS media with 4mg/l NAA+1mg/l BAP, 0.25% activated charcoal, 15mg/l $AgNO_3$ and 30g/l sucrose. While in experiments on indirect regeneration from anthers through callus phase it was observed that after one month of culture, most of the anthers turned brown, but callus initiation was observed at one end of the anthers and the colour of the callus was pale white and compact in almost 100% of the anthers. Best media for callus formation was observed to be MS + 0.1mg/lt kinetin, 0.5mg/lt 2,4-D.

6.4.13 Cucumber

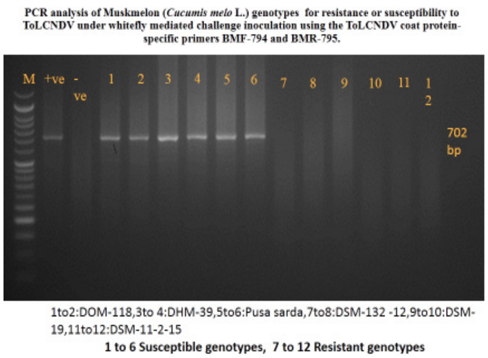
6.4.13.1 Optimization of protocol for development of haploids in cucumber

In cucumber, four genotypes including two inbreds (DC-48, DC-83) and two F_1 hybrids (DC-43 × DC-48 and GyCl-15 × DC-48) were used for induction of haploids through gynogenesis and subsequent development of doubled haploids. Effects of developmental stage of the ovary, temperature stress treatment, different concentration of GA3 and NAA and sucrose concentrations were studied on successful gynogenesis in cucumber. From the studies it was evident that the F_1 hybrids served as the better ex-plant in terms of percentage response and direct regeneration when compared with their parental inbreds. The ovaries cultured on the day of anthesis or one day before anthesis were most suitable for gynogenesis. Temperature stress treatment 4 days at 9.0°C combined with 2 days treatment at 32.0°C and 4-6% sucrose concentration was found to be most suitable for effective gynogenesis to get highest regeneration and direct response.

6.4.14 Muskmelon

6.4.14.1 Identification of novel source of resistance for ToLCNDV resistance in melon

Two novel resistant lines DSM-132 & DSM-19 could be developed from *Cucumis melo* var. *momordica* accessions having high degree of resistance against TOLCNDV in muskmelon. The lowest Vulnerability Index (20.00) was estimated for DSM-132 against ToLCNDV followed by DSM-19 (23.33) while it was very high for susceptible genotypes from oriental melon DOM-118 (90.00) followed by Pusa Sarda (86.66). These results were confirmed by amplification of ToLCNDV specific fragments with PCR primers. The relative ToLCNDV accumulation (Calculated as 2^-ddCT) through Rt-PCR in resistant genotypes DSM132 (1.0), DSM-19 (18.33) and susceptible muskmelon genotypes DOM-118 (22629.48) after challenge inoculation also validated the level of resistance.



DSM-132(DG-12)

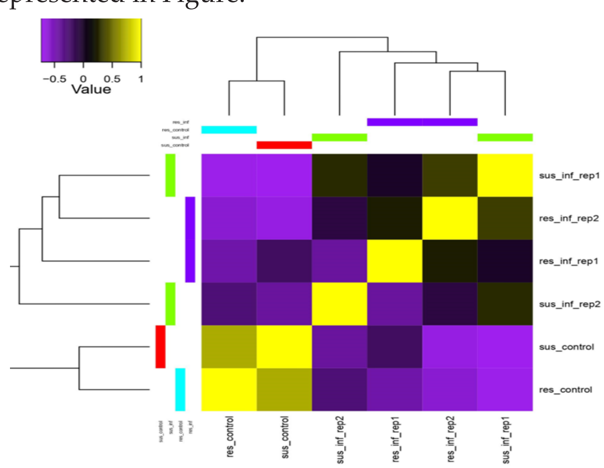
6.4.15 Okra

6.4.15.1 A comparative transcriptome study to identify genes/transcripts and novel markers specific for yellow vein mosaic virus (YVMV) disease resistance in okra

Yellow vein mosaic disease (YVMD) caused by YVMV poses a serious threat to okra cultivation. No markers are yet available to screen for YVMD resistance. Genes/molecular mechanism governing YVMD resistance are not known. Therefore, to identify genes/transcripts and novel markers specific for yellow vein mosaic virus (YVMV) disease resistance in okra a comparative transcriptome analysis of YVMV resistant and susceptible parents was performed. Pusa Sawani was taken as a susceptible parent and DOV-66 was taken as a resistant parent.

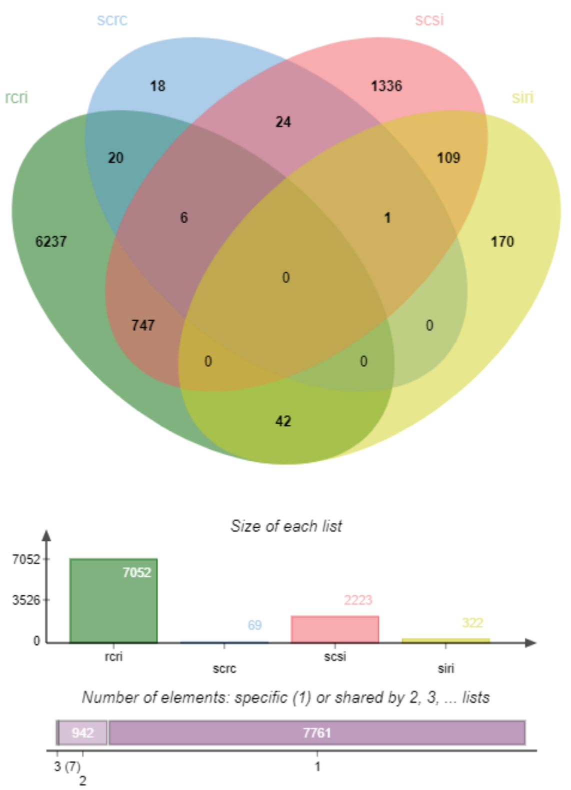
6.4.15.2 Differentially expressed genes (DEGs) identification

A total of 8710 unique DEGs were obtained from the four comparison sets (resistant-control vs. resistant-infected, susceptible-control vs resistant-control, susceptible-control vs susceptible-infected, susceptible-infected vs resistant-infected) with defined parameters (FDR and P-value <0.05 and log2fold change > 2) using the EdgeR. Heat map showing the hierarchically clustered Spearman correlation matrix resulting from comparing the transcript expression values (TMM-normalized FPKM) for each sample is represented in Figure.



Heat map of differentially expressed genes under YVMV infection in YVMV resistant and susceptible parents

The shared and unique differentially expressed genes are represented in the form of Venn diagram. Highest numbers of transcripts (7052) were recorded in the comparison of resistant-control vs. resistant-infected followed by susceptible-control vs susceptible-infected with 2223 number of transcripts. A total of 6237, 18, 1336 and 170 DEGS were unique to the comparison sets resistant-control vs. resistant-infected, susceptible-control vs resistant-control, susceptible-control vs susceptible-infected, susceptible-infected vs resistant-infected, respectively as seen in the Venn diagram.



Differential Venn diagram showing up and down regulated genes under YVMV infection in okra in YVMV resistant and susceptible parents. Ri (resistant-infected), sc (susceptible-control) vs rc (resistant-control), susceptible-control vs si (susceptible-infected), susceptible-infected vs resistant-infected

6.4.16 Onion and garlic

6.4.16.1 Germplasm resources

A total of 66 onion samples were imported from USDA, the USA for cultivation under Indian conditions. The seeds were sown in January and transplanting was done in March. Due to high temperatures during April-May, the plants were unable to survive under high-temperature conditions.

6.4.16.2 Mutation Studies in Onion

Seeds of onion variety Pusa Riddhi were treated with 0.6% EMS and sown in the nursery. Around 50% of the seeds were unable to germinate. Rest germinated seedlings were transplanted and M1 bulbs were planted for bulb formation. M1 bulbs have been planted to generate M2 seeds.

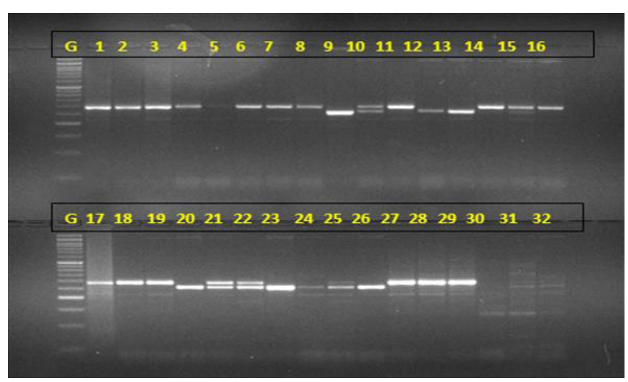
6.4.16.3 Development of breeding lines, seed production, and germplasm maintenance in onion

A total of 120 single crosses between various accessions having desired traits were attempted with male sterile lines. Under DUS program, 47 onion and 14 garlic varieties were maintained by seed production. Experimental trials of hybrid onion (12 entries), germplasm (52 entries) and bulb production of inbreds (96) and exotic (5 lines) were carried out.

6.4.17 Genetics and genomics

6.4.17.1 Identification of polymorphic SSR markers in garlic

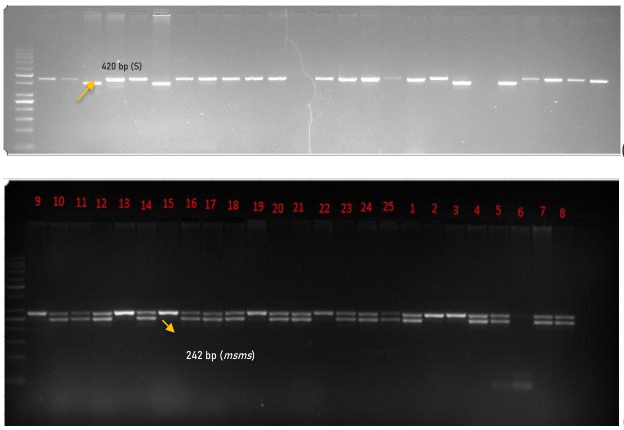
In garlic, 29 accessions were genotyped with 228 SSR markers. Out of 228, 9 SSR markers were found to be polymorphic. From the nine SSR markers, thirty-five (35) alleles were amplified with an average of 3.89 alleles ranging from 2 to 6. SSR markers AsESSR47, AsESSR82 detected the highest number of alleles (6) in all the twenty-nine accessions. The major allele frequency per locus varied from 1.000 (ACM091) to 0.031 (ACE122).



DNA profiling in garlic genotypes using primer GB-ASM-040

6.4.17.2 Studies on hybrid development in onion

Twenty test cross combinations were evaluated for their male sterile and maintainer status. Eighteen onion accessions including two commercially grown open-pollinated varieties (OPVs), four breeding lines, nine doubled haploid (DH) lines viz., PMDH2, PMDH3,



(a)

(b)

PMDH7, Hap2hi3.1.2, Hap2hi3.1.4, Hap2hi3.1.5, Hap2hi3.1.6, Hap2hi3.1.7, and Hap2hi3.1.8, and three hybrids were used for determining the onion cytotype and the genotype at Ms locus. The genomic DNA from 634 individual plants from 18 onion accessions and 208 individuals from the OPVs and exotic lines was extracted individually from young leaves. For identification of cytoplasm, two pairs specific for identification of onion cytoplasm type *viz*., accD, and MKFR were utilized. For determination of *Ms* locus, two primers viz., AcSKP1 and AcPMS, found to be in complete linkage disequilibrium with the onion nuclear *Ms* locus, were employed. A mixture of normal and sterile cytoplasm was identified.

6.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS AND METEOROLOGY

6.5.1 Soil Physics

6.5.1.1 Carbon management index as influenced by tillage, residue and nitrogen management in maize-wheat system

A field experiment was conducted with the treatment comprising of two tillage types [conventional tillage (CT) and no tillage (NT)], two level of mulching (crop residue mulch @ 5t/ha (R+) and without residue (R0)) and 3 level of nitrogen [50% recommended nitrogen dose (RDN); 100% RDN and 150% RDN].

It was observed that after five years of field experiment, maximum SOC concentration was recorded under very labile carbon (VLC) followed by non-labile carbon (NLC), labile carbon (LC) and less labile carbon (LLC). There was decrease in the concentration of labile carbon with depth. NT resulted in significant increase in VLC and LC compared to CT at 0-5 cm depth. Application of crop residue mulch resulted in significant increase in VLC, LC and NLC than no-mulching at 0-5 and 5-15 cm depth. With the increase in N level, very labile carbon increased significantly at 0-5, 5-15 and 15-30 cm depth. Correlation among different organic carbon pools showed that TOC was significantly correlated with mineral associated carbon (MAC), very labile carbon (VLC), labile carbon (LC) and non-labile carbon (NLC) at 0-5 and 5-15 cm depth. Carbon lability index, carbon pool index and carbon management index, computed based on soil organic carbon pools, decreased with the increase in soil depth. Carbon pool index (CPI) and Carbon management index (CMI) increased significantly under NT and crop residue mulching than CT and residue removal, respectively at 0-5 and 5-15 cm depth. With the increased in N level, CPI and CMI increased significantly.

The results suggested that NT with residue retention may be followed in maize-wheat system of Indo Gangetic Plain region to improve the Carbon Management Index of the soil.

Carbon Management Index as affected by tillage, residue and nitrogen management

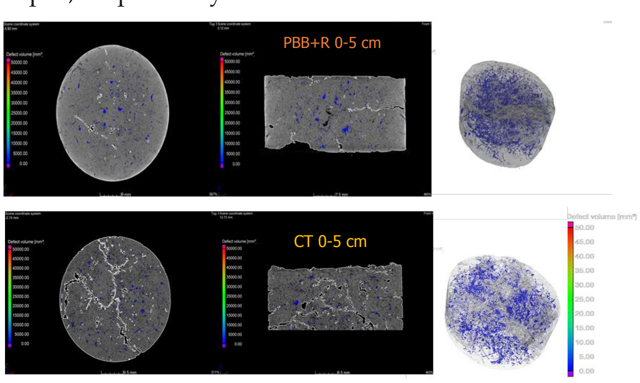
Treatment	Carbon Management Index		
	0-5 cm	5-15 cm	15-30 cm
Effect of tillage			
CT	$185.46^{B\#}$	213.49^{B}	173.43^{A}
NT	249.39^{A}	228.01^{A}	172.51^{A}
Effect of residue mulch			

R_0	198.13^{B}	198.18^{B}	160.21^{A}
R_+	236.72^{A}	243.32^{A}	185.73^{A}
Effect of Nitrogen			
$N_{50\%}$	207.00^{B}	212.42^{A}	153.31^{B}
$N_{100\%}$	215.66^{AB}	220.50^{A}	178.22^{A}
$N_{150\%}$	229.62^{A}	229.32^{A}	187.37^{A}
Mean	**217.43^{a}**	**220.75^{a}**	**172.97^{B}**

#Values in a column followed by same alphabets are not significantly different at $p<0.05$ as per Duncan's Multiple rage test ;The uppercase alphabets and the lower case alphabets are used for comparing treatment and soil depth effects, respectively

6.5.1.2 Variation of hydro- physical properties under different CA practices in wheat

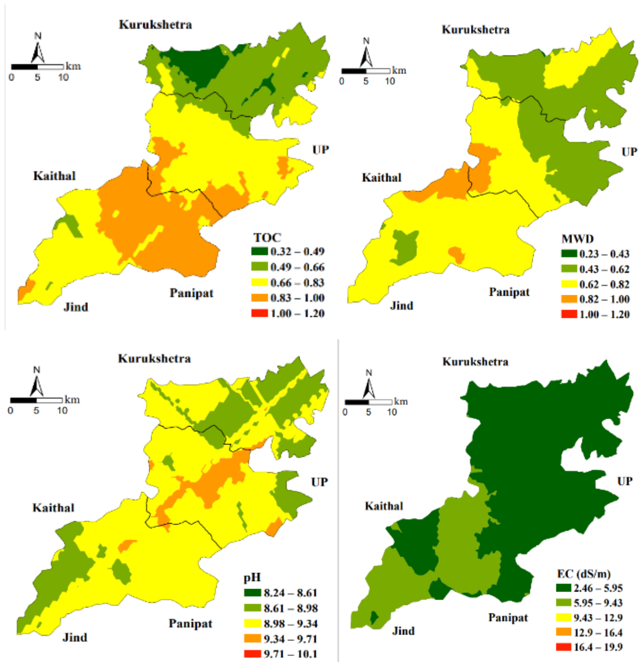
The conventional (CT) and zero (ZT) tillage had significantly lower number of pores (%) in 60- 100 µm size range at 0-5 cm soil depth and significantly higher number of pores (%) in 110-500 µm size range at 5-15 cm of soil depth, which resulted in restricted free-drainage under these alternate tillage and land preparations. More µ-CT derived macroporosity (%) in CT was because of statistically significant more percentage of pore number. Under the alternate tillage practices (PBB, PBB+R, ZT and ZT+R), total organic carbon (TOC) was 15-48 and 17-47% higher than CT at 0-5 and 5-15 cm layers, respectively. Similarly, mean weight diameter (MWD) of aggregates were 14 to 26%, and 7- 18 % higher than CT, at 0-5 and 5-15 cm soil depth, respectively.



Three dimensional (3D) view of pore size distribution of soil in 0-5 cm soil depth of CT and PBB+R

6.5.1.3 Spatial variability of soil properties in Karnal district of Haryana

Spatial variability maps of pH and EC of Karnal district showed widespread variability of soil salinity. As per MWD classification, soils varied from unstable to medium stable category. Organic carbon of the soils was in between low to medium category.



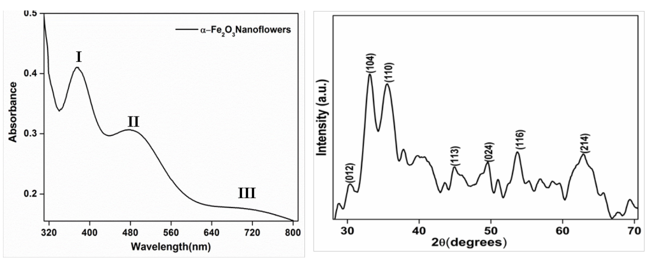
Spatial variability maps of soil properties in Karnal district of Haryana

6.5.2 Bio-physics

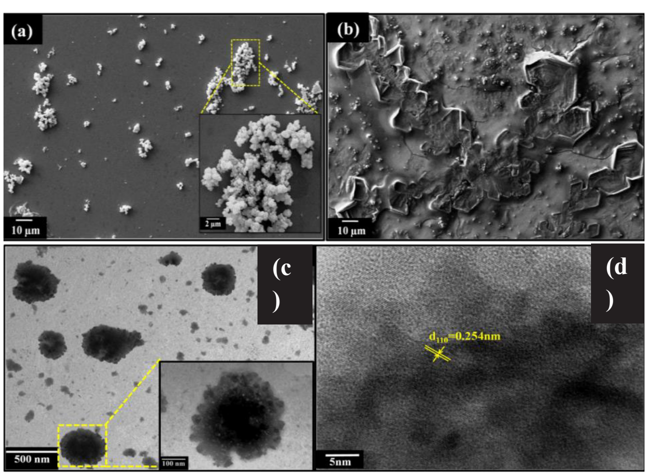
6.5.2.1 Nanosensor for the detection of soil nitrate

A rapid, portable and highly sensitive detection of nitrate is the need of the hour. In this direction, various organic and metal oxide based nanomaterials were explored for the fabrication of nanosensor for nitrate detection in soil. Nanocomposite of multiwalled carbon nanotubes (CNT) and hematite nanostructures was successfully prepared. The specific enzyme immobilization was accomplished onto the nanomaterial electrodes efficiently and characterization studies revealed the optical properties, band gap energies, surface and detailed morphology of nanostructures and nanocomposites. In this method, the nanostructures of hematite (α-Fe_2O_3)

were prepared using Iron (III) chloride hexahydrate and urea at temperature of 150 °C in autoclave followed by cooling and drying of precipitates formed to obtain the nanostructures. For the preparation of nanocomposite of CNT and α-Fe_2O_3, a dispersion of these nanomaterials was prepared combining them in optimized ratio (1: 2, w/w). UV-Visible absorption studies were performed for obtaining the absorption spectra of α-Fe_2O_3 nanostructure. XRD pattern of the engineered nanomaterial was also obtained . To study the surface morphology, scanning electron microscopic images of the nanoamterial were obtained, which revealed that the hexagonal shaped nanoparticles are assembled together to form highly porous nanoflower structures of hematite. After immobilization, the dense and uniform distribution of nanomaterial was changed to highly regular and globular morphology. To further investigate the detailed morphology, TEM observations were also recorded which revealed the crystalline interplanar spacing.



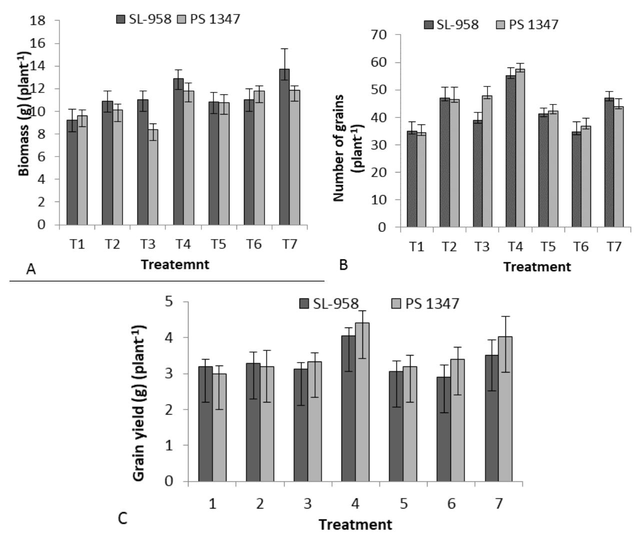
UV–visible absorption spectrum and (b)X-Ray Diffraction (XRD) Spectrum of α-Fe_2O_3 nanostructures



SEM micrographs of flowerlike α- Fe_2O_3 nanostructures, (c) TEM micrographs (inset: high magnification TEM image), and (d) HR-TEM micrograph of flowerlike α-Fe_2O_3 nanostructures

6.5.2.2 Impact of application of ZnO and Fe_3O_4 -nanoparticles (NPs) and $ZnSO_4$ and $FeSO_4$ on soybean crop

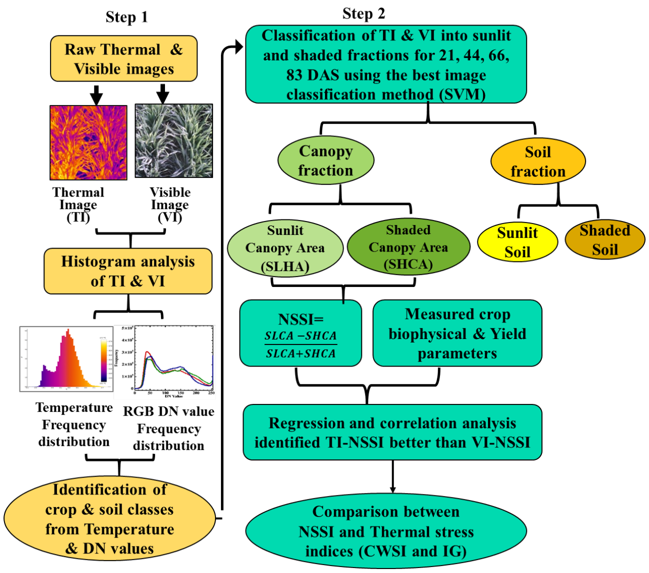
The experiment was conducted on soybean with seven treatments (T1: Control; T2: 25 mg/kg ZnO NPs; T3: 25 mg /kg Fe_3O_4-NPs; T4: 25 mg/kg ZnO NPs + Fe_3O_4 NPs; T5: 25mg/kg $ZnSO_4$ (equivalent to Zn Content in T2); T6: 25 mg/kg $FeSO_4$ (equivalent to Fe in T3) and T7: interactive condition of $ZnSO_4$ + $FeSO_4$, with six replications. The comparison of impact of Zn and Fe_3O_4 nanoparticles was made with $ZnSO_4$ and $FeSO_4$ conventional fertilizers. Result indicated that biomass, number of grains and grain yield ($plant^{-1}$) of soybean varieties were significantly more ($p<0.05$) under interactive conditions of ZnO and Fe_3O_4 NPs (T4) as well as under $ZnSO_4$ and $FeSO_4$ (T7) over the control (T1). Assessment also revealed that the grain yield of soybean crops was higher by 9-10.5% under T4 as compared to T7.



(A) Biomass (g) ($plant^{-1}$) treatment relation (B) Relation between number of grains ($plant^{-1}$) and ZnO- Fe_3O_4 NPs and $ZnSO_4$ and $FeSO_4$ treatments. (C) Grain yield variation with ZnO- Fe_3O_4 NPs and $ZnSO_4$ and $FeSO_4$ treatments.

6.5.2.3 Developed a normalised salinity stress tolerance index (NSSTI) to characterize the wheat genotypes using multivariate techniques

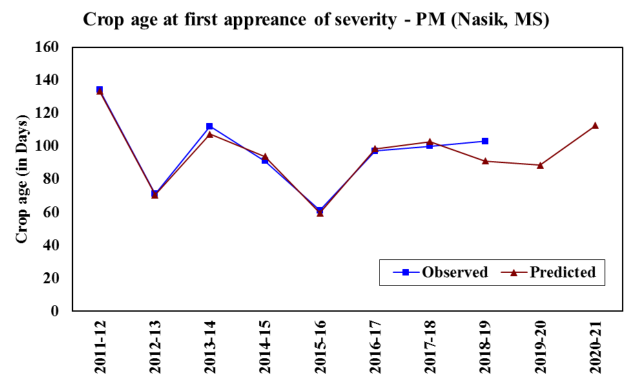
In this study, proximal thermal and visible imaging system were used to separate four different components of the wheat crop, *i.e.*, canopy and soil under



sunlit and shaded conditions using Support Vector Machine method of supervised image classification approach under different moisture stress treatments. A Normalized Sunlit Shaded Index (NSSI) was developed to characterize the status of the wheat crop grown under moisture stress conditions at different growth stages. The results demonstrated that Thermal image-based NSSI (TI-NSSI) had the best correlations with all the measured crop biophysical parameters than the visible image (VI-NSSI). However, the R^2 decreased with an increase in moisture stress. Among the different biophysical parameters tested in this study, TI-NSSI showed the highest significant negative correlation (−0.962***) with Radiation use efficiency (RUE). In general, irrespective of the moisture stress VI-NSSI gave the least relationship with all the biophysical parameters tested. Further regression analysis showed that TI-NSSI could explain the variations in RUE under different moisture stress conditions with R2 > 0.960. Regression analysis with yield showed that TI-NSSI under peak vegetative growth stage (83 DAS) adequately captured the variations in crop yield under moisture stress conditions.

6.5.2.4 Forewarning models on powdery mildew grapes for various characteristics

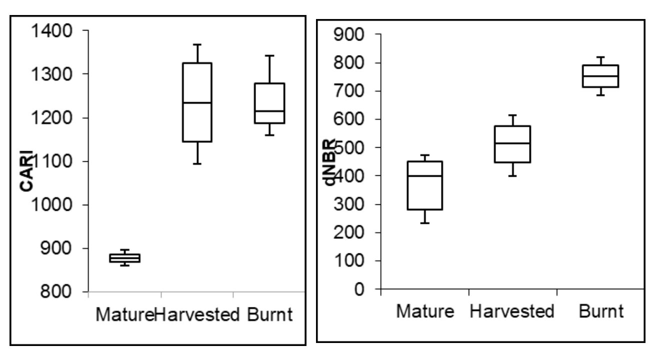
The forewarning models on crop age at first appearance of disease on Powdery Mildew (weather data utilized from 23 SMW to 45 SMW), crop age at maximum severity of disease (weather data utilised from 23 SMW to 52 SMW) and maximum severity of diseases (weather data utilised from 23 SMW to 52 SMW) in the season were developed to predict various characters of diseases for different locations and coefficient of determinations were also generated. Predictions and observed values are in close agreement indicating the stability of the model.



6.5.3 Remote sensing and GIS

6.5.3.1 Identification of suitable multispectral indices for distinguishing paddy harvested and paddy burnt

The field experiment was conducted at MB-14 farm of IARI with treatments of paddy harvested at different height followed by burning of harvested paddy. The hyperspectral observations were taken at three times *viz.*, for mature, harvested and burnt crop. The hyperspectral data was analyzed and re-sampled to

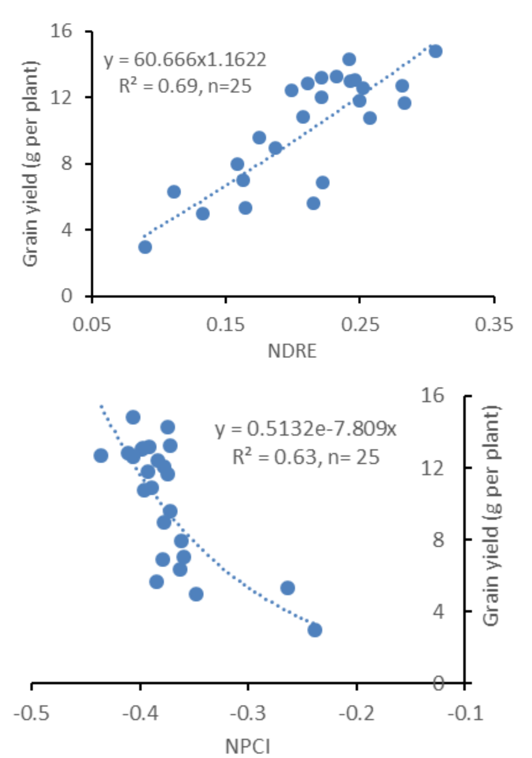


The spectral indices *i.e.* CARI (Chlorophyll absorption ratio index) and dNBR (difference of normalized burn ratio) for mature, harvested and burnt paddy

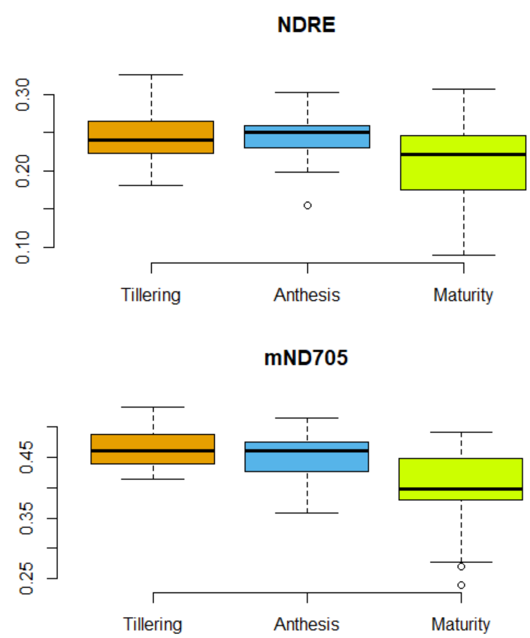
multispectral corresponding to Sentinel-2 MSI bands. We found that CARI (Chlorophyll absorption ratio index) and dNBR (difference of normalized burn ratio) was suitable spectral indices for distinguish between paddy harvested and paddy burnt.

6.5.3.2 Prediction of rice yield using hyper spectral indices

Five rice genotypes (PB-1, P-44, MTU1010, Swarna and Nagina 22) grown with five treatments of Nitrogen (control, urea (100% RDF); Urea loaded Nano Clay Polymer Composite (NCPC, 75% RDF); Urea loaded Nano Clay Biopolymer Composite (NCBPC-I ,75% RDF) and Urea loaded NCBPC-II (75% RDF) under controlled climatic condition at Nanaji Deshmukh Plant Phenomics Centre, IARI. Spectral reflectance data (350-2500 nm) was recorded at three growth stages (40, 55 and 70 DAT) with the help of hand held Spectroradiometer. The spectral data were exported to excel and analysis of these data showed that vegetation indices are related to type of Nitogen with different rice genotypes. Normalized different red edge (NDRE) and normalized pigment chlorophyll index (NPCI) at 70 days after transplanting (DAT) showed a good quantitative relationship with rice yield with R^2 = 0.69 and 0.63, respectively. Spectral index based total N prediction were found better than the N uptake prediction.



Quantitative relationship between rice yield and spectral indices at 70 DAT

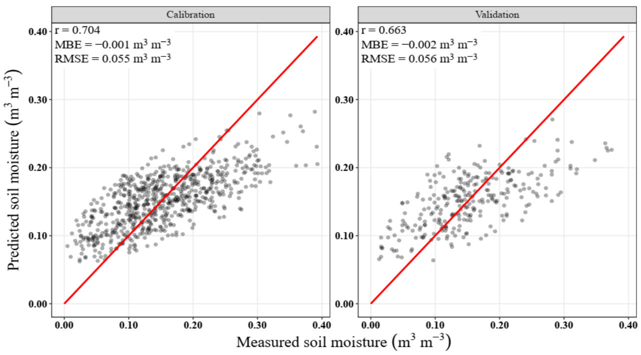


Variation of spectral indices

6.5.3.4 Satellite-based ensemble surface soil moisture estimates for irrigation mapping

An ensemble-of-all approach (combination of microwave-optical-thermal remote sensing) for surface soil moisture (SSM) monitoring was used for irrigation mapping over IARI farm. At first, a comprehensive evaluation of the SSM estimation was made from the most pertinent optical, thermal and microwave-based methods using multi-date SAR data from Sentinel-1 (VV polarization), Sentinel-2, and LANDSAT-8 OLI spread over the post-monsoon season (2020-2021; total 8 dates) in IARI farm. Consequently, the predictions from these approaches were used to build an ensemble model using GBM (Gradient Boosting Method) for SSM retrieval. Model output was finally assessed to irrigation regimes under specified crops. The ensemble model calibration revealed higher correlation (0.704

$m^3\,m^{-3}$) and lower RMSE (0.055 $m^3\,m^{-3}$) between the estimated and measured SSM. The validation plot for ensemble modelling had better accuracy as compared to individual models with RMSE at 0.056 $m^3\,m^{-3}$. The agreement between estimated and measured SSM was also higher (r = 0.663) than TOTRAM /OPTRAM, although lower than WCM. Considerable improvement in MBE (bias) during validation was also recorded for

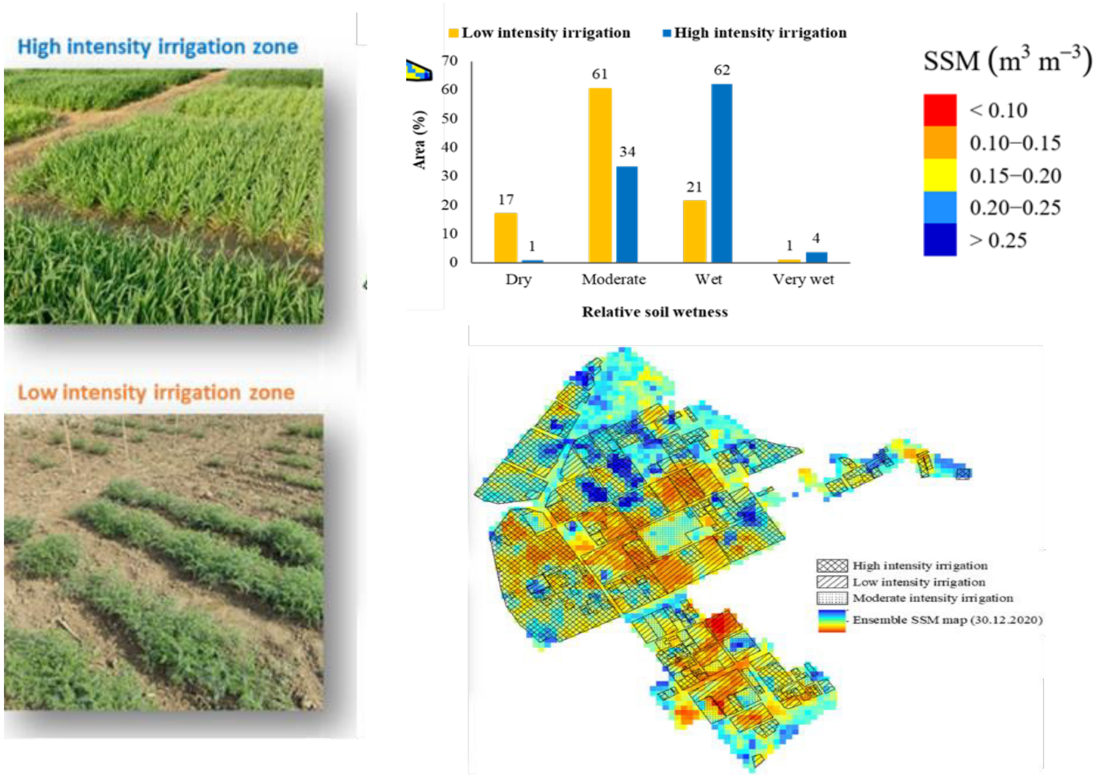


Calibration and validation plots of ensemble SSM estimates from WCM, TOTRAM, OPTRAM-1 (SWIR 1) and OPTRAM-2 (SWIR 2) (pooled across dates) models

ensemble SSM maps (-2.3e-03 $m^3\,m^{-3}$).

The contrasts in soil moisture due to differential irrigation practices were well captured in the aerial extent of 'dry', 'moderately wet', 'wet' and 'very wet' soil. Overall, area under low-intensive irrigated crops remained largely 'dry', with isolated patches of 'wet' to 'very wet' soils. The high-intensive irrigated areas under wheat were clearly discernable under 'moderate' to 'wet' soil moisture classes. Spatial variations in SSM over the entire winter season were consistent with crop cover (fractional vegetative cover).

During early crop growth stages, microwave and optical-thermal approach are better while during later stages, optical approach using SWIR 1 or 2 appears reliable. An ensemble modelling approach combining optical-thermal-microwave based predictive models can be the best option for SSM retrieval covering an entire cropping season with reasonable and consistent accuracy, and can thus aid to irrigation planning.



Areas occupied by high- and low-intensive irrigated crops over the range of soil moisture as mapped (December 30 2020) through the satellite data

6.5.3.5 Soil Moisture estimation by minimizing the roughness and vegetation properties using airborne L and S microwave band

A Comparison between Sentinel-1 and Dubois model backscatter values, difference between the backscatter values with soil moisture and validation outcomes were done for IARI farm New Delhi and Central state farm Hisar. The Dubois model obtained sigma naught values showed an overestimation of the radar backscatter values by 0.4 dB for IARI farm and 0.26 dB for Central state farm Hisar in VV polarization. Although, incorporation of both HH and VV co-polarized datasets will improve the result as stated by some of the literatures. To suppress the vegetation effect of the region, Water Cloud model (WCM) is used. For this, sentinel 1 image of acquisition date 19 Sep 2019 was processed to create backscatter coefficient and the NDVI was calculated from the surface reflectance of Landsat 8 (acquisition date 17 Sep 2019) which were resample to match the 10m pixel spacing of the Sentinel 1. Processing of Sentinel 2 data is going on to extract the NDVI by interpolating the before and after acquired imageries falling close to Sentinel 1 acquisition date. NDVI was used as the value of V1 and V2.

6.5.4 Agricultural meteorology

6.5.4.1 Mustard yield prediction using machine learning approach

Mustard yield prediction was done by machine learning approach using long term weather and mustard yield data. Model was developed by using stepwise multiple linear regression (SMLR) and artificial neural network (ANN), support vector machine (SVM), random forest (RF), using principal component analysis (PCA) techniques. Results showed that among all the six models, PCA-SVM performed best for the study area. Performance of the model developed by optimum combination performed better than the individual. By comparing the performance of the model developed either by variable selection by SMLR individual and optimum combination or variable extraction by PCA individual and optimum combination, variable extraction by PCA performed better than variable selection by SMLR and can be used for district level mustard yield forecast.

6.5.4.2 Weather based agromet advisory

Based on past weather, real time weather and weather forecast for next five days, weather based agromet advisory bulletin were prepared on every Tuesday and Friday in both Hindi as well as in English. These bulletins are sent through electronic media for wider dissemination among farmers and stake holders. Agromet advisory bulletin contains value added medium range weather forecast information (for the next 5 days) for crop management, which is based on decision tools and weather forecast, giving warning to farmers much in advance regarding rainfall variation, its amount and other weather variables including pest/ disease problems etc. so that farmers can decide about crop management, application of nutrients, irrigation scheduling, sowing, harvesting etc. During 2021, 105 agromet advisory bulletins were prepared in Hindi as well as in English and SMS regarding agromet advisory were sent through the m-Kisan portal. Farmers who followed the agromet advisories are able to reduce the input cost by reducing the irrigation, based on the rainfall forecast, number of spray, seed rate and timely management practices based on agromet advisories.

6.6 NATIONAL PHYTOTRON FACILITY (NPF)

The National Phytotron Facility has been serving the plant scientific community of the country since 1987. It has now entered in to the silver jubilee year (2022) of its establishment. During this entire period, the facility has profusely been utilized to conduct experiments on genetics, physiology, plant protection, biochemistry, plant-environment interaction and the development of climate resilient crops. During the year under report (2021), the facility was utilized to conduct various experiments on crop development, recombinant DNA technology, nutrient use efficiency, bio-fortification, gene expression studies etc. The facility was running 24x7 even during lockdown period and all the experiments were completed successfully. In total, 85 new experiments were conducted in the facility in addition to the on-going experiment of the last year. The facility could collect about one lakh rupees as user fee from the paid experiments. A massive program of developing herbicide tolerant soybean varieties has also been initiated in the Phytotron. A soybean variety obtained from the USA is being used as donor of the gene for herbicide tolerance, which is being transferred to 7 Indian soybean varieties through molecular marker-assisted backcross breeding. Successful hybridization resulted in production of more than 600 F_1 seeds, which are being grown to produce BC_1F_1 generation. The old polycarbon-sheets of the glass houses have been replaced with a new one, which has increased quantum of light inside the glass house. The cooling systems of the glass houses have been up-graded to manage the temperature efficiently. The facility has been supporting and providing required experimental conditions to the users all throughout the year.

Herbicide tolerant American soybean variety. It has been used in breeding program to transfer herbicide tolerance in to Indian soybean varieties

7. SOCIAL SCIENCE AND TECHNOLOGY TRANSFER

The support of government programmes and schemes, technological interventions and capacity building have been crucial in socio-economic upliftment of rural poor. The School of Social Sciences carried out studies on assessment of e-NAM, KCC and ecosystem services support; initiated and evaluated Pusa Samachar as an innovative means of technology dissemination; undertook technological interventions for climate resilience and nutritional security; and mobilized groups for agripreneurship. The performance of improved varieties and technologies in OFTs and FLDs were assessed.

7.1 AGRICULTURAL ECONOMICS

7.1.1 e-NAM: Prospects and constraints

The analysis of national level data revealed that only 15 percent of the APMC markets are linked with farmers' participation rate of 13 percent. The major commodities traded are cereals, which account for nearly 40 percent of total volume and 25 percent of the value of trade in 2020-21. The e-NAM prices were found significantly lower than the Agmarknet prices in most of the commodities in the majority of the states. Only 1.6 percent of total food grain production, 2.3 percent of paddy production, and a meager 0.5 percent of wheat production are being traded through e-NAM. Also, inter-marketing trade is almost nil and, hence, acceleration of the speed of unified license issue should be the priority.

7.1.2 Demand and supply projection of millets

A study on demand-supply gap of millets such as bajra, jowar, ragi and small millets revealed that under all scenarios, unless there was an improvement in productivity and area under cultivation, possible reduction in supply could occur in the case of *jowar* and *ragi*, whereas, in the case of *bajra* there might be an improvement in supply. However, in the case of small millets, the production will be improved only if there is a check in area decline. The estimation of demand-supply gap showed that there might be net surplus of around 4 million tonnes in the case of *bajra* and 0.1 to 0.2 million tonnes of small millets by 2033. While in the case of *jowar* and *ragi*, there may be net deficit in the near future to an extent up to 1.14 -1.45 mt and 0.2 - 0.36 mt, respectively, hence measures may be taken to ensure assured supply.

7.1.3 Valuation of ecosystem services

It was estimated that Wayanad paddy ecosystem generated ₹ 6,26,919 per ha worth of ecosystem services annually, of which 77 per cent was non-marketed. The farmers were willing to accept a mean compensation of ₹ 7,933 per ha as incentive to cultivate traditional paddy varieties, which was lower than the Government's incentive under 'Wayanad package scheme'. But these amounts are very low in comparison to the annual value of ecosystem services. The average ecosystem services delivered by the EYC Eastern Yamuna Canal (EYC) in its command area were estimated to be ₹ 1123 million, which is quite higher than working expenses (₹ 757 million) of this canal irrigation system. Both the studies suggest that value of ecosystem services needs to be accounted for in any eco-compensation framework.

7.1.4 Agricultural export and Covid-19 pandemic

The Covid-19 pandemic affected overall exports from India which have fallen to the extent of 6.7 per cent. However, the two sectors have registered positive growth during this period *viz.*, agriculture (17%) and pharmaceutical (18%) sectors. Applying social accounting matrix (SAM) multiplier analysis (2017-18), it was found that agriculture exports saved the GDP_{fc}

fall to the extent of ₹ 1.37 lakh crore Rupees, output demand fall to the extent of ₹ 4.3 lakh crore rupees and labor demand fall to the extent of ₹ 0.3 lakh crore. The household income fall was saved to the extent of Rs. 1.03 lakh crores. There is a need for creation of more employment opportunities and providing personal loans on the subsidized interest rate for the revival of the economy.

7.1.5 Economic impact of rice, soybean and chickpea varieties of NARS

Consumer surplus, producer surplus and total economic surplus generated from the adoption of the varieties of basmati rice (PB 1121, PB 1509), chick pea (JG 11, JAKI 9218, JG 16) and soybean (JS 335, JS 95-60) were estimated. In terms of total economic surplus, PB 1121 generated ₹ 39250 crores (at 2019-20 prices), and PB 1509 generated ₹ 2941 crores (at 2019-20 prices) in the case of rice; JG 11 generated ₹ 397 crores (at 2020-21 prices), JAKI 9218 generated ₹ 978 crores (at 2020-21 prices) and JG 16 generated ₹ 78 crores (at 2020-21 prices) in the case of chick pea. Total economic surplus generated from the soya bean variety JS 335 was ₹ 50111 crores and that from JS 95-60 was ₹ 6749 crores, respectively.

7.1.6 Lending through Kisan Credit Cards in Rural India

A study with sample of 2,932 agricultural households, (560 having and 2372 not having Kisan Credit Card) showed that two-thirds of the borrowed KCC amount was used to purchase agricultural inputs such as fertilizers, seeds, and pesticides, while only about 13 per cent of the borrowed amount was used to purchase durable farming equipment like tractors and threshers. The Coarsened Exact Matching technique showed that the KCC-holder households had ₹ 7058 more farm income per hectare than the non-KCC holders. Finally, access to KCC reduced farmer's dependency on moneylenders for borrowing credits by 25 per cent.

7.2. AGRICULTURAL EXTENSION

7.2.1 ICT based extension

'Pusa Samachar' was launched on August 15, 2020 and first episode of Pusa Samachar was uploaded on August 22, 2020. Every Saturday at 7 pm new episode is being uploaded at IARI official YouTube channel. Total 132 episodes of Pusa Samachar in Hindi, Telugu and Kannada, Tamil, Bangla and Oriya were broadcasted among farmers through You Tube channels as well as whatsApp groups. One dedicated Pusa WhatsApp number (9560297502) has been launched, via which farmers are sending their farm problems with pictures and scientists are replying promptly. There are 17700 subscribers of IARI YouTube Channel with total viewership of ₹ 4.5 lakhs. In every episode time-pecific crop management practices, successful farmer stories, Pusa WhatsApp salah and weather broadcast are being given.

7.2.2 Climate change adaptation

Twenty five demonstrations on climate resilient technologies (direct seeded rice, zero-till wheat, IPM in cotton) were carried out at village Sangel in Mewat, Haryana. Adoption index of zero tillage in wheat has increased to 57 per cent as a result of demonstrations. Social learning based adoption of organic practices was analysed in Gaya district of Bihar. The findings revealed that three behavioural motives attitude, subjective norm and planned behaviour control explained 79.50 per cent of variance in adoption of climate smart technologies.

Study on convergence based extension at Gaya (Bihar) showed increase in water security, technology accessibility, capacity development, and income. The area irrigated in *kharif* and *rabi* with the water harvested in the in the structures now increased to 22.7 ha and 2.63 ha, respectively, while Income from the fish was about ₹ 46.000.

Under ICAR project NICRA, the interventions were made for capacity building of farmers in utilization of Climate Resilient Technologies at NICRA villages in Gurugram (Haryana), Chandauli (Uttar Pradesh), Gaya (Bihar), and Sundarbans (West Bengal). As a result of interventions in project village Dohari in district Gaya (Bihar), adoption of zero tillage has increased to about 200 acres in other villages.

7.2.3 Establishment of Biotech-KISAN Hub at Chitrakoot by ICAR-Indian agricultural research institute, New Delhi

A micro-processing unit was established at KVK Chitrakoot under DBT Biotech KISAN Hub Project. Equipment like hydraulic press, pulper, flour mill, spice mill, mixer cum grinder and other accessories have been provided in the hub from the project for use by the local farmers for processing at community level. A three-day training programme was also conducted on processing and value-addition of agri-horti produce to the farm women of the area. More than 50 farm women were trained.

7.2.4 Expansion activities of Biotech Kisan Hub in Rajasthan (three), Haryana (one) and UP (one)

A total of 2919 demonstrations of improved varieties of paddy, wheat, moong, pigeon pea, mustard and horticultural crops; bio-fertilizers (PSB, AMF, *Azotobacter*, trichoderma, Pusa Sampoorn (NPK), ZNSB, microbial formulations for pest and residue management and agro-techniques were laid out benefitting 1967 farmers. Training on crop production, protection and value addition benefitted as many as 1315 farmers. The vegetable varieties under demonstration resulted in improving income of the farmers besides higher Benefit-Cost ratio. The farmers secured income in range of ₹ 59,520– 78,120. Introduction of Kitchen Garden kits ensured income as well as nutritional security.

7.2.5 Maximizing farm profitability through entrepreneurship development and farmer led innovations

Ten women SHGs were formed in Manjhawali and Swamika. In collaboration with NABARD, two Farmer Interest Groups (FIGs) were mobilized in Fatehpur Biloch. In Fatehpur Biloch and Tigipur village, 2 Farmer Producer Companies were established with 100 members each. Direct marketing initiative to the residential welfare associations in Delhi were undertaken during the pademic. Major constraints in upscaling and out scaling of farmer led innovations were: lack of separate price policy of the government, lack of exclusive extension personnel for promotion, require more complementary technical. inputs, lack of skilled manpower, lack of expertise for validation and no standard set of indicators for validation.

7.2.6 Enhancing nutritional security and gender empowerment

The food consumption pattern and dietary diversity were measured among tribal women (78 households) from Jeypore, Odisha. It was found that majority of the respondents from female group were under underweight category compared to male respondents. Across all the respondents medium Diet Diversity Score (DDS) was majorly noticed.

Demonstrations of improved varieties under Biotech-kisan

7.3. TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1. Out scaling agricultural innovations for enhancing farm income and employment

During *rabi* 2020-21, the project was in operation at three villages, namely, Nidana (Rohtak, Haryana), Maholi (Palwal, Haryana) and Bhagwanpur Chittawan, (Meerut, U.P). The performance of location-specific improved varieties of wheat, mustard, onion, carrot, *methi*, brinjal, and *palak* were assessed through 158 trials over an area of 57.8 ha. The performance of the IARI wheat varieties was found superior as compared to local check.

Net profitability was the highest for HD 3226 (₹ 69,140/ha) followed by HD3086 (₹ 65,462/ha) and HD 2967 (₹ 59,095/ha). HD 2967 and HD 3086 exhibited profuse tillering, no lodging and good *chapati* making quality. Mustard was a new crop introduced and the performance of varieties Pusa Jagannath (1.42 t/ha) and PM 30 (1.36 t/ha) with net profitability of ₹ 54,200/ha and ₹ 50840/ha, respectively, was recorded.

The average yield of late sown wheat varieties HD 3059 and HD 3271 was 4.90 and 4.95 t/ha, respectively. The varieties HD 3226, HD 3086 and HD CSW 18 have good *chapatti* making quality.

Results of *rabi* Crop Demonstrations (2020-21)

Village	Crop	Variety	Yield Demon-strations (t/ha)	Av. yield of local Check (t/ha)	(%) Increase in yield over local check	Average Net Return (Rs./ha)	
						Demonstration plot	Local Check plot
Nidana, Rohtak (Haryana)	Wheat	HD2967	5.22	4.40 (WH711)	18.63	59095	43175
		HD3086	5.55		26.13	65462	43175
		HD3237	4.47		1.70	44631	43175
		HDCSW18	4.65		5.68	48018	43175
		HD3226	5.74		30.45	69140	43175
		HD3271	4.42	4.00 (Raj3765)	10.50	43560	35420
		HD3059	4.55		13.75	46082	35420
	Mustard	Pusa Jagan-nath	1.42	New introduction	-	54200	-
		P M 30	1.36	New introduction	-	50840	-
Maholi, Palwal (Haryana)	Wheat	HD- 2967	5.63	5.00 (WH711)	12.66	91022	79750
		HD- 3086	5.41		8.26	86407	79750
		HDCSW18	5.52		10.5	88968	79750
		HD- 3226	5.40		8.12	86668	79750
		HD- 3237	5.53		10.6	89067	79750
		HD- 3059	4.90	4.45 (Raj 3765)	10.11	77925	69387
		HD- 3271	4.95		11.23	79262	69387
Bhagwanpur-Chittawan, Meerut (UP)	Wheat	HD3086	5.92	4.850 (DBW 303)	22.06	66250	47150
		HDCSW-18	5.76		18.76	62690	47150
		HD 3226	6.13		26.06	69022	47150
		HD3237	5.52		13.81	58630	47150
		HD3271	5.36	45.0 (PBW 373)	19.22	56435	41500
		HD3059	5.01		11.44	49785	41500
	Mustard	Pusa Jagan-nath	2.57	2.25 (Pioneer)	14.78	97050	82500
		PM-26	1.97	1.80 (Coral 432)	9.44	68500	60000

Results of *kharif* Crop Demonstrations (2020)

Location	Crop/Variety	No. of demo.	Area (ha)	Avg. Yield Demo. (t/ha)	Variety and yield of local check (t/ha)	Increase in yield %	Average net return (₹/ha)		Benefit: cost ratio	
							Demo. plot	Local plot	Demo. plot	Local plot
Village Nidana, (Rohtak, Haryana)	Paddy PB-1718	32	12.80	4.73	4.0 (PB1121)	18.35	51416	42000	1.82	1.67
	Paddy PB-1121	20	8.00	4.30		8.00	50120	42000	1.80	1.67
	Paddy PB-1509	20	8.00	4.45		11.25	26800	42000	1.43	1.67
Village Bhagwanpur Chittawan (Meerut, U.P.)	Paddy PB 1509	3.20	4.00	4.93	4.0 (PB 1509)	23.27	32343	22000	1.57	1.44
	Moong Pusa Vishal	1.80	8.00	1.57	1.25 (Desi)	26.00	52500	37500	3.00	2.50
	Moong Pusa 9531	0.50	2.00	1.65		32.00	55625	37500	3.07	2.50
	Moong Pusa 1431	1.00	5.00	1.43		14.40	46500	37500	2.86	2.50

During *kharif* 2020, a total of 72 assessment trials were conducted at village Nidana, Rohtak (Haryana) and Village Bhagwanpur, Meerut (UP) on three paddy varieties (PB-1121, PB-1509 and PB-1718) and moong bean (Pusa 9531, Pusa Vishal and Pusa 1431) covering an area of 28.80 ha. The highest average yield of PB-1718 (47.34 q/ha) was recorded at farmers' field, followed by PB-1509 (44.50 q/ha) and Pusa-1121 (44.50 q/ha). The market rates of these varieties were (@ ₹ 2400, ₹ 2000 and ₹ 2600/q, respectively. PB 1718 fetched the highest net return, *i.e.* ₹ 51,416/- followed by PB-1121 (₹ 50,120/-) and PB-1509 (₹ 26,800/-). At village Bhaganpur Chittawan, Meerut, U.P. 19 assessment trials were conducted on paddy (PB 1509) and moong (Pusa Vishal, Pusa 9531 and Pusa 1431) covering an area of 6.5 ha. The yield of PB 1509 recorded at farmers' field was 23.27 percent higher than the local check. PB-1509 fetched the highest net return, *i.e.* ₹ 32343/- with B: C ratio of 1.57. Its grain quality was also good in terms of maturity, cooking quality, good aroma and weight. In addition to paddy crops, moong demonstrations also performed well and showed 14.40 to 32 percent increase in yield.

During *kharif* 2021, a total of 303 assessment trials were conducted at villages Nidana, Rohtak and Maholi, Palwal in Haryana and village Bhagwanpur, Meerut in UP on paddy varieties (PB-1121, PB-1509, PB 1692, PB 1401, P 2511 and PB-1718) and moong bean (Pusa 9531, Pusa Vishal and Pusa 1431), okra, (Pusa A 5), bottle gourd, (Pusa Naveen), cow pea, (Pusa Sukomal), sponge gourd (Pusa Sneha), brinjal (Pusa Uttam), Amaranthus, (Pusa Lal Chaulai) and vegetable kits covering an area of 104.48 ha.

7.3.2 Technology integration and transfer to strengthen the farming system in partnership mode

During *rabi* 2020-21, under the NEP collaborative program with ICAR institutes and SAUs, 156 demonstrations involving 18 varieties of nine crops in nine states were conducted, covering an area of 34.16 ha at 12 locations. About 52 Wheat demonstrations on IARI varieties HD 2967, HD 3086, HD 2932, HD 3237, HD 3226 and HI 1605 were carried out in an area of 13.20 ha. A total of 17 demonstrations on mustard varieties Pusa Jagannath and PM 26 were conducted in 3.1 ha. 87 demonstrations of lentil (var. L 4076, L 4147), onion (var. Pusa Red, Pusa Riddhi), gram (var. Pusa 547), *palak* (var. All green), pea (var. Pusa Pragati), marigold (var. Pusa Basanti and Pusa Narangi), carrot (Pusa Rudhira) and methi (Pusa Early Bunching) were also laid out. During *rabi* 2020-21, 202 demonstrations covering 19 varieties of 8 crops in an area of 37.89 ha were conducted in collaboration with Voluntary Organizations. The wheat varieties, *viz*., HD 2967, HD 3086, HD 2932, HD 3226, HD 3237, HD 3271, HI 1620, and HI 1628 were demonstrated in 32.0 ha. A total of nine demonstrations of mustard (var. Pusa Jagannath and PM 26) were conducted in 2.40 ha. The lentil (var. L 4076, L 4147 and L4717), onion (var. Pusa Red), gram (Pusa 547), *palak* (var. All Green), pea (var. Pusa Pragati) and marigold (var. Pusa Basanti and Pusa Narangi) were also demonstrated in 3.49 ha area. The feedback on IARI varieties from the various institutions are as follows:

Demonstration of Wheat variety HD 2932 on farmers' fields resulted in a 14.41 percent increase in yield over local check GD-496 and a B:C ratio of 2.43 as compared to 1.94 of the local check. HD 2932 worked well in late sown condition, though it is early compared to GD 496. The variety had more tillers and less lodging problems. The excellent quality of chapati of HD 2932 fetched a better price (₹ 2050 per quintal with a net return of ₹ 51950 per ha). At DRMR, Bharatpur, Rajasthan reported wheat varieties; HD 2967 and HD 3237 resulted in 7.42 and 12.55 per cent increase in yield, respectively, compared to local check Raj 4037, Raj 4079 and Sriram. Both the IARI varieties recorded more tillering, strong stem, lustrous seed, long spikes though they took 10-15 days more to mature than local varieties. The demonstrations of wheat variety HD 2932 in coastal Gujarat yielded an enhancement of 5.73 percent. KVK, Kathua reported wheat variety HD 3226 gave the higher yield of 5.25 t/ha (36.36 per cent higher), followed by HD 3237 (33.80 per cent) and HD 2967 (30.53 per cent) as compared to the local check. Though HD 3237 has been recommended for irrigated fields, it also performed well in restricted irrigation conditions. Other crops, *viz*., lentil (Pusa Shivalik) recorded a 0.92 tonnes per ha yield with a 42.30 per cent increase over the local check. The *palak*, brinjal and onion varieties recorded 28.12, 30.45 and 20.83 per cent higher yields than local check.

The wheat varieties HD 2967, HD 3086, HD 3237 and HD 3226 at KVK, Saharanpur performed better in terms of yield and economic gain than the local cultivars. The variety HD 2967, HD 3226, HD 3086 and HD 3237 recorded 23.52, 23.00, 20.50 and 2.50 per cent increase, respectively, over local check. However, variety HD 2967 had the biggest problem of Karnal Bunt due to the high moisture level of that area (KVK, Saharanpur). At KVK, Kangra, Himachal Pradesh, the demonstrations of chickpea var. P 547, pea var. Pusa Pragati and mustard var. Pusa Jagannath resulted in 27, 33 and 28 per cent increase in yield, respectively, over the local checks. Garden pea cv. Pusa Pragati recorded an average yield of 120 q per ha. Among other vegetables, *palak* cv. All Green and onion cv. Pusa Red recorded 13.0 and 20.0 tonnes per ha yield, respectively, with 21 and 19 per cent increase in yield, respectively, over the local check. At NRRI, Cuttack, the demonstrations of onion variety Pusa Ridhhi yielded 29.5 t/ha as compared to 24.4 t/ha of local check N53. Farmers rated Pusa Riddhi as a good yielder and more pungent. Farmers liked *palak* cv. All Green variety for its high yields of 12.4 t/ha compared to 9.5 t/ha of local Kiran OP variety. This variety has a high potential for adoption for its multi-cut trait, tender and thick leaves. For MPUAT, Udaipur location, the performance of wheat HD 2932, lentil, L 4076 and L 4147 and marigold Pusa Narangi Gainda. The average yields of wheat HD 2932 was 4.28 t/ha compared to the 3.64 t/ha yield of the local check. Farmers appreciated the variety of HD 2932 due to good plant height (83-92 cm), compact ear head, a good number of tillers (385-420 per m^2), medium bold shiny grain and yield, *chapatti* quality. The average yield of lentil L 4147 and L 4076 was 1.26 and 1.30 t/ha, which was 36.21 and 11.35 per cent higher than the local check (0.92 t/ha). Pusa Narangi marigold variety has become very popular there. The variety produces deep orange (saffron colour) flowers that are big, compact with good keeping quality and high yield compared to local check.

At KAU, Thrissur, Kerala, the demonstrations of *palak* All Green fared well with a B: C ratio of 2.1 (KVK, Kannur). At FAARD Foundation, Varanasi, the HD 2967 recorded a 12.19 per cent yield increase over the local check. The high grain yield and resistance to major diseases, superior grain, and chapatti quality are the major appeals of the variety to the farmers. Farmers of the area are ready to replace older varieties with this new variety. Already, some villages of the area have 70 per cent saturation of HD 2967 and a seed chain has been set up with KRIBHCO and NSC, to whom PRDF, Gorakhpur supplies foundation seed for seed production (PRDF, Gorakhpur). HD 2967 faced Karnal bunt problem due to untimely rain at CRD, Gorakhpur. At YFA, Rakhra, Punjab HD 3086 recorded a yield of 2.2 t/ ha, HD 3226 recorded 1.8 t/ha, HI 1620 recorded 2.45 t/ ha and HI 1628 recorded 2.25 t/ ha. At FARMER, Ghaziabad, the highest yield increase of 21.04 and 20.31 per cent was recorded in HD 3271 and HD 3226 respectively. The B: C ratio of HD 3271 was highest (1.87), followed by HD 2967 (1.81), HD 3226 (1.74), HD 3086 (1.64) and HD 3237. Also, a women farmers group '*Mahila Sahbha gita Jaivik Utpadak Samooh*" has been formed at village Sirrora, Salempur, Ghaziabad for small scale value-addition enterprises by VO partner FARMER, Ghaziabad.

The demonstrations of HD 2967 reported an increase in yield of 25.24 per cent (B: C ratio 4.29) and HD 3237 reported that of 23.93 per cent (B: C ratio 3.97) over local check Raj 3077 at KVK, Chomu. Pusa Shivalik was a new introduction to the area and the marigold varieties performed well with a 13.51 per cent increase in yield (B: C ratio 2.10) over local varieties. The share of IARI varieties of wheat, *e.g.* HD 2967, HD 3086 and HD 3237 in *rabi* 2020-21, was 22 per cent over 81 ha area of three villages and the onion varieties, *e.g.* Pusa Madhavi, Pusa Shobha and Pusa Red was 10 per cent in 2.5 ha area of the villages. The three onion varieties yielded 31.5 t/ha, 385 q/ha and 370 q/ha in a total of 28 demonstrations. SHDA, Gorakhpur has initiated an FPO for seed production with the help of NABARD. At Vidya Bhavan KVK, Udaipur the demonstration of wheat variety HD 2967 recorded a 27.6 per cent increase in yield over the rust susceptible local check (Lok 1) with a B: C ratio of 3.0. The variety was the tallest among all local varieties, *e.g.* Raj 40 79, Raj 4238, Raj 4037 and Raj 4120 and the highest number of grain per ear (55).At DRI KVK, Chitrakoot, there was 14.17 per cent increase in yield in wheat variety HD 2932 (B:C ratio 2.62) and a 17.47 per cent increase in yield in HD 3237 (B: C ratio 2.69) over local check-in *rabi* 2020-21 season. The variety HD 2932 was found to be the best in terms of productivity; thus, the farmers of Bundelkhand have been advised to adopt it for the future. The variety HD 3237 was appreciated for high tillering, high production despite late sowing time and best quality chapatti. The chickpea variety Pusa 547 recorded a 28.6 per cent increase in yield over local check with a B: C ratio of 3.13. The centre has established a seed hub and processing plant permitted by the government. At HESCO, Dehradun, wheat cv. HD 2967 recorded an increase in yield of 20.82 per cent over the local check. However, the farmers liked HD 3086 (B: C ratio 1.56) for better yield than HD 2967 and better market rate. The chickpea Pusa-547 has been demonstrated and recorded yield increase of 5.83 per cent. Lentil L 4717 recorded an increase in yield of 22.22 per cent. At ISHARA, Deoria the HD 2967 variety recorded a 17 per cent increase in yield over local check with an average productivity of 4.59 t/ ha. The farmers liked it due to very high tillering compared to local check DDW 16, 60-65 grains per ear, early maturity and soft and tasty *chapatti*. Group formation and production of value added products and seeds are going at various partner organizations. PRDF, Gorakhpur and YFA, Rakhra, Punjab are already involved in seed production. PRDF Gorakhpur has produced 303 q of TL seed. The five FPOs developed by NRRI, Cuttack also have started paddy seed production. MPKV, Rahauri has planned to develop seed bank in collaboration with NSC and Maha Beej.

During *kharif* 2021, under NEP, 281 demonstrations on nine crops with 18 varieties covering an area of 43.30 ha were conducted at 12 locations of ICAR Institutes / SAUs. Under paddy crop, 101 demonstrations were carried out with the paddy varieties, *viz.*, Pusa 2511, Pusa 1850, PB 1718, PB 1509, PB 1121 and PB 1401 in an area of 34.70 ha. Also 180 demonstrations of other crops like moong (Pusa Vishal, Pusa 9531 and Pusa 1431), bottle gourd (Pusa Santusthi), sponge gourd (Pusa Sneha), okra (Pusa A-5), cowpea (Pusa Sukomal), cauliflower (Pusa Meghna), brinjal (Pusa Uttam, Pusa Hara Baigan) and Amaranthas (Pusa Lal Chaulai, Pusa Kiran) were conducted. In collaboration with voluntary organisations, 528 demonstrations on 12 crops with 23 varieties covering an area of 81.55 ha were conducted at 19 locations of Voluntary Organizations. Under paddy crop, 280 demonstrations were carried out with the paddy varieties, *viz*., Pusa 2511, Pusa 1850, PB 1718, PB 1509, PB 1121, PB 1401, PB 1692 and P 44 in an area of 69.98 ha. Also 248 demonstrations of other crops like moong (Pusa Vishal, Pusa 9531 and Pusa 1431), bottle gourd (Pusa Naveen, Pusa Santusthi), brinjal (Pusa Uttam, Pusa Hara Baigan), sponge gourd (Pusa Sneha), cauliflower (Pusa Meghna and Pusa Ashwin), okra (Pusa A5), arhar (Pusa16), cowpea (Pusa Sukomal), and amaranths (Pusa Lal Chaulai, Pusa Kiran) were conducted.

7.3.3 Participatory seed production of improved varieties of IARI at seed hubs

Under participatory seed production of improved varieties of wheat, during *rabi* 2020-21, 35.2 t of HD-2967 wheat seed was produced at PRDF, Gorakhpur, and 5.5 t seed of HD 3226, 5.5 t of HD 3086, 5.62 t of HI 1628 and 6.12 t of HI 1620 were produced at YFAP, Rakhra. During *kharif* 2021, 12.2 t of PB 1509, 32.2 t of Pusa 44 and 3.4 t of PB 1121, 9.4 t of PB 1401and 5.0 t of PB 1718 seeds were produced at Rakhra.

7.3.4 Agricultural technology information centre (ATIC)

ATIC is effectively providing products, services, technologies and information services to the different stakeholders through a 'Single Window Delivery System'.

In ATIC crop cafeteria, live demonstrations of improved varieties *viz*. PB 1509, PB 1637, PB 1121, PB 1718 of paddy and Pusa Jawahar hybrid of maize were laid out for the benefits of visitors

Due to pandemic situation of Covid 19, exposure visits of the farmers were reduced drastically and during the year a total of 9,870 visitors (farmers/farm women/ entrepreneurs/ officials) visited ATIC for seeking advisory services, purchase of Pusa seeds, farm publications, biofertilizers, and for enquiry about training programmes.

A total number of 7,522 farmers calls from 18 states were received through Pusa *Agricom* (A toll free Helpline No.-1800-11-8989) Pusa Help-line (011-25841670, 25841039, 25846233, 25803600) and *Kisan Call Centre* 1800-180-1551 (IInd level) on various aspects of agriculture. Purpose-wise calls were made by the farmers related to seed availability (4,250) followed by production technology (1,850), plant protection (1,280), agro-based enterprises (912), literature (622), biofertilizers (4,15), and others (350).

Pusa seeds and biofertilizer of worth ₹15,36,836/- and farm publication for ₹ 19,090/- have been sold to the farmers during the year.

Four issues of Hindi farm magazine "*Prasar Doot*" were published by the centre during the reporting period. Besides, more than 450 farmers and others got farm advisory services through e-mails during the period. ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators.

7.3.5 *Krishi Vigyan Kendra*, Shikohpur, Gurugram

7.3.5.1 On farm trial (OFTs) and frontline demonstration (FLDs)

The results of OFTs and FLDs organised are as below:

OFT/FLD	Treatment	Results
Integrated Nutrient Management in pearl millet	10 ton FYM + soil test based NPK + NPK liquid fertilizers @ 10 ml/kg seed as seed treatment	Grain and fodder yield under intervention increased by 16.36 and 14.88% over farmers practice, respectively.
Weed management in pearl millet	Atrazine @ 0.75 kg *a.i.* + 2,4-D ethyl ester 0.5 kg *a.i.* per ha. @ 25-30 DAS	17.41% increase in grain yield over no use of weedicides by farmers. The weed population reduced by 71.0%.

Integrated Nutrient Management in wheat	10 q/ha FYM + bio-fertilizers as seed treatment (PSB & *Azotobacter*) + 75% NPK of recommended dose of fertilizers after soil test	Wheat yield under intervention increased by 7.6% (50.56 q/ha) over farmers practice and fetched income of ₹ 78616/- with B:C ratio 2.44 as against ₹ 72980/- with B: C ratio 2.40 in farmers' practice.
Orobanche management in mustard	Glyphosate 41% SL @ 25 g/ha at 30 DAS and 50 g/ha at 55 DAS	Reduced the weed density by 68.75%, percent increase in grain yield was 6.16% (1.75 q/ha) and increase in net income of 6.68% (₹ 9565 /ha).
Management of wilt disease in pea (variety Arkel)	Seed treatment with Thiram and benomyl (1:1) @ 3 g/kg seed before sowing seed + Rhizobium culture @ 400 g/80kg/ha seed and soil treatment with *Trichoderma harzianum* 10 kg mixing with 50 kg FYM/ha.	16.44 % higher green pod yield (55.66 q/ha) of Pea was obtained as compared to farmers practice, (47.80 q/ha and B: C ratio 2.11:1). Net return and B: C ratio was also maximum (₹ 60860/ha and 2.22:1) The no of diseased plants reduced from 15.40 to 5.14/sq meter area.
Management of white rust in mustard (var. RH-749)	Seed treatment with carbendazim 50 WP + @ 2.5 g /kg seed before sowing seed and 2nd spray of Metalaxyl 4% + Mancozeb 64% @ 2 g/l. water solution. A total of 10 trials were conducted.	17.19 % higher grain yield (21.40 q/ha) higher net return and B: C ratio (₹ 99170/ha and 4.97:1) as compared to farners practice (Yield-18.26 q/ha and B: C ratio 4.86:1). The number of diseased plants reduced from 6.24 to 2.38/sq meter area.
FLD on control of both types of weeds (narrow leaves and broad leaves).	Use of Clodinofoppropargyl 15% WP @ 60 g *a.i.* /ha + Metsulfuran methy l20% WP @ 04 g *a.i.* /ha with 25 farmers in 10 ha area.	The weed population reduced by 62.25% as compared with farmers practice where they use Metsulfuran methyl 20%WP to control broad leaves weeds. 7.59% higher grain yield (50.80 q/ha) as against 47.22 q/ha in farmers practice.
Frontline Demonstrations on pearl millet	FLD under AICRP on pearl millet was organized in 10 ha area under bio-fortified variety HHB-299 which is high in iron and Zinc, benefitting 25 farmers of the district.	
Frontline Demonstrations on pulses under NFSM	Area Covered: 50 ha Farmers benefitted: 84	Pigeon pea (var. Pusa Arhar -992): 20 ha area Summer moong (var. MH-421): 20 ha area Chick pea (variety CS-J515): 10 ha area
Frontline Demonstrations on oilseeds under NFSM	A total of 273 demonstrations of mustard varieties (PM-37, RH-749 and RH-725) was organised in Gurugram and Mewat districts of Haryana	
Frontline Demonstrations on wheat	Area covered: 11.4 ha Farmers benefitted: 29 Place: Gururam district	

7.3.5.2 Trainings

Vocational training programmes for rural youth

Nine vocational training programmes were organized for rural youth by *Krishi Vigyan Kendra*, Shikohpur. The details are given as below:

S. No.	Training title	No. of Participants	Duration (days)	Dates	Sponsored by
1	Dress designing and tailoring	17	45	Jan 12 - Feb 25, 2021	KVK
2	Food processing and value addition (in two phases)	13	21	Feb 16-25, 2021 March 2-12, 2021	ARYA
3	Protected cultivation (in two phases)	28	21	Feb 16-25, 2021 March 2-12, 2021	ARYA
4	Motor rewinding for rural youth	10	10	Feb 18 - March 1, 2021	KVK
5	Virtual training on scientific bee keeping	26	3	March 24-26, 2021	NBB
6	Mushroom cultivation (in three phases)	7	21	Sept 14-21, 2021 Oct 04-11, 2021 Oct 22-29, 2021	ARYA

7	Scientific bee keeping	21	7	Dec 8-15, 2021	NBB
8	Food processing and value addition (in two phases)	9	21	Nov 26 - Dec 11, 2021 Dec 13-20, 2021	ARYA
9	Food processing and value addition (in two phases)	5	21	Nov 26 - Dec 20, 2021	KVK

Training under KKA-III: Seven training programmes were organized for farmers on "Diversified Agriculture", under Krishi Kalyan Abhiyan III at Gudhi, Sevka, Besi, Bhangoh, Chajupur, Khosi Kalan, Chahalka, Dalavas villages of district Nuh. A total number of 313 farmers and farm women participated. The farmers were provided the seeds of mustard PM-31 and RH-749 for CFLDs under NFSM.

Farmers Trainings: Fourteen training programmes were organized on various subjects, *viz*., weed management, seed production, INM and plant protection measures of *rabi* crops, drudgery reduction technologies income generation activities for women empowerment, minimization of nutrient loss in processing, benefitting 271 farmers and farm women in different villages of Gurgram district.

7.3.5.3 Agricultural extension activities of KVK, Shikohpur

The agricultural extension activities carried out by KVK, Shikohpur are as below:

Topic	Date	Location	No. of participants
Field day under NFSM pulses Name of crop: Chick pea Variety: CSJ-515 Area: 10 ha with 25 farmers	March 25 and 27, 2021	Tajnagar and Jataula villages of block Farukhnagar, Gurugram district	113
Field day under NFSM oil seeds Name of crop: mustard Variety: PM-31, RH-0749 and RH-0725 Area: 125 ha with 273 farmers	January 27-30, 2021, February 1-2 and February 5, 2021	Goyla, Lokra, Taj nagar, Tirpadi, Akhnaka and Dadola villages of Gurugram and Nuh districts	348
Field day under NFSM pulses Name of crop: summer moong Variety: MH-421 Area: 10 ha with 25 farmers	June 30, 2021	Lokra village of block Pataudi, Gurugram	45
Field day under OFT and FLD in Wheat: OFT on Integrated Nutrient Management and FLD on Weed management in wheat	March 4, 2021 and March 6, 2021	Tirpadi and Lokra villages of Gurugram	62
Field day on pearl-millet	September 16, 18, and 22, 2021	Langra, Joniawas and Harchandpur villages of Gurugram district	123
KisanGosthi on promotion of FPO	January, 13, 2021	Bokhara village, Gurugram	48
KisanGosthi on Food & Nutrition for farmers	August 26, 2021	KVK, Shikohpur, Gurugram	46
Awareness campaign on Balanced use of fertilizers:	June 18, 2021	KVK, Shikohpur, Gurugram	71
Awareness camp under *Jal Shakti Abhiyan*	July 8, 2021 and August 25, 2021	Langra and Tirpadi Villages, Gurugram	69
Awareness camp on Crop Insurance Scheme (online)	July 7, 2021	KVK, Shikohpur, Gurugram	65
Ex-Trainee Meet under ARYA project	9th February 2021	KVK, Shikohpur, Gurugram	23
Farmers-Scientist interaction on Climate Resilient Agriculture and Suitable Varieties	September 28, 2021	KVK, Shikohpur, Gurugram	100
Poshan Vatika Maha abhiyan	September 17, 2021	KVK, Shikohpur, Gurugram	189

Celebration of Important Events at KVK, Shikohpur

Day/Event	Date	Activity	No. of participants
National Science Day	February 28, 2021	Debate on "Science is a boon or curse".	68
International Women's Day	March 8, 2021	Vocational training on dress designing and tailoring	66
World Water Day	March 22, 2021	Lecture on water use	58
World Bee Day	May 20, 2021	Lecture on Augmenting rural farmer's income: The Bee keeping way	77
World Milk Day	June 1, 2021	Lecture on Animal Health and Productivity	36
World Environment Day	June 6, 2021	Lecture on environment	59
ICAR Foundation Day	July 16, 2021	Planting 150 plants of Moringa, *ber*, *Ficus*, sp. and lemon at KVK campus	20
Mahila Kisan Diwas	October 15, 2021	*Kisan Gosthi*	36
World Food Day	October 16, 2021	*Kisan Gosthi*	40
World Soil Day	December 5, 2021	Awareness programme on importance of soil testing, soil health and balanced use of fertilizers was organized	51

8. EMPOWERMENT OF WOMEN IN AGRICULTURE AND MAINSTREAMING OF GENDER ISSUES

Though women make significant contribution in agricultural development and household livelihood security, they continue to be a vulnerable group in social system mainly due to lack of access to resources as well as opportunities for capacity building. Realizing the need of women empowerment for promotion of inclusive development, several initiatives were taken towards capacity building of women in areas of value-addition, nutritional security and collective action.

8.1 Skill building in nutrition sensitive agriculture (NSA) for empowerment of rural women

Five training programmes of three days duration were organized to build skills in preparing value-added products of pearl millet, *hallur* soft bajra atta & soft *makka* atta" through Nutrition Sensitive Agriculture Centres (NSACs) established in Harsanakala and Jagdishpur villages of Sonipat district of Haryana and Sunehra and Basssi villages of Baghpat district of U.P. under the DBT funded project "Skill Building in Nutrition Sensitive Agriculture for Empowerment of Rural Women". Multi-media modules on bajra, machineries to prepare value-added products, importance on nutrition and entrepreneurship were shown to the rural women. Apart from these activities, Pusa Nutri Kitchen Garden Kits were demonstrated and distributed to ensure the consumption of fresh vegetables, which will help in enhancing their nutritional security.

To spread awareness about iron deficiency and symptoms of anemia as well as to promote *hallur* soft bajra *atta* and its usage in various forms such as muffin, cake, biscuits, noodles, *etc.*, apart from chapati; health campaigns were organized in Nutri-Smart villages of Baghpat (U.P.) and Sonipat (Haryana) districts.

8.2. Biotechnology-led socio-economic empowerment of farm women

Celebrating the *Amrit Mahotsav* of India's Independence, trainings were organized on value addition for income generation among women in collaboration with respective KVKs of 7 aspirational

Promotion of Pusa *Nutri* Kitchen Garden Kit

districts, namely, Dholpur, Karauli and Baran of Rajasthan; Balrampur, Shravasti and Bahraich of Uttar Pradesh; and Mewat of Haryana under the Biotech Kisan Hub project. One-day virtual training programme on 'Processing and Value-addition in Turmeric and Coriander" was organized at KVK, Balrampur in which 22 farmers belonging to tribal communities and other villages participated. One-day training programme on "Preservation and Value-addition of banana" organized at KVK Shravasti, was attended by 42 trainees. Skills of the post-harvest management, processing and value addition of mango like preparation of pickles and jams were imparted to 25 trainees through one-day training on "Preservation and Value-addition of mango" at KVK Bahraich-I. KVK, Dholpur in Rajasthan organized a day long training programme on "Potato Processing and Value Addition". Thirty-four (34) trainees (both men and women) from 4 villages (Beelpur, Pathrola Kalan, Dandoli and Dharampura) of the aspirational district, Dholpur of Rajasthan learnt the knowledge and skills of preparation of potato chips, French fries and potato flour. One-day virtual training programme was organized on "Post-Harvest and Value-addition of Seed Spices" at Krishi Vigyan Kendra, Baran through which 25 trainees were benefitted. One-day training programme on "Fruit Processing and Value Addition" was organized at KVK, Mandkaula, Mewat of Haryana. Sixty rural women from Barota, Atta, Manuwash, Saroli, Mandori, Akbarpur Natol, and Mandkaula villages participated in this training programme and learnt the skills of making value-added fruits products like mix fruit *jam*, marmalade, pickles, taffy and lemon squash.

Training on value addition

8.3 Enhancing Nutritional Security and Gender Empowerment

Krishi Vigyan Kendra, Gurugram celebrated 'Poshan Maah' from September 1-30, 2021 during, which a total of five awareness programmes, one vocational training on Nutri garden and one poster competition were organized at different locations. The details of activities organized are given below:

Date	Name of activity	Location	No. of beneficiaries
September 6-10, 2021	Vocational training on "Establishment of nutri-garden to achieve nutrition security at household level"	Tirpadi village	22
September 13, 2021	Poster competition on "Health & Nutrition" for school students	KVK, Shikohpur	17
September 17, 2021	PoshanVatika Mahaabhiyan evam Vriksharopan	KVK, Shikohpur	189
September 22, 2021	Awareness camp on "Nutrients, their role in human body and food sources"	FazilpurBadli village	32
September 23, 2021	Awareness camp on "Nutrients, their role in human body and food sources"	Sakatpur village	21
September 24, 2021	Awareness camp on "Health benefits and processing of nutri-cereals"	Tajnagar village	23
September 25, 2021	Awareness camp on "Nutrients, their role in human body and food sources"	GarhiHarsaru village	44
September 29, 2021	Awareness camp on "Balanced diet, Nutri-thali and Nutri-garden"	KherkiMajra village	20

During these programmes, they were given knowledge about nutrients as well as their role, food sources and requirement of our body. They were motivated to adopt healthy dietary practices and to establish a nutri-garden in their backyard to include more fruits and vegetables in their as well as their family member's diet. They were also made aware about health benefits of nutri-cereals and were motivated to make nutri-cereals like jowar, bajra, *ragi*, *etc*. part of their daily diet. Training on "Establishment of nutri-garden to achieve nutritional security at household level" was organized in which 22 women participated.

On September 17, 2021, *Poshan Vatika Mahaabhiyan evam Vriksharopan* programme was organized at KVK campus in which 189 beneficiaries (118 farmers and farm women and 71 girl students) participated.

8.4 Effectiveness of SHGs for Gender Empowerment

One vocational training was organized on "Food processing, preservation and value-addition" in two phases (Phase I: 16-25 Feb, 2021 and Phase II: 2-12 March, 2021), in which 13 women participated. SHG (Village Dhani Chitra Sen) during Feb-March and were supported with utensils, processing and packaging machines to start value addition as their enterprise. They were also helped in getting FSSAI registration by applying on-line.

Smt. Ravi along with 9 other members of the Sangathan attended a three -week training on "Value Addition under ARYA Project" organized during January 2021. After the successful completion of the training, she started her entrepreneurial work and during April 2020 to March 2021, she prepared a variety of products like candy of *aonla*, papaya, *karonda*; murabba of *aonla*, apple, carrot, beetroot; *aonla* squash and *aam panna, aonla laddoo*, bajra *laddoo*, soy *laddoo*, til *laddoo*, *alsi laddoo*, *gond laddoo etc*. and pickles of various seasonal fruits and vegetables. She launched her products in the market with a name "Daksh Foods". In many of her products, she used *desi khand* in place of refined sugar which has raised the demand of her products. Her hard work fetched IARI Innovative Farmer Award-2021 and one episode on her success was covered and telecasted in the programme "Bemisal Betiyan" on DD-Kisan channel. The success of Smt. Ravi as a woman entrepreneur is encouraging other women in the village to take up processing and value-addition as an enterprise.

The net income of Dev SHG during the year 2021

Name and address of SHG	No. of women	Products prepared	Expenditure (₹)	Gross Income (₹)	Net Income (₹)	B: C ratio
Dev SHG, Dhani Chiterasen village	03	*Aonla* products; pickles of seasonal fruits and vegetables and spices	39150	48300	9150	4.28:1

9. POST GRADUATE EDUCATION AND INFORMATION MANAGEMENT

The Indian Agricultural Research Institute (IARI) has a rich legacy of excellence of more than 116 years in research, teaching and extension. The Post Graduate School of IARI continues to provide National and International leadership in Human Resource Development by awarding Post Graduate degrees in 26 disciplines. So far, 4444 M.Sc., 72 M.Tech. and 5079 Ph.D. students have been awarded degrees including 487 international students. The institute has received accreditation from the National Assessment and Accreditation Council of UGC (3.51/4.00, A^{+}; 2016-2021) as well as National Agricultural Education Accreditation Board of ICAR (2020-2025 with 'A' grade).

9.1 POST GRADUATE EDUCATION

9.1.1 Admission during the Academic Session 2021-2022

The PG School continues to attract students seeking admission to 26 disciplines in all five streams of admission, namely, Open competition, Faculty upgradation, ICAR in-service nominees, Departmental candidates and Foreign students. The admissions to the M.Sc./M.Tech./Ph.D. programme are based on an 'All-India Entrance Test' conducted by the NTA/ICAR. The foreign students are admitted through DARE and are exempted from the written test. During the academic year 2021-22, 253 students (including 6 physically challenged; 2 under CWSF and 1 in Jammu Kashmir Migrant Scheme) were admitted to M.Sc./M.Tech. and 282 students (including 5 physically challenged; 3 ICAR in-service; 8 under faculty upgradation scheme and 2 under departmental technical, 1 in Departmental Scientific scheme and 2 under CWSF) were admitted to Ph.D. courses. Besides, 60 students were admitted under PG Outreach programmes at our sister institutes; (10 students at CIAE, Bhopal; 15 students at IIHR, Bengaluru; 16 students at NIBSM, Raipur; 10 students at NIASM, Baramati and 09 students at IIAB, Ranchi). In addition, 4 International students (2 M.Sc. & 2 Ph.D.) from, Nepal, Syria, Myanmar and Kenya were also admitted. At present, the total number of students on roll is 1744 (467 M.Sc., 36 M.Tech. and 1241 Ph.D.), which includes 24 International students (5 M.Sc. & 19 Ph.D.).

9.1.2. Convocation

The 59th Convocation of the Post Graduate School of the ICAR-Indian Agricultural Research Institute was held on February 12, 2021 (both virtual and physical mode). The ceremony was graced by the presence of Chief Guest Shri Kailash Choudhary, Hon'ble Union Minister of State for Agriculture and Framers' Welfare, Govt. of India along with Dr. Trilochan Mohapatra, Secretary, DARE and DG, ICAR, and Shri Sanjay Kumar Singh, Additional Secretary, DARE and Secretary, ICAR.

The Convocation was declared open by Dr. Ashok Kumar Singh, Director and Vice Chancellor, ICAR-IARI, which was followed by the presentation of Welcome Address and Director's report on the significant research achievements of the Institute during 2021. He shared that two bio-fortified wheat varieties, namely, HD 3298 with 43.1 ppm iron content and 12.1% protein and HI 1633 with 41.6 ppm iron content, 41.1 ppm zinc and 12.4% protein were dedicated to the nation by the Hon'ble Prime Minister of India on the occasion of 75th Anniversary of the Food and Agriculture Organization (FAO) of the United Nations.

Hon'ble Union Minister of State for Agriculture and Farmers' Welfare, Govt. of India presented the Doctor of Philosophy, Master of Science and Master of Technology degrees to the students. In the Convocation Address, Shri Kailash Choudhary exhorted to the students to dedicatedly engage themselves for socio-economic betterment of society through innovations. He applauded the efforts of the scientists for their commitment to sustain the pace of technology generation despite the global pandemic. He also appreciated the efforts of the Institute for the development of new varieties and technologies in the field of agriculture for doubling the farmers' income.

59th Convocation of IARI

A total of 15 varieties were released by the Chief Guest during the convocation, which included Pusa Basmati 1692 of Rice; HD 3298, HD 3293, HI 1633 and HI 1634 of Wheat; Pusa Baby Corn Hybrid-1 of Maize; Pusa Chickpea 20211 of Chickpea; PDL-1, PSL-9 and L 4729 of Lentil; Pusa Mustard 32 of Mustard; Pusa 1641 of Mungbean; DS 3106 of Soybean; Pusa Arhar 2017-1 and Pusa Arhar 2018-2 of Pigeonpea. Dr. Rashmi Aggarwal, Dean & Joint Director (Education) presented the Dean's Report containing brief about PG students research achievements. She congratulated the distinguished students for their hard-earned degrees. She also proposed a formal word of Thanks.

In this Convocation, 252 students (138 M.Sc., 9 M.Tech. and 105 Ph.D.) including 9 International students (3 M.Sc. and 6 Ph.D.) received their hard-earned degrees. The merit medals were presented to 5 students each of Ph.D. and M.Sc.; while one student each in M.Sc. (Mr. Pratheek H.P., Discipline of Plant Physiology) and Ph.D. (Mr. Saheb Pal, Discipline of Vegetable Science) were awarded the Best Student of the Year Awards for their outstanding postgraduate research, academic and extra-curricular activities.

Degrees distribution by chief guest

During the Convocation, the scientists were honoured with Institute's awards for their outstanding contributions in agricultural research. Dr. Sharat Kumar Pradhan, Principal Scientist, ICAR-National Rice Research Institute, Cuttack received XXVI Hooker Award 2018-19 for his outstanding research contributions in the field of "Crop Improvement". Dr. S.K. Jha, Professor, Post Harvest Technology, IARI, New Delhi received XXI Shri Hari Krishna Shastri Memorial Award for the year 2020 for his outstanding research contribution in the field of "Post Harvest Technology". Dr. G.P. Singh, Director, ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana received VIII Rao Bahadur B. Viswanath Award 2018-19 for his outstanding research contribution in the field of "Wheat improvement for abiotic stress tolerance and increasing profitability of wheat farmers". Dr. Anil Rai, Head & Professor (Bioinformatics), ICAR-Indian Agricultural Statistical Research Institute, New Delhi received the Best Teacher Award in Agricultural Higher Education 2020-21.

The degree of Doctorate of Science (*Honoris causa*) was conferred upon two eminent IARI alumni namely Prof. Sanjaya Rajaram and Prof. Rattan Lal, recipient of World Food Prize 2020, who have globally distinguished themselves in the field of science.

9.1.3 Special lectures

Lal Bahadur Shastri Memorial Lecture**:** The Indian Agricultural Research Institute initiated the series of annual lectures in 1968 as a mark of respect to late Shri Lal Bahadur Shastri, the second Prime

Minister of independent India. The 51st Lal Bahadur Shastri Memorial Lecture presentation was made by Prof. Ramesh Chand, Member, NITI Aayog, Govt. of India through virtual mode on February 11, 2021. Prof. R.B. Singh, Former Director, ICAR-IARI, New Delhi and Former Chancellor, CAU, Imphal chaired the session. Dr. Ashok Kumar Singh, Director, ICAR-IARI welcomed the Chairman of the session. Prof. Ramesh Chand delivered highly informative and educative lecture on "Reimagining Agriculture for Transformational Change". He emphasised on crop sciences sector growth needed for better agriculture output and it should be produce centric (demand) than product centric for sustainable production. Dr. Rashmi Aggarwal, Dean & Joint Director (Education), ICAR-IARI, proposed a formal word of Thanks.

Lal Bahadur Shastri memorial lecture

***IARI Foundation Day Lecture*:** On April 1, 2021, the Foundation Day Lecture (pre-recorded) was delivered by Professor Rattan Lal, Director, CMSC, OSU, USA & Recipient of World Food Prize 2020 and Adjunct Professor, IARI, New Delhi, on the topic "Soil Health and Nutrition-Sensitive Agriculture". On this occasion, Dr. Trilochan Mohapatra, Secretary, DARE & DG, ICAR was the Chief Guest and presided over the function and Dr. T.R. Sharma, DDG (Crop Science), ICAR was the Guest of Honour.

***Dr. B.P. Pal Memorial Lecture*:** The 28th Dr. B.P. Pal Memorial Lecture was delivered by Dr. G.R. Chintala, Chairman, National Bank for Agriculture and Rural Development (NABARD), Mumbai on the topic "Resilient Agriculture: The Pivot of Sustainable Development" on July 20, 2021 through virtual mode. Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR), New Delhi presided over the function.

***Teachers' Day Lecture*:** The Teachers' Day Lecture 2021 was organized jointly by the P.G. School and the Genetics Club, IARI on September 5, 2021through virtual mode. The dignitaries paid tributes to Dr. S. Radhakrishnan, the great philosopher, philanthropist and ex-President of India. On this occasion, Dr. Abhay Karandikar, Director, IIT, Kanpur delivered a lecture on the topic "Managing Innovations". Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR), New Delhi presided over the function.

9.1.4 International exposure

The excellence of IARI is recognized internationally. IARI has played a key role in the establishment of i) Afghanistan National Agricultural Sciences and Technology University (ANASTU), Afghanistan; and ii) Advanced Centre for Agricultural Research and Education (ACARE), Yezin Agricultural University, Myanmar.

ANASTU programme: IARI developed a detailed plan for the establishment of ANASTU as a leading University for agricultural research in Afghanistan in 2013. Under ANASTU programme, the first two batches of M.Sc. Agronomy of ANASTU have already graduated (in 2016 and 2018). The students of the 3rd Batch were scheduled to come to ICAR-IARI on August 17, 2021 for thesis submission and graduation, but they could not travel due to the cancellation of international flights from Kabul. In the meantime they are getting online guidance from the IARI Faculty for the completion of their thesis writing. The teaching and research guidance of the 4th Batch of MSc Agronomy are also progressing well in the online-mode, and the practical aspects will be covered when they come to IARI. In 2019 three new M.Sc. courses in Horticulture, Plant Protection and Animal Husbandry were introduced. The Horticulture and Plant Protection courses were taught at the ICAR-IARI, New Delhi, and that of MSc Animal Husbandry was taught at ICAR-

IVRI, Bareilly. The guidance for thesis research of the students is being given online. To facilitate online teaching a tele-education facility has been established at the ICAR-IARI, New Delhi. A similar facility will be developed at ANASTU, when normalcy returns. This year three new MSc courses - Plant Breeding, Soil Science & Water Technology and Agricultural Economics are also expected to start.

ACARE Programme: Under the ACARE programme, to strengthen the postgraduate education and human resource development, IARI in collaboration with YAU, Myanmar successfully conducted two short term (2 weeks) training programmes for the stakeholders of Myanmar Agriculture.

9.2 LIBRARY AND LEARNING RESOURCES

Prof. M.S. Swaminathan National Agricultural Science Library, established in 1905 with a collection of 5,000 publications is now the largest agro-biological library in South-east Asia housing more than five lakh publications comprising scientific journals, research bulletins, monographs, post-graduate theses, scientific reports, reprints and other reference materials. It has more than 2000 members which include students, scientists and technical staff. The library functions as the repository of Food and Agricultural Organization (FAO), and Consultant Group of International Agricultural Research (CGIAR) institutes' publications. The library is well equipped with student facility wing/ reading halls having PCs with Wi-Fi connectivity, internet and e-mail facility for the convenience of the readers. The Library provides reference service, bibliographical services, documentation services; online international abstracting database searches services etc.

9.2.1 Acquisition Programme

9.2.1.1 Books

During the period of report the library received 475 publications which includes 40 in Hindi books, 54 English books and 98 Advances & Annual Reviews. The Library also acquired 73 gift publications, 210 IARI Thesis. Uploaded CDs of 372 Thesis (copy) in Krishikosh.

9.2.1.2 Serials

The Library received 2893 journals/serials through subscription, gifts and exchanges, subscribed to 61 foreign journals, 210 newsletters, gifts 27 titles and 74 Indian journals. Total 88 publications accessioned. Received 78 annual scientific/technical reports of different institutions and 10 bulletins in the library during report period. Library also procured five online journals.

9.2.2 Resource Management

Apart from 2280 active registered members, the library served the users who comes from different agricultural universities/ICAR Institutes. Registered 264 new members (12 staff and 252 students). During the period under report 446 publications were issued and 315 publications returned. Under the Inter Library Loan System 15 documents were issued to various institutions. 187 No dues Certificate were issued.

9.2.3 Document Delivery Service

Resource management section of library is providing a Document Delivery Services to different users of agricultural field through CeRA. Total number of hits 15,360, total login session 778, searches 2757, full text and abstract views 1563. Total number of request received 144 through CeRA and uploaded requested articles in J-Gate.

9.2.4 PGS 501 course

The Library is involved in the post graduate teaching programme with one credit compulsory course entitled PGS 501 (0L+1P) 'Library and Information Services' for M.Sc. & Ph.D. students of all discipline. The objective of this course is to train the students to search the literature of their interest & literature search tools.

9.2.5 Krishikosh

Krishikosh provides ready software platform to implement all aspects of the open access policy, similar to 'Cloud Service' for individual institution's self-managed repository with central integration. These two products of E-Granth (i) Krishikosh and (ii) IDEAL are being used by all SAUs/DUs/CUs & ICAR Institutes. Up to December2021 library uploaded 5545 thesis.

9.2.6. E-Language Lab

With the help of library strengthening program Language lab was established with seating capacity of about 50 participants to facilitate English language classes for IARI foreign/ Indian students with modern facilities like 30 computers with internet facility, interactive board, visualizes, interactive panel, head phones etc. Time to time the language lab is also used for conducting trainings, LIS course, summer and winter school courses of different divisions and Directorate for the benefit of Scientists/ Technical staff.

9.3 AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

Currently, besides bioinformatics activities, the unit is entrusted with responsibility of design, development, hosting and maintenance of the e-resources, to provide internet connectivity to users of IARI, developing ICT in agricultural research, maintaining and updating the Institute's website, Data centre and network management, ASRB Online examination centre, MIS/ FMS implementation and development of backend web applications and its updates. During the reported period the unit developed (i) Prediction system for crop yield and pests using Satellite-based agromet product, (ii) Forewarning models for Downy Mildew and Powdery Mildew for Grapes at Nasik, (iii) Image analysis based on CNN (Convolution Neural Network) for plant village data

10. PUBLICATIONS

An important mandate of the Institute is to develop an information system, add value to information and share the information nationally and internationally. Publications are an integral component of the information system. During the reported period, the Institute scientists brought out quality publications in the form of research papers in peer reviewed journals, books/ book chapters, popular articles, etc. both in English and Hindi. Apart from these publications, the Institute brought out several regular and *adhoc* technical publications both in English and Hindi. The details of these publications are given below:

10.1 In-House Publications

10.1.1 Regular Publications (English)

- IARI Annual Report 2020 (ISSN: 0972-6136)
- IARI News Quarterly (ISSN: 0972-6144) - 4 issues)
- IARI Current Events (Monthly)- 12 issues (Available only on IARI website)

10.1.2 Niymit Prakashan (Hindi)

- पूसा सुरभि (वार्षिक) (ISSN : 2348-2656)
- वार्षिक रिपोर्ट 2020 (ISSN : 0972-7299)
- पूसा समाचार (त्रेमासिक) (ISSN : 0972-7280)
- प्रसार दूत (त्रेमासिक)

10.1.3 Technical Publication

- अध्येता एवं नवोन्मेषी किसान 2021—एक परिचय (ISBN 978-93-83168-56-9)
- A Practical Manual on irrigation Management (ISBN 978-93-83168-57-6)
- किसानों की भागीदारी द्वारा शोध के माध्यम से चिन्हित प्रयोग योग्य उन्नत कृषि प्रोद्यौगिकियाँ (ISBN 978-93-83168-58-3)
- परिनगरीय खेती के नये आयाम (ISBN 978-93-83168-59-0)
- फसल सुरक्षा के नये आयाम (ISBN 978-93-83168-61-3)
- ICAR-IARI: A Paradise of Birds (ISBN 978-93-83168-62-0)
- Good Agricultural Practices for Higher Productivity, Profitability and Resource use Efficiency (ISBN 978-93-83168-63-7)
- Success Stories: ICAR-IARI Biotech-KISAN Hubs (सफलता गाथाएँ: भा. कृ. अनु. प. द् भारतीय कृषि अनुसन्धान संस्थान बायोटेक किसान हब) (ISBN 978-93-83168-64-4)
- Environmental Friendly Indigenous Crop Protection and Resource Management Options (ISBN 978-93-83168-65-1)
- Advanced Methods for trace Level Identification and Estimation of Agrochemicals (ISBN 978-93-83168-66-8)
- Social Value System Development about Judicious Use of Pesticides-A Success Story of the Collaborative Effort of ICAR-IARI and IIL Foundation (TB-ICN: 251/2021)
- Desert Locust: Life Cycle and Management Strategies (TB-ICN: 252/2021)
- A Technology Inventory for Dryland Farming (TB-ICN: 253/2021)
- Crop Cultivars for Farmers' Profitability (TB-ICN: 254/2021)
- Teaching Manual on Principles of Seed Production (TB-ICN: 255/2021)
- Practical Manual on Diffusion and Adoption of Innovation (TB-ICN: 256/2021)
- Instructional Manual on Ethics in Agriculture Research, Education and Extension (TB-ICN: 258/2021)
- Manual on Drone Remote Sensing (TB-ICN: 259/2021)

- Training Manual on Geo-informatics in Agriculture using Open-source Data and Analysis Platforms (TB-ICN: 260/2021)
- POSHAN-IV NutriGreens for Health and Wellness (TB-ICN: 261/2021)
- POSHAN-III Pearl Millet –Maize Oriented Substitution for Healthy All Inclusive Nutrition (TB-ICN: 262/2021)
- Drying and Dehydration of Fruits and Vegetables (TB-ICN: 263/2021)
- Advances in Research Methodology for Social Sciences (TB-ICN: 264/2021)
- Data Analysis with Stata (TB-ICN: 265/2021)
- Analytical Techniques for Impact Assessment of Agricultural Technologies and Policies (TB-ICN: 266/2021)
- रेगिस्तानी टिड्डी : जीवन चक्र और प्रबन्धन कार्यनीतियाँ (ICN: H-184/2021)
- संरक्षण कृषि सतत उत्पादन व लाभ हेतु एक सार्थक विकल्प (ICN: H-185/2021)
- किसानों की लाभप्रदता के लिये फसलों की उन्नत किस्में (ICN: H-186/2021)
- गुणवत्तायुक्त बीज उत्पादन हेतु कृषि यंत्रों का उपयोग एवं रखरखाव (ICN: H-187/2021)
- फसल सुरक्षा के नये आयाम (ICN :H-188/2021)
- पुष्प एवं भू–द्रश्य (ICN: H-189/2021)
- बाजरे की वैज्ञानिक कृषि हेतु आधुनिक प्रोद्योगिकी एवं कृषि यन्त्र (ICN: H-190/2021)
- उन्नत कृषिः अधिक आय एवं पोषण सुरक्षा हेतु उन्नत कृषि प्रोद्योगिकियाँ (ICN: H-191/2021)
- प्रमुख फसलों के फाईटोप्लाज्मा जनित रोगः पहचान एवं नियंत्रण (ICN: H-192/2021)

10.2 PUBLICATIONS AT A GLANCE

1. Research/Symposia Papers		
a)	Research papers published in journals (with international impact factor or NAAS rating 6 and above)	956
b)	Symposia/conference papers	215
2. Books/Chapters in Books		
a)	Books	28
b)	Chapters in books	234
3. Popular Articles		**322**

10.2.1.Research publications (NAAS rating >10)

- Ambaye T G, Vaccari M, Petriciolet A B, Prasad S, Hullebusch E D V, Rtimi S. 2021. Emerging technologies for biofuel production: A critical review on recent progress, challenges and perspectives. *Journal of Environmental Management* **290:** 112627
- Atale N, Mishra C B, Kohli S, Mongre R K, Prakash A, Kumari S, Yadav U, Jeon R and Rani V. 2021. Anti-inflammatory Effects of *S. cumini* Seed Extract on Gelatinase-B (MMP-9) Regulation against hyperglycemic cardiomyocyte stress. *Oxidative medicine and cellular longevity* **5:** 1-14
- Baghel J K, Das T K, Mukherjee I, Nath C P, Bhattacharyya R, Ghosh S, Raj R. 2020. Impacts of conservation agriculture and herbicides on weeds, nematodes, herbicide residue and productivity in direct-seeded rice. *Soil and Tillage Research* **201**: 104634
- Bahuguna R N, Chaturvedi A K, Pal M, Chinnusamy V, Krishna Jagadish S V and Pareek A. 2021. Carbon dioxide responsiveness mitigates rice yield loss under high night temperature. *Plant Physiology* **188**(1): 285–300
- Bana R S, Singh D, Nain M S, Kumar H, Kumar V and Sepat S. 2020. Weed control and rice yield stability studies across diverse tillage and crop establishment systems under on-farm environments. *Soil and Tillage Research* **204:** 104729
- Bansal R, Priya S, Dikshit H K, Jacob S R, Rao M, Bana R S, Kumari J, Tripathi K, Kumar A, Kumar S and Siddique K H M. 2021. Growth and antioxidant responses in iron-biofortified lentil under cadmium stress. *Toxics* **2021:** 1235195
- Bharti A, Prasanna R, Kumar G, Nain L, Rana A, Ramakrishnan B and Shivay Y S. 2021. Cyanobacterium-primed chrysanthemum nursery improves performance of the plant and soil quality. *Biology and Fertility of Soils* **57**: 89–105
- Bhatia A, Drewer J, Jain N, Singh R, Tomer R, Kumar V, Kumar O, Prasanna R, Ramakrishnan B, Kumar

D, Bandyopadhyay S K, Sutton M and Pathak H. 2021. Experimental comparison of continuous and intermittent flooding of rice in relation to methane, nitrous oxide and ammonia emissions and the implications for nitrogen use efficiency and yield. *Agriculture, Ecosystems & Environment* **319**,107571

- Biswakarma N, Pooniya V, Zhiipao R R, Kumar D, Verma A K, Shivay Y S, Lama A, Choudhary A K, Meena M C, Bana R S, Pal M, Das K, Sudhishri S, Jat R D, and Swarnalakshmi K. 2021. Five years integrated crop management in direct seeded rice–zero till wheat rotation of north-western India: Effects on soil carbon dynamics, crop yields, water productivity and economic profitability. *Agriculture, Ecosystems and Environment* **318:** 107492
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11. IP MANAGEMENT, PATENTS, TECHNOLOGY COMMERCIALIZATION AND AGRIBUSINESS INCUBATION ACTIVITIES

The mission of the Zonal Technology Management and Business Planning and Development (ZTM & BPD) Unit is, "Translating Research into Prosperity" which is achieved by doing IP management, technology commercialization and fostering entrepreneurship through business incubation. During the period, the unit has organized following activities:

11.1. TECHNOLOGY COMMERCIALIZATION

Under the IP Management vertical, three patents were granted, two copyrights were registered, two copyright applications were filed and nine varieties were registered under PPVFR. Regarding the prosecution matters, three patent applications' FER responses were submitted and 23 patents were renewed.

During the financial year 2021-22, under Lab to Land Initiative, a total of 73 technologies of ICAR-IARI were transferred to 64 industry partners resulting in total revenue generation of ₹ 63 Lakh.

11.2 AGRIBUSINESS INCUBATION

11.2.1 Agribusiness incubation and incubators' handholding

Pusa Krishi Incubator housed at ZTM & BPD Unit of ICAR-IARI is the hub for supporting and strengthening agribusiness start-ups in every facet of their entrepreneurial journeys. During its past three years remarkable tenure, it has become the lead Knowledge Partner in RKVY-RAFTAAR Scheme of Ministry of Agriculture & Farmers' Welfare, Govt. of India. It organizes a wide array of programs and events to support the agribusiness startup community of the country along with the agribusiness incubators with following pertaining details:

- **ARISE-Moving from Idea to Action:** (for pre-seed stage funding upto ₹ 5 Lakh each)incubation program was launched on June 10, 2021 where 244 applications were received and 11 startups were selected after technical assessment & business viability by adopting a process of twin stage assessment including applications screening and pitch presentations in front of RAFTAAR Incubation Committee Meeting-I (RIC-I).
- **UPJA- Launchpad for Lab to Market:** (for seed stage funding upto ₹ 25 Lakh each) incubation program was launched on May 24, 2021 to scale-up agri-startups that have passed the stage of prototype and have developed products either with market traction or ready for commercialization. In this program, 757 applications were received, and finally 43 (one left the program) startups were selected after technical assessment & business viability by adopting a process of twin stage assessment including applications screening and pitch presentations in front of RAFTAAR Incubation Committee Meeting-I (RIC-I).
- **ABIC Incubation Program:** Applications were invited for long term incubation under ABIC program. Out of 51 applications 12 startups were shortlisted for selection round in front of panel. Finally, four startups were selected for the incubation support.
- **COHORT 2021:** It was virtual two-month incubation program from August 2- October 1, 2021 wherein the cohorts of ARISE 2021, ABIC 2021 and UPJA

2021 were combined into one big cohort of 58 Start-ups venturing into various domains of agriculture. In this well-curated mentor driven intensive incubation program, startup were empowered with 360^0 mentoring support by 216 technical sessions, 232 Business sessions, 58 Intellectual Property sessions, and 222 Financial sessions from IARI Scientists, agribusiness corporate leaders, IP Mentors and financial advisors. On the culmination of Cohort 2021, an online valedictory ceremony for startups was organized on October 1, 2021.

- **The RAFTAAR Incubation Committee Meeting-II (RIC-II):** Meeting was organized from October 4-6, 2021 for the recommendation of funds for 54 startups under the RKVY-RAFTAAR scheme, Govt. of India. Based on the preparedness and stage of start-ups, the RIC- II committee had recommended 20 start-ups for the Pre-seed stage and 23 start-ups for Seed stage for the final consideration and approval by RKVY-RAFTAAR Selection & Monitoring Committee (RC).
- **RKVY-RAFTAAR Selection & Monitoring Committee (RC):** RC Meeting for evaluation of selected startups under RIC-II meetings for ARISE 2021 & UPJA 2021 program was held online under the Chairpersonship of Ms. Chhavi Jha, Joint Secretary, RKVY through online mode at ZTM & BPD Unit, ICAR-IARI, New Delhi on December 2-3, 2021. In this, 19 startups have been finally selected for seed stage Funding and 17 Startup for pre-seed stage funding with a grant-in-aid support of ₹ 4.83 crores.
- **Agri India Hackathon:** It was a virtual hackathon funded by the Ministry of Agriculture and Farmers' Welfare, Government of India. With the help of industry, academia, policy makers, investors, 19 problem statements were finalized and floated. Under this project an online platform was created to invite, evaluate 6109 applications with the help of 100 evaluators and selected 300 start-ups for a preliminary round. These 300 start-ups were mentored by 75 mentors for three consecutive days on technical, business and market aspects by organizing 900 virtual meetings. 24 winners by 30 jury members were selected in 19 problem statements.
- **Agri India Meets:** it was a speaker series of ten Agri India Meet (online) from December, 2020 to July 2021 to create and foster dialogues on various aspects of agriculture with industry veterans, policymakers, entrepreneurs, and other stakeholders.
- **Pusa Krishi Incubation series**: Based on assessment strategies, exercises, need based and customizable content, subject matter analysis, and interactive activities for funded start-ups, an incubation series was organized from April 12- May 18, 2021 for selected startups from 12 RABIs. This series was organized virtually due to Covid 19 pandemic situation during 2020 & 2021. It nurtured around 276 funded start-ups of 12 RABIs by coordinating subject specific experts and mentors from industry.
- **Maitri (Indo-Brazil Agritech Cross Incubation Program) Second Phase:** After a successful first phase in 2019, the second phase of the programme was held virtually from 7 -17 December 2021. The second phase was inaugurated in the presence of the Brazilian Ambassador to India and the Indian Ambassador to Brazil along with senior officials from DST and CEO, Pusa Krishi. Five startups incubated at Pusa Krishi were selected to participate in the programme.This one-of-a-kind initiative highlighted the opportunities available for stakeholders to work together and grow and played as a key instrument for bridging the gaps between two agri-intensive nations.
- **BEEJ Pre Incubation Master class series:** PUSA Krishi organized a two weeks online pre incubation masterclass series BEEJ for young entrepreneurs to learn how to generate, build & scale start-up ideas in the agriculture sector. The primary focus of the program was to support young minds with some innovative idea and aspiration to become an entrepreneur. The applications to apply for the Program were invited from November 24-December 5, 2021, total 130 participants attended

the series and were provided with e-Certificate for their active participation.

- **SRIJAN:** It is a year-long incubation program that nurtures early-stage startups with full-throttle capacity building, infrastructure, and other resources to solve the big challenges in agriculture with innovative solutions. The program was launched on December 22, 2021 and online applications have been invited till January 9, 2022. After pre stage screening, 63 applicants were selected for making final presentation in front of the expert panel.
- **SAMARTH– Innovation and Incubation Induction Program:** A Review meeting for evaluation of incubation activities and to understand the accomplishments and challenges that RABIs have experienced during the implementation of the project was organized on March 22, 2021 for RABIs. The challenges mentioned in the program were addressed by the Lead Knowledge partner and related recommendations were forwarded to the ministry.

11.2.2 Other activities

The Unit has facilitated in executing the MoAs with EFAARMS Pvt Ltd. and Agri Projunction Pvt. Ltd. for online trading of the products and publications of ICAR-IARI. It is first of its kind of arrangement to solve the problem of availability of quality agri inputs to farmers.

12. LINKAGES AND COLLABORATION

The Indian Agricultural Research Institute has linkages with various national and international institutes/organizations. At national level the Institute has close linkages with almost all agricultural sciences research institutes, centers, project directorates, coordinated projects as well as a few other selected institutes of the ICAR. Similar linkages exist for natural resource and socio-economic research institutes. Collaboration exists with almost all state agricultural universities (SAUs), selected conventional universities, several of the institutes of the CSIR and departments of Ministry of Science and Technology such as the Departments of Biotechnology, Space Research, Meteorology, and several other ministries/ departments/organizations/banks of the Government of India, besides some private organizations/banks.

IARI is the lead centre to coordinate the accelerated crop improvement programme for breeding rust resistant wheat varieties involving 10 centres, improving quality in maize which has enabled several SAUs and ICAR institutes to upgrade and update themselves with new tools and techniques. Under the NAIP and NFBSFARA, IARI is the lead centre to develop state of art facilities and infrastructure on food science and phonemics led sciences. The NICRA programme of ICAR performed significantly by developing new genotypes for minimizing the negative impact of climate change in wheat by recombining QTL combinations for drought and heat tolerance apart from documenting the mitigation and adaptation phenomena to changing climate in rice and wheat.

In lieu with the consortia mode of project of ICAR, the Institute has been encouraging linkages and professional collaborations among national institutes to work on major research focus on 'Molecular breeding' for improvement of tolerance to biotic and abiotic stress, yield and quality traits in crops, and 'Hybrid technology' for higher productivity in selected field and horticultural crops. The Institute also identified some of the priority research areas through other ICAR Consortium Research Platforms as Mega seed platform, Genomics platform, Diagnostic and Vaccines, Energy platform, Water platform, Conservation agriculture platform, Farm mechanization and Precision farming, etc.

On public-private partnership mode, the role and participation of private sector in agricultural services is increasing in different forms and capacities. This underlines the need for ensuring effective public-private partnerships and linkages besides improving the structural and operational efficiency and governance of the institutions to make them farmer-friendly. Keeping this in view, the Institute has planned to forge collaboration with some of the private seed sector having strong R&D base and expertise in seed quality enhancement as well as with the advanced centres of research in other countries.

The Institute has extended liaison with private companies for commercialization of its technologies. Many IARI technologies with private and public enterprises have been commercialized.

The linkage system is being studied for strengthening extension under IARI-NGO Partnership programme as well. Linkage with post offices as a new extension model was developed by IARI. The IARI has initiated an innovative extension programme for technology dissemination in partnership with selected NGOs for feasibility trials and promotion of agricultural technologies in their operational areas.

On Post Graduate Education, the Institute has recently approved a collaborative programme with University of Nebraska from USA for strengthening PG education. Efforts are being made to have such programmes with more universities on bilateral basis. The Institute is playing a very important role in institution building in other countries, namely, in the establishment of (i) Afghan National University of Agricultural Sciences and Technology, Afghanistan; and Advanced Centre for Agricultural Research and Education at Yezin Agricultural University, Myanmar. Further linkages extend towards establishment of IARI off-campus in selected ICAR Institutes. The classic examples are start of PhD programmes in IIHR, Bangalore and CIAE, Bhopal. The Institute is helping in the establishment of two IARI like Institution of excellence in Jharkhand and Assam. Students are being admitted to these institutions, namely, M.Sc. at IARI-Assam and IARI–Jharkhand in 5 disciplines *viz.*, Agronomy, Genetics, Soil Science & Agricultural Chemistry, Vegetable Science and Water Science & Technology from the academic year 2015-16.

In the arena of training, the centres of excellence at IARI have established linkages with different national institutions through their regular training programmes and also through other programmes offered through Centre of Advanced Faculty Training.

At the international level, the Institute has close linkages with some of the CGIAR's international agricultural research centres (IARCs), *viz.*, ICRISAT, CIMMYT, IRRI, and ICARDA. It also has linkages with other international organizations, *viz.*, FAO, IAEA, USAID, UNDP, WMO, UNIDO and UNEP. Several bilateral research linkages involving developed and developing countries also exist. These include linkages with USDA, selected universities in USA, Canada, Australia, World Bank, Rockefeller Foundation, Bill & Melinda Gates Foundation, European Commission, JAICA, JIRC, JSPS, ACIAR, AVRDC (Taiwan), etc.

The number of externally funded projects in operation during the period from 01.01.2021 to 31.12.2021 is given below:

Name of Funding Agency	Number of Projects
Within India Department of Biotechnology (DBT), Department of Science & Technology (DST), National Committee Plasticulture Application in Horticulture (NCPAH), Council of Scientific and Industrial Research (CSIR), Department of Agriculture and Cooperation (DAC), Indian Meteorological Department (IMD), Board of Research in Nuclear Sciences (BRNS), Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), Space Application Centre (SAC), Defence Research and Development Organization (DRDO), Ministry of Human Resource and Development (MHRD), National Bank for Agriculture and Rural Development (NABARD), NITI Aayog, Ministry of Environmental, Forest and Climate Change (MoEF&CC), UP Council of Agricultural Research (UPCAR), Bhabha Atomic Research Centre (BARC), Rashtriya Krishi Vikas Yojna (RKVY), Ministry of Food Processing Industries (MoFPI), National Thermal Power Cooperation (NTPC), Ministry of Steel, Central Pulp & paper Research institute (CPPRI), Department of Scientific & industrial research (DSIR) and Indian Council of Agricultural Research (ICAR)	211
Outside India Bill & Melinda Gates Foundation & UK Department of International Development (DFID), Bill & Melinda Gates Foundation, International Fertilizer Develop Centre (IFDC) USA, United Kingdom Research & Innovation (UKRI), ICAR-International Rice Research Institute, ICARDA South Asia & China Regional Program, HarvestPlus-International Food Policy Research Institute, USA, Centre for Agriculture and Bioscience International (CABI), United Kingdom, ICARDA South Asia & China Regional Program, US-National Academies of Sciences, Beutsche Gesellchaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany & CIMMYT	17
Total	**228**

13. AWARDS AND RECOGNITIONS

- Dr. A.K. Singh, Director, ICAR-IARI, elected as Fellow, National Academy of Sciences, India
- Drs H.K. Dikshit, G.P. Mishra, D.K. Yadava and Ranbir Singh received the 'ICAR-Dr. Rajendra Prasad Award' for technical book in hindi with cash prize of Rs 1.0 lakh
- Dr. Archana Sachdev, Principal Scientist, Division of Biochemistry received Panjabrao Deshmukh Outstanding Women Scientist Award-2019
- Dr. M.S. Saharan, Principal Scientist, Division of Plant Pathology elected as Fellow, National Academy of Agricultural Sciences
- Dr. P. Krishanan, Head, Division of Agricultural Physics elected as (i) Fellow, NAAS (ii) Editor-in-Chief, Indian Journal of Agricultural Physics
- Dr. A.K. Dubey, Principal Scientist, Division of Fruits and Horticultural Technology was elected as Fellow, National Academy of Agricultural Sciences
- Dr. Firoj Hussain, Principal Scientist, Division of Genetics, received NAAS Fellowship
- Dr. Gopala Krishnan S., Principal Scientist, Division of Genetics received NAAS Fellowship
- Dr. C.M. Parihar, Senior Scientist, Division of Agronomy awarded with Fellowship, National Academy of Agricultural Sciences, India
- Dr. Radha Prasanna, Professor, Division of Microbiology (i) Identified among top 2% cited Scientist in the world – 2021 listed by Stanford university, USA (ii) Elected as Associate Editor, CABI Agriculture and Bioscience & BMC Microbiology (iii) Member, Editorial Advisory Board, Journal of Basic Microbiology
- Dr. B.S. Tomar, Head & Principal Scientist, Division of Vegetable Science, received Kirti Singh Gold Medal, IAHS
- Dr. Rashmi Aggarwal, Dean, IARI, awarded with T.H. Thind outstanding Plant Pathologist Award, Indian Society of Plant Pathologist
- Dr. P.K. Sahoo, Principal Scientist, Division of Agricultural Engineering awarded (i) Dr. Rajendra Prasad Puraskar for Technical books in Hindi in Agricultural and Allied Sciences, ICAR (ii) Team Award 2020, AICRP on pearl Millet
- Dr. Veda K. Scientist, Division of Biochemistry received Fulbright –Nehru Post-Doctoral Fellowship
- Dr. Debasis Gului, Scientist, Division of Soil Science and Agri. Chemistry elected as Fellow, Fulbright–Nehru postdoctoral Research Fellowships
- Dr. R.N. Padaria, Head & Professor, Division of Agricultural Extension received Best Agriculture Extension Faculty Award 2021 by Agriculture Today Group
- Dr. R. Roy, Principal Scientist, Division of Agricultural Extension received Best Agricultural Extension Professional Award 2021, Agricultural Today Group
- Dr. Gyan Prakash Mishra, Principal Scientist, Division of Genetics, elected as Fellow, Indian Society of Genetics and plant Breeding
- Dr. Vignesh M., Scientist, Division of Genetics, awarded with Srinivasa Ramanujam Memorial Award ISGPB
- Dr. Akshay Talukdar, Principal Scientist, Division of Genetics, elected as Editor, Indian Journal of Genetics and Plant Breeding
- Dr. Robin Gogoi, Principal Scientist, Division of Plant Pathology awarded with BN Chakraborty and Usha Chakraborty Best Teacher award-2020, Indian Phytopathological Society

- Dr. Harshwardhan Choudhary, Principal Scientist, Division of Vegetable Science was elected (i) Fellow, Indian Society of Vegetable Science 2020 (ii) RS Paroda Young Scientist award for 2020, CHAI
- Dr. S.K. Singh, Head and Principal Scientist, Division of Fruits and Horticultural Technology received the Fellowship of SHRD, Society for Horticultural Research and Development, Uttar Pradesh. He was also awarded Fellow of ISGPB, Indian Society of Genetics and Plant Breeding, New Delhi
- Dr. Man Singh, Project Director & Professor, Water Technology Centre elected as Member, Technical Advisory Committee, and Working group, NIH, Roorkee
- Dr. D.K. Singh, Principal Scientist, Water Technology Centre elected as Chief Editor, AET
- Dr. M.K. Singh, Principal Scientist, Division of Floriculture & Landscaping was elected Fellow, The Society of Tropical Agriculture, New Delhi
- Dr. Y.S. Shivay, Principal Scientist, Division of Agronomy elected as Fellow, Indian Society of Plant Physiology
- Dr. T.J. Purakayastha, Principal Scientist, Division of Soil Science and Agri. Chemistry elected as Fellow, Indian Society of Soil Science
- Dr. Adarsh, Principal Scientist, Division of Agricultural Engineering elected as Fellow, Indian Society of Agricultural Engineers, 2020
- Dr. S.P. Singh, Principal Scientist, Division of Agricultural Engineering elected as Fellow, Royal Association for Science-led Socio –cultural Advancement, Lucknow
- Dr. Kalyan K. Mondal, Principal Scientist, Division of Plant Pathology elected as Fellow ARRW 2021, Association of Rice Research Workers, ICAR-NRRI, Cuttack
- Dr. Ranjeet Ranjan Kumar, Senior Scientist, Division of Biochemistry elected as Fellow, Indian Society for Plant Physiology
- Dr. Debashis Chakraborty, National Fellow & Principal Scientist received (i) The XII International Congress Commemoration Award (ii) Dr. K.G. Tejwani Award for Management of Natural Resources (iii) elected as Fellow, West Bengal Academy of Science and Technology, WB
- Dr. Chandra Prakash, Principal Scientist, Regional Station, Katrain elected as Fellow, ISVS
- Dr. K.K. Pramanick received Life Time Achievement Award, Society of Tropical Agriculture, New Delhi
- Dr. Vikas VK, Senior Scientist, Division of Genetics, elected as Fellow, Society for Advancement of Wheat and Barley Research
- Dr. Sangeeta Chopra, Principal Scientist, Division of Agricultural Engineering awarded as Indian Society of Agricultural Engineers Women Distinguished Service Award- 2020
- Dr. Anil Khar, Principal Scientist, Division of Vegetable Science elected as editor, Indian Journal of Horticulture
- Dr. R.K. Yadav, Professor, Division of Vegetable Science, received Fellow award, IAHS
- Dr. Gograj Singh Jat, Scientist, Division of Vegetable Science elected as Associate, IAHS
- Dr. M.K. Verma, Principal Scientist, Division of Fruits and Horticultural Technology received the Fellowship of SHRD, Society for Horticultural Research and Development, Uttar Pradesh
- Dr. Amit Kumar Goswami, Scientist, Division of Fruits and Horticultural Technology, received Young Educator Award – 2021 from NEEDF, New Delhi
- Dr. S.S. Sindhu, Head, Division of Floriculture & Landscaping elected as Secretary of (i) Indian Society of Ornamental Horticulture (ii) Bougainvillea Society of India, DAHS, IARI New Delhi (iii) Rose Society of India (iv) Expert Member, International Association of Horticultural Producers, The Netherlands
- Dr. Kanwar P Singh, Professor, Division of Floriculture & Landscaping elected as Chief Editor, Journal of Ornamental Horticulture

- Dr. Namita, Senior Scientist, elected as (i) Editor, Journal of Ornamental Horticulture (ii) IAHS Associate, Indian Academy of Horticultural Sciences, New Delhi
- Dr. M.K. Dhillon, Principal Scientist, Division of Entomology received Prof. G.S. Shukla award 2020 from the Academy of Environmental Biology
- Dr. Anjali Anand, Principal Scientist, Division of Plant Physiology awarded by JJ Chinoy Gold Medal, Indian Society of Plant Physiology
- Dr. Lekshmy S, Senior Scientist, Division of Plant Physiology (i) elected as plantae Fellow 2021(ii) received RD Asana Gold medal award, Indian Society of Plant Physiology
- Dr. M.S. Nain, Principal Scientist, Division of Agricultural Extension received Dr. O.P. Dhama Memorial Award 2021, Indian Society of Extension Education, New Delhi
- Dr. D. Barman, Principal Scientist, Regional Station, Kalimpong received Prof. S.P. Vij Memorial Award, TOSI
- Dr. P. Nallathambi, Principal Scientist, Division of Genetics awarded with PR Verma Memorial Lecture Award
- Dr. Subhash Babu, Scientist, Division of Agronomy was awarded NESA Young Scientist of the Year Award 2020, National Environmental Science Academy, New Delhi
- Dr. R.S. Bana, Senior Scientist, Division of Agronomy received Best Oral Presentation Award, Central Agricultural University, Imphal, Manipur
- Dr. S.S. Rathore, Principal Scientist, Division of Agronomy awarded (i) Sri Ram Puraskar, Fertilizer Association of India (ii) Eminent Scientist, HARWS 2021 (iii) Nominated as Editor, Annals of Agricultural Research, Indian Journal of Agronomy, Indian Journal of Agricultural Sciences
- Dr. Nayan Ahmed, Principal Scientist, Division of Soil Science and Agri. Chemistry elected as Vice-President, Clay Minerals Society of India
- Dr. M.C. Meena, Senior Scientist, Division of Soil Science and Agri. Chemistry awarded with Young Scientist Award 2020, Mosaic Company Foundation, New Delhi
- Dr. Abir Dey, Scientist, Division of Soil Science and Agri. Chemistry awarded with Scientist of the Year award, ENRF foundation, New Delhi
- Dr. Susama Sudhishri, Principal Scientist, Water Technology Centre awarded Best Scientist award, Agri Vision
- Dr. M. Hasan and Dr. Naved Sabir, Principal Scientist, Centre for Protected Cultivation Technology elected as Member, Vertical farming DST-TIFAC, Vertical Farming Task Force
- Dr. Archna Suman, Principal Scientist, Division of Microbiology elected as (i) Member, Society of Plant Biochemistry and Biotechnology, IARI, New Delhi (ii) Review Editor, Plant Pathogen interactions (Special Section of Frontiers in Plant Science and frontiers in Microbiology)
- Dr. Manoj Shrivastava, Dr. K. Usha and Dr. Shakeel A. Khan, Principal Scientists, awarded International and Distinguished Scientist Award (VGOOD-2021)
- Dr. V.K. Baranwal, Professor, Division of Plant Pathology elected as Editor, Journal of Plant Biochemistry and Biotechnology
- Dr. Kajal K Biswas, Principal Scientist, Division of Plant Pathology received Membership, NASI, Allahabad
- Dr. Debjani Dey, Head, Division of Entomology received Best Oral Presentation in National Conference on Priorities in Crop Protection for Sustainable Agriculture, Imphal, India
- Dr. S. Subramanian, Principal Scientist, Division of Entomology awarded with Distinguished Scientist Award, Sanrang Society of ICAR, IINRG
- Dr. Suresh Nebapure, Scientist, Division of Entomology received Best Oral Presentation Award, National Conference, Central Agricultural University, Imphal
- Dr. Timmanna, Scientist, Division of Entomology received Young Scientist Award, National

Environmental Science Agency, Academy of Environmental Biology

- Dr. Sachin S Suroshe, Principal Scientist, Division of Entomology received Outstanding Scientist Award 2020, New Age Mobilization Society, New Delhi
- Dr. Sagar D, Scientist, Division of Entomology received Best Oral Presentation Award, Central Agricultural University
- Dr. P.R. Shashank, Scientist, Division of Entomology received (i) Young Scientist of the Year Award, Agriculture today group (ii) NESA Young Scientist of the Year Award, National Environmental Science Academy, New Delhi
- Dr. V.S. Rana, Principal Scientist, Division of Agricultural Chemicals elected as Member, DRC, Amity Institute of Phytichemistry and Phytomedicine, Amity University, Noida, U.P.
- Dr. Suneha Goswami, Scientist, Division of Biochemistry, received Budding Researcher Award, International E-conference EIABSHWAR-2020, Department of Biotechnology and Microbiology, Kalp Laboratories
- Dr. Anil Dahuja, Professor, Division of Biochemistry appointed as member of the Expert Committee 2, FSSAI
- Dr. Harbir Singh, Principal Scientist, Division of Agricultural Economics nominated as IPR Expert, ITMC, ICRA-NCIPM, New Delhi
- Dr. D.P. Walia received ISGPB Fellow for the year – 2020
- Dr. G.K. Mahapatro, Head, Regional Station, Pune nominated as (i) Editorial Board Member, Indian Journal of Entomology and Journal of Plant Science and Research
- Dr. Savarni Tripathi, Principal Scientist, Regional Station, Pune nominated as Member, of the Accreditation Panel for the Certification of TCPF & ATL under NCS-TCP, Department of Biotechnology, GOI
- Dr. Madhu Patial received Outstanding Scientist of the Year – 2021 award, Society of Tropical Agriculture, New Delhi

14. BUDGET ESTIMATES & UTILIZATION

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E) for the year 2021-22 under Unified Budge

											(Rs. In Lakhs)
		B.E. 2021-22					R.E. 2021-22				
S. No.	Head	Other than NEH & TSP	NEH	TSP	SCSP	Grand Total	Other than NEH & TSP	NEH	TSP	SCSP	Grand Total
1	2	3	4	5	6	7	8	9	10	11	12
	Grants for creation of Capital Assets (CAPITAL)										
1	Works										
	A. Land										
	B. Building										
	i. Office building	1879.00		0.00	0.00	**1879.00**	1152.56		0.00	0.00	**1152.56**
	ii. Residential building	2208.50		0.00	0.00	**2208.50**	1354.68		0.00	0.00	**1354.68**
	iii. Minor Works	271.00		0.00	0.00	**271.00**	166.23		0.00	0.00	**166.23**
2	Equipments	796.14	100.00	21.00	92.00	**1009.14**	488.35	61.01	17.50	50.00	**616.86**
3	Information Technology	87.50		8.00	0.00	**95.50**	53.67		6.67	0.00	**60.34**
4	Library Books and Journals	79.40		0.00	0.00	**79.40**	48.70		0.00	0.00	**48.70**
5	Vehicles & Vessels	38.31		0.00	0.00	**38.31**	23.50		0.00	0.00	**23.50**
6	Livestock	4.40		0.00	0.00	**4.40**	2.70		0.00	0.00	**2.70**
7	Furniture & fixtures	87.40		1.00	0.00	**88.40**	53.61		0.83	0.00	**54.44**
8	Others										
A	**Total – CAPITAL (Grants for creation of Capital Assets)**	**5451.65**	**100.00**	**30.00**	**92.00**	**5673.65**	**3344.00**	**61.01**	**25.00**	**50.00**	**3480.01**
	Grants in Aid - Salaries (REVENUE)										
1	Establishment Expenses										
	Salaries										
	i. Establishment Charges	23200.00				23200.00	24369.34	0.00	0.00	0.00	24369.34
	ii. Wages										
	iii. Overtime Allowance										
	Total – Establishment Expenses (Grant in Aid - Salaries)	**23200.00**	**0.00**	**0.00**	**0.00**	**23200.00**	**24369.34**	**0.00**	**0.00**	**0.00**	**24369.34**
Grants in Aid - General (REVENUE)											
1	**Pension & Other Retirement Benefits**	21000.00				**21000.00**	22593.59				**22593.59**
2	**Traveling Allowance**										
	A. Domestic TA / Transfer TA	75.00				**75.00**	75.67	0.00	0.00	0.00	**75.67**
	B. Foreign TA	21.88				**21.88**	22.07	0.00	0.00	0.00	**22.07**

	Total – Traveling Allowance	**96.88**	**0.00**	**0.00**	**0.00**	**96.88**	**97.74**	**0.00**	**0.00**	**0.00**	**97.74**
3	**Research & Operational Expenses**					**0.00**					**0.00**
	A. Research Expenses	753.50	40.00	30.00	500.00	**1323.50**	760.21		25.50	430.36	**1216.07**
	B. Operational Expenses	1067.49	160.00	60.00	650.00	**1937.49**	1077.00		51.00	559.46	**1687.46**
	Total - Research & Operational Expenses	**1820.99**	**200.00**	**90.00**	**1150.00**	**3260.99**	**1837.21**	**0.00**	**76.50**	**989.82**	**2903.53**
4	**Administrative Expenses**										
	A. Infrastructure	3322.35			100.00	3422.35	3351.94		0.00	86.07	**3438.01**
	B. Communication	30.00				30.00	30.27		0.00	0.00	**30.27**
	C. Repairs & Maintenance						0.00		0.00	0.00	**0.00**
	i. Equipments, Vehicles & Others	357.00			100.00	457.00	360.18		0.00	86.07	**446.25**
	ii. Office building	650.00			100.00	750.00	655.79		0.00	86.07	**741.86**
	iii.Residential building	550.00			100.00	650.00	554.90		0.00	86.07	**640.97**
	iv. Minor Works	218.00				218.00	219.94		0.00	0.00	**219.94**
	D. Others (excluding TA)	780.00				780.00	786.95		0.00	0.00	**786.95**
	Total - Administrative Expenses	**5907.35**	**0.00**	**0.00**	**400.00**	**6307.35**	**5959.97**	**0.00**	**0.00**	**344.28**	**6304.25**
5	**Miscellaneous Expenses**					**0.00**					
	A. HRD	60.20			50.00	**110.20**	60.74		0.00	43.04	**103.77**
	B. Other Items (Fellowships, Scholarships etc.)	1200.00	60.00	100.00	200.00	**1560.00**	1210.69		85.00	172.14	**1467.83**
	C. Publicity & Exhibitions	140.00				**140.00**	141.25		0.00	0.00	**141.25**
	D. Guest House – Maintenance	70.00				**70.00**	70.62				**70.62**
	E. Other Miscellaneous	200.00	46.00	10.00	58.93	**314.93**	201.78	267.00	8.50	50.72	**528.00**
	Total - Miscellaneous Expenses	**1670.20**	**106.00**	**110.00**	**308.93**	**2195.13**	**1685.08**	**267.00**	**93.50**	**265.90**	**2311.48**
	Total Grant in Aid-General	**9495.42**	**306.00**	**200.00**	**1858.93**	**11860.35**	**9580.00**	**267.00**	**170.00**	**1600.00**	**11617.00**
	Total (Pension+General)	**30495.42**	**306.00**	**200.00**	**1858.93**	**32860.35**	**32173.59**	**267.00**	**170.00**	**1600.00**	**34210.59**
B	**Total Revenue (Grants in Aid - Salaries +Pension+ General)**	**53695.42**	**306.00**	**200.00**	**1858.93**	**56060.35**	**56542.93**	**267.00**	**170.00**	**1600.00**	**58579.93**
	Grand Total (Capital + Revenue)	**59147.07**	**406.00**	**230.00**	**1950.93**	**61734.00**	**59886.93**	**328.01**	**195.00**	**1650.00**	**62059.94**
	Grand Total (Capital +General)	**14947.07**	**406.00**	**230.00**	**1950.93**	**17534.00**	**12924.00**	**328.01**	**195.00**	**1650.00**	**15097.01**

Note: Sub Head wise allocation under Revised Estimate 2021-22 is tentative and is subject to change based on final expenditure figures.

15. STAFF POSITION, APPOINMENTS, PROMOTIONS AND TRANSFERS

(As on 31.12.2021)

Sl. No.	Category	No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	06	02
2)	Principal Scientist	65	34
3)	Senior Scientist/Scientist (S.G.)	170	111
4)	Scientist	337	326
	Total	**578**	**473**
B.	**TECHNICAL STAFF**		
1)	Category III	11	07
2)	Category II	275	152
3)	Category I	278	239
	Total	**564**	**398**
C.	ADMINISTRATIVE STAFF		
1)	Group A	33	20
2)	Group B	279	194
3)	Group C	110	91
	Total	**422**	**305**
D.	SKILLED SUPPORT STAFF	740	549

15.1 SCIENTIFIC STAFF

15.1.1 APPOINTMENT

Name of the Employee	Name of the post	Place of Posting (Division)
Dr. S.K. Mahapatra	Principal Scientist	Soil Science and Agricultural Chemistry
Dr. Deeksha Joshi	Principal Scientist	Plant Pathology
Dr. Sanjay Kumar Singh	Principal Scientist	Genetics
Dr. Archna Anokhe	Scientist	Entomology
Dr. B.P. Mallikarjuna	Scientist	Regional Station, Dharwad
Dr. Chirag Maheshwari	Scientist	Biochemistry
Dr. Madhurima Das	Scientist	Plant Physiology
Dr. Mahesh Kumar	Scientist	Plant Physiology
Ms. Manisha Saini	Scientist	Genetics

Dr. Nikita Gupta	Scientist	Plant Pathology
Dr. Prabhu G	Scientist	Agronomy
Dr. Sandeep Kumar	Scientist	R.S. Karnal
Ms. Seema Sheoran	Scientist	R.S. Karnal
Ms. Truptimayee Suma	Scientist	Water Technology Centre
Dr. Wishwanath Rohidas Yalamalle	Scientist	Seed Science and Technology

15.1.2 TRANSFER

Name of the Employee	Name of the post	Discipline	Place of Posting before transfer Division/RS/PD
Dr. Vinod Kumar Singh	Head & JD (Extension) Acting	Agronomy	Agronomy
Dr. S.V. Sai Prasad	Head Acting	Genetics and Plant Breeding	R.S. Indore
Dr. T.K. Behra	Professor	Vegetable Science	Vegetable Science
Sh. Manjunatha C.	Scientist	Plant Pathology	R.S. Wellington
Sakhare Akshay Sureshrao	Scientist	Plant Physiology	Plant Physiology
Dr. Rajanna G.A.	Scientist	Agronomy	Agronomy
Sh. Anooj S.S.	Scientist	Agricultural Entomology	Agricultural Entomology
Ms. Vanlalruati	Scientist	Floriculture & Land Scaping	Floriculture & Land Scaping
Dr. Sudhipta Gupta	Scientist	Agricultural Extension	Agricultural Extension
Dr. Rahul Phuke Madhavrao	Scientist	Genetics and Pant Breeding	R.S. indore
Ms. Divya Ambati	Scientist	Genetics and Pant Breeding	R.S. indore

15.2 TECHNICAL STAFF

15.2.1 APPOINTMENT

Name of the Employee	Name of the Post	Place of Appointment	Date of Appointment
Shri Vijendra Kumar	Technician (T-1)	Genetics Division	01.01.2021
Shri Praveen		Directorate (PG-II)	04.01.2021
Shri Praveen Gena		CATAT (ATIC)	04.01.2021
Shri Santosh Kumar Meena		Genetics Division	12.01.2021
Smt. Jyoti Tomer		Publication Unit	21.01.2021
Shri Brijesh Kumar		WTC	31.03.2021
Shri Roshan Ranjan		WTC	03.03.2021

15.2.2 PROMOTIONS

Name of the Employee	Post before Promotion	Post aster Promotion
Shri Kishan Lal	SSS	Technician (T-1)
Shri Bhola Paswan	SSS	Technician (T-1)

15.2.3 TRANSFER

Name of the Employee	Post before transfer	Post after transfer
Shri Satish Chand Meena	Technician (T-1)	Technician (T-1)
Shri Parmender Pandit	Technician (T-1)	Technician (T-1)

Shri Prakash Khatiwada	Sr. Technician (T-2)	Sr. Technician (T-2)
Shri Abhishek Meena	Technical Asstt. (T-3)	Technical Asstt. (T-3)
Shri Uday Vir Singh	ACTO (T-7/8)	ACTO (T-7/8)
Smt. Mamta Meena	Technical Asstt. (T-3)	Technical Asstt. (T-3)
Shri B.K. Meena	ACTO (T-7/8)	ACTO (T-7/8)
Shri Gaurav Papnai	ACTO (T-7/8)	ACTO (T-7/8)

15.3 ADMINISTRATIVE STAFF

15.3.1 PROMOTIONS

Name of the Employee	Post before promotion	Post after promotion
Sh. Laxman Singh	Admn. Officer	Senior Admn. Officer
Sh. H.C. Ghildiyal	Admn. Officer	Senior Admn. Officer
Sh. Govind Paunikar	Asstt. Admn. Officer	Admn. Officer
Sh. Jaswant Kumar	Asstt. Admn. Officer	Admn. Officer
Sh. Navdeep Sharma	Asstt. Admn. Officer	Admn. Officer
Sh. Prasenjit	Asstt. Admn. Officer	Admn. Officer
Sh. Prem Singh Rawat	Asstt. Admn. Officer	Admn. Officer
Sh. S.S. Wange	Asstt. Admn. Officer	Admn. Officer
Sh. Shyam Sunder	Asstt. Admn. Officer	Admn. Officer
Sh. Sushi' Kumar	Asstt. Admn. Officer	Admn. Officer
Smt. Roselima Lakra	Asstt. Admn. Officer	Admn. Officer
Smt. Krishna Bisht	Assistant	Asstt. Admn. Officer
Smt. Sonia Rawat	Assistant	Asstt. Admn. Officer
Sh. D.K. Yadav	Assistant	Asstt. Admn. Officer
Smt. Om Prabha	Assistant	Asstt. Admn. Officer
Smt. Satinder Kaur	Assistant	Asstt. Admn. Officer
Smt. Pushpa	Assistant	Asstt. Admn. Officer
Smt. Gaytri Kapoor	Assistant	Asstt. Admn. Officer
Sh. Subhash Shankar Damse	Assistant	Asstt. Admn. Officer
Smt. Vinita	Assistant	Asstt. Admn. Officer
Sh. A.K. Robin	UDC	Assistant
Sh. Arun Chopra	UDC	Assistant
Smt. Shama Sharma	UDC	Assistant
Smt. R.K. Bindra	UDC	Assistant
Smt. Durgesh Sharma	UDC	Assistant
Sh. Rajeev Gupta	UDC	Assistant
Sh. Raj Kumar	UDC	Assistant
Sh. Anoop Toppo	UDC	Assistant
Sh. Sanjay Kumar	UDC	Assistant
Sh. D.S. Negi	UDC	Assistant
Sh. Beg Ram	UDC	Assistant
Smt. Sanju Kumari	UDC	Assistant

Smt. Kavita Mokashi	UDC	Assistant
Sh. Parshuram	UDC	Assistant
Sh. Maheshwar Dass	UDC	Assistant
Sh. R.S. Sirari	LDC	UDC
Sh. Dharam Vir	LDC	UDC

15.3.2 TRANSFERS

Name of the employee	Post before transfer	Post after transfer
Sh. Ravinder Singh	Senior Admin. Officer	Chief Admin. Officer
Sh. Chaman Singh	Finance & Accounts Officer	Senior Finance & Accounts Officer
Sh. R.S. Bhatt	Finance & Accounts Officer	Finance & Accounts Officer
Sh. Yogesh Kadian	Senior Admin. Officer	Senior Admin. Officer
Sh. Jaswant Kumar	Asstt. Admn. Officer	Admn. Officer
Sh. Navdeep Sharma	Asstt. Admn. Officer	Admn. Officer
Sh. Prasenjit	Asstt. Admn. Officer	Admn. Officer

16. POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLED PERSONS

16.1 POLICY DECISIONS AND ACTIVITIES

The decisions and activities undertaken for the benefit of the differently abled persons are as follows:

- The benefits to the differently abled candidates in service matter as per instructions of ICAR/DOPT. Govt. of India as the case may be is followed.
- Five per cent of the total numbers of seats in each scheme of admission open to Indian nationals are reserved for differently abled candidates subject to their being otherwise suitable as per the norms of ICAR/Govt. of India. During the year 2021-22, eleven physically challenged students (six M.Sc./M.Tech and five Ph.D.) were admitted against the reserved seats for differently abled candidates. However, in the event of there being no eligible suitable differently abled candidates in the earmarked discipline, to fill up the mentioned number of seats, such unfilled seats shall be transferred to other disciplines, where eligible suitable differently abled candidates are available for filling these seats.

16.2 NUMBER OF BENEFICIARIES AND THEIR PERCENTAGE IN RELATION TO TOTAL NUMBER OF BENEFICIARIES

The number of beneficiaries with disabilities and their percentage in relation to total number of beneficiaries as on December 31, 2021 are as follows:

Category	Total No. of beneficiaries	No. of beneficiaries with disability	Percentage (%)
Technical	399	06	1.50
Administrative	310	09	2.90
Skilled Support Staff	549	06	1.09

17. OFFICIAL LANGUAGE (RAJBHASHA) IMPLEMENTATION

Article 343 of the Constitution, says that Hindi shall be the Official Language of the Union Government. To implement the objectives in letters and spirit, ICAR-IARI is making consistent progress in the use of OL in agricultural research, education, extension as well as in administration.

17.1 OFFICIAL LANGUAGE IMPLEMENTATION COMMITTEE

An Official Language Implementation Committee (OLIC) is constituted by the institute under the chairmanship of Director and the Committee ensures compliance of policy and rules of official language Act 1963 and O.L. rules of 1976. All the Joint Directors, Head of Divisions and Comptroller are ex officio members of OLIC and Deputy Director (OL) is its member-secretary. During the period under report, the meeting of this committee was organized regularly in each quarter and necessary suggestions and instructions were given for promoting the use of Hindi in various official/research activities and the effective implementation of Official Language. To ensure follow up action on the decisions taken in these meetings, subcommittees were also constituted in different Divisions, Regional Stations and the Directorate.

17.1.1 Inspection of progressive use of official language

As per the recommendations of the OLIC and to achieve the targets fixed in the annual program of the Department of Official Language, Ministry of Home Affairs, Govt. of India, an OL Inspection Committee was constituted under the chairmanship of Dr. Indramani, Head, Agriculture Engineering Division. The Committee inspected the progressive use of OL in all the Divisions, Units and sections of the Directorate. The committee gave valuable suggestions for making the desired progress of OL implementation in the concerned Division/Section/Center, etc. and submitted inspection reports.

17.2 AWARD SCHEMES/COMPETITIONS

During the year 2021 many competitions/award schemes were also initiated to motivate the employees of the institute to do their maximum work in Hindi. A large number of officers and employees of different categories of staff participated in these activities. During the year following activities were organized:

17.2.1 Award scheme for doing maximum official work in hindi

This award scheme of the Department of Official Language, Ministry of Home Affairs, Govt. of India, was implanted as per the directives of the Department Employees of the institute were given cash awards for doing their maximum official work in Hindi in the whole year.

17.2.2 Hindi vyavahar pratiyogita

Hindi Vyavahar Pratiyogita was organized amongst the different divisions and sections of Directorate separately and two divisions and sections each were awarded shield for doing maximum work in hindi during the whole year. In the period under report, Water technology Center and Entomology Division amongst the divisions and Regional station Karnal, Regional station Katrain, Kullu Ghati amongst the Regional stations were chosen to give the prizes.

17.2.3 Awards for popular science writing in different journals

A competition for Popular Article Writing was organized for scientists/technical officers of the institute and winners were awarded first, second, third and three consolation prizes of ₹ 7000/-, 5000/-, 3000/ and ₹ 2000/- (each) respectively for their published articles in different journals.

17.2.4 Pusa vishisht hindi pravakata puraskar

Pusa Vishisht Hindi Pravakta Puraskar was given jointly to two scientists for their outstanding lectures in different training programs. Evaluation was done on the basis of recommendations of course coordinator and feedback of the trainees. The Puraskar carries a cash prize of ₹ 10,000/- and a certificate.

17.3 HINDI CHETNA MAAS

This year Hindi Chetna Maas was celebrated from September 14 to October 13, 2021. A "Hindi Poem Recitation" competition was organized. In order to encourage the officials/employees to do their official work in Hindi, various competitions were organized. This year also due to COVID -19 competitions were organized in both online and offline mode. Hindi Poem Recitation, extempore, debate was organized through zoom app and Hindi noting and drafting, quiz, Hindi Typing and general knowledge competition (only for the skilled supporting staff of the institute) were organized in offline mode. A total of 07 competitions were organized. Employees from all the categories of the institute participated in these competitions enthusiastically. Hindi Week/Hindi Day/Hindi Fortnight were also celebrated in different divisions and regional stations of the institute. Many competitions were organized and participants were given prizes and certificates.

18. TRANSFER OF TECHNOLOGY

Application of latest technologies and practices is vital for effective resource management and enhancing crop productivity and income. Therefore, the institute lays immense emphasis upon transfer of technologies to accelerate their rate of diffusion and adoption. The institute carried out programmes such as Mera Gaon Mera Gaurav (MGMG), Schedule Cast-Sub Plan (SC-SP), and ST-SP development of NEH region. Pusa *Krishi Vigyan Mela* and training programmes were organized for the capacity building of farmers.

18.1 Transfer of Technology in North Eastern Hill Region

The farmers of NEH region were provided vegetable kits for homestead nutritional gardening as well as 1650 quintals of potato seeds and 2599 kg seeds of vegetable crops (carrot and radish) and marigold through different KVKs of the region for enhancing yield and income as well as nutritional security.

18.2. Interventions under Scheduled Caste Sub-Plan (SC-SP)

18.2.1. Demonstrations of improved varieties and input support

The main objective of the scheme is to give a thrust to economic development of families of SC categories below the poverty line, by providing resources for filling the critical gaps. Since the schemes/programmes for SCs may be depending upon the local occupational pattern and the economic activities available, the Sates/UTs have been given full flexibility in utilizing the allocation with the only condition that it should be utilized in conjunction with SCP and other resources available from other sources like various Coorporations, financial institution *etc*. The institute has been implementing SC-SP programme since 2019.

During 2020-21, 5724 SC farmers were covered in seven districts of two states. The institute organized a total of 10412 demonstrations of its improved varieties of paddy, wheat, mustard, lentil, chickpea and vegetables including *palak*, carrot, onion, garden pea and vegetable kits for kitchen garden. IARI improved varieties have recorded 10-17 percent yield increase over the local checks in these demonstrations across the locations. During *kharif* 2021-22, 10615 SC farmers were covered in 23 districts of 3 states. Demonstrations of IARI improved varieties of paddy, mungbean, pigeon pea and vegetables were organized. Several farmers-scientist's interfaces and training programmes were organized across the districts. Seven training programmes for SC farmers were organized under at different locations on improved crop management technologies of paddy, mungbean, mustard and vegetables. Critical inputs other than quality seeds of IARI improved varieties, including zinc fertilizer and plant protection chemicals were also distributed to the farmers under this programme. Small tools and implements including spades (1200 Nos.), *khurpa* (950 Nos.) as well as Knapsack manual (440 Nos.) and battery operated (120 Nos.) sprayers were distributed to SC farmers and farm labourers.

18.2.2. Training programmes for marginal farmers

One-day training for 25 farmers of districts Bulandshahr and Ghaziabad in Uttar Pradesh engaged in protected cultivation was organized. The farmers were also provided seedlings of tomato and chrysanthemum for cultivation under polyhouse.

Training on protected cultivation

They all were provided secateurs and budding knife and rootex-2 to exercise making of seedlings and sapling on their own.

An awareness cum training programme on "Farmer Producer Organization (FPO) for Farmers' prosperity" was conducted by the Division of Agricultural Economics, ICAR- Indian Agricultural Research Institute, New Delhi on December 4, 2021 at Fatehpur-Rajpur village, Aligarh district, Uttar Pradesh.

18.2.3 Scheduled Caste Sub-plan (SC-SP) activities at Regional Station

Under SC-SP, 600 Assam lemon, 4000 arecanut seedlings, 1000 black pepper, 500 orchid, 100 guava, 70 litchi plants were distributed among the SC farmers (800) of Darjeeling, Kalimpong, Jalpaiguri, and Cooch-Bihar districts of North Bengal.

18.3 Interventions under Tribal Sub-Plan

Mobile Feed block machine (1 number), Feed and fodder crusher (1 No.), Feed and fodder mixer (1 No.), Pusa Basmati thresher (4 No.), Manual Chaff cutter (5 No.) and Pre-germinated paddy seeder (60 No.) were distributed among the tribal farmers under TSP Scheme.

18.4 *Mera Gaon Mera Gaurav* (MGMG)

The MGMG programme is aimed to increase the farmer-scientist interface to reduce the delay in delivery of authentic information to the target group of farmers. To promote the direct interface of scientists with the farmers to hasten the lab to land process, *Mera Gaon Mera Gaurav* is being implemented by IARI in 120 clusters comprising of 600 villages by 480 scientists of the Institute along with IASRI and NBPGR. The objective of this scheme is to provide farmers with the required information, knowledge and advisory regularly by adopting villages. Under MGMG 1922 filed interventions were made benefitting 13668 farmers.

Sevan demonstrations of wheat (HD 2967) and mustard (Pusa Mustard 31) and 68 demonstrations on mini kitchen garden kit comprising of onion (Pusa Madhvi), Spinach (Pusa Bharti) and carrot (Pusa Rudhira) were conducted in Jagdishpur, Bayanpur villages of sonipat, Haryana under MGMG programme. visit to Waira Firozpur, Beehta, ThalInayatpur, Badhda Vazidpur and Karauthi villages of Siyana block of Bulandshahar District (U.P.) on March 19, 2021. To appraise the farmers about latest IARI technologies and to understand their problems in farming and suggest solutions. Under MGMG at IARI RS, Kalimpong, a total of 5 training programmes, 200 demonstrations and 10 awareness programmes covering 400 farmers were conducted. Improved technologies of Darjeeling mandarin (Nucellar seedling, grafted planting materials, mulching technique to control fruit fly), healthy sucker of Varlangey cultivar of large cardamom, seed of major vegetables (brinjal, cabbage, cauliflower, tomato, chilli, green peas, bottle gourd, bitter gourd *etc.*) and growing rootstock of Darjeeling mandarin were promoted under the programme.

18.5 Pusa Samachar: Multimedia-Based Innovative Extension Model for Information Dissemination

Video based extension initiative in form of 'Pusa Samachar' was launched on August 15, 2020 to disseminate and educate the farmers and other stakeholders about the latest technologies and seasonal cultural practices. Every Saturday at 7 PM new episode are uploaded on IARI official YouTube channel. A total of 132 episodes of Pusa Samachar in Hindi, Telugu, Kannada, Tamil, Bangla and Odriya were broadcasted among the farmers through You Tube channels as well as whatsapp groups. One dedicated Pusa Whats App number (9560297502) has been launched, via which farmers can send their farm problems with pictures

Details of activities under MGMG programme.

Total No. of Groups formed	No. of Scientists Involved	No. of villages covered	No. of field activities conducted	No. of messages/ advisory sent	Farmers benefited (No.)
121	503	621	1922	737	13668

for getting reply promptly from scientists. There are 17700 subscribers of IARI YouTube Channel with total viewership of 4.5 lakhs. In every episode time specific crop management practices, successful farmers' stories, Pusa WhatsApp salah and weather advisory broadcast are given.

Content Analysis of 39 episodes of Pusa Samachar (Hindi) was done. A total of 128 topics were covered in 17 different disciplines/areas including farmers success stories. The discipline-wise coverage of topics were found as Agronomy (17.20%), Genetics (12.50%), Plant Pathology (8.60%), Vegetable Science (21.10%), Horticulture (5.46%), Entomology (6.25%), Protected Cultivation (2.34%), Agricultural Engineering (3.12%), Microbiology (4.68%), Soil Science (1.56%), Economics (0.78%), Floriculture (1.56%), Student based Topic/Career (0.78%), Biochemistry (2.34%), Agricultural Chemicals (0.78%), Extension (0.78%) and Success stories of Farmers (0.15%).

Pusa Samachar in regional languages

18.6 Pusa *Krishi Vigyan Mela* 2021

Pusa *Krishi Vigyan Mela* 2021 was organised on theme "*Atma Nirbhar Kisan*" at the IARI mela ground from February 25-27, 2021. The mela was inaugurated by Sh. Narendra Singh Tomar, Hon'ble Union Minister of Agriculture and Farmers Welfare, Government of India and presided over by Hon'ble Minister of State for Agriculture and Farmers Welfare, Sh. Kailash Choudhary. Dr. Trilochan Mohapatra, Secretary, DARE & Director General, ICAR and Dr. Sanjay Singh, Additional Secretary (DARE) & Secretary (ICAR) were the Guests of Honour. Dr. A.K. Singh, Director IARI; Dr. V.K. Singh (Joint Director, Extension); Dr. Indramani Misra, Head, Division of Agricultural Engineering and Dr. J.P.S. Dabas, In-charge, CATAT also graced the occasion. IARI Fellow Awards were bestowed upon 5 farmers on the occasion. Hon'ble Union Minister Sh. Narendra Singh Tomar appreciated the *mela* for providing a unique platform for interaction among farmers and the experts from all over the country.

He reiterated on the Government's efforts to implement programme for benefit of the farmers and urged all the farmers to reap maximum benefits from the newly developed varieties and technologies. He also emphasized that the credit and flow of private investment in the agricultural sector and the formation of FPOs will help in realizing the long-cherished dream of Hon'ble Prime Minister in developing the *Atmanirbhar* Bharat. Sh. Kailash Chaudhary also appreciated the Pusa *Krishi Vigyan Mela* and lauded the farmers as well as agricultural scientists for realizing

Inauguration of Pusa *Krishi Vigyan Mela*-2021

significant increase in annual agricultural production, even in the Covid-19 pandemic. He appreciated the IARI fellow farmers and the Padamshri awardee farmers present on the occasion for their progressive outlook towards agriculture. He congratulated IARI for developing the Pusa Farm SunFridge for reducing spoilage of the perishable horticultural produce. He stressed upon the importance of timely availability of market facilities for the farmers, for which Government has increased the outlay on infrastructure.

Prize distribution to famers by Chief Guest

Farm technologies developed by the Institute for sustainable agricultural development were displayed in a huge thematic pandal. Besides, live demonstrations on improved crop varieties, vegetables production technology and IFS models; farm machineries and Pusa Farm SunFridge were displayed to provide First-hand experience to farmers. The farmers were provided free 'farm consultancy services' including soil and water testing at the *mela* site by the agricultural scientists.

Pusa Farm SunFridge

A total of 120 stalls, put up by ICAR Institutes, public and private sector organizations, NGOs, and farm entrepreneurs displayed their technologies and products. The *mela* also provided a platform to many organizations, agro-entrepreneurs and progressive farmers to directly sell their agri-products to the consumers. More than 40,000 visitors from different parts of the country including farmers, farm women, extension workers, entrepreneurs, students and others visited the *mela*. Also, for the first time many stakeholders could took benefit from the live webcasting of the *mela* in different parts of the country.

Water conservation model

Five technical sessions on different themes of agricultural importance *viz.*, "Agricultural Reforms and Entrepreneurship Development" (Session 1); "Improved Agricultural Technologies for Higher Production and Profitability" (Session 2); "Women Empowerment" (Session 3); "Technologies for NRM and Value Addition" (Session 4) and 'Innovative Farmers Meet' (Session 5) were organized and the farmers' queries were also addressed by scientists of different disciplines during the three-day mela. The session on 'Innovative Farmers Meet' was chaired by Dr. K.V. Prabhu, Chairperson, PPV & FRA. In this session, the awardee IARI Innovative farmers and Fellow Farmers of 2021 shared their rich experiences of farming and innovations practiced by them.

Seeds of high yielding varieties of different crops worth ₹ 32.31 lakhs were sold through both Pusa Seed Sale Counter and through online orders. Besides, rice worth ₹ 1.00 lakhs, pearl millet flour (Hullur), corn flour (Makai), microgreen kits worth ₹ 14.8 thousand and bio-fertilizers worth ₹ 1.35 lakh were also sold during the mela. Twenty five STFR meters were also sold/ booked during *mela* time.

Four publications useful for farmers and agri-entrepreneurs including Prasar Doot, Fellow and Innovative Farmers: 2021, crop cultivars for farmers' prosperity and *Kisano ke labharth: Phaslon ki unnat kisme* were released.

The valedictory function was graced by Sh. Kailash Choudhary, Hon'ble Minister of State for Agriculture and Farmers Welfare, Dr. Trilochan Mohapatra, Secretary, DARE and Director General-ICAR and Dr. D.K. Yadav, ADG (Seed), ICAR were the Guests of Honour. IARI Innovative Farmers Awards were bestowed to 35 farmers belonging to 21 States/UTs of the country. Shri Kailash Chaudhary emphasized on the government priorities in the field of agricultural research and farmers' welfare. He also appreciated the institute's effort to develop new varieties and agriculture technologies. He briefed about the various measures taken by the government of India in the current year's budget for the welfare of farmers, farming and the agricultural sector. Dr. T. Mohapatra affirmed that the scientific interventions in agriculture have potential to improve the farmers' income manifolds. He also assured that ICAR scientists were ready to work with farmers to achieve the goal of doubling the farmers' income. He emphasized on the use of digital platforms for the better dissemination of varieties and technologies in agriculture.

18.7 Training and Capacity Building

The Institute organized several National and International short-term training courses (regular, *adhoc* and individual) and refresher courses in specialized areas for the scientists of NAREES. In addition, some special training/ workshops courses were also organized for the benefit of professionals, farmers and extension workers.

18.7.1. Training programmes organized by divisions and regional stations

Name of the training programme	Duration	No. of trainees
Division of Agricultural Chemicals		
Bioprospecting of Natural Resources for the Production of Bio-pesticide	March 15-19, 2021	32
Division of Biochemistry		
12 days training program on "Journey of pearl millet – from Land to Lab to Plate"	March1-12, 2021	32
One day training on "Know how methodology of Hallur and Makai" to Arpan Nutrition Pvt. Ltd.	February 01, 2021	2
One day e-Workshop on 'Biomolecules, Bio-resources and Biotechnology'	January 15, 2021	100
Division of Agricultural Economics		
Data Analysis with Stata	January 25-29, 2021	41
Analytical Techniques for Impact Assessment of Agricultural Technologies & Policies	March 17-27, 2021	50
Time Series Techniques for Forecasting in Agriculture	December 1-10, 2021	54
Division of Agricultural Extension		
Online training programme on Life Skill Enhancement and Personality Development for technical personnel.	November 16-20, 2021	25
Division of Floriculture & Landscaping		
Floriculture & Landscaping for "Work Charged Staff (*Malis*) of Rashtrapati Bhavan" -1st Batch	March 16 – 22, 2021	22
Floriculture & Landscaping for "Work Charged Staff (*Malis*) of Rashtrapati Bhavan" -2ndBatch	April 5-11, 2021	25

Floriculture & Landscaping for "Work Charged Staff (Malis) of Rashtrapati Bhavan" -3rd Batch	July 14-20, 2021	22
Division of Microbiology		
Production of carrier and Liquid based Biofertilizers of Pusa Bio-Phos and Pusa Bio-Potash for the officials of Department of Horticulture, Citrus Estate, Hoshiarpur, our technology licensee partners under PPP through Agrinnovate India Ltd,	November 23-26, 2021.	4
Production of Liquid based Biofertilizers of Pusa Bio-Phos to officials of M/s Indore Biotech, Indore (MP), our technology licensee partner under PPP through Agrinnovate India Ltd	December 7-8, 2021	2
e-Workshop on 'Biomolecules, Bio-resources and Biotechnology'	January 15, 2021	20
Division of Plant Pathology		
Biological control of pest and diseases of crops through microbes" at IARI, New Delhi under Biotech- KISAN	March 24 -25, 2021	36
Online Training on Genetic Fidelity Testing and Virus Indexing of Tissue Culture Raised Plants	March 08-12, 2021	25
Division of Seed Science and Technology		
Capacity building training programme on Seed Production (Mustard, Wheat and Barley)	January 12-14, 2021	57
Capacity building training programme on OECD Seed Certification (Mustard, Wheat and Barley)	February 8 -11, 2021	172
Capacity building training programme on OECD Post-Harvest Technologies for Better Seed Quality (Potato, Wheat and Barley)	March 15-17, 2021	61
Capacity building on Seed Testing for Quality Assurance (Mustard, Wheat and Barley)	July 6 -9, 2021	131
International online training programme on Seed Production and Quality Evaluation for the officials of AARDO member countries	July 28–August 7, 2021	72
Capacity building training programme on Seed Quality Enhancement (Mustard, Wheat and Barley)	September 22-24, 2021	148
Division of Soil Science and Agricultural Chemistry		
Management of soil health for sustainable development	March 22-27, 2021	25
17th Advanced Level Training in Soil Testing, Plant Analysis and Water Quality Assessment	December 07-27, 2021	20
Regional Station, Indore		
Wheat & wheat seed production technology	January 04, 2021	19
On farm Training of tribal Wheat farmers	January 06, 2021	62
Monitoring and On farm Training of Wheat farmers "Nutrients and Insect Pest Management"	January 21, 2021	23
Wheat & wheat seed production technology and Durum wheat uses and processing.	January 29, 2021	15
Field day and On farm Training of tribal Wheat farmers	February 03, 2021	52
Monitoring and On farm Training of Wheat farmers	February 10, 2021	104
Training for Durum wheat FPOs of Indore district	February 27, 2021	63
Wheat Production Technology	July 11, 2021	57
Wheat and wheat seed Production Technology	September 03, 2021	51
Implements distribution and farmers training in Inter-culture in field crops, use of Chaff cutter for Dairy animals and maize Sheller to reduce drudgery under TSP	September 08, 2021	125
Bio-fortified wheat varieties and nutrition	September 17, 2021	112

Wheat and wheat seed Production Technology	September 28, 30 and October 13, 2021	149
Field preparation and use of balanced fertilizer for wheat cultivation in Tribal Areas	October 21, 2021	39
On Farm Training "Wheat Sowing in Tribal Areas"	October 26, 28 and November 02, 2021	93
On Farm Training "Wheat Sowing Methodology"	October 30 and November 9, 12, 2021	133
Wheat and wheat seed Production Technology	November 11, 17, 24, 2021	178
Wheat Production Technology	November 26, 2021	145
Regional Station, Kalimpong		
Adoption of scientific plant protection measure in large cardamom cultivation	January 8, 2021	30
Scientific agronomic and weed management practices in large cardamom cultivation	February 16, 2021	40
Training programme on farm machinery	January 8, 2021	80
Adoption of plant protection measure in large cardamom	January 5, 2021	40
Regional Station, Karnal		
Virtual Training Programme on "Maintenance Breeding in Field Crops" organized by IISS, Mau in collaboration with IARI Regional Station, Karnal	January 19, 2021	100
Use and maintenance of agricultural implements in quality seed production' organized by IARI, Regional Station, Karnal.	March 8-10, 2021	25
Regional Station, Katrain		
One day training programme on "Temperate Vegetable Production" for the SC farmers under the Scheduled Caste Sub-Plan (SCSP) organized by ICAR-IARI Regional Station, Katrain	February 09-10, 2021	80
Three days farmer's training programme on "Seed Production technologies of temperate vegetables and flowers" by ICAR-IARI Regional Station, Katrain	March 2-4, 2021	20
Organization of "Cabbage Day" at IARI Regional Station, Katrain	December 21, 2021	50
One day training programme on "Doubling farmer's income through vegetable cultivation" for the SC farmers under the Scheduled Caste Sub-Plan (SCSP) organized by ICAR-IARI Regional Station, Katrain.	December 28, 2021	40
Regional Station, Shimla		
Training programme on Apple, Pear, Kiwi, pomegranate, stone fruits and strawberry cultivation, wheat-barley cultivation.	November 13, 2021	30
Training for apple growers in tribal area of Kinnaur District	February 11-12, 2021	35
Training programme training-pruning of temperate fruit crops and their propagation techniques in association with Ambuja cement foundation, Darlaghat.	November 12, 2021	35
One day training cum Kishan Gosthi on cultivation of temperate fruit cultivation, wheat and barley in association with Ambuja Cement Foundation, Darlaghat .	March 23, 2021	200
Seed Production Unit		
"Beej utpadan ek kadam atma nirbharta ki or" Organized at Jalalpur, Shikarpur	March 13, 2021	50
"*Rabi subjio ki beej utpadan Taqnekee*" was organized at Rajpura, Meerut.	March 20, 2021	55

18.7.2 Training programmes organized by the centre for agricultural technology assessment and transfer (CATAT)

In all, 15 on-campus training programmes were organized for agriculture officials and progressive farmers of different States. These programmes were attended by 513 participants from Rajasthan, Punjab, and NCR Delhi.

Name of the training programme	Duration	No. of trainees
Peri-urban agriculture	March 8,10,12,17, 2021	200
Organic farming (ATMA, Hoshiarpur)	March 16-18, 2021	20
Pre- seasonal training for *Kharif* crops	August 10-11, 2021	25
Flowers cultivation(Rose & marigold)	August 16, 2021	25
Organic farming & its certification	August 19, 2021	25
Agricultural diversification through vegetables & market linkage.	August 24, 2021	25
Pre- seasonal training for *Kharif* crops	August 26-27, 2021	75
Production Technology of Cole crops	September 10, 2021	25
Preservation of fruits & vegetables	September 17, 2021	25
Improved agri. practices & post-harvest management' sponsored by ATMA, Ajmer	September 14-20, 2021	31
Safe and judicious use of pesticides	September 21, 2021	25
Integrated nutrient & disease management	September 28, 2021	25
Improved technologies for *Rabi* crops	December 15-16, 2021	72

18.7.3 Off-campus trainings

Training and demonstration on the use of BGA and its application in paddy crop were organized at Nidana (Rohtak), Haryana on July 26, 2021. One-day farmer-scientists interaction and awareness campaign sponsored by BEDF(APEDA) was organised on 'Judicious use of pesticides and Good Agricultural Practices of Basmati Rice' on September 10, 2021 at Village Tigipur, Delhi and on September 22, 2021 at Village Dariyapur, Delhi for 100 farmers. The officials of KVK Ujjawa, Development department, Delhi, Doordashan, Aaskashwani also participated in the programme. Two Animal health care camps were organized at village Mahauli (Palwal), Haryana on August 31, 2021 and Nidana (Rohtak), Haryana on September 15, 2021.

18.7.4 Off-campus Exhibitions

CATAT Participated in an exhibition during "India International Trade Fair", at Pragati Maidan, New Delhi from 14-27 November, 2021 for the display /sale of IARI technologies, products, services and publications.

18.8 Agricultural Extension Activities at Regional Stations

Activities/ Name of Regional Station	Duration	No. of participants
Regional Station, Pusa, Bihar		
Field day on Role of wheat seed production in doubling farmers income in village Sakri Kothhi Man of Muzaffarpur district of Bihar	March 11, 2021	35
Field day on Enhancing farmer's income through conservation agriculture technologies and pulse integration in Eastern India" under IARI- ICARDA Collaborative Project in village Bahadurpur Patauree of Samastipur district of Bihar	March 19, 2021	35

Farmers' visit from KVK Darbhanga.	February 9, 2021 and February 17, 2021,	750
Participated in three days *Kisan Mela* at Dr. Rajendra Prasad Central Agricultural University, Pusa Bihar. Various varieties of wheat, paddy, moong and papaya were demonstrated at the IARI stall.	February 07-09, 2021	1000
Regional Station, Shimla		
Field Day on Nursery production and Training, Pruning and Grafting of Temperate Fruit Crops at IARI, Horticulture Research Farm, Dhanda	January 16, 18, 20 and 22, 2021	50
Talks on Apple, Pear, Kiwi, pomegranate, stone fruits and strawberry cultivation, wheat-barley cultivation at Halot, H.P	October 16, 2021	25
Farmer's Day on Introduction of temperate fruit crops in existing cropping system	February 03, 2021	25
Farmer's Day on Production technology of Temperate fruit under SC-SP in collaboration with NBPGR, Shimla	April 17, 2021	200
One day training cum *Kishan Gosthi* on cultivation of temperate fruit cultivation, wheat and barley in association with Ambuja Cement Foundation, Darlaghat.	March 23, 2021	200
Farmers Field School Cultivation of Fruit Crops and nursery techniques as well as cultivation of wheat and barley crops.	September 23, 2021	35
Participated in North Indian *Krishi Mela* at SKAUST, Jammu displayed technologies, delivered lectures and distributed extension materials to the farmers.	October 7-11, 2021	--
Participated in Three days Exhibition cum Agriculture Fair at Solan, H.P. organized by Friendz Exhibition cum Promotion, New Delhi.	September 28-30, 2021	--

19. SERVICE THROUGH QUALITY SEED & PLANTING MATERIALS

19.1. SEED PRODUCTION OF FIELD CROPS (January 1 to December 31, 2021)

19.1.1 Seed Production at Seed Production Unit, IARI, New Delhi

Details of seed production at Seed Production Unit & farmer's field

Crop	Total No. of varieties	Classes of seeds*(in tonne)				Total (tonne)
		NS	BS	IARI Seeds /(TFL)		
				At Institute	Under FPSP	
Wheat	10	5.400	134.880	0.160	176.95	317.390
Paddy	10	0.000	2.655	2.180	221.855	226.720
Chickpea	06	0.275	0.895	0.789	7.041	9.000
Pigeon pea	03	0.050	0.680	0.675	0.690	2.065
Lentil	03	0.325	1.500	0.633	2.000	4.458
Moong	04	0.10	1.000	0.500	7.785	9.385
Mustard	08	0.05	2.753	7.512	8.577	18.892
Total	**44**	**6.200**	**144.363**	**12.449**	**424.898**	**587.891**

*NS-Nucleus seed, BS-Breeder Seed, TFL-Truthful Label Seed (IARI Seed), FPSP-Farmers participatory seed production

Funds generated = ₹ 4,72,00,000

19.1.2 IARI Regional Station, Karnal

At IARI-Regional Station, Karnal, 512.02 tonnes seed of different crop varieties of cereals, pulses, oil seeds and forage crops was produced during this period. A total of 3.003 tonnes nucleus, 190.088 tonnes breeder and 319.088 tonnes of IARI seed were produced.

Seed production of field crops during 2020-21

Type	No. of Crop(s)	No. of Varieties	Seed production (q)			
			Nucleus	Breeder	IARI	Total
Cereals	4	25	30.02	1897.31	3167.82	5095.15
Pulses	3	4	0.01	7.39	--	7.40
Oil seeds	1	6	--	4.62	9.26	13.88
Others	1	1	--	--	13.80	13.80
Total	**8**	**36**	**30.03**	**1909.32**	**3190.88**	**5130.23**

Funds generated: ₹ 2,42,50,000

19.1.3 IARI Regional Station, Bihar

During 2021, 2076.33 quintals of quality seed was produced at the station including breeder, nucleus and TFL seeds of different crops. Under participatory seed production programme a total of 632.48 quintals of wheat seed of HD 2967 was produced. The details are given as under.

Seed produced (Unprocessed seed) during 2020-21

Sl. No.	Season	Crop	Variety	Category-wise seed production (q)				
				NS	Breeder seed	TFL	FPSP	Total
1	*Kharif*-2020	Paddy	Pusa Sugandha 5	0.00	0.00	73.56	0.00	73.56
			Pusa-44	0.00	0.00	30.51	0.00	30.51
			Pusa Samba -1850	0.00	0.00	29.05	0.00	29.05
			PNR-381	0.00	0.00	74.21	0.00	74.21
			Total	**0.00**	**0.00**	**207.33**	**0.00**	**207.33**
		Pearlmillet	Pusa Composite-383	0.00	0.00	03.63	0.00	03.63
			Pusa Composite-701	0.00	0.00	01.24	0.00	01.24
			Total	**0.00**	**0.00**	**04.87**	**0.00**	**04.87**
2	*Rabi*-2020-21	Wheat (unpro-cessed seed)	HD -2967	13.58	813.96	0.00	632.48	1460.02
			HD-3086	0.00	264.20	0.00	0.00	264.20
			HD-2733	0.00	23.26	24.10	0.00	47.36
			HD-2985	0.00	0.00	07.255	0.00	07.255
			HI-1563	02.85	28.48	0.00	0.00	31.33
			HD-3118	0.00	0.00	02.42	0.00	02.42
			HI-1612	02.60	02.99	0.00	0.00	05.59
			HD-3171	04.32	05.21	0.00	0.00	09.53
			HI-1621	0.00	02.99	0.00	0.00	02.99
			CSW-18	0.00	0.00	04.41	0.00	04.41
			HD-3249	01.84	11.04	0.00	0.00	12.88
			HD-3226	0.00	06.14	1.73	0.00	07.87
			Total	**25.19**	**1158.27**	**39.915**	**632.48**	**1855.855**
		Lentil	L-4717	0.00	0.00	02.14	0.00	02.14
			L-4727	0.00	0.00	0.08	0.00	0.08
			L-4147	0.00	0.00	0.09	0.00	0.09
			PDL-1	0.0	0.00	0.10	0.00	0.10
			PSL-9	0.00	0.00	0.15	0.00	0.15
			Pusan Shivalik	0.00	0.00	0.03	0.00	0.03
			Pusa Vaibhav	0.00	0.00	02.39	0.00	02.39
			Total	**0.00**	**0.00**	**04.98**	**0.00**	**04.98**
		Mustard	Pusa Tarak	0.00	0.00	0.70	0.00	0.70
			Pusa Vijay	0.00	0.00	0.027	0.00	0.027
			Pusa Agrani	0.00	0.00	0.035	0.00	0.035
			Pusa Gold	0.00	0.00	0.01	0.00	0.01
			Pusa -25	0.00	0.00	0.017	0.00	0.017
			Pusa -26	0.00	0.00	0.02	0.00	0.02
			Pusa -27	0.00	0.00	0.02	0.00	0.02
			Pusa -28	0.00	0.00	0.017	0.00	0.017
			Total	**0.00**	**0.00**	**0.846**	**0.00**	**0.846**
		Pea	Pusa Pragati	0.00	0.00	0.84	0.00	0.84
			Pusa Shree	0.00	0.00	01.25	0.00	01.25
			Total	**0.00**	**0.00**	**02.09**	**0.00**	**02.09**

Funds generated = ₹ 1,25,00,000

19.2 SEED PRODUCTION IN HORTICULTURAL CROPS (January 1 to December 31, 2021)

The production of quality seed of horticultural crops (Vegetables, Fruits & Flowers) was undertaken at institute farm, regional stations and under farmer participatory seed production programmes, respectively. The crop-wise details of the production of various classes of seeds are given below.

19.2.1 Vegetable crops

Following is the detail of vegetable crops seed production by the IARI at its Regional Stations and Seed Production Unit in 2021.

19.2.1.1 Seed Production Unit, IARI, New Delhi

The production of quality seed of 29 varieties of 21 horticultural crops (vegetables & flowers) was 14737.9 kg, which comprised of nucleus seed (80.25 kg), breeder seed (834.4 kg) and IARI seed/ TFL seed 13822.485 kg (3336.70 & 10485.785 kg) at institute farm and also under farmer participatory seed production programmes, respectively at the Seed Production Unit, ICAR-IARI, New Delhi.

Seed production of flowers & vegetables crops

Crop	Total No. of variety (ies)	Classes of Seeds* (in kg)				Total production (kg)
		NS	BS	IARI Seeds / (TFS)		
				At Institute	Under FPSP	
Palak	02		68.0	1122.0	505.0	1695.00
Amranth	01	1.0		102.0	-	103.00
Bakla	01	2.0		25.0		27.00
Methi	02	7.0	60.0	388.0	-	455.00
Bottle gourd	02	2.0	7.9		997.0	1006.90
Sponge gourd	01	0.5	6.0	-	236.7	243.20
Cowpea	01				313.0	313.00
Turnip	01	1.0		90.0	-	91.00
Radish	01	5.0	17.0	408.0	620.0	1050.00
Carrot	02	5.0	8.0	0.0	2499.0	2512.00
Bathua	01	0.5	-	8.0	-	8.50
Veg. mustard	01	1.0	-	218.0	-	219.00
Onion	03	1.0	6.5	6.5	506.085	520.085
Onion bulb	02	-	660.0			660.00
Brinjal	01	0.5		21.0		21.50
Tomato	01	0.25		19.0	-	19.25
Cherry tomato	01			0.70		0.70
Garden pea	01	50.0	-	880.0	4112.0	5042.0
Okra	01	2.0			543.0	545.0
Marigold	03	0.5	1.0	22.0	154.0	177.5
Sounf	01			2.0		2.0
Sem	01	1.0		24.5	-	25.5
Total	**29**	**80.25**	**834.4**	**3336.7**	**10485.785**	**14737.9**

**NS-Nucleus seed BS-Breeder Seed, TL-Truthful Label Seed (IARI Seed) & FPSP-Farmers participatory seed production

Funds generated = ₹ 55,00,000

The details of seeds produced at different Divisions and Regional Stations are as follows;

Seed production at Division of Vegetable Science, IARI, New Delhi

			Class of Seed (in kg)			
Rabi 2020-21			BS	TL	FPSP	Total (kg)
Sl. No.	Crop	Variety				
1	Cauliflower	Pusa Kartik Sankar (Hybrid)	-	6.50	-	6.50
		Pusa Meghna	2.50	15.50	-	18.0
		Pusa Sharad	-	4.20	-	4.20
2	Carrot	Pusa Rudhira	10.0	110.0	-	120.0
		Pusa Vrishti	-	10.50	-	10.50
		IPC-3	-	5.80	-	5.80
		Pusa Asita	-	15.0		15.0
3	Chilli	Pusa Sadabahar	5.0	14.50	-	19.50
4	*Methi*	PEB	10.0	60.0	-	70.0
5	Onion	Pusa Ridhi	20.0	26.0	-	46.0
		Pusa Shobha	5.0	10.0	-	15.0
		Pusa Sona	0.70	-	-	0.7
6	Garden pea	Pusa Shree	27.0	30.0	-	57.0
		Pusa Prabal	25.0	3.0	-	28.0
		Pusa Pragti	-	26.0	-	26.0
7	*Palak*	All Green	25.0	100.0	-	125.0
		Pusa Bharti	-	110.0	-	110.0
8	Radish	Pusa Chetki	10.0	61.0		71.0
9	*Bathua*	Pusa Green	2.0	3.50	-	5.50
		Pusa Bathua No. 1	-	2.0	-	2.0
10	*Methi*	Pusa Kasuri	-	51.50	-	51.50
11	Vegetable mustard	Pusa Sag-1	-	55.0	-	55.0
12	Turnip	Pusa Sweti	-	12.0	-	12.0
13	Winter bean	Pusa Udit	-	14.50	-	14.50
		Pusa Sumeet	-	28.0	-	28.0
14	Radish	Pusa Mridula	-	35.0	-	35.0
15	Tomato	Pusa Rohini	-	4.50	-	4.50
		Pusa Sadabahar	-	0.30	-	0.30
16	Bunching onion	Pusa Soumya	-	0.70	-	0.70
17	Cherry tomato	Pusa Cherry Tomato-1	-	0.50	-	0.50
		Sub-Total	**142.20**	**815.50**	**-**	**957.70**
Summer 2021						
1	Bottle gourd	Pusa Santushti	3.0	-		3.0
2	*Bhindi*	Pusa Bhindi-5	22.50	5.0		27.50
3	Bitter gourd	Pusa Aushadhi	1.10	3.70		4.80
		PH-4	-	2.80		2.80
4	Muskmelon	Pusa Madhurima	0.280	-		0.280
5	Pumpkin	Pusa Vishwas	1.20	1.0		2.20
6	Ridge gourd	Pusa Nutan	4.20	1.70		5.90

7	Sponge gourd	Pusa Sneha	2.10	6.50		8.60
8	Cowpea	Pusa Dharni	10.0	50.0		60.0
		Pusa Sukomal	-	2.50		2.50
9	Brinjal	Pusa Oishiki	1.0	1.20		2.20
		Pusa Vaibhav	-	17.50		1.750
10	Cucumber	Pusa Long Green	1.0	0.400		1.40
		Pusa Parthenocarpic Cucumber-6	-	0.250		0.250
		Sub -Total	**46.380**	**76.80**		**123.180**
Kharif **2021**						
1	Amaranth	Pusa Kiran	-	76.00	-	76.00
2	*Bhindi*	Pusa Bhindi-5	10.00	5.50	-	15.50
3	Brinjal	Pusa Hara Baingan-1	1.00	2.00	-	3.00
		Pusa Vaibhav	2.00	10.00	-	12.00
4	Bottle gourd	Pusa Naveen	1.20	-	-	1.20
5	Cow pea	Pusa Dharni	5.00	30.00	-	35.00
6	Sponge gourd	Pusa Shreshtha (F-1)	-	3.00	-	3.00
		Pusa Shreshtha (M)	1.00	-	-	1.00
		Pusa Shreshtha (F)	0.50	-	-	0.50
		Sub-Total	**20.7**	**126.5**		**146.7**
		Grand Total	**209.28**	**1018.8**		**1227.58**

Funds generated = ₹ 8,22,404

19.2.1.2 Seed production at IARI Regional Station, Karnal, Haryana

Crop	Total No. of variety (ies)	Classes of seeds* (in kg)				Total production (kg)/ No.
		NS	BS	IARI Seeds /(TFS)		
				At Institute	Under FPSP	
Tomato	5	0.055	12.545	0	0	12.6
Brinjal	1	0	0.05	0	0	0.05
Methi	2	0	187.20	0	0	187.2
Palak	2	2.4	318.0	45.0	0	365.4
Onion	4	0	28.85	7.8	0	36.65
Pea	3	36	580	0	1127.0	1743.0
Radish	4	0	20.3	34.70	0	55.0
Carrot	4	0	31.5	16.7	0	48.2
Cauliflower	2	0	1.3	0	0	1.3
Chilli	2	0	2.16	0	0	2.16
Cowpea	3	2.6	3.75	13.2	0	19.55
Longmelon	1	0.12	0	0.8	0	0.92
Cucumber	1	0	0.05	0	0	0.05
Okra	1	0	85.0	4.48	0	89.48
Dolichos	1	0	1.8	0	0	1.8
Total	**36**	**41.175**	**1272.505**	**122.68**	**1127.0**	**2563.36**

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed (IARI Seed) & FPSP-Farmers participatory seed production

Funds generated = ₹ 14,50,000

19.2.1.3 Vegetable seed production at IARI Regional Station, Katrain, Himachal Pradesh

Crop	Variety (ies)	Classes of seeds* (in kg)				Total (kg)
		NS	BS	IARI Seeds/(TFS)		
				At Institute	Under FPSP	
Beet root	Detroit Dark Red	1.50	2.00	15.00	-	18.50
Brinjal	Pusa Purple Cluster	0.40	0.35	2.30	-	3.05
	Pusa Purple Long	0.35	5.85	-	-	6.20
	Pusa Anupam	0.10	-	-	-	0.10
Broccoli	Pusa Broccoli KTS-1	0.20	1.10	10.10	-	11.40
Brussel's sprouts	Hild's Ideal	0.03	-	2.80	-	2.83
Cabbage	Golden Acre	0.45	-	47.50	-	47.95
	Pusa Cabbage-1 (F_1)	0.11	-	-	-	0.11
	Pusa Hybrid-81 (F_1)	-	-	2.10	-	2.10
	Pusa Hybrid-82 (F_1)	-	-	3.23	-	3.23
Capsicum	Pusa Capsicum-1	0.15	-	1.39	-	1.54
	California Wonder	0.23	-	7.80	-	8.03
Cauliflower	Pusa Snowball Hybrid-1 (F_1)	0.08	-	0.21	-	0.29
	Pusa Snowball Hybrid-2 (F_1)	0.05	-	-	-	0.05
	Pusa Hybrid 301 (F_1)	0.06	-	0.34	-	0.40
	Pusa Snowball K-1	0.04	-	-	-	0.04
	Pusa Snowball-1	0.02	0.50	-	-	0.52
	Pusa Purple Cauliflower-1	0.03	-	-	-	0.03
	Pusa Himjyoti	-	-	0.40	-	0.40
Cucumber	Japanese Long Green	0.25	1.00	3.40	-	4.65
French bean	Contender	28.00	220.50	167.50	-	416.00
Knol-khol	White Vienna	0.15	3.50	19.00	-	22.65
	Pusa Virat	-	-	40.90	-	40.90
Kale	Pusa Kale-64	-	-	20.50	-	20.50
Lettuce	Chinese Yellow	0.17	-	13.40	-	13.57
	Great Lakes	0.04	-	3.15	-	3.19
Onion	Brown Spanish	1.50	-	22.30	-	23.80
Palak	Pusa Harit	75.00	-	1886.50	-	1961.50
Paprika	Kt-PL-19	0.05	-	0.19	-	0.24
Parsley	Moss Curled	0.17	-	19.63	-	19.80
Pea	Lincoln	28.00	-	319.50	-	347.50
Radish	Japanese White	2.20	25.50	83.60	-	111.30
	Pusa Himani	3.00	13.00	83.50	-	99.50
Spinach	Virginia Savoy	3.00	-	32.00	-	35.00
Summer squash	Pusa Alankar (F_1)	0.37	-	3.40	-	3.77
Tomato	Roma	0.23	-	3.70	-	3.93
Turnip	Purple Top White Globe	1.10	3.10	30.10	-	34.30
Total		**147.03**	**276.40**	**2845.44**	**-**	**3268.87**

Funds generated: ₹ 28,37,023

19.2.1.4 Regional Station, Pusa, Samastipur, Bihar

Sl. No.	Season	Crop	Variety	Category wise seed production (q)				
				NS	Breeder Seed	TFL	FPSP	Total
1	**Summer**	Moong	Pusa Vishal	0.00	0.00	0.23	0.00	0.23
		Vegetables						
		Chilli	Pusa Sadabahar	0.00	0.00	0.05	0.00	0.05
		Bottle guard	Pusa Santusti	0.00	0.00	0.0086	0.00	0.0086
		Bottle guard	Pusa Navin	0.00	0.00	0.0028	0.00	0.0028

		Brinjal	Pusa Shyamla	0.00	0.00	0.001	0.00	0.001
		Brinjal	Pusa Hara	0.00	0.00	0.0006	0.00	0.0006
		Brinjal	Pusa Shafed	0.00	0.00	0.00005	0.00	0.00005
		Papaya	Pusa Dwarf	0.00	0.00	0.0225	0.00	0.0225
		Okra	A-5	0.00	0.00	0.039	0.00	0.039
		Sponge guard	Pusa Nutan	0.00	0.00	0.0056	0.00	0.0056
		Sponge guard	Pusa Shresth	0.00	0.00	0.0002	0.00	0.0002
			Total	**0.00**	**0.00**	**0.13035**	**0.00**	**0.13035**

Funds generated: ₹ 2,50,000

19.2.2 Fruit crops

Following is the detail of fruit plants multiplied and revenue generated by the IARI during 2021 is given below.

Details of planting material production in fruit crops

Sl. No.	Crop	Cultivar (s)	IARI RS, Karnal	IARI, New Delhi	IARI RS, Samastipur	IARI RS, Kalimpong	IARI RS, Shimla	Total
1	Mango	Amrapali	1742	1884	200	-	-	3826
2	-do-	Mallika	788	680	225	-	-	1693
3	-do-	Pusa Arunima	166	1536	250	-	-	1952
4	-do-	Pusa Surya	221	271	-	-	-	492
5	-do-	Pusa Pratibha	100	881	-	-	-	981
6	-do-	Pusa Lalima	104	456	-	-	-	560
7	-do-	Pusa Shrestha	257	389	-	-	-	646
8	-do-	Pusa Peetamber	79	321	-	-	-	400
9		Pusa Deepshikha	-	34	-	-	-	34
10	-do-	Pusa Manohari	-	354	-	-	-	354
11	-do-	Other cultivars	330	2021	-	-	-	2351
12	Lemon	Kagzi Kalan	3909	1931	1500	-	-	7340
13	Acid lime	Pusa Abhinav & Pusa Udit	-	805	-	-	-	805
14	Sweet orange	Pusa Round & Pusa Sharad	-	409	-	-	-	409
15	Pummelo	Pusa Arun	-	41	-	-	-	41
16	Mandarin	Darjeeling mandarin	-	-	-	9500	-	9500
17	Grape	Pusa Urvashi	-	181	-	-	-	181
18	-do-	Pusa Navrang	-	608	-	-	-	608
19	-do-	Pusa Aditi, Pusa Trishar, Pusa Swarnika and Pusa Purple Seedless	-	1626	-	-	-	1626
20	Guava	Allahabad Safeda	841	-	-	-	-	841
21	Litchi	Sahi	-	-	1500	-	-	1500
22	Apple	Different varieties	-	-	-	-	2032	2032

23	Peach, pear, plum, cherry, apricot, almond, walnut, pomegranate	Different varieties	-	-	-	-	1153	1153
24	Kiwifruit	Different varieties	-	-	-	-	2733	2733
25	Strawberry	Different varieties	-	-	-	-	2182	2182
26	Large cardamom	Different varieties	-	-	-	7000	-	7000
27	Papaya	Seedlings	149	149	3794	-	-	4092
		Seed (kg)	-	-	-	11.2		11.2
		Total	-	-	-	-	-	**52832**

Funds generated: Division of Fruits & Hort. Tech. = ₹ 8,52,642, IARI RS, Karnal = ₹ 7,00,000, IARI RS, Samastipur = ₹ 3,50,000, IARI RS, Kalimpong = ₹ 3,50,000, IARI RS, Shimla = ₹ 6,67,000

19.2.3 Ornamental crops

Following is the detail of ornamental crops seed and planting material production by the IARI, Seed Production Unit and its Regional Stations in 2021.

Planting material production in Ornamental Crops

Sl. No.	Crop	Variety(ies)	FLS, IARI, New Delhi	SPU, IARI, New Delhi	IARI RS, Kattrain	IARI RS, Kalimpong	Total (kg/ No.)
			Seed (kg)				
1	Marigold	Pusa Arpita, Pusa Deep, Pusa Bahar	20	70	-	-	90.00
2	Marigold	Pusa Naranagi Gainda, Pusa Basanti	150	120	-	-	270.00
3	Winter seasonal flowers	Different flowers	15	-	3.94	-	18.94
						Total	**378.94**
			Vegetatively propagated material				
4	Bougainvillea	All named varieties	5000	-	-	-	5000
5	Rose	All named varieties	6500	-	325	-	6825
6	Amaryllis	Pusa Suryakiran	7500	-		-	7500
7	Lilium and Licoris	Different varieties	-	-	245	4500	4745
						Total	**24070**

Funds generated: Division of Floriculture and Landscaping, IARI, New Delhi = ₹ 4,50,000, IARI RS, Kalimpong = ₹ 50,000.

20. MISCELLANY

I. Ongoing Projects at IARI as on 31.12.2021

School of Crop Improvement	:	59
School of Horticultural Sciences	:	28
School of Crop Protection	:	47
School of Natural Resource Management	:	59
School of Basic Sciences	:	20
School of Social Sciences	:	13
ZTM & BPD Unit	:	1
FOSU	:	1
Total	**:**	**228**

II On-going contract research/consultancy/contract service project at IARI as on 31.12.2021 18

III. Scientific Meetings Organized

a) Workshops	18
b) Seminars	10
c) Summer institutes/Winter school	Nil
d) Farmers' day (s)	237
e) Others	29
Total	**294**

IV. Participation of Personnel in Scientific Meetings

India

a) Seminars	205
b) Scientific meetings	344
c) Workshops	130
d) Symposia	68
e) Others	95
Total	**842**

Abroad

a) Seminars	03
b) Scientific meetings	11
c) Workshops	07
d) Symposia	nil
e) Others	08
Total	**29**

V. Suggestions Given / Decisions Taken at the Meetings of Senior Management Personnel Academic Council (January 1, 2021 to December 31, 2021)

- Revision and adoption of BSMA recommended Course Curricula for the Semester System from the Academic Session 2020-21
- Introduction of three new awards i) Best Woman Scientist Award, ii) Dr. H.K. Jain Memorial Young Scientist Award and iii) NABARD Young Researcher Award
- Institution of NABARD-Prof. V.L. Chopra Gold Medal Award of the year
- To initiate Diploma and PG Diploma Courses at IARI, in some of the areas like (i) Organic Farming; (ii) Good Agriculture Practices for Basmati rice cultivation
- Discontinuation of Post Harvest Technology discipline and it's both the sub disciplines. Discontinued sub-discipline "Post harvest Technology of Horticultural Crops" was merged with "Post Harvest Management" under the discipline of Horticultural Sciences (M.Sc. and Ph.D. - Horticulture) and discontinued sub discipline "Post Harvest Engineering & Technology" was merged with "Processing and Food Engineering" of Agricultural Engineering Discipline (M. Tech. and Ph.D.).

Research Advisory Committee

Comments of SMD on the proceedings of the Research Advisory Committee (RAC) meeting of ICAR-Indian Agricultural Research Institute (IARI), New Delhi held under the Chairmanship of Prof. R.B. Singh on December 22-23, 2021.

School of Crop Improvement

- Screening of advanced lines should be undertaken for identification of specific traits related to host plant resistance to insect-pest and diseases, and gene pyramiding should be the focus of future research
- IARI needs to establish speed breeding facilities for different crops for its own use and also make it accessible to users from other Institutes and industry. The Phytotron facility of the Institute should be judiciously utilized for the purpose
- GMS based recurrent selection, haplotype-based selection and developing genotyping chips for selection, which are highly rewarding, should be developed. In rice, prospects of commercial exploitation of apomictic F1s should be examined. Further, use of heterotic clusters in maize, pearl millet and sorghum should be intensified. Nutri-fortification of crop varieties is yet another high priority area to be pursued. Productivity and quality of nutri-cereals should further be improved to promote their expanded production
- Inducible glaucousness/waxiness trait in wheat may be identified and used for improving drought and heat tolerance
- Use of Pusa 1692 for late planting and direct seeded rice (DSR) may be explored. In pigeon pea, the extra early variety PusaArhar 16 and ICPL 88039 (already being cultivated in Bundelkhand region) should be tried on closer spacing with delayed planting to increase yield.
- Plant varieties should be protected under PPV&FRA and commercialized through an appropriate licensing mechanism using various PPP models including PSUs.
- To address the edible oil demand and minimize import, newly developed varieties of rapeseed and mustard and other oilseed crops, along with specifically worked out agronomies, should be targeted to suitable rice-fallow areas which have remained largely untapped. The thrust on pulses improvement and enhanced production should be maintained.

School of Horticultural Sciences

- Screening and breeding for developing dwarfing rootstocks in fruit crops should be taken up as one of the major objectives in new research programme. Genetic improvement of horticultural crops using genomics and heterosis breeding should be strengthened.
- Grafting in vegetables to reduce incidence of diseases in Solanaceous and Cucurbitaceous crops should be given due attention for sustainable protected cultivation.
- Development of processing type tomato needs to be the focus as a National agenda. Adopting a value-chain approach, post-harvest management and value addition should be high research priority for most horticultural crops.
- Pollination using stingless bees, bumble bees and honeybees in greenhouse production and apple orchard needs to be promoted.
- Technologies for pesticide residue free production of fruits and vegetables should be promoted.
- Upscaling of the production and supply of sapling and other planting materials of fruit crops throughout the country through public-private partnership mode should be accelerated.
- IARI-should focus research also on urban farming and roof top gardening. It would be appropriate to rope in house wives in this endeavor.
- Horticulture is a major driver of national economy, food and ecological security, eradication of mal-nutrition and poverty. Therefore, barren and marginal lands should be brought under cultivation of fruit crops to achieve SDG2, and also for ushering inclusive growth. Promotion of urban horticulture will greatly enhance nutritional and environmental security. Need-based tropicalization of certain non-tropical species should be promoted to expand area under desired fruits, such as apple.

School of Natural Resource Management

- Plant–microbial interaction and Plant-Soil interaction for enhancing plant resistance to pests, nutrient mining and carbon dynamics in the soil should be regularly studied for newly developed varieties.

- PUSA decomposer is an excellent product for in situ crop residue management. Efforts may also be made to target it through municipal corporations for effective treatment of different wastes including domestic, flower waste, etc. Also, it is recommended to have accelerated compost making unit in every village and modalities need to be worked out for its implementation and wide adoption.
- Soil health should be looked in the prism of eco-systems services and in its entirety (soil fertility, water use, soil microbial biomass production, carbon content, tillage, crop production, climate change, greenhouse gas emission), not in isolation.
- Location specific components of IFS model should be taken up in a particular region. Efforts should be made to improve upon existing IFS models and farmers should be involved in the development of suitable farming systems. Collaboration with local animal husbandry department and other line departments will help in spread of IFS among farmers.
- School of NRM and Plant Protection together, should develop a frame work for forecasting of insect- pest and disease incidence in crops along with weather based agro-advisory to help farmers minimize crop losses.
- Crop based calendar (sowing window) based on the availability of moisture content after latest precipitation should be made available to the farmers for better crop establishment.
- Collaborative work with private sector, industry is very much required to develop smart Agro machinery fitted with Sensors, IoT, etc.
- With advancement in knowledge base, precision farming needs to be looked in a different perspective. Sensing, monitoring, use of data analytics, automated precision delivery systems need to be integrated in precision agriculture. Inclusive digitalization in agricultural value chains should be scaled up.
- Pusa Farm Sun Fridge may be popularized at Taluka level with CSR fund from Industries, and flexibility in design be built as per requirement and economic condition of the user
- Irrigation management (surface, sub-surface, micro) may be evaluated in terms of management flexibility in addition to water saving. Fertigation scheduling for precision nutrient uptake and higher water productivity practices may be popularized.
- Policy document on drone is an excellent beginning and technologies to be developed for drone aided precision agriculture, crop estimation, and chemicals spray.
- A comprehensive study on ZBNF, its variant forms, and organic farming including agronomical, microbial, soil health particularly nutrient status, environments, sustainability, productivity, income, yield levels, and other related aspects may be carried out at IARI for scientific validation of ZBNF, Natural and Organic Farming.
- India has the lowest water productivity of rice. More studies on direct-seeded rice should be conducted targeting reduction in wateruse and improvement in crop yields and quality by considering new rice genotypes (early maturing, high yielding, herbicide resistant varieties) and improved agri-machineries
- Develop integrated nutrient management system including microbes. Adopting a One Health approach, importance of soil health andits relation with plant, animal, and human health, as well as with overall carbon economy, needs to be studied as they are interlinked.

School of Crop Protection

- Strengthen taxonomy and targeted exploration of insects, diagnostic kits for pests of quarantine importance, emerging diseases like false smut of rice and biological control through natural enemies in collaboration with ZSI, FRI and NBAIR.
- Basic studies on insect/pathogen x host plant x environment interaction, understanding genetic basis of resistance and identification of markers linked to resistance genes for major insect pests

and pathogens need to be strengthened. Major focus should also be placed on identification and deployment of resistance genes from wild relatives of crops.

- We must develop the technology and deploy transgenic resistance (both deployment of novel traits and RNAi based gene silencing) to control major insect pests and diseases including nematodes and viruses to minimize pesticide application for conservation of the environment.
- Disease prediction models based on artificial intelligence and machine learning should be developed to support drone-based technologies and expert systems for crop pest management in close association with School of NRM and various AICRP projects.
- Rapid action force should be in place to tackle invasive and emerging insect pests and diseases, the recent examples are FAW in Corn and thrips in Chilli.
- IPM research should receive focussed attention, as presently it is not sufficiently addressed
- Sensitive methods for detection of pesticide residues in export commodities should be developed along with quality assurance of pesticide formulations to check spurious pesticides and also for addressing the problem of spurious pesticides. Studies on efficacy of known pesticides should be strengthened at IARI.
- IARI must develop a mechanism to generate resources for discovery of new molecules with a potential for use in crop health management, mining of bioactive secondary metabolites from horticultural waste and weeds growing abundantly in collaboration with the industry be taken up.
- Research on formulation of pesticides should be financially supported by industry. EPN powder formulation related research is highly promising, and should be taken forward for commercialization.

School of Basic Sciences

- The School of Basic Sciences should create a state of art facility for plant hormone estimation, which will help answer fundamental questions in basic sciences.
- QTLs identified in one genetic background need to be validated in different genetic backgrounds for their use in MAS.
- Similar to the technologies developed for pearl millet, rancidity in walnuts/almonds may also be addressed, as they have high commercial value.
- Phenomics and other omics data generated may be used in Data Science for their better application.
- Five potential strategic outputs may be identified and discussed with other schools to develop applications. These may have ecological, Agreed economic, social, and sustainability impacts. Projects/subprojects should be aligned with SDGs.
- Transcriptome and omics experiments should be conducted with genotypes with minimal genetic difference such as NILs, mutants and their parents.
- To enhance the throughput in functional genomics of rice, short duration cv. Kitaake may be used
- Drosophila, Bacterial, Yeast and Arabidopsis Genetics Labs need to be established at IARI for discovery research. Enhanced understanding of bio-processes will help in promoting productive nature-positive agriculture and in realizing More from Less for More.

School of Social Sciences

- Policy guidelines for realising remunerative price for biofortified cultivars depending upon nutrient value and distribution through public distribution system should be brought out to alleviate malnutrition in the Country.
- Science communication to stakeholders should be emphasized. Mechanisms for documentation and communication of research findings to the government and policy makers, farmers and other end-users need to be strengthened. A course may be developed to enhance skills in science communication.
- The research in social science should adopt a proactive approach to justify support for the

research in physical and biological sciences. Social science research should lay emphasis upon prioritization of research areas of the institute and guide towards demand/market driven research.

- Evaluation of government schemes should be taken up to provide evidence-based shortcomings in order to improve implementation and effectiveness/systemwide impact of the schemes. The convergence of government schemes needs to be promoted and recommendation if any should be made to avoid duplication.
- Studies should be taken up on Agriculture-food-environment nexus in relation to the concepts like sustainable food system and virtual water trade and its effect. Research should be strengthened on ecosystem valuation, and should also aim at raising farmers' sensitivity to common resource pool issues like ground water.
- Impact assessment studies on IARI technologies should be regularly taken up, and such analyses should be based on the information provided by the technology generating researchers themselves. The studies should be led by socio-economists and extension staff in close collaboration with the technology generators and the farmers in a participatory mode.
- Studies should be undertaken on employment generation, skill development, entrepreneurship, Start Ups, and efficacy of FPOs; collective action of communities; policy bottlenecks in adoption of technologies; analysis of value chains with emphasis on processing, value addition, quality improvement; testing of social science interventions in fields; extension approaches for rainfed system and developing region specific models in crop insurance should be undertaken.
- Mobile app for Frequently Asked Questions (FAQs) should be developed for some important crops to benefit the farmers. These should act as knowledge-based decision system to support farmers.
- Scientific studies on pros and cons of recent Farm Bills including the science-based policy support for arriving at MSP in different crops (C2+50% of C2 or otherwise), may be undertaken. NITI Aayog should be consulted in undertaking this study as the system is generally not on the same page in calculating MSPs.

General Recommendations

- Need to plug in Internet of Things, artificial intelligence, machine learning, robotics image processing, and data handling in applied and basic research. Several start-ups are trying to leverage technologies such as Internet of Things, drones, digital data, visualization in agriculture but there is disconnect between them and the biological part of the solution. IARI may initiate efforts to mentor and motivate them for development of digital based technology for crop production, storage and marketing. Need to develop sensors for diagnosis of a specific stress among the multiple stresses that can occur in the field conditions. IARI should also collaborate with IITs, IIITs, IISc, IISERs, etc. who have expertise in different component of ML, AI, Robotics and IoT to develop solutions for major issues facing agriculture and food science. Scaling up inclusive digitalization in agricultural value chains will thus become a high priority.
- Value addition, food quality and safety, and secondary agriculture may be given greater emphasis to develop cogent and coordinated projects.
- The Institute should serve as a credible source of validated scientific documentation/information and particularly for dispelling misinformation. For example, information on ZBNF.
- IARI should also serve as clearinghouse for validated opinion and validated data, which will actually help policy framing and inputs for regulatory aspects. For example, on regulation of GE and gene edited crops, IARI should be proactive in guiding the policies on commercialization of GE technologies. Large number of GE technologies developed by public funded Institutions and industries are on the shelves for want of regulatory

approval. Transgenic technology should also be harnessed for ensuring food security of India. For example, clearance of products like Bt brinjal, HT Cotton, Barnase/Barstar mustard etc., may be expedited to increase both production and productivity of crops.

- Public private partnerships need to be promoted in technology development in the model of Stanford or MIT or Tel Aviv University.
- Adopting a multi-stakeholder, interdisciplinary, and integrated approach, team work should be promoted and the credit sharing mechanism should be established to enhance team work. Every team member should know his /her role and responsibility in the team and should be assessed accordingly, thus institutionalising differentiated accountability.
- Partnership with ICAR Institutes, CSIR, private sector. Technology providers (Researchers), beneficiaries (farmers and consumers) and developers (manufacturers) need to work together. Currently private sector is also doing significant work on technology development and hence a closer collaboration is required to synergise Science Social Responsibility with Corporate Social Responsibility.
- Promotion of entrepreneurship and Public-public partnership (IARI-SAU partnership) is required to address the entire value chain and linking farmers with markets by using a platform approach keeping in view needs of the small farmers and poor consumers. In this context, efficacy of consortia approach may be assessed.
- Management may make effort to raise the average research productivity of the Institute. Particularly targeting the middle group of performers for enhancing their productivity.
- Actual fund allocation from the ICAR to research needs to be increased. It is important to mobilize resources through externally aided projects. In addition to increasing direct spending on research the impact of it in terms of technologies actually disseminated is of key importance. To track this, the financial statements may include a carve-out of revenues actually accrued through technology licensing and technical collaboration with Industry.
- Action taken report on RAC recommendations should have clear short-term, mid-term and long-term actions. Prioritization, monitoring, impact assessment, learning, on course correction need to be a regular, serious exercise to be done systematically through PME mechanism. Institutionalization of PME and mid-course corrections and prioritization are mandatory to ensure efficient utilization of resources and desired outputs and outcomes.
- Science communication must be enhanced, and policy papers and briefs for many technologies need to be developed in consultation with social scientists wherever needed and possible.
- Impact of IARI developed technologies need to be assessed and proper documentation of the research output is required.
- Generate a reliable and creditable data Bank for making knowledge-based decisions in precision agriculture and conservation agriculture. Further, it will be useful in providing correct/credible information to public. For example, the status of India with reference to Human Development Index, and progress towards Sustainable Development Goals are often controversial.
- By 2050, India's population will swell to about 1.8 billion people, and to meet their requirements, the production must increase by at least 70%. Strategies have to be developed to attain this goal. Whether wide adoption of ZBNF will be able to meet the demand? Generate scientific evidence for Zero Budget Natural Farming and its capacity/potential to meet the productivity required for the growing population by conducting suitably designed long term experiments before it is advocated as component of cropping system.
- IARI should establish an Endowment for generation and utilization of funds for its activities. It may also explore soft loan from NABARD/World

Bank/Asian Bank for specific programs.

- IARI may include Alumni and noted Industry people as adjunct faculty.
- Sincere and strong efforts should be made to make IARI as a global university by transforming it into a MERU under NEP 2020.
- Committee expressed great satisfaction on excellent academic, administrative and financial progress of the institute.

V. Resource Generation (April, 2021-January-2022)

1) Consultancy & other services

Consultancy services: nil

Contract research: ₹ 8156172/-

Contract service: ₹ 268600/-

Training: ₹ 143500/-

Total (A): ₹ 8568272/-

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed: ₹ 63806273/-

(b) Commercialization: ₹ 4483343.36/-

(c) Prototype manufacturing: ₹ 8886476/-

Total (B): ₹ 77176092.36

3) Post Graduate School receipt

Training Programme

(a) Foreigners & Indians: Nil

M.Sc./Ph.D. Programme

(b) Institutional economic fee from foreign scholars under Work Plan: Nil

(c) Receipt from Registrar (A) Account No. 5432 (9029.201.4314) all fees except institutional economic fee: ₹ **40,77,000**

(d) Receipt deposited in Director's Account No. C-49 (9029.305.17) for theses evaluation, PDC & Misc. (does not include refund of IARI scholarship by students): ₹ **21,29,506**

Total (C): ₹ 62,06,506

Grand Total (A+B+C): ₹ 8568272 + ₹ 77176092.36 + ₹ 62,06,506 = ₹ 9,19,50,870.36

VI. All India Coordinated Research Projects in Operation during the year January 1, 2021 to December 31, 2021

Project Headquarters

1. All India Coordinated Project on Plant Parasitic Nematodes with integrated Approach for their control
2. All India Network Project on Pesticide Residues
3. All India Coordinated Research Project on Honey Bees and Pollinators

VII. Foreign visitors during January 1 to December 31, 2021

S.No.	List of foreign visitors and details of Visit	Date of Visit
1.	The delegation from Eritrea H.E. Mr. Osman Saleh Mohammed, Foreign Minister of Eritrea visited at IARI, New Delhi	09.04.2021
2.	The delegation from Israel H.E. Amb. Naor Gilon, Ambassador of Israel to India visited at ICAR-Indian Agricultural Research Institute (IARI),New Delhi	18.11.2021

Israel delegation with IARI team

Delegation from Eritrea

Appendix 1

PROJECTS SANCTIONED

❖ **Externally Funded Projects in Operation during the Period (01.01.2021-31.12.2021)**

Name of Funding Agency	Number of Projects
Within India 1. Department of Biotechnology (DBT) 2. Department of Science & Technology (DST) 3. National Committee Plasticulture Application in Horticulture (NCPAH) 4. Council of Scientific and Industrial Research (CSIR) 5. Department of Agriculture and Cooperation (DAC) 6. Indian Meteorological Department (IMD) 7. Board of Research in Nuclear Sciences(BRNS) 8. Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA) 9. Space Application Centre (SAC) 10. Defence Research and Development Organization (DRDO) 11. Ministry of Human Resource and Development (MHRD) 12. National Bank for Agriculture and Rural Development (NABARD) 13. NITI AAYOG 14. Ministry of Environmental, Forest and Climate Change (MoEF&CC) 15. UP Council of Agricultural Research (UPCAR) 16. Bhabha Atomic Research Centre (BARC) 17. Rashtriya Krishi Vikas Yojna (RKVY) 18. Ministry of Food Processing Industries (MoFPI) 19. NTPC 20. Ministry of Steel 21. Central Pulp & Paper Research Institute (CPPRI) 22. Department of Scientific & Industrial Research (DSIR) 23. Indian Council of Agricultural Research (ICAR)	211
Outside India 1. Bill & Melinda Gates Foundation & UK Department of International Development (DFID) 2. Bill & Melinda Gates Foundation 3. International Fertilizer Development Centre (IFDC), USA 4. United Kingdom Research & Innovation (UKRI) 5. International Rice Research Institute 6. ICARDA South Asia & China Regional Program 7. HarvestPlus-International Food Policy Research Institute, USA 8. Centre for Agriculture and Bioscience International (CABI), United Kingdom 9. ICARDA South Asia & China Regional Program 10. US-National Academies of Sciences 11. Beutsche Gesellchaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany & CIMMYT	17
Total	**228**

❖ **Number of On-going projects at IARI as on 31.12.2021 (School-wise information)**

Sl. No.	Name of School	No. of Projects
1	School of Crop Improvement	59
2	School of Plant Protection	47
3	School of Basic Science	20
4	School of Natural Resource Management	59
5	School of Social Science	13

6	School of Horticultural Sciences	28
7	ZTM & BPD Unit	1
9	FOSU	1
	Total	**228**

List of All India Coordinated Research Projects

Sl. No.	Name of the project	Division
Project Head Quarters		
1	All India Coordinated Project on Plant Parasitic Nematodes with integrated Approach for their control.	Division of Nematology
2	All India Network Project on Pesticide Residues	Division of Agricultural Chemicals
3	All India Coordinated Research Project on Honey Bees and Pollinators	Division of Entomology
National Centres functioning at IARI under AICRP		
4	All India Network project on Soil Biodiversity - Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)	Division of Microbiology
5	All India Coordinated Project on Long Term Fertilizer Experiments	Division of Soil Science & Agricultural Chemistry
6	All India Coordinated Research Project on Soil Test Crop Response Correlations	Division of Soil Science & Agricultural Chemistry
7	All India Coordinated Research Project on Floriculture	Division of Floriculture & Landscaping
8	All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries	Division of Environmental Sciences
9	All India Coordinated Research Project on Soybean	Division of Genetics
10	All India Coordinated Research Project on Fruits	Division of Fruits & Hort. Technology
11	All India Coordinated Research Project on N.S.P.(Crops)	Division of Seed Science & Technology and IARI RS, Karnal
12	All India Coordinated Research Project on Mustard	Division of Genetics
13	All India Coordinated Research Project on Wheat	Division of Genetics
14	All India Coordinated Research Project on Rice	Division of Genetics
15	All India Coordinated Research Project on Pulses	Division of Genetics
16	All India Coordinated Research Project on Vegetable	Division of Vegetable Science.
17	AINP on Whitegrubs and other Soil Arthropods (AINPWOSA)	Division of Entomology
18	All India Coordinated Wheat & Barley Improvement Project (AICW&BIP)	K.V.K. Shikohpur, Gurgaon
19	Front Line Demonstration on Pearl Millet – AICRP Pearl Millet under National Food Security Mission (NFSM)	K.V.K. Shikohpur, Gurgaon
20	All India Coordinated Research Project on Vegetable Crops	IARI RS, Katrain
21	Adhoc Cooperating Center of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Indian Institute of Soil Science, Bhopal	Division of Soil Science & Agricultural Chemistry

22	All India Coordinated Research Project on Ergonomics & Safety in Agriculture (ESA)	Division of Agril. Engineering
23	All India Coordinated Research Project on Pearl Millet	Division of Agronomy
24	All India Coordinated Research Project on Rapeseed-Mustard	Division of Agronomy
25	All India Network Research Program on Onion & Garlic (AINRPOG)	Division of Vegetable Science
26	Engineering interventions for enhanced nutritional security of pearl millet during milling and storage under AICRP on Pearl Millet	Division of Agricultural Engineering

List of Sanctioned Contract Research Project in 2021

S.No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End
1.	Dr. Rajiv Kumar Singh, Division of Agronomy	Evaluation of fortified NP (7-21-0) liquid and fortified calcium oxide suspension (CaZBo) on growth and productivity of tomato, and cole crops	FMC India Private Limited	17-06-21	16-06-2022
2.	Dr. Swati Saha, Scientist SS, Regional Station, Pune	Evaluation of seaplant extracts and its effect on viral disease management in vegetables (Cucumber and Okra)	Sea6Energy Pvt Ltd, Bangalore	29-07-2021	28-07-2022
3.	Dr. M. Sivasamy, Principal Scientist & Head, Regional Station-Wellington	Development and Evalution of high yielding and nutrient rich Oats variety for Value Addition	M/S. Marico India Pvt. Ltd.	10-09-2021	10-09-2024
4.	Dr. M.C. Meena, Senior Scientist , Division SS&AC	Effect of Seaweed extract based growth promoter on crop productivity and soil health	IFFCO	21.09.2021	20.09.2023
5.	Dr. R.S. Bana, Senior Scientist, Division of Agronomy	Foliar fertilization using new fertilizer formulations and bio stimulant for enhancing nutrient-use efficiency and crop productivity	Yara Fertilizer India Pvt Ltd	18.09.2021	17.09.2023
6.	Dr. Rajiv Kumar Singh, Division of Agronomy	Evaluation of Amifol-K, Folur-S and Maxflow-Mg on growth and productivity of okra, Tomato and cucumber crops	Tradecrop Rovensa India pvt ltd.	18.08.2021	17.08.2022

List of Sanctioned Consultancy Project in 2021

S.No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End
1.	Dr. S.S. Sindhu, Head, Division of Floriculture and Landscaping	Audit of tree plantation survival of Horticulture, East Delhi Municipal Corporation	East Delhi Municipal Corporation	30.09.2021	90 Man days
2.	Dr. S.S. Sindhu, Head, Division of Floriculture and Landscaping	Audit of tree plantation survival of Horticulture, South Delhi Municipal Corporation	South Delhi Municipal Corporation	26.11.2021	50 Mandays

List of Sanctioned Contract Service Projects in 2021

Sl.No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End
1.	Mr. Santosh Watpade, Scientist, IARI Regional Station, Shimla	Efficacy of new agrochemicals on apple (Malus X domestica)	Syngenta India Ltd	15.04.2021	14.04.2023
2.	Mr. Santosh Watpade, Scientist, IARI Regional Station, Shimla	Evaluation of bio-efficacy of SYN 547407 10% w/v DC against Mites in Apple	Syngenta India Ltd	21.08.2021	20.08.2023

Number of on-going contract research/consultancy/contract service projects at IARI as on December 31, 2021

Sl.No.	Name of School	No. of project (s)
1.	School of Crop Improvement	03
2.	School of Plant Protection	01
3.	School of Basic Sciences	-
4.	School of Natural Resource Management	10
5.	School of Social Sciences	-
6.	School of Horticultural Sciences	04
	Total	**18**

Appendix 2
Members of Board of Management of IARI
(As on 31.12.2021)

Chairman

Dr. A.K. Singh
Director, ICAR-IARI, New Delhi

Members

Dr. Rashmi Aggarwal
Dean & Joint Director (Education) (Acting), ICAR-IARI, New Delhi

Dr. Prakash Shastri
Professor (Plant Pathology)
College of Agriculture, Rajmata Vijiyaraje Scindia Krishi Vishwavidyalaya (RVSKVV)
Khandwa, M.P.

Shri Akhilesh Kumar
Shyama Bhavan, Mathiya Zirat
Motihari, East Champaran (Bihar)

Dr. Rajendra Prasad S.
Vice-Chancellor
University of Agricultural Sciences, Bengaluru (Karnataka)

Dr. S.K. Malhotra
Agriculture Commissioner
Deptt. of Agril. and Cooperation
Ministry of Agriculture & Farmers Welfare, Krishi Bhawan, New Delhi

Prof. Pratap Bhanu Singh Bhadoria,
Agri. & Food Engg., IIT Kharagpur
West Bengal

Dr. V.P. Singh, Padamshree,
Ex-principal Scientist, Division of Genetics

Shri Ramkumar Saharawat
Garhi, Sakhawatpur, Tehsil Budhana, District- Muzaffanagar

Dr. T.V.R.S. Sharma
Former Emeritus Scientist & Principal Scientist,
Central Island Agricultural Research Institute, Garacharma, Port Blair

Dr. V.K. Singh
Joint Director (Extension) and Head, Agronomy
IARI, New Delhi

Dr. Rajbir Yadav
Head, Division of Genetics
IARI, New Delhi

Dr. Alka Singh
Head, Division of Agricultural Economics
IARI, New Delhi

Dr. K. Annapurna
Head, Division of Microbiology
IARI, New Delhi

Dr. Pramila Krishanan
Head, Division of Agricultural Physics
IARI, New Delhi

Dr. Anupama Singh
Head, Division of Agricultural Chemicals,
IARI, New Delhi

Dr. Sheilly Praveen
Head, Division of Biochemistry
IARI, New Delhi

Dr. S.S. Sindhu
Head, Division of Floriculture & Landscaping
IARI, New Delhi

Smt. Sanjeevan Prakash
Comptroller, ICAR-IARI
Jharkhand

Shri Madhu Vyas
Secretary-cum-Commissioner (Development)
Govt. of NCT of Delhi

Member - Secretary

Sh. Pushpendra Kumar
Joint Director (Adm.), IARI

Appendix 3
Members of Research Advisory Committee of IARI
(As on 31.12.2021)

Chairman
Dr. R.B. Singh
Former President NAAS and
Member National Commission on
Farmers, New Delhi

Members
Prof. (Dr.) Nazeer Ahmad
Director,
ICAR-CITH & former VC,
SKAUST (K), Srinagar

Dr. H.C. Sharma
Ex-Vice Chancellor
YSPUHF, Solan

Dr. Praveen Rao
Vice Chancellor
PJTSAU, Hyderabad

Dr. Mruthyunjaya
Former Director
ICAR-NIAP, New Delhi

Dr. K.K. Narayanan
Founder Director, Sthayika Seed
Pvt. Ltd. &
Director & CEO of Agrigenome
Labs Pvt. Ltd. Benguluru

Dr. S.P.S. Khanuja
Former-Director
CSIR-CIMAP, Lucknow

Dr. Sanjay Kumar
Director
CSIR-Institute of Himalayan
Bioresource Technology,
Palampur, H.P.

Dr Navtej Singh Bains
Director Research,
PAU, Ludhiana

Dr. A.K. Singh
Director,
ICAR-IARI, New Delhi

DDG (CS), ICAR Krishi Bhawan
As per the nomination on the
Management Committee under
Rule 66(a) (5)

Member – Secretary
Dr. C. Viswanathan
Head and Principal Scientist
Division of Plant Physiology
ICAR-IARI, New Delhi

Appendix 4

Members of Academic Council of IARI

(As on 31.12.2021)

Chairperson
Dr. A.K. Singh
Director

Vice-Chairperson
Dr. Rashmi Aggarwal
Dean & Jt. Director (Edn.)
(Additional charge)

Members
Dr. Ashok Kumar
Director, NBPGR
(Additional Charge)

Dr. Ajit Kumar Shasany
Director, NIPB

Dr. Rajender Parsad
Director, IASRI

Dr. B.N. Srinivasamurthy
Director, IIHR, Bengaluru
(Additional charge)

Dr. C.R. Mehta
Director, CIAE, Bhopal

Dr. A.K.Singh
Joint Director (Res.) (Additional charge)

Dr. B.S. Tomar
Joint Director (Extn.)
(Additional charge)

Dr. A.K. Sikka
Former DDG (NRM), ICAR
IWMI Representative-India &
Principal Researcher
International Water Management Institute, New Delhi

Dr. P. Das
Former DDG (Agril. Extn.)
ICAR, New Delhi

Dr. B.D. Singh
Professor Emeritus
BHU, Varanasi

Dr. C. Devakumar
Former ADG
ICAR, New Delhi

Dr. Man Singh
Project Director, WTC
(Additional Charge)

Dr. K.M. Manjaiah
Associate Dean
(Additional charge)

Dr. (Ms.) Neera Singh
Professor, Agricultural Chemicals

Dr. (Ms.) Alka Singh
Professor, Agricultural Economics

Dr. D.K. Singh
Professor, Agricultural Engineering

Dr. R.N. Padaria
Professor, Agricultural Extension

Dr. T.K. Das
Professor, Agronomy

Dr. Anil Dahuja
Professor, Biochemistry

Dr. Anil Rai
Professor, Bioinformatics

Dr. Sudeep Marwaha
Professor, Computer Application

Dr. (Ms.) Debjani Dey
Professor, Entomology

Dr. Soora Naresh Kumar
Professor, Environmental Sciences

Dr. K.P. Singh
Professor, Floriculture and Landscaping

Dr. O.P. Awasthi
Professor, Fruits and Horticultural Technology

Dr. Vinod
Professor, Genetics

Dr. (Ms.) Radha Prasanna
Professor, Microbiology

Dr. P. Krishnan
Professor, Agricultural Physics

Dr. Cini Varghese
Professor, Agricultural Statistics

Dr. Alka Arora
Professor, Computer Application

Dr. Manish Srivastav
Professor, Fruit Science

Dr. Debasis Pattanayak
Professor, Molecular Biology and Biotechnology

Dr. M.R. Khan
Professor, Nematology

Dr. Veena Gupta
Professor, Plant Genetic Resources

Dr. V.K. Baranwal
Professor, Plant Pathology

Dr. Madan Pal Singh
Professor, Plant Physiology

Dr. Ram Asrey
Professor, Post Harvest Management

Dr. Monika Atul Joshi
Professor, Seed Science & Technology

Dr. S.P. Datta
Professor, Soil Science & Agricultural Chemistry

Dr. R.K. Yadav
Professor, Vegetable Science

Dr. Man Singh
Professor, Water Science & Technology

Dr. Anil Sirohi
Master of Halls of Residences

Shri V.R. Srinivasan
Comptroller

Dr. A. Nagaraja
Elected Faculty
Principal Scientist, Fruit Science

Dr. (Ms.) Renu Pandey
Principal Scientist, Plant Physiology

Shri Deep Chand
Incharge, IARI Library

Mr. Shohaib Chauhan
President, PGSSU

Mr. Sujay B.K.
Students' Representative to the Academic Council

Member Secretary
Shri Pushpendra Kumar
Registrar

Appendix 5

Members of Extension Council of IARI

(As on 31.12.2021)

Chairperson

Dr. A.K. Singh, Director, IARI, New Delhi

Members

Dr. Rashmi Aggarwal, Dean, IARI, New Delhi-12

Dr. Rajbir Yadav, Head, Genetics & School Coordinator, Crop Improvement

Dr. Indra Mani, Head Agril. Engg. and School Coordinator, Natural Resource Management

Dr. C. Vishwanathan, Head, Plant Physiology, and School Coordinator, Basic Sciences

Dr. S.S. Sindhu, Head, Floriculture, School Coordinator, Horticultural Sciences

Five Scientists representative of IARI

Dr. Sunil Pabbi, Head, Microbiology, IARI

Dr. S.K. Singh, Head, Fruits and Horticultural Technology, IARI

Dr. B.S. Tomar, Head, Veg. Sci., , IARI

Dr. Gyanendra Singh, I/C. Seed Production Unit, IARI

Dr. J.P.S. Dabas, I/c CATAT, IARI
One Project Coordinator/Project Director

Dr. Man Singh
Project Director, WTC, IARI

Dr. V.K. Pandita, Head, IARI Regional Station, Karnal

One Representative of Deptt. of Agriculture, MoA & FW

Dr. S.K. Malhotra, Agril. Commissioner, MoA & FW

Sh. A.P. Saini
Govt. Officer, Govt. of NCT of Delhi

Sh Dalbir Singh
One Extension Scientist representative of Livestock Development and Animal Health Cover

Dr. Mahesh Chander, Head (Extension), ICAR-IVRI, Izzatnagar, Bareilly

Director (Farm Information Unit) Directorate of Extension, KrishiVistar Sadan, Behind Agro. Division, IARI Campus New Delhi

Dy. Director General (AE), ICAR)

Jt. Director (Extension), IARI, New Delhi

Jt. Director (Research), IARI, New Delhi

Jt. Director (Admn.), IARI, New Delhi

Member-Secretary

Dr. R.N. Padaria, Head, Ag. Extension, IARI, New Delhi

Dr. Neil Devasahayam, World Vision India (V.O. Representative) 16, Pant Marg, New Delhi 110001 neil_devasahayam@wvi.org

Mr. Rajesh Aggarwal, Managing Director, (Agro Industry Representative) Insectiside India Limited, 401-402, Lusa Tower, Azadpur Commercial Complex Delhi-33) 9810089093 (email: rajesh@insecticidesindia.com)

Sh. Arvind Jha (DD Representative)/Marcel Tirkey
The Additional Director General DD Kisan CPC, 175, Asian Games Village Complex
Siri Fort, New Delhi

Sh. Shiv Nandan Lal (The Additional Director General Representative)
All India Radio, Akashwani Bhawan
New Delhi

Sh. V.R. Srinivisan, Comptroller, IARI, New Delhi

Farmers:

Shri. Pritam Singh, Panipat (HR)

Shri Sukhjeet Singh, Sangrur , Punjab

Appendix 6

Members of Institute Research Council (IRC)

(As on 31.12.2021)

Chairperson
Director, IARI

Co-chairperson
Joint Director (Research), IARI

Members
Deputy Director General (Crop Sciences), ICAR
All Project Directors/Project Coordinators of IARI
All Heads of Divisions / Regional Stations of IARI
All Principal Investigators of IARI

Member Secretary
In-charge, PME Cell, IARI

Appendix 7

Members of Institute Joint Staff Council (IJSC)

(As on 31.12.2021)

Chairman
Dr. A.K. Singh
Director, IARI, New Delhi

Members (Official side)
Joint Director (Extension), IARI, New Delhi

Joint Director (Research)

Head, IARI, Regional Station, Karnal

Head, Regional station, Shimla

Comptroller, IARI, New Delhi

Secretary (Official side)
Joint Director (Adm.), IARI, New Delhi

Members of the Staff Side (Elected)

Sh. Raj Kumar
UDC, Directorate, Secretary (Staff side), IARI, New Delhi

Sh. Ganesh Rai
T-3, Division of Entomology

Sh. Atiq Ahmed
T-5, Agricultural Physics

Sh. Veer Pal Singh
T-5, CPCT

Sh. Bhavesh Kumar
T-2, ME Unit, Directorate

Smt. Sonia Rawat
Assistant, Directorate

Sh. Pankaj
UDC, Directorate

Sh. Satyendra Kumar
AAO, Directorate

Sh. Bijender Singh
SSS, CATAT

Sh. Raj Pal
SSS, Directorate

Sh. Shashi Kant Kamat
SSS, Seed Production Unit

Sh. Umesh Thakur
SSS, Audit, Directorate

Appendix 8

Members of Grievance Committee of IARI

(As on 31.12.2021)

Chairperson
Dr. B.S. Tomar
Joint Director (Extn.) (Acting)

Members (Official Side)
Dr. Raj Singh
Head, Agronomy (Acting)

Sh. Ravinder Singh,
Chief Admin. Officer., Directorate

Sh. Harshit Aggarwal,
Sr. Admn. Officer, Directorate

Members of the Staff Side (Elected)
Dr. A. Nagaraja,
Principal Scientist, Division of Fruit & Horti. Technology

Sh. Dharampal,
STA, Division of Seed Science and Technology

Ms. Shivani Bidhuri,
Assistant, Directorate

Sh. B.N. Rai,
SSS, FHT

Member-Secretary
Smt. Vinita,
AAO, IMC

Appendix 9

Personnel

(As on 31.12.2020)

Directorate

Director
Dr. A. K. Singh

Joint Director (Research) (Add. Charge)
Dr. A.K. Singh

Dean & Joint Director (Education) (Add. Charge)
Dr. Rashmi Aggarwal

Joint Director (Extension) (Add. Charge)
Dr. B.S. Tomar

Joint Director (Adm.) & Registrar
Mr. Pushpendra Kumar

Principal Scientist (PME)
Dr. Pramod Kumar

Incharge, Publication Unit
Dr. G.P. Rao

Comptroller
Mr. V.R. Srinivasan

Chief Administrative Officers
Mr. Sanjeev Kumar Sinha

Agricultural Chemicals
Head (Acting)
Dr. Anupama Singh

Professor

Dr. (Ms.) Neera Singh

Network Project Coordinator
Dr. K.K.Sharma

Agricultural Economics
Head (Acting)

Dr. Alka Singh

Professor
Dr. Alka Singh

Agricultural Engineering
Head (Acting)
Dr. Indra Mani

Professor
Dr. D.K. Singh

Agricultural Extension
Head (Acting)

Dr. R.N. Padaria

Professor
Dr. R.N. Padaria

Agricultural Physics
Head (Acting)
Dr. P. Krishnan

Professor
Dr. P. Krishnan

Agronomy

Head (Acting)
Dr. Raj Singh

Professor
Dr. T.K. Das

Biochemistry

Head (Acting)
Dr. Aruna Tyagi

Professor
Dr. Anil Dahuja

Entomology

Head (Acting)
Dr. Debjani Dey

Professor
Dr. Debjani Dey

Floriculture and Land-scaping

Head (Acting)
Dr. S.S. Sindhu

Professor
Dr. K.P. Singh

Fruits and Horticultural Technology

Head (Acting)
Dr. S.K. Singh

Professor
Dr. Manish Srivastav

Genetics

Head (Acting)
Dr. Rajbir Yadav

Professor
Dr. Vinod

Microbiology & CCUBGA

Head (Acting)
Dr. Sunil Pabbi

Professor
Dr. Radha Prasanna

Nematology

Head (Acting)
Dr. Uma Rao

Professor
Dr. M.R. Khan

Project Coordinator Honey Bee (Acting)
Dr. Balraj Singh

Plant Pathology

Head (Acting)
Dr. Rashmi Aggarwal

Professor
Dr. V.K. Baranwal

Plant Physiology

Head (Acting)
Dr. C. Viswanathan

Professor
Dr. Madan Pal

Food Science & Post Harvest Technology

Head (Acting)
Dr. Vidya Ram Sagar

Professor
Dr. Ram Asrey

Seed Science and Technology

Head (Acting)
Dr. S.K. Chakraborty

Professor
Dr. S.K. Chakraborty

Soil Science and Agricultural Chemistry

Head (Acting)
Dr. R.N. Pandey

Professor
Dr. S.P. Datta

Vegetable Science

Head (Acting)
Dr. B.S. Tomar

Professor
Dr. Ramesh Kumar Yadav

Centre for Environment Science and Climate Resilient Agriculture (CESCRA)*

Head (Acting)
Dr. Bhupinder Singh

Professor
Dr. Naresh Kumar S.

Water Technology Centre

Project Director (Incharge)
Dr. Man Singh

Professor
Dr. Man Singh

Centre for Agricultural Technology Assessment and Transfer

Incharge
Dr. J.P.S. Dabaas

Centre for Protected Cultivation Technology

Incharge
Dr. Indra Mani

Agricultural Knowledge Management Unit (AKMU)

Incharge
Dr. Amrender Kumar

Agricultural Technology Information Centre (ATIC)

Incharge
Dr. N.V. Kumbhare

Farm Operation Service Unit

Incharge
Dr. Manoj Khanna

National Phytotron Facility

Incharge
Dr. Akshay Talukdar

Seed Production Unit

Incharge
Dr. Gyanendra Singh

Zonal Technology Management & Business Planning and Development (ZTM & BPD) Unit

Incharge
Dr. Neeru Bhooshan

IARI Library

Incharge (Library Services)
Dr. Madan Pal

IARI Regional Station, Shimla

Head (Acting)
Dr. K.K. Pramanick

IARI Regional Station, Indore

Head (Acting)
Dr. K.C. Sharma

IARI Regional Station, Kalimpong

Incharge
Dr. Dwijendra Barman

IARI Regional Station, Karnal

Head
Dr. V.K. Pandita

IARI Regional Station, Katrain

Head (Acting)
Dr. Chandar Prakash

IARI Regional Station, Pune

Head
Dr. G.K. Mahapatro

IARI Regional Station, Pusa

Incharge
Dr. K.K. Singh

IARI Regional Station, Wellington (The Nilgiris)

Head (Acting)
Dr. M. Sivaswamy

IARI Rice Breeding & Genetics Research Centre, Aduthurai

Incharge
Dr. M. Nagarajan

IARI Centre for Improvement of Pulses in South, Dharwad

Incharge
Dr. B.S. Patil

IARI Krishi Vigyan Kendra, Shikohpur, Gurgaon

Incharge
Dr. Anamika Sharma

*Formerly Division of Environmental Sciences and including Nuclear Research Laboratory.

Mandate

- Basic, strategic and anticipatory research in field and horticultural crops for enhanced productivity and quality.
- Research in frontier areas to develop resource use efficient integrated crop management technologies for sustainable agricultural production system.
- Serve as centre for academic excellence in the areas of post-graduate and human resources development in agricultural science.
- Provide national leadership in agricultural research, education, extension and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards.

ICAR-Indian Agricultural Research Institute
Pusa, New Delhi-110012
Tel.: 011-25843375, 25842367, Fax: 011-25846420
E-mail: director@iari.res.in Website: www.iari.res.in