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2015-16

ICAR–Indian Agricultural Research Institute
New Delhi-110 012

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(Deemed University)
New Delhi - 110 012

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PREFACE

Agricultural production must increase by 60% by 2050 with dwindling cultivable land and resources under the vagaries of global climate change, while enhancing farmers' income and environmental sustainability. To address these challenges, IARI has made focused research and developed several technologies for crop production & protection in the background of improved natural resource management strategies to mitigate/adapt to the changing climate challenges. While addressing the core issue of "more crop per drop" and degraded soil - water resources, the institute took lead in developing several fresh/waste water management and resource reuse/ recycling protocols, standardized a number of micro- irrigation & protected cultivation technologies and water conserving bio- engineering measures, besides commercializing hydrogel formulations and developing precision farming & decision support systems for effective forewarning and contingent planning of extreme weather conditions, degraded soil water resources, pests and crop conditions during growing seasons. To manage degraded soils and improve fertilizer use efficiency, IARI has also developed an improved Pusa STFR meter for suggesting crop and soil based fertilizer recommendations and supporting Soil Health Card Scheme of the government. Besides this, the institute laid special focus on developing several new farm machinery, resource conservation technologies, climate smart and GHG emission mitigation strategies, and beneficial microbes for sustainable natural resource and crop management.

All these efforts integrated with genomic- aided precision breeding programs resulted in accelerated development of a number of varieties & hybrids with improved yield, quality and adaptability in the field and horticultural crops. The visionary research programme on speciality breeding for conservation agriculture (CA) resulted in the release of a bread wheat variety HDCSW 18, specifically suitable to CA, which is expected to enhance the wheat yield and environmental benefits to the larger areas of CA in the country. A Fe - and Zn-micronutrient rich bread wheat variety HS 562 and a semi-dwarf *durum* wheat variety HD 4728 were also released for different regions of the country. A short duration *Basmati* rice variety Pusa Basmati 1609, with inbuilt blast resistance, was released to minimize resource use and enhance yield in the *Basmati* growing regions. A dual purpose pearl millet variety Pusa Composite 701 and an extra-large seeded *Kabuli* chickpea variety Pusa 3022 and soybean variety, Pusa 12 (DS12-13) were also released. In mustard, a double zero (erucic acid <2% and glucosinolates <30ppm) variety Pusa Double Zero Mustard 31 with an average seed yield of 2.38 t/ha was released for the first time. Twelve varieties/hybrids of vegetables viz., bitter gourd (Pusa Rasdar and Pusa Purvi), summer squash (Pusa Pasand), Cherry tomato (Pusa Cherry Tomato 1), early cauliflower (Pusa Kartiki), snowball cauliflower (Pusa Snowball Hybrid 1), β-carotene rich cauliflower (Pusa Kesari VitA 1), muskmelon (Pusa Sarda and Pusa Mudhurima) long melon (Pusa Utkarsh), round melon (Pusa Raunak) and parthenocarpic cucumber (Pusa Seedless Cucumber 6) were also developed. In fruit crops, two mango hybrids (H 1-5 and H 12-5), three grapes hybrids (R_1P_9, ER-R_1P_{19} and ER-R_2P_{36}) with special quality were developed. In ornamental crops, two varieties in gladiolus (Pusa Srijana and Pusa Unnati) and a marigold variety (Pusa Bahar) were released for commercial cultivation. Two promising varieties of Chrysanthemum (Chrysanthemum Little Orange and Chrysanthemum Pink) were also developed. The Institute has also made commendable progress in development of several molecular diagnostic protocols for early diagnosis and management of many fungal and viral diseases.

The so developed natural resource management and crop production/protection technologies were widely disseminated vide a National Agricultural Fair *"Krishi Unnati Mela-2016"* organized during March 19-21, 2016, that was inaugurated by Hon'ble Prime Minister of India, Shri Narendra Modi. About 500 public and private exhibitors from across the country participated and over 1 lakh visitors gained benefit from the Fair. For speedy dissemination of technologies from lab to land, IARI also adopted several villages under *Mera Gaon Mera Gaurav* programme. In addition, the Institute met the needs of the farmers through Agricultural Technology Information Centre (ATIC), *Kisan Call Centre* (1800-180-1551) and *mKrishi*.

The institute is also mandated to impart quality agricultural education in the country. The 54th Convocation of the Post Graduate School of Institute was held on February 5, 2016 with the Hon'ble President of India, Shri Pranab Mukherjee as the chief guest. Many scientists and students received prestigious awards and recognitions, and brought laurels to the Institute. The Institute's achievements during this year are expected to contribute significantly to improve environmental sustainability, profitability and livelihood food security of the Nation.

I express my appreciation to the entire annual report editorial and publishing team for bringing out this report in time.

June 29, 2016
New Delhi

(Ravinder Kaur)
Director (Acting)

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.

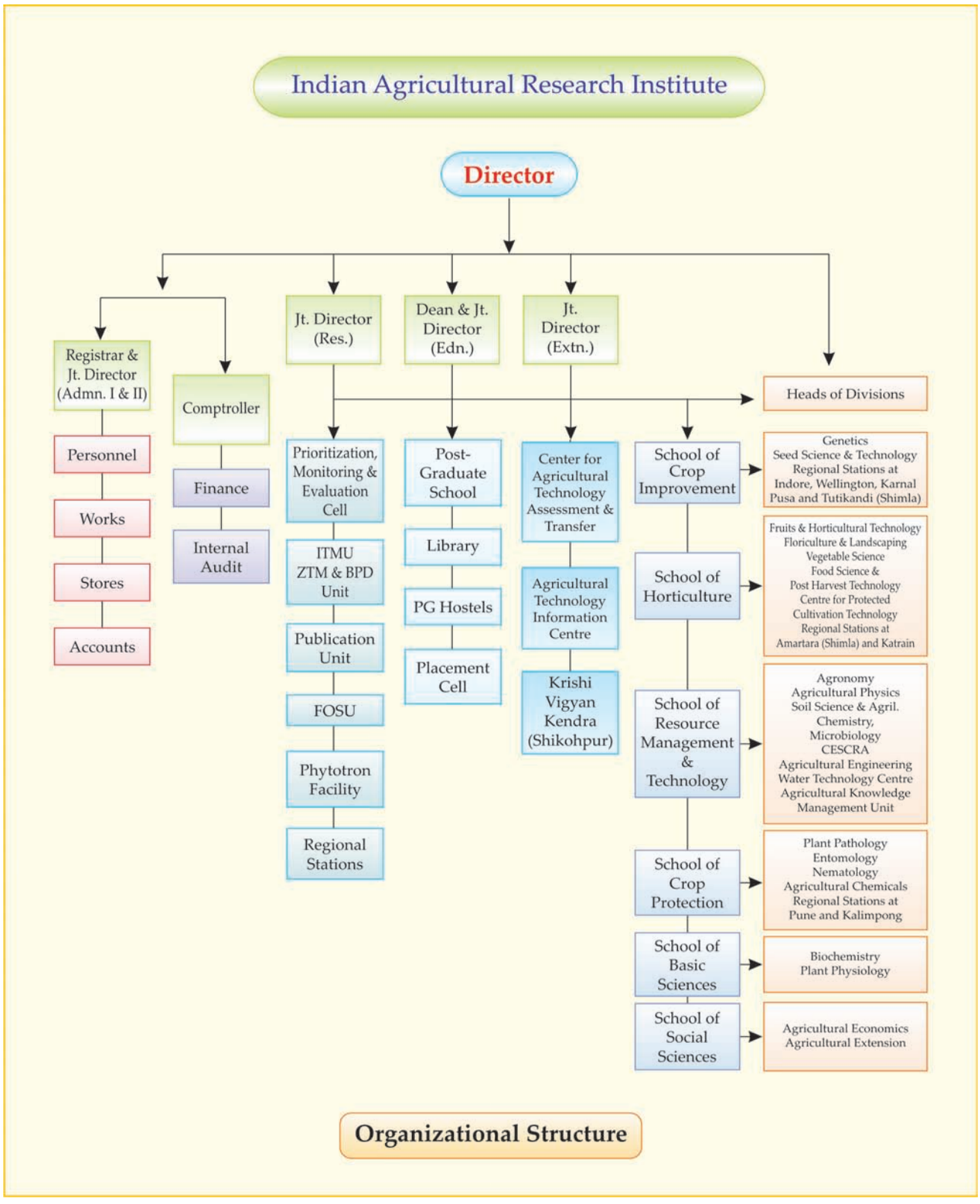
The growth of India's agriculture during the past more than 100 years, is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout 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 28.08° N and 77.12° E, the height above mean sea level being 228.61m. The climate is sub-temperate and semi-arid. The mean maximum daily temperature during the hot weather (May-October) ranges from 32.2 °C to 40 °C and the mean minimum temperature from 12.2 °C to 27.5 °C. June to September are rainy months during which about 500 mm of rainfall is received. Winter sets in from mid-November and is delightful. The mean maximum temperature during winter (November-March) ranges from 20.1 °C to 29.1 °C and the mean minimum temperature from 5.6 °C to 12.7 °C. During winter, a small amount of rainfall (about 63 mm) 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 20 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3016 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹40093.65 lakh (Plan & Non-Plan) for the year 2015-16.



Organizational Structure

EXECUTIVE SUMMARY

The Indian Agricultural Research Institute (IARI) employed cutting-edge science and technologies to develop several crop varieties with improved yield, quality and adaptability, resource management technologies, and pest and disease management methods, farm machineries, protected cultivation methods and food processing techniques for enhancing the input use efficiency, farm profit and environmental sustainability. One of the most significant and most visible achievement of the institute was the adoption of IARI wheat and rice in over 80% of the area in Punjab, Haryana, Uttarakhand, and Western Uttar Pradesh in about 9 million hectares during the 2015-16 seasons. This spoke of the faith the farmers of the region reposed in Pusa technologies. In addition to the regular extension activities on empowering farmers with new agricultural technologies, the Institute has implemented *Mera Gaon Mera Gaurav* programme on a large scale. The National Agricultural Fair "*Krishi Unnati Mela – 2016"* was inaugurated by Hon'ble Prime Minister of India, Shri Narendra Modi on March 19, 2016. Hon'ble President of India, Shri Pranab Mukherjee graced the 54th Convocation of the Institute as the Chief Guest. The salient achievements of IARI in research, extension and education during 2015-16 are summarized below:

The School of Crop Improvement has developed improved varieties of wheat, rice, pearl millet, chickpea, mustard and soybean with higher yield, better nutritional quality and resistance to biotic and abiotic stresses during the year. Wheat variety HD 2967 ruled with an estimated 10.5 million hectares area making large inroads into eastern plains of Uttar Pradesh, Bihar to become the no.1 variety of the country. A novel breeding programme initiated few years back with a vision to breed varieties that are specifically adapted to conservation agriculture (CA) yielded success with the release of a bread wheat variety HDCSW 18 specifically suitable to CA for first time in the world. HDCSW 18, with an average grain yield of 6.28t/ha, was released by State Variety Release Committee (SVRC) for irrigated early sown conditions of National Capital Region (NCR) of Delhi. Wheat variety HD 3117 was also released by SVRC for irrigated late sown conditions of NCR of Delhi with an average grain yield of 4.7t/ha. It is also resistant to both brown and yellow rusts and tolerant to Karnal bunt. A high yielding wheat variety HS 562 with good *chapatti* and bread making qualities, and rich in Fe (38.4ppm) and zinc (34.5ppm) was identified for release under timely sown rainfed and irrigated conditions of Northern Hills Zone. A semi-dwarf *durum* wheat variety HD 4728 with an average yield of 5.42 t/ha and genetic potential of about 6.5 t/ha was identified for release under timely sown irrigated conditions in Central Zone.

Maintaining its leadership role in *Basmati* rice varieties, the Institute has released Pusa Basmati 1609, a MAS derived blast resistant Basmati rice variety with *Piz5* and *Pi54* genes for blast resistance, and with seed to seed maturity of only 120 days and average yield of 4.6 t/ha for commercial cultivation in the *Basmati* growing regions of the Uttar Pradesh, NCR of Delhi, Uttarakhand and Punjab. This variety has resistance to neck blast, and moderate resistance to leaf blast. A large field trial experimentation confirmed double productivity of the Pusa dwarf version of tall rice variety Kala

Namak. Towards hybrid wheat development, about 270 new hybrid combinations were made using five superior CMS lines and >70 restores. Double haploid production in wheat *via* crossing of F_1 wheat plants with *Imperata cylindrica* followed by embryo rescue and colchicine treatment was standardized, and DH plants were developed. Marker assisted recurrent selection (MARS) for combining QTLs for drought and heat tolerance led to the development of several superior genotypes in wheat. Marker aided introgression of known QTLs for drought and heat tolerance into elite cultivars viz., HD 2967, DBW 17, HD 2733 and GW 322 was initiated. QTL mapping for grain nutritional quality in wheat led to the mapping of 11 QTLs for grain micronutrient content including five QTLs viz., QGZn.iari-2A, QGZn.iari-4A, QGZn.iari-5A, QGZn.iari-7A and QGZn.iari-7B for grain Zn concentration with 3.2-14.4% phenotypic contribution. To effectively solve a major emerging problem of bakanae resistance, a rapid protocol for screening bakanae resistance in rice has been developed and a major QTL, *qBK1.2* with phenotypic variation of 24.07 % and two minor QTLs, namely, *qBK1.1*and *qBK1.3* on chromosome 1 were mapped. Maize research made considerable progress in molecular characterization of endosperm modifier loci in QPM inbreds and development of mapping populations for endosperm modifiers. In pearl millet, phenotypic and molecular characterization of large number of germplasm lines led to the identification of lines with desirable starch content and high grain Fe and Zn content. In mustard, molecular markers linked were used for introgression of low glucosinolate and white rust resistance traits. For development of double low mustard genotypes, two backcross populations were generated i.e., PM30/PDZ1// PM30 and PM24/ PDZ1//PM24. These populations are being analyzed for low glucosinolate trait linked markers. In pulses, basic research was focused on genetic structure and diversity analysis of chickpea, pigeonpea and lentil. In vegetable crops, black rot resistance genes were introgressed from alien *Brassicas* to cauliflower, and several markers linked to important diseases of vegetables were identified. A dual purpose pearl millet variety Pusa Composite 701 was identified for release in 'A zone' comprising regions of Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh, Madhya Pradesh and Delhi. It produced an average grain yield of 2.3t/ha with high degree of resistance to downy mildew and blast diseases. An extra-large seeded *Kabuli* chickpea variety Pusa 3022 with an average yield of 1.8t/ha was released for cultivation in the states of Punjab, Haryana, western Uttar Pradesh, northern Rajasthan, Jammu & Kashmir, Delhi, Himachal Pradesh and Uttarakhand. In mustard, the first double zero (erucic acid <2% and glucosinolates <30ppm) variety Pusa Double Zero Mustard 31 with an average seed yield of 2.38 t/ha was released for timely sown irrigated conditions of NCR of Delhi and adjoining areas in the states of Haryana, Rajasthan and UP. This yellow seeded variety has 40.56% seed oil content and matures in 144 days. In soybean, Pusa 12 (DS12-13) with mean yield of 2.29t/ha was released for cultivation in North Plains Zone. It is resistant to yellow mosaic virus, soybean mosaic virus (YMV), *Rhizoctonia* aerial blight and bacterial pustule.

The School of Horticulture has made significant achievements in developing several varieties and hybrids with high yield and nutritive quality in important vegetable, fruit and ornamental crops. In vegetables, two varieties of bitter gourd (Pusa Rasdar and Pusa Purvi), one variety each in summer squash (Pusa Pasand), Cherry tomato (Pusa Cherry Tomato 1), and early cauliflower (Pusa Kartiki), and a snowball cauliflower hybrid Pusa Snowball Hybrid 1 were released by Delhi State Sub Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops. In addition, ICAR-IARI Variety Identification

Committee identified six varieties in different vegetables, viz., Pusa Kesari VitA-1 (β-carotene rich) of cauliflower, Pusa Sarda and Pusa Mudhirma in musk melon, Pusa Utkarsh in long melon, Pusa Raunak in round melon and Pusa Seedless Cucumber 6, a parthenocarpic variety of cucumber. In snowball cauliflower hybrids, KTH-42-5 (62.27 t/ha), KTH-111(57.72 t/ha) and KTH-127(57.63 t/ha) were found to be promising for yield and quality traits. Promising lines with high β-carotene content ranging from 10 to 15 ppm were identified in early and mid-early genetic backgrounds. Two cabbage hybrids KTCBH 705 (56.58 t/ha) and KTCBH-905 (50.07 t/ha) which outperformed the check Pusa Cabbage Hybrid 1 (41.54 t/ha) under Delhi condition were developed.

The gynoecious line PVGy-201 in bitter gourd was commercialized through ZTM& BPD Unit of the Institute. New bitter gourd hybrids Pusa Rasdar × Sel 2, PDM × S 59 (PH-3) and PVGy201 × S-59 (DBGH 159) were found promising and produced fruit yield of 27.4 t/ha, 24.50 and 26.10 t/ha, respectively, and one hybrid DBGH 542 performed best both in field and protected conditions. The gynoecious hybrids of cucumber DGCH 18 and DGCH 15 yielded 29.4, and 27.0 t/ha which were 31.8 and 21.1 per cent higher, respectively, than the check Pant Sankar Khira 1 (22.3. t/ha). The brinjal hybrids DBHL-211 (long purple, 53.1 t/ha), round fruited hybrid trial DBHR 91 (65.4 t/ha, purple round), DBHR-112 (59.1 t/ha, purple round), DBHR 190 (61.4 t/ha, purple round) were found superior over check Pusa Hybrid 6 (48.5 t/ha). One selection of tomato, Sel 60 with large and round fruits (around 100g), was found suitable for growing under low cost polyhouse conditions. Three advanced breeding lines of okra DOV 66, DOV 92 and DOV 8 with resistance to YVMV disease and a yield potential of 18.0, 17.7 and 17.6 t/ha, respectively, were identified.

In fruit crops, concerted efforts were made to develop new varieties, hybrids and root stocks. Promising mango hybrids H 1-5 for highest pulp content (74.13%) and H 12-5 for red pigmentation on the fruits were developed. In grape, three hybrids, namely, R_1P1_9, ER-R_1P_{19}, ER-R_2P_{36} with TSS ranging from 20-24°Brix and early maturity, were developed. In papaya, P 9-5, a gynodioecious genotype was identified which showed the earliest flowering (76 days after planting) and fruit ripening (125 days after fruit set) with orange–yellow flesh of fruit, semi dwarf stature and medium size fruits. The molecular marker (SCAR C09/20) could validate hermaphrodite plants of gynodioecious genotypes and SCAR W11 marker could differentiate hermaphrodite plants. Under rootstock breeding in mango, the highest yield efficiency was found in Pusa Surya on Kurakkan rootstock, Mallika on Olour rootstock and Dashehari on Kurakkan rootstock. In citrus rootstocks, lemon cv. Kagzi Kalan was found the best on *Karna khatta* rootstock with the highest fruit weight (50.73 g), while juice recovery was maximum (50.63%) on RLC-4 rootstock. The intrinsic water use efficiency of kinnow was higher on *Troyer citrange*, Rangpur lime and rough lemon rootstocks.

In ornamental crops, two varieties of gladiolus Pusa Srijana and Pusa Unnati suitable for cut flowers, bouquet preparation, garden display and floral arrangement were developed. Two promising selections of Chrysanthemum were identified. In marigold, Pusa Bahar was identified by IARI variety identification committee for release. It produces 50-60 flowers per plant with compact, flattened, attractive and large size (8-9 cm) yellow coloured flowers.

The Institute also made commendable contribution to the identification, improvement and characterization of several genetic stocks possessing unique economically important traits

in different crops, microbes and insects. In wheat, a large number of lines were screened for various biotic and abiotic stresses including physiological trait based phenotyping for drought and high temperature tolerance. In rice, genotypes such as Athadapunnu, C101A51, Chandana, IR 58025B, Panchami, PAU 201, Pusa 1342 and Varun Dhan were found to be highly resistant to bakanae disease caused by *Fusarium fujikuroi*. A total of 225 rice germplasm accessions were analyzed for iron and zinc concentration in brown rice and polished rice through energy dispersive X-ray fluorescence spectroscopy. Eighty five *O. rufipogon* accessions were assessed for the presence of the restorer/ maintainer allele based on candidate gene based markers for two gene governing fertility restoration in wide abortive (WA) cytoplasm, namely, *Rf3* and *Rf4*.In maize, inbreds tolerant to *Turcicum* leaf blight (TLB) and *Maydis* leaf blight (MLB) were identified. Sweet corn inbreds with *sh2sh2/su1su1* genetic constitution has been developed. Similarly, waxy inbreds with *wx1wx1* genetic constitution have also been developed. A new set of inbreds were screened for their response to drought and waterlogging at different critical growth stages under drought and waterlogged stress conditions. Promising germplasm/genotype/inbreds with *crtRB1*, *lcyE* (for provitamin A), *opaque2*, *opaque16* (for QPM), *VTE4* (for vitamin E), *sh2, su1, sh2/su1* (for sweet corn), wx1 (for waxy), *lpa1*, *lpa2* (for low phytate) and CMS-system (for male sterility) have been maintained. In pearl millet, 1091 diverse germplasm lines including cytoplasmic male sterile lines, maintainers and restorers are being maintained.

In chickpea, two advanced generation breeding lines, BG 12-119 and BG 14-14 and two varieties KAK 2 (*Kabuli*) and K 850 (*Desi*) were found to be tolerant to dry root rot caused by *Rhizoctonia bataticola.* One hundred and seventy seven land races of chickpea obtained from ICARDA representing fifty seven countries of the West Asia and North Africa (WANA) regions were extensively screened for yield and *Fusarium* wilt. ILC 0 from Latvia has shown resistance to *foc 4* and *foc 5* races of wilt. In pigeon pea 300 germplasm lines received from ICRISAT were evaluated for disease resistance. Male sterile lines of medium duration (along with their maintainers), restorers and 18 wild species were also procured. *Vigna umbellata* was identified as a genetic resource for Al to develop Al tolerant genotypes in *V. mungo* and *V. radiata.* In *Brassica*, 762 germplasm lines belonging to *B. juncea*, *B. carinata*, *B. napus*, *B. rapa*, *B. oleracea*, *B. nigra*, *B. tournifortii*, *B. caudatus*, *R. caudatus*, *R. sativa*, *S. alba*, *Eruca sativa*, *Crambe* spp., *Lapidium* spp., *Camellina* spp. and related wild species have been maintained by selfing and used in crossing programmes. Seventeen new accessions of *Brassica* for earliness, dwarf plant type, long siliqua and high siliquae density were added. In soybean, one hundred and thirty three genotypes were screened and three genotypes, namely, DS 12-5, SL 958 and SL 900 were identified as moderately resistant to CPMMV. Fifty nine accessions of onion and related wild species were collected from different parts of India (Leh, Ladakh and Jammu & Kashmir) and Central Asian countries (Uzbekistan, Kazakhstan, Krygyztan and Tajikistan). At IARI Regional Station, Katrain, 130 germplasm of cabbage received from NBPGR have been characterized. In mango, polyembryonic germplasm viz., Indonesia, Latra, Chandrakaran, Moovandam, Peach and Mylepelian were introduced and grafted on rootstock. New turf grasses viz., St. Augustine variegated, Zoysia grass (*Z. japonica*, *Z. materella*), Crow foot grass and Bermuda grass (variant TNAU) were collected and added to the germplasm.

Under biosystematics and identification services, 3952 fungal cultures representing Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained with an

addition of 98 fungal disease specimens and 48 different fungal cultures at Indian type culture collection (ITCC). In insects, larvae of seven white grub (Coleopteran insect) species viz., *Holotrichia fissa, Lepidiota stigma, Lepidiota albistigma, Phyllognathus dionysius, Anomala polita, Anomala ruficapilla* and *Anomala varivestis* were characterized through 126 line drawings and 126 photographs. In hemiptera, two new species of *Hishimonus* were isolated from Himachal Pradesh and Uttarakhand, India. A new Lepidopteron insect species *Oeonistis altica* from Arunachal Pradesh was reported. In nematodes, a strain of *Heterorhabditis* was isolated from extreme cold desert condition of Leh Ladakh, Jammu and Kashmir, India and named as L22. Digitization of 128 specimens of nematodes belonging to 93 type species has been completed using programmable motorized axioimager microscope.

The School of Natural Resource Management (NRM) of IARI addressed pertinent issues of national importance with a major focus to develop scale neutral, low-cost, climate resilient and practically feasible farm technologies. Standardization and validation of efficient input management technologies, resource conservation technologies, irrigation and moisture management, biofertilizer and residue recycling technology, precision agriculture, soil health and soil quality management practices, food quality and post-harvest management, farm machinery, energy management and budgeting, remote sensing and resource inventorization, genotype × environment compatibility as well as value addition interventions, have been the leading research priorities of NRM School. The effective management of rhizospheric diversity, crop husbandry, farm mechanization and post-harvest management of field crops, vegetables, fruits, flowers and agri-horticultural based productions systems got special attention in the research curriculum. Development of new farm machinery, resource conservation technologies, climate smart and GHGs emission mitigation practices, food biofortification, beneficial microbes/ consortia/biofilms, precision farming and monitoring techniques, etc. by the School of NRM have given new dimensions and strength to the research and technology development of IARI on crop and resource management.

A study to diversify the rice-wheat cropping system carried out for six consecutive years with cotton-wheat (C-W), pigeon pea-wheat (P-W) and maize-wheat (M-W) with suitable conservation agriculture (CA) practices, namely, zero-till (ZT) permanent narrow bed (70 cm), ZT broad bed (140 cm) and ZT flat bed with both seasons crop residue revealed that C-W system was superior. Comparison of different tillage methods and crop residue incorporation showed that zero tillage + 5 t/ha maize residue retention + 75% N + 25% N based on Green Seeker resulted in saving of N to the extent of 19 kg/ha as compared to conventional tillage in wheat. Comparative analysis of Zn and sulphur coated urea with prilled urea in three *Basmati* cultivars viz. Pusa Basmati 1121, Pusa Basmati 1 and Pusa Basmati 6 showed that significant yield improvement can be achieved using zinc coated urea. Carbon input and carbon sequestration efficiency in inceptisol under rice-wheat cropping system indicated that thirty two years of continuous application of FYM, straw and green manure that supplemented 50% of fertilizer N, significantly increased soil carbon and aggregate stability and aggregate protected carbon.

Development, standardization and commercialization of new farm machinery, food processing protocols and beneficial microbes/consortia/ biofilms brought laurels to the Institute. The Pusa Soil Test Fertilizer Recommendation (STFR) Meter was improved with the incorporation of two more nutrient analysis protocols for iron and manganese. Now it can analyze twelve important soil parameters

viz., pH, EC, OC, available nutrients (P, K, S, Zn, B, Fe and Mn), and gypsum and lime requirement. Standardization of irrigation technologies both under field and protected conditions as well as waste water treatment and reclamation technology further encompassed the relevance of NRM research. Software for irrigation scheduling in wheat, maize, soybean and mustard using single and dual crop coefficients estimated from weighing type field lysimeters were developed which will be useful for achieving *more crop per drop*. Agricultural equipments/machineries, namely, tractor operated bund packer, raised bed seed-cum-fertilizer plot drill, gladiolus planter, precision paddy planter for direct-seeding, planter for system of wheat intensification (SWI), solar powered refrigerated storage system and evaporatively cooled storage structure for fruits and vegetables were developed and demonstrated. Several biofertilizers based on BGA, microbial inoculants for enhancing phosphorus nutrition, products for enhancing microbe-mediated nutrient cycling under non-flooded (aerobic) and flooded (anaerobic) conditions in rice-wheat cropping system, microbes for alleviation of water deficit stress in crops were developed.

Standardization and validation of food processing protocols and value addition interventions led to the development of vacuum packaging for enhancing shelf-life of pomegranate arils, shrink wrapping of minimally processed baby-corn, pasteurization treatments on the quality of ready-to-serve watermelon juice, extrusion processing variables on finger millet and pearl millet flours, bittergourd chips, concentric encapsulation of β-carotene and anthocyanin in ω-fatty acids and other products.

The School of crop protection undertook studies on diversity analysis, diagnostics and integrated management of nationally important pests and pathogens. Genetic diversity analysis was accomplished for wheat rust races, *Fusarium* spp., *Tilletia indica, Alternaria brassicae, Colletotrichum* and *Penicillium spp.* New phytoplasma diseases were identified on wheat, ornamental crotons (16Sr I group), *Rosa* species (16Sr I & II groups) and *Celosiaargentea* species (16Sr II-D subgroup). Molecular diagnostic protocols have been developed for fungal (*Puccinia striiformis tritici, Tilletia indica, Fusarium fujikuroi and Magnaporthe oryzae*), bacterial (*Ralstonia solanacearum, Bacillus* spp.) and viral pathogens (*Potato virus X* and begomoviruses species, namely, ToLCNDV, ToLCBV, ToLCPalV, ToLCGV and ToLCJoV infecting tomato) which will help in early diagnosis for better management of these diseases. LAMP based diagnosis protocol has been developed for *Puccinia striiformis tritici* and *Ralstonia solanacearum*. The plant endophytic *Pseudomonas putida* BP25 and *Bacillus megaterium* BP17 were found to release broad spectrum microbial volatile organic compounds (MVOCs) mainly pyraxenes which were effective against pathogens and nematodes. Metabolome analysis of *Trichoderma* species revealed presence of isoharzianic acid (iso-HA), Harziandione (92%), fungitoxic Thazin-1-one (0.7%), 1,5-dihydro-1- 4-methoxyphenyl (0.88%), Phenol, 2,4-Di-tert-butylphenol (42.68%), Phthalic acid (6.07%), etc., with fungistatic activity. Talc based bioformulations of *Pseudomonas fluorescens* (DTPF-3) and *Bacillus amyloliquefaciens (*DSBA-11) were found effective in controlling tomato wilt. Consortia of rhizobacteria, S2BC-1 and TEPF-Sungal and *Trichoderma harzianum*-S17TH with *Chaetomium globosum*-CG-A was found effective for the management of *Fusarium* wilt of tomato.

Transcriptome analysis revealed genes associated with *Lr24* - mediated resistance in wheat. Cross infectivity of *Bipolaris* species on wheat and rice was confirmed. Effect of temperature on toxicity of Bt*cry* toxin against *Earias vitella* showed that extreme temperature enhanced the toxicity of

BGII and cry2Ab2. Double stranded RNA construct for silencing osmoregulatory gene in green peach aphid, *Myzus persicae* was demonstrated by using feeding assays. High-quality transcriptome sequence data of *H. indica* IJs was generated. Management of nematodes based on gene silencing approaches were developed and validated. RNAi technology has been successfully utilized for management of *Meloidogyne incognita* infesting brinjal, as transgenic brinjal expressing *flp*18, *flp*14, *msp*1, *msp*18, *msp*20 and *msp*40 are in various stages of development. Bacterial strains for management of nematode infestation have been identified. Entomopathogenic nematodes like *Heterorhabditis indica* infecting *Galleria mellonella* were found to be effective for biocontrol of white grubs.

Significant progress has been made in agrochemicals design and discovery. Various hydrogel based formulations with better water absorption capacity were developed. Decontamination methods for removing pesticides from water and soil were standardized. Degradation of bifenthrin by microbes sourced from contaminated soil, remediation of pesticide contaminated water using nZVI-clay composites and degradation of atrazine and its metabolites using enrichment culture were standardized. Efficient weed management strategies were developed for management of weeds in maize, wheat, gladiolus, lentil and onion crops.

The focused basic and strategic research of the Institute led to the identification and validation of donors, QTLs and genes for biotic and abiotic stress tolerance and nutritional quality in different field and horticultural crops, and development of state-of-art non-destructive phenotyping methods, GIS and remote sensing methods for crop and resource characterization and management. A low-cost tube based rhizotron for non-destructive root phenotyping was developed. Hyperspectral reflectance based spectral indices, partial least square regression (PLSR) and support vector machine (SVM) methods were developed for assessment of relative water content for drought phenotyping, nitrogen stress monitoring and weed discrimination in different crops. To understand and regulate root system architecture (RSA) which plays key role in nutrient and water acquisition, microarray and real-time RT-PCR expression analysis were carried out, and five root tissue-specific and osmotic stress inducible genes viz., *MYB TF*, *bZIP TF*, *FBOX132*, *PP2C* and *USP* were cloned from drought tolerant rice cv. Nagina 22. Rice transgenic overexpressing the stress hormone abscisic acid (ABA) receptor 6 (ABAR6) with enhanced drought tolerance was further analysed to understand the mechanisms that contribute to stress tolerance. Detailed physiological and scanning electron microscopy analysis of the transgenic rice plants overexpressing ABAR6 gene showed that the transgenic rice plants used about 30% less water due to the efficient ABA-mediated stomatal regulation. By using *de novo* transcriptome sequencing, heat shock transcription factor *HsfA2d* and rubisco activase (RCA) were cloned and characterized from wheat. Immunoblot analysis showed that the RCA antibody is highly specific, and the RCA levels were high in thermotolerant wheat cv. Raj 3765 under heat stress as compared to thermosensitive HD 2329. Analysis of the role of oxygen-sensing genes in waterlogging stress tolerance in waterlogging tolerant and susceptible inbreds of maize revealed that ethylene responsive *ERF VII* genes are important regulators of waterlogging tolerance in maize.

Towards improving nutritional quality of soybean, significant progress has been made to characterize genes involved in the metabolism of nutritionally important compounds such as α-tocopherol and isoflavones, and the antinutrient factor phytic acid. Gene involved in synthesis of α-tocopherol viz., tocopherol methyl transferases

(γ-TMT1, γ-TMT2 and γ-TMT3) and ABC1 like kinase which controls recycling of α-tocopherol were cloned and sequenced from soybean. The isoflavone synthesis pathway gene isoflavone synthase (IFS1), flavanone 3-hydroxylase and chalcone reductase were cloned and plant transformation gene constructs using seed-specific conglycinin promoter from soybean were developed. Agrobacterium-mediated half seed transformation method was standardized and the soybean transformation efficiency was improved to >10%. Gene silencing constructs were developed to silence inositol phosphate kinase genes *GmIPK1* and *GmIPK2* using seed specific *vicilin/ conglycinin* promoters for reducing seed phytate content in soybean.

The multi-stage wheat yield forecasting using statistical models and InfoCrop model revealed that the InfoCrop model performs better than weather based statistical models for forecasting yield at different growth stages of the crop. A web based Decision Support system (DSS) using crop simulation model InfoCrop wheat was developed to identify best sowing date of a specific wheat cultivar. A web enabled Decision Support System (DSS) for near real time crop growth monitoring at district level based on multi-temporal satellite remote sensing data was also developed. Real time monitoring of residue burning using satellite data available from recently established IARI Satellite Ground station could detect burning event and intensity with high level of accuracy, and district-wise total paddy residue burring was estimated for Punjab and Haryana.

The School of Social Sciences and Technology Transfer studies on policy reforms and development of agricultural markets, analyzed the variation in progress of agricultural marketing reforms in different states. In Tamil Nadu, the APMC act has been already implemented, while Bihar, Kerala and Manipur have not adopted APMC act. Evaluation of *e-mandis* in Karnataka to draw lessons from it and to incorporate it in to the National Agricultural Marketing (NAM) initiative of the Govt. of India. Performance of wheat varieties evaluated using primary survey data for the year 2014-15 revealed considerable yield gap between farmers' fields and demonstration plots. Nearly 90 percent of the farmers adopted HD 2967 variety in Punjab and reported a mean yield of 5.5 t/ha. Four structural breaks have been identified in the agricultural GDP for the period. The fishery sector registered the highest growth during phase II. Within the agriculture sector for food grains, the first structural break was identified in 1965 and the second structural break was identified in 2002. For the pulses, the structural break was found in the year 2000. For the oilseed crops, the years 1988 and 1999 were identified as structural break points which indicated the impact of Technology Mission on Oilseeds (TMO) and impact of liberalization.

The IARI Post Office Linkage Extension Model was designed and validated for effective outreach mechanism for frontline extension system. The model expanded in partnership with the *Krishi Vigyan Kendras* (KVKs) in sixty districts of 14 states covering more than 175 branch post offices. Vulnerability analysis of communities in coastal areas of Sunderbans revealed a high degree of livelihood vulnerability (Livelihood Vulnerability Index <0.163) not only due to high exposure to natural calamities, but also due to poor status of financial assets and physical assets among the communities. Community based action and social learning strategy was deployed to promote technologies for climate change adaptation in experimental village Sanghel of Mewat district and Mumtajpur village of Gurgaon district in Haryana. Studies on maximising farm profitability through entrepreneurship development and farmer led innovations (FLI) revealed two types of forward linkages in FLIs. Besides, three types of marketing

channels were identified and it was found that processors received higher share in consumer price than producer in almost all agricultural enterprises. A nutria-smart village model was conceptualized and data were collected from project villages through a structured interview schedule to know the dietary habits. Individual Diet Diversity Score (IDDS) for all the respondents revealed that IDDS of male respondents was 8.0, female 7.6, boys 7.9 and girls 7.6, respectively.

Mera Gaon Mera Gaurav, a sensitization workshop, chaired by Dr. T. Mohapatra, Director, ICAR-IARI, was held at B. P. Pal Auditorium on 6th November, 2015. About 300 scientists of IARI and IASRI were briefed about the goal of the programme and detailed methodology of implementing the programme. The programme was launched on a large scale by adopting more than 500 villages. Eleven varieties of wheat, spinach, pea, lentil and mustard were assessed during *Rabi* 2015-16 through 158 trials in farmers' fields covering an area of 56.10 ha. During *Kharif* 2015, 467 assessment trials were conducted on paddy, maize, sorghum, pearl millet, pigeon pea, cowpea, *mungbean*, bottle gourd, *okra* and musk melon covering an area of 186.18 ha. Under technology integration and transfer to strengthen farming system in partnership mode during *Rabi* 2014-15 a total number of 541 demonstrations were conducted covering an area of 127 ha across 15 locations for 21 varieties of wheat, mustard, lentil, pea, gram, *palak*, carrot, tomato and marigold in collaboration with ICAR institutes and SAUs. During *Kharif* 2015, a total of 284 demonstrations of paddy, *mungbean*, pigeon pea, *palak* and maize covering an area of 73.70 ha were also conducted. In collaboration with Voluntary Organizations, 627 demonstrations were conducted on 17 varieties of paddy, pigeon pea, *moong*, maize, bottle guard, okra, cowpea, and muskmelon covering an area of 170.93 ha at 22 locations.

During *Rabi* 2014-15, 58 and 25 tonnes of seed of wheat cv. HD 3086 and HD 2967, respectively, were produced under participatory seed production at YFAP, Rakhra. At PRDF Gorakhpur, seed of wheat cv. HD 3059 (15t), HD 3043 (10.84t), HD 2733 (5.6 t) and HD 2967 (26.3 t), mustard cv. Pusa Vijay (11.8 t) and pea cv. Pusa Pragati (0.05t) was produced. Special extension programmes and capacity building activities were implemented for rural women to empower them

Agricultural Technology Information Centre (ATIC) is effectively providing products, services, technologies and information services to the different stakeholders through a '*Single Window Delivery System*'. In ATIC, farm advice facility was provided to farmers through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600), Pusa Agricom 1800-11- 8989, exhibitions, farm literatures and letters. A second level of *Kisan Call Centre* (1800-180-1551) has also been established at ATIC to address the problems/queries of farmers of Delhi state. As a novel initiative, drip irrigation system for fruit orchard and nutri-gardens were demonstrated in crop *cafeteria* for the benefit of the visitors. High density fruit trees orchard planted with lemon (Kagzi Kalan), Mango (Amrapali), Guava (Lucknow 49, Allahabad *Safeda* and Lalit), Ber (Banarasi Karaka and Gola) were demonstrated.

The Institute's KVK, Shikohpur, Gurgaon conducted nine On-farm trials (OFTs) on different field/farm based problems including 2 trials on animal based problems. During the period, 250 demonstrations covering an area of 101.80 ha in oilseeds, pulses, cereals and vegetable crops were conducted by the Kendra under different thematic areas. For speedy dissemination of technologies, 1290 extension activities were organized by the Kendra. The IARI Regional Stations Karnal (Haryana), Pusa (Bihar), Indore (MP), Shimla and Katrain (HP), Wellington and Aduthurai (TN)

also significantly contributed to the dissemination of improved IARI varieties and technologies to the farmers through FLDs and other extension interventions like trainings, exhibitions and farmers friendly literatures.

The National Agricultural Fair "*Krishi Unnati Mela - 2016*" was organized at the campus of ICAR-IARI, New Delhi during March 19-21, 2016 jointly in collaboration of DAC&FW, Ministry of Agriculture and Farmers' Welfare and Indian Council of Agricultural Research (ICAR). Hon'ble Prime Minister of India, Shri Narendra Modi inaugurated the *"Krishi Unnati Mela"*. Different ICAR Institutes, State Agricultural Universities, development agencies, leading companies from public and private sector and Voluntary Organizations participated and displayed their technologies and products. Over 1 lakh visitors and 500 public and private exhibitors from across the country participated and gained benefit from the Fair.

The 54th Convocation of the Post Graduate School of IARI was held on February 5, 2016. Hon'ble President of India, Shri Pranab Mukherjee as the Chief Guest delivered the convocation address. At this convocation, a total of 120 M.Sc., 07 M.Tech., and 115 Ph.D. degrees were awarded. Four courses in Agronomy i.e., Principles and Practice of Weed Management, Water Management, Agronomy of Oilseed Crops and Pulses and Agronomy of Commercial Crops were taught in Tele-Education mode by IARI faculty to the students of Afghanistan National Agricultural Sciences and Technology University (ANASTU). The IARI library continued to provide services to the students and the scientific community of IARI and other institutions of the country. The Institute brought out several quality publications in the form of scientific peer reviewed research papers in high impact journals, symposia papers, books/chapters in books, popular articles, technical bulletins, regular and *ad-hoc* publications, both in English and Hindi, to disseminate the information on the Institute's mandated activities.

For protection of intellectual property, the Institute filed four PCT applications, three patents with four renewals of existing patents, along with three responses to First Examination Report and one hearing and one amendment and commercialized 13 innovative technologies from North Zone-1 of ICAR. Several national and international short-term training courses (regular, *adhoc* and individual) and refresher courses were conducted in specialized areas for the scientists of NAREES. In addition, many special training courses, and other capacity building programmes were also organized for the benefit of professionals, farmers and extension workers. New linkages and collaborations with several national and international institutions were initiated. Many scientists, students and faculty of the Institute received several prestigious awards and recognitions, and brought laurels to the Institute.

1. CROP IMPROVEMENT

The primary objective of the crop improvement programme continues to be productivity enhancement coupled with nutritional quality of various field crops. Modern tools of molecular breeding are integrated in the breeding procedures making the targeted improvement precise and efficient. A number of improved varieties with higher yield, better nutritional quality and tolerance to biotic and abiotic stresses suited to different agro-ecological conditions have been developed during the reporting period. Besides, a large number of promising genotypes in several crops are under various stages of evaluation in 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

HDCSW 18. First wheat variety of the country arguably in the world, specifically bred for conservation agriculture (CA) was released by Delhi State Seed Sub-Committee for irrigated early sown conditions for NCR region. It gave an average grain yield of 6.28 t/ha under conservation agriculture and have genetic potential of more than 7 t/ha when cultivated with surface residue of rice and maize of previous season under zero-till situation. It possesses tolerance to high temperature at seedling stage and resistance to brown rust.

HD 3117. A high yielding wheat variety was released by Delhi State Seed Sub-Committee for irrigated late sown conditions for NCR region. The variety produced an average grain yield of 4.7t /ha (tilled conditions) and 4.79 t/ha under conservation agriculture. It showed resistance to brown and yellow rusts and tolerance to Karnal bunt. It has 11.7 percent protein content.

1.1.1.2 Varieties identified

HD 4728. A semi-dwarf (89 cm), high tillering *durum* wheat variety, HD 4728 with an average yield

HDCSW 18

HD 3117

HD 4728

of 5.42 t/ha and genetic potential of more than 6.5 t/ha under timely sown irrigated conditions was identified for release in Central Zone. HD 4728 with lustrous and bold grains (48.3g/1000-kernels), matures in 120 days, and possesses resistance to both stem and leaf rusts. It is at par in quality with the existing checks and had the least yellow berry incidence.

HS 562. A high yielding wheat variety, HS 562 was identified for release under timely sown rainfed and irrigated conditions of Northern Hills Zone. HS 562 produced an average grain yield of 3.6 t/ha under rainfed conditions and 5.27 t/ha under irrigated conditions. It has shown good levels of field resistance to leaf and stripe rusts. The variety has good *chapatti* and bread making qualities and is also rich in micronutrients like Fe (38.4 ppm) and zinc (34.5 ppm).

HS 562

1.1.1.3. Elite lines under All India Coordinated Wheat Improvement Programme

Eighty four genotypes were evaluated in all India coordinated trials under various production conditions across the country during *Rabi* 2015-16. Of these, three bread wheat genotypes HD 3171, HD 3209 and HI 1605, and one *durum* wheat genotype HI 8759 are under final year of testing. HD 3209 is a NIL of HD 2932, developed by marker assisted backcross breeding and carries leaf rust resistance genes *Lr19*/*Sr25* and *Sr26*.

1.1.1.4 Evaluation of wheat genotypes for morphological and quality characteristics

Genetic diversity studies carried out based on 17 morphological and quality characters revealed that genotypes CBW 38, HS 240, QLD 33, HD 2428, K. SONA, HD 2009, HW 384, UP 2425, HD 2643, HW 588, IND 359 and HD 2824 were genetically diverse and gave highest *per se* performance for different attributes. Character association analysis undertaken in 64 wheat genotypes for hectoliter weight and grain hardness revealed that for improving the hectoliter weight of wheat genotypes more emphasis should be given on characters like grain width, grain diameter, flag leaf area, grain weight per spike and days to heading.

Varieties HI 1531, C 306 and HW 2004 were comparable with high yielding Australian wheat genotypes. The root density was very high in upper 10 cm soil depth and gradually declined as the roots moved downward up to 40/50 cm deep. Better growth and deep root penetration of the genotype facilitated greater moisture absorption and contributed to increased grain yield.

1.1.1.5 Agronomic and delayed senescence related parameters in 206 RIL population and identification of genomic regions for these traits

Parents WL 711, C 306 and 206 RILs were sown in the WTC field during 2014-15. The stress was generated by giving differential irrigation regimes; 5 irrigations in water irrigated treatment and 3 stress treatment. During this year effective stress did not develop due to excess rainfall especially in the post anthesis stages. The parent RIL differed considerably in morphological, physiological and yield characters both under irrigated and water stress environments. Agronomic parameters, such as grain yield, biomass, and 1000-grain weight and grain number have been recorded in the RIL population under both water regimes. Delayed senescence related parameters have been recorded in this year also to identify stable genomic regions for the traits. Two major QTLs on 3B and 3 D were identified for SPAD value at 30 days after anthesis under water stress condition. Two minor QTLs on chromosome 4A and 6B were identified for SPAD at 30 days after anthesis under water stress condition. A major QTL on chromosome 3B was identified for percentage reduction of green flag leaf area at 25 days after anthesis explaining 11% of phenotypic variation under water deficit stress condition. A consistent and minor QTL on chromosome 6B was identified for green flag leaf area at 25 days after anthesis under water deficit stress condition.

1.1.2 Barley

1.1.2.1 Elite barley lines under All India Coordinated Barley Improvement Programme

Eight barley genotypes were being tested in Northern Hills Zone under all India coordinated testing for grain yield and dual purpose.

1.1.3 Rice

1.1.3.1 Varieties released and notified

Pusa Basmati 1609. Pusa Basmati 1609 is a MAS derived blast resistant *Basmati* rice variety having genes *Piz5* and *Pi54* with seed to seed maturity of only 120 days and average yield of 4.6 t/ ha. It is semi-dwarf, non-lodging, high yielding and possesses superior grain and cooking quality traits and most importantly it has resistance to neck blast and moderate resistance to leaf blast. It has been released for commercial cultivation in the *Basmati* growing regions of the Uttar Pradesh, National Capital Region of Delhi, Uttarakhand and Punjab.

Pusa Basmati 1609

1.1.3.2 Elite lines in All India Coordinated Rice Improvement Programme

A total of 21 genotypes are at different stages of testing in the AICRIP trials during *Kharif* 2015. It includes 7 near isogenic lines (NILs) which are being tested in AVT2-BT in four different genetic backgrounds, namely, Pusa Basmati 1 with blast resistance gene *Pi9* (IET24570); Pusa Basmati 1121 with bacterial blight resistance genes, *xa13* and *Xa21* (IET 24565, IET 24566); Pusa Basmati 6 with bacterial blight resistance genes, *xa13* and *Xa21* (IET24573), blast resistance genes, *Pi54* and *Piz5* (IET24575, IET24576) and Pusa Sugandh 5 with both bacterial blight resistance genes, *xa13* and *Xa21*, and blast resistance genes, *Pi54* and *Piz5* (IET24577). Besides these, there were four entries in AVT1 including one Basmati genotype (IET24599) in AVT1-BT, 1 entry (IET24359) in AVT-IM, two entries (IET25480, IET25481) in AVT-NIL (Blast). The NILs in AVT-NIL (Blast) includes genotypes in the background of BPT5204 with three genes for blast resistance, namely, *Pi54*, *Pi1* and *Pita* (IET25480, IET25481). There were ten new entries

in Initial varietal trials of AICRP including 4 entries (IET25390, IET25398, IET25401, IET25418) in IVT-BT, 3 entries (IET25490, IET25506, IET25516) in IVT-MS, 2 entries (IET25425, IET25429) in IVT-ASG and 1 entry (IET25574) in IVT-E-TP were tested in the AICRIP trials during *Kharif* 2015.

1.1.3.3 Incorporation of herbicide tolerance trait into rice varieties

An EMS (ethyl methane sulfonic acid) induced mutant line of rice mega variety Nagina 22 tolerant to the herbicide Imazethapyr was identified. The gene *Als* (acetolactate synthase) on chromosome 2 has been found responsible for herbicide tolerance and marker assisted backcross breeding is being employed to incorporate the *Als* gene into the elite rice varieties, namely, Pusa Basmati 1121 and Pusa Basmati 1509.

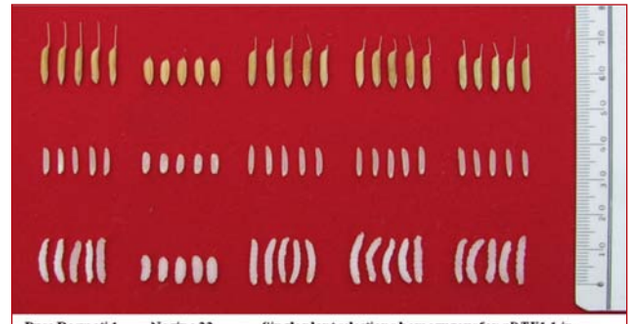
N 22-HTM **Pusa Basmati 1121**

1.1.3.4 Developing multiple biotic stress resistance in *Basmati* rice varieties

Advanced generation backcross derived lines possessing both bacterial blight (*xa13*+*Xa21*) and blast (*Pi2*+*Pi54*) resistance genes in the genetic background of Pusa Basmati 1121 and Pusa Basmati 6 have been generated.

1.1.3.5 Marker assisted incorporation of drought tolerance in rice varieties

Marker assisted backcross breeding adopted to incorporate the QTLs governing drought tolerance such as *qDTY1.1* from N 22 and *qDTY3.1* from



Pusa Basmati 1 (Recipient) **Nagina 22 (Donor)** **Single plant selections homozygous for *qDTY1.1* in BC_3F_2 generation**

IR81896-B-B-142 into the genetic background of Pusa Basmati 1 and Pusa 44, respectively. A total of six BC_3F_3 families homozygous for *qDTY1.1* and 36 families homozygous for *qDTY3.1* in the genetic background of Pusa 44 have been identified.

1.1.4 Maize

1.1.4.1 Material in All India Coordinated Maize Improvement Programme

The following material tested in various AICMIP trials:

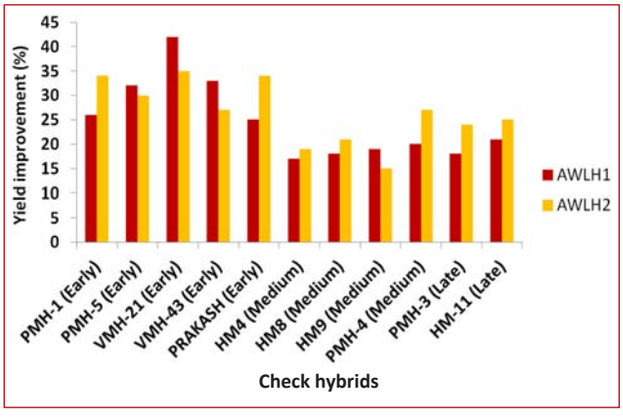
Name of the AICMIP trial	No. of entries	Name of the material	Traits
IVT-early	1	AH 7006	Grain yield
IVT-medium	2	AH7007, AH 7009	Grain yield
IVT- late	1	AH 7000	Grain yield
IVT	1	ASKH-4	Sweet corn
IVT	1	APH-27	Provitamin A
AVT-I	1	AH-9001	Grain yield
AVT-I	1	ASKH-1	Sweet corn + baby corn
AVT II	1	AQH4 (EDV)	QPM
AVT II	1	AQH8 (EDV)	QPM
AVT II	1	AQH9 (EDV)	QPM
AVT II	1	APQH9 (EDV)	Provitamin A + QPM

1.1.4.2 Abiotic stress breeding

In order to identify maize hybrids tolerant to waterlogging stress, a trial was conducted at three locations (IARI, New Delhi, Pantnagar, Uttarakhand and RRS, Pusa, Bihar) under waterlogged conditions.

Waterlogging tolerant maize hybrids, AWLH 1 (left) and AWLH 2 (right)

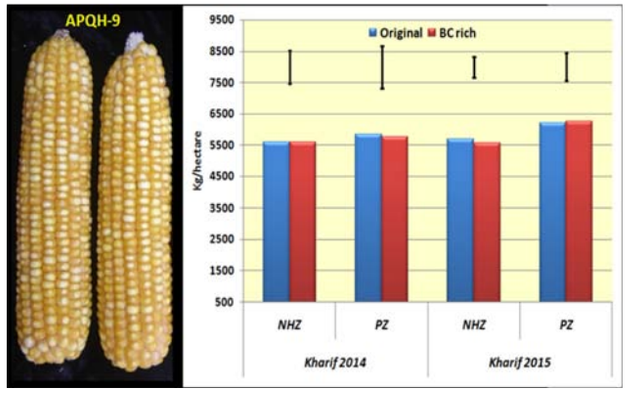
Two experimental hybrids AWLH 1 (CML 425 × MGUD1) and AWLH 2 (CML 425 × HKI 1105) developed at IARI were tested along with released hybrids and checks. The performance of AWLH 1 and AWLH 2 was better than checks and released hybrids across-locations and the yield superiority of these hybrids were 15 to 45% over other hybrids.



Yield advantage of maize experimental hybrids (AWLH 1 and AWLH 2) over released hybrids and checks under waterlogging stress conditions across three locations

1.1.4.3 MAS-derived provitamin A rich hybrid

Marker-assisted selection was employed to introgress favourable allele of β-*carotene hydroxylase* (*crtRB1*) into the parental inbreds of extra early hybrid, Vivek QPM 9. Mean kernel β-carotene in the MAS-derived hybrid (APQH 9) was 17.8 µg/g, while it was 2.1 µg/g in the original hybrid. It also possesses high tryptophan (0.80% in endosperm protein). During *Kharif*

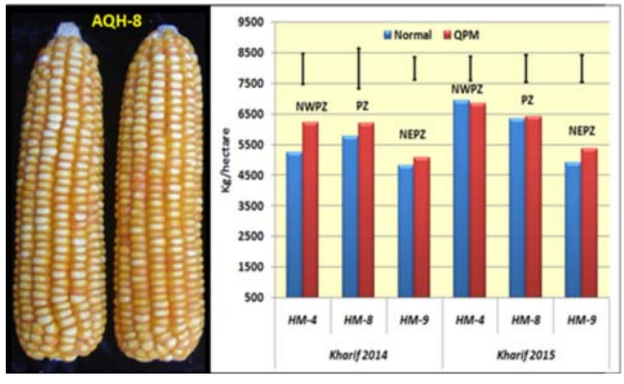


Grain yield of original and improved version of Vivek QPM 9 in AICRP trials

-2014 and -2015, the improved hybrid was evaluated in NHZ and PZ under the AICRP. The grain yield of the improved version was found to be at par with the original hybrid. It is country's first multi-nutrient rich maize hybrid developed through breeding approaches.

1.1.4.4 MAS-derived QPM hybrids

Recessive *opaque2* allele was introgressed into the parental inbreds of HM 4, HM 8 and HM 9. The MAS-derived QPM version of HM 4 (AQH 4: 0.73% tryptophan, 2.7% lysine in protein), HM 8 (AQH 8: 0.92% tryptophan, 3.9% lysine in protein) and HM 9 (AQH 9: 0.79% tryptophan, 3.9% lysine in protein) possess higher essential amino acids compared to original hybrids. The improved versions of these hybrids were evaluated in different zones (NWPZ for HM 4; PZ for HM 8 and NEPZ for HM 9) under

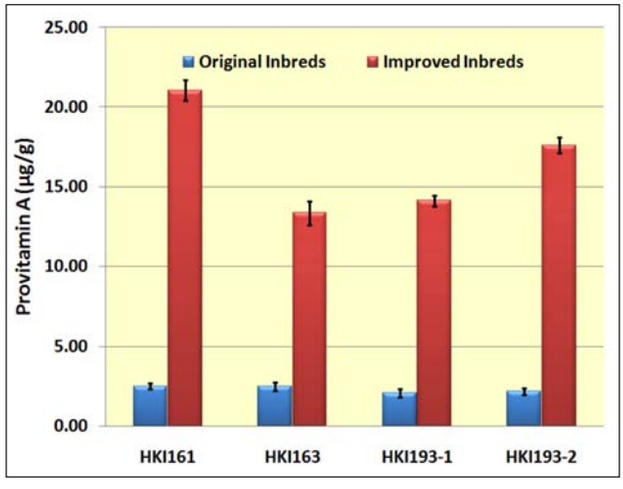


Grain yield of original and QPM version of hybrids in AICRP trials

AICRP during *Kharif* 25014 and 2015. The grain yield of the improved version was found to be at par with the original hybrid.

1.1.4.5 Marker-assisted pyramiding of crtRB1 and lcyE in QPM hybrids

QPM inbreds, HKI 161, HKI 163, HKI 193-1 and HKI 193-2 (parents of QPM hybrid: HQPM 1, HQPM 4, HQPM 5 and HQPM 7) have been targeted for introgression of both *crtRB1* and *lcyE* alleles using marker assisted selection. Segregants of BC_2F_2 generations having *opaque2*, *lcyE* and *crtRB1* in homozygous conditions have been selected. The newly derived introgressed progenies possess high mean provitamin A (~13-21 µg/g) compared to original inbreds (~2.5 µg/g). Plant and cob characteristics of improved inbreds were similar to original inbreds. These newly derived QPM inbreds with high provitamin A will be used in reconstituting the original hybrids.



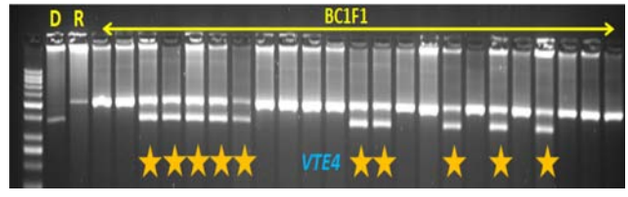
Provitamin A in original and improved inbreds

1.1.4.6 Further enhancement of lysine and tryptophan in QPM

HKI 161, HKI 163, HKI 193-1 and HKI 193-2 (parents of HQPM 1, HQPM 4, HQPM 5 and HQPM 7) were targeted for introgression of *opaque16* allele (from Chinese hybrid donors) using marker-assisted selection. Genotype with *o2o2/o16o16* possesses more lysine and tryptophan than *o2o2* alone. BC_2F_2 generation were genotyped, and 12 segregants with *opaque2* and *opaque16* were selected for generating QPM hybrids with enhanced lysine and tryptophan.

1.1.4.7 Enhancement of vitamin E in QPM hybrids

A diverse set of maize inbreds were screened for presence of favourable allele of *VTE4*. The favourable allele is capable of enhancement of α-tocopherol from 7-10 µg/g to 22-32 µg/g in maize kernel. Of the 453 inbreds screened, only four inbreds with favourable allele of *VTE4* were identified, and one inbred was used as donor in the marker-assisted breeding programme. Provitamin A rich version of QPM inbreds that are parents of four popular hybrids (HQPM 1, HQPM 4, HQPM 5 and HQPM 7) have been targeted for introgression of *VTE4* allele. In BC_1F_1 populations, plants desirable for *VTE4*, *crtRB1* and *opaque2* were selected, and used for generating BC_2F_1 populations.



Segregation of VTE 4 allele in BC_1F_1 population

1.1.4.8 Enrichment of provitamin A and vitamin E in sh2sh2-sweet corn hybrids

SWT 16, SWT 17 and SWT 18, parental inbreds of two promising *sh2sh2*-based sweet corn hybrids (ASKH 1 and ASKH 2) were targeted for enrichment of both provitamin A and vitamin E through introgression of *crtRB1* and *VTE4* alleles, respectively. BC_1F_1 populations were genotyped, and six segregants with favourable alleles of *sh2*, *crtRB1* and *VTE4* were selected, and used to develop BC_2F_1 populations. Provitamin A rich parental inbreds (HKI 161, HKI 163, HKI 193-1 and HKI 193-2) of popular QPM hybrids (HQPM 1, HQPM 4, HQPM 5 and HQPM 7) were also trageted for introgression of *shrunken2* allele. In BC_1F_1 populations, plants

desirable for *crtRB1*, *opaque2* and *shrunken2* were selected for generating BC_2F_1 populations. The MAS-derived inbreds will be used for developing provitamin A rich sweet corn hybrids.

1.2 MILLET

1.2.1 Pearl Millet

1.2.1.1 Variety identified

Pusa composite 701. A high yielding dual purpose pearl millet variety was identified for release in 'A zone' comprising regions of Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh, Madhya Pradesh and Delhi. It produced an average grain yield of 2.31 t/ha with high degree of resistance to downy mildew and blast diseases. This variety was developed through controlled pollination followed by mass selection involving 7 high yielding, early maturing, downy mildew and blast resistant lines.

1.2.1.2 Population development and evaluation

Of three promising pearl millet composite entries submitted for testing in Population Trial in AICPMIP 2015, Pusa composite 709 (MP 570) and Pusa composite 710 (MP 571) ranked first and second among 18 test entries evaluated at 10 locations with an average grain yield of 2697 and 2666 kg/ha which is higher than the best check Pusa Composite 383 (2619 kg/ha).

1.2.1.3 Hybrid development and evaluation

A total of 346 hybrid combinations developed during *Kharif* 2015 and summer 2015 at ICRISAT and 134 hybrids were evaluated in different station trials during *Kharif* 2015.

1.2.1.4 Maintenance breeding of cytoplasmic male sterile lines

A total of 2392 paired crosses were attempted in 55 CMS lines (A/B) belonging to A_1, A_4 and A_5 cytoplasms for maintenance. Seven hundred twenty six bulk crosses were made in 6 promising CMS lines for further utilization in developing hybrids with good grain yield and fodder.

1.2.1.5 Pearl millet genotypes with cream/white coloured grain

Special emphasis on development of white grain material was laid and 1016 lines of white grain colour were developed and evaluated.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Variety released

Pusa 3022. It is an extra-large seeded *Kabuli* chickpea variety which is suitable for cultivation in the states of Punjab, Haryana, western Uttar Pradesh, northern Rajasthan, Jammu & Kashmir, Delhi,

Elite entries in all India coordinated pearl millet improvement trials

Name of trial	Entry name	Pedigree	Zone of testing
IHT (M)	Pusa 1501	ICMA 92777 x PPMI 295	A and B
	Pusa 1502	ICMA 92777 x PPMI 1213	A and B
	Pusa 1503	MS 411A x PPMI 1002	A and B
	Pusa 1504	ICMA 92777 x DPR 7	A and B
Pusa 1504 topped in A zone and was promoted to Advanced Hybrid Trials (M)			
PT (A/B)	Pusa Composite 709		A and B
	Pusa Composite 710		A and B
	Pusa Composite 711		A and B
Pusa Composite 709 and 710 ranked first and second and were promoted to Advance Population Trials in zone A			

Kabuli **chickpea variety Pusa 3022**

Himachal Pradesh and Uttarakhand. The variety Pusa 3022 was released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural crops in October 2015. It was derived from the cross BG 1048 x BG 1082 following pedigree breeding method. Its average grain yield is 1.8 t/ha which is 10.4 % higher than the best check. Its duration is 145-150 days and has 100-seed weight of 36-40 g. It is moderately resistant to *Fusarium* wilt, dry root rot, *Ascochyta* blight and *Botrytis* gray mold.

1.3.1.2 Promising chickpea genotypes in all India coordinated trials

Altogether 18 promising chickpea genotypes were tested in 10 different multi-location trials under AICRP on Chickpea during *Rabi* 2014-15.

1.3.1.3 Selection of breeding material resistant to *Fusarium* wilt disease

F_4 (154 crosses) and F_5 (32 crosses) segregating populations were screened in the *Fusarium* wilt sick plot for selecting resistant populations and plants. Out of 154 F_4 populations tested, 79 resistant and high performing types were advanced to F_5 for further evaluation and selection. In case of F_5, 665 (*desi*) and 170 (*Kabuli*) single plant selections made based on the disease resistance and phenotypic superiority. Out of 70 advance breeding lines evaluated, 18 wilt resistant and high yielding types selected for further testing in multi-location trials under AICRP on chickpea.

1.3.1.4 Developing chickpea cultivars tolerant to herbicide

In *Rabi* 2014-15, 21 herbicide tolerant lines selected at different locations were screened for tolerance to Imezathapyr under sprayed (Imezathapyr) and unsprayed (control) conditions. The dose of Imezathapyr used was 75g/ha and spraying done after 40-50 days of sowing. Visual observation was recorded 10 days after spraying on 1-5 scale (1– tolerant and 5 – susceptible). ICCIL 04021, ICCIL 04004, ICCV 10, ICCIL 04016 and ICCV 96836 were found to be relatively tolerant. The level of tolerance for the herbicide was observed to be low in cultivated chickpea germplasm. The potential of induced mutagenesis for developing herbicide tolerant chickpea is also being studied. Three doses of EMS (0.4%, 0.6% and 0.8%) were used to treat 5 kg seeds of Pusa 372 and grown at the IARI Regional Centre, Dharwad during off-season (July-October, 2015). M_2 seeds harvested were sown at the IARI, New Delhi during *Rabi* 2015-16 and spraying of herbicide Imezathapyr (@ 75g/ha) was done in this M_2 population. The seeds could be harvested from few putative tolerant plants for further screening and selection.

1.3.2 Pigeon pea

Pigeon pea lines with compact erect plant type with early maturity (135 days), bold seed size and 4-5 seeds per pod have been developed. With respect to development of hybrids, three newly developed A lines viz., Pusa 922A, Pusa 2001A and Pusa Dwarf A were developed and grown in isolation along with respective B lines to produce A lines. Ten R lines of short duration maturity group have been developed. Twenty five R lines have been developed from inter-specific cross Pusa 33 x *Cajanus scarabaeoides* for A_2 cytoplasm.

1.3.3 Lentil

High grain iron and zinc lentil line L 4704 registered with NBPGR. The germplasm line possesses high grain Fe (136.91 mg/kg grain) and Zn (71.69 mg/kg grain). The plants are erect and height ranges 40-44 cm, days to 50% flowering ranges from 70-74 with maturity duration of 130-135 days. The 100 - seed weight of L 4704 is 2.5 g. Seed testa colour is brown and pattern of seed testa is dotted in nature along with orange red cotyledon. Number of pods per plant ranges between 160-165 with a single plant yield of 6.0 to 6.5 g.

L 4704

1.4 OILSEED CROPS

1.4.1 *Brassica*

1.4.1.1 Variety released

Pusa Double Zero Mustard 31. It is the first double zero (Erucic acid <2% and glucosinolates <30ppm) Indian mustard variety in the country. It has been released for timely sown irrigated conditions of National Capital Region of Delhi including Delhi and adjoining areas in the states of Haryana, Rajasthan and UP. Its mean seed yield is 2.38 t/ha in multi-location trials. It is a yellow seeded variety with 40.56% oil content and matures in 144 days. Improved oil and seed meal quality (Canola quality) makes this variety beneficial for farmers, traders and consumers.

Pusa Double Zero Mustard 31

1.4.1.2 Elite entries in coordinated trials

Seventeen genotypes were contributed to various AICRP RM trials at national level including early, timely and late sown conditions. Three double low genotypes viz., PDZ 1, PDZ 2 and PDZ 4 and two low erucic acid genotypes viz., LES 49 and LES 50 were in AVT-I.

1.4.1.3 Hybridization and pre-breeding

A total of 256 crosses were attempted for various objectives viz., short duration with bold seed (10), white rust resistance and quality (63), drought tolerance (6), other traits like oil content, shattering, etc. (8), double low quality (38), heat tolerance (6), cold tolerance (4), and for yield improving traits (100). In addition, 22 interspecific crosses were also attempted utilizing *B. napus*, *B. carinata, B. nigra* and *B. rapa*. Off season nursery facility at IARI Regional Station, Wellington was used.

1.4.1.4 Hybrid breeding

CMS development and maintenance. Four CMS lines were evaluated and maintained by full-sib crossing between pollen tested A-line and respective true to type B - line plants. Twenty paired crosses were attempted for maintenance of each of these set of lines (A & B lines). To transfer nuclear genome form 26 genetic backgrounds to different sterility inducing cytoplasms viz., *Moricandia arvensis (mori), Diplotaxis erucoides (eru)* and *Diplotaxis berthautii (ber)*, 73 backcrosses (BC_2-BC_9) were attempted in three pairs each.

Restorer development. Backcrosses (BC_2-BC_3) were attempted to transfer the *Rf* gene, which restores fertility in *mori*, *eru* and *ber* sterile cytoplasms, to 51 nuclear backgrounds. Restorers (in BC_4F_3 and BC_5F_2 generations), which were developed through MABB

for transferring *Rf* gene to 5 genetic backgrounds, were surveyed for *Rf* gene in homozygote condition. Homozygous dominant plants were selfed for their utilization in next season. For development of restorers through pedigree selection, 74 progenies were raised and the plants from fixed progenies were selfed. Eighty three progenies which were developed through limited back crossing followed by pedigree selection were raised for practicing selection.

Hybrid development and evaluation. Nine hybrids along with four checks were raised for evaluation in the station trial. Seed of these nine and eight new hybrids was developed through hand pollination for testing/retesting in the station trial during 2016-17.

Evaluation of elite pure lines. A total of 142 entries bulked during 2014-15 were evaluated in six replicated trials under early, timely, rainfed and late sown conditions. These entries also includes 22 low erucic acid and double low genotypes of which ten genotypes were developed through marker assisted backcross breeding in the background of Pusa Mustard 21 and Pusa Karishma.

1.4.2 Soybean

1.4.2.1 Variety released

Pusa 12 (DS 12-13). Soybean **v**ariety Pusa 12 (DS 12-13) was released for cultivation in North Plains Zone in the 71st meeting of the CVRC. DS12-13 (2.286 t/ha) has shown 32% higher and stable yields over the best check SL 688 (1.726 t/ha) in the three years of trials in the North Plains Zone. This variety is resistant to yellow mosaic virus, soybean mosaic virus (YMV), *Rhizoctonia* aerial blight (RAB) and bacterial pustule (BP). It is tolerant to insect attack. It has bold seeds (100- seed weight is 10.53g), good seed longevity and high oil content (19.6%). DS 12-13 has recorded a mean yield of 2.286 t/ha over 3 years in 13 trials.

Field view of soybean variety, Pusa 12 (DS 12-13)

1.4.2.2 Kunitz trypsin inhibitor (KTI) free soybean lines

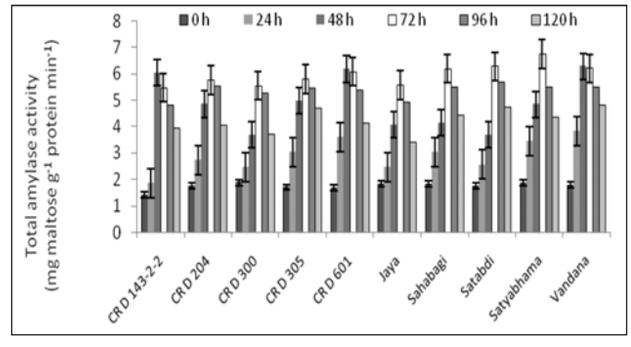
Through marker-assisted backcross breeding (MABB) approach, four Kunitz trypsin inhibitor (KTI) free soybean lines were developed. Seeds have been multiplied for further testing in multi-location field trials.

1.5. SEED SCIENCE AND TECHNOLOGY

1.5.1 Seed Quality Traits

1.5.1.1 Rice

Ten rice varieties were evaluated for seed vigour traits and associated metabolites. Significant variations in seed filling rate i.e., biomass accumulation at 20 days and loss of moisture from seed i.e., seed desiccation at 30 days, after anthesis were recorded. Association between thousand seed mass (test weight) and speed of germination (r=0.60**) was established. Seed test weight was higher in CR Dhan 305 (23.3 g), Satyabhama (22.9 g), Vandana (21.4 g) and Sahabhagi (21.3 g). Total amylase activity during seed germination was higher in Satyabhama, CR Dhan 601, Sahabhagi, Satabdi and Vandana. On the other hand, remobilization of non-structural carbohydrates (NSCs) from stem reserves during seed filling was



Total amylase activity in seeds and developing seedlings in 10 rice varieties (CD at P=0.05 is depicted over the bars, and it was significant only up to 72 hours only)

higher in CR Dhan 601, Satabdi, Satyabhama, CR Dhan 305 and Vandana, ranging between 45 and 55%. Finally, varieties, namely, Satyabhama, Vandana and Sahabhagi were identified with higher seed vigour.

1.5.1.2 Wheat

Two recombinant inbred lines (RILs) i.e., WL711× C 306 and HI1500 x DBW43, developed for drought tolerance, were analysed for seed vigour traits by conducting experiments in the laboratory, phytotron and field conditions. Associations between seed vigour and grain yield, biomass, harvest index, 1000-seed mass and various root and shoot characteristics were established.

1.5.1.3 Seed quality in single zero *B. juncea* genotypes differing in seed coat colour

Seed germination was significantly affected by seed coat color in *B. juncea* genotypes. Significantly low germination was observed in yellow seed coat color genotypes (91.8%) in comparison to black seed coat colour genotypes (93%). Similar trend was observed in Vigour Index I and Vigour Index II indicating that seed with darker seed coat was more vigourous compared to lighter ones. Seed coat colour is influenced by the phenolic compounds like anthocyanin content, melanin and phenol contents. It was observed that yellow-seeded genotype had lower anthocyanin, melanin and phenol contents compared to black-seeded genotypes. Due to presence of above phenolic compounds, the dark coloured genotypes were found to be accompanied with slow water uptake and higher mean germination time (1.66d) compared to yellow seeded genotypes (1.1d). The imbibitional behaviour was significantly associated with seed colour, melanin and phenol contents.

1.5.2 Standardization of Seed Priming

1.5.2.1 Pigeon pea

Varietal differences for water imbibition pattern were observed in four varieties of pigeon pea. It took 30h for pigeon pea seeds to start the radicle protuberance. Soaking of pigeon pea seeds in water for 10h at 25^{0}C resulted in significant improvement of seed germination, vigour index I and vigour index II over untreated control seeds. The germination of variety Pusa 992 was found to be relatively sensitive to higher temperatures than other three varieties viz., Pusa 991, Pusa 2001 and Pusa 2002. Significantly higher germination, vigour index I and vigour index II over control were observed when exposed at 40^{0}C for 6h.

1.5.2.2 Soybean

Varietal differences for water imbibition pattern were observed in four varieties/ advanced lines viz., PS 1347, Pusa 9712, SL 688 and PS 1341 of soybean. Exposure of soybean seeds for 1 h at 40^{0}C resulted in better vigour.

1.5.2.3 Specialty maize

Maize varieties, hybrids, parental lines and genetic pools of different compositional groups were evaluated for physiological seed quality and imbibitional behaviour. Among different groups; sweet corn genotypes were most prone followed by QPM types and waxy and popcorn genotypes were least susceptible to germination under low temperature (15 and 20^{0}C). Among the seed enhancement treatments, hydropriming (17h/25°C) was best for improving seed emergence and early vigour both under field and lab conditions as compared to other treatments (halo-primimg (KNO_3), matrix priming (Vermiculite), bio-priming (*Trichoderma viridae*). Sweet corn lines (double recessive mutants, shrunken, shriveled lines) and QPM genotypes absorbed higher quantity of water and waxy types the least, indicating differential behaviour due to compositional variation. The grain compactness studies revealed that sweet corns (shrivelled texture and sugary nature) and popcorn had the lowest and highest grain toughness, respectively, which had influence on its susceptibility to stored grain pest and storability.

1.5.3 Phenotyping and Genotyping of Soybean Genotypes for Seed Quality

Post harvest management for keeping the quality of seed intact is a major constraint in soybean [*Glycine max* (L.) Merrill], hence phenotyping of 129 soybean genotypes was done for seed quality traits.

A negative correlation was observed between 100-seed weight and seed quality. A positive but weak association was registered between field emergence and seed storability (r=0.38); plant height and seed storability (r=0.52); days to 50% flowering and seed storability (r=0.35). Out of these, 59 genotypes with seed sufficient quantity were stored for eight months under laboratory ambient conditions (25±2^{0}C Av. temperature and 65±5% RH). Based on various physiological parameters, 10 genotypes each from good and poor storer were chosen and used for detailed physical, physiological, biochemical and molecular analysis. Black, smaller seed with grey hilum attributed to better seed quality and vigour. Based on correlation coefficient values, any of these SVI (r=0.98), SV II (r=0.97), and/or EC(r= -0.93)] either individually or in combination may be used as better indices of seed vigour. EC and Malondialdehyde (MDA) contents showed higher values in poor storer than those in good storer genotypes. Significantly higher antioxidant enzymes activity was recorded in good storer genotypes. During the polymorphic studies between good and poor storers, out of 46 SSR markers used, 23 were found to be polymorphic. Genetic similarity coefficients obtained using 23 SSR markers, grouped 20 genotypes into four clusters. SSR marker Satt423 was found to discriminate between good and poor storer distinctly. Based on the detailed physical, physiological and biochemical parameters, three genotypes viz., AMSS 34, G 2651and G 2253 were identified as better storer which may be used in soybean crop improvement programme.

1.6 SEED PRODUCTION OF FIELD CROPS

The Seed Production Unit at IARI, New Delhi and three Regional Stations of IARI viz., Karnal, Indore, and Pusa ,Bihar were involved in the seed production of different varieties of IARI which include nucleus, breeder and truthfully labelled seeds. The details are as follows:

Seed production (t)

Crop Group	Nucleus Seed	Breeder Seed	IARI Seed	Total Seed
Seed Production Unit, IARI, New Delhi				
Cereals	3.76	82.11	271.245	357.115
Pulses	1.188	3.96	4.577	9.725
Oilseeds	-	1.987	10.508	12.495
Regional Station, Karnal				
Cereals	3.688	155.154	338.879	497.721
Pulses	0.077	3.754	0.626	4.457
Forages	0.011	0.50	1.256	1.767
Oilseeds	0.028	4.523	1.241	5.792
Others	-	-	0.540	0.540
Regional Station, Indore				
Cereals	-	221.6	-	221.6
Regional Station, Pusa, Bihar				
Cereals	-	46.375	188.913	235.288
Pulses	-	0.178	2.318	2.496
Oilseeds	-	-	1.384	1.384
Others	-	-	0.505	0.505
Total	8.752	520.141	821.992	1350.885

2. HORTICULTURAL SCIENCE

Nutritional security is the major issue before the country today than ever before. The School of Horticultural Science have made coordinated efforts in comprehensive multi-location based research programmes on improvement of vegetable, fruit and floricultural crops using conventional and biotechnological tools, development of production technology for open and protected environments and effective dissemination of various technological options. Breeding efforts made to enrich vegetables for intrinsic and extrinsic (shape, size, colour, texture) quality traits in order to combat malnutrition and enhance consumer preference. Breeding in perennial fruit crops was planned for achieving better quality and higher productivity. Breeding of ornamental crops with novel characters like plant habit, flower colour, form shape and scent was initiated to enhance ornamental value. Several varieties and hybrids were identified/released either through All India Coordinated Research Projects, Delhi state or Institute's committee during the year. New promising lines/hybrids have also been developed.

2.1 VEGETABLE CROPS

2.1.1 Cole Crops

2.1.1.1 Cauliflower

Variety identified and released. Pusa Kesari Vit A-1 is the first ever indigenously bred biofortified β-carotene (8- 10 ppm) rich cauliflower variety. Its curds are orange coloured, compact and very attractive with semi-self blanching growth habit. It is suitable for September – January growing period. Average marketable curd weight is about 1.250 kg with an approximate marketable yield of 40.0 – 45.0 t/ha.

β-carotene rich cauliflower variety, Pusa Kesari Vit A-1

One cytoplasmic male sterile (CMS) based F_1 hybrid, Pusa Snowball Hybrid 1 was developed by IARI Regional Station, Katrain and released for its commercial cultivation in NCR Delhi. It has snow white compact curd and average marketable curd weight of 1.52 kg.

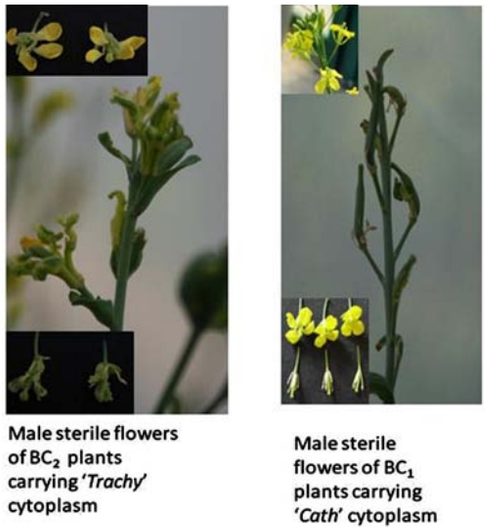
Snowball cauliflower hybrid, Pusa Snowball Hybrid 1

Promising hybrids. In early group, out of 18 self incompatibility (SI) and 102 CMS based hybrids evaluated along with 10 hybrids from private seed companies, 4 SI and 14 CMS hybrids were found promising having optimal marketable yield (~40 t/ha). Of the 12 CMS F_1 hybrids evaluated in mid-early group along with 14 from private seed companies, 8 were promising (50 t/ha). In mid-late group, 27

(23 CMS and 4 SI based) hybrids were evaluated of which 18 CMS and 3 SI were found promising having marketable yield of 50 t/ha.Twenty one test hybrids of snowball cauliflower from IARI-Regional Station, Katrain were evaluated in Delhi condition and best performers were KTH 42-5 (62.27 t/ha), KTH 111(57.72 t/ha), KTH 127(57.63 t/ha) and KTH 1187 (52.8t/ha).

At IARI Regional Station, Katrain, a total of 105 CMS based F_1 hybrids were evaluated for various horticultural traits. Among them the hybrid, Ogu-1A x 13-05 was the highest yielder (65.6 t/ha) with all desirable traits. Other promising hybrids were Ogu33A x Kt-178 (62.3 t /ha), Ogu1A x Kt-25 (58.3 t/ha). Introgression of Ogura cytoplasm into another 20 lines of cauliflower is in progress and BC_6 generations have been developed. They were evaluated for seed yield potential and the lines Ogu 76A (32.5g/plant), Ogu 111A (29.6g/plant) and Ogu HL A (25.3g/plant) had very high seed yield and were suitable for use in hybrid breeding programme.

Introgression of *Trachystoma ballii* and *Diplotaxis catholica* into the nuclear back ground of cauliflower var. Pusa Snowball K 1 is in progress and BC_4 and BC_3 generations have been developed through *in vitro* embryo rescue. Cytological study revealed gradual chromosome elimination during this process.



Floral of cauliflowers introgressed with *Trachystoma ballii* and *Diplotaxis catholica* male sterile cytoplasms

For introgression of another male sterile cytoplasm *Moricandia arvensis* was used to cross with cauliflower var. Pusa Snowball K 1.

Breeding for black rot disease resistance. Fifty five RILs population/inbred lines were evaluated for resistance to black rot disease by inoculating with *Xcc* race 1, 4 and 23. Individuals were scored in the range of 3 to 9, indicating variable pattern for resistance. The resistant individuals in RILs population of Pusa Sharad × BR 207 were advanced to F_6 generation and Pusa Himjyoti × BR 2 to F_8 generation.

Breeding for β-carotene content in early and mid-early maturity group. A total of 220 '*Or*' gene carrying lines from six genetic backgrounds were evaluated. Among this, in early cauliflower BC_2F_3 BC_3F_2, BC_4F_1, F_5 generations in the background of Pusa Meghna, CC 14 and DC 41 5 were evaluated for their β-carotene content and other qualitative and quantitative traits. In mid-early cauliflower, 9 elite lines were identified in BC_2F_3 BC_3F_2, BC_4F_1 and F_5 generations in the backgrounds of DC 309, DC 18-19 and CC 35. The β-carotene content were estimated using UPC[2] method. The promising lines from early and mid-early genetic backgrounds were identified with high β-carotene content ranging from 10-15 ppm.

2.1.1.2 Heading broccoli

Purple heading broccoli was found to be promising for cultivation in *Rabi* season. Its average head weight was 722.5 g, rich in anthocyanin (30.31±0.68 mg/100g fw) and it was ready to harvest in 90-100 days after transplanting. The marketable yield potential of Pusa Purple Broccoli was recorded to be 27.02 t/ha, significantly higher than Palam Samridhi (21.82 t/ha).

Thirty hybrids of broccoli developed at IARI Regional Station, Katrain by using 7 CMS lines were evaluated for yield and horticultural traits against private sector hybrid Lucky procured from open market. Hybrid 30A × Sel. 3 recorded highest yield (17.9 t/ha) followed by VCHA × EC 676710 (15.2 t/ha) which were at par with the check (15.6 t/ha).

2.1.1.3 Cabbage

At IARI Regional Station, Katrain, 60 CMS based F_1 hybrids of cabbage developed by utilizing 5 CMS lines and 12 testers were analyzed for their performance for yield, horticultural and nutritional quality traits. The CMS based hybrid 1A × CH 6 (1.74 kg) recorded significantly highest head size followed by 208A × C 122 (1.66 kg). Three hybrids, 1A × CH 6, 831A × C 122 and 9A × Sel 5-83-6 took 60, 62 and 63 days to head maturity, respectively. Among the SI based F1 hybrids, S 645 × C 121 recorded the maximum head weight (1.4 kg) against the best check Nirmal 68 (1.19 kg) and other promising hybrids were S 681× S 691, S 681 × S 645, S 645 × C 1 and S 645 × C 121. The red cabbage hybrids RCGA × ZH (1.30 kg), RRMA × C 121 (1.19 kg) and KRA × ZH (1.18 kg) exhibited significantly higher net head weight.

Out of 22 test hybrids of cabbage from Regional Station, Katrain, KTCBH 705 (56.58 t/ha), KTCBH 905 (50.07 t/ha), KTCBH 822 (47.92 t/ha), KTCBH 83 (45.02 t/ha), and KTCBH 706 (43.47 t/ha) outperformed the check Pusa Cabbage Hybrid 1 (41.54 t/ha) in Delhi condition.

Microspore culture techniques were standardized for development of doubled haploids (DHs) in cabbage. The DH population was evaluated for various horticulture traits. For diversification of CMS system, The BC_2 and BC_3 generations with *Trachystoma ballii* and *Diplotaxis catholica* male sterile cytoplasms were further backcrossed with Golden Acre as recurrent parent.

2.1.2 Cucurbitaceous Crops

2.1.2.1 Bitter gourd

Varieties released. Two varieties of bitter gourd, Pusa Rasdar and Pusa Purvi were released by Delhi State Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops.

Pusa Rasdar is the first variety of bitter gourd suitable for cultivation in protected condition. Fruits are smooth, non-prickled with tender skin and fleshy. The average fruit weight is 115 g with average yield of 450 kg under 100 sq.m. insect proof net-house and 400 kg under 100 sq.m. polyhouse.

Pusa Purvi is the first improved variety of short fruited bitter gourd in the country suitable for making stuffed vegetable. Fruits are dark green colour, small in size (4-5 cm × 3-4 cm) with pointed tubercles, prickled, and crispy flesh with high dry matter. Average yield is 8.7 t/ha.

Promising genotypes. The gynoecious line PVGy-201 reaches edible stage after 40 days from sowing; fruits dark green with discontinuous ridges and individual fruit weight: 70-80g. This line was licensed to M/S Namdhari Seeds Pvt. Ltd., Bengaluru for commercialization through ZTM & BPD Unit of the Institute.

Twenty eight hybrid combinations were evaluated and among them, Pusa Rasdar × Sel 2, PDM × S 59 (PH 3) and PVGy 201 × S 59 (DBGH 159) were found promising and produced fruit yield of 27.4 t, 24.50 t and 26.10 t/ha, respectively. The two hybrids, PH 3 and DBGH 159 were included in IET trial under AICRP-VC. The hybrid DBGH 542 performed better both in field and protected conditions.

2.1.2.2 Cucumber

Variety identified. Pusa Seedless Cucumber 6 is the first extra early (40-45 days for first fruit harvest) improved variety of parthenocarpic gynoecious cucumber suitable for cultivation in protected condition. It was identified by the Institute Variety

Pusa Seedless Cucumber 6

Identification Committee. Fruits are attractive, uniform, dark green, glossy, cylindrical, straight, slightly ribbed, non-hairy, non-warty, slightly striped at blossom end and has tender skin and crispy flesh. Average fruit length, width and weight are 14.24 cm, 3.45 cm & 105 g, respectively. Average fruit yield is 126 t/ha (1260 kg/ 100 m^2) during winter season (off-season, November-March).

Promising genotypes. Out of the 187 germplasm stocks and advanced breeding lines and 25 new collections evaluated, genotypes DC 83 and DC 22 yielded 19.4 and 17.8 t/ha showing an increase of 22.0% and 11.9% over check Pusa Uday (15.9 t/ha), respectively. These selections were promoted to AVT-I in AICRP (VC) trial. Out of 28 F_1 hybrids evaluated, gynoecious hybrids DGCH 18 and DGCH 15 yielded 29.4 and 27.0 t/ha which were 31.8 and 21.1 per cent higher than the check Pant Sankar Khira 1 (22.3. t/ha), respectively, and advanced to AVT-I of AICRP (VC) trial. Seed multiplication of promising gynoecious parthenocarpic lines DPaC 6, DPaC 9, Gherkin lines DG 5, DG 8 and DG 11 and tropical gynoecious line DGC 102 and DGC 103 were carried out under insect proof net house.

Fifteen gherkin lines evaluated, the lines DG 8 and DG 3 were found most promising and gave an average yields of 864.4 kg and 776.0 kg in 100 sq.m. polyhouse, respectively, which were significantly higher than private company check Annaxo (725.7 kg).

Breeding for downy mildew resistance. During *Kharif* season, 197 lines were screened for downy mildew resistance. DC 70 and DC 77 showed highly tolerant disease reaction to downy mildew under challenge inoculation besides having high yield and other desirable horticultural character. Inheritance of downy mildew was studied and it was found to be controlled by single recessive gene. Out of 19 F_1 hybrids evaluated, DCH 16 (22.0 t/ha) and DCH 19 (21.6 t/ha) were promising with high yields and tolerant to downy mildew disease.

Marker assisted backcross breeding for gynoecious trait. The G 421 cucumber line (donor parent) was crossed to Pusa Uday with the former as the male parent. Foreground selection was done by functional SCAR marker CsACS1G specific to the *F* locus in F_2 and BC_1F_1 mapping populations. Two simple sequence repeat (SSR) markers, namely, SSR-13251 and SSR-15516 linked to *F* locus were used for the identification of homozygous and heterozygous plants. A total of 192 BC_1F_1plants were genotyped with the two linked markers (SSR-13251 and SSR-15516) and the SCAR markers. Those showing the presence of CsACS1G specific SCAR marker but homozygous for the linked markers were selected in the process of foreground selection.The identified heterozygous plants were subjected to segregation and selection process. In this study, 18 plants heterozygous for *F* locus were selected using these three markers and were phenotypically matched to Pusa Uday for multiple lateral branching, indeterminate growth habit and fruit characters. These plants were selfed to produce the BC_1F_2 and BC_1F_3 population. The recurrent parent genome recovery was analyzed in BC_1F_3 generations using SSR markers which allowed identification of plants similar to the recurrent parent. For background profiling of BC_1F_3 cucumber plants, from out of a total of 859 markers, fifty two markers were found polymorphic. Background analysis revealed that the recurrent parent genome (RPG) recovery ranged from 60.63 to 78.72% in BC_1F_3 generation.

2.1.2.3 Luffa

Promising genotypes. In sponge gourd, out of 48 selections evaluated in station trial during spring summer season, DSG 43 (12.0 t/ha), and DSG 33 (12.3 t/ha) showed an increase in yield of 6.19% and 8.85%, respectively, over check Kalyanpur Hari Chikni (11.3 t/ha). Out of 27 sponge gourd F_1 hybrids evaluated, DSGH 52 (14.3 t/ha) and DSGH 34 (15.4 t/ha) showed an increase in yield of 26.55 and 36.28%, respectively over check Kalyanpur Hari Chikni. These selections and F_1 hybrids were promoted to AVT-I AICRP (VC) trial. In ridge gourd, out of fifteen F_1 hybrids evaluated, DRGH 4 and DRGH 11were found promising with an average yield of 17.4 t/ha and 15.6 t/ha, respectively. A gynoecious line DRGGL 8 showing true gynoecious expression was isolated from a genetic stock ridge

gourd and maintained by standardized doses of sliver thiosulphate for induction of male flowers.

Promising sponge gourd genotyeps for seed oil content. Forty four sponge gourd genotypes were screened for seed oil content and oil quality. The lines VRSL 12 (29.77%, 59.61%), DSG 26 (27.98%, 68.92%), VRSL 9 (24.41%, 61.03%), PSG 100 (23.76%, 56.31%) and VRSL 15 (22.20%, 63.40%) having high oil and linoleic acid content in seed, respectively, were identified.

2.1.2.4 Pumpkin

Promising genotypes. Seventy five genotypes of pumpkin were assessed for various qualitative, quantitative, mineral and bio-chemical attributes, of which seven genotypes were found promising viz., DPU 6 (fruit length, diameter and weight; flesh thickness; fruit yield per plant and per hectare; seed yield per plant; K; total antioxidant activity), DPU 26 (fruit length; flesh thickness; fruit yield per plant and per hectare; K; Ca; Mg; Fe; Mn; Cu; Zn), DPU 51-3 (harvest index; fruit yield per plant and per hectare; 100-seed weight; seed yield per plant), DPU 75 (days to opening of first female flower; fruit weight; harvest index; fruit yield per plant and per hectare; phenol; total carotenoids).

Total carotenoids in the fruit ranged from 32.67 to 432.42 µg/g FW with highest in DPU 76 (432.42) which was statistically at par with DPU 80 (428.37). Iron content exhibited a wide range of variation (736.18 to 19484.40 µg /100g FW) in the different genotypes. Significantly, higher content of iron was observed in the genotype DPU 62 (19484.40). Significantly higher zinc content was exhibited by the genotype DPU 3 (1226.01), followed by DPU 26 (835.91).

2.1.2.5 Musk melon

Varieties identified. Pusa Sarda is a first variety of Sarda melon which can be grown in net-house under north Indian plains conditions. Its fruit are golden yellow, roundish to elongated globe shaped with average weight of 1.1 kg. Fruits get ready for first harvest in about 85-90 days. Fruit flesh is thick, greenish white, and very crispy with high sweetness (TSS 13.6^{0}B). It can be stored for 15 to 20 days. Its average yield is 5.44 t/1000 m^2 under net-house.

Pusa Sarda

Pusa Madhurima is a ovate to obovate shaped muskmelon variety with high yield (22.45 t/ha) and increased shelf life. Its fruit average weight is 775 g. Fruits get ready for harvest in about 80 days. The rind colour of fruit is creamish yellow with green sutures. Fruit flesh is thick, green, juicy and crispy with medium musky flavour and high sweetness (TSS 12^{0}Brix). Fruit surface is grooved with moderate netting and is slipable at maturity. Fruits attain nipple shape at peduncle end. Its leaves are weakly lobed and shows andromonoecious sex expression.

Pusa Madhurima

Promising selections and hybrids. Sixteen advanced lines of muskmelon were evaluated in station trial during summer 2015 and genotypes DM 154-7 (21.2t/ha) and DM 159-8 (20.2t/ha) were found promising. Promising selections of sarda melons

for protected cultivation were DHM 145 (5.09 t/1000 m^2 area with TSS 12.9 ^{0}Brix), DHM 159 (4.33 t/1000 m^2 area with TSS 13.2 ^{0}Brix). Twenty eight hybrid combinations from melon genotypes of 3 horticultural groups *inodorous*, *cantaloupinensis* and *momordica* of *C. melo* were evaluated in station trial during summer 2015 and yield performance of DMH 5 [Pusa Madhuras (*cantaloupensis)]* × [DM 159 (*inodorous*)] was significantly higher (25.2 t/ha), with TSS 12.8 ^{0}Brix.

2.1.2.6 Long melon

Variety identified. Pusa Utkarsh is the first early maturing variety of long melon for spring summer season cultivation under north Indian plains. Fruits set ready for first harvest in 45-50 days after sowing in spring summer season. Fruits are slightly curved, medium long (length 52 cm), thin (diameter 2.4 cm), light green, smooth non-prominent ridges, shiny with tender skin, crispy flesh, and free from bitterness. Each fruit weighs 130-145 g at marketable stage. Seeds light tan in colour. Average fruit yield 29.2 t/ha during spring summer season.

Pusa Utkarsh

2.1.2.7 Summer squash

Variety released. Pusa Pasand was released by Delhi State Variety Release Committee for cultivation in Delhi NCR region. It is first early improved flattish round variety of summer squash for spring summer season cultivation under open and off-season winter cultivation under protected condition. Its fruits are attractive light green, shiny, uniform, flattish round, 70-80 g with tender flesh. First harvesting is 45-50 days after sowing in spring summer season. Average fruit yield is 16.3, 24.1 and 22.9 t/ha during spring summer season under open field condition; naturally ventilated polyhouse and plastic low tunnel during winter season, respectively.

2.1.2.8 Round melon

Variety identified. Pusa Raunak is the first early maturing variety of round melon for spring summer season cultivation for North Indian plains. Fruits become ready for first harvesting in 55-60 days after sowing. It produces 8-10 fruits per vine. Young fruits at marketable stage are attractive green, shiny, uniform, flattish round in shape, 5 cm in diameter. Flesh is white, tender, less-seeded and has good cooking quality. Each fruit is medium in size and weighs 60 g at marketable stage. The seeds are black in colour with ridged border. Average fruit yield 7.59 t/ha during spring summer season.

Pusa Raunak

2.1.3 Solanaceous Crops

2.1.3.1 Brinjal

Promising genotypes. A total of 136 genotypes were evaluated, of which G 5 (round purple), G 23 (round purple), G 43 (round purple), G 92 (purple

long), G 94 (small oval purple), Sel 195 (oval white), G 164 (green long), G 185 (oblong pink), and DB 1 (long dark purple) were found promising with an average yield of 39.8 t/ha, 41.5 t/ha, 43.4t/ha, 36 t/ha, 30.1 t/ha, 35.41 t/ha, 42.5 t/ha, 38.7 t/ha, and 43.5 t/ha, respectively.

Promising hybrids. In long fruited hybrid trials, DBHL 211 (long purple, 53.1 t/ha) was found superior over check Navina (49.1 t/ha). In round fruited hybrid trial DBHR 91 (65.4 t/ha, purple round), DBHR 112 (59.1 t/ha, purple round), and DBHR 190 (61.4 t/ha, purple round) were found superior over check Pusa Hybrid 6 (48.5 t/ha).

Promising genotypes for bioactive compounds. A total of 60 genotypes were evaluated for their biochemical content. Maximum phenolic content was recorded in G 190 (3350.87 µg gallic acid/g fresh weight) followed by Pusa Upkar (3159.38 µg gallic acid/g fresh weight). Highest cupric ion reducing antioxidant capacity (CUPRAC) was found in G 190 (33.14 µmoltrolox/g) followed by PPC (27.51 µmoltrolox/g), Pusa Upkar (26.66 µmoltrolox/g) and ferric reducing antioxidant power (FRAP) was highest in G 190 (20.69 µmoltrolox/g) followed by PPC (17.77 µmoltrolox/g) and Pusa Bindu (16.82 µmoltrolox/g). Among the 18 hybrid combinations taken, highest phenolic content was observed in DBSR 91 x Pusa Upkar (1278.75 µg gallic acid/g fresh weight) followed by G 190 x Selection 195 (913.13 µg gallic acid/g fresh weight). The antioxidant CUPRAC found maximum in PS x PPL (14.07 µmoltrolox/g) followed by DBSR91 x Pusa Upkar (11.03 µmoltrolox/g). FRAP was highest in PS x PPL (7.63 µmoltrolox/g) followed by 190-10-12 x Pusa Uttam (7.22 µmoltrolox/g).

Promising genotypes and wild accessions resistance to Phomopsis blight. Among 109 genotypes, DB 6, H 183, and G 128 were found to be resistant under natural disease epiphytotic field condition. The wild accessions EC 790352 (*S. sysimbrifolium*), *S. khasisnum*(AC-1), EC 790365(*S. xanthocarpum*) were found to be resistant under field condition. Two interspecific hybrids (PusaUttam × *S. incanum*), (Pusa Shyamla × *S. incanum*) were evaluated for *Phomopsis* blight resistance and all F_1 plants were resistant and backcrossed with Pusa Uttam and Pusa Shyamla, respectively.

Promising genotypes and wild accessions resistance to Fusarium wilt. A total of eighty cultivated genotypes were evaluated under natural field condition. Among the genotypes, G 17, G 30, Pusa Bhairav, and among wild accessions, EC 790354 (*S. macrocarcarpum*), EC 790352 (*S. sysimbrifolium*) and *S. khasianum* (AC 1) were found to be resistant.

2.1.3.2 Tomato

Promising hybrids. In a station trial, 54 F_1 combinations were evaluated for yield attributes, fruit characters, pericarp thickness, firmness and quality attributes. The hybrids DTH 176 (43.0 t/ha), DTH 158 (42.4 t/ha) were found be better than the check Pusa Hybrid 4 (41.4 t/ha). More than 150 breeding lines and germplasm were also evaluated for fruit weight, pericarp thickness and TSS. The promising genotypes for fruit weight were EC 806911(200g), EC 814911 (170g) and DTBR 14 (120 g), and showed 100-150 % increase over check, Pusa hybrid 8. The range for pericarp thickness was 0.3-1.0 mm and the promising genotypes were DTBR 32 (0.8) and DTBR 1 (0.8) and DTBR 6 (0.8).

Screening for ToLCV resistance. In a station trial on screening of tomato against ToLCV, 104 genotypes including parental lines and 55 F_1s were screened during *Kharif* for resistance against TLCV. DT 419 with only 19% PDI was the most promising breeding line for TLCV resistance and other traits were also desirable for fruit weight (81 g), no of fruits per plant (43), pericarp thickness (5 mm) and TSS (3.4 ^{0}B). Other promising lines with PDI less than 50% were EC 814916 (20), EC 814917 (22), and hybrids were DTH 107 (26), DTH 104 (30), EC 814913 (30), DTH 101 (49) and DT 434 (45). Three *S. habrochaites* accessions (EC 803499, EC 803501, EC 803502) had moderate resistance to late blight. The *S. chilense* accession EC 803505 had high level of resistance to TLCV under field conditions. The interspecific hybridization was carried out using accessions EC 803493, EC 803499, EC 803501, EC 803502 with Pusa Rohini, N 5, and GF 1.

Interspecific crosses. The interspecific crosses of (15SB × LA1777) × P 120 and (15SB× LA1777) × Pusa Rohini were screened during *Kharif* 2015 for TLCV and were found to be tolerant to leaf curl and late blight. The crosses were made with Pusa Rohini, and Pusa 120 and EC 814916 parental lines carrying *Ty-2*, *Ty-3*, *Ph-2*, *Ph-3* and *I-2* genes for resistance to leaf curl, late blight and *Fusarium* wilt.

Promising genotypes growing for protected cultivation.Thirty genotypes including inbred lines and F_1 were evaluated under protected environment. Earliest 50% flowering was recorded in Sel 3 (20 days after transplanting) followed by 120 × PR (27 days after transplanting). Sel-(HSK) recorded lowest flower cluster at 5th node followed by Sel 6 (5.5 nodes). Inter-cluster distance was recorded maximum in Sel 6 (3.75 nodes). The maximum fruit weight was obtained in Sel 60 (~115g), fruits/plant in Sel 2 (80), pericarp thickness in Sel 6 (8 mm), TSS in Sel 6 (5.1) and lycopene content in LP-2 (10.4mg/100g). Sel 60 is an promising line with TSS 5.6^0 Brix, lycopene 6 mg/100 g, average fruit weight of 115 g, fruits attractive red, round in shape, thick fleshed (8 mm) and average yield of 7.250 kg/ plant with crop duration from October-April.

Sel 60, a promising tomato line showing heavy fruiting with large and round fruits (around 115 g) under low cost polyhouse

2.1.3.3 Chilli and sweet pepper

Phenotypic evaluation for leaf curl disease. Promising selections having leaf curl tolerance and good fruit shape and yield were made in 42 F_4 families during *Kharif*, 2015. The maximum disease score showed by the promising lines was one with slight leaf curling at the tip of the plants. Artificial screening of identified resistant lines to leaf curl causing begomoviruses (DLS-Sel 10 and WBC-Sel 5) with infectious clone of TLCV was carried out on 15 days seedlings along with susceptible genotypes Pusa Jwala, LCA 424 and GVC 111. After 15 days of infestation, the susceptible genotypes LCA 424 and Pusa Jwala showed symptoms of yellowing and curling while the resistant lines were free from disease curling symptoms.

Promising lines and hybrids. Fifty lines of capsicum were evaluated at IARI Regional Station, Katrain and the lines KTC 134 (26.30 t/ha), KTC 145 (25.50 t/ha) and KTC 131 (25.10 t/ha) had outperformed consistently for marketable fruit yield. Among the 50 hybrids, KTCH 13-Y (2.56 kg/plant) gave the highest marketable fruit yield per plant followed by KTCH 155 (2.52 kg/plant) and KTCH 141(2.51kg/plant) under polyhouse conditions. The hybrid KTCH 141 had performed consistently better over last two years under polyhouse conditions.

2.1.4 Root and Bulbous Crops

2.1.4.1 Carrot

Promising genotypes. In heat tolerant group, 26 CMS based hybrids along with five private sector hybrids were evaluated, out of these, five hybrids were most promising for root yield potential (up to 30 t/ha) and quality traits. Out of 33 hybrids, nine hybrids had juice recovery more than 50% and four had TSS more than 10 °B. In normal season carrot, out of 60 CMS based hybrids evaluated, 7 hybrids were found to be most promising with higher yield potential (>45 t/ha). Out of 21 inbred lines evaluated for early season (for heat tolerance), four inbred lines were promsing for root yield (>25 t/ha). Four inbred lines were identified in early group having high juice recovery (up to 50%) and it was highest in IPC 116 (57.5%). The TSS was

highest in IPC 75 Red (10.5 °B) and PM Dark Orange (10.1 °B).

In temperate carrot, 46 germplasm lines were evaluated for root yield and its contributing traits. Genotypes KS 20 (30.20 t/ha), KS 5 (29.90 t/ha) and KS 73 (29.37 t/ha) had revealed high root yield potential. Among 81 CMS based hybrids, the highest marketable root yield was recorded in the hybrid KTCH 750 (34.0t/ha) followed by KTCH 2820 (32.70 t/ha) and KTCH 759 (310.75 t/ha).

2.1.4.2 Onion and Garlic

Promising genotpyes identified. During *Kharif* season, a total of 53 accessions of onion including commercial varieties and landraces were evaluated for their bulbing potential. It was observed that Bhima Red and Phule Samarth were high yielders and formed proper bulbs. During *Rabi* season, 51 varieties of onion and 15 varieties of garlic were evaluated under DUS programme. In garlic, PGS 204 and PGS 200 yielded significantly higher (19.5 and 17.7 t/ha) as compared to the commercial check variety where the marketable yield was 13.2 t/ha. In onion, trial on breeding tolerance exhibited that accession POS 008 had low bolters in two different dates of planting.

2.1.5 Leguminous Crop

2.1.5.1 Garden pea

New genetic material developed. Among 13 new bulks/genotypes evaluated against 4 checks (GP 17, Arkel, Pusa Pragati & VL 10), the promising genotypes were recorded as GP 912 (13.15 t/ha), GP 1101 (12.82 t/ha) and GP 1102 (11.49 t/ha) against the best check GP 17(103.2 t/ha). The promising lines GPE 1 (6.10 t/ha), GPE 3 (6.88 t/ha) and GPE 4 (7.99 t/ha) were found promising for fresh pods consumption and were highly resistant to powdery mildew.

Based on screening against *Fusarium* wilt in sick plot, three genotypes GP 6, GP 55 and GP 942 were found to be highly resistant and four genotypes GP 17, GP 48, GP 473, GP 941 were resistant. Inheritance study for wilt resistance in three crosses involving Arkel and Pusa Pragati as susceptible parents revealed that the gene responsible for resistance in genotypes GP 17, GP 55 and GP 6 are monogenic dominant in nature as the 3:1 ratio was observed in F_2 segregating population. Besides, 235 crosses ($109F_2$, $40F_3$, $26F_4$, $50F_5$, $10F_6$) were retained for further selection/evaluation.

2.1.6 Malvaceae Crop

2.1.6.1 Okra

Promising genotypes. Eighty seven okra lines (parental and advanced lines) were evaluated for yield and yield attributes, fruit quality and YVMV resistance. Four okra advance lines, namely, DOV 66, DOV 92, DOV 8 and DOV 12 and one hybrid DOH 1 were found resistance to yellow vein mosaic virus (YVMV) under field conditions i.e., 100% free from YVMV up to 90 days after sowing. However, Pusa A-4, Pusa Sawani and Arka Anamika showed 33%, 90% and 56% YVMV disease infestation, respectively. On the basis of molecular screening through rolling circle amplification (RCA), genotypes DOV 92 and DOV 66 showed absence of β-DNA after 90 days of sowing and were free from symptom of YVMV. However, Pusa Sawani showed presence of β-DNA and symptom of YVMV disease. These lines showed high yield and YVMV disease resistance for the last 3 years. Three advanced breeding lines, namely, DOV 66, DOV 92 and DOV 8 yielded higher than the hybrids and having resistance to YVMV disease with yield potential of 18.0, 17.7 and 17.6 t/ha, respectively. From fruit quality view point, genotype DOV 26 recorded less mucilage (3.35%). DOV 62 recorded high protein content (2.42%) and DOV 29 recorded high total leaf chlorophyll (1.74 mg/g). Pod length after 4 days of anthesis was recorded maximum in DOV 66 (7.14cm) followed by DOV 92 (6.72 cm).

Screening against leaf hopper under field conditions, out of 24 genotypes, DOV 92, DOV 66 and DOV 8 were found most tolerant to leaf hopper. However, maximum infestation (leaf hopper population) was recorded on middle leaf followed by top and lower leaves of plants. Leaf curling on top, middle and lower leaves were 30%, 20% and 10%, respectively.

Promising hybrids. Out of 21 selected F_1 cross combinations, 7 F_1 combinations were selected with a yield range of 21.3 to 27.0 t/ha with dark green fruits and showed tolerant to YVMV. Earliest 50% flowering (42 days) and 11 picking was recorded in DOH 1. Out of 130 accessions of *A. moschatus*, *A. tetraphyllus*, *A. caillei*, *A. ficulneus* and *A. angulosus* evaluated, 7 accessions were found completely free from YVMV, 2 accession recorded < 10% and 9 accessions < 20% YVMV incidence.

DOH 1, a promising okra hybrid with dark green fruits, having resistance to YVMV and tolerance to leaf hopper

2.1.7 Leafy vegetable

2.1.7.1 Lettuce

Promising genotypes identified. Out of 28 genotypes evaluated, two were of Iceberg/heading type, 4 butterhead, 17 loose leaf, 4 cos or romaine and 1 stem lettuce type. The promising selections are Sel 1 (41t/ha) followed by Sel 2 (35t/ha) and Sel 3 (32.5 t/ha). Based on quality analysis, highest chlorophyll content was observed in Chinese yellow (3.20 mg/100 g) and ascorbic acid in EC 687337 (8 mg/100 g).

2.2 FRUIT CROPS

2.2.1 Mango

Promising hybrids. Nine cross combinations were attempted by employing Amrapali, Mallika, Pusa Arunima and Kesar as female parents and Sensation, Janardan Pasand, Irwin and Pusa Arunima as male donor parents. Seventy-eight mango hybrids belonging to different cross combinations and their parents were evaluated for different physico-chemical parameter during the period under report.

Hybrid 11-2

Hybrid 1-5 **Hybrid 2-14**

Out of which, 13 had more than 200 g fruit weight. The maximum fruit weight was noted in H 11-2 (352.9 g) followed by H 1-11 (286.4 g). Pulp percentage was maximum in H 1-5 (74.13%) followed by H 11-2 (71.55%). The fruits of hybrid H 12-5 had maximum red pigmentation on the peel followed by H 11-2.

The hybrids of Amrapali × Sensation crosses were analysed for fruit quality attributes. The β-carotene content detected using QPLC ranged between 387 to 9537 µg/ 100 g pulp. Among the total 19 compounds detected as flavouringagents, (E)-Ocimene, β-Pinene, 3-Carene, Limonene, β-Caryophyllene and β-Humulene were the major detected at all the four stages (unripe, mature, ripe and over-ripe).Among indigenous cultivars, the frequency of jelly seed was maximum in Dashehari (20.0 and 36.6%) in artificially ripened and tree ripe fruits. Hybrids H 12-5 and H 11-2 showed high intensity of red pigmentation on the shoulders.

Performance of mango varieties on polyembryonic rootstocks. The heaviest fruit in Pusa Arunima (251.28 g) and Amrapali (186.38 g) was recorded on Kurakkan rootstock followed by K-5 rootstock (219.45 g). However, Pusa Surya bore bigger fruits on K-5 rootstock (271.43 g) followed by Kurakkan. Pulp content in Pusa Arunima was significantly higher than Olour (72.17%) and K 2 (70.22%). The highest yield efficiency was found in Pusa Surya on Kurakkan

rootstocks (1.70 kg/m^3) and minimum in Pusa Arunima on K 3 rootstock. The estimated yield in Pusa Arunima (18.27 tonnes/ha), Pusa Surya (11.39 tonnes/ha) and Amrapali (18.81 tonnes/ha) was maximum on Kurakkan rootstock. The maximum yield efficiency in Mallika was observed on Olour rootstock (0.47 kg/cm^2 TCSA), while in case of Dashehari it was on Kurakkan rootstock (0.42 kg/ cm^2 TCSA).

2.2.2 Grape

Promising hybrids. Three hybrids, namely, Hy. R_1P_9 (Banqui Abyad × Perlette), ER-R_1P_{19} (Pearl of Csaba × Beauty Seedless), ER-R_2P_{36} (Pearl of Csaba × Beauty Seedless) consistently matured very early in the last week of May. Hybrids Pusa Trishar (12.3 kg/vine) as well as Pusa Aditi (9.8 kg/vine) were good yielders on trellis system. The maximum bunch weight was recorded in Pusa Trishar (448 g/bunch) followed by Pusa Aditi (425 g/ bunch).

Twelve hybrids were found promising in terms of high TSS, of which three best hybrids were ER-R_2P_{36} (PoC x Perlette) (23°Brix) followed by ER-R_2P_{16} (BS x Perlette) (22.1°Brix), and ER-R_2P_4 (PoC x BS) (20.4°Brix).

2.2.3 Citrus

Promising acid lime clones. Clone ALC 107 had significantly higher fruit weight (71.15 g) followed by ALC 2 (55.75 g), Pusa Udit (44.12 g), which was non-significant with Pusa Abhinav (38.17 g) and ALC 45 (36.70 g). The highest juice content (52.45%) was measured in ALC 5, which was statistically at par with Pusa Abhinav (51.08%) and Pusa Udit (48.13%). Seeds/fruit varied from 5.0 in Pusa Abhinav to 22.17 seeds/fruit in ALC 107. The number of fruits/ tree was found to be the highest in Pusa Udit (500.0) followed by ALC 2 (486.7), Pusa Abhinav (477.7) and ALC 45 (352.0).

Evaluation of Tangerine cultivars. Murcott proved to be 43 and 48 days earlier to harvest than Dancy and Kinnow, respectively. Dancy proved to be the most productive cultivar (82.55 kg/ tree), while the highest fruit weight (217.18 g), juice (46.79%) and TSS (11.38°Brix) contents with thinnest peel (2.41 mm) were recorded in Murcott.

Citrus hybridisation. Under rootstock breeding programme using different cross combinations, maximum fruit set at 15 DAP was recorded in Rangpur lime × Troyer cross (72.50%) followed by Rangpur lime × Sacaton (57.14%) and Rangpur lime × Morton (53.85%), while lowest was found in Yama Mikan × Morton (5.00%). In scion breeding, total 574 flowers have been crossed. Two cross combinations in lime improvement, i.e., Kagzi Kalan × Pusa Abhinav and Konkan Seedless × Pusa Abhinav and eight combinations in sweet orange and mandarin improvement were attempted. Maximum fruit set was

ER- R_2P_{36} (PoC x BS)

Hy. R_1P_9 (Banqui Abyad x Perlette)

ER- R_1P_{19} (PoC x BS)

Murcott

Dancy

recorded in Konkan Seedless × Pusa Abhinav (96.77%) and minimum in Pummelo × Kinnow (35.71%).

Evaluation of citrus hybrids against Phytophthora nicotianae. Of the 36 hybrids evaluated with Citrumelo (resistant) and Jambhiri (susceptible) through lesion length against the inoculation of *Phytophthora nicotianae*. The hybrids, namely, P × TC 37, P × TC 38, P × TC 42, P × TC 45, P × TC 48, P × TC 49 and P × TC 58 along with Citrumelo showed resistance against the tested species of fungus, while the rest of hybrids were susceptible.

Mutagenesis studies in Kinnow. Delayed maturity (mid-February) was recorded in the mutants M 10-4 and M 25-1. The average number of seeds/ fruit were significantly lower in the mutants M 25-1 (10-12) and M 15-7 (12-14) as compared to parent Kinnow (wild type), where the average number of seeds/fruit normally varied from 30 to 35.

Performance of lemon cv. Kagzi Kalan on rootstocks. Trees of lemon on *Karna khatta* rootstock had highest fruit weight (50.73 g) which was non-significant with trees on RLC 4 (47.30 g), while juice recovery was found to be the highest on RLC 4 (50.63%) and minimum on *Billikichli* and sour orange. Most of the rootstock produced seedless fruit except *Jatti khatti* and *Billikichli*. Rootstock influenced the peel thickness significantly and maximum peel thickness was measured on *Karna khatta* rootstock (1.13 mm). The maximum leaf N (2.44%) and K (1.63%) contents were recorded on Attani 2 and RLC 4 rootstocks, while leaf P concentration were highest on *Karna khatta*. Leaf Ca (3.38%) and Mg (0.34%) were maximum on rough lemon and *Jatti khatti*. Iron and manganese were recorded to be the maximum on RLC 4 and rough lemon, respectively.

Performance of Kinnow on rootstocks. Scion leaves of Kinnow on *Karna khatta* (89.47%) and rough lemon (88.61%) maintained higher relative water content. The photosynthetic rate (*A*) and internal cellular CO_2 (*Ci*) were significantly higher in scion leaves of Kinnow on *Jatti khatti* rootstock (6.9; 251.63 µmol m^{-2} s^{-1}) followed by trees on rough lemon (5.81; 218.75 µmol m^{-2} s^{-1}). The stomatal conductance(*gs*) and transpiration rate (*E*) followed a pattern similar to *A* and *Ci* thus recording higher *gs and E* values in scion leaf on *Jatti khatti* (0.095; 4.02 mmol m^{-2} s^{-1}) and rough lemon without any significant difference. The intrinsic water use efficiency (WUE*i*) was recorded maximum on *Troyer citrange*, Rangpur lime and rough lemon rootstocks (96.64 µmol m^{-1} H_2O m^{-2} s^{-1}). The antioxidant enzymes superoxide bismutase (SOD) (60.49unit $min^{-1}mg^{-1}$ protein) and peroxidase (POD) (31.20 µ mole tetra-guaiacol formed $min^{-1}mg^{-1}$protein) were most active in scion leaf budded on rough lemon rootstock; whereas catalase (CAT) activity (11.19 µ moles of H_2O_2 hydrolysed mg^{-1} protein min^{-1}) and proline accumulation (354.0 µg g^{-1} of FW) were higher in scion leaves of Kinnow on sour orange rootstock.

2.2.4 Papaya

Sex expression. The sex identification in papaya was made using morphological, physiological and molecular markers. The higher frequency of the female and hermaphrodite plants was observed in black and dark brown coloured seeds across the genotypes. The dark brown colour exhibited higher number of male plants among the dioceious genotypes (Pusa Nanha and P 7-2 × SAM). However black colour seeds gave rise to higher number of the female plants in case of Pusa Nanha and P 7-2 × SAM.

SCAR T12 marker produced a band (~800 bp) in male and hermaphrodite plants but not in female plants among the dioecious and gyndioecious genotypes. The band size ~375bp (SCAR SDSP) was present only in hermaphrodite plants but not in female plants among genotypes studied. The SCAR marker C 09/20 with ~1000 bp band size was present only in hermaphrodite plants but not in female plants, while SCAR C 09/20 could validate hermaphrodite plants of the two gyndioecious genotypes. SCAR W11 marker with a band size of ~825bp was present only in hermaphrodite plants but not in female plants. The $GACA_4$ the P1 (~ 600 bp) amplicon was present in male and female plants but not in hermaphrodite plants. The P 2 (~2 kb) amplicon was present only in female plants but not in male and hermaphrodite plants. The P 3 (~3 kb) amplicon present only in P 7-2 × SAM genotype but not in others.

Promising genotypes. Out of 16 genotypes evaluated, P 9-5 a gynodioecious genotype had the earliest flowering (76 days after planting), earliest fruit ripening (125 days after fruit set), long fruiting zone (125 cm), orange-yellow flesh of fruit, semi dwarf stature plant (179 cm), medium size fruits (975-1545 g), highest total phenols (105.6 mg/100 g) and total flavonoids (39.6 mg/100 g), minimum infection of papaya ring spot virus (19.5) and least infestation of papaya mealy bug and spider mites.

P 9-5

Papaya ringspot virus type Papaya (PRSV-P) resistance. At IARI Regional Station, Pune, the maximum reduction in the infestation of PRSV-P was recorded in the cross of Pusa Giant × PS 1-1 (57%), while the average reduction was 35%. When crosses were made with dioecious papaya lines of Pune Selections, the maximum reduction was recorded in the cross of PS 3 × PS 1-1 (41%), while the average reduction was 32%. PRSV-P severity at fruit maturity stage was maximum in Madhu Bindu (89%) and minimum in CO 7 (43%). Maximum per plant yield and average fruit weight were recorded with CO 6 (37 kg/plant, and 1416 g), and minimum in Arka Prabhat (13 kg/plant, and 865 g). CO 6 had the maximum (75%) and Arka Prabhat had the minimum (43%) proportion of productive plants.

Promising gynodioecious lines. The fruiting behavior of hermaphrodite and female plants was different in gynodioecious Pune Selections. Yield of female plant was 18% more than hermaphrodite plants. Similarly, number of fruits per plant was also more in female plants and was maximum in PS 1-1. Average weight of fruit was 8% more in hermaphrodite plants than the fruit of female plants.

2.2.5 Temperate fruits

Two apple hybrids viz., Pusa Amartara Pride (Royal Delicious × Prima) and Pusa Gold (Golden Delicious × Tydeman's Early Worcester) were developed at IARI Regional Station, Shimla. Pusa Amartara Pride is red coloured, ripened one week earlier than Royal Delicious, larger in size, with higher juice content and TSS values. Pusa Gold is bright golden coloured hybrid with a bright red blush without stripes, and round and uniform in shape.

IARI Regional Station, Shimla has also identified a multiscionic rootstock suitable for grafting in different stone fruits such as apricot, peach, plum, almond and

cherry. It is highly precocious and starts fruiting in the same year after grafting with more than 90% graft success.

At IARI Regional Station, Shimla, an easy and low cost technique for large scale multiplication of kiwifruit plants was developed. The overall rooting success obtained in different cultivars of kiwifruit varied from 67% in Toumri (male) to 86% in cultivars, Abbott and Bruno, whereas cv. Hayward exhibited 75% rooting.

In strawberry at IARI Regional Station, Shimla, large scale runner production was undertaken by establishing runner beds and production of 4.98 to 42.15 runners per plant was obtained. The cultivar Jutogh Special produced the maximum number of runners per plant (42.15) followed by Missionary (34.09) and Larson (33.07).

2.3 ORNAMENTAL CROPS

2.3.1 Rose

Pre breeding in rose for powdery mildew resistance. The field screening against powdery mildew was done in 20 species and 50 varieties of rose during the year. Among species, *Rosa glutinosa* (EC 025999), *Rosa slancensis* (EC 037349), *Rosa sp.* (EC 018586) and *Rosa brunonii* (IC 564794) exhibited field tolerance to powdery mildew. Among the varieties viz., Arjun, Raktagandha, Sadabahar, Shabnam, Sindoor, Raja Surinder Singh of Nalagarh and Arunima showed field tolerance to the disease. Varieties such as M. S. Randhawa, Pusa Gaurav, Ranjana Lalima, Pusa Arun, Pusa Mohit and Deepak exhibited susceptibility towards powdery mildew.

Pollen studies of fragrant varieties. Screening of eleven fragrant varieties was carried out for pollen diameter and pollen viability (%). The pollen viability was determined by acetocarmine test and the pollen diameter was measured with the help of Stereozoom microscope (80 x). Highest pollen diameter was observed in cv. Midas Touch (47.69 cm) and lowest in cv. Karen Blixen (31.23 cm). Highest pollen viability was observed in cv. Rose Sherbet (76.72%) and lowest in cv. Eiffel Tower (37.37%). Pollen diameter and pollen viability were reported to be positively correlated with hip set in rose. Among the tested fragrant varieties, Bonne Nuit, Rose Sherbet, Jadis and Pusa Mahak had higher pollen viability (%) and bold pollens.

2.3.2 Gladiolus

Varieties released. Pusa Srijana**,** a selection among the progeny obtained from the cross between Berlew and Heady Wine**.** It produces spikes of more than 85 cm and florets range from 15-17 in numbers on medium long sturdy spikes. It is very good multiplier producing 3.10 corms and 27.44 cormels from each mother corms. It takes 73.22 days to first floret opening after planting. Floret colour is attractive purple group (N-78B) (dark pink/mauve). It is highly suitable for garden display.

Pusa Unnati, a selection among the progeny obtained from the cross between Berlew and Heady Wine. It produces spikes of more than 115 cm and floret number ranges from 16-20 and has very long strong/ sturdy spikes. It is very good multiplier producing 2.88 corms and 49.78 cormels from each mother corm. This is medium to late flowering hybrid and takes 107 days to first floret opening after planting. Floret colour is red purple group (72B). Highly suitable for cut flowers, bouquet preparation, garden display/ kitchen garden, floral arrangement and landscaping as well.

A field view of Pusa Unnati

2.3.3 Chrysanthemum

Promising genotypes. One selection, Chrysanthemum Pink obtained from open pollinated population of cv. Jaya was found promising. It bears semi double flowers (6.2 cm dia.) with pink ray florets and prominent yellow disc. It is a late variety, blooming from mid-December to January. It is suitable for spray and pot culture. Another selection Chrysanthemum-Little Orange obtained from cv. Lalpari having plants height of 65 cm with a good spread of 50 cm also found promising. It bears semi double medium size flowers (3.5 cm dia.) with orange red ray florets and yellow disc. The plant is very sturdy and does not require staking. It is a no pinch no stake type suitable for spray and pot culture.

Chrysanthemum Pink

Chrysanthemum Little Orange

2.3.4 Marigold

Variety identified. The marigold variety Pusa Bahar flowers in 90-100 days after sowing. The plants are vigorous, attaining a height of 75-85 cm. It produces compact, flattened, attractive and large size (8-9 cm) flowers of yellow colour. The variety is very floriferous producing on an average 50-60 flowers per plant. The main flowering time is mid-January to March in northern plains. It was identified by IARI Variety Identification Committee.

2.3.5 Promising Genotypes for Ornamental Potted Plants

Twelve species/varieties of different potted plants were studied under open, glasshouse, 30% shade net and 50% shade net for their growth and development under Delhi conditions. The genotypes, Zamia Palm, *Araucaria*, *Syngonium* and *Dracena marginata* performed well under open conditions. However, Zamia palm, China palm, *Dracena marginata*, *Dracena variegata*, *Philodendron xanadu*, *Araucaria cookie* and cordyline performed well under 50% shade net while species like Areca Palm, Zamia palm, China palm, *Dracena marginata, Dracena variegata* and *Philodendron xanadu* performed well under 30% shadenet.

2.3.6 Eustoma

At IARI Regional Station, Katrain, 12 Eustoma hybrids/varieties were introduced and evaluated for their suitability for cut flower production under mid Himalayan region. The maximum stem length was recorded in Echo Double Champagne (55.4 cm) followed by Echo Double Blue (52.3cm), Echo

Promising genotypes of Eustoma ideal for cut flower production at IARI, Regional Station, Katrain

Double Pink (49.1cm). Eustoma hybrid Echo Double Lavender produced the maximum (15.2) number of flower buds per plant followed by Echo Double Blue (14.7). The maximum flower size (8.6 cm) and vase life (16.0 days) was recorded in Echo Double Blue. Echo Double Blue, Echo Double Champagne and Echo Double Lavender were found promising for cut flower production. Agro-techniques were standardized for commercial cultivation of Eustoma. The optimum time to raise Eustoma nursery was identified as mid to late February. Seed germination was reduced significantly (61.5%) upon covering the seeds with the soil/ germination media. Under glass house conditions, in June transplanted seedlings, the first flush of flowering was harvested in August (58 days) and 2nd flush of flowering appeared in October - November (131 days). The glasshouse grown plants did not show any rosetting and behaved as biennial crop.

2.3.7 Lilium

A study was conducted on performance and impact of different level of harvesting of flower shoot on bulbs and bulblets production of LA hybrid lily cultivars Pavia, Ercolana and Brindisi in Northern plain conditions. The minimum days taken for flowering were observed in cultivar Brindisi (70.10 days) followed by Ercolana (73.10 days) and Pavia (76.82 days). The maximum length of flower shoot (121.06 cm) with diameter (0.851cm) and number of flower buds/shoot (6.13) were recorded in Pavia. The maximum yield of bulbs and bulblets were recorded in disbudding of flowers with harvesting of flower shoot at 40 cm above the ground surface in cultivar Pavia.

Evaluation of varietal performance of LA hybrid lily in northern plains

At IARI Regional Station, Katrain, non - vernalized bulbs of 19 lilium hybrids were evaluated for various vegetative and floral traits under open field. Significantly, earliest flowering was recorded in cv. Cilesta (223.5 days) followed by Best Seller (229.8 days). Plant height was observed maximum in Yellow Ween (110.2 cm) which was found to be at par with Cilesta (100.5 cm) whereas minimum plant height was noticed in Navona (49.4 cm). Inflorescence length was observed maximum in Tresser and Salmon Classic. Interspecific crosses made in 2014 were evaluated for their vegetative and floral traits. Selfed progenies of *Lilium formosanum* took minimum number of days (293.0 days) to flowering from seed sowing followed by KILH 13 x Oriental cv. Siberia (314.0 days). All progenies bear white, single, trumpet shaped flower with mild fragrance.

In order to identify the obligate and non-obligate vernalization requirement segregants of *Lilium longiflorum*, selfed seedlings of *Lilium longiflorum* were transplanted in pots at IARI Regional Station, Katrain. After 10-12 weeks, seedlings of selfed seed lot had many basal leaves arising from below the soil line and some seedlings had elongating internodes with

Non-obligate vernalization requiring (left), and Obligate vernalization requiring (right)

stems emerging above the soil line. Stems continued to elongate until they terminated in at least one flower. Stem emergence of seedlings occurred over five months i.e., from July, 2015 to first fortnight of November, 2015.

2.3.8 Iris

Thirty inter-specific crosses were made among bulbous and rhizomatous Iris. Seed setting was found only in two cross combinations i.e., *Iris himalayana* x *Iris hollandica* and *Iris himalayana* × Iris cv. Eldardo. Seeds of both the crosses germinated in 29 days.

2.4 SEED PRODUCTION OF HORTICULTURAL CROPS

The Division of Vegetable Science, Seed Production Unit, IARI, New Delhi, IARI Regional Stations at Karnal, Katrain, Pune and Pusa (Bihar) produced nucleus, breeder and IARI seed of different horticultural crops. These centres produced 446.5, 4036.5 and 6025.6 kg of nucleus, breeder and IARI truthfully labeled seeds, respectively, of different horticultural crops during the period under report. In addition to seed production, 11104 saplings of fruit trees were also produced in 3 Centres of the School of Horticulture.

Seed production of horticultural crops (kg)

Division/Unit/station	Seed Production (kg)			
	Nucleus	Breeder	IARI-TL	Total
Division of Vegetable Science				
Vegetables	34.00	36.35	619.25	689.60
Regional Station, Karnal				
Vegetables	39.00	2,594.00	1,164.00	3,797.00
Seed Production Unit, New Delhi				
Flowers	-	-	40.80	
Vegetables	250.00	1,245.00	2,106.40	3,601.40
Regional Station, Katrain				
Vegetables	123.51	161.10	2,046.20	2,330.81
Regional Station, Pusa				
Papaya			22.00	22.00
Vegetables			27.00	27.00
Total	**446.51**	**4,036.45**	**6,025.65**	**10,467.81**

Propagation of horticultural crops

Division/Unit/station	Number of saplings
Seed Production Unit, New Delhi	1,493
Regional Station, Karnal	7,441
Regional Station, Pusa	2,170
Total	**11,104**

3. GENETIC RESOURCES AND BIOSYSTEMATICS

The Institute has an active programme for collection, maintenance, evaluation and utilization of germplasm in various crops. A large number of germplasm lines including some wild species were collected, evaluated and maintained as active germplasm and utilized in pre-breeding and genetic enhancement in various crops. The chapter also includes biosystematics and identification services related to fungi, insects and nematodes to explore, conserve and enrich the culture collections.

3.1 CROP GENETIC RESOURCES

3.1.1 Wheat

Maintenance and utilization of germplasm. About 250 diverse accessions of wild relatives from more than 10 species of wheat are being maintained for more than a decade. Some of these accessions are being utilized in alien introgression programme. Several introgression lines derived from *Aegilpos markgrafii*, *Ae. speltoides* and *Triticum militinae* were cytologically stabilized and evaluated for rust resistance. A total of 1800 indigenous and exotic genetic resources were rejuvenated through planting and evaluated for different traits.

Pre-breeding and handling of segregating materials. A total of 2800 early segregating and advanced breeding lines of wheat were evaluated for rust resistance and agronomic features at rust hot spot, Dhaulakuan, of which 1706 were selected as part of the process of developing superior breeding lines. Besides, 1584 segregating plants representing to 66 diverse crosses of wheat were selected for advancing to next generations.

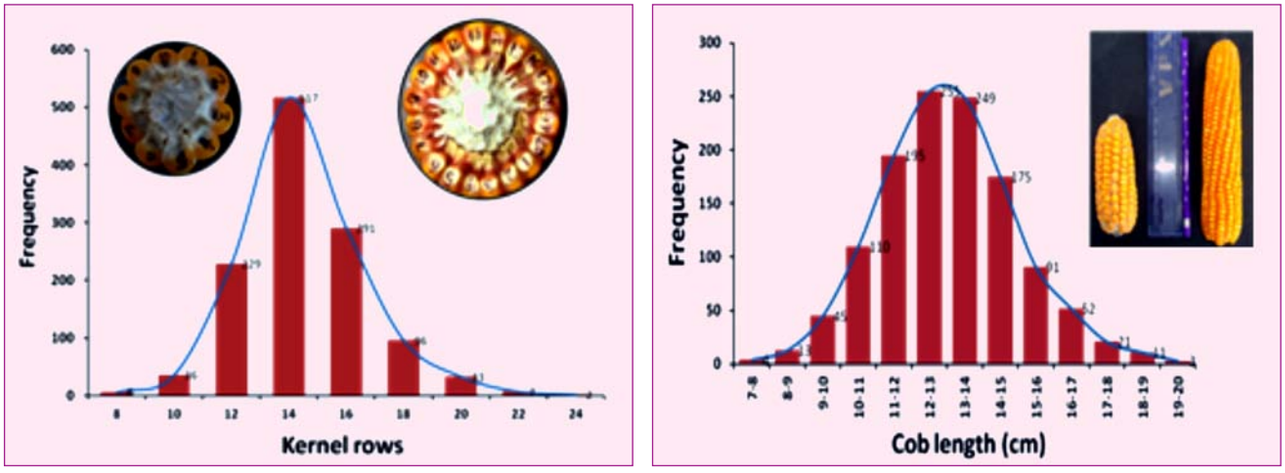
3.1.2 Rice

Characterization for protein, iron and zinc content in rice germplasm. A total of 225 rice accessions were analyzed for protein concentration using Kjeldahl method. The protein concentration (g of protein per 100 g of sample) ranged from 3.43 (CN 1268-7) to 10.87 (Uphar). In addition, they were analyzed for iron and zinc concentration in brown rice and polished rice through energy dispersive X-ray fluorescence spectroscopy. Iron concentration ranged from 6.5 ppm (Jayati) to 23.1 ppm (Sah Pasand) in brown rice and 0.7 ppm (Lout Anzoul) to 12.3 ppm (IC 2127) in polished rice. Zinc concentration ranged from 13.6 ppm (HUR36) to 46.2 ppm (Karuppu Nel) in brown rice and 8.2 ppm (Sagar Dambha) to 40.9 ppm (Karuppu Nel) in milled rice. Mapping populations will be generated for the identification of QTLs governing high iron and zinc.

Assessment and utilization of wild species of rice. A total of 85 *O. rufipogon* accessions were assessed for the presence of the restorer/ maintainer allele based on candidate gene based markers for two gene governing fertility restoration in WA cytoplasm, namely, *Rf3* and *Rf4*. Based on the analysis, the accessions were grouped into different groups, out of which 16 were found to possess restorer allele for both the genes. A set of 9 new crosses have been attempted with different *O. rufipogon* accessions for parental line diversification.

3.1.3 Maize

Variation in component traits of yield. A set of 1500 newly developed inbreds were characterized for their cob traits. Huge genetic variability was identified for cob length, kernel rows, kernel weight and cob girth. The variation for kernel rows/cob was ranging from 8 to 24 rows and for cob length, it was 8 to 19 cm. Mapping populations are being developed using contrasting genotypes for those traits to map QTLs.



Genetic variation available in the newly developed maize inbred lines

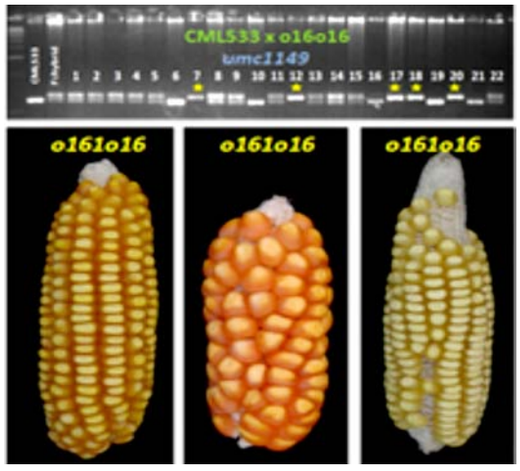
Abiotic stress tolerant genotypes. New set of 60 inbreds were screened for their response to drought and waterlogging at different critical growth stages under drought and waterlogged stress conditions. ML 358, SKV 235, SKV 143 and SKV 239 were identified for waterlogging tolerance. SKV 181, SKV 143, SKV 512, SKV 203, SKV 1072, SKV 613 and SKV 559 were identified for drought tolerance. SKV 143 and SKV 239 have been identified as a source of tolerance for both drought and waterlogging stresses.

Identification of tolerant genotypes under water logging stress based on shoot and root characters

Identification of tolerant genotypes under drought stress based on seedling traits

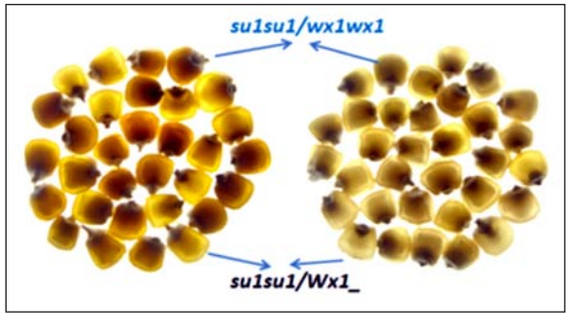
Biotic stress tolerant genotypes. Fifteen inbred lines were identified for resistance against various diseases, viz., the inbreds PDM 56 DIM 101, DIM 316, LM 13, DIM 211, PDM 6507, DDM 301, DIM 208, DIM 304, DDM 314, DIM 345, CDM 341, DIM 310, DDM 309 and PDM 6571 were resistant to both turcicum leaf blight (TLB) and maydis leaf blight with a disease score of less than 2.0 based on two year data.

Development of novel inbreds with opaque16 allele. Four F_1 populations (CML 533 x *o16o16*, CML 537 x *o16o16*, CML 161 x *o16o16* and CML 193 x *o16o16*) were received from Guizhou Institute of Upland Food Crops, GAAC, China. F_2 populations developed at IARI were genotyped by SSR linked to *opaque16* (*o16*) allele. Progenies with *o16o16* and desirable agronomic characteristics have been selected. These are the first set of inbreds with *opaque16* allele developed in India, and available in the breeding programme. These inbreds hold great potential in QPM breeding programme for further enhancement of lysine in endosperm.



Segregation of *opaque16* allele in F_2 population. Cob characteristics of inbreds with *opaque16* allele

Novel genotypes with sugary1 and waxy1 allele. *Sugary1* (*su1*) and *waxy1* (*wx1*) are the important genes that regulate starch biosynthesis in maize. Recessive *sugary1* allele enhances kernel sweetness, while recessive *waxy1* blocks the synthesis of amylose and in turn enhances the synthesis of amylopectin. Two mutant inbreds, (i) *su1su1* and (ii) *wx1wx1* were crossed, and F_2 seeds were developed. Seeds having *sugary* phenotype were separated, and seeds with *su1su1/wx1wx1* were identified on light box. The segregants with both mutant alleles are novel, and hold promise in specialty corn breeding programme.



Segregation of waxy 1 allele in sugary1 background

Genetic resources for nutritional quality and specialty traits. Promising germplasm/genotype/ inbreds with *crtRB1*, *lcyE* (for provitamin A), *opaque 2*, *opaque 16* (for QPM), *VTE 4* (for vitamin E), *sh2*, *su1*, *sh2/su1* (for sweet corn), wx1 (for waxy), *lpa1*, *lpa2* (for low phytate) and CMS-system (for male sterility) have been maintained.

3.1.4 Pearl Millet

Maintenance of germplasm. A total of 1091 germplasm lines of pearl millet including cytoplasmic male sterile lines, maintainers and restorers are being maintained at IARI. The traits include early flowering, high tillering, thick spike, bristled spike, long spike, variations in compactness of the spike, grain colour, etc.

3.1.5 Chickpea

Germplasm tolerant to dry root rot disease. Two advanced generation breeding lines, BG 12-119 and BG 14-14 and two varieties KAK 2 (*Kabuli*) and K 850 (*Desi*) were found to be tolerant to dry root rot caused by *Rhizoctonia bataticola.*

Screening of chickpea genotypes for dry root rot tolerance in sick pots

Phenotyping a diverse set of chickpea genotypes for drought tolerance parameters. A diverse set of genotypes were evaluated for different traits under normal and stressed environments. There was a reduction in all the traits in drought environment compared to that of normal environment. The maximum reduction was observed in number of filled pods per plant (15.9%) followed by number of seeds per plant (14.9%) indicating relatively higher sensitivity of these traits to terminal drought. Drought susceptibility index (DSI) for seed yield ranged from 0.24 to 2.69 with an average value of 1.11. The highest DSI was recorded for variety GLW 91(2.69) and the lowest (0.27) for ICC 4958. These genotypes possessed different physiological mechanisms to cope up with the effect of drought and hence providing

ample opportunities for breeding to combine them together for developing drought tolerant genotypes. The genotypes L 550, Pusa Green 112 and ICC 92944 have shown higher mean values for yield and other associated characters like lower DSI, higher harvest index, higher biomass yield and grain yield. Characters like seed yield per meter row under terminal drought condition exhibited significant positive correlation with number of primary branches, number of secondary branches, biological yield, harvest index, root length and relative water content that can be used for selecting genotypes with specific adaptation to drought stress.

Pre-breeding to broaden the genetic base of chickpea using land races from West Asia and North Africa (WANA) region. Fifteen F_1s involving Indian germplasm and wild species / land races were produced. Also, 15 advance backcross lines involving Pusa 256 x *C. echinospermum* (BC_2F_6) were evaluated. BC_2F_3 lines of Pusa 5023 x Gokcee cross were generated (20) for transfer of drought tolerance from Gokcee to Pusa 5023. Landraces and wild species from WANA region have also been identified as donors for early flowering (IG 5884, IG 5851), early maturity (IG 5860, IG 5843), high (50 g and above) 100-seed weight (IG 6003, IG 5982), high yield per plant (IG 5862, IG 5858) and high Membrane Stability Index (ILWC 118, ICC 17207, ILWC 21).

3.1.6 Pigeonpea

Two hundred ninety germplasm lines (50 lines for Wilt, 98 for SMD and 142 for *Phytopthora* blight resistance) received from ICRISAT were evaluated with respect to disease resistance. Male sterile lines of medium duration (along with their maintainers), restorers and 18 wild species were procured.

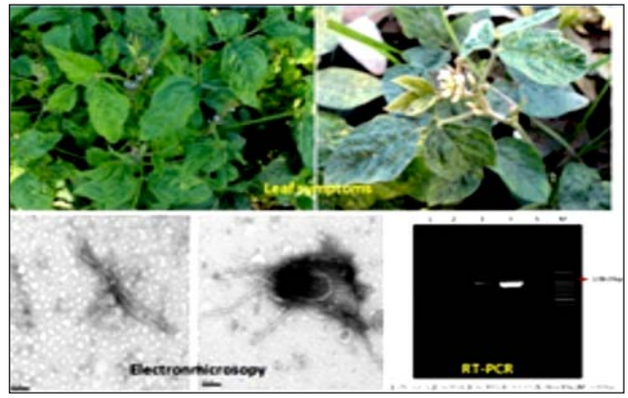
3.1.7 Oilseed *Brassica*

Maintenance of germplasm. A total of 762 germplasm lines including *B. juncea* (457), *B. carinata* (170), *B. napus* (31), *B. rapa* (44), *B. oleracea* (6) *B. nigra* (12), *B. tournifortii* (2), *B. caudatus* (1), *R. caudatus* (4), *R. sativa* (1), *S. alba* (1), *Eruca sativa* (6), *Crambe* spp. (2), *Lapidium* spp (1), *Camellina* spp. (1) and wild species (23) have been maintained by selfing and used in crossing programme. Seventeen new accessions for earliness, dwarf plant type, long siliquae and high siliquae density were added.

Breeding for white rust resistance. Breeding material (F_3, F_4 and BC_2F_3) generated by crossing popular varieties of Indian mustard with white rust resistance donors like Bio-YSR, BEC 144, BEC 286, Heera and EC 399299 was screened for white rust resistance during off-season at IARI Regional Station, Wellington. Two hundred forty seven single plant progenies showing immune to resistant reaction to white rust were raised during main season and 144 single plants have been selected from 67 progenies showing resistant reaction to white rust.

3.1.8 Soybean

Screening and identification of resistance sources against Cowpea mild mottle virus disease in soybean. A distinct strain of Cowpea mild mottle mosaic virus (CPMMV) infecting soybean was reported from India in 2013. One hundred thirty three genotypes were screened and three sources of resistance against CPMMV in soybean were identified. The resistance was confirmed by sap inoculation and the presence of the virus was also confirmed through RT-PCR by designing primer specific to coat protein gene and NaBp of CPMMV. The virus was confirmed through electron microscopy. Three genotypes DS 12-5 (19.08%), SL 958 (20.18%) and SL 900 (20.54%) were



CPMMV symptoms, gel showing CPMMV specific primer and electron micrographs of CPMMV

identified as moderately resistant. On Sap inoculation, these lines did not develop any mottling symptoms whereas the susceptible genotype (JS 335) showed severe symptoms of leaf mottling.

3.1.9 Vegetables

Cauliflower. In early group, 46 fertile inbred lines were evaluated, maintained and used for hybrid development. Ten SI lines, namely, cc12, 13, 14, 15, vv, ccM, 327-14-8-3, 395aa, 351aa and xx were assessed for curding ability, tested for SI level and selected plants were multiplied through bud pollination. *Ogura* CMS system established in three genetic backgrounds (Pusa Meghna, DC 41-5 and DC 23000) was maintained and used in hybrid development. In total, 69 inbred lines were evaluated for horticultural traits, field reaction to diseases (downy mildew, black rot, alternaria blight and *Sclerotinia* rot) and maintained by sib and bud pollination. Besides, eight new CMS converted lines were used in hybrid development. Characterization of 43 CMS lines in cauliflower along with their maintainers was done using 13 morphological characters of flowers.

In mid-early maturity group, 7 SI lines, namely, cc 32, cc 35, cc 22, ccm 5, ccm 8, ccm & cc were assessed for curding ability, tested for SI and advanced through bud pollination. Sixty eight inbred lines were evaluated, maintained and promising inbreds were used for hybrid development. Ogura CMS system established in three genetic back grounds was evaluated, maintained and exploited in hybrid development.

In mid-late group, Ogura CMS system established in two genetic back grounds was evaluated, maintained and used in hybrid development. CMS conversion continued into 18 new genetic back grounds. Individuals of advance generations of 55 RILs for black rot were evaluated for disease and horticultural traits and advanced to next generation.

In snowball cauliflower, 105 lines along with 15 CMS lines and their maintainers were maintained as core set of germplasm.

Cabbage. Two CMS lines of 'no-chill' cabbage were maintained and conversion process of four lines of tropical 'no-chill' cabbage into CMS lines was continued by backcross. The CMS lines were characterized using 13 morphological characters. At IARI Regional Station, Katrain, 130 germplasm of cabbage received from NBPGR have been characterized and about 50 already available germplasm lines of cabbage along with 8 self-incompatible lines, 15 CMS lines and their respective maintainers have been maintained.

Broccoli. At Katrain, 15 germplasm and 5 CMS lines along with their maintainer lines were purified and maintained.

Bitter gourd. A total of 51 genotypes were evaluated for yield and earliness traits. The gynoecious lines, PVGy 201 and PDMGy 201 were found superior for first female flower appearance and first fruit harvesting which indicates their earliness and early fruit harvest. The genotype Sel 51 has recorded highest yield per plant. Out of 30 genotypes, 4 genotypes evaluated under protected conditions (net house) the genotypes DBGS 32-1 and BBGS 57 were found promising and produced 386 and 370 kg fruits per 100 sqm, respectively.

Cucumber. A total of 65 germplasm with novel traits consisting of gynoecious lines, carotene rich cucumber, *Cucumis hytivus* disease resistant lines, parthenocarpic and gherkin types, *Cucumis sativus* var. *hardwickii* and multiple pistillate types collected from NBPGR and other sources were maintained and utilized in the breeding programme.

Luffa. Sixty and 55 germplasm/advance breeding and virus resistant lines of sponge gourd were evaluated during spring summer and *Kharif* season, respectively and promising lines were maintained. In ridge gourd, 32 and 46 advance breeding lines including Satputia and its genetic stock were evaluated during spring summer and *Kharif* season, respectively and promising lines were maintained. A gynoecious genetic stock of ridge gourd was developed which segregates into gynoecious and hermaphrodite (Satputia) in the ratio of 1:1 and maintained by sibbing utilizing Satputia as pollen parent.

Pumpkin. Seventy five germplasm/ advanced breeding lines of pumpkin were evaluated and maintained.

Muskmelon and watermelon. One hundred seventy three lines of muskmelon and related species were evaluated and maintained. One hundred six exotic lines of watermelon and related species were evaluated and maintained.

Long melon and Round melon. Twenty two and twenty germplasm/ advanced breeding lines of long melon and round melon, respectively, were evaluated and maintained. Long melon line DLM 19-2 with segmented leaf was maintained.

Brinjal. One hundred fifty one working germplasm lines were evaluated and maintained. Fourteen wild species including 9 exotic wild accessions from AVRDC, Taiwan were grown for seed regeneration and characterization.

Sweet Pepper. Twenty five new accessions of different *Capsicum* spp. obtained from USDA were evaluated, characterized and maintained for various horticultural traits. Fifty germplasm lines of sweet pepper were purified and maintained. Three CMS lines along with their maintainers of sweet pepper were purified and maintained.

Carrot. Inbred lines of early season (21) and normal season (58) carrot were evaluated and maintained. One hundred five accessions (from NBPGR) were evaluated for their root traits and multiplied by selfing for further use. Also maintained 5 CMS lines in early group and 11 CMS lines in normal season and used for hybrid development using twelve promising fertile inbreds. Forty six germplasm lines and 26 CMS lines along with their maintainers were maintained at IARI Regional Station, Katrain.

Onion. An exploration trip to Leh, Ladakh, J&K was undertaken during August, 2015 and 28 accessions of onion and related wild spp. were collected. These wild species are being maintained at NBPGR, Bhowali for further utilization. In addition to this, 31 accessions comprising of onion, garlic and wild species were collected from Central Asian countries (Uzbekistan, Kazakhstan, Krygyztan and Tajikistan) and have been sent to NBPGR, Bhowali and CITH, Srinagar for maintenance. This material will be used for screening against insect- pests, diseases and other breeding traits.

Wild species collected from Ladakh, J&K: (a) *Allium* spp., (b) *A. schoenoprasum*, (c) A. *cyathophorum* and (d) *A. prszewalskianum*

Fifty two commercial varieties, 191 onion germplasm and 383 lines comprising of first generation inbreds and F_1's were planted for seed production. All the varieties developed by IARI (Pusa Red, Pusa Riddhi, Pusa Madhavi, PWF, PWR, Sel 126, Early Grano) were planted under isolation in open field conditions for seed production to maintain the varieties.

Garden pea. Thirty germplasm lines of garden pea were evaluated for wilt and powdery mildew diseases and maintained the resistant lines.

Okra. One hundred forty cultivated and 21 wild accessions of okra were maintained.

Lettuce. Forty four lettuce germplasm lines were evaluated and maintained. Out of these, 3 are Iceberg/ heading type, 7 butter head, 28 loose leaf, 4 cos or romaine and 2 stem lettuce types.

Minor leafy vegetables. Twenty lines of *Chenopodium*, 6 lines of *palak*, 5 lines of spinach, 14 lines of fenugreek and 23 lines of *Amaranth* were maintained.

3.1.10 Fruits

Six polyembryonic germplasm lines of mango, i.e., Indonesia, Latra, Chandrakaran, Moovandam, Peach and Mylepelian were introduced and grafted on rootstock. *Mangifera odorata* and *M. sylvatica* were collected from HETC, Saharanpur with the objective to utilize them in hybridization programme. Besides, germplasm, namely, Jahangir, Husanara, and Elaichi were also introduced during the period. Scion sticks of mango germplasm (33) were brought from Gangian, Punjab; HETC, Basti and Sharanpur and IIHR, Bengaluru, and grafted on seedling rootstocks.

3.1.11 Ornamental Crops

Rose. Three new varieties (Fire Fighter, Snow Winter and Sweet Surrender) were collected. The species *Rosa banksiae* was collected from Katrain.

Gladiolus. This year, seven new cultivars were collected from IIHR, Bengaluru and PAU, Ludhiana and planted for evaluation. The cultivars collected are: Arka Aayush, Arka Sindur, Arka Sapna, Arka Sagar, Arka Nazrana, Arka Shakti and Punjab Gold. Besides, twenty five varieties/hybrids of gladiolus are being maintained and used for crop improvement programme at Regional Station, Katrain.

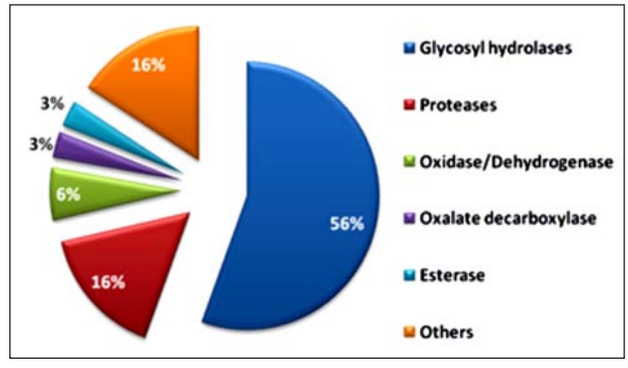
Other flower crops. Forty five cultivars of Lilium, 3 species of Lilium (*Lilium lancifolium, L. formosanum, L.longiflorum*), 15 Eustoma hybrids/varieties , 25 varieties of Tulip, 22 varieties of Narcissus, 22 varieties of iris, 23 varieties of dahlia, 12 varieties of Alstroemeria, Accidenthera bicolor, and other bulbous crops like, torch lily, wattsonia, canna, Amaryllis, Freesia, cyclamen, zinger lily, Lycoris, primula, primrose, temperate orchids and some wild ornamentals are being maintained and used for crop improvement programme at the Regional Station, Katrain.

Turf grasses. Five new turf grasses viz., St. Augustine variegated, Zoysia grass (*Z. japonica, Z. materella*), Crow foot grass and Bermuda grass (variant TNAU) were collected and added to the germplasm during the year.

3.2 MICROBIAL GENETIC RESOURCES

3.2.1 Extracellular Proteome Profiling of *A. terreus*

Extracellular proteome profiling of *A. terreus* CM20 using liquid chromatography coupled tandem mass spectrometry (LC–MS/MS) identified 63 proteins. Functional classification revealed the hydrolytic system to be composed of glycoside hydrolases (56%), proteases (16%), oxidases and dehydrogenases (6%), decarboxylases (3%), esterases (3%) and other proteins (16%). Twenty families of glycoside hydrolases (GH) (1, 3, 5, 7, 10, 11, 12, 15, 16, 28, 30, 32, 35, 43, 54, 62, 67, 72, 74 and 125), and one family each of auxiliary activities (AA7) and carbohydrate esterase (CE1), were detected, unveiling the vast diversity of synergistically acting biomass-cleaving enzymes expressed by the fungus.



Functional classification of proteins detected in the *A. terreus* CM20 secretome using LC-MS/MS

3.3 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.3.1 Pathogens

Maintenance and preservation of fungal specimens/cultures. About 50,198 fungal specimens at HCIO; 3952 fungal cultures representing Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina at ITCC were maintained under different preservative methods. An Attempt has been initiated to revise the taxonomy of several fungi such as *Chaetomium* spp. and *Penicillium* spp. The fungal

collection was enriched by new addition of 98 fungal diseased specimens at HCIO and 48 different fungal cultures at ITCC. In all, 375 authentic fungal cultures and 45 bacterial cultures were supplied on payment to various scientific and industrial institutions on request. A total of 288 cultures /specimen were identified up to species level. Mostly these are plant pathogens, post harvest pathogens, bio-control agents and industrial use fungi belong to Hyphomycetes followed by Coelomycetes and Zygomycetes.

HCIO specimens of *Cercospora* (1278 specimens), *Alternaria* (272 specimens) and *Helminthosporium* (148 specimens) were compiled with scanned images, passport data and taxonomic descriptions. Nine species of *Chetomium* were digitized along with the taxonomic descriptions.

DNA Barcoding of fungi. Forty four isolates identified through ITS sequences were selected for multigenes viz., actin, β-tubulin, calmodulin, rpb2 and tef-sequence based analysis. The comparative analysis of six regions sequence data revealed that even though the grouping of *Chaetomium* species was better using ITS region but the barcode gap and PCI were lesser compered to β-tubulin and rpb2. So the ITS region was selected as primary barcode as it resulted in best identification and grouping of *Chaetomium* species., but due to less barcode gap and PCI, a secondary barcode β-tubulin was proposed. A new project on Indian *Chaetomium* (CITCC) has been initiated at BOLD (Barcode of life database) and the sequences of primary barcode (ITS) of *Chaetomium* species were submitted in CITCC and the barcode was obtained.

3.3.2 Insects

Hymenoptera. An annotated checklist of genus *Andrena* of India was compiled from all the published literature available on *Andrena* for the last three and a half centuries. An in depth analysis of the checklist revealed that *Andrena* is represented in India by 23 subgenera and 54 species including the three new species described during the present studies. All the available synonyms have been included. Distribution of subgenera and species has been included along with several new records . Species of this genus were found to be distributed in the states of Rajasthan, Punjab, Himachal Pradesh, Gujarat, Uttarakhand, Uttar Pradesh, Bihar, Jammu and Kashmir and Delhi.

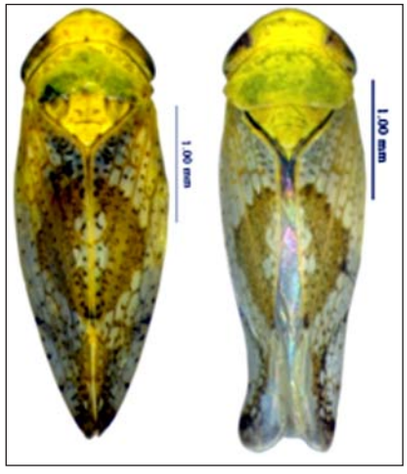
Coleoptera. Surveys were carried out in 21 locations covering three districts in seven states for white grub species diversity. Egg external morphology of eight species viz., *Holotrichia serrata, Holotrichia reynaudi, Miridiba* sp., *Anomala elata, Anomala polita, Anomala ruficapilla, Anomala varicolor* and *Anomala varivestis,* belonging to Melolonthinae and Rutelinae were studied through light microscopy and Scanning Electron microscopy. The egg morphometrics and chorionic ultrastructures of each species were documented and described.

Larval characterization of seven white grub species viz., *Holotrichia fissa, Lepidiota stigma, Lepidiota albistigma, Phyllognathus dionysius, Anomala polita, Anomala ruficapilla, and Anomala varivestis* were carried out and described through 126 line drawings and 126 photographs. This is the first documentation of larval descriptions of these scarab species.

DNA barcoding of seven species viz., *Holotrichia reynaudi, Holotrichia fissa, Phyllognathus dionysius, Anomala anguliceps, Anomala bilobata, Anomala elata* and *Anomala ruficapilla* of Melolonthinae was carried out through partial mt co1 sequencing and sequences submitted to NCBI. Scanning electron microscopy studies of antennal sensilla were carried out in six species of Melolonthinae viz., *Holotrichia serrata, H. nagpurensis, H. consanguinea, Lepidiota mansueta, Leucopholis lepidophora* and *L. burmeisteri* and documented the type, distribution and density of mechanoreceptors and chemoreceptors in both the sexes. Studies on gut anatomy of two species viz., *Lepidiota mansueta* and *Maladera insanabilis* were carried out.

Diptera. Survey and collection were carried out in seven locations and collected more than 200 specimens of Syrphidae belonging to 32 different species of ten genera.

Hemiptera. Survey and collection were carried out in 14 different locations in IARI, New Delhi, Punjab, Haryana, Karnataka and Meghalaya. Revision of genus Maiestas completed with redescription, checklist and key for 15 species. Two new species of *Hishimonus* described from Himachal Pradesh and Uttarakhand, India. Two new species of genus *Webbolidia* discovered from India.



***Hishimonus nauniensis* sp. nov. *Hishimonus pantanagarensis* sp. nov.**

Lepidoptera. Survey and collection were carried out at 7 different locations, and 830 specimens samples were collected and processed during the year. Checklist of Genus *Leucania* from India prepared, which includes 4 subgenera and 19 species. New report of species *Oeonistis altica* (Linnaeus, 1768) (Erebidae: Arctiinae: Lithosiini) from Arunachal Pradesh, India. *Mythimna obscura* (Moore) a new record to western Himalaya. DNA barcodes of *Tuta absoluta* was carried out through partial mtCOI sequencing and sequences submitted to NCBI (KP814055-57).

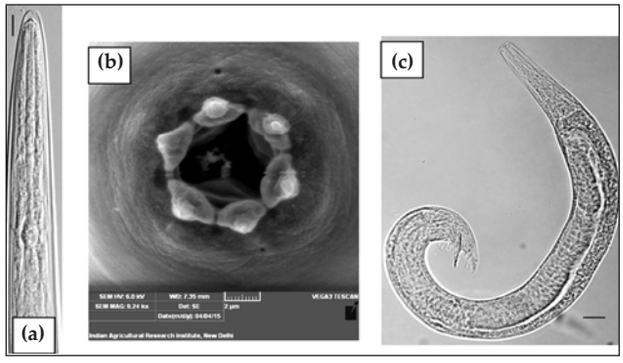
Male **Female**

***Mythimna obscura* (Moore)**

3.3.3 Nematodes

Nematode taxonomy. ITS based molecular identification was carried out for eight isolates of *Meloidogyne graminoicola* collected from all over the country, and they were confirmed as various populations of *Meloidogyne graminicola*. A strain of *Heterorhabditis* was isolated from extreme cold desert condition of Leh Ladakh, Jammu and Kashmir, India and named as L 22. Studies using morphological, morphometric and molecular methods suggested that *Heterorhabditis* L 22 strain was close to *H. bacteriophora.* The symbiotic bacteria in L 22 strain was identified as *Photorhabdus luminescens* ssp. *laumondii*. Presence of this subspecies of bacteria has only been reported in *H. bacteriophora*. Comparisons of Cox1 and partial rDNA sequences with other species also suggested it to be an unreported species and both morphological and morphometric characters indicated *Heterorhabditis* L 22 strain to be a new species.

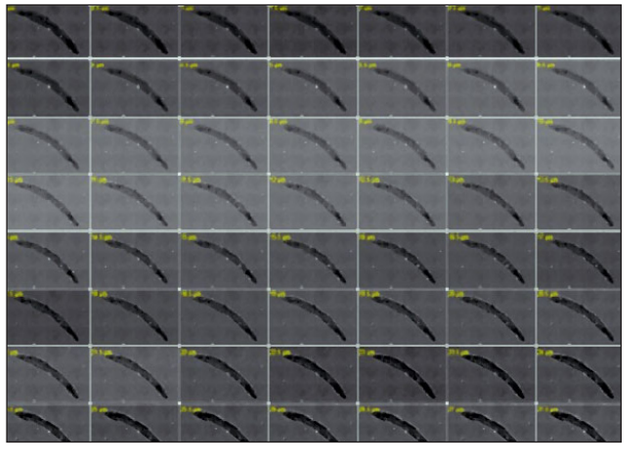
Diversity studies of plant parasitic nematodes in the rhizosphere of the mango and guava at IARI revealed the presence of seven species of plant parasitic nematodes viz., *Helicotylenchus indicus, Hemicriconemoides strictathecatus, Rotylenchulus reniformis, Hoplolaimus indicus, Mesocriconema sphaerocephala, Tylenchorhynchus mashhoodi* and *Tylenchulus semipenetrans*. Amongst the plant parasitic nematodes in mango orchard *H. strictathecatus* was in highest numbers followed by *H. indicus* while that of *T. mashhoodi* was least. *M. sphaerocephala* was recorded for the first time on guava and mango. In guava, *H. indicus* was having maximum density followed by *H. strictathecatus* and *Hoplolaimus indicus.* Comparison of morphometric characters of different nematode species with original description of species along with subsequent reports of the same species indicated new range of variations in the morphometric characters of *H. strictathecatus* and *Hoplolaimus indicus*. Host specific variability in the morphometric characters of nematode species was also found. Additionally, finer morphological details of *Hoplolaimus indicus, Helicotylenchus indicus* and *H. strictathecatus* were studied using the Scanning electron microscope. The sequencing of internal transcribed spacer (ITS)



***Heterorhabditis* L 22 strain. a) Infective juvenile (bar=10µm); b) *En face* view showing six labial papillae of hermaphrodite, and c) male (bar=20µm)**

also confirmed the citrus nematode, *Tylenchulus semipenetrans* from the rhizosphere of guava.

Digitization of type specimens of National Nematode Collection of India has been undertaken to develop digital images for providing online access of the various nematode descriptions. Presently, digitisation of 128 specimens belonging to 93 type species has been completed using programmable motorized Axioimager microscope employing 63x oil objective at 0.5µm depths. This is done by taking several thousand images which are stitched together to get an image of the entire worm.



Digitization of National Nematode Collection of India

4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

Efficient crop and resource management (seed/soil/water/nutrients/agro-chemicals/energy/machinery, etc.) for higher productivity, food quality, profitability and environmental sustainability are challenging tasks. These issues were adequately addressed through research programmes in various divisions in the School of Crop and Natural Resource Management. Efficient management of crops and resources under various cropping systems in conventional and conservational mode have been the major focus to develop scale neutral, low-cost, climate resilient and practically feasible farm technologies. Standardization and validation of efficient input management technologies, resource conservation technologies, irrigation and moisture management, biofertilizer and residue recycling technology, precision agriculture, soil health and soil quality management practices, food quality and post-harvest management, farm machinery, energy management and budgeting, remote sensing and resource inventorization, genotype × environment compatibility as well as value addition interventions, have been the leading research priorities of the School of Crop and Natural Resource Management. The effective management of rhizospheric diversity, crop husbandry, farm mechanization and post-harvest management of field crops, vegetables, fruits, flowers and agri-horticultural based productions systems got special attention in the research curriculum. Development of new farm machinery, resource conservation technologies, GHGs emission and its mitigation practices, climate smart agricultural practices, and food biofortification, beneficial microbes/ consortia/biofilms, precision farming and monitoring techniques ,etc. by this School have given new dimensions and strength to the research and technology development of IARI. Impact assessment of different agricultural management options in changing climate scenario have been also studied and documented.

4.1 AGRONOMY

4.1.1 Conservation Agriculture (CA) for Sustainable Crop Production and Resource Use in Wheat-Based Cropping Systems

To diversify the rice-wheat cropping system, a study was carried out for six consecutive years in, cotton-wheat (C-W), pigeon pea-wheat (P-W) and maize-wheat (M-W) with suitable conservation agriculture (CA) practices, namely, zero-till (ZT) permanent narrow bed (70 cm), ZT broad bed (140 cm) and ZT flat bed with both seasons crop residue. Among these cropping systems, C-W system was found superior to P-W and M-W systems in terms of

System productivity and net returns in wheat-based cropping systems with CA practices

CA practice	System productivity (t/ha)			Net returns (₹ thousand /ha)		
	C-W	P-W	M-W	C-W	P-W	M-W
CT flat bed	12.25	10.06	8.81	127.2	125.1	111.2
ZT narrow bed	13.72	10.22	8.65	154.9	126.9	113.3
ZT narrow bed with residue	14.74	10.87	9.45	158.4	127.2	112.9
ZT broad bed	13.72	10.84	9.06	149.0	126.9	116.8
ZT broad bed with residue	14.88	11.15	9.55	159.0	126.3	113.8
ZT flat bed	13.35	9.81	9.01	145.6	125.7	117.9
ZT flat bed with residue	13.99	10.81	9.67	146.6	125.6	120.2
LSD (P ≤ 0.05)	0.72	0.56	0.43	4.7	3.2	2.6

system productivity and net returns. Crop residue retention during both seasons was superior to no residue treatment in all establishment methods. ZT permanent broad bed (PBB) with residue resulted in 2.63 tonnes higher system productivity and 25% higher net returns in C-W system over conventional till (CT) flat bed. Zero-till PBB with residue resulted in significantly higher SOC at 0-5 cm soil layer and saved almost 25% N application to both crops. C-W system under ZT PBB with residue out-performed the conventional rice-wheat system.

4.1.2 Conservation Agriculture in Rice-Mustard Cropping Systems for Enhanced Productivity and Resource-Use Efficiency

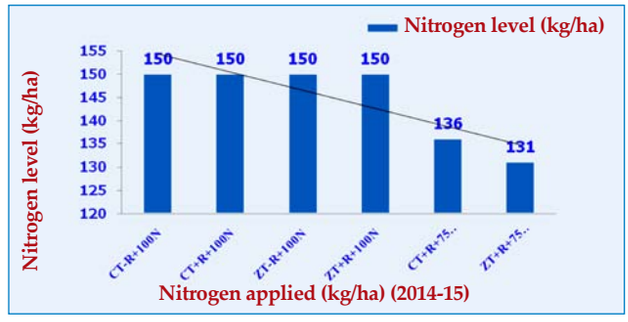
A study was carried out for four consecutive years to replace conventional transplanted rice (TPR) with direct seeded rice (DSR)-mustard system, involving CA practices. Results show that ZT DSR-summer mung bean (SMB) residue retention-rice residue (RR) retention in ZT mustard (ZTM) – ZT summer mungbean (SMB) results in higher system productivity and net returns over conventional TRP- CTM (Conventional tilled mustard) system. This treatment gave higher system water productivity than TPR-CTM or ZTM. This resulted in a considerable improvement of SOC, and total N in the surface (0-5 cm) soil and showed a considerable reduction in global warming potential (GWP) through reduction in methane emission from rice field. Therefore, it may be visualized that such CA based crop production strategy may provide more adaptation and mitigation to climate change.

System productivity and returns in rice-mustard cropping system with CA practices

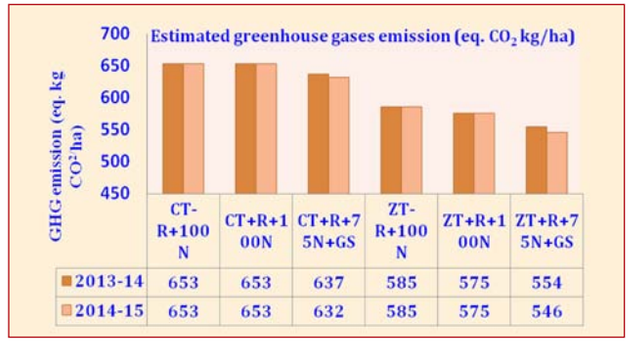
Treatment	Net returns	
	Systems rice equivalent yield (t/ha)	(₹thousand /ha)
ZTDSR – ZT mustard (ZTM)	8.38	74.4
ZTDSR - ZTM + rice residue (RR)	9.58	86.8
ZTDSR + brown manuring (BM) –ZTM	8.93	79.9
ZTDSR + BM –ZTM + RR	9.88	89.9
Mungbean residue (MBR) + ZTDSR –ZTM – ZT SMB	11.84 (2.40) REM	107.3
MBR + ZTDSR – ZTM + RR - ZTSMB	12.49 (2.60)	112.6
TPR – ZTM	9.89	81.7
TPR – CTM	9.89	79.8
LSD (P ≤ 0.05)	0.66	11.2

4.1.3 Conservation Agriculture for Improving Soil Health and GHGs Mitigation

A study comprising of CT without residue + 100% N (based on soil test value) (CT-R+100% N), CT + 5 t/ha maize residue incorporation + 100% N (CT+R+100% N), CT + 5 t/ha maize residue incorporation + 75% N + the rest N based on Green Seeker (CT+R+75% N+GS), ZT without residue + 100% N (ZT-R+100% N), ZT + 5 t/ha maize residue retention + 100% N (ZT+R+100% N) and ZT + 5 t/ha maize residue retention + 75% N + the rest N based on Green Seeker (ZT+R+75% N+GS) was carried out to evaluate the effect of conservation agriculture on soil health and GHGs emission in wheat. It was observed that the zero tillage + 5 t/ha maize residue retention + 75% N + the rest N based on Green Seeker (ZT+R+75% N+GS) resulted in saving of N to the extent of 19 kg/ha as compared to CT wheat. ZT with residue helped in moderating soil



Amount of N saving by Green Seeker based N application in wheat



Estimated greenhouse gases emission from wheat due to tillage, residue and N use (using Info RCT model)

temperature by protecting crop from adverse effect of low temperatures during germination as well as high temperature during reproductive phase. ZT+R+75% N+GS resulted in maximum increase during soil temperature up to the end of February, thereafter caused a decline in soil temperature in March and April. ZT + R + 75N + GS resulted in highest soil moisture retention in wheat at 0-15 cm depth throughout the crop growth stages.. This treatment, also, resulted in reduction in GHG emission by 15% compared to CT plot without residue fertilized with 100% N.

4.1.4 Effect of Different Seedling Age on Seed Productivity and Quality of Rice Variety PB 1509

Different aged seedlings viz., 20, 23, 26, 29, 32, 35 and 38 days old of rice variety PB 1509 raised through staggered sowing of nursery were transplanted in puddled field on July 20, 2015 at Karnal. There was a gradual reduction in panicles/m^2 with increase in seedling age. Number of filled seeds/panicle and seed weight/panicle were significantly higher in 20 and 23 days old seedlings compared to 35 and 38 days old seedlings. An increase of 14.9 and 10.9% in number of filled seeds/panicle and 15.1 and 14.3% in seed weight/panicle in 20 days old seedlings compared to 35 and 38 days old seedlings was noticed. Highest seed yield was recorded with 20 days old seedlings which was 12.7 and 6.0% higher than 38 and 35 days old seedlings, respectively.

4.1.5 Wheat Productivity and Seed Quality as Affected by N and Seed Rates

A field experiment was conducted at Karnal for wheat variety HD 3086 to standardize N levels for variable seed rates. Application of N improved the yield attributes and seed yield of wheat up to 120 kg N/ha. Plant height, length of spike and number of seeds/spike showed increase with increasing N levels, however 1000 – seed weight showed a significant reduction beyond 120 kg N/ha. Highest seed yield was recorded at 120 kg N/ha which was at par with 160 kg N/ha. The optimum economic dose of N was 155.9 kg/ha with a corresponding seed yield of 5478.9 kg/ha and an additional profit of ₹ 35990/ha over no N. Seed yield and yield attributes remained unaffected between different seed rates. Germination of wheat was also not influenced with N doses and seed rates.

4.1.6 Effect of Urea Coating with Zinc and Sulphur on Productivity of *Basmati* Rice Cultivars

A field experiment was conducted to evaluate the effect of different nitrogen levels with 2% zinc and 3% sulphur coated urea compared to prilled urea in three *Basmati* cultivars viz., PB1121, PB1 and PB6 at Karnal. PB1 recorded highest length of panicle, panicles/m^2 and filled seeds/panicle whereas maximum plant height and 1000 – seed weight was recorded with PB 1121. Seed yield with N @75 kg/ha through zinc coated urea was found at par with 100 kg N through prilled urea. The per cent increase of 25.5 and 17.93, and 23.1 and 15.7 in seed yield at 100 kg and 75 kg N through zinc coated urea compared to absolute control (no nitrogen and no zinc) and no nitrogen, respectively was also noticed.

4.1.7 Effect of Foliar Application of Iron and Zinc on Performance of Rice under Rice-Wheat Cropping System

A higher number of effective tillers/m^2 was recorded up to three sprays of $ZnSO_4$ (0.5%) at 50, 60 and 70 days but declined with its 4 splits at Pusa, Bihar. Effective tillers/m^2 increased with increase in number of spray at different stages of growth of rice. Likewise, 4 sprays of $FeSO_4$ (1.0%) at 40, 50, 60 and 70 days increased effective tillers/m^2. The highest grain yield was recorded with $FeSO_4$ (1.0%) sprayed at 40, 50, 60 and 70, days followed by three spray of $ZnSO_4$ (0.5%) at 50, 60 and 70 days.

4.1.8 Effect of Method and Time of Fertilizer Application in Wheat

At IARI Regional Station, Indore, broadcasting of 50% N + 100% of P and K at sowing + 50% N applied in two splits after first and second irrigations recorded highest grain and biological yields of 4.83 and 12.47 t/ha, followed by two splits i.e., basal and 50% N top

dressed before first irrigation (4.66 and 12.38 t/ha). However, when fertilizers were applied as drilled or mixed with seed recorded higher grain yields (4.97 and 4.86 t/ha) under three N splits i.e., N applied as basal and after first and second irrigation.

4.1.9 Effect of Sowing Method and Row Spacing on Wheat

An investigation was carried out at Indore for two wheat sowing techniques viz., sowing after pre-irrigation and dry sowing followed by irrigation and 5 row spacings (15.0, 17.5, 20.0, 22.5 and 25.0 cm). Results revealed that difference in grain yield was not significant in both sowing methods (5.61 and 5.35 t/ha). Maximum grain yield (5.73 t/ha) was recorded with 22.5 cm row spacing which was at par with the 20 cm row spacing, but significantly higher than the rest of the row spacings.

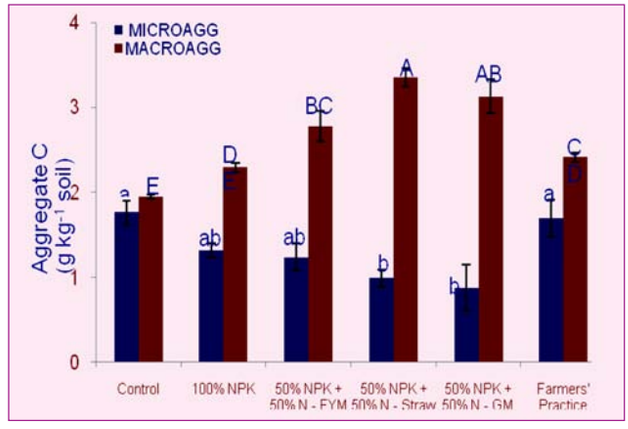
4.1.10 Effect of Method of Sowing and Seed Rate on Wheat

A field experiment was laid out in combination of three sowing methods viz., broadcasting, line sowing and cross sowing and four seed rates viz., 100 kg/ha (SR_1), seed based on 1000 grain weight (SR_2), 25% higher over SR_2 (SR_3) and 50% higher over SR_2 (SR_4) at Indore. Results indicated that grain yields in broadcast (4.70 t/ha) or line sowing methods (4.70 and 4.57 t/ha) were at par but significantly higher over cross sowing (4.27 t/ha). However, trend of biological yield was different and maximum yield was observed with line sowing (14.04 t/ha), followed by cross sowing. However, maximum grain yield was observed with seed applied based on 1000 - grain weight (4.59 t/ha) followed by 100 kg seed/ha and further increase in seed rate gradually decreased the grain yield.

4.2 SOIL MANAGEMENT

4.2.1 Carbon Sequestration, Aggregation and Clay Humus Stability under Long-Term Fertilizer Application and Manuring

Carbon input and carbon sequestration efficiency in Inceptisol under rice-wheat cropping system was evaluated. Results indicated that thirty two years of continuous application of FYM, straw and green manure (GM) that supplemented 50% of fertilizer N, significantly increased soil carbon and aggregate stability and aggregate protected carbon under rice-wheat system in Inceptisol of Ludhiana, Punjab. Total soil carbon (TSC) and total organic C (TOC) were highest in the treatment receiving 50% NPK+50%N-straw, while the total inorganic C (TIC) was highest in the treatment receiving 50%NPK+50%N-FYM. The sharp decrease in microaggregates and concomitant increase in macroaggregates in integrated manuring and fertilization treatments clearly indicated the role of manure in the formation of stable macro-aggregates and enhancing associated C. Glomalin, increased significantly under 50% NPK + 50% N - straw. Clay humus stability was assessed under different treatments of the long-term fertilization experiments (LTFE) at IARI using sequential extraction of humus. It has been observed that the clay-humus stability was related to the non-labile (resistant pool) of carbon. Treatments T_2 (100% optimal NPK), T_3 (150% optimal NPK), T_5 (T_2 + Zn@ 5kg/ha in *rabi*) and T_9 (T_2 + S@ 45 kg/ha) were found to be more effective for stabilizing SOC.



Long-term effect of manuring and fertilization on aggregate associated C in Inceptisol under rice-wheat cropping system

4.2.2 Effect of Application of Amendments on Metal Content in Edible Portion of Crops

Long-term effect of manuring and fertilization on (a) aggregate stability and (b) aggregate associated C

Effect of lime application on the metal content (mg/kg) in edible portion of crops

Treatment	Zn			Cd			Pb		
	Wheat	Spinach	Lentil	Wheat	Spinach	Lentil	Wheat	Spinach	Lentil
Control	107	486	86.2	1.01	8.06	293	0.33	4.38	67.8
Lime @ 12.5 g/kg	84.6	420	80.3	0.77	4.52	147	0.21	3.64	51.8
Lime @ 25 g/kg	79.3	385	75.5	0.57	4.36	140	0.20	3.55	38.5
Lime @ 50 g/kg	75.3	283	60.3	0.27	3.27	95	0.17	2.56	32.9
CD (0.05)	16.1	61.7	7.36	0.22	0.87	33.5	0.07	0.79	9.31

in Inceptisol under rice-wheat cropping system was needed. A greenhouse experiment was conducted to assess the effect of application of different amendments on metal content in edible portion of wheat, lentil and spinach grown on zinc smelter-contaminated soils. Amendments comprised of lime, fly ash, single super phosphate (SSP) and rock phosphate + *Sesbania* at different gradiants were used for study. Results indicated that application of lime was most effective in arresting the transfer of Zn, Pb and Cd in edible portion of wheat, lentil and spinach. Spinach showed the highest metal accumulation efficiency followed by wheat and lentil.

4.2.3 Long Term Impact of Sewage Irrigation on Metal Accumulation in Soil and Rice Grain

A case study was undertaken to assess the risk of sewage-irrigated soils in relation to the transfer of trace elements to rice grain in peri-urban agricultural lands under Keshopur Effluent Irrigation Scheme (KEIS) of Delhi. which have been receiving irrigation through sewage effluents since 1979. Under rice crop, there was also a significant build-up of phosphorus (339%), sulfur (130%), zinc (287%), copper (352%), iron (457%), nickel (258%), lead (136%) and cadmium (147%) in sewage irrigated-soils as compared to that

Effect of long term irrigation with sewage effluents on metals and metalloid content in soils under rice

Plant nutrients, metals & metalloid	Sewage irrigated				Tubewell-irrigated		
	Range	Mean	S.D. (±)	#(%)	Range	Mean	S.D. (±)
Zn (mg kg^{-1})	1.73 - 46.7	17.8**	12.8	287	2.50 - 7.46	4.60	2.03
Cu (mg kg^{-1})	1.27 - 60.7	12.3*	9.65	352	1.01 - 4.68	2.72	1.25
Fe (mg kg^{-1})	13.8 - 202	83.6**	41.0	457	9.48 - 19.2	15.0	3.08
Mn (mg kg^{-1})	3.96 - 23.1	10.7**	3.30	-38.5	11.8 - 26.4	17.4	5.73
Ni (mg kg^{-1})	0.09 - 5.13	1.43**	0.94	258	0.26 - 0.73	0.40	0.18
Pb (mg kg^{-1})	0.22 - 8.55	3.95**	1.22	136	0.97 - 2.05	1.67	0.40
Cd (µg kg^{-1})	10.5 - 312	97.3**	57.0	147	12.3 - 70.3	39.4	19.6
Cr (µg kg^{-1})	traces - 41.0	15.3**	8.59	—	ND	ND	—
As (µg kg^{-1})	2.80 - 240	50.6	41.4	—	20.8 - 68.4	40.5	15.4

#(%), increase or decrease over tubewell-irrigated soils; S.D., standard deviation; (*) and (**) indicate that difference between means of sewage and tubewell water irrigated soils are significant at 5 and 1% probability levels, respectively.

of tubewell water-irrigated soils. The values of hazard quotient (HQ) for intake of trace toxic elements by human through consumption of rice grain grown on these sewage irrigated soils were well within the safe permissible limit. The variation in Zn, Ni, and Cd content in rice grain could be explained by solubility-FIAM to the extent of 49.9, 41.2 and 42.7%, respectively. As high as 36.4% variation in As content in rice grain could be explained solubility-FIAM model.

4.3 NUTRIENT MANAGEMENT

4.3.1 Improvement in Pusa Soil Test Fertilizer Recommendation (STFR) Meter

Capability of Pusa STFR meter has been improved with the incorporation of two more nutrient analysis protocols for iron and manganese. Now it can analyzes twelve important soil parameters viz., pH, EC, OC, available nutrients (P, K, S, Zn, B, Fe and Mn), and gypsum and lime requirement. It has the provision of making fertilizer recommendation for 100 crops including field crops, horticultural crops and spices. Data storage capacity was enhanced for 50 samples in switch-off condition. Provision of using a numerical key pad was made for convenient data handling. It could be connected to PC through a computer-interface and the results can be communicated to the farmers through instant SMS on a pre-registered cell phone. So far, it has been licensed to nine firms for commercial production, out of which two firms have already started marketing of Pusa STFR meter.

4.3.2 Evaluation of Nano-Clay Polymer Composites (NCPCs) Loaded with Urea and Neem Oil

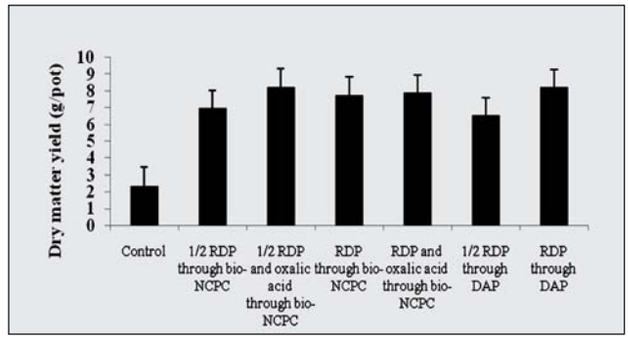
A series of NCPCs were prepared using two types of polymers (polyacrylamide and starch grafted polyacrylamide) with different concentrations of bentonite. The NCPCs were loaded with urea (1:1 ratio on weight basis) and neem oil (0 and 1% of nitrogen loaded) and the products were evaluated under greenhouse pot culture using rice as a test crop. Results indicated that the apparent recovery (AR) for urea, NCU and urea+ DCD applied at 90% N varied from 41 to 48%, whereas for the NCPCs with 90% recommended N dose, the value varied from 49 to 69%. The AR values increased with a decrease in N rates. Optimum clay content in NCPC was worked out as with 12%.

4.3.3 Effect of Hydrophobised Nano Clay on Efficacy of P Loaded Nano Clay Polymer Composite

A pot experiment was conducted to evaluate effect of hydrophobised nano clay on efficacy of P loaded nano clay polymer composite in maintaining available P in soil using wheat as a test crop. For this purpose, P loaded nano clay polymer composite (NCPC) was prepared using hydrophobised nano clay by modifying montmorillonite surface with a surfactant, cetyl trimethyl ammoniam bromide (CTAB). Results indicated that P uptake by wheat increased from 3.32 mg kg^{-1} in DAP treated pot to 8.71 mg kg^{-1} in P loaded NCPC treatment in red soil, the corresponding values for alluvial soils were 4.45 to 9.78 mg kg^{-1}. Further, P fixation was considerably reduced in both the soils. Phosphorus use efficiency in case of P-NCPC increased from 16 to 47% and 21 to 51% in red and alluvial soils, respectively, over DAP-treated pots.

4.3.4 Synthesis and Evaluation of P loaded Starch Based Nano Clay Polymer Composite (NCPC)

In order to make NCPC economically viable, starch based bio-NCPC was prepared using varying concentration of clay, where 50% of acrylic acid replaced by starch. A greenhouse experiment was conducted to



Effect of P loaded NCPCs on yield of wheat

evaluate the efficacy of bio-NCPC loaded with oxalic acid and P in increasing P availability in alluvial soil in wheat. Results indicated that half of recommended dose of P (RDP) through bio-NCPC and RDP through DAP fertilizer were equally effective in enhancing the dry matter yield of wheat. However, combined application of ½ RDP and oxalic acid through bio-NCPC was superior to ½ RDP through bio-NCPC.

4.3.5 Enhancing the Solubility of Rock Phosphates

In order to enhance the solubility of low-grade Purulia and Udaipur rock phosphate (RP), a mixture of RP, organic acids loaded NCPC and phosphate solubilizing bacteria (PSB, *Pseudomonas striata*) was prepared. SEM images and FTIR spectra of treated RP indicated a significant change in the original 100-mesh size RP due to treatment with organic acids and PSB. The incubation experiment showed a positive impact of the organic acids on the P release from RP, and oxalic acid was more effective than citric acid in this regard. The two indigenous RPs maintained almost comparable available P in soil throughout the period of incubation. Results of greenhouse experiments showed that in case of wheat, the performance of DAP (used as standard P-fertilizer) in terms of yield and P uptake was better over the treated RPs. But residual effect of treated RPs in maintaining P supplying capacity of soil was better than DAP for rice.

4.3.6 Soil Test Crop Response (STCR) Based Nutrient Management for Gladiolus

Soil test crop response correlation studies was carried out using gladiolus (var. Trader Horn) as a test crop in an Inceptisol of Delhi. The nutrient requirment for the production of 100 kg of gladiolus spike was 1.27 kg of N, 0.21 kg of P and 1.28 kg of K. For corms, it was 1.94, 0.32 and 1.98 kg of N, P and K, respectively. The per cent contribution of N, P and K from soil available nutrient pool, fertilizer and FYM were 27.4, 29.5 and 20.5% for N, 52.4, 18.17 and 10.1% for P and 31.1, 73.0 and 15.0% for K, respectively. These basic data were used for the development of fertilizer prescription equations and ready reckoner of NPK fertilizer doses alone and in conjugation with FYM for a range of soil test values and desired yield targets (±10% of potential yield of the variety) of gladiolus spike and corm.

Soil test based fertilizer prescription equations involving IPNS for targeted yield of gladiolus spike

Fertilization programme	Fertilizer prescription equation
NPS alone	FN = 4.28T – 0.93 SN
	FP = 1.15T – 2.89 SP
	FK = 1.76T – 0.43 SK
NPS + FYM	FN = 4.28T – 0.93 SN – 0.69 FYM
	FP = 1.15T – 2.89 SP – 0.56 FYM
	FK = 1.76T – 0.43 SK – 0.21 FYM

Note: FN, FP and FK – fertilizer N, P and K in kg/ha, respectively; T- target yield in kg/I SN, SP and SK– alkaline $KMnO_4$ – N, Olsen's-P and neutral normal ammonium acetate K in kg/ha, respectively; FYM represents dose of farmyard manure (t/ha)

4.3.7 Development of Nutrient Management Protocols for Conservation Agriculture in Maize-Wheat Cropping System

Different N management options comprised of basal application of 80, 50 and 33% of recommended dose N fertilizer (150 kg N ha^{-1}) followed by need-based top dressing as suggested by Green Seeker, and N sources and methods of its application were evaluated. In both maize and wheat, CA comprised of no tillage with 40% of maize and wheat residue retention on the soil surface, while conventional tillage (CT) was followed with crop residue removal. Results revealed that maize grain yield was statistically similar under both cultivation practices i.e., CA (7.47 t ha^{-1}) and CT (7.48 t ha^{-1}), whereas grain yield of wheat was significantly higher under CA (5.0 t ha^{-1}) than that of CT (4.71 t ha^{-1}). Green Seeker based N requirement was less under CA in both the crops. Among N sources and methods of application, band placement of slow release modified urea materials (i.e., USG and IFDC-product) resulted in higher yields or nitrogen use efficiency (NUE) compared with urea broadcasting. In CA, Walkley-Black C (WBC) and mineral-N (NH_4^+-N + NO_3^--N) contents were significantly higher compared

with CT in the surface layer (0 – 15 cm depth). Similarly different fractions of SOC (microbial biomass carbon (MBC) and particulate organic matter carbon (POMC) and N (microbial biomass N(MBN) and particulate organic -N (POM-N) were significantly lower under CT. The application of CR+50% recommended dose of P along with P solubilising culture (PSB +AM combined use) in maize-wheat cropping sequence significantly improved biomass and growth rate of wheat root. Highest root growth rate was observed under 50% CR+50% recommended P along with PSB + AM inoculation. The CR+ 50% RDF + PSB + AM was statistically at par with CR+150% RDF in respect of yield and P uptake by wheat.

4.3.8 Use of Sludge as a Non-Conventional Source of Nutrients

Sludge samples were collected from sewage treatment plants located in Okhla, Delhi gate nallah, Nilothi, Pappankalan and Coronation Pillar and characterized for pH, EC, total N and micronutrients. Nutrient values of sludge (biosolids) vary with sources and treatment processes. Sludges were neutral (pH 5.6 to 7.1), however wide variations were observed in EC, total N and micronutrient content. A field experiment was initiated in 2014-15 to assess the feasibility of using sewage sludge (SS) as a source of nutrients under maize-wheat. Results indicated that the highest yield of wheat was obtained with the application of 100% NPK+ 2.5 t ha^{-1} SS and up to 50% fertilizer N can be substituted by SS without significant yield loss.

4.4 WATER MANAGEMENT

4.4.1 Irrigation Water Management Using Waste Water

4.4.1.1 Impact assessment of waste water and nitrogen under different land configuration in mint

An experiment was conducted to assess the impact of waste water irrigation and N under different land configuration in mint (cv. Kosi). The experiment consisted of two sources of irrigation water (ground water and waste water) and three levels of N 0, 37.5 and 75 kg/ha (100% recommended dose) under raised and flat bed conditions. Irrigation with wastewater significantly increased the herb (10.6%) and oil yield (10.3%) compared to that of ground water. Application of 100% recommended dose of N (75 kg / ha) along with ground water irrigation produced herb and oil yield of 21.8 t/ha and 149.3 kg/ha which was statistically at par with the application of 50% (20.8 t/ ha and 147.2 kg/ha) recommended dose of N under waste water irrigation thereby showing 50% (37.5 kg / ha) saving of applied N.

4.4.1.2 Devising alternative land-water management strategies in brinjal for reducing soil/consumer health hazards due to waste water irrigations

The impact of different land-water management strategies on pollutant load and transport, crop yield and quality of waste water irrigated brinjal was studied. The results showed that the treatments containing waste water irrigation has produced 10% higher yield as compared to ground water irrigated plots. Maximum yield was obtained in the treatment containing waste water with flood method of irrigation and basin land configuration (48 t/ha). The available N status of the waste water irrigated plots was significantly increased as compared to ground water irrigated soils.

4.4.1.3 Evaluation of growth, quality and colour of turf grass under different waste water irrigation schedules and planting methods

The growth, quality and colour of turf grass cultivar Selection-1 planted under two planting methods (with or without sub-soil plastic mulch) and three waste water irrigation schedules (75%, 100% and 125% of ETc) were investigated under 2 years old planted turf grass. Results illustrated that waste water irrigated plots were associated with greater missing than acceptable rating/threshold (i.e., value 5) for turf grass colour and quality (ranging between 6.5 to 8.0 for most months of the year excepting 3 months from December 2014 to February 2015). These turf grass colour/quality values were observed to be comparable to those for the ground water irrigated plots. In general, turf grass grown on sub-soil plastic

mulch and irrigated at 125% ETc were observed to be associated with higher quality/colour.

4.4.2 Irrigation Water Management Using Ground Water

4.4.2.1 Water productivity in different cropping systems under conservation agriculture practices

An experiment was conducted in collaboration with CIMMYT-India with 3 cropping systems,viz., cotton-wheat (C-W), pigeon pea-wheat (P-W), maize-wheat (M-W) and 7 tillage-and residue-management practices. System water productivity (SWP) was highest in zero tillage broad bed with residue. Among the cropping system, C-W resulted in higher water and system productivity compared to P-W and M-W systems. A 60.3, 67.9 and 63.5% irrigation water savings and 49.4, 56.1 and 58.7% total water saving was recorded in C-W, P-W and M-W cropping system, respectively.

4.4.2.2 Drip fertigation technology for cotton

An experiment was conducted to study the effect of fertigation and irrigation system on cotton yield (var. RCH - 602 B11). Three irrigation systems: one surface and two subsurface at lateral depths of 15 cm and 30 cm inline drip irrigation system having 30 cm dripper spacing was used to irrigate the plants on 120 x 30 cm plant geometry. Weekly fertigation frequency for the cotton crop was given at three different doses: 100% RDF (300-100-250 kg N:P:K), 80% RDF and 60% RDF. The maximum yield (2.47 t/ha) was obtained in 100 % RDF in weekly fertigation frequency by placing the lateral at 15 cm depth.

4.4.3 Climate Change and Modeling

4.4.3.1 Trend analysis of climatological parameters in Haryana

Long term trend analysis using Modified Man-Kendall test and Sen's slope estimator of different districts of Haryana in the trans-IGP region using 41 years (1969-2009) rainfall, minimum and maximum temperature showed that there is an increasing trend of rainfall for Kaithal and Palwal districts of Haryana. For Kaithal there was significant increase with z-value of 2.59. However, non-significant decreasing trend was observed for other districts of Haryana. Further, trend analysis for maximum temperature showed an increasing trend for all districts except for Kaithal, however the trend was statistically significant only for Bhiwani district with z-value of 1.47. Contrastingly, it was observed that the trend of minimum temperature increased significantly for all districts of Haryana.

4.4.3.2 Simulation of wheat yield under foliar potassium fertilization in irrigated saline environment using AquaCrop Model

A field experiment was conducted to generate data for simulation of FAO AquaCrop Mmodel for mitigation of the adverse effect of salinity. Two wheat cultivars (i.e., one salt tolerant KRL-1-4 and other salt sensitive HD 2894) under four salinity levels (viz., GW (1.7 dSm^{-1}), 4, 8 and 12 dSm^{-1} were tested under foliar and non-foliar treatments. The model evaluation parameters viz., model efficiency (ME), index of agreement (d) and R^2 for model validation of grain yield were found to be 0.86, 0.95 and 0.96, respectively, under all treatment levels. The model

Cotton crop under drip irrigation system

was validated for biomass using ME, d and R^2 as 0.91, 0.97, and 0.93, respectively. The model validation results for water productivity were 0.60, 0.82 and 0.93 for ME, d and R^2, respectively. It was observed that the AquaCrop Model prediction for grain yield was better as compared to biomass and water productivity for all treatment levels. Nonetheless, the FAO AquaCrop model can be used for prediction of grain yield of wheat using both foliar and non-foliar potassium fertilization under irrigated saline environment.

4.4.3.3 Development of surface irrigation design and operational guidelines at IARI Farm

Border/basin irrigation events were monitored under wheat crop to collect data on waterfront advance, inflow rates, topography and time of cutoff (T_{cutoff}). Three irrigation events at three locations at IARI farm were monitored, one each in bare soil, initial crop stage and middle crop growth stage. The collected data were used for estimating surface irrigation parameters using inverse methodology in WinSRFR model. Surface irrigation parameters for infiltration and roughness characteristics for three locations at IARI showed insignificant variations. T_{cutoff} was determined for IARI farm to achieve 75% or more application efficiency. Different combinations of field sizes for various inflow rates were also simulated to determine T_{cutoff} for targeted application efficiency of 60% and 75% with water requirement efficiency of 100%. Surface irrigation operational guidelines prepared will be ready reckoner for farmer for adopting best border/basin size/layout for achieving higher application efficiency.

4.4.3.4 Development of software for irrigation scheduling in wheat, maize, soybean and mustard using single and dual crop coefficients estimated from weighing type field lysimeters

A software named "*Crop Coefficient Estimator and Irrigation Scheduler (CCEIS)*" was developed for crop coefficient estimation and irrigation scheduling of wheat, maize, soybean and mustard crop using JAVA programming language. The background data base of the software acquired from lysimeter experiment.

It was developed using water budgeting protocol in which irrigation scheduling was suggested based on crop evapotranspiration and soil moisture information. The CCEIS software comprised of a computational module, graphic user interface (GUI) and background databases. Computational module includes calculation methods for estimation of crop coefficient values and preparation of irrigation schedules which uses soil parameters, crop parameters, climatic parameters and irrigation methods as input data. CCEIS software was tested under different scenario to predict crop evapotranspiration and irrigation scheduling of selected crops. Developed software is user-friendly having flexibility of periodic apdation which can be used for judicious irrigation scheduling for enhancing water productivity of crops and cropping system of the region.

4.4.4 Water Conservation under Rainfed Conditions

4.4.4.1 Development of optimal size of ridge and furrow for enhancing soil water and nutrient availability under rainfed conditions

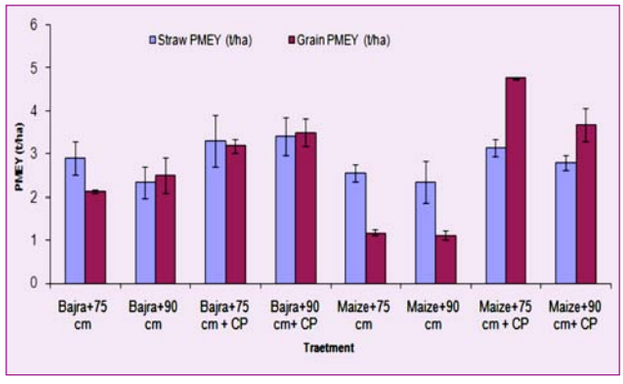
An experiment was conducted during *Kharif* season of 2014-15 with different sizes of ridge and furrows (RF) viz., 30:30, 45:30, 60:30, 75:45, 90:45

Pearl millet, maize and soybean under different ridge and furrow water conservation system

and control in pearl millet (var. Pusa composite 443), maize (var. Pusa composite 3) and soybean (Pusa composite 9712) to get the optimal size of RF for respective crop for enhancing soil water and nutrient availability under rainfed conditions. It was observed that SOC in soybean plot is 15.5% and 4.85 % higher over maize and pearl millet plots, respectively. The trend of SOC in various RF ratio was 60:30>75:45>45:30>90:45>30:30>control plots. Highest microbial activity was recorded at 45:30. High soil glomalin content, lowest soil respiration activity in 60:30 reflects enrichment of soil C, less mineralization and consequent loss of SOC. It was observed that RF ratio 45:30 for pearl millet, 90:45 for maize and 60:30 for soybean were superior in terms of pearl millet equivalent yield.

4.4.4.2 Efficacy of basin tillage conservation practice to enhance rainfed crop yield

Basin tillage (BT) and inter space of 75 cm and 90 cm spacing between pits in pearl millet (var. Pusa composite 443) and maize (var. HQPM 1) crops in pits and cow pea (var. Pusa Sukomal) as inter crop in inter space) were tested to study the effect of different combinations of basin tillage size and inter space on soil water and nutrient availability. It was observed that pearl millet at 90 cm, maize at 75 cm spacing and cowpea in maize at 75 cm spacing performed better. The intercropped yield of pearl millet and maize compared to respective sole crop. But there is significant difference between 75 cm and 90 cm spacing in case of maize with intercropping, 75 cm spacing is having 29.2% more yield than 90 cm spacing.



Pearl millet equivalent yield under basin tillage method

4.5 PROTECTED CULTIVATION TECHNOLOGY

4.5.1 Evaluation of Coloured Capsicum Varieties under Evaporative Cooling

Two big fruited capsicum var. Bachata (yellow), Paserella (red) and three varieties of small fruited type, orange (var. 9967422), yellow (var. 9956434) and red (var. 9954559) were evaluated. Among the small fruited varieties, variety 9956434 (yellow) had the highest fruits yield (11.50 kg/m^2) followed by orange fruited var. 9967422 (10.40 kg/m^2) and red fruited variety, 9954559 (8.80 kg/m^2). However, the fruits yield was maximum (9.75 kg/m^2) in big fruited capsicum var. Paserella followed by var. Bachata (9.60 kg/m^2).

Small size (baby) coloured capsicum under polyhouse with pad & fan system

4.5.2 Varietal Evaluation of Chilli under Fad and Fan System for Off-season Growth and Fruiting

Five varieties of red chilli, namely, AHB 170, VNR 332, Indus 365, Nirala and Preeti were evaluated for growth and fruiting. Chili hybrid, VNR 332 was compact, semi determinate and produced quality fruits (7.7 kg/m^2) as compared to the rest of varieties and hybrids during off-season (Nov-Feb) under polyhouse.

4.5.3 Evaluation of Bitter Gourd and Cucumber under Different Protected Structures

The evaluation of bitter gourd (Pusa Rasdar) and cucumber (Pusa Seedless cucumber 6) was undertaken inside insect proof net-house and naturally ventilated polyhouse, respectively. It was found that maximum fruits yield (17.5kg/ m^2 in bitter gourd and 15.5 kg/m^2 in cucumber) remained economical under September planting combined with application of NPK @ 25:17:26 kg/1000 m^2.

4.5.4 Direct Seeding and Transplanting Response on Fruits Yield of Summer Squash with and without Plastic Mulch under Poly-tunnel with Drip Irrigation System

Direct seeding and transplanting of different summer squash varieties viz., Astralian-Green, Pusa Alankar, Aditya, Sandhya, Sunnyhouse, Orilia and Pusa Pasand were undertaken with and without plastic mulching using low plastic tunnel. Long fruited variety, Pusa Alankar and round fruited variety, Pusa Pasand recorded maximum yield of fresh fruits, 90.7 t/ha and 42.5t/ha, and income ₹ 4.15 lakh/ha and ₹1.80 lakh/ha, respectively, from the crops transplanted on plastic mulch during off-season under low-tunnel. However, the direct seeded crop recorded poor germination (63%) with delayed flowering and fruiting by 24 days than the transplanted crop.

4.5.5 Development of Long and Round Fruited Indeterminate (vine) Type Varieties of Summer Squash (Zucchini) Suitable for Protected Structures (Polyhouse and Net-house) during Off-season

Attempts were made to develop indeterminate (vine) type of summer squash (zucchini) for cultivation undern protected structures during off-season. Keeping in view, an indeterminate *Desi* type local germplasm having small fruit with more seeds was collected from high altitude of Lohaghat, Uttarakhand and crossed with cultivated variety Australian Green (long fruited) and Pusa Pasand (Round fruited) to develop $F_{1.}$ F_1, F_2 and backcross materials were evaluated during 2014 and the lines selected from different segregants were followed selfing every year to select the better lines having desired plant type and continued upto 4^{th} generation. These lines having long inter-

node, medium leaf canopy, thick stem, good fruits characters, and indeterminate growth habit were evaluated for yield potential, and the yield was found 3-5 kg/ plant during off-season (November to March) under polyhouse protected structure.

4.5.6 Evaluation of Leafy Vegetables under Soilless Cultivation

Evaluation of leafy vegetables, namely, spinach, amaranths, kale, parsley, celery, pokchoi, lettuce, garden mint, and multiplier onion including some exotic root (radish, turnip and carrot) and fruit (summer squash,

capsicum, tomato and broccoli) vegetables for urban and peri-urban cultivation was conducted in soil-less medium using a mixture of coco-peat, perlite and vermiculite in 3:1:1 by volume in different containers. The preliminary results showed that the leafy vegetables viz., spinach, amaranths, kale, celery, pokchoi and lettuce could perform well when planted in UV-stabilized, 10 cm plastic pots. However, the parsley planted in plastic pots of 15 cm performed better.

4.5.7 Studies on Bending Response in Greenhouse Rose, Variety Tajmahal

It was observed that the plants bended with two shoots/plant at a time had longer stems (78.6 cm) and better quality flowers (9.3 cm diameter across). Highest number of cut stems (7.4/plant) were produced in the plants bended with 3 shoots/plant which remained non-significant with plants bended with 2 (6.5/plant) and 1 (6.3/plant) shoots at a time.

4.5.8 Studies on Off-season Flower Induction and Flower Forcing in Chrysanthemum

Chrysanthemum varieties (Thai Chen Queen, Yellow Star, White Star and Zembla) were planted under polyhouse and open field for offseason evaluation under the influence of plant growth regulators. Zembla sprayed with 50 ppm brassinosteroid could induce normal flowering and produced good quality flowers under greenhouse (10.5 cm diameter with 97.8 cm stem length) followed by open fields (9.4 cm diameter with 68.2 cm stem length).

4.5.9 Studies on Virtual Crop Growth in Chrysanthemum

Different wavelengths of light were separated through LEDs at white, blue, red to have an acclimation light @ 110-120 μmol $m^{-2}sec^{-1}$ individually and also from a combined 80% red 20% blue LEDs as best treatment compared with white light sourced from HPS tubes/lamps. The flower induction was observed in 39 to 42 days in all the varieties exposed and had a non-significant variation except for number of leaves attained, varied from 22 (Thai Chen Queen) to 36 (Zembla) to become generative.

Virtual growth and flowing in chrysanthemum under LEDs

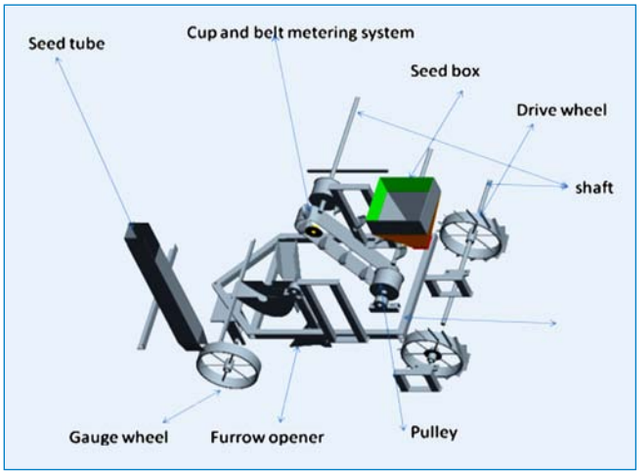
4.5.10 Estimation of Crop Water Productivity and Yield for Capsicum in Soil-less Cultivation

Crop water productivity and yield were estimated for greenhouse *capsicum* grown in soil-less grow bags. Two irrigations were applied when WHC reduced by 10 and 20%, respectively. The crop water productivity was found to be maximum 48, however, yield per plot was maximum (42 kg), respectively, in I_1F_1 and I_2 F_2 strategy.

4.6 AGRICULTURAL ENGINEERING

4.6.1 Design and Development of Gladiolus Planter

A gladiolus planter was designed based on the optimum parameters of the planting materials. The maximum equatorial diameter and average polar diameter of 58.08 and 20.65±3.36 mm, respectively, were considered for design of cell size and shape of the metering system. The mean sphereicity of the corms was 34.91. The bulk density and true density of the corms were 0.53±0.03 and 1.11±0.32 g/cc, respectively. The effects of orientation of planting corms on germination, number of flowers per peduncle, length of peduncle and percentage of flowering peduncles were observed from the field experiment. The design



Prototype gladiolus planter

drawing of the gladiolus corm planter was prepared on Creo design software.

4.6.2 Design and Development of Tractor Operated Bund Packer

The tractor operated bund packer was designed with the objectives to develop a bund packer- cum -shaper for reducing drudgery of farm workers, and to develop machine for combined operations of bund forming and packing in single pass for saving fuel and resources. In order to check seepage the bund former-cum-packer also compressed the accumulated soil mass from top. The spacer/ roller diameter of bund packer should be more than the required decrease in height of bund. The number of bunds in an hectare could be around 21 and total bund length could be about 2050 m. The bund formed with bund former is packed or firmed manually with spade and feet. This activity is time consuming and labour intensive. Normally a person can pack or firm the formed bund 100-150 m length in an hour. Design of the bund former-cum-packer consists of commercial available disc type bund former, rectangular tool bar frame, and packing unit (concentric cylindrical roller, drive shaft, conical disc, compressive shanks, etc). The developed bund former-cum-packer unit was evaluated.

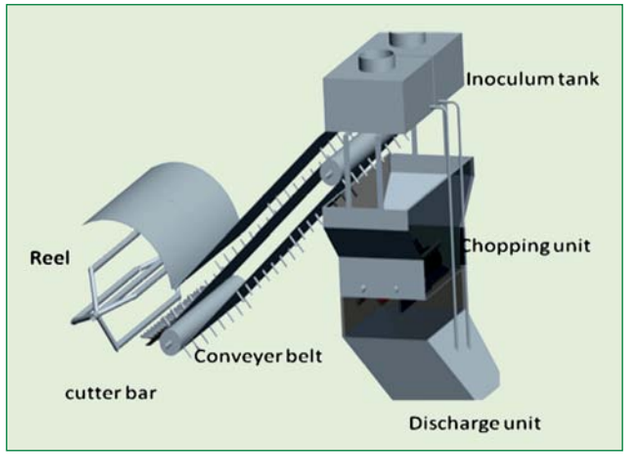
Details of bund packer

Sl. No.	Particulars	Values
1.	Size of packed bund, mm (Top width, Bottom width, Height)	(250, 560-580, 210)
2.	Shape of packed bund	Trapezoidal
3.	Speed of tractor, km/h	2.93 (2nd low gear)
4.	Capacity, m length/min	48
5.	Saving in manual labour	19 to 24 times
6.	Water holding capacity of packed bund	No breakage of bund, no seepage

4.6.3 Design and Development of Paddy Straw Collector-cum-Chopper

A paddy straw collector-cum-chopper was designed with the provision of collection, conveying, chopping, delivering in compact rows and applying the

recommended dose of fungal inoculum to degrade it rapidly. Experiments were conducted to determine the optimum size of paddy straw best for composting. The three sizes of paddy straw were allowed to decompose in 60 litre perforated lid plastic bins after adding cow dung, soil, and compost in the ratio of 8.1:0.5:0.5 with varying rates of inoculant. Paddy straw size of 4-5 cm and 1000 g inoculants/t of material was optimum for rapid composting with pH level of 6.97, electrical conductivity 0.5 dS/m, nitrogen 0.78 %, potassium 0.69%, phosphorus 93.7 ppm with C: N ratio reaching to 18.7. Paddy straw collector-cum-chopper consisted of reel assembly; reciprocating cutter bar, chain and sprocket type conveyor mechanism, chopping rollers, hopper and plastic tank containing mixture of cow dung, soil and fungal inoculum. Repeated application of shear and impact chops the paddy straw into pre-determined size for further processing. The chopped straw pieces passes through the hopper and falls on the ground in the form of compact row. The spraying of the recommended dose of cow dung, soil and fungal inoculum from the water tank placed at the back end of paddy straw collector-cum-chopper ensures the rapid degradation of paddy straw.



Paddy straw collector-cum-chopper system

4.6.4 Development of Permanent Raised Bed Seed-cum-Fertilizer Plot Drill

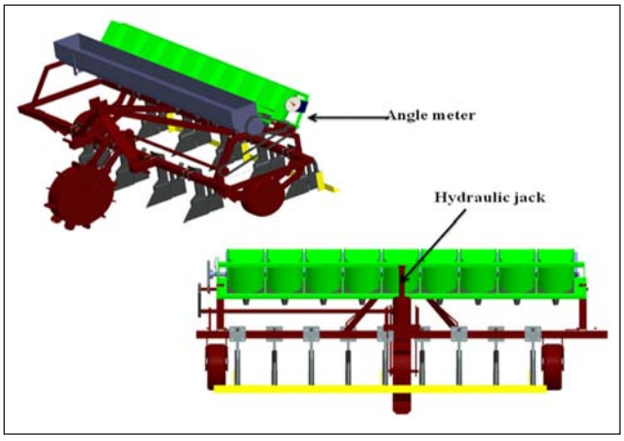
A tractor operated permanent raised-bed seed-cum-fertilizer plot drill was designed and developed

Permanent raised bed seed-cum-fertilizer plot drill

in the Division of Agricultural Engineering, IARI, New Delhi. The furrow opener of the plot drill was double disk type to work smoothly in heavily trashed field. This machine is suitable for sowing in experimental plots under conservation agriculture, where there are permanent raised beds and number of crop varieties is to be sown in similar field conditions. Double-disk furrow opener with plain rolling coulter operating at speed of 2 km/h gave optimum performance at 4 to 8 cm depth compared to other type of furrow openers. Double disk furrow opener disturbed the soil least and did not collect the residue.

4.6.5 Design and Development of Precision Paddy Planter for Direct-Seeding

A precision paddy planter for direct sowing was designed. The precision was obtained with speed synchronization of peripheral speed of seed plate with forward speed using speed sensor, pulse width modulator and DC motor. For design of seed metering system, physical properties of three paddy seeds of varieties i.e., Pusa 1121, Pusa 44 and BPT 5205 were determined. The grain length varied from 7.32 ±0.61 to 13.79 ±0 .93 mm, breadth from 2.16±0.21 to 2.58±0.06 mm, sphericity from 43.66± 2.45 to 30.56±3.49, 1000-grain weight from 14.37 to 32.6 g, angle of repose from 25.25 to 33.68 and bulk density from 524.6 to 667.56 kg/m^3. The observed values were used to design the seed metering cells for different varieties with cell diameter ranging from 10 to 14 mm. The highest angle of repose observed in Pusa 1121 was used to have a seed hopper slope of 35^o to ensure free flow of seed. Three types of seed metering shapes i.e., slanting, semi-circular and rectangular were designed and evaluated on sticky belt with electronic metering mechanism. Slanted



Prototype of paddy planter for direct-seeding

metering mechanism performed better with forward speed of 2 km/h and angle of inclination of 35°. For better precision in direct sowing a hydraulic jack and angle meter has been provided for maintaining proper hopper angle as per seed variety and recommended seed rate. Prototype of 9-row paddy planter for direct sowing is designed having sensor based electronic speed synchronization system.

4.6.6 Design and Development of Planter for System of Wheat Intensification (SWI)

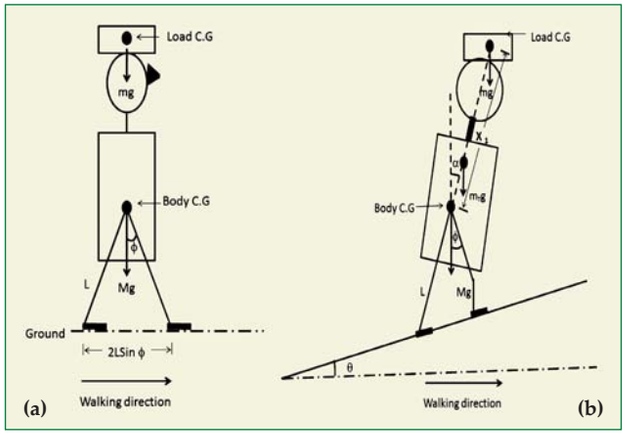
A manually operated planter was designed for system of wheat intensification (SWI). The SWI is not becoming popular due to intensive labour requirement inspite of the yield increase in this method. The experiment was conducted to optimize number of seeds per hill, row-row and hill-hill spacing. From the experiment, higher yield was observed in case of treated seeds. Two seeds per hill at 20×20 cm spacing for row and hill recorded maximum yield. The engineering properties of wheat seed were recorded for design of different components of the planter.

Prototype

Planter for system of wheat intensification

4.6.7 Biomechanical Model for Energy Consumption in Manual Load Carrying on Indian Farms

A biomechanical model was developed to predict metabolic energy cost for carrying load manually in different modes and ground inclinations. Experiments on selected modes with selected loads (head, back and shoulder and 10, 15, 20 kg load) at different slopes (0, 5, 10%) were conducted in laboratory set-up. Twelve farm workers (6 male and 6 female) working on local farm were selected and trained to walk on treadmill. A biomechanical model was developed by incorporating parameters related to operator, ground inclination and load. Operator parameters included human efficiency, body weight and height of the worker. Load parameters considered were weight of load and mode of load carrying. Positive inclination i.e., upward slope was considered for experimental and modeling purpose. The developed model had high co-relation (co-efficient of 0.95) between measured and predicted values of metabolic energy consumption (KJ/min). Developed biomechanical model indicated that frontal torque requires higher physiological energy than sagittal torque of same magnitude.



Person carrying load on Head; (a) walking on horizontal surface, and (b) walking on inclined surface

4.6.8 Development of Compost Inoculant Mass Production System

A system for mass production of compost inoculant was developed with the following functional requirement: Mechanical agitation, alternate direction agitation, removable contact component and window for monitoring operation. The system consists of Geared DC motor: 60 rpm, 12V, 3 kg-cm, 5 W; adjustable direction control, vertical staggered Al blade agitation unit, Agitator connected with drive with connecting pin and transparent top for monitoring.

Compost inoculant mass production system

4.6.9 Development of Solar Powered Refrigerated Storage System

An insulated storage structure of 4 m^3 capacity for storage of fruits and vegetables (~1000 kg) was developed. It was fabricated with G.I. sheet on the outer side and polycarbonate sheet on the inner side. In between these sheets, glass wool was filled to provide the insulation. This storage is connected to a refrigerator of 292 L capacity and the system is powered by solar photo-voltaic panels (SPV) of 400Wp (100Wp each solar module, open circuit voltage 17V). Based on optimization of connected load and the solar power available, 4 solar panels of 100 Wp each were used. Out of these solar panels, two solar panels of 100 W each were connected in series to make a string of 24V. Total 2 strings were made in this way. Each string was then connected in parallel to increase the current. The DC power of the solar panel was converted into single phase AC power with the help of a MPPT solar inverter (1400VA). A battery (24V, 150Ah) was used to provide back up to the system in the absence of solar energy. Preliminary evaluation of the storage at no-load was carried out. The temperature and relative humidity inside was lower than ambient by 8.6^{0}C and 27.4%, respectively. Further studies are in progress to reduce the storage temperature for safe storage of fresh fruits & vegetables.

Solar powered refrigerated storage system with solar power pack

4.6.10 Evaporatively Cooled Storage Structure for Fruits and Vegetables

Solar powered evaporatively cooled storage structure comprising of a solar powered exhaust fan and cooling pump for wetting the pads, was fabricated for storage of 500 kg fresh fruits and vegetables to increase their shelf-life, The ambient air-dry bulb temperature was 29.5 – 41.1°C (av. 35.6°C). The drop in temperature inside evaporatively cooled storage structure (ECSS) was 6.8 – 14.6°C, while the ambient relative humidity (RH) was 19 – 50% with the average being 32%. The increase in RH inside the cooler was up to 59% which helped in keeping the vegetables fresh.

Solar powered evaporatively cooled storage structure

4.6.11 Farm Operation Services

The Farm Operation Services Unit (FOSU) of IARI has four basic/major component viz., i) Farm operation management, ii) Irrigation system management, iii) Biomass/crop residue management, and iv) Weed management in non-cropped area. The FOSU managed all field operations including field preparations to crop sowing, harvesting and threshing in 750 acres of IARI farm using indigenous/imported machines. Timely tillage, field preparations, laser leveling, sowing, inter-culture and harvesting of the experimental fields were accomplished. FOSU has provided irrigation water to 750 acres of IARI fields by 18 tube-wells linked by two big water reservoirs of 45 lakh litres capacity each. To augment the water availability, four new tube-wells were redeveloped. FOSU has collected biomass using Biomass Grabber during *Kharif* & *Rabi* seasons to the tune ~1600 trollies from IARI farm and transported it to "Biomass Utilization Unit" for preparing compost. This compost was also distributed to all the users at IARI experimental farms. Weed control work was carried-out in non–cropped area of IARI farm i.e., farm road sides, bunds, channels, *Nala* sides. FOSU has upgraded its machinery through purchase of rotavators and rigid type cultivator. For maintenance of tractors and vehicles, automatic tyre inflation facility was installed. FOSU also maintained all the tractors and farm machinery available in different divisions and units of the Institute. All the DPL's and contractual labour to different divisions/projects of IARI were managed and also ensure timely payment of wages & EPF, ESI for all the DPL working in the Institute.

4.7 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

4.7.1 Effect of Particle Films on Fruit Cracking and Post-harvest Quality of Pomegranate

The particle film, Surround, was imported from France and a trial was laid-out on its use in pomegranate cultivar, Bhagwa. Three sprays of Surround (3%) were given at fortnightly interval, starting from 15th June, 2015. Surround-treated pomegranate developed very good red colour (Hunter 'a' value = 46.4) than untreated fruits. The Surround-treated fruits had very low incidence of fruit cracking (2.5%) and sun-burning (2.2%) than untreated ones (36.5 and 18.3%, respectively). Similarly, the incidence of bacterial blight was significantly reduced (12.6%) in Surround-treated fruits than control. The post-harvest quality of Surround-treated fruits was significantly improved over untreated fruits.

Sun burn injury in pomegranates | **Surround-treated healthy pomegranates**

4.7.2 Vacuum Packaging for Enhancing Shelf-life of Pomegranate Arils

Minimally processed pomegranate arils were packed in 70 micron thick PP film (vacuum and MA packaging) and stored at 6±1^{0}C for 30 days. It was revealed that vacuum packed arils retained 4 times higher anthocyanin (110.5 mg L^{-1}) upto 30th day of storage. Interestingly, total phenol content remained unaffected with the change in packaging environment.

4.7.3 Shrink Wrapping of Minimally Processed Baby-corn

Pre-peeled baby-corn as a convenience product is amongst one of the popular vegetables marketed

for direct consumption. Owing to the decline in organoleptic quality during marketing, it loses its value. Stabilized pre-peeled baby-corn was, thus, developed by application of acidulants and reducing agents followed by shrink wrapping. The shrink wrapped cobs maintained their quality in terms of best retention of colour and sweetness for about 12 days when treated with cysteine. Edible coatings such as whey protein concentrate (1%), carboxy methyl cellulose (1%), sodium alginate (2%) were not found suitable in maintaining the quality of the peeled cobs.

4.7.4 Effect of Pasteurization Treatments on the Quality of Ready-to-Serve Watermelon Juice

The effect of pasteurization methods on qualitative, sensorial parameters were evaluated during three months refrigerated storage of the pasteurized ready-to-serve watermelon juice. All the three pasteurization methods viz., thermal, irradiation and micro-wave were found to have a significant effect on most of qualitative attributes of juice. Residual POD activity was 33.3, 66.67 and 50% using thermal, irradiation and micro-wave pasteurization, respectively, which was found to have a significant correlation with the colour change of the juice immediately after pasteurization. Total phenolic content reduced upto 66% in control samples compared to 23, 27 and 24 in the samples pasteurized using thermal, irradiated and microwave methods, respectively. Sensorial ranking for flavour and taste were found to be 3.26, 3.18 and 3.0, 3.2 for thermal and microwave treatments, respectively. Microbial loads in the thermal and microwave pasteurized juice were below the limit (< 1 log CFU / mL).

Friedman's mean rank for sensory quality of treated watermelon juice

4.7.5 Solvent Retention Capacity of Selected Wheat Varieties in Relation to *Chapatti* Making Quality

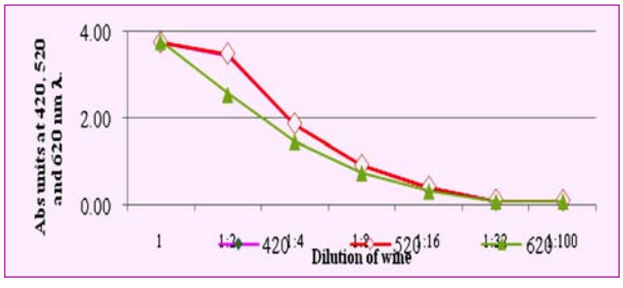
Indian wheat varieties have most desirable traits for making flat bread (*Chapatti*). The suitability of selected Indian wheat varieties for *chapatti* based capacity (SRC) and pasting properties was studied. Significant differences ($p<0.05$) exists between varieties w.r.t. water absorption power, SRC and pasting properties. SRC for water varied from 72.7 to 103.5%; sodium carbonate ranged from 104 to 141.3%; sucrose ranged from 113.9 to 141.3% and lactic acid ranged from 75.3 to 124.1%. *Chapatti* made from var. GW 432 and TRAJ 1482 had high SRC, swelling power, extensibility, and sensory score. Exotic genotype Cucupre displayed significantly ($p<0.05$) lower SRC, low swelling, higher pasting profile (high peak, final viscosity, set back and breakdown values), lower extensibility, higher tensile strength and lowest *chapatti* score. SRC had moderate correlation with sensory score, and can sufficiently predict *chapatti* making quality.

4.7.6 Effect of Extrusion Processing Variables on Finger Millet and Pearl Millet Flours with Respect to their Resistant Starch

Response surface methodology was used to study the effect of amylose content, moisture, screw speed and barrel temperature and their interactive effect on the extrudate properties. Amylose in the fingermillet and pearlmillet flours were found to have significant effect on the bulk density, sectional expansion index and resistant starch of the extrudates. Expansion of extrudates was negatively correlated to amylose ($p = 0.022$). Barrel temperature was found most prominent for modification of RS in fingermillet and pearlmillet extrudates. Higher amylose content leads to formation of more resistant starch in extrudates of both fingermillet and pearlmillet. The effect of screw speed and barrel temperature was mostly seen of the water absorption index and water solubility index. Quadratic regression model ($R_2>0.68$) was found appropriate to model the physico-chemical parameters of exrudates as function of extruder and raw material properties.

4.7.7 Grapes as a Matrix for Drinks and Fermentation

A study on use of growth elicitors' viz., benzothiadiazole and methyl jasmonate to increase the phenolic content was done. The flavonoid and total phenols were found to increase in the treated grapes. Titratable acidity in juices ranged between 0.88–3.4% in benzothiadiazole treated grapes and between 8–16% in methyl jasmonate treated grapes. Also a low Brix between 8% to a maximum of 16% at harvest in grape berries were observed. The harvest (1st week of June, 2015), indicated low maturity for use in an appropriate fermentation of the grapes (here red wine as a trial). All the fermentations indicated a stuck fermentation indicating a requirement of higher sugars and nutrients for yeast growth and utilization. Red grapes cv. Pusa Navrang, thus requires a higher maturity at harvest for use in fermentation matrices. Color stability as a result of co-pigmentation effect indicated by a minimum loss of color at concentration necessary for co-pigmentation was observed. The final product contained alcohol (% ABV) in the range of <7 to 8.7% in finally racked and cold stabilized wine.



Indicative color stability: Co-pigmentation effect, in red wine from Pusa Navrang grapes after racking (69 D from start of fermentation)

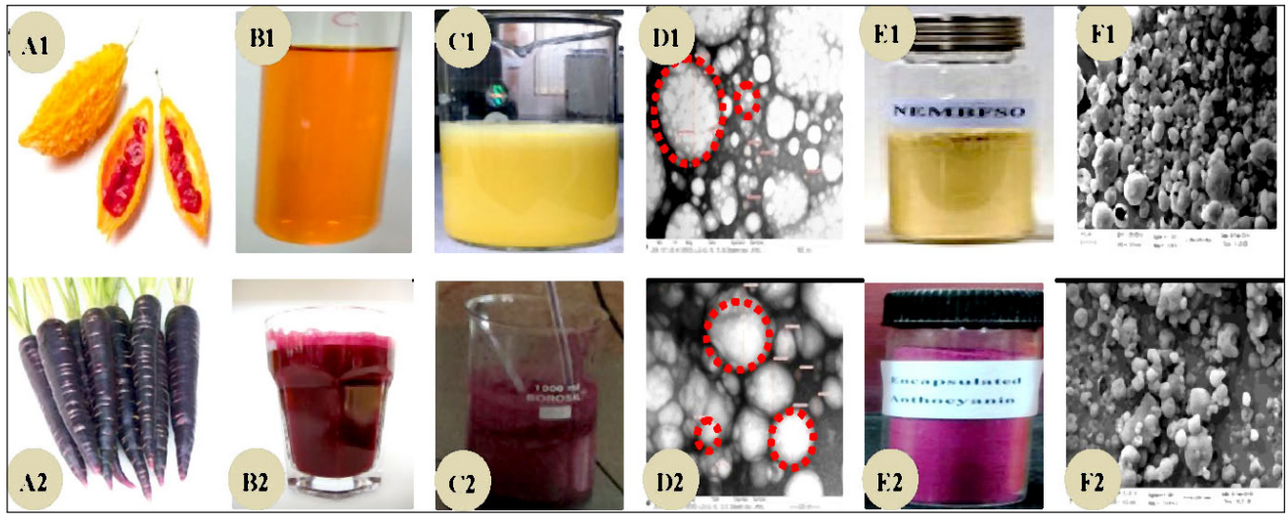
4.7.8 Bitter gourd Chips

Crunchy ready-to-eat bitter gourd chips were developed. Blanching time of 4 min was found appropriate for retaining colour of the product. Roasting of blanched slices at lower microwave power level was found to be more efficient in quality

retention of the chips. The chips had chlorophyll content of 67.5 mg/100 g, carotenoid content of 10.5 mg/100 g, ascorbic acid 25.3 mg/100 g, total phenol 257.6 mg/100 g, and anti-oxidant content of 13.1 µmol Trolox/g.

4.7.9 Concentric Encapsulation of β-carotene and Anthocyanin in Ω-fatty Acids and Novel Encapsulants Complex

β-carotene and anthocyanins extracted from ripe bittergourd pericarp and black carrot were encapsulated separately using both rice-bran oil (rich in γ-oryzanol and Ω-6 fatty acids) and flax seed oil (rich in Ω-3 fatty acids) by high pressure homogenization. The homogenized emulsions were subsequently encapsulated using a combination of jackfruit seed polysaccharide and soy/whey protein isolate by spray drying. Concentric encapsulation not only enhanced the stability of β-carotene, anthocyanin, γ-oryzanol, Ω-3 & Ω-6 fatty acids but also ensured targetted and sustained delivery. Stability studies indicated that encapsulated β-carotene, anthocyanin, γ-oryzanol, Ω-3 & Ω-6 fatty acids could be stored for 6 months at room temperature with a maximum of 20% degradation. Release kinetics indicated sustained release of the ingredients over a period of 12 hours under both stomach and gut conditions.



A1–ripe bitter gourd; A2–black carrot; B1–extracted β-carotene; B2–extracted anthocyanin; C1–encapsulated β-carotene with rice bran/flax seed oil; C2–encapsulated anthocyanin with rice bran/flax seed oil; D1–TEM image of C1; D2–TEM image of C2 anthocyanin encapsulated with rice bran/flax seed oil; E1–β-carotene and rice bran/flax seed oil encapsulated with protein-polysaccharide complex; E2–anthocyanin and rice bran/flax seed oil encapsulated with protein-polysaccharide complex; F1–SEM image of E1; and F2–SEM image of E2

4.7.10 Pulsing in Gladiolus to Extend Vase Life

An experiment on pulsing of gladiolus was conducted to extend the vaselife of cv. Melody Open. Seven pulsing solutions viz., 200 ppm 8 HQC, 8HQC 200 ppm + 10% sucrose, 300 ppm 8 HQC + 20% sucrose, 300 ppm 8 HQC + 10% sucrose, 400 ppm $Al_2(SO_4)_3$ + 20% sucrose, sucrose 20%, and were compared with control (distilled water). The cut spikes were pulsed for 4 hours in different pulsing solutions and after that their vase life was evaluated in distilled water. It was observed that pulsing of cut spikes with 400 ppm $Al_2(SO_4)_3$ + 20% sucrose resulted in maximum vase life (12.88 days) and was at par with sucrose 20%. Maximum water uptake (52.17 ml) and floret size (8.19 cm) was observed in flowers pulsed with 20% sucrose.

4.7.11 Pigment Studies in Rose

Twenty-five rose varieties were screened for their total anthocyanin content using colour value index, which is an indicator of total anthocyanins. The total anthocyanin content differed significantly among all the varieties. The variety Pusa Bahadur recorded the highest anthocyanin content (22.95 CV g^{-1} fresh weight) followed by Rose Sherbet (14.13 CV g^{-1} fresh weight) and Suryakiran (10.8 CV g^{-1} fresh weight). Minimum anthocyanin content was recorded in white coloured varieties i.e., Iceberg, Mridula and Shabnam (0.0275, 0.0475 and 0.18 CV g^{-1} fresh weight, respectively).

4.7.12 Histological Studies in Rose

Histological studies were conducted in rose varieties viz., Dulhan, Haseena, Pusa Abhishek, Raja Surendra Singh of Nalagarh, Sailoz Mookharjee, Surkhab and Manmatha to document the location of anthocyanin pigments in different cell layers of rose petals. It was observed that both adaxial and abaxial epidermal cells produce pigments in all varieties except Haseena and Dulhan. However, in varieties viz., Manmatha and Pusa Abishek, both adaxial and abaxial epidermal cells produced pigments but the intensity had been more in adaxial surface.

4.8 MICROBIOLOGY

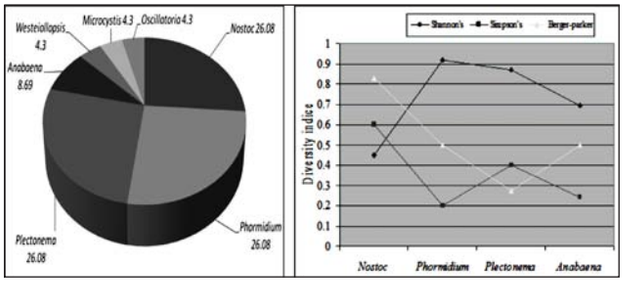
4.8.1 BGA-based Composite Liquid Inoculant for Sustaining Crop Productivity and Soil Health Improvement

Liquid formulation of BGA biofertilizer was prepared using combination of carriers, emulsifiers and binders. Of the 54 different formulations

prepared, four formulations viz., 3, 4, 10 and 11 were found best in terms of both physical stability and biological activity. These formulations were kept at different storage temperatures of 4^0C, 28^0C and 40^0C. The observations made after one year of incubation revealed that the selected formulations gave a relatively constant consistency index which was more in formulations kept at 4^0C followed by 28^0C and 40^0C. Formulation 3,4,10 and 11 continued to be stable in terms of pH, viscosity and breaking length for the observation period of one year. These formulations also maintained viable cyanobacterial cell population between 1.9 to 2.2 × 10^4 and ARA (nitrogen fixing ability) of 36-40 µmole C_2H_4/mg Chl./hr. Further assessment of these preparations for efficacy and shelf life is continuing.

4.8.2 Bio-prospecting Rhizospheric and Endophytic Cyanobacterial Diversity among Selected Genotypes of Rice for N Uptake and Crop Yield

Colony forming units (CFU/ml) for different cyanobacterial genera were counted and their per cent abundance was calculated particularly for rhizospheric soils. Genera-wise distribution showed *Nostoc, Phormidium* and *Plectonema* to be more abundant, while *Anabaena. Westiellopsis*, *Microcystis* and *Oscillatoria* were least. Diversity analysis was undertaken using standard indices, namely, Shannons Diversity Index (H), Simpsons Index of Diversity (SI) and Berger-Parkers Index (D). Diversity indices calculated depicted variable patterns. Shannon's diversity index (H) depicted the diversity of cyanobacterial flora. Bergerparker index is indicative



Per cent abundance and diversity indices of cyanobacterial genera from selected rice varieties

of low evenness. Shannon's diversity index was highest for *Phormidium* and lowest for *Nostoc*, Berger parker index was highest for *Nostoc* and lowest for *Plectonema*, Simpson's index was highest for *Nostoc* and lowest for *Phormidium.* Pigments and N-assimilatory enzymes (nitrate reductase and glutamine synthetase) studied at 15th day of incubation showed variation among the cyanobacterial isolates. Total chlorophyll and carotenoids were found highest in isolate SR10. The phycocyanins formed a dominant component of total phycobilins in cyanobacteria. The NR and mean glutamine synthetase (GS) activity differed significantly amongst cyanobacterial isolates. GS activity ranged from highest of 57.0 µmole γ glutamyl hydroxamate/mg chl in isolate SR 6 to the lowest of 13.87 µmole γ glutamyl hydroxamate/mg chl in isolate SR7.

4.8.3 Encapsulated Microbial Inoculants for Phosphorus Nutrition and Crop Productivity

Spores of *A. niger*, an efficient organic P-mineralizer were encapsulated in different blends of natural polymers such as agar, starch, alginate, and acacia gum to develop a formulation for improving phosphorus (P) nutrition in soil. Bentonite clay was examined to improve the mechanical strength of capsules. Average diameter of dried alginate beads ranged between 2 and 2.5 mm and average weight was 25-30 mg. The diameter of the agar beads was dependent on the shape of casting material used and average size varied from 7 to 8 mm when wet and from 3 to 4 mm after drying. The swelling ratio of agar and alginate beads ranged from 156 to 432%. The higher concentration of bentonite clay impeded the swelling ratio of beads from 432 to 310%. The fungal spores encapsulated in different polymer matrices retained their capacity to solubilize inorganic phosphate to the extent of 60–70% of added Ca-P and mineralize organic-P by producing acid phosphatase enzyme. The viable cell population of different encapsulated formulations ranged from 60 ×10^3 to 21×10^7 cfu g^{-1} bead. Soil incubation studies for kinetics of cell release from different bead formulations recorded enhanced values of 5×10^6 g^{-1} bead with progressive incubation up

to 60 days compared to the population count of 3×10^3 at 20 d. The supplementation of polymer matrix with macro - and micro - nutrients improved the release of viable fungal spores from alginate beads.

4.8.4 Enhancing Microbed Mediated Nutrient Cycling under Non-flooded (Aerobic) and Flooded (Anaerobic) Conditions in Rice-Wheat Cropping System under Irrigated Conditions

Flooding or soil compaction can create microaerophilic conditions to anoxic conditions in the rhizosphere by limiting the concentrations of oxygen. The measurement of total oxidant demand (TOD) provides the amount of oxidant required to oxidize all reactive species. The TOD was measured in different soil types and in field soils under three different modes of cultivation. The TOD ranged from 1.3 to 16.1 [MnO_4^-] g/L which varied, largely due to soil types and to some extent due to the period of flooding. The microbial activities as influenced by the cultivation methods [conventional and direct-seeded rice (DSR)] and the distance from plant roots (rhizosphere versus non-rhizosphere) were monitored to understand the competition for carbon, energy and oxygen between rice plants and microbial communities in the field experiment of rice for the second year in a row. The potential nitrification activity in the rhizosphere was more under the DSR method of planting. But, the activities of urease were more influenced by the DSR method with fertilizers [half dose of N (55 kg N) with recommended doses of P (60 kg) and K (50 kg)] and cyanobacterial inoculant (BF1-BF4). The growth of rice plants altered the microbial activities, albeit marginally in some functions. Real-time quantification of copy numbers of bacterial *amoA* gene showed that the application of *Mesorhizobium ciceri* along with fertilizers led to decreased gene copies of 9.77×10^4 g^{-1} under the DSR method. The anammox gene copies were in the ranges of 1.37×10^4 to 5.88×10^4 g^{-1}. The archaeal and bacterial communities in these soils were analyzed by the PCR-denaturing gradient gel electrophoresis (DGGE) method. These analyses suggested that the modes and methods of rice cultivation had influenced the structures of archaea and bacteria; the application of chemical fertilizers led to clustering of many DGGE profiles together.

4.8.5 Microbes Mediated Water Stress Alleviation in Crops

Ten bacteria selected for their osmotolerance were evaluated for their plant growth promoting (PGP) traits under *in vitro* conditions. Except two, all the cultures showed an increase in P- solubilization under osmotic stress, however IAA production reduced under stress conditions. Interestingly Gibberellic acid production by the cultures was observed only under osmotic stress conditions. An increase in ammonia production by the cultures was observed under osmotic stress. Isolate MKL 4 2 showed the highest ammonia production. Except for four cultures (MMS 3, MKS 1, MAS 2 and MAL 3), the rest six showed siderophore production under no stress conditions and the same was not affected under osmotic stress. Isolate MAL 2 showed highest siderophore production. Isolates MMR 1 and MAL 3 improved shoot fresh and dry weights of pearl millet under water stress in a pot experiment. Isolate MMR 1 significantly improved seedling vigour of the inoculated plants in presence of 20% PEG 6000. On inoculation with these cultures under water stress conditions (20% PEG) seed germination ranged from 82.2 to 100%. In an uninoculated control, germination reduced to 93.3% and 17.8% in presence of 10% and 20% PEG 6000, respectively.

4.8.6 Bacterial Endophytes for Plant Growth Promotion

Brassica. carinata varieties Pusa Swarnim and Pusa Aditya were analysed for endophytic bacterial colonization that varied from 1.5×10^6 to 1.2×10^{10} in root, stem and leaves of plant samples. Based on morphology, 32 selected putative endophytic bacteria have been assessed for plant growth promotion attributes and abiotic stress tolerance. Out of which,18 isolates were found to produce growth hormone in the range of 120 to 2480 µg IAA/mg protein, P solubilisation 2.02 to 90.61µgP/mg protein, K solubilisation 1.07 to 38.5µg K mg^{-1} protein. All 18 potential plant growth

promoting isolates were found to tolerate heat stress of 50^0C and drought stress (40% PEG). Among the six potential endophytic bacteria (*Pantoea dispersa, Pantoea* sp., *Klebsiella variicola, Lactococcus lactis, Bacillus cereus and Staphylococcus hominis*), *Lactococcus lactis* was the most effective plant growth promoter. Eight *Pantoea* strains isolated from maize and wheat endo-sphere possessed major and micronutrient solubilization activities. Solubilization indices for P (PSI), K (KSI) and Zn (ZSI) varied from 3.7 to 5.3, 2.3 to 4.7 and 2.8 to 5.1, respectively. Among *Pantoea* isolates production of siderophore (SPI) and IAA varied from 3.5 to 5.0 and 83.3 to 190 $\mu g\ mg^{-1}$ proteins. These *Pantoea* isolates may prove to be potential bioinoculant for diverse crops in sustainable agriculture. In another experiment, chickpea endophytic (CE) bacterial isolates were screened for PGPR traits *in vitro* and evaluated for their potential to enhance the nodulation. No improvement in nodulation was seen, however, chickpea plant growth was increased significantly (11 to 70%) over uninoculated control.

4.8.7 Design and Development of Technologies for Utilization of Biomass as Feed and Other Value Added Products

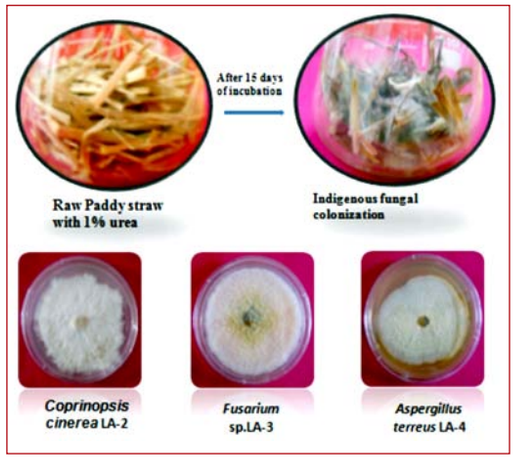
Studies have been conducted on the biomass production potential and the nutritional as well as anti-nutritional indicators of *A. microphylla*. High average biomass production was observed during summer months as compared to the winter months. Seasons affected the frond color of the organism mass multiplied outdoor and the frond color changed from green to red during the winter season. Consequently, the profile of secondary metabolites, such as anthocyanin, phenolics, flavanoid and tannin, may act as anti-nutritional compounds increased during the winter season with a corresponding decrease in the protein content. However, in summer, most of the important nutritional indicators, such as crude fat, crude protein, crude fibre, amino acid and the vitamin content did not show significant variation in response to the season. The foliage showed the presence of protease inhibitor but was found to be free from toxins such as aflatoxins and pesticide residues and phytate. Thus, *A. microphylla* could be exploited as potential feed supplement due to high rates of biomass production and favorable proximate composition of the biomass.

4.8.8 Development of Low-cost Technologies for Utilization of Biomass as Fuel

A study on paddy (var. Pusa 2511) straw was subjected to biological pretreatment with white-rot fungus, *Trametes hirsuta* and simultaneously with steam pretreatment at 121°C. Comparison was made on the basis of resultant saccharification efficiencies of differentially pretreated paddy straw to evaluate biological pretreatment methodology. The cellulose content in steam pretreated paddy straw was observed to be 39.5%, whereas for biological pre-treatment it was 37.6% with respective lignin content of 14.2 and 4.7% on dry weight basis. Lignin removal was substantially higher in biological pre-treatment compared to steam pre-treatment. The saccharification yields of biological pretreatment were similar to steam pre-treated paddy straw. Highest saccharification efficiency was observed after 24 h, at 2% substrate loading, for both biological (76.5%) and steam pre-treatment (74.1%). Whereas, maximum production of sugar (52.91 g/L) was observed in biologically pretreated biomass at 10% glucan loading after 24 h. Fermentation of enzymatic hydrolysates (2% substrate loading) with *Saccharomyces cerevisiae*, yielded ethanol from biologically pretreated biomass (0.86 g/L) and steam pretreated biomass (1.13 g/L). Overall, ethanol yield from biomass hydrolysates was lower than control, suggesting presence of inhibitory factors in hydrolysates and necessitating detoxification.

4.8.9 Design and Development of Mechanical and Biological Techniques for *In- situ*/*Ex-situ* Biomass Degradation

Three indigenous fungi were isolated from paddy and wheat straw and screened for their ability to produce lignocellulolytic enzymes under submerged conditions. Of the 3 fungi, *Coprinopsis cinerea* LA2 was selected based on its superior laccase (721.62 IU/g) production ability for *ex situ* degradation of



Isolation of indigenous fungi for *in situ* decomposition of crop residues

paddy/wheat straw. Biodegradation studies under unsterilized conditions with *C. cinerea* LA2 and *Cyathus stercoreus* ITCC 3745 were carried out with 0.1 and 0.2% urea to evaluate the colonization potential of the fungi on wheat/paddy straw under solid state. Paddy straw with 0.2% urea was found to be better inducer of lignocellulolytic enzymes.

4.8.9.1 Degradation of paddy straw

The degradation (*in situ*) of the chopped paddy straw and the improvement in soil health parameters were analysed by dividing the field into four strips, (S_1, S_2, S_3 and S_4) each with 5 m x 1.5 m size. Two strips (S_1 and S_3) were treated with fungal inoculum and two (S_2 and S_4) were kept untreated. Tractor drawn rotavator was used to mix the straw thoroughly with soil in S_3 and S_4 strip, while S_1 and S_2 were allowed to stay on top of the soil. The NPK content increase of 39.3, 32.6 and 42.6%, respectively, in S_3 in comparison to 34.3, 26.8 and 35.7% in S_4 signifies the importance of fungal inoculum in improving the soil health by paddy straw degradation in 45 days. In S_3, the available carbon increased from 0.43 to 0.62% in 45 days interval. The treatment S_4 showed an increase of 0.42 to 0.5. The evolution of CO_2 in S_1, S_2 and S_4 was 14.9, 18.6 and 16.8%, respectively, against 14.5 % in S_3. The increase in dehydrogenase activity from 57.51 to 111.04 µg TPF g^{-1} 24 h^{-1} in S_3 and simultaneously increase in CO_2 evolution from 272.8 to 319.1 mg indicated rapid degradation within 36 days.

4.8.9.2 Degradation of agrowastes

Based on the hydrolytic activity, one bacterial (TAB2) and two fungal strains (TAF3 and TAF2) were found to exhibit higher enzymatic potential at low temperature (10°C). The isolates were further screened for colonisation on various substrates mainly citrus waste, flower waste, vegetable waste, paddy straw, and in all the substrates the fungal growth was observed.

4.8.9.3 Degradation of flower waste

Flower waste collected from Sai Temple, Nazzafgarh area, New Delhi was composted in cemented pits at the Division of Microbiology, IARI, New Delhi. Each pit contained 100 kg of flower waste, a good quality soil and compost. Samples were collected periodically to analyse for C, N, P, K and phytotoxicity. The flower waste compost was prepared within 45 days and the finished product showed no phytotoxicity.

A **B**

Flower waste: (A) before, and (B) after decompsition

4.8.10 On-farm Evaluation of Microbial Inoculants in Different Crops and Agro-ecosystems of India

Results of OFT/FLD conducted during 2015-16 at different KVKs across the states showed that application of BGA @ 1.25 kg/ha and combined inoculation of liquid NPK + liquid Zn replaced 10-25% of chemical fertilizer and gave 0.12 - 0.15 and 0.16 - 0.21 t/ha additional yield over farmers' practice

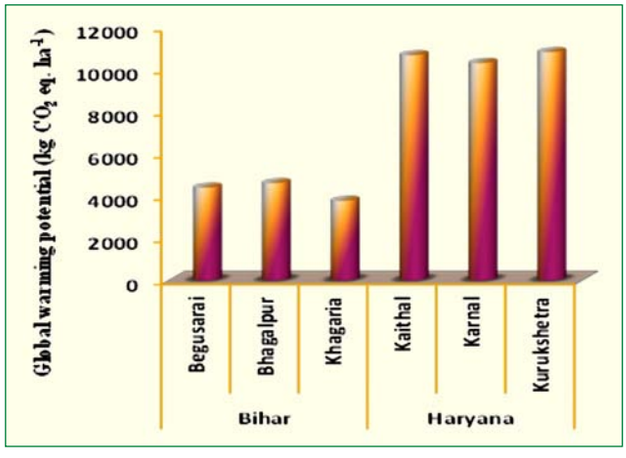
(FP) and recommended dose of fertilizers(RDF), respectively. Treatment with 75% chemical fertilizer + BGA and 75% chemical fertilizer + liquid NPK + liquid Zn gave ₹65,300-74,500 and ₹71,400-76,100/ha net returns, whereas RDF and FP gave ₹60,240-68,300 and ₹ 57,250-65,250/ha net returns, respectively. Farmers were very much satisfied with the role of biofertilizers in enhancing rice yield. The average increase the rice grain yield across the locations due to application of BGA and PSB was 6-10% over FPs.

Liquid formulations (*Azotobacter,* NPK, Zn and K) of biofertilizers were found user friendly, cost effective and potential sources of partial crop nutrition in rice and other crops at different locations in north-west and eastern India. On an average, inoculation of *Azotobacter,* NPK, Zn and K increased the rice grain yield by 5-11%, 5-10%, 4.5-5.5% and 2.5-4.5%, respectively over the FP across the locations. Response of liquid Zn and K biofertilizer in brinjal at KVK, Durg was very impressive where liquid biofertilizers applied with drip irrigation system. Compost inoculants tested at KVK, Rohtas (Bihar) and KVK Anta (Rajasthan) reduced the composting time by 15-25 days. *Azolla* was in huge demand from all the KVKs as well as individual farmers and they liked it for use as cattle feed. Many KVKs were assisted to establish *Azolla* production units at their farm as well as farmers fields, and inoculums and training were provided to those KVKs and farmers. Large number of farmers (>850) across the states were trained about the importance and use of biofertilizers in crop production.

4.9 ENVIRONMENTAL SCIENCE AND CLIMATE RESILIENT AGRICULTURE

4.9.1 Global Warming Potential of Rice-Wheat Cropping System in the Indo-Gangetic Plains

A survey of rice-wheat growing farmers in three districts of Haryana (Kaithal, Karnal and Kurukshetra) and Bihar (Begusarai, Bhagalpur and Khagaria) was conducted. The survey data were used as input in modified InfoRCT model. Both parts of the IGP significantly differed in green house gases (GHGs) emissions and their global warming potential (GWP). The GWP of rice-wheat cropping system (RWCS) of Haryana was 148.4% higher than that of Bihar. The simulated average global warming potential of conventional rice-wheat cropping system was 4268±179 kg CO_2/ ha in middle-IGP (Bihar) and 10605±680 kg CO_2 /ha in the Trans-IGP (Haryana). However resources conservation technologies (RCT) like system of rice intensification (SRI), direct-seeded rice (DSR) and zero-tillage wheat (ZTW) showed lower GWP than the conventional method of cultivation. Rice had higher contribution than wheat in GWP of rice-wheat cropping systems in both the states. The continuous flooded transplanted puddle rice (CFTPR), use of electric pump for irrigation and application of high amount of nitrogenous fertilizer were identified as main contributors of GWP.



Global warming potential of rice - wheat system in middle and trans-Indo-Gangetic plains

4.9.2 Impact of Conservation Practices on Greenhouse Gas Emission in Cotton-Wheat Cropping System

Emission of CO_2 and N_2O was monitored in cotton-wheat cropping system with resource conservation technologies (RCT's), such as zero tillage, residue retention and different planting methods from soils.

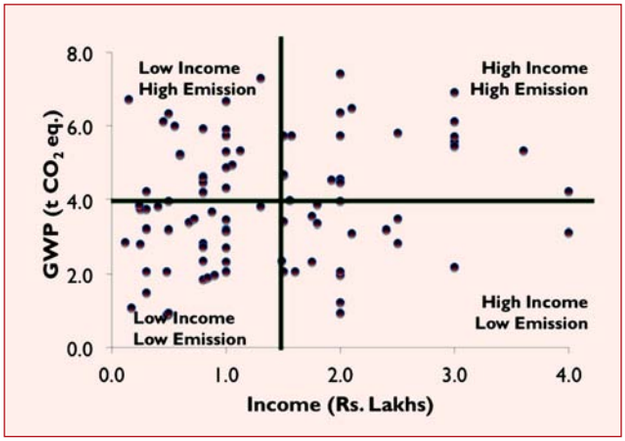
Zero tillage increased N_2O emission (8%) in cotton; however, the different planting methods of narrow bed and broad bed planting had no significant impact on N_2O emissions. Retention of residue increased N_2O emissions by 17 - 20% in cotton.

4.9.3 Mitigating GHG Emission in Rice-Wheat System with Crop Diversification

In north-western plains, the rice-wheat system emits 3 to 4 t CO_2 eq./ha. The emission could be reduced by 70 – 80% with crop diversification from rice-wheat to maize-wheat system. In the maize-wheat system again, use of neem oil coated urea and dicyndiamide reduced the global warming potential by 10 – 15% and increased grain yield by 4 – 5% over the conventional practices.

4.9.4 Whole-farm Emission of Greenhouse Gases and their Mitigation

Emission of GHGs was estimated at farm level under climate-resilient technologies, such as direct-seeded rice, zero-tillage in wheat, summer *moong* in rice-wheat system, green and brown manuring, mulching, protected cultivation of vegetables, drip irrigation, bio-fertilizers, raised bed planting and integrated pest management in Mumtajpur and Lokara cluster villages of Pataudi block of Gurugram district in Haryana. The whole-farm emission of GHGs in these villages varied from 0.9 to 12.5 ton CO_2 eq. per farm. Cluster analysis of greenhouse gas emission with farm income of households revealed that majority of farms have high emission but low income, while some farms could earn more with low emission of GHGs. Efforts are being made to identify and promote such technologies and farm practices with high income but low emission.



Relationship of GHG with farm income of households at Mumtajpur and Lokara villages in Gurugram, Haryana

4.9.5 Impact of Elevated CO_2 and Temperature on GHG Emission in Rice

Experiments were conducted growing rice varieties Pusa 44 and Pusa Basmati 1509 in open top chambers for assessing the impact of elevated air temperature (+1.5°C) and increased atmospheric CO_2 (550 ppm) on global warming potential (GWP) of soil under urea, neem oil coated urea (NOCU) and urea coated with urea stabilizer Limus. Elevated temperature significantly increased emission of both CH_4 and N_2O. No significant interactive effects of increased levels of CO_2 and temperature were observed on N_2O emission; however the increase in CH_4 was significant. The application of neem oil coated urea and *Limus* coated urea significantly decreased the GWP over urea under elevated temperature and also in the interaction treatment.

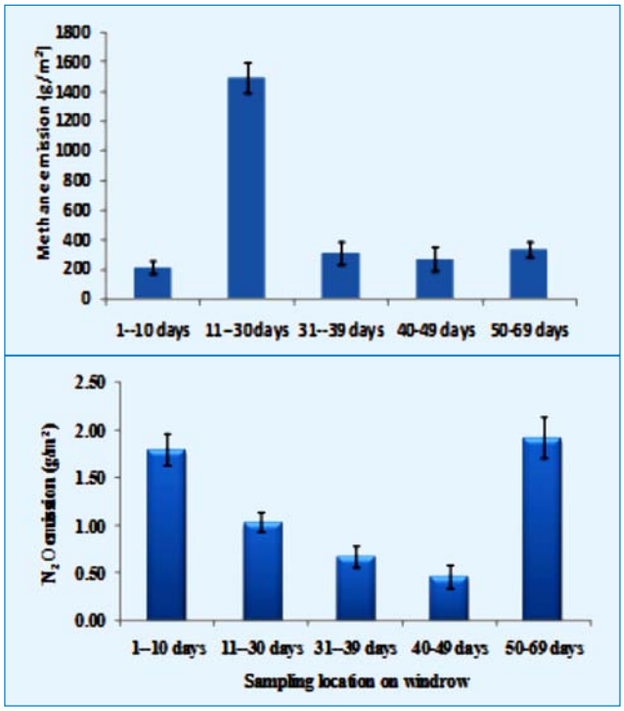
Emission of CH_4 (kg/ha) under elevated CO_2 and temperature in rice

Nitrogen treatments	Ambient CO_2 and temp.	Elevated CO_2	Elevated temp.	Elevated CO_2 and temp.
Control	19.04a*	25.63a	23.12a	25.92a
Urea	25.27c	30.47b	29.51c	33.80c
Limus	22.50b	29.59b	26.85b	30.35b
NOCU	23.08b	29.12b	27.58b	31.27b

***Means followed by the *same letter* in the columns did not differ significantly ($P \leq 0.05$) by DMRT**

4.9.6 Emission of GHG during Composting of Municipal Solid Waste

Delhi generates approximately 8309 tons waste per day and only 4150 tons per day is processed. Aerobic composting with windrows method after proper segregation of municipal solid waste (MSW) is recognized as a cost-effective method and the compost can be used in fields, orchards and gardens as soil



Emission of methane and nitrous oxide during aerobic composting of municipal solid waste

amendment. This technology not only reduces the quantum of waste to be disposed at the landfill site but also reduces the emission of greenhouse gases (GHG's) from landfills, leaching of pollutants to aquifers and ground water. In Delhi, approximately 400-480 tons of waste is processed by aerobic composting per day. Emission of methane and nitrous oxide from aerobic composting of MSW with windrows method was quantified. Methane emission was higher during 11-30 days of composting whereas N_2O emission was high during initial 8-10 days and started declining at later stage. During the stabilization of compost N_2O emission increased but methane emission decreased due to more availability of oxygen. The total methane emission was 1.11 kg/tonne MSW and nitrous oxide was 0.0034 kg/tonne MSW composted.

4.9.7 Mitigating Nitrous Oxide Emission from Soil with Microbial Interventions

The nitrous oxide (N_2O) can be transformed to nitrogen gas (N_2) by those bacteria and archaea harboring the *nosZ* gene responsible for N_2O reductase enzyme production, which is the only known N_2O sink in the biosphere. With this aim, to isolate N_2O reducing microbes, soil samples and sea sediments were collected from flooded rice fields of Coochbehar district, West Bengal and from Zuhu, Mumbai, respectively. Total seven different strains were isolated and four were found to have N_2O reduction capacity. One of the isolate (CNS-2) from Coochbehar rice field soil was found to have 73% reducing capacity.

4.9.8 Economic Assessment of GHG Mitigation in Rice – Wheat System

The economic analysis of some emerging GHG mitigation technologies for rice – wheat system of the IGP was carried out. The experiment consisted of eight treatments, including conventionally tilled wheat (CTW), zero tilled wheat (ZTW), transplanted puddled rice (TPR), dry direct-seeded rice (DSR), intermittent wetting and drying (IWD), application of rice straw (RS) with ZTW and use of neem oil-coated urea (NOCU) in TPR and ZTW. ZTW showed higher yield and B : C ratio compared to CTW alongwith reduction in fuel consumption. In spite of lower yield under DSR and IWD, saving of water, labour and energy in these treatments lowered the cost of cultivation and enhanced B : C ratio similar to TPR. Application of rice straw and NOCU showed positive impact on crop yield. The B : C ratio of rice – wheat system ranged from 1.62 to 1.86 in the first year and from 1.86 to 2.16 in second year. The B : C ratio was significantly higher in all the treatments in rice–wheat system compared to conventional system i.e., CTW–TPR. The ZTW + RR – DSR showed highest B : C ratio followed by ZTW + DSR in both the seasons.

4.9.9 Impact of Elevated CO_2 and O_3 Ozone Interaction on Crop Growth and Productivity of Maize

Experiments were conducted in free air ozone (O_3) and carbon dioxide (CO_2) enrichment rings (FAOCE) to quantify the impact of elevated ozone and carbon dioxide interaction on crop growth and productivity of maize. Two levels of elevated ozone 60 ppb and

80 ppb and 550 ppm of elevated CO_2 concentration were taken for growing maize variety PEHM 5. The presence of 60 ppb and 80ppb O_3 led to 11% and 15% decline in the yield of maize. The presence of 550 ppm of elevated CO_2 alongwith elevated O_3 increased the yield of maize by 8 and 6%, respectively, over the elevated O_3 levels alone. Thus, elevated levels of CO_2 were able to counter the reductions in yield due to elevated O_3.

Greenhouse gas intensity and B:C ratio of different rice-wheat combinations

Treatments	GHG intensity (GWP/Yield)		B : C ratio	
	I year	II year	I year	II year
CTW-TPR	0.190d	0.213d	1.62a	1.86a
ZTW-TPR	0.190d	0.223d	1.75b	2.00b
ZTW-IWD	0.160b	0.183b	1.75b	2.01b
ZTW-DSR	0.103a	0.120a	1.77b	2.05b
ZTW+RR-DSR	0.103a	0.123a	1.86c	2.16c
(ZTW-TPR)+NOCU	0.173c	0.200c	1.74b	1.99b

Means followed by the *same letter* in the columns did not differ significantly (P ≤ 0.05) by DMRT

4.9.10 Impacts of Elevated Carbon Dioxide on Productivity and Nitrogen Fixation in Legumes

Mungbean and cowpea crops were grown inside and outside the Free Air Carbon dioxide Enrichment Facility (FACE), in IARI field with two CO_2 levels i.e., ambient (395 ppm) and elevated (550±20 ppm) with five levels of phosphorus (0, 8, 12, 16 & 20 mg P/kg soil) and with and without cyanobacteria (*Calothrix sp*.) inoculation. Elevated CO_2 level increased photosynthesis rate, leaf area and chlorophyll content of both the crops, which were ultimately reflected in 33.4% increase in seed yield in mungbean and 24.6% increase in pod yield in cowpea crop. Application of cyanobacteria further improved yield of both the crops. Nitrogen fixation by both the legumes increased under high CO_2 level. P dose of 16 mg/kg recorded highest N fixation in mungbean, while P dose of 20 mg/kg showed maximum N fixation in cowpea crop. More N fixation and better root growth improved soil N status and other biological properties of soil in increased CO_2 treatment. Elevated CO_2 level caused increase in soil organic P and subsequent decrease in inorganic P in both the crops. The study showed that elevated CO_2 and cyanobacteria application enhanced productivity and N fixation in both the legumes, with cowpea being more efficient than mungbean crop. Application of P is important for enhancing productivity and N fixation of legumes under changing climatic scenario.

4.9.11 Ammonia Volatilization in Wheat under Different Temperature Regimes and Nitrogen Levels

Ammonia (NH_3) volatilization is the major process of loss of N from soil. Effect of high temperature on ammonia volatilization and yield under different N levels in wheat crop was studied with four different temperature regimes viz., ambient temperature, temperature gradient tunnel (TGT), plus 3°C and plus 5°C and four different levels of N, viz., 0, 90, 120 and 150 kg/ha. The rate of NH_3 volatilization enhanced with the dose of N-application and was mostly emitted upto the 6th day of fertilizer N application. Ammonia volatilization ranged from 4.2–20.4 kg/ha/season with highest at 150 kg/ha N application i.e., 13.6% of applied N was lost as NH_3.Volatilization increased with elevated temperature.

Ammonia volatilization in wheat with various temperature and nitrogen levels

Treatment	Ammonia volatilization (kg N/ha)			
	N_0	N_{90}	N_{120}	N_{150}
Am. T	0.11	0.25	0.26	0.39
Am. T Cont	1.00	6.41	9.30	10.11
T+3°C	2.30	8.50	11.00	11.75
T+5°C	2.50	9.81	13.90	14.35

LSD (P=5%) N: 0.2, T: 0.2, NxT: 0.4

4.9.12 Particulate Matter Pollution Load at IARI and its Impact on Rice Varieties

Impact of particulate matter (PM) pollution load on rice crop was assessed at IARI farm. The PM pollutants (PM_{10}, PM_5, $PM_{2.5}$ and PM_1) load was collected through active monitoring done by GRIMM

and quantified and characterized for it source. Average mass concentration during the crop growth period was found to be maximum and minimum for PM_1 and $PM_{10,}$ respectively. Fall in PM ambient load was observed after rainfall, but again it increased within a week. Dominant elements in particulate matter air parcel identified through SEM-EDS analysis were carbonaceous, Si, K, Ca, Cl and Na. The deposition rate of the atmospheric particulate matter on rice varieties canopy *vis – a – vis* rice varieties leaf characteristics such as area, anatomy, stomatal density and frequency, trichome density and frequency were quantified. It was found that deposition rate varied between the varieties as well as with the leaf area. The positive correlation was observed between SPM deposition rate and leaf area of rice plants.

4.9.13 Impacts of Air Pollution on Crops

Leaf samples of rice at the maturity stage were collected from the various locations around the Dadari Thermal Power Plant. It is observed that nitrogen, phosphorus, potassium, sulphur and carbon content of the leave were significantly increased with the increasing distance from the thermal power plant, however, total suspended particulate matter (SPM) deposition on leaf was decreased with the increase in distance.

4.9.13.1 Air pollution due to burning of rice and wheat crop residues

Farmers follow rice – wheat cropping system in the Indo-Gangetic plains, and due to use of combine for harvesting, huge amount of crop-residue is generated. About 60 to 84% of rice residues and 48-72% of wheat are burnt in the fields. Burning of crop residue leads to the emission of various toxic gases, greenhouse gases and particulate matter (PM) in the atmosphere. Average concentration of PM 2.5 and PM 10 was 401.9 µg/$m^3$and 527.5 µ/gm^3 due to rice residue burning and 342.9 µg/m^3 and 471.84 µg/m^3 due to wheat crop residue burning, respectively,. Organic carbon constituted the major fraction of PM2.5. The SEM images of rice PM 2.5 showed the abundance of soot particles, carbon particles and silica. Whereas, wheat PM 2.5 showed more soot and carbon particles. Major elements in particulate matter of rice and wheat crop residues were carbon, oxygen and silica which contributed 78.4% in rice and 84.7% in wheat. The X-Ray Diffraction of rice and wheat straw ash indicated the presence of silica, potassium chloride, and potassium calcium phosphate.

4.9.13.2 Effect of particulate and gaseous pollutants on growth and sulfur nutrition of crops

Between the two wheat cultivars, *durum* wheat responded positively to elevated SOx and NOx levels in terms of growth and sulfur nutrition. It was evident also from a higher concentration of leaf and whole plant S level compared to other experimental treatments. Chickpea appears to be sensitive to particulate pollutants which could inhibit the gas exchange rate in this crop more severely than the other experimental crops as was evident from a relatively higher reproductive efficiency of chickpea in tunnel with normal filter that removed the particulate pollutants from the growth environment when compared with the normal air environment control. Barley appears to perform exceptionally well in an environment free of noxious gases and particulate pollutants. It can be concluded that amongst the four experimental crops, *durum* wheat shall be benefitted under condition of elevated SOx and NOx in the environment. However, threshold values for these pollutants across crops need to be determined.

Among the crops, chickpea showed maximum degree of reduction in yield followed by barley and wheat by existing load of gaseous and particulate air pollution. Chickpea registered about 55% reduction in seed yield, which was attributed to 40% by gaseous and 15% by SPM pollution. Similarly barley accounts for 33% reduction in grain yield by ambient air pollution where 10% loss was recorded by gaseous and 23% by suspended particulate matter. The wheat species both *aestivum* and *durum* recorded comparatively less extent of yield reduction as compared to barley and chickpea by air pollution, but the pattern of yield loss in *durum* wheat was similar to barley where suspended particulate matter pollution showed greater reduction

in yield (17-23%) as compared to gaseous air pollution (6-10%), whereas in *aestivum* wheat, gaseous air pollution caused greater loss in yield (20%) compared to SPM load in ambient air (3%), which may possibly be due to rough leaf surface in barley and *durum* wheat.

4.9.14 Phosphorus Dynamics in Conservation Agriculture Practices for Rice-Based Cropping System

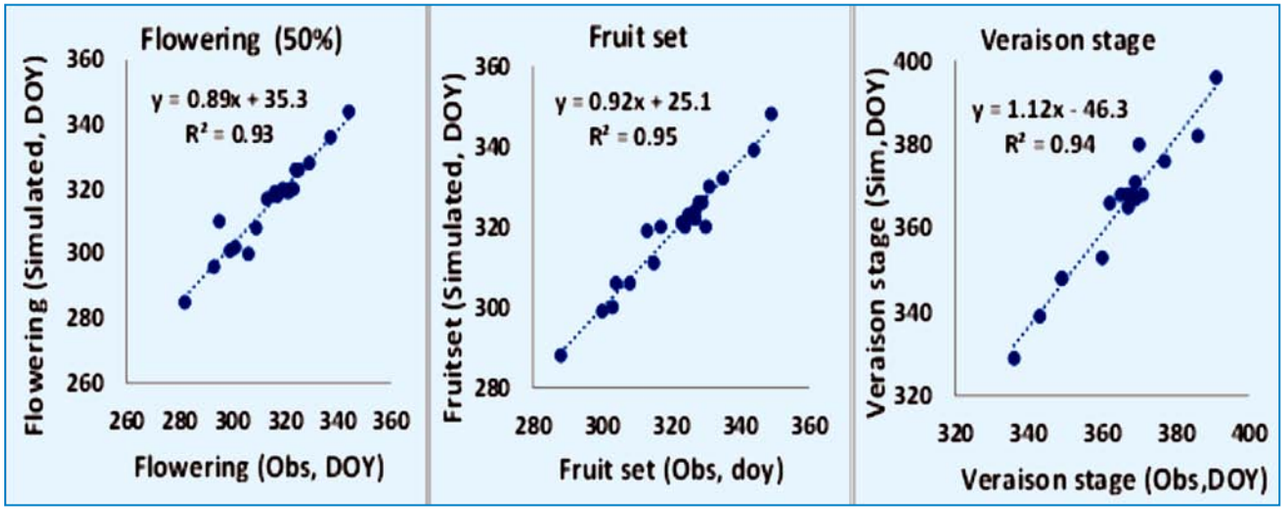
The highest available P were recorded in transplanted rice-zero till wheat (TPR-ZTW) and lowest available P were recorded in direct seeded rice - zero till wheat + rice residues (DSR-ZTW + RR) treatment. Further, sub surface soil (15-30 cm) had low available P content in comparison to surface soil (0-15 cm) across the treatments.

4.9.15 Effects of Modified Urea on Nitrogen-use Efficiency and Yield of Rice

The highest grain yield of 4.98 t/ha was recorded from PGUG and the lowest value of 2.4 t/ha was obtained from control. The N use efficiency value increased when N was applied as phosphogypsum coated urea granule (PGUG) compared to other treatments. Soil enzymes activity also improved in PGUG treatment.

4.9.16 Application of Grape Model for Forecasting the Phenological Events in Grape

The phenology module of grape simulation model was calibrated and validated for its predictive performance in 40 farmers' fields during 2013-14 and 2014-15. The model was run at daily step to test the efficiency to simulate dates of pre-bloom, 50% flowering, fruit set, veraison and harvest at 18° Brix. Simulation date of veraison stage could be improved from 0.71 in 2013-14 to 0.84 in 2014-15. This model, further was used to forecst the the grape phenological events in 33 farmers'vine yards during 2015-16 to demonstrate the satisfactory level of accuracy for its decision support application in grape management. The simulation efficinecy has been at a R^2 of over 0.93 for flowering, fruit ste and veraison stage.



Validation of phenology module for events during 2015-16 in grape vineyards of Nasik

5. CROP PROTECTION

Pests and diseases cause quantitative and qualitative losses in field and horticultural crops. One of the contributing factors to the gap between theoretical and actual crop yield lies in the effective use of crop protection products. Major impacts of the changing climate and cropping pattern is the rising complexities in pest and pathogen dynamics, hence there is need to plan crop protection strategies that include cultural, biological and chemical methods to provide most effective and sustainable options. Predicted changes in rainfall and heat as a result of global climate change will be the most severe in developing countries and also impact the demographics of agricultural pest populations. The school of crop protection develops and employs innovative control measures to counteract the impact of insects, plant diseases and weeds. During the year under report, diversity studies, resistance in hosts against major pests and pathogens, identification of some new diseases and development of diagnostic protocols were undertaken. Correct diagnosis is prerequisite to sustainable management. Besides biological control measures novel chemical molecules were identified to form a part of integrated management. Identification of sources of resistance against major pests and pathogens were also undertaken, which shall be used for breeding resistant crop varieties. These crop protection strategies will improve the yield and bring about economic benefits.

5.1 PLANT PATHOLOGY

5.1.1 Pathogen Diversity, Race Profiling and New Diseases

***Fusarium* species.** Virulence analysis of 94 isolates of fungus *F. fujikuroi* causing bakane in rice on a new set of 10 different rice genotypes revealed existence of twenty pathotypes. Pathotype 3 was widely prevalent and distributed in Punjab, Haryana and Uttar Pradesh states of India. Isolation and characterization of fungal pathogens inciting vascular wilt of tomato in Delhi, Uttar Pradesh and Himachal Pradesh indicated the association of two species, *F. solani* and *F. oxysporum*.

***Puccinia triticina*.** Molecular characterization of twenty four leaf rust fungul pathotypes using URP markers showed a positive correlation between URP based clustering and virulence/avirulence behaviour, geographical origin and evolution time of different leaf rust pathotypes. Analysis showed two major clusters, in cluster I, subgroup Ia comprised of pathotypes 12, 12-1,12-3, 12-4, 77-5, 77-2, 162-1, 77-3, 106, 77-4, 77-7 and 77-9, of South Indian origin while Subgroup Ib represented North Indian pathotypes viz. 12, 12-2, 104-3, 104-4, 162, 104, 104-1, 104-2, 12-1, 12-4 except 77-6 and 77-1.

***Puccinia graminis tritici*.** Thirty one stem rust fungus samples were collected from field and race analysis using differential sets revealed that the Race 40 A was predominant.

***Tilletia indica*.** Surveys conducted in Ghaziabad, Meerut, Hapur, Bulandshar of Uttar Pradesh confirmed the incidence of Karnal bunt which ranged from 0.2 to 15% in wheat crop. Surveys in markets located in Nazafgarh, Bahadurgarh, Narela, Aligarh,

A B

Infected wheat spikes of Karnal bunt (A) and Bunted grains(B)

Bulandsahar and Dadri revealed 0.7 to 19.5 percent coefficient of infection of Karnal bunt.

Alternaria brassicae. A collection of 32 isolates of *Alternaria brassicae* fungus causing dark leaf spot of crucifers in India could be grouped into five vegetatively compatible groups (VCG groups) based on standard assays.

Colletotrichum. *Colletotrichum orbiculare* (=*C. lagenarium*) fungus isolated from cucumber affected by anthracnose disease were characterized by ITS sequencing. In pathogenicity study, isolate CUCO-MT was highly virulent, exhibiting maximum growth at pH 5-8 and temperature range 18-28° C.

***Penicillium* spp.** MLST (Multi Locus Sequence Typing) was done for 45 isolates representing 14 *Penicillium* species based on β-tubulin, calmodulin, ITS and rpb2 regions and putative barcode region has been identified.

Association of distinct atypical satellite molecules with CLCuD – begomovirus. Fifteen betasatellites and 18 alphasatellites isolates from leaf curl infected cotton from Punjab and Rajasthan were sequenced and analyzed. Beta satellites from cotton showed 72-99% nt identity among them and 34-97% with other betasatellites. Alphasatellite molecules shared 69-100% nt identity among them, and 40-98% with other begomovirus associated alphasatellites, showing extensive diversity in Indian alphasatellite molecules.

Begomovirus on carrot. In carrot, leaf curl symptoms were identified in the carrot improvement trial in Division of Vegetable Sciences, IARI. A begomovirus, *Pedilanthus leaf curl virus* and an alphasatelliete croton leaf curl alphasatellite virus were identified from the diseased plants.

Carrot plants showing severe leaf curl symptoms

Grapevine leafroll-associated virus 4 on grape. Association of *Grapevine leafroll-associated virus* 4 was confirmed in vineyard orchards of Maharashtra on the basis of ELISA and sequencing of coat protein gene. The study indicated widespread occurrence of GLRaV-4 in Indian vineyards.

Characterisation of phytoplasma associated with brinjal little leaf. Twenty four BLL strains from eight states of India characterized on the basis of sequence comparison of 16S RNA, secA, secY genes and phylogeny and RFLP analysis lead to identification of 16SrII-D and 16SrVI-D subgroups. Transmission test and population dynamics study confirmed *Hishimonus phycitis* as a natural vector and *Cannabis sativus* and *Portulaca oleracea* as new alternative hosts of BLL.

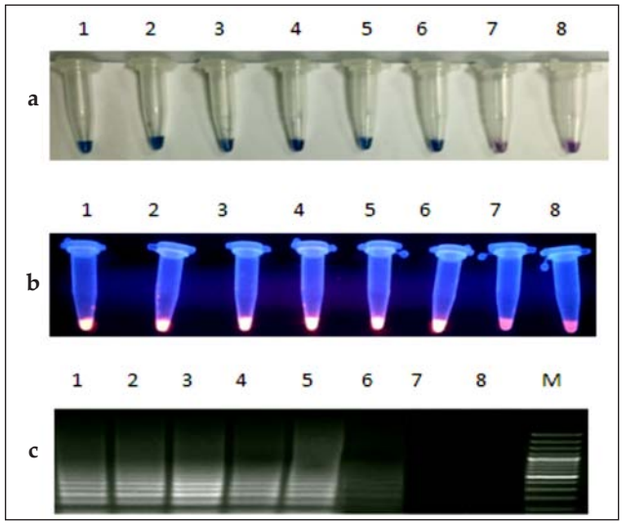
New efficient natural vectors of sugarcane grassy shoot phytoplasma in India. *Maieseas portico* (MP) (Melichar) and *Cofana unimaculata* (CU) (Signored) were proven new natural and potential vectors to transmit the Sugarcane grassy shoot phytoplasma from diseased to healthy sugarcane plants in transmission assays.

Other phytoplasma diseases. New phytoplasma diseases have been identified on ornamental species of ornamental crotons (16Sr I group), *Rosa* species (16Sr I & II groups) and *Celosia argentea* species (16Sr II-D subgroup) on the basis of 16Sr DNA sequences, phylogeny and RFLP analysis.

5.1.2 Molecular Diagnostics

***Fusarium* spp.** A gene based specific marker was developed for the detection of the fungus *Fusarium fujikuroi* causing bakanae disease of rice. The sensitivity assay of PCR based primer was upto 10 pg of *F. fujikuroi* DNA.

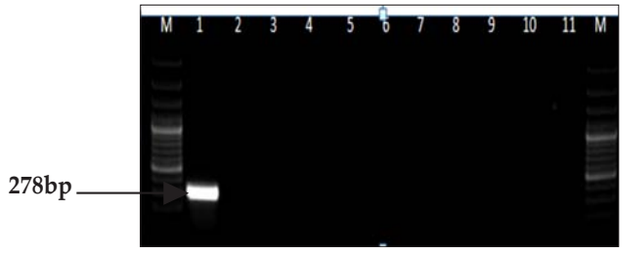
Puccinia striiformis tritici. A loop mediated isothermal amplification (LAMP) based protocol targeting ketopentoate reductase gene was standardized



Sensitivity of LAMP assays of *Puccinia striiformis tritici* using (a) HNB dye (b) EtBr (c) DNA laddering in agarose gel electrophoresis. Lanes from left to right: 1(100ng); 2 (10ng); 3 (1ng); 4 (100pg); 5 (10pg); 6 (1pg); 7 (100fg); 8 (10fg); M (1kb molecular marker, Fermentas)

and validated for detection of fungus *P. striiformis tritici* causing yellow rust of wheat.

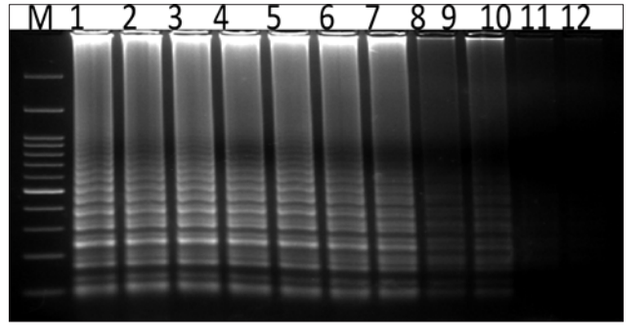
Bipolaris oryzae. A robust PCR-based diagnostic marker ($RABO_{278}$) was developed to detect fungus *Bipolaris oryzae*, designed from hypothetical small secreted protein gene specific to *B. oryzae*. The detection limit of marker was 1.0 pg and 10.0 fg with conventional PCR and qPCR assays respectively. The brown spot could also be detected in rice leaves at pre-symptomatic stage.



Agarose gel showing specificity of BoRA-278F and BoRA-278R primers set to *B. oryzae* using genomic DNAs of different isolates of *Bipolaris spp.* and other fungal genera. M: 100bp molecular marker; 1: DNA templates of *B. oryzae* (BO-1); 2: *Bipolaris sorokiniana* (BS-112); 3: *B. sorokiniana* (BS-75); 4: *Puccinia triticina* (77-5); 5: *P. striiformis* (46S119); 6: *Alternaria triticina;* 7: *Fusarium fujikuroi;* 8: *Rhizoctonia solani* (4505); 9: *Aspergillus niger;* 10: rice leaf DNA and 11: sterile water

Tilletia indica. A qPCR-based diagnostic assay from ITS region was developed to detect the presence of fungus *Tilletia indica* in soil. This marker specifically amplified 150 bp amplicon only in *T. indica* isolates. The detection limit of marker was 10 pg and 100 fg with conventional PCR and qPCR, respectively. This method can be used for rapid and specific detection and quantification of *T. indica* teliospores in soil/ grains.

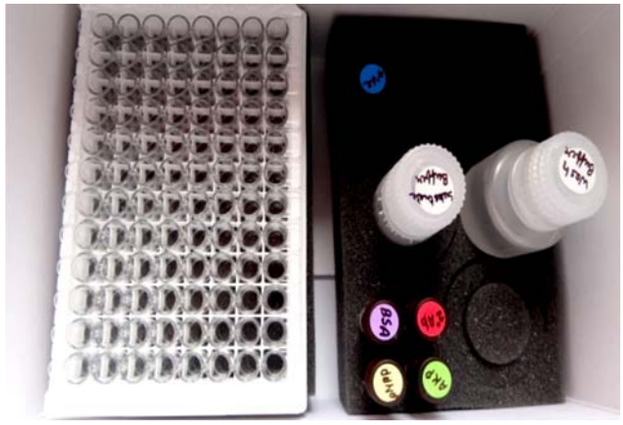
Ralstonia solanacearum. A Loop-mediated Isothermal Amplification **(**LAMP)-based detection protocol targeting *egl*62 was developed for *Ralstonia solanacearum*, the incitant of bacterial wilt of solanaceous crops. The LAMP assay can potentially be used for preliminary screening for *R. solanacearum.*



Sensitivity of *egl* gene based primer in LAMP technique for detection of *Ralstonia solanacearum.* M= 1KB Ladder; Lane 1= 100ng DNA (UTT-25); Lanes 2-12: 10^{-1}-10^{-11} of 100ng DNA (UTT-25) of *R. solanacearum*

Simultaneous detection of polyketide producing bacterial strains of Bacillus spp. PCR was validated for the simultaneous detection of of macrolactin (793 bp), difficidin (705 bp), and bacillaene (616 bp) in 23 strains of *Bacillus* spp. *B. amyloliquefaciens* DSBA-11 and *B. subtilis* DTBS-5 were positive for all the three polyketides genes while *B. pumulis* and *B. licheniformis* showed only two polyketide genes. The soil from Meghalaya (Shilong) showed higher percentage (55%) of polypeptides producing *Bacillus* strains followed by Uttarakhand (46.46 %) and Delhi (40.0%).

DAS-ELISA kit for diagnosis of Potato virus X (PVX). A DAS ELISA kit for detection of Potato virus X (PVX) was developed for commercialization. The kit



Photograph of in-house PVX-DAS ELISA kit

includes PVX antibody coated ELISA plates, blocking agent bovine serum albumin (BSA), secondary antibody, enzyme conjugated antibody, substrate as well as buffers for washing. It was validated using both purified PVX coat protein and PVX infected potato samples collected from field.

Multiplex RT-PCR for detection of 4 viruses and greening bacterium in Citrus. A degenerate primer was designed to detect *Indian citrus ringspot virus* (ICRSV) and *Citrus yellow vein clearing virus* (CYVCV) of genus Mandarivirus. A multiplex polymerase chain reaction (mPCR) assay for detection of CYVCV, *Indian citrus ringspot virus* (ICRSV), *Citrus yellow mosaic virus* (CYMV), *Citrus tristeza virus* (CTV) and a bacterium, Candidatus Liberibacterasiaticus (CLa) associated with huanglongbing (HLB) common in Indian citrus orchards was developed.

Diagnosis of six begomoviruses infecting tomato in India. A highly specific PCR diagnosis was developed and validated for six begomoviruses species ToLCNDV, ToLCBV, ToLCPalV, ToLCGV and ToLCJoV infecting tomato in India. The sensitivity of the specific detection was 5 pg of viral DNA.

5.1.3 Biocontrol Agents and their Bioprospecting

Molecules from endophytic bacteria. The plant endophytic *Pseudomonas putida* BP25 and *Bacillus megaterium* BP17 released broad spectrum microbial volatile organic compounds (MVOCs) which were mainly pyraxenes and were effective against pathogens such as *Phytophthora capsici, Pythium myriotylum, Magnaporthe oryzae, Giberella moniliformis, Rhizoctonia solani, Colletotrichum gloeosporioides, Xanthomonas axonopodis* pv. *punicae, Xanthomonas oryzae* pv. oryzae, *Ralstonia solanacearum* and plant parasitic nematode, *Radopholus similis*.

Molecules from Trichoderma. Metabolome analysis of *Trichoderma* species revealed presence of isoharzianic acid (iso-HA), Harziandione, a stereoisomer of HA (92%), fungitoxic Thazin-1-one(0.7%), 1,5-dihydro-1- 4-methoxyphenyl (0.88%), Phenol,2,4-Di-tert-butylphenol (42.68%), Phthalic acid (6.07%), Heneicosane (1.95%),6-hydroxycariophyllene (3.36%), Cyclonerolidol (9.74%) etc having fungistatic activity.

Management of bacterial wilt disease of tomato. Talc based bioformulations of *Pseudomonas fluorescens* (DTPF-3) and *Bacillus amyloliquefaciens (*DSBA-11) @ 5 g/ liter as soil drench at transplanting of tomato at Chaffi village (Nainital), Uttarakhand, showed reduced wilt incidence (15.27%) as compared to 47.55 % in control.

Management of Fusarium wilt of tomato. Compatibility of the rhizobacteria, S2BC-1 and TEPF-Sungal and *Trichoderma harzianum*-S17TH with *Chaetomium globosum*-CG-A was studied to develop consortium. CG-A exhibited significant antagonism against the pathogen isolate-TOFOL-VRF and exhibited positive interactions on growth assays. *In vitro* growth assays involving cell free culture (CFC) filtrates indicated that the growth of either of the bacterial antagonists was not inhibited by the CFC of the other rhizobacterial or fungal isolates therefore microbial consortia can be utilized for management of Fusarium wilt of tomato.

5.1.4 Evaluation of Crop Genotypes for Disease Resistance and Mechanisms of Resistance

Rice. Rice entries (354) when evaluated against rice blast isolate, U73-i7-k127-z03-ta002 showed resistant reaction in 25 genotypes. In an another

trial, out of 26 entires evaluated, Raminad STR-3, Rasi, *O.minuta*, Zenith, Tadukan, Tetep, and BL122 were found resistant. Among 65 International Rice Blast Nursery lines evaluated, twelve IRBN lines were found resistant. Out of 667 entries from Indian Institute of Rice Research, Hyderabad evaluated against sheath blight of rice, entries- 2506, 2902, 2903, 1803, 3306, 3303, 3016, 1505, 01/111, 04/102, Tetep and VL-31817 were moderately resistant. Out of fifty four wild rice accessions evaluated, three accessions ILS-11-1, ILS-12-5 and ILS-5-2 were found resistant. Of 9235rice plants belonging to 749 entries from Division of Genetics using Xoo Race 4, only 6 entries out of 249 MAS derived lines were found resistant; while 392 lines (including 34 advance backcross derived lines in the background of PB1121 carrying *Xa38*) were found to be moderately resistant and 278 lines were moderately susceptible. In NHSN entries for bacterial blight screening**,** out of 131 entries, none was found resistant.

Wheat. Among the 699 preliminary disease screening nursery (PDSN) wheat entries evaluated for rusts resistance, forty entries were found to be highly resistant against all the three rusts at adult plant stage. Out of three hundred and nineteen CVT wheat genotypes evaluated for rusts at seedling stage (SRT), twenty three entries were resistant. With regard to yellow rust resistance thirty five entries of CVT showed resistance to yellow rust at seedling stage. Race specific (78S84 and 46S119) APR response of AVT IInd and AVT Ist year wheat entries (173) revealed that some of the wheat genotypes *viz.* HD 4730, WH 1164, HD 3086, PDW 314, HD 4728, HD 4730, TL 2942, HPW 349, HS 596, HS 597, HS 599 etc possess high degree of resistance to both the pathotypes. Evaluation of wheat genotypes of IPPSN (1619), PPSN (526), EPPSN (77) and MDSN (41) revealed that 745, 233, 25 and 16 entries, respectively were found to be resistant against leaf rust. Out of sixty exotic wheat germplasm (CIMMYT Mexico Core Germplasm Panel, CIMCOG) evaluated against yellow rust both at seedling and adult plant stages, eight entries showed resistance. Slow rusting/adult plant resistance assessed through host response and epidemiological parameters revealed a positive correlation with FRS, rAURPC and r. Out of 23 CIMMYT lines, only one line with *Sr* 24 gene (BTSR 24 AG) was absolutely free from stem rust. This line could be exploited as a source of resistance to stem rust in wheat breeding programme. Nine lines conferred moderate levels of resistance. Durum wheat genotypes HG110, IWP 5019, B662 and Line 1172 were identified as diverse sources of resistance to stem and leaf rusts, and were submitted to NBPGR, New Delhi for germplasm registration. HI 8738, a durum line was found to be resistant to all three rusts, leaf blight, Karnal bunt and flag smut based on multi-location testing over four crop seasons. HI 8724, HI 8725 and HI 8728 were found to be resistant to all three rusts. HI 8739 and HI 8742 were found to be resistant to stem and leaf rusts, karnal bunt and flag smut. Hence, these genotype could be utilized as a source of multiple disease resistance in wheat improvement. Among 179 entries (79 KBSN and 100 AVT) screened for resistance to Karnal bunt, 6 entries remained free from KB infection. Among 611 lines of wheat screened for spot blot resistance under field conditions, 17 genotypes were found to be resistant.

Maize. Out of 388 maize genotypes evaluated against maydis leaf blight (MLB), and banded leaf and sheath blight (BLSB), 226 entries were found resistant to MLB disease, 17 entries resistant to BLSB and only 15 entries were resistant against both the diseases. Out of 64 inbreds of IIMR evaluated against MLB and BLSB, 16 entries, showed resistant reaction to MLB and 4 entries for BLSB disease and 2 entries [EI 670 and IIMRQPM03-113] were resistant to both diseases. Another 25 DQL lines were evaluated against MLB disease, of which 7 lines were tolerant to MLB. Out of 50 inbred lines developed by IARI breeders, only 2 inbreds lines were resistant to MLB and none were resistant to BLSB disease.

Pearl millet. Among 1380 entries of early genetic trials and mapping population screened against *Magnaporthe grisea*, only 5 entries (6573, 8793, 8794, 9884 and 9885) showed high resistance.

Chickpea. Among the 174 entries evaluated against *Fusarium oxysporum* f.sp. *ciceris* under field

conditions, 24 entries were promising against wilt. Among 205 entries evaluated for Ascochyta blight under net house conditions, W-25, W-28, W-34, W-35, W-36 and W-40 showed high resistance.

Soybean. A total of 15 (trap nursery), 40 (IVT) and 13 (AVT) entries of soybean were evaluated under AICRP against major diseases. Among the IVT entries, 5 found highly resistant against yellow mosaic, 4 found highly resistant against bud necrosis. Among the AVT entries, MACS1407 was very promising as it exhibited highly resistant reaction against both yellow mosaic and bud necrosis under Delhi conditions.

***Role of Ty- based resistance loci in tomato against tomato leaf curl virus*:** DNA methylation at cytosine nucleotides is a reversible epigenetic modification that plays a key role in regulation of gene expression as well as silencing invading viral genomes. In the pathway of RNA silencing, sRNA (24nt) leads to sequence specific methylation of viral DNA. To determine if the Ty-2 gene has a role in methylation-based viral genome silencing, six tomato genotypes (with or without resistance loci) were used to analyze symptom severity, viral titre and cytosine methylation in viral genome. Among the six tomato genotypes, one, which does not contain any resistance loci (S genotype), showed ~40% cytosine methylation, out of which 22% was symmetrical and 28% was asymmetrical. Plants of R1 genotype, harboring Ty-1 loci, showed 10% enhancement in methylation levels, both at symmetrical and asymmetrical levels as compared to S genotype. Tomato genotypes with Ty-2 loci, alone or in combination with Ty-1 loci, showed 20% increase in total methylation levels. However, a further increase of 2–3% was observed in genotype R5, with 8–10% increase in symmetrical and asymmetrical cytosine methylation over that of the S genotype tomato plants. This observation suggests that the Ty-2 loci products contribute towards increase in methylation-based viral genome silencing mechanism and an incremental increase was observed when pyramided with the Ty-1/Ty-3 loci.

5.1.5 Epidemiology and Disease Management

Yield loss estimation against bakanae disease of rice. Yield loss due to bakanae disease of rice was estimated in susceptible rice genotype Pusa Basmati 1121 under inoculated conditions during the years 2014-15 and 2015-16. Relationship between bakanae incidence and yield loss indicated about 12% yield loss at 10% incidence of bakanae disease.

Prediction of brown spot disease in rice. Number of lesions/cm^2 of leaf area was found to be influenced by temperature and duration of high relative humidity (>95%). Number of lesions increased significantly (p<0.05) from 25° to 30°C when duration of RH was 15-30 h.

Effect of temperature on Protein Kinase A (PKA) activity in rice blast fungus Magnaporthe oryzae. Appressorium development is an important step for fungal infections. In *M oryzae*, causal agent of leaf blast in rice, appressoria formation was found to be associated with PKA activity. Higher degree of PKA activity was observed at 29°C than at 22°C which was distinctly absent at 34°C, which is the maximum limit for normal growth of the pathogen.

***Yield loss assessment due to yellow rust of wheat disease*:** Yield loss due to yellow rust infection was estimated in susceptible & resistant genotypes grown under protected and unprotected conditions. The losses varied between 1.2-69.2% depending on the degree of resistance of variety. Maximum yield reduction of 69.2% was observed in cultivars, like Agra local, A-30-9-1 and Kathia red which are highly susceptible to stripe rust followed by HD 2733 (14.1%), PBW 590 (32.6%) and PBW 343 (36.35%).

Rust trap nurseries in Southern hills. Ug 99 trap nursery was monitored continuously for the occurrence of Ug 99 race variants in southern hill zone but its variants could not be observed in the trap nursery so far.

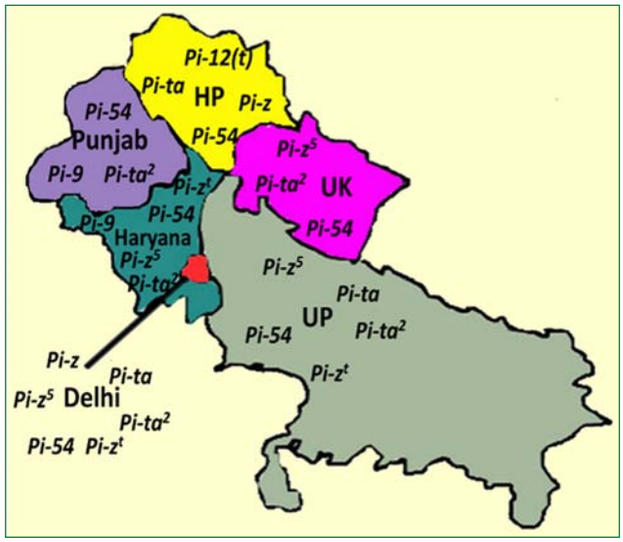
Management of bakanae disease of rice. Nursery drenching with carbendazim @ 2.5% showed minimum disease incidence. Seeds of carbendazim treated plants were subjected to residue analysis, and

the results indicated that the use of 2.5% carbendazim as nursery drenching was safe as no residues could be observed.

Management of brown Spot of Paddy. Seed treatment with Carboxin (37.5% ai) and Thiram (37.5% ai) @2.5 gm/kg seed and seedling dip in suspension of *Pseudomonas flourescens* @ 10gm/litre followed by two sprays of Propiconazole 25% EC @ 0.1% at 45 days and 60 days after transplanting was most effective in reducing the brown spot disease in paddy.

Field efficacy of new fungicide molecules against false smut disease in Paddy. Ten fungicides were evaluated against false smut disease as foliar spray in the field on variety Pusa Sugandh 5. Copper fungicides such as Kocide and Blitox-50 were most effective in reducing the disease incidence.

Management of blast disease of rice. Effective blast resistance genes were identified, viz., *Pi9, Pi54, Pi12(t), Pizt* and *Piz5. Pi54, Pita2, Pizt, Pita* and *Piz5* for Uttar Pradesh; *Pita2, Piz5, Pi9, Pi54* and *Pizt* for Haryana; *Pita2, Pita, Pi54, Piz5, Piz, Pi9* and *Pizt* for Delhi region; *Pi54, Pita2* and *Pi9* were effective for Punjab; *Pita2, Pi54* and *Piz5* were effective for Uttarakhand; *Pi54, Pi12(t), Piz* and *Pita* were effective for Himachal Pradesh.



Effective blast resistance genes identified for deployment in different *Basmati* rice growing regions of India

Integrated management of spot blotch of wheat. Integrated application of balanced fertilization N: P_2O_5: K_2O (120:60:40 kg/ha) + Zn: S: B (5:30:1.0 kg/ha) + seed treatment with carboxin + thiram @ 2.5 g/kg seed + two foliar sprays of propiconazole 25% EC @ 0.1% at the time of initiation of disease followed by second spray at 20 days interval resulted in 99% reduction in disease severity along with 60% higher grain yield. In another experiment, seed treatment with Carboxin (37.5%) + Thiram (37.5%) WS @ 2.5gm/kg seed + two foliar sprays of Propiconazole 25 per cent EC @ 0.1 per cent; first at boot leaf stage and second at 20 days after first spray, gave the best results in reducing the spot blotch of wheat as well as increasing the 1000 grain weight and grain yield of wheat.

Management of BLSB disease of maize. Out of eight fungicides tested for management of BLSB disease, Validamycin (0.1%) was found superior followed by Azoxystrobin (0.05%). Ten new molecules of Micro Chemicals (India), Mandsaur (MP) were found effective under *in vitro* against *Macrophomina phaseolina, R. solani, Sclerotium rolfsii* and *Magnaporthe oryzae.* Karmaar (Micropungin, N+S with Cu, Zn & Mn) and XiRid (Cu 9%) were also found effective for the management of BLSB disease of maize.

Integrated management of root rot disease and fruit disorders (bumpiness) in papaya. Soil mounding with organic mulch resulted in maximum fruit yield/plant (43.17 kg/plant) followed by plastic mulch with soil mounding (41.68 kg/plant) and soil drenching with carbendazim @ 0.2% (40.27 kg/plant) for management of root rot diseases of papaya. However, integrated treatment of soil mounding with organic mulch and drenching with carbendazim resulted in least disease incidence (3.33%) and significantly, highest fruit yield. Further, basal application of borax @ 5.0 g/plant was found most effective for the management of fruit (bumpiness) deformity in papaya.

Integrated field management of virus diseases of vegetable crops. Among the different mulches, silver colour polythene mulch (SM) proved most effective

in reducing virus disease incidence upto (0.5%) and recording maximum yield (34.77t/ha) followed by BM (2.16%). In muskmelon also silver colour polythene mulch with row cover was found most effective in controlling virus disease incidence.

Paddy straw for viral disease and their insect vector management. In another experiment, paddy straw mulching showed relatively lower number of thrips and whiteflies and viral diseases transmitted by them in capsicum and Bhindi.

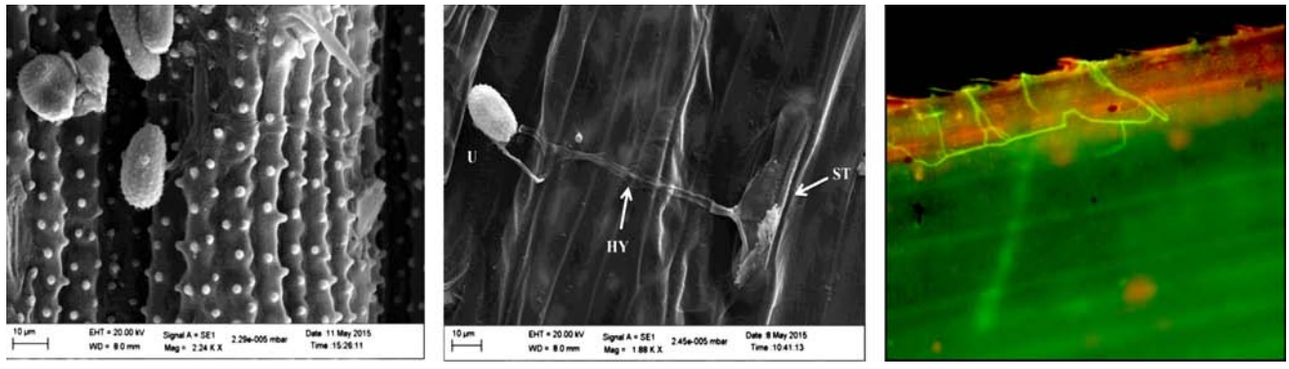
5.1.6 Host Microbe/Virus Interaction

Mechanisms of Lr24 based resistance in wheat. Transcriptome analysis of two near isogenic wheat lines differing for *Lr24* gene in genetic background of leaf rust susceptible variety HS240 revealed that 659 genes were differentially expressed of which 349 genes were upregulated. The important upregulated genes were ABC transporter C, coatomer alpha subunit, E3 ubiquitin-protein ligase, auxilin-related protein 2, callose synthase, receptor-like protein kinase, wall-associated kinase, serine/threonine-protein kinase PRP4 protein, and disease resistance protein RPM1. Significant among the 310 repressed genes were heat shock ATPase, calmodulin-binding transcription activator 4, cell division cycle protein, and ER degradation-enhancing alpha-mannosidase protein in the HS240+*Lr*24. A total of 1407 and 1078 SNPs were also detected in HS240 and HS240+*Lr*24, respectively.

Differential gene expression linked with *Lr24* resistance in wheat through transcriptomics

Parameters	HS240 (susceptible)	HS240+*Lr24* (resistant)
No. of transcripts	68688	66415
Assembly size	37.9 Mb	34.6 Mb
Unigene prediction	61211	59840
Prediction of coding CDS / ORFs	24264	22964
Functional annotation of predicted CDS/ORFs	23127	21827
Gene ontology mapping distribution of CDS		
(i) Biological process	1068	1030
(ii) Cellular process	1326	1234
(iii) Molecular functions	1352	1321
SNP discovery	1407	1078
Simple sequence repeat (SSR)	1112	1013

Characterization of non host resistance in rice-Puccinia non-host system. A total of 57 rice accessions including seven cold tolerant varieties when screened against non host pathogen, *Puccinia graminis tritici* 40A, it was observed that Pgt40A "interacts" with rice genotypes albeit without any pustule formation. *P. graminis tritict* (Pgt40A) entered the rice stomata and colonized intercellular spaces of mesophyllic cells as evident in fluorescence & scanning electron microscopy and qPCR based pathogen quantitation assays. Certain rice accessions - responded to Pgt40A colonization by a strong defense response in the form of hypersensitive reaction that never culminated in pustules. The Pgt40A interaction on non host had resulted in expression of several genes such



a b c

Fluorescence and scanning electron microscopic images of stomatal entry of *Puccinia graminis tritici* 40A: a. Rice (non host); b. wheat (host); and c. Colonization of rice leaf by rust fungus as seen in fluorescence microscopy

as NPR1-3, PR3, PR1-1, ICS1 [Salicylic Acid (SA) pathway]; PDF2-2, LOX2, MYC2, AOS2; PAL1, PAL2, PAL3 [Phenylpropanoid (PP) pathway] and ACO4, ACS6.

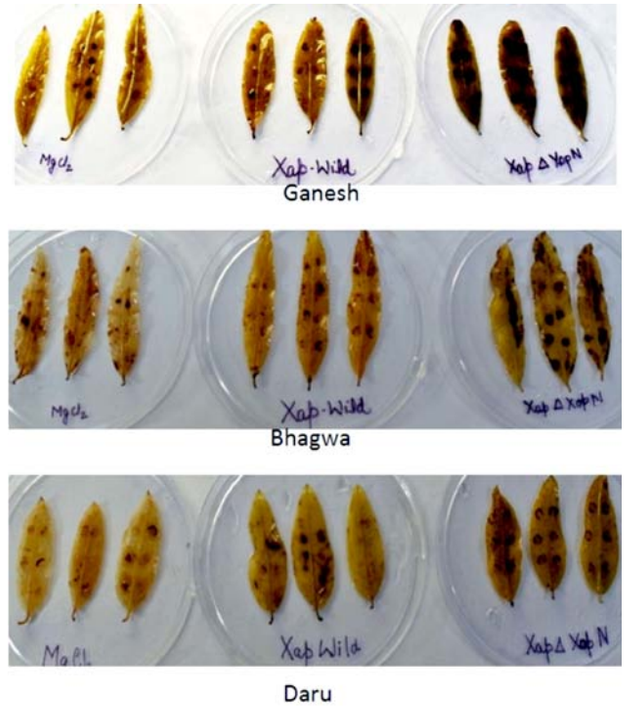
Genetics of resistance to leaf rust in wheat cultivars. Genetic analysis of resistance in wheat PBW 590, HS 507, HW 5216 and WH 1021 to leaf rust pathotypes, 77-1 (109R63), 104B (29R23) and 106 (0R90) revealed the presence of three dominant independent genes for resistance each in PBW 590 and HS 507, two dominant independent genes for resistance in each HW 5216 and WH 1021. Analysis of BC_1 and BC_2 with pathotype 106 (0R9) confirmed the above number of genes.

Cross infectivity of Bipolaris species on wheat and rice. Twenty isolates of *B. oryzae* were isolated from rice leaves showing the symptoms of brown spot. Infectivity of wheat pathogen, *B. sorokiniana* and rice pathogen, *B. oryzae* on rice and wheat could be established. Interestingly mixed inoculation of conidial suspension of both the pathogens revealed synergism for causing disease as indicated by high disease severity on both the hosts. PCR assay with *B. sorokinion* and *B. oryzae* specific markers further confirmed this observation.

Histopathological studies on resistant and susceptible genotypes of mungbean. Development of various infectious structures, evidence for direct and indirect penetration of *Rhizoctonia solani* was observed on mungbean leaves in histopathological assays. Study also indicated differences in xylem element and lignin content on resistant and susceptible cultivars.

Pathogenicity genes of Fusarium. Five constitutively expressed genes (*FOW2* and *ChsV* along with *FOW1, FOXG_01583,* and *FOXG_035444*) in *F. oxysporum* isolate, TOFOL-CPCT were identified and characterized. Gene sequence analysis revealed that *FOW2* and *ChsV* were closely associated (99-100%) to the Zn (II)2Cys6-type transcription regulator and class V chitin synthase, respectively. Further phylogenetic analyses revealed that the genes were grouped along with the corresponding ones of other isolates of *Fusarium* a single cluster. To establish the role of these genes in the pathogenicity of the fungal species, silencing vectors encoding hairpin RNA of each of the gene fragments were constructed in a two-step PCR based cloning, and introduced into the fungal genomic DNA. Silencing of either of the genes resulted in less virulent fungal phenotypes with altered physiological characteristics like sporulation and growth on solid media.

XopN regulates the ROS-mediated early defense response in pomegranate during bacterial blight pathogenesis. Plant restricts the bacterial infection by sudden production of reactive oxygen species, particularly H_2O_2. XopN, a T3SS-effector of *Xanthomonas axonopodis* pv. *punicae* (Xap) regulates the ROS accumulation of pomegranate for successful infection during bacterial blight development. H_2O_2 accumulation was quantified in pomegranate leaves upon challenged inoculation with Xap wild and a XopN deficient mutant and it was evident that



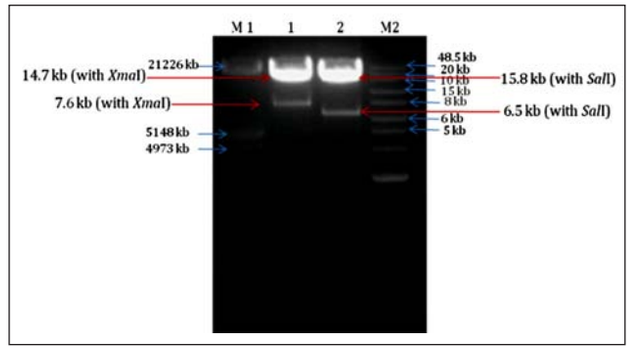
H_2O_2 accumulation assay as regulated by XopN of Xap in different pomegranate germplasm; Brown deposition indicates the H_2O_2 accumulation; intensity of the deposition is directly propotional to the accumulation

H_2O_2accumulation was higher in absence of XopN compared to wild irrespective of the germplasm.

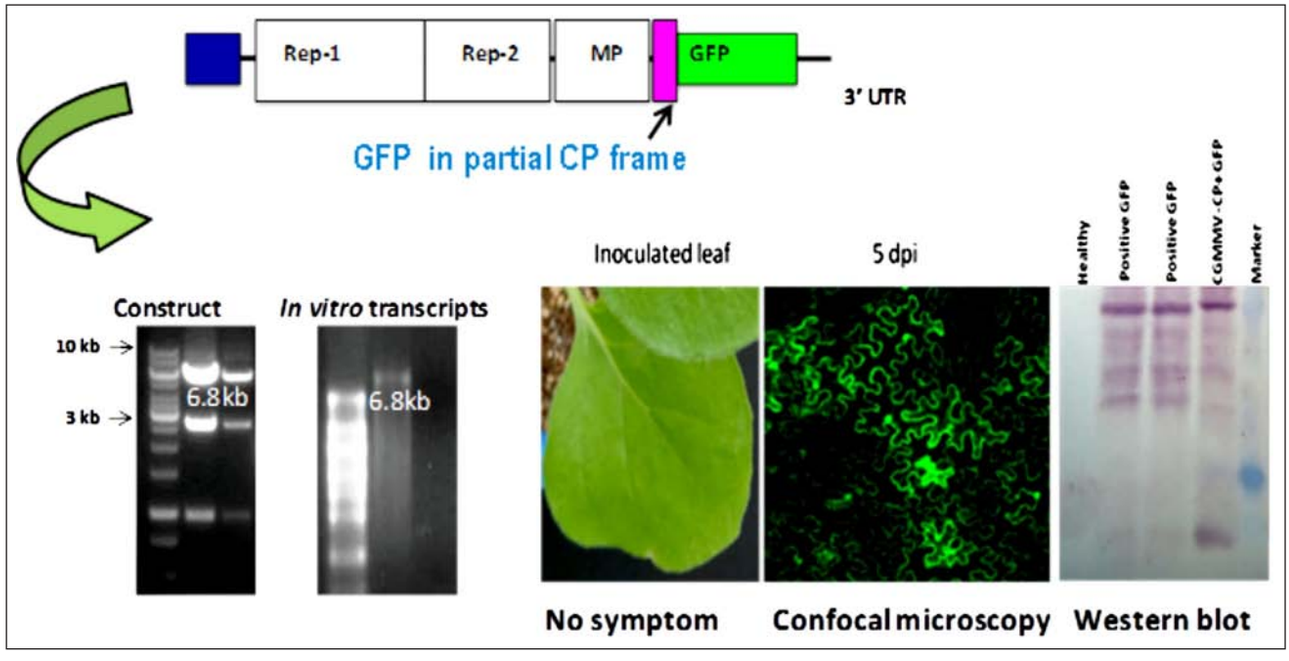
CGMMV based vector for expression of foreign protein in plant. A stable infectious clone of cucumber green motile mosaic virus (CGMMV) was used for expression of green fluorescent protein (GFP) in tobacco (*Nicotiana benthamiana*). The GFP gene was inserted at the stop codon of coat protein (CP) in full-length genome of CGMMV under the transcription control of T7 promoter as well as 35S promoter. The inoculated plants with the constructs developed symptoms, virions and GFP. The CP deleted CGMMV vector containing GFP did not produce symptoms and virions but expressed GFP in plant by 5-7 dpi.

CGMMV based plantibody to papaya ringspot virus. The genome of CGMMV was utilized to express light chain variable (VL) antibody fragment of the papaya ringspot virus (PRSV) in *Nicotiana benthamiana*. Infiltration of *Agrobacterium* containing CGMMV-VL construct in *N. benthamiana* resulted in development of CGMMV symptoms by 13 days post infiltration (dpi). The presence of VL transcript in infiltrated plants was detected up to 18 dpi by RT-PCR and the recombinant CGMMV virions were observed in the electron microscope.

Development of an infectious construct of Banana streak Mysore virus (BSMyV). A partial dimer, 1.8-genome of *Banana streak Mysore virus* (BSMyV) was cloned in tandem orientation in the binary vector pCAMBIA2300 and agro-mobilized into plants (construct named as pC6BSV7.6). It showed infectivity when it was co inoculated with



Agarose gel electrophoresis showing restriction analysis of infectious clone of BSMyV. Lane M1 - Takara high molecular weight Lambda marker, Lane 1- restriction using *Xma*I enzyme, Lane 2 - restriction using *Sal* I enzyme and Lane M2 - NEB quick load 1kb extend ladder



Expression of foreign protein with plant virus vector (CGMMV) in *Nicotiana benthamiana*

Plants inoculated with dimer of *Banana streak Mysore virus* (BSMyV) and suppressor protein P19 (a) Plants inoculated only with dimer of BSMyV (b) along with mock inoculated and healthy plants

viral suppressor constructs to tissue culture derived banana plants (Grand Naine: AAA). Infectivity of BSMYV was also confirmed by Immuno-capture PCR and rolling circle amplification. This is the first successful demonstration of pathogenicity for any of Badnavirus having endogenous counterparts.

5.2 ENTOMOLOGY

5.2.1 Integrated Pest Management

5.2.1.1 Cereals

Rice

Evaluation of rice germplasm against brown planthopper (BPH): Out of nineteen rice germplasms possessing different resistant genes, evaluated against brown planthopper (BPH), two lines, RP 2068-18-3-5 and T-12 (ACC56988) were found to be moderately resistant (3-5 damage score), while Ptb33 and and OM 4498 were rated as moderately susceptible (5-7 damage score). Remaining 15 germplasms including, IR 64, Pokkali and Rathu Heenati were found to be susceptible.

Effect of spray volume on imidacloprid efficacy against BPH as influenced by elevated CO_2: Under elevated CO_2, imidacloprid was found to be most effective @ 700 l/ha followed by 600, 500 and 400 l/ha with corresponding mortality of 57, 40, 39 and 23 % at 1 day after spraying (1 DAS). At 3 DAS, BPH mortality was less than 50 % with 400, 500 and 600 l/ha, while it was observed to be 62 % with 700 l/ha. Under ambient CO_2, different spray volumes did not differ with regard to BPH mortality at 1 DAS. However, significant differences were observed among the different spray volumes with respect BPH mortality at 3 and 5 DAS. The data revealed that higher spray volume was required at elevated CO_2 than ambient CO_2 to produce similar mortalities. BPH sucking rate was also higher under elevated CO_2, consequently, yield loss due to BPH was observed to be higher under elevated CO_2 compared to ambient CO_2. Higher spray volume may thus be required to effectively control BPH under climate change situation.

Effect of crop phenology on BPH infestation as influenced by elevated CO_2: Effect of three transplanting dates *viz*., 1 July, 16 July and 1 August, on BPH infestation on Pusa Basmati 1401 under elevated CO_2 (570±25 ppm) and under ambient CO_2 was studied. Under elevated CO_2, BPH population peaked simultaneously at 90 DAT both in 1st (165.2 ± 18.6 hoppers/ hill) and 2nd (255.2 ± 12.3 hoppers/ hill) transplanting, whereas it peaked (220.7 ± 12.9 hoppers/hill) at 80 DAT in 3rd transplanting. The 2nd transplanting had the highest peak incidence of BPH followed by 3rd transplanting under elevated CO_2.

Under ambient CO_2 in the pot experiment, the BPH population peaked at 90 DAT both under 1st (45.6 ± 5.1) and 2nd (82.4 ± 5.8 hoppers/hill), while in 3rd transplanting peak BPH population (127.2 ± 3.8 hoppers/hill) occurred at 80 DAT. Under ambient CO_2 in the field experiment, BPH population peaked at 90 DAT in 1st (39.6±4.0 hoppers/ hill) and 2nd (86.3±11.7 hoppers/hill) transplanting, whereas it peaked (137.8±7.18 hoppers/hill) at 80 DAT in 3rd transplanting. Under ambient CO_2, third transplanting thus resulted in significantly higher BPH population followed by 2nd transplanting both in the pot as well as the field experiment.

The study thus revealed the highest BPH population with 2nd transplanting under elevated

CO_2 and with 3rd transplanting under ambient CO_2, therefore the recommendation of early transplanting that is now in vogue will continue to be valid under climate change also.

Validation of coupled BPH-Info Crop model under elevated and ambient CO_2. Coupled BPH-InfoCrop rice simulation model was validated for pest population as well as crop-pest interactions under elevated CO_2 vis-à-vis ambient CO_2. Simulated and observed BPH number were found to be proximal under elevated CO_2 (R^2 = 0.961; P<0.0001) and ambient CO_2 (R^2 = 0.893; P<0.0001). Simulated yield loss due to BPH was observed to be 19.6% compared to 23.1% observed yield loss under ambient CO_2, with corresponding losses being 34.5 and 38.5% per cent under elevated CO_2. The model can thus be used to simulate crop-pest interactions under climate change.

Maize

Damage potential of different agro-ecological populations of Chilo partellus in resistant and susceptible maize genotypes. The damage potential of *Chilo partellus* populations were determined on resistant (CPM 15 and CPM 18) and susceptible (Basi Local) maize genotypes and these studies showed significant variability in damage potential of different agro-ecological *C. partellus* populations. The leaf damage (except for Hyderabad, Parbhani and ICRISAT populations), deadhearts, larval weight, and larval survival of different agro-ecological *C. partellus* populations were significantly lower on resistant than on susceptible maize genotypes. Further, the leaf damage, deadhearts, larval survival and larval weight in resistant as well as susceptible maize genotypes by different agro-ecological *C. partellus* populations also varied significantly. In case of resistant maize genotypes, the leaf damage and deadhearts by *C. partellus* larvae from Hisar, Coimbatore and Jhansi populations were significantly more than other populations. In case of susceptible maize genotypes, the leaf damage by *C. partellus* populations from Jhansi, ICRISAT and Hyderabad; and deadhearts by Jhansi, Surat and Hyderabad *C. partellus* populations were significantly lower than other populations. However, the larval survival was significantly higher in Coimbatore and Surat populations as compared to other *C. partellus* populations.

5.2.1.2 Vegetables

Okra. A trial was conducted to investigate the implications of herbivore induced plant volatiles (HIPV's) in biointensive pest management in okra.

Impact of various HIPV mixtures on population of whitefly and predator, *C. septempunctata* in okra.

Treatment	Whitefly population (Nymphs/ leaf)			*C. septempunctata* population (Adults or grubs/ plant)		
	Pre spray	3DAS	7DAS	Pre spray	3DAS	7DAS
1	1.83(1.67)	0.95(1.39)	0.81(1.32)	0.03(1.01)	0.37(1.17)	0.30(1.14)
2	1.79(1.67)	0.88(1.37)	0.74(1.30)	0.07(1.03)	0.37(1.17)	0.40(1.83)
3	1.96(1.70)	0.99(1.40)	0.81(1.34)	0.13(1.06)	0.33(1.15)	0.37(1.17)
4	2.06(1.73)	0.76(1.32)	0.73(1.30)	0.17(1.07)	0.43(1.20)	0.33(1.15)
5	2.02(1.73)	0.72(1.29)	0.63(1.28)	0.00(1)	0.47(1.21)	0.40(1.18)
6	2.13(1.76)	0.75(1.30)	0.60(1.26)	0.03(1.01)	0.43(1.20)	0.47(1.21)
7	2.37(1.82)	0.53(1.23)	0.70(1.30)	0.10(1.04)	0.67(1.30)	0.37(1.17)
8	2.14(1.75)	0.48(1.21)	0.41(1.19)	0.03(1.01)	0.63(1.28)	0.47(1.21)
9	2.11(1.75)	0.41(1.18)	0.34(1.15)	0.07(1.03)	0.60(1.26)	0.63(1.28)
10	2.31(1.80)	3.07(2.01)	3.38(2.08)	0.03(1.01)	0.10(1.05)	0.10(1.05)
CD	N/A	0.26	0.35	N/A	0.09	0.08

Figures in parenthesis are square root transformed; DAS- days after spray

Three HIPV's (viz. Methyl salicylate, β- caryophyllene, Cis-hexanal) selected to find their possible effects on coccinellids and their respective host population at different concentrations revealed that the coccinellids viz. *Coccinella septempunctata, Cheilomenes sexmaculata, Brumoides suturalis, Coccinella transversalis, Curinus coerruleus* etc. responded positively to aforesaid HIPV's. Highly positive significant responses were recorded in the plots treated with mixtures of HIPV's. A significant increase in coccinellids population also significantly reduced its host population.

5.2.1.3 Soybean

Field screening of germplasm for resistance to major insect pests. Twenty lines of AVT I&II when evaluated against stem fly and YMV of soybean under both protected and unprotected conditions, showed AVT lines *viz*., KDS-780, DSB-28.3, KDS-869, KDS-726, DSB-21, KDS-753, PS-1347, PS-1092, SL-1028, SL-983, PS-1550, SL-955 to be highly resistant to yellow vein mosaic and whitefly. Forty IVT lines of soybean (Code: 1-40) when evaluated against stem fly and yellow vein mosaic of soybean showed no line to be highly resistant or resistant while 21 lines were moderately resistant.

5.2.1.4 Oilseeds

Standardization of artificial screening technique for aphid (Lipaphis erysimi) resistance in rapeseed and mustard under field conditions. The population and damage by aphid (*Lipaphis erysimi)* rapeseed mustard varies across the season and regions, and is difficult to identify genotypes with tolerance to this pest under natural conditions. Therefore an artificial screening technique was standardised for aphid, resistance in rapeseed and mustard under field conditions. Out of three different screening techniques *viz*., twig cage, plant cage and plot cage taking six diverse genotypes, twig cage technique showed significant and consistent variability in aphid damage score, aphid population score, aphid resistance index and aphid population multiplication rate among the test rapeseed mustard genotypes, and was found most reliable, economic, and easy for screening of rapeseed and mustard genotypes under artificial infestation conditions in the field.

5.2.2 Storage Entomology

The populations of *Tribolium castaneum* collected from stored wheat in FCI godowns of five states *viz*., Uttar Pradesh, Punjab, Haryana, Madhya Pradesh and Rajasthan along with a susceptible strain collected from TNAU, Coimbatore, were screened with two discriminating doses of phosphine *viz*., 0.03 and 0.25 mg/l. The populations were also screened by molecular markers for resistant allele. Phosphine resistance was found to be governed by autosomal gene and more than one major gene is responsible for resistance to phosphine.

Molecular diagnostics have been developed for detection of resistance to fumigant phosphine in stored product insects like red flour beetle, *T. castaneum* and lesser grain borer, *Rhyzopertha dominica*. Molecular analyses using CAPS markers revealed the prevalence of strong resistance to phosphine in field populations of *T. castaneum* (26 No.) and *R. dominica* (17 No.) collected from UP, MP, Punjab, Rajasthan and Haryana states.

5.2.3 Biological Control

Foraging behavior of the natural enemies. Functional response of the *Cheilomenes sexmaculata* to the different prey densities of cowpea aphid, *Aphis craccivora* was showed the Type-II functional response. The searching efficiency, handling time, and maximum rate of predation was worked out as 0.01 day, 1.07/day and 100, respectively using scattered plot of 1/Ha and 1/HT.

Development of stress tolerant strains of bio-control agents. Temperature induced physiological stress often associated with enhanced generation of reactive oxygen species (ROS) leading to oxidative damage. In the present study, the mealybug, *Phenacoccus solenopsis* population was exposed to high temperature i.e. 40^0C at different time interval (0 to 6hr). The levels of change of peroxidase varied between the populations over the time period. During

the first one hour of exposure the expression level was high in Delhi and Ludhiana (Punjab) population. Thermal stress resulted changes in the level of catalase in all three populations of mealybug.

Three populations of *Aenasius arizonensis* when exposed to high temperature i.e. 40^{0}C for varying time period, resulted in substantial variation in the level of stress enzymes *viz*., catalase, peroxidase and super oxide dismutase. The Punjab population of *A. arizonensis* showed high level of super oxide dismutase than the other two indicating that the Punjab population was more tolerant than the other two populations.

Studies on host egg storability. Large number of host eggs are produced in a mass production facility, therefore, there is a need for their storability for sustained production of egg cards. A comparison of percentage of emergence, development time and percentage of female progeny of *Trichogramma japonicum, T. chilonis, T. achaea* and *T. ostriniae* on differently aged eggs of *C. cephalonica* was made to assess whether the host eggs produced in excess could be stored for future use. There was a preference for freshly laid eggs, however, two days old eggs were also equally suitable to all the test parasitoids except *T. ostrinae.* The study revealed that the host eggs could be stored and effectively used only for two days.

5.2.4 Insect Physiology

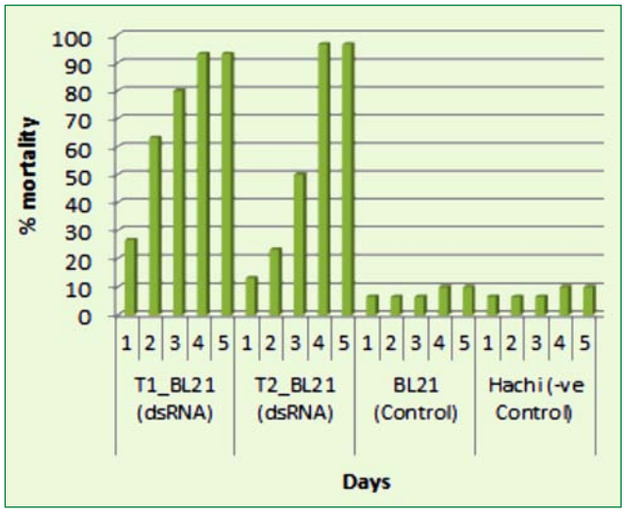
Characterization of Bt isolates by PCR amplification using different Cry gene primers isolated from insects and soil. The *cry* gene content of thirty native *Bt* strains along with four reference *Bt* strains were determined by PCR analysis. Three *Bt* strains viz., *Bt* var. *kurstaki* HD-1, HD-73, VKK-BB2, out of 7 potential strains, showed the expected amplicon size of 276 bp of *cry1* gene whereas, VKK-AC2 amplified novel band of 150 and 100 bp. Similarly for *cry2* gene, only one *Bt* strain gave amplification of expected amplicon size of 689-701 bp. However all the short listed *Bt* strains *viz.*, VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2 and VKK-PX1 amplified novel band of 275-292 bp with *cry4* gene specific primers.

Double stranded RNA construct for silencing osmoregulatory gene in green peach aphid, Myzus persicae by feeding assays. The *Escherichia coli* strain

Comparisons of percentage of emergence, development time and female progeny of *Trichogramma japonicum, T. chilonis, T. achaea* and *T. ostriniae* on differently aged eggs of *Corcyra cephalonica.*

Parameters	*Trichogramma* species	Host age (days)		
% Emergence		0	2	4
	T. japonicum	98.01 ± 1.56	80.70 ± 2.33	50.51 ± 1.49
	T. achaea	97.46 ± 2.93	95.07 ± 2.35	66.96 ± 2.07
	T. chilonis	95.85 ± 2.85	95.13 ± 1.76	63.77 ± 2.23
	T. ostriniae	89.30 ± 3.21	72.37 ± 4.05	55.15 ± 3.01
Development(days)				
	T. japonicum	9.30 ± 1.01	9.10 ± 0.36	8.27 ± 0.31
	T. achaea	9.20 ± 0.26	8.97 ± 0.15	8.59 ± 0.19
	T. chilonis	9.50 ± 0.36	9.27 ± 0.21	8.23 ± 0.15
	T. ostriniae	9.70 ± 0.26	9.50 ± 0.20	7.34 ± 0.29
% Female progeny				
	T. japonicum	83.98 ± 3.43	68.03 ± 2.70	42.60 ± 2.60
	T. achaea	86.73 ± 1.45	81.35 ± 2.26	50.01 ± 1.48
	T. ostriniae	90.41 ± 3.93	88.43 ± 3.04	41.09 ± 2.40

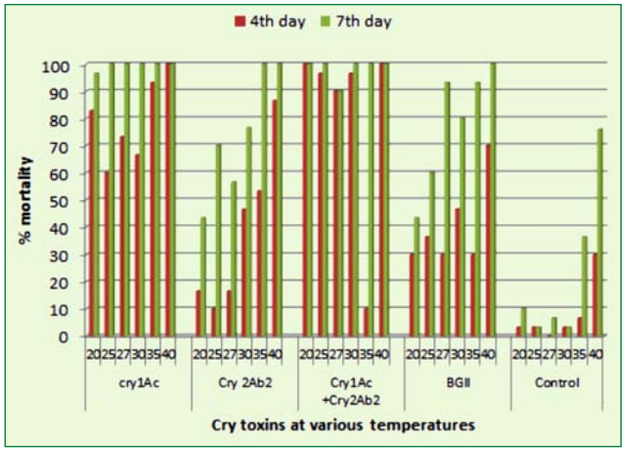
The observations are mean of three replications



Efficacy of BL21 expressing sucrase specific dsRNA against adults of *M. persicae*

BL21 (DE3) which is unable to degrade dsRNA, was transformed to produce dsRNA targeting the osmoregulatory genes *sucrase* (*suc*) specific to *M. persicae.* Up to 96.7% aphid mortality was obtained after 96 h in comparison to 10% mortality in control. Results suggested that RNAi in *M. persicae* could be triggered by ingestion of dsRNA expressing bacteria.

Effect of temperature on toxicity of Bt Cry toxin against Earias vitella. Toxicity of Bt toxins, viz., Cry1Ac, Cry2Ab2, Cry 1Ac+Cry2Ab2 (mixture), and Boll Guard II (BGII) cotton seed powder at 1ppm dose when evaluated at different temperatures showed that on 4th day the maximum mortality (98%) was observed in Cry1Ac+Cry2Ab2 and was found to be significantly different from all other toxins at all the temperatures. The results showed that temperature did not have effect on highly toxic Cry1Ac+Cry2Ab2, but extreme temperature (20°C, 35°C and 40°C), enhanced the toxicity of BGII and Cry2Ab2.



Effect of temperature on the toxicity of Cry toxins against neonates of *Earias vitella*

Studies on Endosymbionts. Enterobacteriales were found to be the dominant (62 %) gut bacterial community in *Lepidiota mansueta*. The data showed the presences of *Enterobacter cloacae*, *Klebsiella pneumonia*, *Acinetobacter* sp. and *Clostricium thermocellum* as dominant gut bacterial isolates. Gut bacterial strains identified in cotton bollworm and diamond back moth *viz*., *Pseudomonas stutzeri, Bacillus safensis and Stenotrophomonas rhizophilai* showed high endoglucanase activity and *Bacillus safensis* showed very high lipases activity.

Diagnostic PCR coupled with fluorescence *in situ* hybridization (FISH) analysis demonstrated that insecticide susceptibility in Indian *B.tabaci* biotypes could be correlated with relative abundance of endosymbionts. *viz*., *Rickettsia* and *Cardinium*. Comparatively higher susceptibility of *B. tabaci* biotype, Asia II7 to organophosphate, pyrethroid and neonicotinoid insecticides could be attributed to the higher infection frequency of endosymbionts like *Cardinium* (Chi-Square test, $P < 0.001$, $n = 30$) and *Rickettsia* (Chi-Square test, $P < 0.05$, $n = 30$).

A range of bacteria belonging to different genera have been isolated and characterized from the fruit fly gut and ovipositor of laboratory reared as well as field collected melon fruit fly, *Bactrocera cucurbitae* based on 16S rRNA gene sequencing. Total 112 bacterial isolates have been identified. Some of the important bacteria were *Klebsiella variicola, Bacillus methylotrophicus, Enterococcus faecalis, Serratia marcescens, Serratia sp., Bacillus pumilus, etc.*

5.2.5 Insect Toxicology

Different collected populations of whitefly, *Bemisia tabaci* reared separately on various hosts viz., brinjal,

cotton and tomato exhibited significant difference in their susceptibility towards neonicotinoids. The populations reared on cotton were found to be more tolerant to neonicotinoids. Similarly, the activities of detoxification enzyme cytochrome P450 (Cyt P450) among *B. tabaci* populations reared on cotton recorded the highest value. The results clearly demonstrated the role of host plants in altering the pest susceptibility to insecticides and their detoxification enzymes levels. Studies on time mortality relationship were conducted to discriminate between susceptible and tolerant populations using fixed diagnostic dose of 2 per cent concentration of neonicotinoids. Based on LT99 data, a diagnostic time of 20 minutes was set to separate susceptible from tolerant phenotypes while a time of more than 24 hours was needed to bring 99% kill in high tolerant populations. Increased time beyond 20 minutes may be the first and quick diagnostic symptom for development of tolerance in the population.

Semiochemicals. Fourteen different plant volatiles were analyzed through electroantennogram (EAG) for response of maize stem borer, *Chilo partellus* towards these volatiles at different concentrations (0.1, 1.0, 10, 100 µg/µl) and it was found that at the lowest concentration (0.1µg/µl) â-pinene induced highest repose by gravid female.

Effect of Insecticidal Treatments on foraging activities of pollinators. Response of imidacloprid treatment on foraging activities of pollinators was assessed as seed dresser and foliar application alone and in combination with seed treatment and foliar treatment on cotton crop. Seed treatment with imidacloprid 48% FS (Gaucho® 600 FS) was carried out @ 5 g a.i./kg seed whereas foliar application was carried out @ 20 and 30 g. a.i./ ha. Great diversity of the Hymenopteran pollinator fauna in cotton agro-ecosystem was observed at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi, as evidenced by the fact that seventeen Hymenopteran pollinators viz., *Apis dorsata, Apis cerana indica Apis florea, Apis mellifera, Ceratina smaragdula, Ceratina viridissima, Nomada solitaria, Xylocopa* sp. of family Apidae; *Campsomeriella thoracica* and *Campsomeriella* sp. of family Scoliidae; *Megachile bicolor, Megachile lanata* and *Megachile* sp. of family Megachilidae; *Lasioglossum* sp. and *Halictus* sp. of family Halictidae; and *Philanthus* sp.of family Crabronidae, regularly visited the cotton crop throughout the crop growth period**.** Differences in foraging activities of pollinators on seed treated and untreated crop was not visible in cotton. However, foraging activities were adversely affected by the foliar application of imidacloprid on cotton.

5.3 NEMATOLOGY

5.3.1 Entomopathogenic Nematodes

Interactions of parasitic and beneficial nematodes with rhizosphere microbes and insect pests. Out of six strains of EPNs isolated from soil samples, four were identified as *Heterorhabditis* sp. while the remaining two belonged to *Steinernema* spp. The virulence potential of these six indigenous EPN as indicated by LD50 at 36 and 48 h revealed that *Steinernema* strain 1 and *Heterorhbditis* strain 4 were most pathogenic.

Field application of formulated Galleria cadavers infected with Heterorhbditis indica. A field trial conducted in Bigas, Hapur by applying 60 days old coated *Galleria* cadavers (@ 3000/acre) provided 65 % control of white grubs as compared to untreated control.

Management of primary reproductives of termite, Microtermes spp by Heterorhbditis indica. EPNs were found to be effective against primary reproductives of

Three day old *Galleria* cadavers infected with *H. indica* (left); coated cadaver (right)

termites. Exposure of alates (winged reproductives) of subterranean termite, *Microtermes* spp to sterilized soil pre treated with *H. indica* infected *Galleria mellonella* cadavers resulted in 100% mortality within 48 h and up to 3000 *H. indica* IJs emerged after 8 days of infection. The lethal median (LT_{50}) time to kill the winged reproductives of *Microtermes* spp was 32.9 h and 48.4 h for *H. indica* and *S. abbassi*, respectively.

Proteomic analysis on host specificity in Photorhabdus – Heterorhbditis indica symbionts. Host specificity preferences for three species of *Heterorhabditis* and their bacterial symbionts showed a total of 43 proteins, 7 hypothetical proteins including novel transcription factors and several membrane localized proteins.

***Cloning of insecticidal genes of native Photorhabdus luminescens* subsp. *Akhurstii*.** Based on *in silico* analysis, different candidate genes were selected from the sequence information of *Photorhabdus luminescens* TT01 and W14. e.g. toxin complexes (Tc series – *Tca, Tcb, Tcc, Tcd*), Txp 40 toxin, Pir proteins, Rtx like genes, MCF genes, *Photorhabdus* Virulence Cassettes (PVCs) etc. Partial sequences of the insecticidal genes like *Tca, Tcb, Tcc, Tcd, Txp 40, Rtx, MCF etc*. were amplified and sequenced from the entomopathogenic bacterium, *Photorhabdus luminescens* subsp *akhurstii*. Sequences of various genes have been submitted to the NCBI database.

5.3.2 Nematode Management

A field experiment was carried out to investigate the effect of *Trichoderma harzianum* (Th) seed treatment alone and in combination with carbofuran and phorate against reniform nematode, *Rotylenchulus reniformis* on chickpea. The results revealed that individual application of *T. harzianum* @ 5 and 10% reduced the reniform nematode population compared to combined application either with carbofuran and phorate.

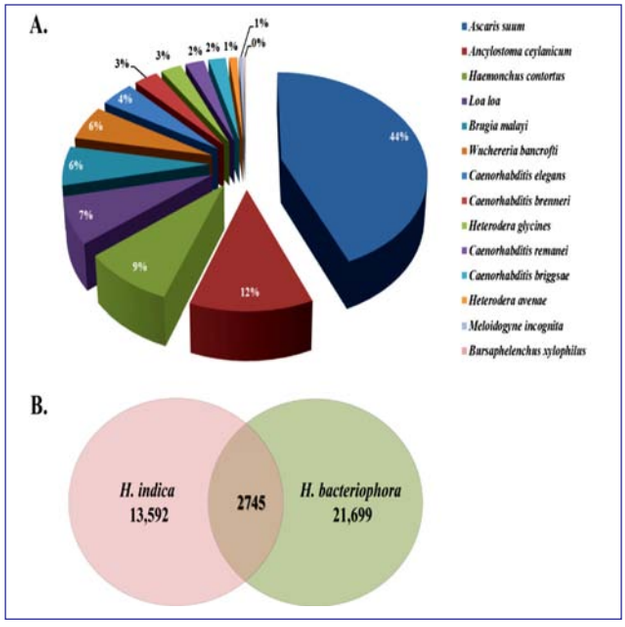
In order to map the gene governing resistance in rice to root-knot nematode, *Meloidogyne graminicola*, the resistant cv. Abhishek was crossed with the Bangla Patni, a highly susceptible genotype to generate F_2 population. Out of 419 STMS markers used in the parental polymorphism survey, 94 markers were found to be polymorphic. Resistant and susceptible bulks with 10 plants each were generated for bulked segregant analysis using 94 identified polymorphic markers. After phenotyping and genotyping of mapping population the marker *HvSSR10-21* was identified to be linked with the resistant locus in cv. Abhishek at a distance of 18.1 cM with the LOD score of 8.5. The significant LOD score value indicates the linkage between identified marker and the resistant locus against *M. graminicola*. The gene was thus designated as *Mg1(t)*.

A field evaluation of the chalcones (C1 and C2), and Schiff bases (ST1 and T1) was conducted during *Kharif* season of 2015-16. Among the chemicals tested maximum plant height was observed in ST1 and maximum reduction in the number of galls at 25 DAT was observed in chalcone (C2).

5.3.3 Nematode Genomics

High-quality transcriptome sequence data of H. indica IJs was generated. The de-novo sequence assembly using Velvet-Oases pipeline resulted in 13,593 unique transcripts at N50 of 1,371 bp, of which 53% were annotated by blastx. *H. indica* transcripts showed higher orthology with parasitic nematodes as compared to free-living nematodes like *C. elegans*, a species to which *H. indica* is more closely related. Comparison of the transcripts with complete genomes of other closely related rhabditid nematodes through reciprocal blast approach showed 3,364 orthologs of *C. elegans*, 3,103 of *C. briggsae*, 3,171 of *C. remanei*, 2,164 of *P. pacificus* and 346 of *H. bacteriophora*. However, higher numbers of orthologs were identified when the transcripts were compared to the animal parasitic nematodes - 9,685 orthologs in *A. suum*, 6,819 in *Strongyloides ratti* while other parasites like *Meloidogyne hapla*, *M. incognita*, *B. malayi* and *Trichinella spiralis* ranked in between these two nematodes. In addition, GO term analysis for all predicted proteins in IJ transcriptome of *H. indica* was carried out to determine the distribution of genes in different functional categories.

A total of 2,374 secreted proteins were predicted including several important proteins related to neuropeptide signaling, 33 hydrolases, 38 peptidases that have a known role in degrading insect tissues, five transcription factors 13 members of protein kinases, 12 members of phosphatases and several known stress response genes such as glutathione peroxidases, heat shock protein 70 and heat shock protein 90. Approximately 1.4% of the total transcripts were found to be encoded by different repetitive elements, of which 1.21% belonged to simple repeats, and 0.29% were low complexity repeats. A total of 31 retroelements were found in the transcripts, with 4 long interspersed repeat elements (LINEs). Also, 15 DNA transposons of different classes, 103 small RNA, and three satellites were found. Twenty-four orthologs of *C. elegans* RNAi pathway effector genes were discovered in *H. indica* IJ transcriptome, including *nrde-3* that is reported for the first time in any of the parasitic nematodes. An ortholog of *C. elegans tol-1* was also identified. Further, 272 kinases belonging to 137 groups, and *several previously unidentified members of important gene classes were identified.*



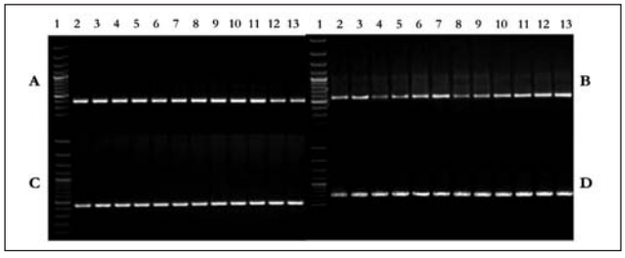
A. Distribution of the top 10 nematode species with most homologs to *Heterorhabditis indica* (The distribution was calculated using best blastx hits). B. Venn diagram of *H. indica* transcripts matching *H. bacteriophora* proteins in a standalone blast

5.3.4 Molecular and Physiological Nematology

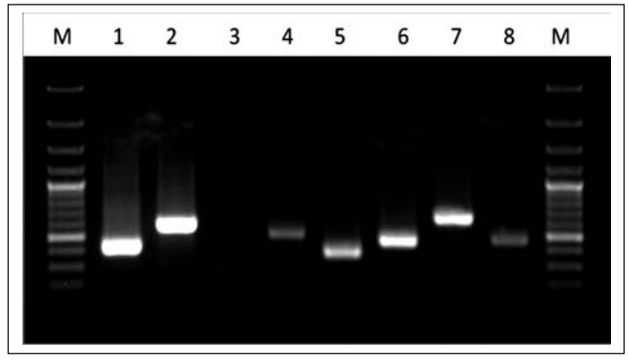
Comparative defence gene expression in rice upon root-knot nematode (RKN) infection. Role of major hormone-regulated plant defence pathways in compatible/incompatible rice-RKN (*Meloidogyne graminicola*) interaction were investigated using genes involved in salicylate/jasmonate/ethylene pathway, for their differential expression through qRT-PCR in most susceptible (Pusa Basmati 1) and resistant (Vandana) genotypes of rice. Data demonstrated that upon early infection, basal host defences are activated in both susceptible and resistant plants, whereas it is ostensibly suppressed during later stage of infection in susceptible plants. Specifically, genes involved in SA biosynthesis (but not SA signaling), JA and ET pathway and PR genes have positive effect on resistance response of rice to nematode infection. On the other hand, during compatible interaction RKN interfere with the hormone homeostasis of plants to suppress the systemic defence signalling, and, consequently, progression of nematode disease occurs due to establishment and maintenance of functional feeding site in susceptible plants.

5.3.5 Transgenic Approaches for Control of Plant Parasitic Nematodes

Transgenic (T_1) tomato lines (cv. Pusa Ruby) were developed with the RNAi gateway constructs of *Mi-cpl-1* gene. Using gene specific, sense, antisense and antibiotic marker PCR-positive events were selected. Based on the Southern, northern and qRT-PCR analysis, four events were selected for standard bioefficacy studies against *M. incognita*. Nematode multiplication factor which reflects the successful establishment of nematodes in the host plants was reduced significantly in transgenic lines by 60-80.8% compared to the wild type plants at 35 days after inoculation. A substantial reduction in *Mi-cpl-1* expression was also recorded in females extracted from RNAi plants. Therefore, transgenic tomato plants had exhibited partial resistance against root-knot nematodes.



PCR confirmation of *Mi-cpl-1* gene in tomato transgenic lines T_0 (T_0)



cDNA amplification of housekeeping genes. Lane M: 100 bp DNA Ladder/Marker, Lane 1. 18SrRNA (416bp), Lane2: GAPDH (586bp), Lane3: RuBP (269bp), Lane 4: Actin (501bp), Lane 5: CSD (369bp), Lane 6: STPP (456bp), Lane 7: ATP SE (636bp), Lane 8: PPI (465bp)

Evaluation of transgenic brinjal plants of T3 and T4 generations expressing double stranded RNA of *flp14, flp18, msp1, msp18* and *msp20* genes of *M. incognita* gave about 65-70 % reduction in nematode multiplication factor. The transgenic plants did not show any unwanted effects on the growth and development of the plants. All the transgenic plants of different events and genes were confirmed for gene integration by PCR amplification of the target gene and also the presence of both sense and antisense strands essential for the generation of double stranded RNA. Expression of transgene in the transgenic plants was confirmed by qRT-PCR.

In order to initiate gene expression studies using quantitative real time PCR in *Polianthes tuberosa,* (tuberose) reference genes were isolated and characterized. Four conventional candidate reference genes; 18S ribosomal RNA (*18SrRNA*), Ribulose bisphosphate (*RuBP),* Glyceraldehyde 3 phosphate dehydrogenase (*GAPDH*), Actin and four novel genes; Coatomer subunit delta (*CSD*), Peptidyl-prolyl isomerase (*PPI*), Serine/threonine-protein phosphatase, (*STPP*) and ATP subunit (*ATP SE*) were evaluated in tuberose. The transcript abundance of these genes was analyzed in eleven different tissues like young leaf, leaf sheath, root, immature flower bud, mature flower bud, open flower, stamen, ovary, stigma, petals and flower tube. Three RT-qPCR statistical analysis methods, BestKeeper, NormFinder and geNorm were used to evaluate the stability of gene expression that indicated expression of *PPI* and *CSD* to be most stable across all the tested tissues. The stability of these two genes was also confirmed across four popular commercial varieties and, under biotic and abiotic stresses. Utility of *PPI* in tuberose as a reference gene is a pioneer report in plants whereas, usefulness of *CSD* as a stable reference gene has been demonstrated for the first time in a crop besides the model plant, *Arabidiopsis*.

5.4 AGRICULTURAL CHEMICALS

5.4.1 Chemo and Bio-prospecting for Agrochemicals through Design, Discovery and Development of Novel Processes and Products

Synthesis, molecular docking and antifungal activity of pyridine carbohydrazides. Thirty two nicotinamide hydrazones were characterized and evaluated *in vitro* against phytopathogenic fungi, *Rhizoctonia solani* and *Sclerotium rolfsii*. N-Methyl benzylidene-pyridine-6-mercapto-3-carbohydrazide exhibited the best antifungal activity against *R. solani* and *S. rolfsii* with EC_{50} values of 11.7 ppm and 39.8 ppm, respectively. In the molecular docking simulation of most active derivative, the bonding was observed with HIS207, TRP164, TYR83 and SER27 of the homology model with lowest bonding energy.

Trigger release formulation of anthocyanin. *In vitro* study of a target release formulation of anthocyanin suggested that the release of anthocyanin from the formulation is pH dependent. More than 60%

anthocyanin was released within 3h at neutral pH. Further, *in vivo* study suggested that the formulation was able to deliver the trapped anthocyanin as it was found in the blood of mice after 6 h of feeding.

Synthesis and bioactivity of thiadiazole derivatives. Five potent antifungal and antinemic thiadiazole derivatives were synthesized, characterized and nano-sizing using the polymer encapsulation method. During *in vitro* evaluation, both nano-sized and conventional sized thiadiazole derivatives were found effective against two tested fungi (*Rhizoctonia bataticola* and *R. solani)* and a tested nematode (*Meloidogyne incognita*).

Synthesis and bioefficacy evaluation of halogenated Schiff bases. A series of halogenated Schiff bases were synthesized by the condensation of 5-fluoro-2-hydroxy acetophenone and 3,5-dichloro-2-hydroxy acetophenone with propyl-, pentyl-, hexyl-, heptyl-, octyl-, nonyl-, dodecyl-, tetradecyl-, hexadecyl- and octadecyl-amines. Among them, N-propyl-3, 5-dichloro-2-hydroxyacetophenonimine was found to be the most active against both *Rhizoctonia solani* (ED_{50} 8.02 mg/L) and *Sclerotium rolfsii* (ED_{50} 21.51 mg/L).

Effect of ozonation on nutritional parameters of fruits. Ozonation for 15 min resulted in 47.8 and 65.72% reduction in ascorbic content of capsicum and grapes, respectively, while 30 min ozonation resulted in 60.17 and 77.46% reduction, respectively.

5.4.2 Innovations in Agricultural Formulations and Application Technology for Safety and Efficacy

Agri-residue based Hydrogel Composites. Two series of cellulosic grafted poly acrylate hydrogel composites were synthesized employing rice straw and rice husk as the filler materials. The rice straw and rice husk based composites exhibited water absorbency in the range of 580 to 750 gm/gm and 650 to 850 gm/gm, respectivelyon pure water basis. Rheological investigation revealed significantly superior mechanical strength of the prepared composites as compared to the corresponding filler free hydrogels.

Phosphorus enriched biopolymeric hydrogel clay composites. The refined bench scale protocol for enriching polymeric hydrogel composites with 20 percent phosphorus exhibited sustained release characteristics over a period of four months and showed significant improvement in seed yield in garden pea as compared to control.

Cellulose nanowhiskers from Rice straw. Reaction conditions for extraction of cellulose nanowhiskers from rice straw have been standardized. Characterization by SEM revealed the size of extracted fibers in the range of 26-35 nm.

Cellulosic hydrogel with pH sensitive properties. Biopolymeric clay hydrogels composites, synthesized from crosslinking of carboxymethylcellulose with citric acid in presence of bentonite, were used to develop base triggered release formulations (TRFs) of thiamethoxam (3-(2-chloro-1, 3-thiazol-5-ylmethyl)-5-methyl-1, 3, 5-oxadiazinan-4-ylidene (nitro) amine) through an *ex-situ* encapsulation technique. The kinetics study of triggered release in water (pH 7, 8, 9, 10, 11) showed that the release from developed TRFs followed Gallagher–Corrigan equation and higher release rate of thiamethoxam was observed at basic pH than neutral condition (pH 7).

Amphiphilic aerogel and controlled release of herbicide. A novel light weighed aerogels absorbed around 1000-1500% and 1000-1200% water and chloroform, respectively. The aerogels have been used to load >99% imazethapyr to prepare controlled release herbicide formulations due to amphiphilic nature.

5.4.3 Food Safety, Risk Assessment of Crop Protection Products and Residue Management

5.4.3.1 Pesticide risk assessment

Persistence of chlorpyrifos and profenofos on cauliflower. Supervised field trials were conducted to estimate the residues of chlorpyrifos and profenofos on cauliflower (var. PSBK1). The residues of chlorpyrifos and profenofos were detected till 10 and 15 days after

application at the recommended and double the rate of application, whereas a waiting period of 3 days is proposed for consumer based on the Codex limits, 2009 and UK MRL.

5.4.3.2 Environmental fate of pesticides

Effect of biochars on pyrazosulfuron-ethyl leaching and degradation in an Inceptisol soil. Degradation studies of pyrazosulfuron-ethyl in laboratory incubated Inceptisol suggested that in no biochar control the herbicide was more persistent in flooded soil than nonflooded soil. Biochar amendment to soils enhanced herbicide persistence, both in flooded and nonflooded soils, but effect was more pronounced in nonflooded soils. Herbicide was more persistent in rice biochar-amended soil than wheat biochar-amended soils and high temperature (600°C) biochars had more inhibitory effect than biochars prepared at 400°C. Herbicide metabolites *viz*., SAE and SAA were quantified and amount recovered from different treatments varied with moisture status and content/nature of biochar.

5.4.3.3 Decontamination studies

Degradation of bifenthrin by microbes sourced from contaminated soil. Contaminated soil obtained from bifenthrin formulating industry was used to degrade bifenthrin in soil and liquid broth. Seven bacterial strains that efficiently degraded bifenthrin upto 48-72% were identified as *Klebsiella pneumoniae* sp., *Brucella melitensis* sp. and *Pseudomonas stutzeri*. The half life of bifenthrin was 108.4 days in non sterile soil as compared to 76.5 days in sterile soil. 4-Hydroxy bifenthrin (major) and bifenthrin aldehyde and bifentrin acid (minor) were identified as bifenthrin degradation products.

Remediation of pesticide contaminated water using nZVI-clay composites. Nano-zero valent iron (nZVI) composites were used as adsorbent for the removal of thirteen pesticides from water at 1 ppm level with respect to each pesticide at 1:200 adsorbent:water ratio. Results suggested CTMAB- or BTBAC-bentonites showed >90% pesticide removal. The nZVI-BTBAC modified clay showed the removal efficiency of more than 87% for nine pesticides and 20-80% removal of the remaining four pesticides.

Degradation of atrazine and its metabolites using enrichment culture. An atrazine degrading enrichment culture was used to study degradation of atrazine metabolites *viz*. hydroxyatrazine, deethylatrazine and deisopropylatrazine in mineral salts medium. Results suggested that the enrichment culture was able to degrade only hydroxyatrazine and it was used as the sole source of carbon and nitrogen. The atrazine degrading microbial consortium was immobilized in sodium alginate and when stored at room temperature (24±5°C), was effective in degrading atrazine in aqueous medium up to 90 days.

Low cost biosorbent for atrazine and imidacloprid removal from water. Low cost biosorbents their biochars were used for atrazine and imidacloprid removal from water at 1:33.3 adsorbent:solution ratio and 1-5 µg mL^{-1} concentration of pesticides. Results suggested that Eucalyptus bark was the best adsorbent to remove both pesticides with K_{Fads} values of 169.9 and 85.71 for atrazine and imidacloprid respectively. Desorption results suggested that highest adsorption and lowest desorption for both atrazine and imidacloprid onto eucalyptus bark.

Effect of pH on flucetosulfuron degradation. Effect of solution pH (4, 7 and 9) on the persistence of flucetosulfuron was studied. Results indicated that the herbicide was most stable at neutral pH, became unstable at acidic and very unstable under alkaline conditions. Dissipation half life of flucetosulfuron under alkaline and neutral pH was 50 and 150 days, respectively.

5.4.3.4 Analytical methods

Standardization of multi residue method for 38 fungicides and 7 neonicotinoids in honey. LC-MS-MS methods for the estimation of 38 fungicides and 7 neonicotinoids from honey were standardized. The linearity range was 1 to 10 ppb for the different fungicides and 5 to 200 ppb for different neonicotinoids in honey.

Standardization of multi residue method for 4 aflatoxins in animal feed. The method for extraction of aflatoxin B_1, B_2, G_1 and G_2 from the aquatic animal feed and poultry feed was optimized by using the AOAC 2007.01 and buffered QuChERS method. The samples were estimated by LC-MS-MS. The LOD and LOQ for each aflatoxin was 0.1ng/mL and 2 ng/mL, respectively. Higher recovery was observed in the buffered QuChERS method with percent recovery in the range of 98 ± 0.02, 97 ± 0.03 and 95 ± 0.01for bird feed, fish feed and tortoise feed, respectively.

Standardization of multi residue method for colured contaminants in pulses. The method for extraction of dyes from the legumes was optimized by using the AOAC 2007.01 and buffered QuEChERS method. The samples were estimated by LC-MS-MS. The LOD and LOQ for each dyes were 0.1µg/mL and 2 µg/mL, respectively. Higher recovery was observed in the buffered QuEChERS method with percent recovery in the range of 98 ± 0.03 and 97 ± 0.02 for lentil and mung been respectively.

Magnetic molecularly imprinted polymers as cleanup tool for selective extraction of Sudan1. Magnetic molecularly imprinted polymer (MMIP) was synthesized using Sudan1 as the template molecule, methyl methacrylate as monomer, EGDMA (cross linker) and AIBN (initiator), polyvinyl pyrollidene as disperser and Fe_3O_4 in oleic acid as stabilized magnetic particle. MMIP was used to remove Sudan1 (10 ppm) from water at 1:200 adsorbent:water. Results revealed that MNIP could remove ~70% of Sudan1, whereas MMIP removed >99% of Sudan1 from the fortified water.

Protocol for standardization of method for multiclass pesticides in rice and tea by GC/MS-MS. A modified QuEChERS method developed for extraction and cleanup of the 73 pesticides (including organochlorine, organo phosphorous, synthetic pyrethroides and herbicides) from basmati rice and tea matrix. Seventeen organo-chlorinated pesticides, 14 synthetic pyrethroids, 24 herbicides, 15 organophosphorous and 3 other insecticides can be identified and quantified by this method.

5.5 WEED MANAGEMENT

5.5.1 Integrated Weed Management in Maize-wheat System under Conservation Agriculture

A study was carried out under conservation agriculture (CA) on integrated weed management (IWM) combining weed and N management in

Nitrogen and weed management effects on maize and wheat yields under CA

Agronomic Practices	Weed dry weight (g/m^2) in maize	Maize (t/ha)	Wheat (t/ha)
Weed management			
Weedy check (maize)/weedy check (wheat)	8.7	4.34	4.64
Atrazine + pendimethalin (0.75 + 0.75 kg/ha,tank-mixed) as pre-emergent(maize)/pendimethalin +carfentrazone-ethyl (1.0 + 0.02 kg/ha) as pre-emergent(wheat)	3.0	4.74	4.96
Brown manuring(maize)/ clodinafop-propargyl+ carfentrazone-ethyl (0.06 + 0.02 kg/ha) as post-emergent(wheat)	6.7	4.81	5.46
LSD (P ≤ 0.05)	3.7	0.40	0.48
Nitrogen management (both maize and wheat)			
100% basal	6.7	4.31	4.75
50% basal+25% broadcast+rest through GS	5.7	5.22	5.41
50% basal + rest through GS	6.0	4.79	4.99
80% basal + rest through GS	6.0	4.63	4.92
LSD (P ≤ 0.05)	0.8	0.29	0.20

maize-wheat system. Results showed that herbicide combination (atrazine + pendimethalin) and brown manuring+2,4-D had significant influence on the reduction in weed dry weight and increase in maize yield by 12%, while, mean wheat grain and straw yields increased by 9 and 8%, respectively in the optimised GS–N treatments. The post-emergent clodinafop-propargyl + carfentrazone had 10 and 21% higher mean grain yield than pre-emergent pendimethalin + carfentrazone and weedy check, respectively.

5.5.2 Efficient Weed Control in Gladiolus

Study on weed control strategy in gladiolus, showed that application of atrazine 0.75kg/ha PE + carfentrazone 0.03kg/ha post-emergence resulted in the highest reduction in weed dry weight, which was comparable with atrazine 0.75kg/ha PE+ residue (5 t/ha), atrazine 0.75kg/ha PE+ metsulfuron 0.005 kg/ha post-emergence and metribuzin 0.4 kg/ha PE+ residue. Application of metribuzin 0.4 kg/ha PE+ residue gave the highest marketable spikes and net returns in gladiolus.

5.5.3 Density and Nitrogen Effects on the Interference and Economic Threshold of *Phalaris minor* in Wheat

A study on density and nitrogen effects on the interference and economic threshold (ET) of *Phalaris minor* in wheat undertaken indicated that the doses of N and *Phalaris minor* densities significantly influenced the competition of *P. minor* in wheat. Higher dose of 180 kg N/ha proved beneficial towards reduction of *P. minor* interference on wheat. Similarly, higher density of *P. minor* reduced the yield and yield attributes of wheat and caused greater interference.

5.5.4 Effect of Tillage, Method of Establishment and Weed Management Practices on Performance of Maize in Maize-Wheat Cropping System in North East Plains Zone

At IARI Regional Station, Pusa (Bihar), an experiment was undertaken to evaluate various weed management practices under different establishment methods of maize. Growing of maize on raised bed and ridge was found at par with respect to weed density. The application of tank mix (atrazine @ 0.5 kg/ha + pendimethalin 0.5 kg/ha) as pre emergence, followed by one hand weeding proved best combination for weed control across the planting methods.

5.5.5 Evaluation of Pre and Post Emergence Herbicides for Weed Control in Lentil

The dominant weed flora in the experimental field was *Chenopodium album*, *Coronopus dydimus*, *Anagalis arvensis* and *Rumex dentatus* among broad leaf weeds and *Phalais minor* as grassy weed. Significantly lower weed dry weight was recorded in pre emergence Pendimethalin @ 1.0 l/ha fb hand weeding at 45DAS and pre emergence Pendimethalin @ 1.0 l/ha fb by Imazethapyr 75g/ha. Application of Pendimethalin @ 1.0 l/ha fb by Imazethapyr 75g/ha and Pendimethalin @ 1.0 l/ha fb hand weeding at 45DAS and Pendimethalin @ 1.0 l/ha fb Quizalopfop at 45 DAS recorded significantly higher seed yield than weedy check. Seed germination was not affected by the application of different herbicides.

5.5.6 Evaluation of Different Herbicides and their Doses in Onion Nursery

Different weed control methods including herbicides as pre and post emergence application and manual hand weeding were evaluated for weed control and toxicity to onion seedlings. Pendimethalin at 0.25, 0.50, 0.75 and 1.0 l/ha and Oxyflourofen 0.15 l/ha were applied as pre emergence application and Pendimethalin 0.25 l/ha and Imazethapyr 10 and 15g/ha were applied as post emergence spray at 20 days after sowing and two hand weeding at 15 and 30 DAS were the treatments for weed control. Pendimethalin 0.25 l/ha both pre and post emergence application was not toxic to onion seedling in terms of seedling length and seedling dry weight and was at par with two hand weeding treatment. Oxyflourofen (0.15 l/ha), Imazethapyr (10and 15g/ha) and Pendimethlin (0.75 and 1.0 l/ha) were found toxic to onion seedlings.

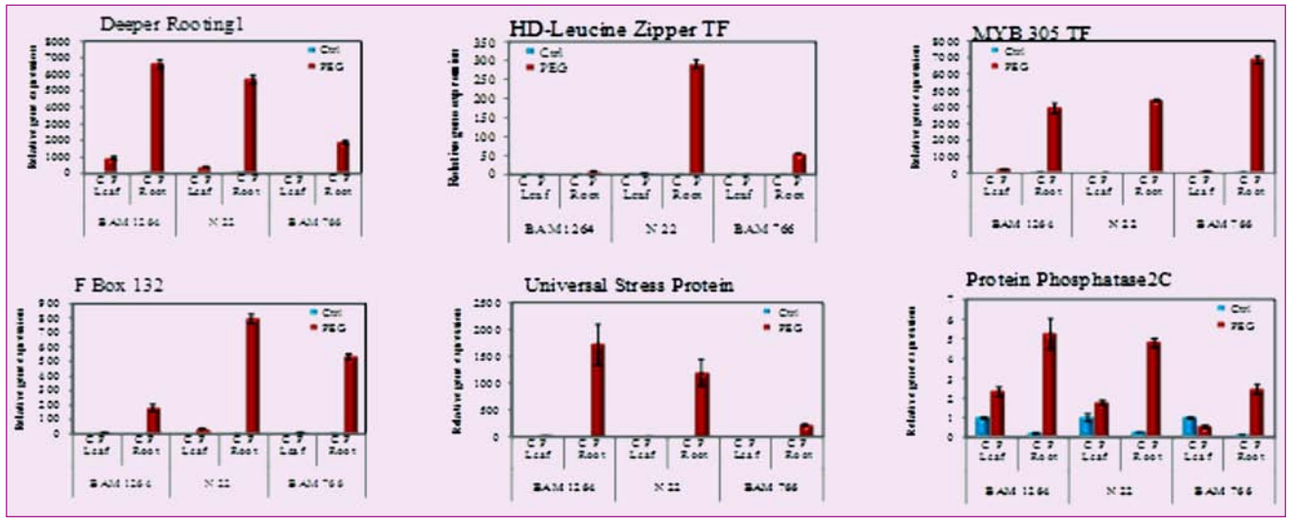
6. BASIC AND STRATEGIC RESEARCH

Significant progress has been made in the area of development of non-destructive high throughput phenotyping methods, identification of donor, genes and quantitative trait loci (QTLs) for quality and tolerance to biotic and abiotic stresses in various field and horticultural crops, and the use of crop simulation models and remote sensing methods for natural resource management. Genes for root traits in rice, heat tolerance in wheat, waterlogging tolerance in maize and nutritional quality in soybean were cloned and characterized. A major QTL *qBK1.2* for bakanae disease resistance in rice and many QTLs for drought tolerance and grain nutritional quality in wheat were mapped. Marker assisted recurrent selection (MARS) was utilized to combine several QTLs for drought and heat tolerance in wheat. Marker assisted selection (MAS) was used to introgress genes for low erucic acid and low glucosinolates to develop double low mustard varieties. Anther culture method for haploid production was standardized in soybean. Genetic diversity analysis and phenotyping of pulses for abiotic stress tolerance helped identification of contrasting set of germplasm lines for yield improvement. Transfer of black rot resistance genes from alien *Brassica* species in to cauliflower was accomplished. Significant progress has been made in the use of InfoCrop Wheat model for DSS and remote sensing for district level monitoring of crops, residue burning, land use and land cover classification. This section briefly summarises salient achievements of IARI in these areas.

6.1 GENOMICS AND MOLECULAR BIOLOGY

6.1.1 Cloning of Stress Inducible Root-specific Genes and Promoters from Rice

Root system architecture (RSA) plays key role in nutrient and water acquisition. RSA is regulated by drought stress. Towards identification of candidate genes for RSA and root-specific stress-induced promoters, 30 candidate genes which showed drought regulated root specific expression in microarray analysis were selected. Semi-quantitative RT-PCR expression analyses of these genes were carried out to analyse their expression in root and shoot tissues of



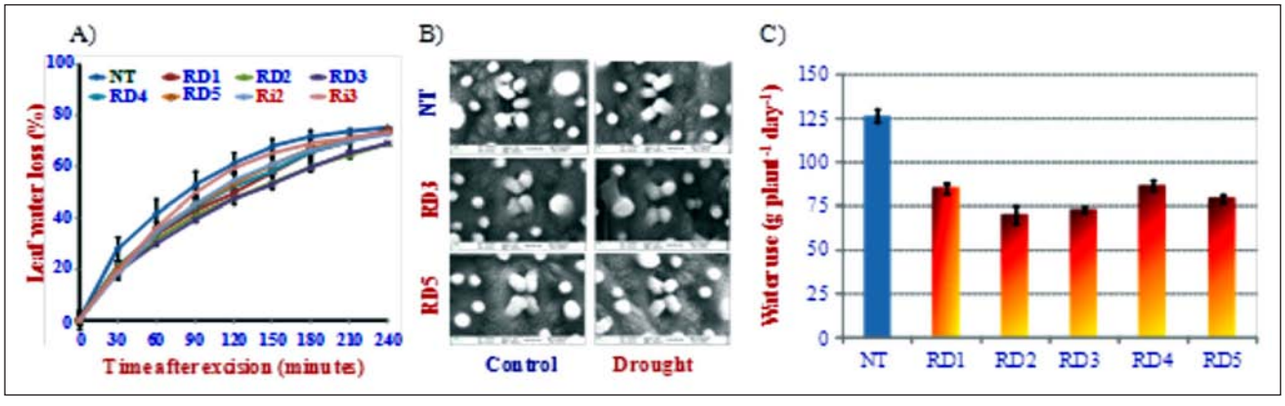
rice seedlings imposed with osmotic stress. Based on their tissue-specific and stress inducible expression, eight genes were selected for quantitative real-time RT-PCR validation. Of these *MYB*, *bZIP*, *FBOX132*, *PP2C* and *USP* genes showed root-specific and osmotic stress inducible expression. For functional validation, the coding sequences of these genes were cloned and sequenced from rice cv. Nagina 22 and the promoter of OsMYB was cloned and sequenced from rice genotype RCPL1-3C.

6.1.2 Physiological Mechanism of ABA Receptor (ABAR) Conferred Drought Tolerance in Rice

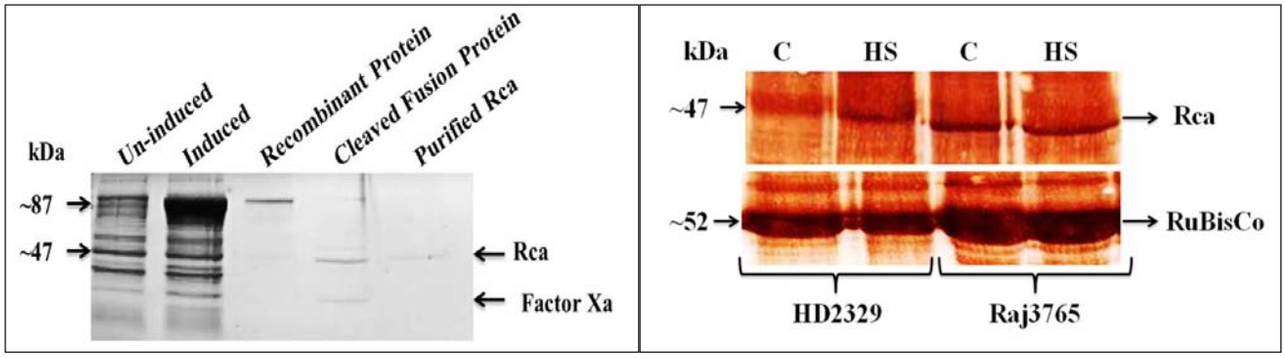
To validate the function of plant stress hormone abscisic acid (ABA) receptors (ABARs) in abiotic stress tolerance, rice transgenics expressing *OsABAR6* gene under the stress inducible *AtRD29A* promoter were developed. These transgenics showed enhanced cellular tolerance to dehydration under greenhouse conditions. Since ABA is a major regulator of transpiration and water use efficiency, these two traits were analysed in T2 transgenic and non-transgenic (NT) rice lines. Excised leaf water loss assay showed that water loss from the leaves of $P_{AtRD29A}$::*ABAR6* rice transgenics is slower than that of NT. Scanning electron micrography revealed that stomata are partially closed immediately after excision, and stomatal closure occur very fast in transgenics. The *ABAR6* and NT rice lines were subjected to 3 cycles of water-deficit stress (-80 kPa) and recovery, and water use by these plants were evaluated by gravimetric measurements under greenhouse conditions for over a period of one month. Transgenic rice plants used about 30-45% less water as compared to NT plants. The results showed the potential of *ABAR6* gene for minimizing the water use by rice plants.

6.1.3 Characterization of Heat Stress Responsive RuBisCo Activase (RCA) from Wheat

By using *de novo* transcriptome sequencing, heat shock transcription factor *HsfA2d*, with a potential role in heat tolerance was identified and cloned from HD 2329. Proteomic analysis with iTRAQ led to the identification of Oxygen Evolving Enhancer Protein (OEEP) as most abundant differentially expressed protein followed by RCA in wheat under heat stress. Since RCA is key for maintenance of photosynthesis under normal and heat stress environments, the CDS of *TaRCA1*was cloned from wheat cv. HD 2985 (GenBank acc. no. KC 776912) for detailed characterization. *TaRCA1* was expressed in *E. coli* strain BL21, purified and antibody was raised. Immunoblot analysis showed that the RCA antibody is highly specific, and the RCA levels were high in thermotolerant wheat cv. Raj 3765 under heat stress as compared to thermosensitive HD 2329.



Overexpressing *ABAR6* gene minimises transpirational water loss and total water use in rice. A) Excised Leaf Water Loss, B) SEM of stomata, and C) Daily water use per plant. NT, Non-transgenic; Transgenics overexpressing ABAR6 under RD29A promoter (RD1 to RD5); Ri, ABAR6 RNAi lines

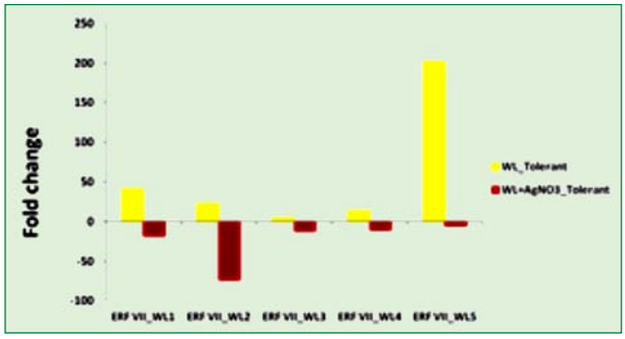


Production of RCA antibody and immunoblot analysis of RCA levels in wheat. A) Heterologous expression *TaRCA* gene in *E. coli*. PAGE of isolated BL/RCA fusion protein and purified RCA protein; B) Immunoblot analysis of RCA accumulation in wheat in control (C, 22°C) and heat stress (HS, 42°C for 2 h) conditions

6.1.4 Genes for Waterlogging Tolerance in Maize

Maize is highly sensitive to waterlogging. To analyze the role of oxygen-sensing genes of ERF VII family genes in waterlogging stress tolerance, the expression pattern of these genes were analyzed in control (no AgNO3 treatment) and $AgNO_3$ treated seedling of tolerant inbred line HKI 1105 under waterlogging stress. *ERF VII* genes were expressed and up-regulated under waterlogging stress. $AgNO_3$, an inhibitor of inhibits ethylene response, was found to reduce the expression of ERF VII family genes and also conferred waterlogging sensitivity to HKI 1105. This experiment revealed that ethylene responsive *ERF VII* genes are important regulators of waterlogging tolerance in maize.

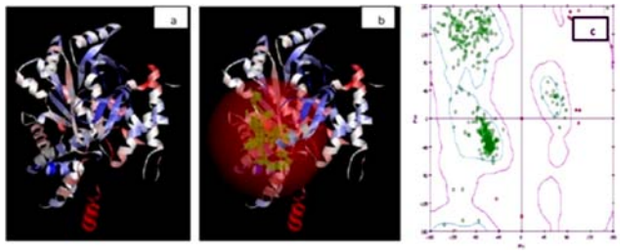
Transcriptome comparison between waterlogging tolerant maize inbred line CML 425 and sensitive inbred V 372 subjected to waterlogging stress showed that genes encoding alanine fermentation, pentose phosphate pathway, jasmonate regulation, flavonoid biosynthesis, nitrogen metabolism, delineating proteins of the root cortex, ethylene, lignin biosynthesis, cell wall loosening and cell elongation were up-regulated in tolerant CML 425 in root. In shoot, genes encoding lignin biosynthesis and cell wall digestibility, auxin responsive, flavonoid biosynthesis, ethylene formation, delineating proteins of the root cortex, protein kinases, cell wall loosening and cell elongation were up-regulated in tolerant but down-regulated in susceptible genotype. These candidate genes will be further explored to develop gene based markers.



Expression levels of ERF VII family genes in response to $AgNO_3$ treatment under waterlogging stress in maize

6.1.5 *In silico* Characterization of Bitter Gourd ACS (Mc-ACS) Proteins

The sex of the flower produced in cucurbits is determined by ACC synthase (ACS) involved in ethylene biosynthesis. Ethylene promotes female flower by inhibition of stamen development, while AgNO3 treatment induces male flowers. All five ACS genes of bitter gourd were analyzed to understand whether Ag+ interacts with ACS enzyme. The homology modelling approach was employed to determine 3D structure of McACS proteins, and these structures were further used as input to predict protein-ligand interaction active site for Ag+ binding. The created model has shown lower value of DOPE



Predicted 3D structure of McACS2 protein. a) Homology model predicted by alignment with template (1B8G, PDB database), b) Protein-ligand interaction site and hydrophobic pocket for binding of Ag^+ ions and c) Ramachandran plot showing the authenticity of predicted model

(Discrete Optimized Protein Energy) score (-51,898.2) and PDF (Probability Density Function) energy (18,181.7) with respect to other models. The overall stereochemical quality of 3D structure of protein was validated by using Ramachandran plot. The G31 located in the hydrophobic pocket appears to interact directly with Ag+. This suggests that binding of Ag+ to the ACS enzyme, in addition to the receptors may result in promotion of male flowers.

6.2 BIOCHEMISTRY

6.2.1 Soybean Nutritional Quality Improvement

For improving nutritional quality of soybean, research work is in progress to enhance the nutritionally important compounds such as α-tocopherol and isoflavones, and reduce the antinutrient factor phytic acid.

6.2.2 Characterization of Tocopherol Pathway

To understand the α-tocopherol accumulation in soybean, genes coding for tocopherol synthesis (tocopherol methyl transferases: γ-TMT1, γ-TMT2 and γ-TMT3) and ABC1 like kinase which controls recycling of α tocopherol were characterized. γ-TMT1 and γ-TMT2 expressions were more abundant in leaves, whereas γ-TMT3 expressions were significantly higher in seeds. The complete CDS of γ-TMT1, γ-TMT2 and γ-TMT3 and ABC1 like kinase were cloned and sequenced (NCBI GenBank accession: γ-TMT1 - KR090518, γ-TMT2 - KR090520 and γ-TMT3- KR071858, ABC-1 like kinase, KR149810).

6.2.3 Characterization of Phenylpropanoid Pathway Genes

Isoflavones are a group of secondary metabolites with nutritional benefits and nutraceutical value. Phenylpropanoid pathway provides precursors for synthesis of isoflavones. Quantitative RT-PCR analysis were carried out for transcription factors and enzyme coding genes (SPL9, MYB96 variant X1, CHI3, HBF, MYB65, MYB176, TCP3, TCP4, UDP-glucose-flavonoid 3-O-glucosyltransferase and WD-40 repeat family protein) for phenylpropanoid pathway and miRNAs (miRNA12, miRNA24, miRNA26, miRNA28 and miRNA29) which regulate these genes. The complete CDSs of two isoforms of isoflavone synthase (IFS) were cloned (IFS1, KP843618; IFS2, KT581120). Gene silencing constructs were developed for flavanone 3-hydroxylase and Chalcone reductase, using seed-specific conglycinin promoter from soybean.

6.2.4 Characterization of Genes Involved in Seed Phytate Accumulation

Reduction of seed phytate content is a promising approach for increasing mineral and protein bioavailability in soybean. Microarray based gene expression profiling to study differentially expressed genes of phytic acid biosynthesis pathway revealed stage-wise regulation of eight genes, namely, myo-Inositol-3-phosphatesynthae (*MIPS*), Inositol phosphate kinase (*IPK1 to 4*), MRP ABC transporter gene (*MRPABCC5*), Inositol 1,3,4,5,6-pentakisphosphate 2-kinase (*IPK1*) and Inositol polyphosphate 6-/3-/5-kinase (*IPK2*) involved in synthesis and accumulation of phytic acid. The expression pattern correlated with the accumulation of phytate in the seed at different stages of seed development. Gene silencing constructs were developed to silence *GmIPK1*and *GmIPK2* using seed specific *vicilin/conglycinin* promoters. Agrobacterium-mediated half seed transformation method was standardized and the soybean transformation efficiency was improved to >10%.

6.3 PLANT PHYSIOLOGY

6.3.1 Non-destructive High Throughput Phenotyping

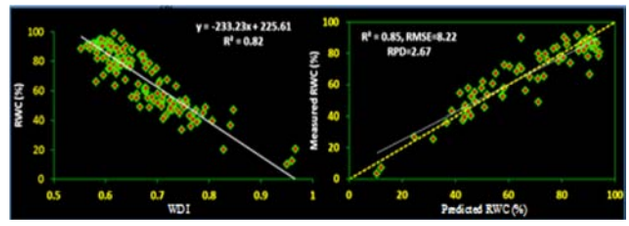
6.3.1.1 A tube based rhizotron for non-destructive root phenotyping

A rhizotron was developed for *in situ* observation of roots in PVC tubes. Clear glass tubes (38 mm dia x 200 mm length) were inserted horizontally into PVC pipes (16 cm diameter) at different depths. The distribution of roots adjacent to the walls of clear glass tubes was imaged by inserting a small web camera (with LED lights) into the glass tubes. The real time root images can be stored in a laptop or mobile phone attached to the camera. A significant correlation (r = 0.79) was observed between the root length of wheat imaged by camera and measured by destructive method.

Wheat plants growing in tube rhizotron (left). The rhizotron components include - PVC pipes, glass tube and web camera (middle). A snapshot of wheat roots (right)

6.3.1.2 Non-destructive assessment of plant water status in rice and wheat

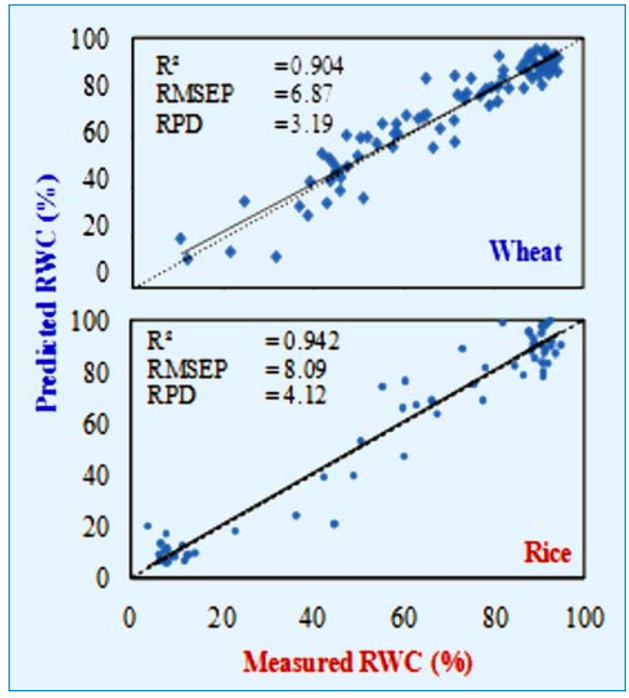
Plant water status measured as relative water content (RWC) is not only an indicator of stress levels in plants but also indicates water mining and transpiration minimization traits of plant. Since conventional measurement of RWC is time consuming and labour intensive, efforts were made to develop non-destructive techniques based on hyperspectral signatures of crops. Reflectance spectra (400-2500nm) were collected using ASD FieldSpec 3 spectroradiometer from 20 rice genotypes grown in pot culture under control and drought stress conditions. The reflectance from each wavelength was correlated with RWC to identify new wave bands that show high correlation with RWC. A new Water Deficit



Prediction model proposed (WDI) for assessment of RWC in rice. a) Correlation of WDI with RWC, b) Validation of WDI based RWC prediction model. The Root Mean Square Error (RMSE) and RPD (=SD/RMSE) values indicate the proposed model is good predictor of RWC

Index (WDI=1496nm/1796nm) was developed which showed high correlation with RWC (R^2=0.87). WDI predicted RWC better than the previously reported spectral indices.

One of the limitations of hyperspectral data analysis is the strong multicollinearity that leads to high correlation. To avoid this problem, partial least square regression (PLSR) and support vector machine (SVM) approaches were used to estimate RWC in



Relationship between relative water content (RWC) measured manually and predicted by using partial least square regression (PLSR) model in wheat and rice

rice and wheat genotypes grown in pot culture conditions. The prediction models developed based on PLSR as well as SVM approaches predicted RWC with high accuracy with RMSE values of 8.1 and 6.5%, respectively, in rice. Similarly, this approach was also found to be very useful to assess RWC and drought tolerance in wheat.

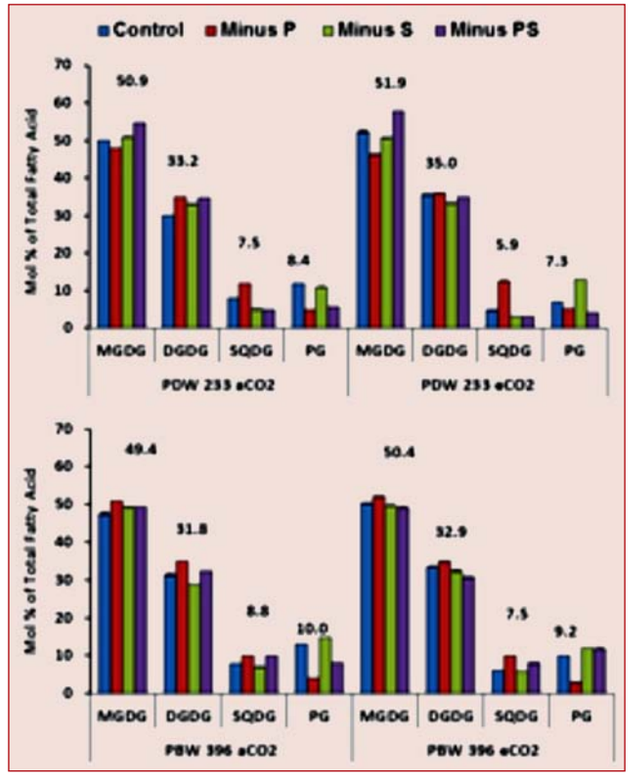
6.3.2 Plant Nutrient Use Efficiency and Deficiency Tolerance

6.3.2.1 Phenotyping of rice germplasm for N and P deficiency tolerance

To identify genotypes with high N and P uptake and use efficiency, a total of 152 rice germplasm were screened under N and P and dual-nutrient deficiency stresses in hydroponics. BAM 4797, NERICA L-44, BAM 247, NERICA-L 42, NERICA-L 26 were found to be tolerant to N deficiency, whereas RPBIO 226, SOMCAU 70A, BAM 759, Kali Kamod were sensitive to N deficiency. Bakal, NDR 359, Vanaprabha and Kalanamak were identified as tolerant genotypes to dual N and P deficiency stress conditions.

6.3.2.2 Sulphur and elevated CO_2 regulate phosphorus use efficiency

The interactive effects of P (5 µM and 500 µM) and [CO_2] (400 and 700 µL L^{-1}) with different S (10 µM and 2000 µM) levels on wheat cultivars PDW 233 and PBW 396 were studies. P deficiency under elevated CO_2 reduced the amount of phosphatidyl glycerol (PG) but increased sulfoquinovosyl diacylglycerol (SQDG) by 2.5 fold under sulphur sufficient conditions. The low P/S treatment caused a significant reduction in PG in both varieties but SQDG was higher in PBW 396 than that in PDW 233. The *TaNPC4* coding for Phosphatidylcholine-hydrolysing phospholipase C/ non-specific phospholipase C, was highly induced by e[CO_2] in shoot which corresponded with the high levels of DGDG and MGDG in shoot. The transcript of *TaPLDæ1, TaSQDG1* and *TaSQDG2* were highly induced in response to e[CO_2]. The *TaSQDG1* was highly induced by low P/S, while relative expression of *TaSQDG2* was higher under low P in both root and shoot tissues. Higher expression of *TaSQDG2* probably led to the increase in SQDG in shoot under low P in both the varieties. This suggests that elevated [CO_2] may help plants acclimate to P deficiency by altering its membrane lipid composition if sufficient S is available.



Interactive effect of [CO_2] and nutrients on membrane lipid composition in wheat

6.3.3 Heat and Drought Tolerance of Rice

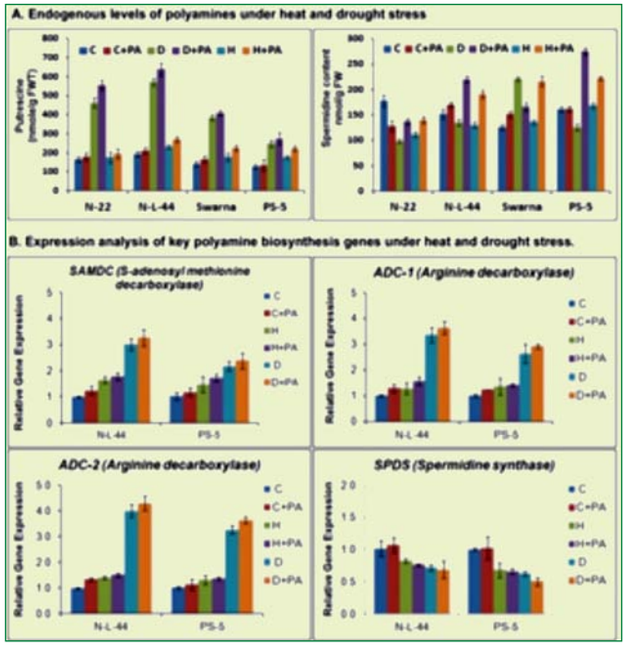
6.3.3.1 Nocturnal starch degradation under high night temperature

Starch accumulated by photosynthesis during day is used at night to support increased respiration under high night temperature. Rice genotypes, Vandana and Nerica-L 44 were exposed to moderate (1.5°C) increase in night temperature (HNT) from post anthesis to maturity to investigate the changes in nocturnal starch degradation pathway. HNT reduced the pre-dawn starch content by 20% as compared to normal conditions in Vandana. However, Nerica-L

44 did not show any discernible change between control and HNT stress. The activity of α-amylase also increased marginally in Vandana under HNT. Among the products of starch breakdown maltose levels increased preferably. The expression levels of the α-amylase genes, *Amy2* and *Amy3* were less in Nerica-L 44 but *Amy3* was up regulated in Vandana under HNT suggesting its role in starch breakdown under HNT.

6.3.3.2 Role of polyamines in heat and drought stress tolerance

The association between endogenous levels of polyamines and tolerance to heat and drought at reproductive stage was analyzed in four contrasting rice cultivars. Both drought and heat stress induced polyamines biosynthesis and accumulation in all cultivars. However, significantly higher accumulation was recorded in tolerant cultivars, namely, Nagina 22 and Nerica-L 44. The expression levels of genes coding for polyamine synthesis were induced under both heat and drought stress. However, the expression levels were significantly higher under drought as compared with heat stress. Foliar application of polyamines prior to the exposure to heat stress resulted in higher pollen viability and spikelet fertility.



Endogenous levels of polyamine (A) and expression of key polyamine biosynthesis genes under drought and heat stress in rice at reproductive stage

6.3.4 Heat and Drought Tolerance of Wheat

6.3.4.1 Flag leaf epicuticular wax content in wheat

Epicuticular wax play key role in radiation reflectance, and thus minimize energy load on the canopy that drive transpiration. Hence, wax content of flag leaf in 31 wheat genotypes at anthesis was estimated. Wax content showed wide variation from of 14.7 μg cm^{-2} (HD 2643) to 42.4 μg cm^{-2} (HD 4713). Based on the wax content, wheat genotypes were classified in 4 distinct categories. Extreme contrasting genotypes with low (HD 2643, C 306, DBW 14, HD 2402, Kalayan Sona, HD 2987, HD 2009) and high (HD 4713, Baviacora 88, Kundan, HD 4719, Raj 3765) wax content were identified, and the physiological basis is being analyzed.

6.3.4.2 Molecular analysis of staygreen in wheat

The expression analysis of genes associated with Chlorophyll metabolism/degradation pathway viz., *Staygreen1 (TaSgr1)* and *Phaeophorbide A oxygenase* (*TaPaO*) in wheat cultivars differing in drought tolerance and staygreen trait were studied. The *TaSgr1* expression increased under drought over control in drought tolerant and staygreen genotypes. The non-staygreen genotypes (CBW38 and HW2033) showed higher expression of *TaSgr1* under drought as compared to functional staygreen genotypes (CHIRYA7 and HW2041). The *TaPaO* expression increased under drought over control in both drought tolerant and staygreen genotypes. The non-staygreen genotypes showed higher expression of *TaPaO* under drought as compared to staygreen genotypes. The expression of photosystem II structural protein viz., D1 Protein (*TaPsbA*) and oxygen evolving complex 23 KDa protein (*TaPsbP*), and rubisco small subunit (*TarbcS*) decreased under drought. The staygreen genotypes maintained higher expression of these genes under drought as compared to non-staygreen genotypes.

6.4 GENETICS

6.4.1 Wheat

6.4.1.1 Wheat hybrid development

About 270 new hybrid combinations were made using five superior CMS lines and >70 restores. Ten each in A, B and R lines were maintained, and being extensively used in AxR crosses for exploitation of heterosis. Crosses were made and will be used for large scale seed production of 10 A lines to be used in hybrid seed production in next *Rabi* season. These lines were found to be perfect maintainer and have synchronized flowering time. The seed setting in A lines were found to be optimum to sustain hybrid seed production. These lines will be used for large scale seed production of hybrids to be targeted for multi-location testing.

6.4.1.2 Development of wheat double haploids (DH)

Seven DH plants were produced *via* crossing of F_1 wheat plants with *Imperata cylindrica* followed by embryo rescue and colchicine treatment. A method was also developed for wheat DH production by crossing it with maize. F_1 plants from two crosses were emasculated and pollinated by fresh maize pollen. After 24 h of pollination, the florets were treated with three different concentrations of 2,4-D viz., 100, 130 and 150 ppm by cavity drop technique. Frequency of caryopsis development was >95% in pollinated spikelets. After 14-17 days of pollination, caryopses were removed from the ear, caryopses with floating embryos were identified and were kept at 4°C for two more days. Caryopses were aseptically dissected and free floating embryos are cultured in a plant regeneration media at 15-17°C with 8/16h of light and of dark period. Good frequency of embryo formation (>20%) was observed at 100 ppm 2,4-D concentration. The plantlets are being grown and their genetic constitution (haploid genome) is being confirmed.

Stages up to embryo rescue in development of doubled haploid in wheat

6.4.1.3 Marker assisted gene/QTL introgression for biotic and abiotic stress tolerance

Thirty lines were developed with stem rust resistance *Sr2* and *Sr36* genes (for stem rust race 117-group pathotypes) pyramided in *durum* wheat HI 8498 background with high recovery of recurrent parent genome. Marker aided introgression of known QTLs for drought and heat tolerance into elite cultivars viz., HD 2967, DBW 17, HD 2733 and GW 322 was initiated. Backcross populations were advanced to BC_1/BC_2 F_2 after tracking QTLs for fore-ground selection and recurrent parent genome selection using 70-90 microsatellite markers. The homozygous lines for QTLs BC_1/BC_2 progenies also showed >90% recurrent parent genome recovery.

QTLs mapped in the RILs of C 306 X MACS and HW 2004 X HD 2967 for physiological traits in wheat

Trait	Qtl present in C306XMACS		Qtl present in HW2004XHD2867	
#=Nobel qtl report *=reported qtl	2010-2011	2011-2012	2010-2011	2011-2012
#EGC	--	--	--	#Qtld.egc(ch6)
#CT p	#Qtla1.ctp(ch16)	#Qtlb1.ctp(ch8) #Qtlb2.ctp(ch13)	#Qtlc1.ctp(ch1) #Qtlc2.ctp(ch2) #Qtlc3.ctp(ch9)	#Qtld1.ctp (ch8)
CT a	--	Qtlb1.cta (ch1) Qtlb2.cta(ch1) Qtlb3.cta(ch8)	Qtlc1.cta(ch10)	Qtld1.cta(ch7) Qtld2.cta(ch20)
CT g	--	Qtlb1.ctg(ch8)	--	--
RWC	Qtla.rwc(ch2)	--	Qtlc1.rwc(ch20)	Qtld1.rwc(ch11)
#MSI	#Qtla.msi(ch9)	--	#Qtlc1.msi(ch19)	
#CCI	--	#Qtlb1.cci(ch8) #Qtlb2.cci(ch12)	#Qtlc1.cci (ch20)	#Qtld1.cci (ch8)
Proline	Qtla1.pro (ch1) Qtla2.pro (ch8)	--	--	--
*St WSC	--	Qtlb1.stwsc(ch21) Qtlb2.stwsc(ch21)	--	--
SGsd*2	--	Qtlb1.sgsd2(ch15)	--	*Qtld1.sgsd2(ch6)
SGsd*3	--	Qtlb1.sgsd3(ch10)	--	Qtld1.sgsd3(ch6)
*SG*4	--	Qtlb1.sg4(ch10)	--	*Qtld1.sg4(ch6)
SGhd*2	Qtla1.sghd2(ch12) Qtla2.sghd2(ch12)	Qtlb1.sghd2(ch10)	Qtlc1.sghd2(ch10)	--
SGhd*3	Qtla1.sghd3(ch2) Qtla2.sghd3(ch12) Qtla3.sghd3(ch12)	Qtlb1.sghd3 (ch10) Qtlb2.sghd3 (ch15)	Qtlc1.sghd3 (ch10)	--
SGhd*4	Qtla1.sghd4(ch12) Qtla2.sghd4(ch12)	Qtlb1.sghd4(ch10) Qtlb2.sghd4(ch15)	Qtlc1.sghd4(ch10)	--

6.4.1.4 Marker assisted recurrent selection (MARS) for combining QTLs

MARS populations were generated from four primary crosses involving 8 independent parents and

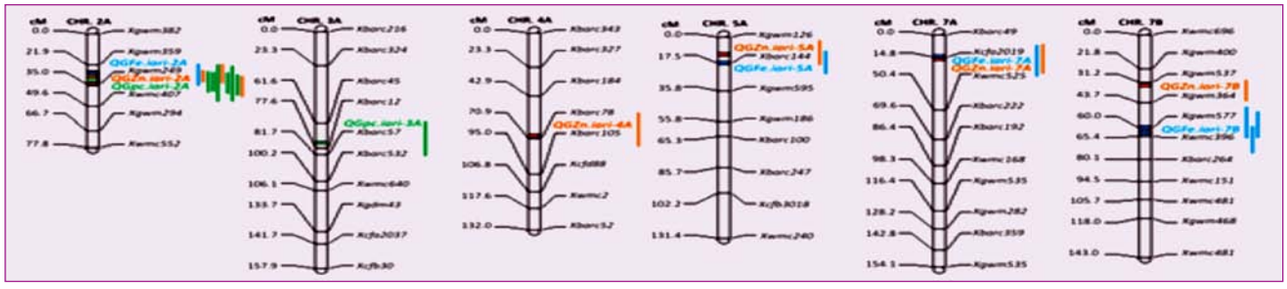
a total of about 800 F_5 families were obtained. These were phenotyped in two environments viz., drought and restricted irrigation and elite genotypes were selected which were used for interfamily intermatings. The crosses were advanced using off-season nurseries and the four base populations, namely, DBW43 × HI1500, HUW510 × HI1500, BW 7203 × BW 9149, PBW 442 × BWL 0056 are now in F_8 generation. These were sown in alpha-lattice design and phenotyped for physiological and yield traits under irrigated and rainfed conditions. Data was recorded according to the trait dictionary of CIMMYT for early vigour, days to heading, flag leaf emergence, CC values, canopy temperature, NDVI, chlorophyll fluorescence, flag leaf area, yield and related traits. These base populations were genotyped with microsatellite markers linked with previously reported QTLs for drought tolerance, and selected RILs were intermated. In these MARS populations, single nucleotide polymorphism (SNP) genotyping is being carried out for enabling the identification of QTLs with higher resolution.

6.4.1.5 Diversity studies based on quality characters in wheat

Trait association analysis in 64 wheat genotypes for hectoliter weight and grain hardness revealed that for improving the hectoliter weight of wheat genotypes more emphasis should be given on characters like grain width, grain diameter, flag leaf area, grain weight per spike and days to heading. For improving the kernel hardness, selection for characters viz., flag leaf area, grain width, grain weight per spike, grain diameter and number of spikelets per spike will be useful. Genetic diversity studies based on 17 morphological and quality characters revealed that genotypes CBW 38, HS 240, QLD 33, HD 2428, Kalyan Sona, HD 2009, HW 384, UP 2425, HD 2643, HW588, IND 359 and HD 2824 were genetically diverse and gave highest *per se* performance for different attributes.

6.4.1.6 QTL mapping for grain nutritional quality in wheat

Phytase, iron, zinc and inorganic phosphate levels in the grains of 122 wheat germplasm including *T. spelta* were estimated. HD 3118 was found to have lowest levels (168 mcg/mL) of phytic acid as against high levels (>400 mcg/mL) found in several cultivars. Since HD 3118 is a high yielding variety, the low phytic acid levels found in this variety will serve as a thresh hold value of phytic acid in wheat breeding aimed at enhanced bioavailability of micronutrients. Abiparental mapping population of the cross WH 542 x synthetic derivative (*Triticum dicoccom* PI 94624/*Aegilops squarrosa* (409)//BCN from CIMMYT, Mexico) consisting of 324 RILs was phenotyped in six environments for grain micronutrient content. Linkage analysis performed using MapMaker/EXP 3.0 led to the identification of 11 QTLs for grain micronutrient content. Five QTLs viz., *QGZn.iari-2A*, *QGZn.iari-4A*, *QGZn.iari-5A*, *QGZn.iari-7A* and *QGZn.iari-7B* for grain Zn concentration with 3.2-14.4% phenotypic contribution were identified. For grain Fe concentration, four QTLs, namely, *QGFe.iari-2A*, *QGFe.iari-7B*, *QGFe.iari-7A* and *QGFe.iari-5A* were mapped which together explained 20.0% phenotypic variance for Fe. Two QTLs (*QGpc.iari-2A* and *QGpc.iari-3A*) were identified for grain



QTLs identified for grain iron, zinc and protein concentration in 288 RILs of the cross WH 542 x Synthetic derivative. Q, QTLs; abbreviation of the trait name (*GFe, GZn, Gpc*; grain iron, grain zinc, grain protein concentration, respectively) with a full stop; Institute name (*iari*) in lower case and chromosome number on which the QTL is located. The QTL peaks have been shown on the linkage groups and the confidence intervals by the bars (blue color for *GFe*, orange color for *GZn* and green color for *Gpc*)

protein content which explained 4.3-18.8% variation for protein content.

6.4.2 Rice

6.4.2.1 Molecular mapping of QTLs for Bakanae disease resistance in rice

A rapid protocol for screening bakanae resistance in rice has been developed and QTL mapping was conducted in a RIL population from a cross between highly susceptible parent Pusa Basmati 1121 and highly resistant parent Pusa 1342. A major QTL, *qBK1.2* with phenotypic variation of 24.07 % and two minor QTLs, namely, *qBK1.1* and *qBK1.3* on chromosome 1 were mapped.

6.4.2.2 Development of mapping populations for various traits in rice

Phenotyping of large set of genotypes led to the identification of Nerica-L 44 and Nagina 22 as heat tolerance. A RIL population from the cross Pusa Basmati 1 x Nerica-L 44, Pusa 44 x Nerica-L 44 and Pusa 44 x Nagina 22 are being generated. For development of population for nested association mapping population, three common parents, namely, Nagina 22, IR58025B and Swarna were crossed with 27 different founder parents. Of which, 35 crosses are in F_4, 8 crosses are in F_3 and 25 crosses are in F_2 generation.

6.4.2.3 Identification of genotypes with low phytic acid

Phytic acid strongly binds to metallic cations of Ca, Fe, K, Mg, Mn and Zn making them unavailable for humans. A total of 275 Nagina 22 mutants and 255 rice germplasm lines were screened for low phytic acid using high inorganic phosphate (HIP) assay and two mutants, AGM-11 and AGM-150, and one germplasm line, GP 301 were identified with low phytic acid content.

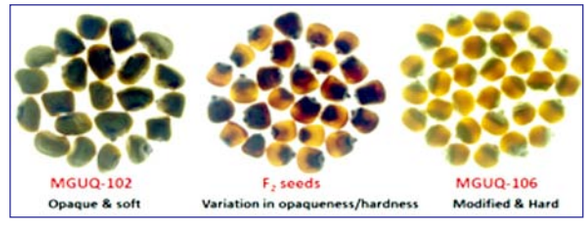
6.4.3 Maize

6.4.3.1 Molecular characterization of endosperm modifier loci in QPM inbreds

Modifier loci in QPM play vital role in achieving acceptable degree of kernel hardness, and lysine and tryptophan concentration. A set 46 diverse QPM inbreds with wide variation for endosperm modification (25-100% opaqueness), tryptophan (0.056-0.111%) and lysine (0.223-0.444%) were characterized using 83 SSRs linked to modifier loci. The frequency of unique- and rare- alleles was more for amino acid modifications, as compared to modification of endosperm. The phylogenetic analyses grouped the inbreds into three major clusters. The study led to the identification of suitable crosses for accumulation of endosperm- and amino acids- modifiers. QPM inbreds with desirable modifications identified here would serve as suitable donor for both *opaque2* and modifier loci in the marker-assisted backcross breeding strategy.

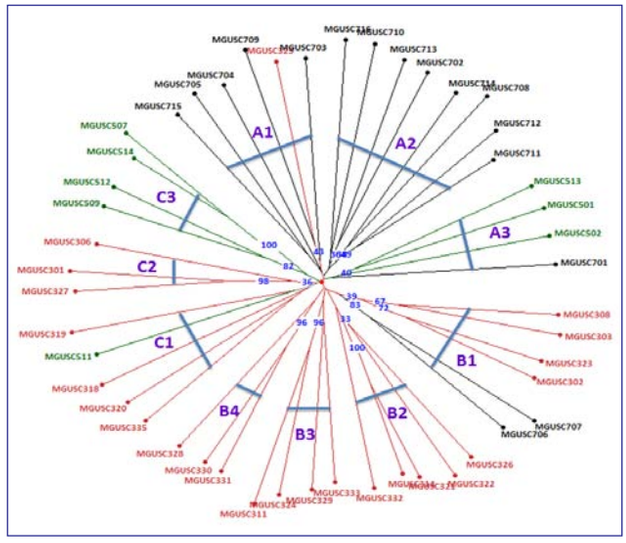
6.4.3.2 Development of mapping populations for endosperm modifiers

MGUQ102, an *opaque2* inbreds possessing 100% opaqueness and soft endosperm was crossed with two hard endosperm-based *opaque2*-based inbreds, MGUQ106 and CML161 (a CIMMYT line). The F_2 mapping populations will help in localizing and validating modifier loci, and the information can be effectively utilized in the QPM breeding programme.



6.4.3.3 Molecular characterization of sweet corn inbreds

A set of 48 diverse sweet corn genotypes (*su1su1*, *sh2sh2*, and *su1su1/sh2sh2*) were analyzed using 56 SSR markers. It generated a total of 213 alleles with mean of 3.8 alleles per locus. The average PIC was 0.50, and the pair-wise genetic dissimilarity ranged from 0.33-0.87 with a mean of 0.73. Neighbor-Joining based clustering pattern grouped the inbreds into three major clusters each with few sub-clusters. In general, each of the *su1su1-*, *sh2sh2-* and *su1su1/sh2sh2*-types were together in specific clusters. Based



Neighbor-Joining based clustering pattern of the inbreds for *su1su1*, *sh2sh2*, and *su1su1*/*sh2sh2* alleles

on the grouping pattern and genetic dissimilarity, prospective heterotic combinations in various genetic backgrounds (*sh2sh2* × *sh2sh2*, *su1su1* × *su1su1*, *su1su1*/*sh2sh2* × *su1su1*/*sh2sh2*, *sh2sh2* × *su1su1*/*sh2sh2* and *su1su1* × *su1su1*/*sh2sh2*) were identified.

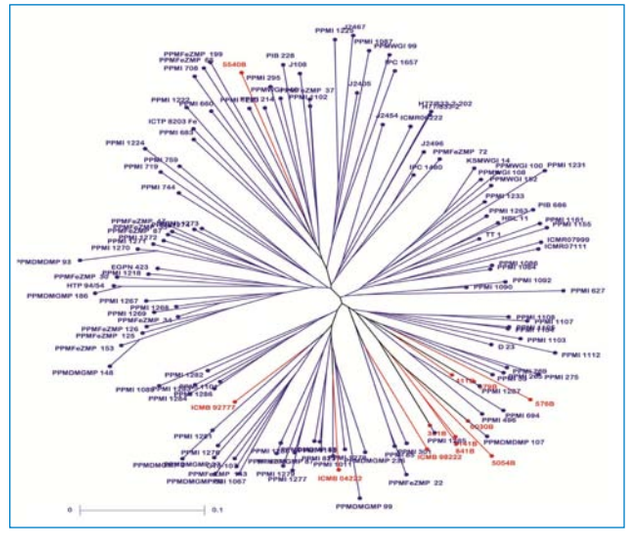
6.4.4 Pearl Millet

6.4.4.1 Phenotyping of pearl millet lines for total grain starch content and seedling thermotolerance

Starch is the major storage form of carbohydrate in pearl millet. The physico-chemical properties of the starch affect the textural characteristics of the food preparations made from grains. For special food product development, 78 genotypes were analyzed for total starch content. Genotypes 16864 and P 7-3 showed highest (81%) and lowest (31%) starch content, respectively, and the mean value of 78 genotypes was 59.9%. A set of 240 pearl millet genotypes were grown in growth chambers in NPF, and were subjected to artificial heat stress (35ºC and 42ºC). Physiological data viz., CTD, SPAD, Leaf area, RWC and MSI were recorded after 4h of treatment showed that genotypes ICMB 92777, J 104 and TT-1 were most tolerant.

6.4.4.2 Molecular diversity studies in pearl millet genotypes with high grain iron content

An association mapping panel comprising 130 pearl millet genotypes including two checks for high grain Fe content (ICMB 98222 and Dhanshakti) were evaluated in alpha lattice design with 3 replications at 3 locations (IARI New Delhi; IARI-Regional Research Center, Dharwad, Karnataka and NBPGR-Regional Station, Jodhpur, Rajasthan) during *Kharif* 2014 and 2015 for grain Fe and Zn content. The same set was genotyped with 115 SSR markers to understand diversity at the molecular level. A total of 17 newly developed restorer lines and 3 hybrids of pearl millet were grown in seven different locations during *Kharif* 2015. GGE analysis suggested PPMI 915 (G 17), PPMI 912 (G 14) and PPMI 913 (G 15) as lines with highest and stable mean Fe and Zn content.



Molecular Diversity of pearl millet genotypes with different levels of grain iron content

6.4.4.3 Development of mapping populations (RILs)

Eight mapping populations viz., WGI 148 × ICMR 09999, WGI 52 × WGI 148, WGI 148 × WGI 52, PPMI 683 × PPMI 627, 5141 × TPR 14, 1P1 × 1P2, 2P1 × 2P2 & 4P1 × 4P2 and PPMI 759 × ICRI-10-15677 for mapping QTLs for traits such as downy mildew resistance, high grain iron and zinc, early flowering, thick and long

spike were advanced, which are at different stages in RIL development.

6.4.5 *Brassica*

6.4.5.1 MAS for white rust resistance

Molecular markers linked to white rust and oil quality traits were validated. Marker At2g36360 reported linked to white rust in Donskaja was found polymorphic between Donskaja and Pusa Mustard 24 / Pusa Mustard 30. The marker At5g41560 reported linked to white rust in BEC 144 and Heera, was found polymorphic only between BEC 144 and recipient parents PM24/ PM30, while it was monomoprphic between Heera and PM24/ PM30.

6.4.5.2 MAS for quality traits

Molecular markers linked with total glucosinolate content in *Brassica* viz., GRE1, GRE5, At5g101, At5gAJ30, At5g41, At5g67, Myb28 were used for parental polymorphism. These markers will be used for foreground selection to develop double low high yielding genotypes. A total of 276 SSR markers located on different chromosome were used for study the polymorphism among recipient and donor parents. Of these, 54 markers were found polymorphic (20%). To introgress white rust resistance in high oil quality genotypes BC_1F_1 population were generated from crosses PM30/ Donskaja//PM30 and PM24/ Donskaja//PM24. The foreground selection was done using the At2g36360 marker. Plants from both these populations possessing Donskaja allele were also analyzed for *Fae1.1* and *Fae1.2* alleles imparting low erucic acid. The SNP 591 and SNP 1265 of *Fae1.1* were found polymorphic between parents having high and low erucic acid content, whereas, for *Fae1.2* gene SNP 237 found to differentiate low and high erucic acid. These SNPs were converted into CAPs marker for their utilization in breeding program. These plants were selected and backcrossed again with the respective recipient parents viz., PM 30 and PM 24. For development of double low genotypes, two backcross populations were generated i.e., PM30/PDZ1//PM30 and PM24/ PDZ1//PM24. These populations are being analyzed for low glucosinolate trait linked markers.

6.4.5.3 Effect of cytoplasm and genetic backgrounds of parental lines on fertility restoration

Isonuclear alloplasmic cytoplasmic male sterile (CMS) lines with *Moricandia arvensis (mori), Diplotaxis erucoides (eru), D. berthautii (ber)* cytoplasms were developed in the six diverse genetic backgrounds of *B. juncea* (NPJ 112, NPJ 139, LES 1-27, SEJ 8, EC 308575 and Pusa Agarni). To assess the effect of sterile cytoplasms and nuclear backgrounds of parental lines (A & R) on fertility restoration, crosses were attempted between these 18 CMS lines with six restorers possessing fertility restorer gene from *M. arvensis*. Comparison of the mean percent pollen fertility in 108 single cross hybrids revealed that the hybrids based on *mori* cytoplasm were significantly different from that possessing *ber* and *eru* cytoplasms. Paired comparisons of the mean pollen fertility (%) of hybrids revealed that pollen fertility in hybrids was influenced by the genetic backgrounds of parents. Per cent pollen fertility and seed set in the hybrids did not show any significant correlation neither in open nor in self-pollinated conditions. Despite low pollen fertility, normal seed set was observed in some genetic backgrounds of hybrids, which indicates that the new sterility inducing cytoplasms i.e., *eru* and *ber* can be used for exploitation of heterosis in Indian mustard.

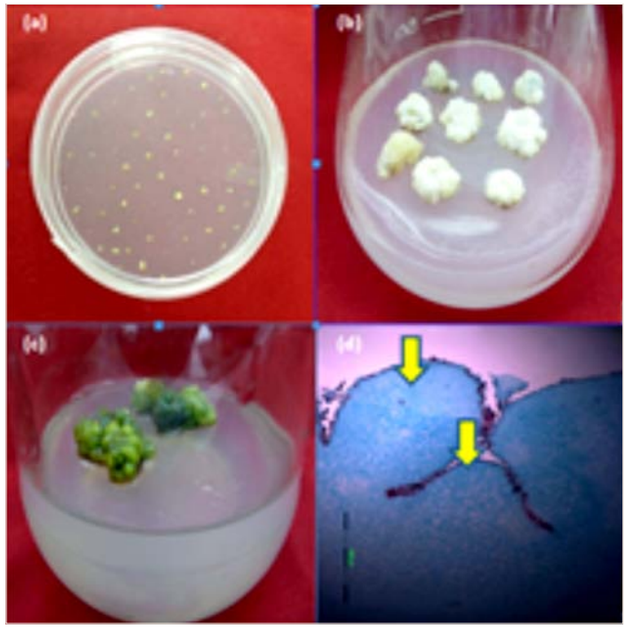
6.4.5.4 Phenotyping for identification of '0' and '00' genotypes

For identifying low erucic acid and double low genotypes from various breeding populations, maintenance breeding of double and single low varieties and advance lines, a large number of single plants and bulks are phenotyped through biochemical analysis. For low erucic acid, 2731 single plants/ bulks were analyzed of which 2658 were having <2% erucic acid. Likewise, 3401 single plants/bulks from double low quality material were also screened for their glucosinolate content and 454 plants/bulks were possessing <30 ppm glucosinolate.

6.4.6 Soybean

6.4.6.1 Anther culture of soybean

Anther culture protocol was established in soybean. The floral buds of 2.0-3.0 mm size containing microspores at uni-nucleate stage were most responsive for anther culture and organogenesis. Soybean genotypes, namely, JS 335, SL 958 and SL 688 were cultured on B5 medium supplemented with different concentrations of plant growth regulators, sucrose and organic compounds for callus formation and organogenesis. Combination of 10.0 mg L^{-1} 2,4-D and 0.5 mg L^{-1} BAP supplemented with 90 g l^{-1} sucrose and 10% v/v of coconut water in B5 medium was found best medium for callus induction (64.11%). Murashige and Skoog medium supplemented with 2.0 mg L^{-1} BAP + 1.0 mg L^{-1} thidiazuron gave shoot bud-like structures, in contrast B5 medium promoted only root organogenesis. Anther derived callus was confirmed through flow cytometry and root tip cell of anther callus derived roots were confirmed to be haploid through root tip staining (chromosome number n= 20).



Anther culture and shoot-bud like structure formation in soybean genotype JS 355: (a) Callus induction on B5 medium supplemented with 10 mg L^{-1} 2,4-D + 0.5 mg L^{-1} BAP + 10% coconut water + 9% sucrose; (b) anther callus at 45 days, (c) : anther callus derived shoot bud like structure on medium MS + 2.0 mg L^{-1} BAP + 1.0 mg L^{-1} TDZ, and (d) microtome section of shoot bud-like structure differentiation (10 X)

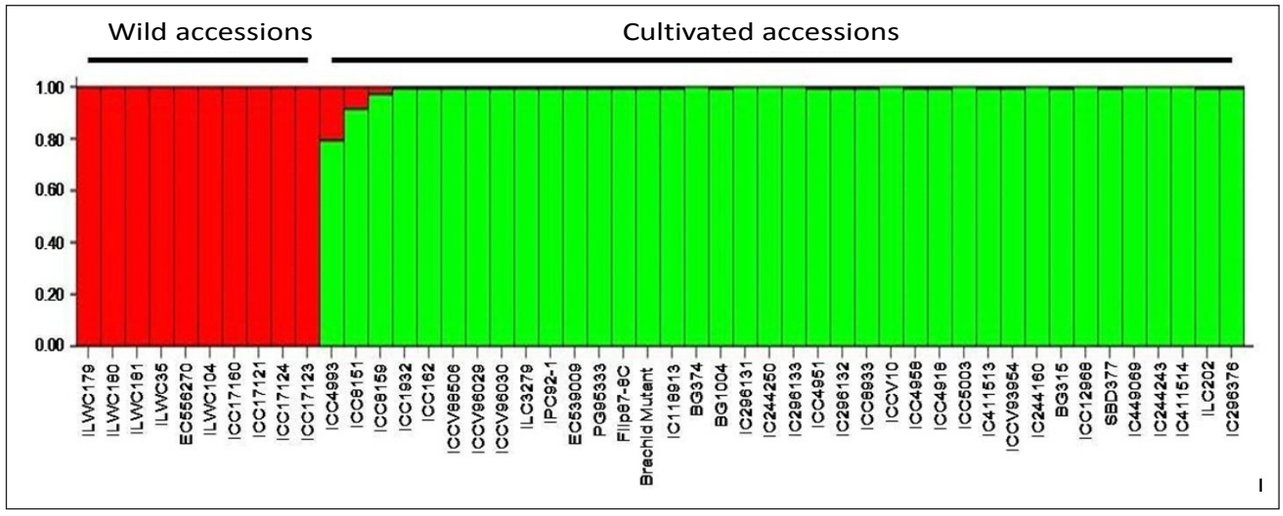
6.4.6.2 Identification of genotypes with high somatic embryogenesis and regeneration potential

A total of 22 soybean genotypes were screened to evaluate the capacity of embryo initiation, differentiation, maturation and plantlet conservation using standardized protocols. Among genotypes, Bragg was most responsive to induction (with 91.11% and av. 38.40 embryos/callus mass), proliferation (89.47%) and differentiation (78.95%); however, SL 688 gave the highest maturation frequency (91.57%). Highest SE germination was recorded in SL 525 (85.67%), whereas highest survival was observed in JS 335 (82.22%). Genotype Pusa 37 gave the poor response. Fifteen genotypes which were identified as responsive were Bragg, Bragg-Palampur, Pusa 5, Pusa 12, Pusa 14, Pusa 16, Pusa 24, Pusa 40, Pusa 9814, SL 688, SL 525, SL 979, SL 958, DS 2706 and DS 2708.

6.4.7 Pulses

6.4.7.1 Genetic structure and diversity analysis of the primary gene pool of chickpea

Members of the primary gene pool of chickpea, including 38 accessions of *Cicer arietinum*, 6 of *C. reticulatum* and 4 of *C. echinospermum*, were investigated using 100 SSR markers to analyze their genetic structure, diversity and relationships. We found considerable diversity in them with a mean of 4.8 alleles per locus. The polymorphic information content ranged from 0.040 to 0.803 with a mean of 0.536. Most of the diversity was confined to the wild species which had higher values of polymorphic information content, gene diversity and heterozygosity than the cultivated species. An unrooted neighbor-joining tree, principal coordinate analysis and population structure analysis revealed differentiation between the cultivated accessions and the wild species. This will contribute to more efficient identification, conservation and utilization of chickpea germplasm for various genetic studies and breeding to broaden the genetic base of cultivated chickpea.



Genetic relatedness of the 48 accessions of chickpea

6.4.7.2 Genetic diversity in *Lens* species

Genetic diversity in 86 accessions belonging to three species of genus *Lens* was assessed using 12 genomic and 31 EST SSR markers. Genomic SSRs exhibited higher polymorphism as compared with EST SSRs. GLLC 598 produced 5 alleles with highest gene diversity value of 0.80. Among the studied subspecies/species, 43 SSRs detected maximum number of alleles in *L. orientalis*. Based on Nei's genetic distance cultivated lentil *L. culinaris* subsp. *Culinaris* was found to be close to its wild progenitor *L. culinaris* subsp. *orientalis*. The Prichard's structure of 86 genotypes distinguished different subspecies/species. Higher variability was recorded among individuals within population than among populations.

6.4.7.3 Genetic diversity of *Lens* species with different adaptations to drought and heat stresses

Genotyping of 278 genotypes using 35 SSR markers identified 258 alleles. Genetic diversity and polymorphism information contents varied between 0.321-0.854 and 0.299-0.836, with mean value of 0.682 and 0.643, respectively. The genotypes were clustered into 11 groups. Drought tolerant genotypes were grouped in cluster 6, while sensitive ones were mainly grouped into cluster 7. Cluster analysis further grouped the wild accessions on the basis of species and sub-species into 5 clusters. Physiological traits under drought stress were significantly different among microsatellite clusters. Similarly, genetic diversity of 119 lentil genotypes was assessed using SSR markers and physiological traits under heat stress 35/33°C at seedling and 35/20°C at anthesis stages. In these genotypes, 35 SSR markers exhibited 209 alleles, and the genetic diversity and polymorphism information content values varied between 0.0494-0.859 and 0.0488-0.844, respectively. Genotypes were clustered in to 9 groups based on SSR markers. Physiological traits under heat stress were found to be significantly different among SSR clusters. These findings suggest that drought and heat adaptation is variable among the genotypes and genotypes from contrasting clusters can be selected for breeding programmes aimed at improving abiotic stress tolerance in lentil.

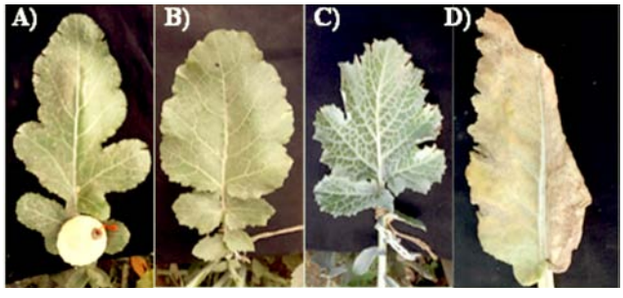
6.4.8 Cauliflower

6.4.8.1 Development of double haploids

Doubled haploid (DHs) population were developed using the F_1 of interspecific population of *Brassica oleracea* (var. Kt 25) x *B. carinata* (var. JTC 1, resistant to race 4 of *X. campestris* pv. *campestris*). This population will be used for rapid back cross conversion through application of DH technology.

6.4.8.2 Transfer of black rot resistance from alien *Brassicas* to cauliflower

Alien *Brassica* species accessions viz., *B. juncea* (Pusa Bold), *B. nigra* (IC56072), *B. juncea* (Pusa Vijay), *B. carinata* (NPC 9) were found to be resistant to black rot disease for all the *Xcc* races (Race 1, 4 and 6) on artificial inoculation under field conditions. To transfer black rot resistance, the F_1 inter-specific crosses of cauliflower with *B. nigra* and *B. juncea* were generated using *in vitro* embryo rescue. These F_1 plants were raised in pots under open field conditions and confirmed as true hybrids. A pollen viability study revealed pollen sterility in all the F_1 inter-specific hybrids. All the F_1plants of cauliflower (DC 401) × *B. juncea* (Pusa Vijaya) exhibited symptomless resistance against *Xcc* race 1 and 6, while for the *Xcc* race 4 most of them showed resistance or partial resistance. Cauliflower DC 401 was used as pollen parent to generate BC_1 population using *in vitro* embryo rescue. The resistant BC_1 plants (cauliflower Pusa Sharad × *B. carinata* NPC 9) were backcrossed with different accessions of cauliflower and BC_2 plants were generated using *in vitro* embryo rescue technique.



Black rot disease reaction under field conditions: A) The interspecific F_1 (resistant) of cauliflower × *B. nigra*. B) The interspecific F_1 of cauliflower × *B. juncea;* C) The BC_1 of cauliflower with *B. carinata* NPC 9; and D) cauliflower DC401 (susceptible). Photographs were taken 30 days after artificial inoculation

6.4.8.3 Marker development for black rot and downy mildew resistance

A linkage map of three markers along with the block resistance locus covering 36.30cM distance was developed and found that intron length polymorphic markers At1g70610 and At1g71865 flanked the resistant locus (*Xca1bc*) at a genetic distance of 6.2 and 12.8 cM, respectively, in *B. carinata*. A total of 111 RILs of F_4 generation of *B. carinata* (NPC 17 x NPC 9) were advanced to F_5 generation for mapping black rot resistance. Ninety two F_7 RILs of Pusa Himjyoti (susceptible) x BR 2 (resistant) were used for mapping of downy mildew resistance. SSR marker analysis identified linkage of $BoGMS742_{249}$ and $BoGMS0030_{260}$ markers with the downy mildew resistance gene at 6.4 and 4. cM distance, respectively.

6.4.9 Biotic and Abiotic Stress Tolerance in Melons

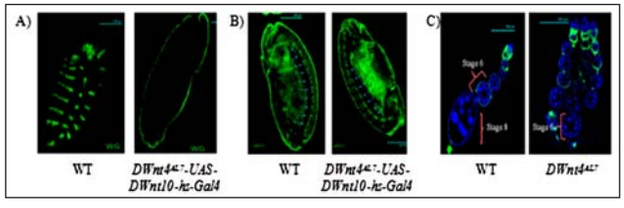
Snapmelon line DSM 11-6 carries *Fusarium* wilt resistant allele of functional marker developed from LRR region of *Fom-2* gene. Two SCAR markers $Fom2\text{-}R_{408}$ and $Fom2\text{-}S_{342}$ were validated in F_2 population of Kashi Madhu and DSM 11-6 by bulk segregating analysis and used for identification of resistant genotype. Screening of 132 lines of watermelon led to the identification of *C. lanatus* var. *citroid* and two lines from *C. colocynthis* resistant to tospovirus. Drought tolerance of 96 lines were evaluated under controlled conditions in phytotron, and 6 lines belonging to *C. lanatus* var. *citroid* and *C. lanatus* var. *lanatus* were identified as drought tolerant.

6.4.10 PCR Markers to Identify Cytoplasm and *Ms* Locus in Onion

Analysis with three cytoplasmic (OSN, MKFR, *accD*) and four nuclear (OPT, jnurf13, AcSKP1, AcPMS1) markers showed that Sel 121-1 had 100% sterile (*S*) cytoplasm whereas Sel121-2, Pusa Red and Pusa Madhavi had 88, 33 and 17% S cytoplasm, respectively. Early Grano and Pusa Riddhi did not possess S cytoplasm. Analysis of 33 commercial varieties revealed the presence *S* cytoplasm in two varieties. Nuclear markers were not found in linkage disequilibrium with the *Ms* locus and constitution of *Ms* alleles by OPT was different from other three markers which were in conformity with each other. The results revealed that *accD* marker is ideal for cytoplasm determination, while for the *Ms* locus tagging, more markers need to be evaluated.

6.4.11 Drosophila

A study was carried out to understand the interaction between four *Wnt* genes located on chromosome 2 in *D. melanogaster.* Of these genes, the *wingless* has been well studied, while *DWnt4, DWnt6* and *DWnt10* were less understood. Six mutants of *DWnt4* gene were isolated using EMS mutagenesis. $DWnt4^{AL7}$-UAS-*DWnt6-hs-Gal4* and $DWnt4^{AL7}$-UAS-*DWnt10-hs-Gal4* embryos showed a rescue of the $DWnt4^{AL7}$mutant phenotype. Expression of *Wg* and *Arm* in the embryos of $DWnt4^{AL7}$ where *DWnt6* or *DWnt10* is overexpressed was studied. Expression of *wingless* was not observed after overexpressing *DWnt6* and *DWnt10* in $DWnt4^{AL7}$ mutant background. $DWnt4^{AL7}$-UAS-*DWnt6-hs-Gal4* embryos showed reduced expression of *Arm*, while in $DWnt4^{AL7}$-UAS-*DWnt10 -hs-Gal4* the *Arm* expression levels were similar to that of wild type. Although previous studies have shown that *DWnt4* regulates ovarian sheath morphogenesis, the mutants isolated in this study did not show defects in ovaries. Hence, germline clones of $DWnt4^{AL7}$mutant were created, and found that individual germarium were able to grow only till stage 6 of oogenesis.



Expression of *wingless* (A) and *Arm* (B) genes, and germarium development (C) in $DWnt^{AL7}$ mutant of *Drosophila*

6.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS, AND METEOROLOGY

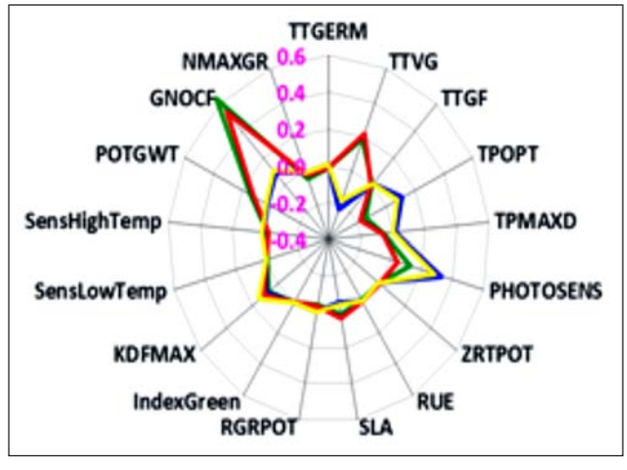
6.5.1 Bio-Physics and Crop Simulation Modeling

6.5.1.1 Effect of elevated CO_2 on soil properties and root nodule biophysics in chickpea

Effect of elevated CO_2 on soil aggregation, carbon and other nutrient availability and soil enzyme activities in relation to root and nodule biophysics in chickpea cv. Pusa 1105 was studied in an open top chamber (OTC) experiment. Greater hydrophobicity of soil aggregates and hence, soil resistance to slaking was enhanced under CO_2 enrichment with no effect on capillarity of aggregates and other soil hydrophysical parameters. Soil labile C fractions (water soluble carbohydrate and microbial biomass C) significantly increased with marginal decrease in recalcitrant C. Higher root growth and bulky nodules with higher starch and soluble sugar contents, and nitrogenase activity were observed under elevated CO_2. A greater partitioning of C to roots and higher N_2 fixation in chickpea stabilized the net C:N ratio in the soil. Higher soil biological activity under CO_2 enrichment resulted in marginal depletion of recalcitrant C with increase in labile C pools. These may offset the soil C stability in a legume-based agroecosystems under the enriched CO_2 conditions in the semi-arid regions.

6.5.1.2 Sensitivity analysis of cultivar input parameters in Web InfoCrop wheat model

Sensitivity analysis of cultivar input parameters were characterized on the outputs of yield and growth variables of Web InfoCrop Wheat model. The model was assessed for each combination of 17 input cultivar parameters tested under moisture-deficit and temperatures stress conditions in four different places. The most dominant cultivar parameters identified were TPOPT, TTVG, KDFMAX, GNOCF, POTGWT



Correlation of cultivar parameters with yield

and PHOTOSENS which were associated with LAI, growth, grain number and thermal time accumulation. Simulation with all the cultivar parameters or with only the most sensitive cultivar parameter input showed significantly high correlation with the results from the field experiments. The application of sensitivity analysis to reduce the number of model input cultivar parameters, and thus useful in saving time and cost, as it identify only few sensitive parameters for which field experiment needs to be conducted.

6.5.1.3 Multi-stage wheat yield forecast using statistical and crop simulation models

Multi stage wheat yield forecast at different growth stages of the crop were done at the district level using weather based statistical and InfoCrop model. For developing district level weather based statistical models, long term weather data and wheat yield data were acquired from India Meteorological Department, Pune and state department of Agriculture, respectively. Composite weather variables calculated and model were developed using step-wise multilinear regression equation. These models were used to forecast yield at mid-season (45 days before harvest) and pre harvest stage (25 days before harvest). Yield forecast at different growth stages of the crop were also done by InfoCrop model. The results revealed that the InfoCrop model performs better than weather based statistical models for forecasting yield at different growth stages of the crop. Also the yield forecast done by the InfoCrop model at pre harvest stage was better as compared to yield forecast done at mid-season stage. This study showed that Infocrop model is better than statistical model for yield forecasting.

6.5.1.4 Web based decision support system to identify best sowing date of wheat

A web based Decision Support system (DSS) using crop simulation model InfoCrop wheat was developed to identify best sowing date of a specific wheat cultivar. This was created using Visual Studio Express, SQL Server, NET framework 4.0 and hosted along with the web based crop simulation model web InfoCrop Wheat at http://InfoCrop.iari.res.in. The users after registration, have the right to insert, edit or update and delete data within their private domains. Based on the information about the cultivar, location, soil, weather and management conditions specified by the user, the DSS runs the InfoCrop wheat model and identifies the best sowing date as a function of yield output from the crop simulation runs. The goodness of fitting performed by comparing the observed and simulated best sowing date for a particular location, the relative RMSE values were within the good 10–15% range, percent BIAS (PBIAS) ranged between 11.6% and 7.6%.

6.5.2 Remote Sensing and GIS

6.5.2.1 District scale crop monitoring system

A web enabled Decision Support System (DSS) for near real time crop growth monitoring at district level based on multi-temporal satellite remote sensing data was implemented. Satellite derived weekly Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI) and Daily Rainfall products were generated for crop pixels and averaged in each district for 2015-2016 *Kharif* and *Rabi* seasons. Based on these parameters, regular anomaly indicators of Standardized Precipitation Index (SPI), Temperature Condition Index (TCI day and night) and Crop Condition Index (CCI) were generated for the 579 districts of country. The historical and real-time basic parameters and anomaly indices were archived in a database for each district and made accessible through a web portal http://creams.iari.res.in to all stakeholders for their decision making. The indices could capture the meteorological drought in Maharashtra, Telangana, Karnataka and Uttar Pradesh. The CCI showed poor crop condition in Maharashtra, Madhya Pradesh, Gujarat, Telangana, Karnataka and Uttar Pradesh during *Kharif*.

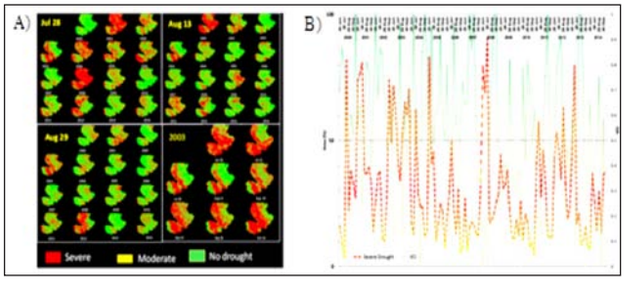
6.5.2.2 Monitoring crop residue burning during October-November 2015

Open crop residue burning in the months of October and November after the harvest of paddy in the states of Punjab and Haryana is prevalent problem. Real time monitoring of residue burning between 18

October and 20-November 2015 using satellite data available from recently established IARI Satellite Ground Station was undertaken. The daily thermal infrared images from MODIS, VIIRS and AVHRR sensors were used to determine a large anomaly in the Land-Surface-Temperature (LST), an indicator of active fire. Fire intensity was also estimated based on the extent of LST anomaly. This system could detect burning event and intensity with high level of accuracy. District-wise total paddy residue burring was estimated and at state-level it was 1316600 ha (47% of paddy area) in Punjab and 237300 ha (20% of paddy area) in Haryana.

6.5.2.3 Remote sensing based agricultural drought monitoring

Remote sensing based agricultural drought monitoring in frequent drought prone regions of Maharashtra, Marathawada region comprised of nine districts (Aurangabad, Ahmednagar, Jalna, Bid, Latur, Osmanabad, Solapur, Satara and Sangli) was conducted using long term time series MODIS NDVI products (16 days MVC) for the period June to October during 2000 to 2014. Vegetation Condition Index (VCI) derived from long term NDVI data was considered for assessing drought severity in terms of severe, moderate and no drought for VCI values less than 0.35, 0.35 to 0.5 and above 0.5, respectively. Spatio-temporal trend of drought severity for the study region was monitored using remote sensing derived drought index VCI. A comparative evaluation of drought severity was done with percentage area (more than 50 %) under severe drought and VCI and revealed similar trend. Results could indicate drought event days and year for a region.



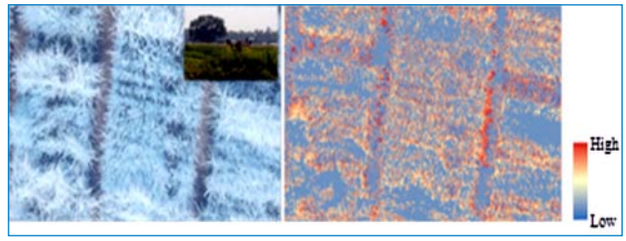
Spatiotemporal variability of drought severity (A) and Drought Severity over the years (B) derived from Remote Sensing based drought index :VCI

6.5.2.4 Nitrogen stress monitoring and weed discrimination using hyperspectral remote sensing in wheat

Field experimentations on wheat crop for monitoring N stress using hyperspectral derived indices during *Rabi* 2014-15 was conducted with varying Nitrogen doses i.e. 30, 60, 90, 120, 150, and 180 kg per ha. Univariate modelling was done using suitable spectral indices for leaf N prediction. VOGa, RI-1dB and RI-2dB showed significant and high r^2 values (~0.65) with estimated tissue nitrogen levels. Spectral observations were taken in wheat experiment with five different weeds with varying population density per m^2 of wheat crop and analyzed for spectral separability. Frequency of statistical difference resulting from one way ANOVA with post-hoc Tukey HSD test (95% significance level, $\alpha = 0.05$) of the mean reflectance of different crop-weed combinations at every band indicated maximum number of weed pairs can be separated, which is at red region followed by SWIR 1 and SWIR 2 regions.

6.5.2.5 Field phenotyping of rice and wheat genotypes using low flying drones

To phenotype rice and wheat crops using unmanned aerial vehicle (Quadcoptor and fixed wing UAV) fixed with visible camera and camera having blue green and NIR bands. These UAVs were used to capture the images of the experimental field of rice and wheat from above at the height of about 10 meter. The NIR image could be used to derive NDVI images.



NIR image captured using UAV and derived NDVI image of rice field with different genotypes

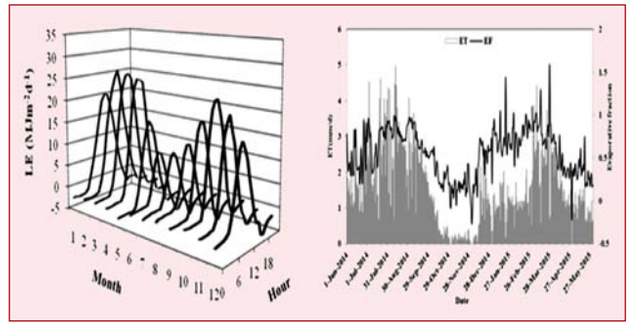
6.5.2.6 Generation of land use/land cover classes over IGP using time-series MODIS EVI product

A study was undertaken to detect the spatio-temporal changes in land use/ land cover with special emphasis on cropland in Indo-Gangetic region (IGP) using MODIS time-series EVI product (MOD13A1) having 500 m spatial resolution. Different land cover classes were generated for three years (2001, 2006 and 2012) using time-series MODIS EVI satellite data.

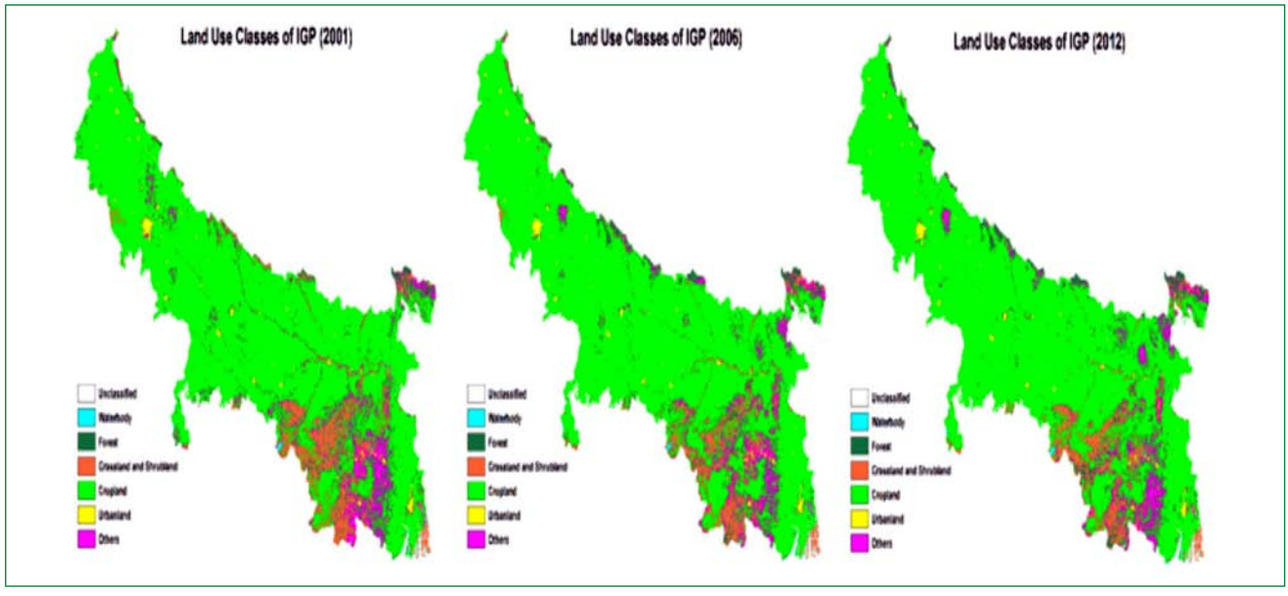
6.5.3 Agricultural Meteorology

6.5.3.1 Surface energy balance of cropland using scintillometery

Energy/heat fluxes over a cropland are important to understand the interaction between the crop surface and atmosphere including practical applications in crop yield prediction and water resources management. A large aperture Scintillometer (LAS) instrument, complemented with an automatic weather station, has been installed in the experimental covering a path length of 990 m of intensively cultivated irrigated agricultural landscape. The diurnal and seasonal patterns of radiation, sensible and latent heat fluxes and evaporative fraction were measured for maize in *Kharif* and wheat in *Rabi* seasons of 2014-15. The biophysical parameters (LAI, soil moisture, crop height) were recorded at a temporal resolution of fortnight basis along the LAS path length at usual sampling distance. LAI had a significant positive correlation with latent heat flux (r = 0.56) and a negative correlation with sensible heat flux (r = -0.63). Soil moisture had a significant negative correlation with sensible heat flux (r = -0.77). The average ET from cropland was 1.58 mm d^{-1} and total ET was 543 mm over the twelve months study period. The Bowen ratio for both *Kharif* and *Rabi* seasons was 0.75 and 0.57, respectively.



Month-wise diurnal variation in latent heat flux and the daily variations in actual evapotranspiration (ET) and evaporative fraction (EF)



Land use/land cover classes over IGP for different periods

6.5.3.2 Agromet advisory services

Agromet advisory bulletins are prepared based on the past and current weather data to forecast weather for the next five days. It is published in Hindi and English on every Tuesday and Friday. The agromet advisory bulletin contains summary of previous week's weather, value added medium range weather forecast information (for the next 5 days) and crop management, and gives advice to farmers in advance regarding rainfall and other weather variables including pest/disease problems, etc., so that farmers can decide on sowing, crop management, application of nutrients, irrigation scheduling, harvesting, etc. During 2015-16, a total of 103 agro-advisory bulletins were prepared in Hindi and English. SMS were sent to the farmers through m-Kisan portal. These advisories are sent to IMD for preparation of national bulletins and uploaded on the IMD website (www.imdagrimet.gov.in) and farmer portal (farmer.gov.in) in both Hindi and English. The bulletins are also sent to ATIC, KVK, Shikohpur, KVK Ujawa, IKSL, NGO, ATMA, State Agriculture, e-choupal, Krishi Darsan, All India Radio and local Hindi newspaper through E-mail for wider dissemination to farmers. These bulletins are also uploaded on the Institute webpage. Feedback received from the farmers from different villages of NCR Delhi showed that agromet advisory bulletin is very useful for various inputs and crop management activities. It helps reduce cost of cultivation, save inputs and increase net profit.

6.6 PHYTOTRONICS

The controlled environmental facilities of the National Phytotron Facility (NPF) was hugely used by scientists and students from IARI and other ICAR institutes including University of Delhi (South Campus) and others to conduct critical experiments related to climate change, transgenic crops, gene expression and regulation, physiology of nutrient use efficiency, plant-pathogen interaction, biochemical and genetic interventions for crop improvement, etc. During this year, 186 new experiments were accommodated along with a few previous on-going experiments. Most of these experiments were conducted by the post-graduate researches (48.39%) for PhD, and scientists for in-house projects of ICAR institutes (47.31%).The paid experiments from external funded projects and non-ICAR institutes were 4.30%. During 2015-16, an amount of ₹ 9,36,172/- was collected at NPF as users' fee. The NPF was visited by a number of domestic and foreign visitors including the delegates from Sweden and Ecuador.

7. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

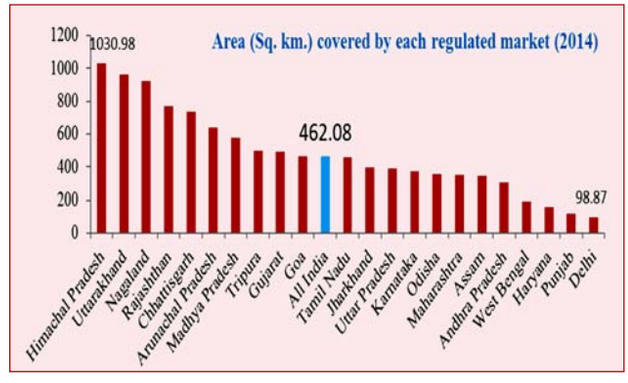
Today, Indian agriculture is capital intensive and is moving towards attaining sustainable growth to feed the fast growing population. At the same time it is earning foreign exchange through exports. Research in the School is focused to address the issue of impact assessment, investment, energy requirement, agricultural markets reforms including e-markets, and changing scenario of trade and innovations in access to credit, etc., in the area of economics. The agricultural extension, technology transfer and assessment programmes are concentrated on demonstration and evaluation of the technology generated, especially the new varieties developed by the institute and also on developing innovative extension models. Research efforts initiated to connect agriculture with nutrition at rural level. Rural women and youth have been trained to take up alternative vocational employment and to become entrepreneurs themselves along with the extension initiatives like information and farm advisory services, on farm testing, trainings, field days, exhibition, feedback mechanism, publication of farm magazines and extension literature. National fair organized at ICAR-IARI, New Delhi and *Mera Gaon Mera Gaurav* programme initiated in the Institute.

7.1 AGRICULTURAL ECONOMICS

7.1.1 Policy Reforms and Development of Agricultural Markets

Market innovations and market reforms were examined across the states and *mandis* in India. Study on agricultural marketing reforms indicated that variation existed in the achievement of progress of agricultural marketing reforms in different states. Tamil Nadu is the state where the APMC act already provides the reforms and on other hand Bihar, Kerala and Manipur have not adopted APMC act. Administrative action is initiated for reforms in Mizoram, Meghalaya, Haryana, J&K, Uttrakhand, West Bengal, Delhi and Uttar Pradesh. In remaining states, reforms to APMC Act have been done for Direct Marketing, Contract Farming and Markets in Private/ Coop Sectors. Data on state-wise details of subsidy released for developing marketing infrastructure indicated that Maharashtra have received the major share (30%) in the total subsidy released, followed by Madhya Pradesh (19 %). Punjab and Andhra Pradesh also received decent share of more than 10 percent. Subsidy share of eastern states like Bihar, Chhattisgarh, Assam and West Bengal was meagre. A total of 4199 cold storage units exist in India with a storage capacity of 15.38 million tonnes. Nearly 90 percent of these are created by private sector. Share of cooperative sector in cold storages is just above 7 percent and that of public sector is 3 per cent. Several alternative marketing forms have been initiated in India as a part of innovations in marketing. Direct marketing by producers, marketing through farmers groups, electronic trading, contract and contact farming are some of them.

Study on the reforms in agricultural marketing suggested that the reforms provide for establishment of private markets/yards, direct purchase centres,



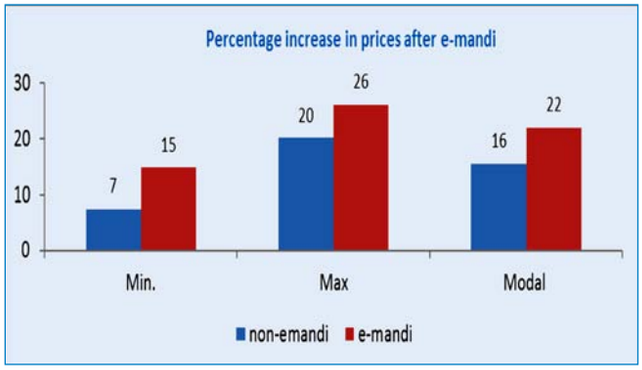
consumer/farmer markets for direct sale, and special markets for commodities in the country. Regulation and promotion of contract-farming and prohibition of commission agency in any transaction of agricultural commodities with the producers are other important features. Out of the total number of agricultural markets in India, only one fourth is regulated. Andhra Pradesh and Maharashtra holds the highest share (12%) in total regulated markets. Bihar, Kerala, Manipur and Mizoram do not have any regulated market since these states have either repealed or not enacted the market regulation act. Share of principal and submarket yards in the total markets regulated are 35 per cent and 65 per cent, respectively.

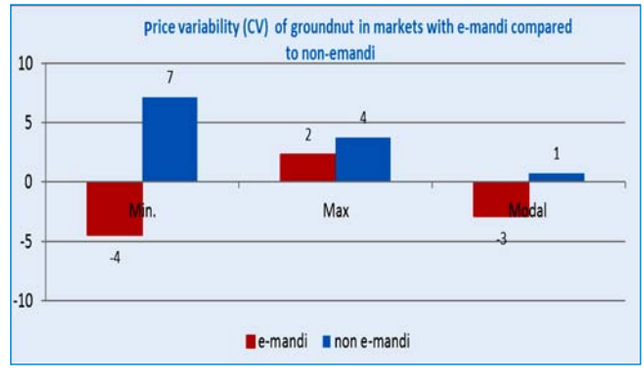
Result of the analysis of the area covered per regulated market in different states indicated that Punjab, West Bengal and Haryana are better in area coverage. Each regulated markets in these states needs to cover a total area of just above 100 sq. km. On the other hand Meghalaya, Arunachal Pradesh and Himachal Pradesh have comparatively low intensity of regulated markets due to which each market needs to serve a total area of about 1000 sq. km.

The analysis revealed that majority of the food processing industries (> 50%) are concentrated in five states (AP, TN, Telangana, Maharashtra and Punjab) in terms of number of factories in operation while, in terms of value of output Maharashtra, UP, Gujarat, TN and Haryana are major states which accounted for about 50 per cent of the value of output. The trend analysis revealed that food processing industry has registered an impressive growth of 11 per cent per annum in terms of value of output during 2001-2013. During the same period, total number of factories raised to 4 per cent and total number of workers employed raised to 3 per cent per annum.

7.1.2 *e-mandi*

Under digital India programme, Government of India is giving much emphasis on connecting each and every APMC market across India through National Agricultural Market (NAM) initiative. This is based on experience of *e-mandis* in Karnataka state. The study evaluated *e-mandis* in Karnataka to draw lessons from it to incorporate in to NAM. The survey was conducted from various stakeholders including farmers, commission agents, traders and administrators regarding performance of *e-mandi*. The modal price in *e-mandi* increased by 22 percent compared to only 16 per cent in non-*e-mandi*. Whereas price variability decreased in *e-mandi* by 3 per cent when compared to increase of 1 per cent for non-*e-mandis*. Farmers' opinion survey revealed that about 90 per cent of the farmers opined that the-mandi has increased the transparency in price discovery and all of them were satisfied with the timely payment for their product (everyday by 2 pm). Majority of the farmers (57 %) expressed that collusion among the traders reduced after introduction of the *e-mandi*. However, about 47 per cent of the farmers informed that they were not very much aware about the *e-mandi* process. The study also examined the various constraints faced by traders. The results indicated that the 45 per cent of the traders fear for taxation which was the major impediments in adoption of *e-mandis*. Access





to the computers by traders either of their own or arrangements by APMC market and slow broadband connectivity was the other major hindering factors for wider adoption. Therefore, it is necessary to provide the computer facilities with power backup and improved broadband connectivity for successful implementation of the *e-mandi*. Also training on use of computers and operation of *e-mandi* to the traders and farmers to increase awareness is the need of the hour.

7.1.3 Impact Assessment of Improved Agricultural Technologies

Impact of IARI wheat varieties. Performance of wheat varieties was evaluated using primary survey data for the year 2014-15 and found that yield gap prevails on farmers field and that observed in demonstration plots. Nearly 90 percent of the farmers adopted HD 2967 variety in Punjab with a mean yield of 5.5 t/ha. The variety HD 2967 has been adopted by almost all the sample farmers of Ludhiana district of Punjab. The farmers have accepted and appreciated the variety. It is reported to be giving higher grain yield, good grain quality, more straw yield and there is less occurrence of diseases. The important feature of the variety are bold grains, good taste and good straw for cattle. The plant does not lodge. There was in general year there was in general more infestation of rust in the reporting year on account of poor weather conditions; however, it is not attributable to this variety. The sources of purchase of seed as reported by the farmers are PAU, Ludhiana (20%), private seed dealers (38%), progressive farmers (17%), and farm saved (25%). The impact analysis of wheat crop showed that the adoption of HD 2967 variety has enhanced the profitability of farmers recording Rs 14000/ ha higher incremental returns over the existing variety. The secondary data analysis to understand the relationship between yield and fertilizer use shows continuous increase in fertilizer use during the period 2000-2012.However,in the recent years there was a decrease in fertilizer use though yield increase sustained. This is primarily on account of varietal introduction especially of IARI variety HD2967.The share IARI varieties in total supply of certified seeds in Punjab and Haryana were found to be 71 per cent and 42 per cent in the year 2014 which increased from 17%and 5% in the year 2011 respectively. The analysis of diversity of IARI wheat varieties in four major states reveals predominance of single variety HD 2967 in Punjab, in Haryana and UP a good mix of the IARI varieties and in Madhya Pradesh prevalence of two IARI varieties, HI 1544 and HI 8498.

Impact of IARI rice varieties. The performance of three IARI rice varieties based on field demonstration data shows that Pusa-44 variety gave an average yield of 4.5 t/ha showing an incremental yield gain of 26 per cent over other varieties. PB-1 variety recorded an increase in average yield of 13-31 per cent over local variety. Pusa 1121 showed an average increase in yield ranging from 10-12percent over other varieties. The analysis of primary data from Ludhiana district of Punjab reveals that non-basmati varieties Pusa 44 and PR 122/121 were adopted by 29.73 and18.92 per cent of farmers, respectively. Pusa1121 (21.62 %) and PB 1509 (29.73 %) were the most adopted variety in sample area of Punjab.

7.1.4 Structural Breaks in Agriculture Growth, Technology and Smallholder's Productivity in India

The Indian economy has progressed steadily with a sustained increase in GDP growth overtime. However, the growth of the agricultural sector during different periods has been distinctly different, and has exhibited structural breaks at certain points of time. In this context, identification of the structural breaks would be helpful in identifying the causative factors that have contributed to the breaks in the structure. By using Pruned Exact Linear Time (PELT) method four structural breaks have been identified in the agricultural GDP for the period of 1960-61 to 2013-14, viz.: i) Phase I: 1960-61 to 1983-84, ii) Phase II: 1983-84 to 1996-97, iii) Phase III: 1996-97 to 2005-06 and iv) Phase IV: 2005-06 to 2012-13. Growth of both the agriculture and allied sectors decelerated during Phase III followed by Phase IV. The fishery sector registered the highest growth during phase II,

indicating that growth became more broad-based. Within the agriculture sector for food grains, the first structural break was identified in 1965 and the second structural break identified in2002. For the total pulses the structural break was found in the year 2000. For the total oilseed crops two structural break points were identified, viz., 1988 and 1999, which indicates the impact of Technology Mission on Oilseeds (TMO) and impact of liberalization.

The study also estimated that total factor productivity (TFP) continues to be the major determinant of agricultural growth. TFP growth for major crops in India was estimated during 1999-2011. As indicated in table, in all the crops, technical change has contributed more to the TFP growth with less impact from efficiency change. Among the major oilseed crops, groundnut and rapeseed/mustard have registered positive changes in the TFP during the post TMO period at national level.

Total factor productivity growth in major crop in India (% per year)

Crop	1999-2000	2000-2011	1999-2011
Rice	3.9	2.3	2.5
Wheat	3.6	2.7	2.9
Maize	-	4.9	4.9
Pigeon pea	1.4	-1.7	-1.2
Chick pea	-5.0	5.1	0.5
Groundnut	-1.6	1.4	0.3
Rapeseed/ mustard	2.0	0.6	0.9
Cotton	-4.6	10.4	3.0

Farm-size productivity analysis for wheat (Punjab, Haryana, UP), sugarcane (UP, Maharashtra) and cotton (AP, Maharashtra, Gujarat) was analyzed by using Cobb–Douglas production function with the help of Plot level summary data under the cost of cultivation scheme, DES, MOA for the period 2010-11. The analysis showed positive relationship between crop area and productivity in wheat and sugarcane and negative relationship was observed for cotton. Efficiencies estimation using Data Envelope Analysis showed that there were inefficiencies in the wheat production as technical, allocative and economic efficiencies were estimated as 0.73, 0.72 and 0.53 in Haryana and 0.76, 0.80 and 0.61 in Punjab, respectively. It is important to note that inefficiencies in wheat production were found to be higher on marginal and small farms as compared to large farms. Thus, farm-size productivity analysis revealed mixed relationship under different crops.

7.2 AGRICULTURAL EXTENSION

7.2.1 Development of Innovative Agricultural Extension Models

IARI Post Office Linkage Extension Model (IPOLEM) has been designed and validated for effective outreach mechanism for frontline extension system. This model has expanded in partnership with the *Krishi Vigyan Kendras* (KVKs) in sixty districts of 14 states covering more than 175 branch post offices. The model was found to be effective in dissemination of farm information to the remotely located farmers. The model has been successful means for making improved agricultural technologies available in the rural areas in relatively lesser time and cost. Capacity building interventions were organized by the KVKs for branch post masters and farmers helped them in knowledge empowerment and skill development. Interaction with the partner KVKs were organized at Zonal KVK Workshop organized by ATARI, Zone VII, Jabalpur and KVK, Ujjain during September 9-11, 2015.

During *Kharif* 2015-16, seeds of 5.5 t paddy (PB 1121, PB 1509, P 2511, P 44, P 1612), 40 kg maize (PC 3) and vegetables including 167 kg bottle gourd (Pusa Naveen) and 14 kg okra (Pusa A4) were sent to the farmers and branch post masters for result demonstration. In *Rabi* 2015-16, 6.3 t wheat seeds (HD 3086, HD 2967, HD 2733, HD 2985, HD 2932 and HD 2851), 1.08 t mustard seeds (Pusa Mustard 26 and Pusa Mustard 28), were sent to the post masters and KVKs in the project locations. Two hundred kg seed of mungbean (Pusa Vishal) were also sent to the project locations during 2016 spring/summer season.

IARI varieties reaching farmers through post office model

The performance of IARI varieties was assessed during the year 2015-16. IARI variety Pusa 1509 was not preferred by majority of the farmers in Uttrakhand, Haryana and Western Uttar Pradesh due to low market price. Performance of Pusa 44 was better (about 12%) compared to the prevailing variety (Saryu 52, MTU 7029). Performance of fine grained rice (Pusa 2511) was better than local fine grained (Indrasan, Gobindobhog and Sambha Mansoori). Pusa 2511 performed well (17% yield advantage) in West Bengal, M.P. and U.P. Farmers preferred the variety for shorter duration and less water requirement. But the variety fetched low market price as reported by the farmers of Sheopur (M.P.). The wheat variety HD 2967 performed well with an average yield of 5.5 t/ha. HD 2967 was preferred by farmers across project locations for more yield and grain size. HD 2733 and HD 3086 were less affected by hail storm. Pusa Mustard 26 and 28 were preferred by the farmers for yield and high oil content (~40%). Pusa Mustard 26 was preferred by the farmers because of its short duration (107 days). The B:C ratio of Pusa Mustard 26 was recorded as high as 1:4.78. Horizontal diffusion of IARI varieties through multiplication in demonstrations has been estimated to cover 1088 ha, 1400 ha, 3020 ha area in wheat, paddy and mustard, respectively, during 2015-16.

In order to disseminate technologies other than improved varieties, demonstration on bio-fertilizers and Pusa Hydrogel were also conducted under the project in *Kharif* 2015-16. Hydrogel application saved 1-2 irrigations in wheat, mustard and maize. Demonstrations on BGA and liquid zinc resulted 5-7 percent yield increase over the farmer's practice of not using bio-fertilizer. Similarly in *Rabi* 2015-16, demonstrations on liquid Azotobacter (6 l) and Pusa Hydrogel (115 kg) were conducted in wheat, mustard, chickpea, lentil and vegetables like tomato, cabbage, cauliflower, etc. in 22 districts of 8 states.

Extension strategy for climate change adaptation. Vulnerability analysis of communities in coastal area of Sunderbans undertaken with randomly selected 50 households revealed a high degree of livelihood vulnerability (Livelihood Vulnerability Index <0.163). It was observed that vulnerability was not only due to high exposure to natural calamities, but also due to poor status of financial assets and physical assets among the communities. Analysis of adaptation strategy revealed that none of the farmers had adopted crop insurance, while a majority of the households had adopted crop diversification (55%), change in cropping sequence (67%), diversification in income generation activities (67%), and increase in height of bunds (67%) as adaptation strategy. Mixed cropping and shift to shrimp cultivation were adopted by a few of the households (8%). Lack of resources (Garret score 40), lack of extension support (Garret score 38.74), and lack of knowledge on advanced technologies (Garret score 37.5) and infrastructure (Garret score 32) were identified as the major barriers.

Community based action and social learning strategy were deployed to promote technologies for climate change adaptation in experimental village Sanghel of Mewat district and village Mumtajpur of Gurgaon district in Haryana. In an experimentation on direct seeded rice technology a group of 30 farmers under social learning system expressed highly significant (P<0.01) difference in areas of detailed understanding about technology, decreased perceived risk of technology, lesser time in learning and reduction in decision making time as compared to the farmers under individual learning system.

Action research was initiated for devising institutional mechanism for climate change adaptation in coastal village Achutdaspur, Jagatsinghpur in Odisha. A group of climate smart farmers was formed and registered as '*Maa Kuttam Chandi Krushak Committee'*, Achutdaspur, Jagatsinghpur (Odisha). To promote the varieties suitable for deep water (CR Dhan 500, CR Dhan 505, Jayanti Dhan, and Jalamani) and for salt tolerance (Luna Sampad, Luna Barial, Luna Subarna) a concept of village seed bank was initiated with the committee members. Field demonstrations in 0.20 acres were laid out for each variety. Linkage was established with KVK, Jagatsinghpur (OUAT), ICAR-NRRI, Cuttack, NABARD, and State Agricultural Department.

ICT based extension model. An action research was conducted to assess the impact of mobile phone based farm advisory using Direct to Farm service of CABI. Bihar state was randomly selected. A baseline survey of villages in Vaishali district of Bihar state was conducted to assess the current status of knowledge and adoption of improved rice package of practices and usage of mobile phone based agro-advisory. The farmers entirely depended upon input agency or salesman for nutrient, pest and weed management. The relative importance of the messages desired by the farmers at various crop stages was also identified through PRA. Tillering and flowering were identified as the most important growth stages where advisory was most required. Content for rice package of practices was developed by a team of IARI scientists and delivered to the rice farmers in the project village in Bihar as voice message through collaboration with CABI India, New Delhi. A total of 28 voice messages were delivered to the farmers in experimental villages during *Kharif* 2015.

7.2.2 Maximising Farm Profitability through Entrepreneurship Development and Farmer Led Innovations (FLI)

India having diverse climatic conditions and other resources is a leading producer in most of food products, but these are subjected to very low level of processing and low value addition Cumulative wastage is also very high. Developing farmers' competencies in secondary agriculture, value addition, specialty agriculture and farmer led innovations need to be promoted. It was found that increasing urban demand, avoiding distress sale and available marketable surplus were found to be the factors impacting the marketing decisions. Primary and secondary value addition, seed production, protected cultivation of vegetables and flowers, dairying and fruit production and primary processing were prioritized as promising agri- ventures based on SWOT and Micro-screening exercises conducted in seven villages in Haryana, M.P. and H.P. Focus group discussions for mobilizing for agri-enterprise uptake were conducted and establishment of self help groups and farmer interest groups were facilitated. Three case studies of farmer innovators showed that the Farmer Led Innovations were mostly reconfiguration of existing resources giving incremental adjustments. Three types of marketing channels were identified and it was found that processors passing even through longest chain received higher share in consumer price than producer in almost all agricultural enterprises.

Factors favoring decision for secondary agriculture

Factors	Rank
Increasing demand in urban areas	I
To avoid distress sale	II
Marketed and marketable surplus availability	III
Price of value added product	IV
High market margin obtained	V
To minimize wastage	VI
Transportation facilities to market	VII
Skilled labour availability	VIII
Changing consumer needs	IX
Consumer satisfaction and loyalty	X
Competition from the market	XI
Rising disposable income in hand	XII
Branding and new look of products	XIII

Two types of forward linkages in FLIs were identified. The first was Production comprising variety and strain, cultivation practices, yield, cost of production. The second was Marketing comprising marketing costs due to transport, loading/ unloading, commission, packing, market entry fees, grading, Fair Price, Price fixation on quality and Influence of price of competitive crops. The analysis of backward linkage matrix showed that presence of governmental development bodies at field level was found to be minimal.

An interaction meet of IARI- Farm Innovators was organized where 80 farm innovators and marketing agencies interacted with the researchers of various disciplines. A *Whatsapp* group of these was created as a platform using social media for sharing of experiences, providing advisory and information on the topic of interest.

Farmer Innovator Interaction Meet at ICAR- IARI, New Delhi

7.2.3 Enhancing Nutrition Security and Gender Empowerment

The dietary habits of people of a region have substantial implications for the quality of life of its population. 'Dietary habit' broadly indicates the types, variety and quality of food intake. In this background, under in house project "Enhancing Nutrition Security and Gender Empowerment" a nutri smart village model was conceptualized and data have been collected from project villages through a structured interview schedule to know the dietary habits. The food consumption pattern, dietary diversity and its determinants of the sample individuals in the selected villages was assessed using the primary data collected during the year 2015–16. The recall was administered to the individual respondents during the above period. Individual Diet Diversity Score (IDDS) based on FAO guidelines (2013) was calculated for all the respondents. It was found that IDDS of male respondents was 8.0, female 7.6, boys 7.9 and girls 7.6 respectively. The results found that IDDS was high for male groups compared to female groups since male groups were consuming more of milk and milk products. Simpson Index of Dietary Diversity (SIDD) was calculated to know the richness and variety of food consumed. It was found that SIDD was 0.76, 0.71, 0.77, 0. 69 for boys, girls, male and female respectively. SIDD scores were a bit more for male groups. This is due to the fact that the intake of food quantity was more in male groups compared to female groups. Nutrition status of men, women and children were calculated using Body Mass Index (BMI). The results show that altogether 18 percent men, 33 percent women, 58 percent girls and 47 percent boys were falling under underweight, severely underweight and very severely underweight category respectively. Knowledge level of men, women and children was calculated. Men and boys had low level of knowledge related to nutrition

compared to women and girls since women were more exposed to *anganwadi* workers under ICDS programme. Women respondents relied for most of the nutrient related information from ICDS followed by *anganwadi* workers and SHGs. Men relied on television for nutrient related information.

Field day on Pusa 30 (mustard) variety of IARI (with <2% erucic acid content) was organized on Feb.27, 2016 at Lehchoura, Baghpat (U.P.) to highlight its health benefit. Scientists-Farmers' interface was organized in project villages. 155 field demonstrations were conducted during *Kharif* and *Rabi*, 2015 on various crops like late sown wheat, mustard, berseem (fodder crop) and vegetables in project villages of Baghpat and Sonepat districts and no. of beneficiaries were 155. Nutrition day awareness campaign was conducted. e-Agri Nutri centre has been conceptualized and the process of establishment has been initiated. Multi stakeholders meeting conducted for establishing e-agri nutri centre with connecting Dreams, KVK, Farmers' Group (NABARD) and SHGs. SHG members were mobilized and capacity building of SHGs regarding nutrition is being done. Exposure visit of 150 farmers and farm women from project villages of Baghpat and Sonepat districts to IARI was conducted during National Agricultural Fair, 2016. On farm trainings on nutri kitchen garden kit to farmers from project villages were given.

7.2.4 Ensuring Sustainable Agricultural Development and Livelihood Security in Lower Shivalik Range of Uttrakhand (DST)

The project aims to provide S&T solutions to address issues/problems of community of Shivalik region thereby enhancing the quality of life. The project is being implemented in Roorkee, Laksar and Narsan blocks of Haridwar district, Uttarakhand since October 2015. Twelve villages were identified (Tanshipur, Imlikhera, Paniwala and Hireheri of Roorkee block, Alawalpor, Bhikkampor, Kabulpuri and Rampur Raighati of Laksar block, and Basawankheri, Sadauli, Kumrari, and Thoi of Narsan block).

A pilot study of the project area has been undertaken and the problems identified were: low yield of crops, viz., paddy, mustard, wheat, maize, mungbean, etc., (yield of major crops including paddy, wheat and maize was very low compared to national average); low productivity of vegetables; and post-harvest losses and poor value addition of agricultural produce.

In order to address the identified problems technological interventions were designed for *rabi* 2015-16 season. On-farm demonstrations on improved IARI wheat varieties HD 2967 (11) and HD 3086 (22) were laid out. Vegetable demonstrations for summer 2016 season on bottle gourd (Pusa Naveen) (38) were also laid out in Narsan and Laksar blocks. Benchmark survey data was collected from the farmers in the project location and analyzed.

7.2.5 *Mera Gaon Mera Gaurav* (MGMA)

The Indian Council of Agricultural Research (ICAR) has initiated innovative intervention named "*Mera Gaon Mera Gaurav*" to promote the direct interface of scientists with the farmers to hasten the lab to land process. The objective of this scheme is to provide farmers with required information, knowledge and advisories on regular basis by adopting villages. Under this scheme scientists will select villages as per their convenience and will remain in touch with the selected villages and provide information to the farmers on technical and other related aspects in a time frame through personal visits or on telephone. ICAR-IARI also implemented the scheme by adopting villages in 50 to 100 km. radius around the institute. A total 115 teams of multidisciplinary scientists of ICAR-IARI and ICAR-IASRI have been formed to work in 115 clusters of five villages each, i.e., covering 575 villages in NCR and nearby districts. One contact farmer from each village cluster has been identified so that they will help our scientists in carrying out farmers-scientist interface. The teams started visiting the allotted clusters and baseline information for the village clusters has been documented. Demonstrations on late sown variety of wheat (HD 3059) were organized in the clusters after harvest of sugarcane.

Hon'ble Minister of State for Agriculture and Farmars Welfare Dr. Sanjeev Kumar Balyan during launching programme of MGMG by ICAR-IARI

A sensitization workshop, chaired by Dr. T. Mohapatra, then Director, ICAR-IARI, in presence of Dr. J. P. Sharma, Joint Director (Extension) and Dr. Indra Mani Mishra, Nodal Officer of *Mera Gaon Mera Gaurav* was held at B. P. Pal Auditorium, CAR-IARI on November 6, 2015, where, about 300 scientists of ICAR-IARI and ICAR-IASRI were briefed about the goal of the programme and detailed methodology of implementing the programme. ICAR-IARI New Delhi organized Field Day on improved technologies on crop varieties, production, protection and post-harvest technologies and launched '*Mera Gaon Mera Gaurav*' at Kakda village, Muzaffarnagar, Uttar Pradesh on December 20, 2015. Dr. Sanjeev Kumar Balyan, Hon'ble Minister of State, Ministry of Agriculture and Farmers Welfare was the Chief Guest and Dr. J. S. Sandhu, DDG (Crop Science), ICAR was the Guest of Honour of the event.

Director, ICAR-IARI welcoming the Guests and the farmers at the laungh of MGMA

7.3 TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Outscaling Agricultural Innovations for Enhancing Farm Income and Employment

The project is in operation in four villages, namely, Khajurka (Palwal, Haryana), Kuthbi (Muzaffarnagar, U.P), Rajpur (Aligarh, U.P) and Beenjpur (Alwar, Rajasthan). Based on agro-eco-system analysis of the project area, 11 varieties of wheat, spinach, pea, lentil and mustard were assessed during *Rabi* 2014-15 through 158 trials on farmers' fields covering an area of 56.10 ha. In village Rajpur, wheat variety HD 3086 gave an average yield of 4.1 t/ha which was 36.67 per cent higher than the local check; PBW 343 (3.2 t/ha) and resulted in B:C ratio of 1.55. Good tillering, bold grain, high yield, less lodging, less damage on grain quality was observed irrespective of heavy rainfall during grain maturation period. HD 2967 was affected due to Karnal Bunt in Kutbi (Muzaffarnagar). Pea variety Pusa Pragati, in Khajurka, performed very well (yield 10.63 t/ha.) having solid, long, dark green pods, with

high sweetness and good marketability. The crop was a new introduction in the area. Lentil variety L 4147 was well accepted for its taste, gave an average yield of 1.22 t/ha.

During *Kharif* 2015, in all 467 assessment trails were conducted on paddy, maize, sorghum, pearl millet, pigeon pea, cowpea, moong, bottlegaurd, *bhindi* and muskmelon covering an area of 186.18 ha. Highest yield of Pusa 1612 i.e. 5.85 t/ha was recorded at farmers field followed by Pusa 1460 (5.36 t/ha), Pusa 1401 (5.20 t/ha), Pusa Basmati 1 (5.10 t/ha), Pusa Basmati 1509 (4.55t/ha) and Pusa 1121 (4.42 t/ha). However, a majority of the farmers preferred Pusa Basmati 1 and improved Pusa Basmati 1 (Pusa Basmati 1460). In village Khajurka, yield of all paddy varieties was affected due to lodging caused by heavy rains and storm in first week of October. Although among *basmati* varieties, Pusa Basmati 1509 gave highest yield 5.05 t/ha but economic returns were less as compared to Pusa Basmati 1121 and Pusa Basmati 1401 because of low market price. *Azolla* + BGA application in paddy Pusa Basmati 1 could save fertilizer application by 50 per cent i.e., saving of one bag of urea. The grain quality was also good in terms of maturity and weight even after lodging of the crop. The performance of moong variety Pusa Vishal was also good as 18 trails of this variety gave an average yield of 0.76 t/ha, since paddy crop was sown late due to delayed monsoon and farmers could get three cuts. Farmers felt that if this variety is sown in time it may fetch up to 4-5 pickings due to profuse branching and longer period of pod formation. Its grain size is smaller than local check (SML-668) but market price is same. In village Rajpur cowpea and *bhindi* were new introduction. Cowpea variety Pusa Sukomal gave an average yield of 4.13 t/ha and was well accepted by the farmers for its taste and soft texture. All the paddy varieties performed better than local check. Farmers are growing Pusa Basmati 1121 and Pusa Basmati 1 by purchasing seed from the local market and own seed. Farmers could not get good market price from Pusa Basmati 1509. Muskmelon, P Madhuras was also liked by the farmers due to its shape, medium size and green colour. In village Beenjpur, four *bajra* varieties were assessed and they could not perform better that local check (Pro Agro 9444).

Horticultural Interventions

Under horticultural interventions, saplings of IARI mango varieties Pusa Arunima (50 plants), Mallika (50 plants), Pusa Amrapali (50 plants) and Lemon c.v. *Kagzi Kalan* (50 plants) were provided for promoting horticultural crops in village Kutbi. Lemon c.v. *Kagzi Kalan* (30 plants) and Guava c.v. *Punjab Pink* (65 plants) were sown in orchard development at village Rajpur.

7.3.2 Technology Integration and Transfer to Strengthen Farming System

The partnership project is being implemented with selected ICAR Institutes / SAUs/VOs in different parts of the country. Suitable farm production, plant protection and post-harvest technologies and farm enterprises were identified based on participatory analysis and joint consultations for profitable farming system during workshops held at Institute. The technologies were assessed through demonstrations, trainings, field days etc by the partner organizations.

During *Rabi* 2014-15 a total number of 541 demonstrations were conducted covering an area of 127 ha. across 15 locations for 21 varieties of wheat, mustard, lentil, pea, gram, spinach, carrot, tomato and marigold crops in collaboration with ICAR institutes and SAUs. In collaboration with 25 Voluntary Organizations, during Rabi 2014-15, a total of 1279 demonstrations covering an area of 429.37 hectares, for 25 varieties of wheat, mustard, lentil, pea, gram, spinach, carrot, tomato, marigold crops and hydrogel were conducted. Overall adverse effect on yield of *Rabi* crop was observed due to heavy rainfall at the time of maturity and harvesting in all varieties of wheat, lentil and mustard in North India.

7.3.3 Seed Production of Improved Varieties of IARI by Voluntary Organizations or NGOs

Under Seed production programme of improved varieties of wheat, during *Rabi* 2014-15, at Young

Farmers Association of Patiala (YFAP) Rakhra 58 t seed of Wheat, HD 3086 and 25 t of HD 2967 was produced. At Participatory Rural Development Foundation (PRDF) Gorakhpur, seed of wheat HD 3059 (15 t), HD 3043 (10.84 t), HD 2733 (5.6 t), HD 2967 (26.3 t), mustard (Pusa Vijay) 11.8 t and pea (Pusa Pragati) 0.05 t was produced.

During *Kharif* 2015, 28 t of PB 1509, 22 t of P 1612, 66 t of paddy varieties Pusa 44, and 32.9 t of Pusa 1121 were produced at Rakhra.

7.3.4 Front Line Demonstrations on Wheat in Collaboration with IIWBR

During *Rabi* 2014-15, 12 FLDs on wheat at Kheda Kishan village of Aligarh district (UP) were conducted on newly released wheat variety DBW 88 and use of bio-fertilizer (*Azotobacter* + Phosphate Solubilizing Bacteria) in HD 3086 and WH 1105. Yield was affected due to untimely rain in March and April.

7.3.5 National Agricultural Fair "*Krishi Unnati Mela-2016*"

National Agricultural Fair *"Krishi Unnati Mela-*2016" was organized at the campus of ICAR-IARI, New Delhi during March 19-21, 2016 in joint collaboration of DAC&FW, Ministry of Agriculture and Farmers Welfare and Indian Council of Agricultural Research (ICAR). Different ICAR Institutes, State Agricultural Universities, development agencies, leading companies from public and private sector and Voluntary Organizations participated and displayed their technologies and products. Over 1 lakh visitors and 500 public and private exhibitors from across the country participated and gained benefit from the Fair.

Exhibition of improved technologies of agriculture, horticulture, animal husbandry, dairy and fisheries, farm machinery and equipments as well as live demonstrations of varieties and practices were some of the major highlights of the fair. Sale of high yielding seeds and plants was another attraction of the event. The fair was organized in the sprawling Mela Ground of the prestigious Indian Agricultural Research Institute, New Delhi.

Hon'ble Prime Minister of India, Shri Narendra Modi, inaugurated *Krishi Unnati Mela* on March 19, 2016. Hon'ble Prime Minister, in his address, emphasized the important role of rural economy in enhancing and pushing up the national economy which largely depends on agricultural growth. He appreciated the initiative of organizing National Agriculture Fair, which is an effective outreach mechanism to demonstrate new technologies and innovations directly to the farmers. He advised farmers to practice diversified agriculture *i.e.*, regular farming of cereals, fruits, vegetables etc; plantation of tree species for timber on edges of the farms; and animal husbandry which should include dairy, fisheries, poultry and also the profitable bee keeping. He also suggested adoption of organic agriculture and value addition for increasing profitability and income from farming. Stressing the need of effective market linkages for farmers, he elaborated upon the e-market initiative of the government. He further elaborated on some of the recent initiatives of the Government such as Soil Health Card Scheme, *Pradhan Mantri Krishi Sinchai Yojana, Pradhan Mantri Fasal Bima Yojana* and called upon farmers to take full benefits of these schemes which have been launched for welfare of the farming community.

Performance of FLD – IIWBR (Wheat) during *Rabi* 2014-15

Technology	Variety	No.of dem.	Area (ha.)	Yield Demo. Plot (t/ha.)	Av. Yield Check Plot	% increase over check
Newly released Variety	DBW 88	6	3.00	4.13	3.90 (PBW 502 and PBW 550)	5.71
Use of Bio-fertilizer	HD 3086 WH 1105	24	22	4.603.78	4.26 (HD 3086) 3.48 (WH1105)	8.707.03
	Total	12	7.00			

The Prime Minister also launched a Mobile App called *Kisan Suvidha* for providing various farmer friendly services. Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers' Welfare highlighted the major features of the National Agriculture Fair and also appreciated Hon'ble Prime Minister for his keen interest, dedication and involvement in farmers' welfare. Dr. Sanjeev Kumar Balyan, Hon'ble Union Minister of State for Agriculture and Farmers' Welfare, delivered welcome address. Shri Mohanbhai Kundariya, Hon'ble Union Minister of State for Agriculture and Farmers' Welfare proposed the vote of thanks. Hon'ble Chief Ministers of Chhattisgarh, Haryana, Rajasthan and Meghalaya and Agriculture Minister of Madhya Pradesh and Secretary, DAC&FW were the other dignitaries present on the dais.

During three day *mela*, nine technical sessions were organized on important themes *viz*., PM *Fasal Beema Yojana*, PM *Krishi Sinchai Yojana*, Integrated Farming System (Horticulture and Fisheries), Agricultural Marketing, Integrated Farming System (Crop-Livestock), Processing & Value Addition, Increasing Crop Productivity and Enhancing Soil Health and Govt. Schemes related to each of the theme areas. Farmer – Scientist Interaction and Interaction with Innovative Farmers were also one of the major attractions and received huge participation of the farmers visiting the *Mela*.

On concluding day, Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers' Welfare delivered the valedictory address and also launched a mobile app called *Pusa Krishi*. Speaking on the occasion he remarked that "The app will work towards fulfilling the call of Hon'ble Prime Minister of India for taking technology from Lab to Land". The app will provide farmers with information related to new varieties of crops, resource conserving practices in crop cultivation as well as farm machinery and implements which will help in increasing returns to farmers.

Hon'ble Ministers of State for Agriculture and Farmers' Welfare, Shri Mohanbhai Kundariya and Dr. Sanjeev Kumar Balyan graced the occasion along with other senior officials of the Ministry. Five farmers were bestowed with IARI Fellow Award and 39 farmers were conferred with Innovative Farmers' Award in recognition of their outstanding contribution in agricultural innovations, technology development and dissemination in partnership with IARI.

A farm-woman receiving *Krishi Karman* Award from Hon'ble Prime Minister of India, Shri Narendra Modi in *"Krishi Unnati Mela*-2016"

7.3.6 Off-campus Exhibitions

- Horti fair *Sangam* 2015 at Barahi, Hazaribagh, Jharkhand from 27-28 June, 2015.
- Agri-Exhibition and *Kisan Goshthi*, organized in collaboration with 'Uttarakhand Jan Vikas Manch', Dehradun at district Udham Singh Nagar, Uttarakhandh on June 22, 2015.
- Two days Exhibition and kisan goshthi organized by ICAR from August 20 to 21, 2015, at Seema Suraksha Bal ground, Dipra Kothi, Motihari, Bihar on the occasion of laying of foundation stone of NRC on Integrated Farming System.
- "Agri-Tech world: International exhibition on Agriculture and Horticulture" from October 7 to 9, 2015 along with IARI regional Station, Karnal and IIWBR, Karnal.
- Agricultural Exhibition during Rabi Kisan Sammelan in Delhi on October 17, 2015 at Ravi Patwari Dharmashala, Daulatpur, Nazafgarh, New Delhi.
- "International trade fare at Pragati maidan from November 14 to 27, 2015.
- Demonstrated IARI technologies on the occasion of Field day and inaugural ceremony of Mera Gaon Mera Gaurav programme of IARI on December 20, 2015 at village Kakda, Block Shahpur, Muzaffarnagar, Uttar Pradesh.
- "Smart Horticulture, 2016" exhibition (February 12-13, 2016), displayed IARI technologies at Bhubaneswar, Odisha.
- *Kisan mela* organized by Young Farmers Association, Rakhra, Patiala on March 12, 2016.
- Exhibition during organization of "International Year of Pulses" at ICAR-IIPR, Kanpur on March13, 2016.

7.3.7 Agricultural Technology Information Centre (ATIC)

ATIC provided Pusa products, services, technologies and information services to the different stakeholders through a 'Single Window Delivery System'. Besides farm advisory services at ATIC, farmers are given farm advice through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600), Pusa Agricom (1800-11- 8989), exhibitions, farm literatures and letters. A second level of *Kisan Call Centre* (1800-180-1551) was also established at ATIC problems/queries of farmers of Delhi state. Information & advisory needs of the visitors are also being catered through touch panel *kiosks*, revolving scrollers, laminated posters information museum, plant clinic, farm library and exhibits related to agriculture implements, seed samples, bio-fertilizers displayed at the centre.

Live demonstrations were laid out at ATIC on *kharif* Paddy varieties Pusa Basmati 1, Pusa Basmati 1121, Pusa Sugandh 5, Pusa Basmati 1401, Pusa Basmati 1509, maize var. Pusa Composite 3, Pusa Composite 4, Moong var. Pusa Vishal. In *rabi* live demonstrations of wheat varieties: HD -2733, HD 3086, HD 2851, HD 2967, HD 2894, HD 2932 and HD 3059; mustard varieties Pusa Vijay and Pusa Mustard 26, Vegetables: In summer season: pumpkin var. Pusa Vishwas, okra var. Pusa A 4, *lobia* (Cowpea) var. Pusa Sukomal, cucumber var. Japanese Long Green, onion var. Pusa Red, *bathua* var. Pusa Bathua -1, sponge gourd var. Pusa Sneha, brinjal var. Pusa Uttam, bottle gourd var. Pusa Naveen, *palak* var. Pusa Harit, chilli Var. Pusa sadabahar, tomato var. Pusa gaurav, *Amaranthus*, var. Pusa Kiran. In winter season cauliflower var. Pusa Hybrid 2, Broccoli var. KTS 1, Radish var. Hybrid 1, beet var. Crimson Globe, *knol khol* var. W. Vienna, Tomato var. Pusa Rohini, *methi* var. PEB, Methi Pusa Kasuri. Among flowers, five varieties of *Gladiolus,* viz., Shabnam, Sinayana, Srijan, Kiran and Cidushi and one variety of marigold var. Pusa Narangi Gainda demonstrations were laid out. Medicinal Garden, Nutrition garden and fruit orchard were also maintained.

Drip irrigation system was demonstrated for fruit orchard and nutri-garden was demonstrated in crop *cafeteria* for the benefit of the visitors. High density fruit trees orchard planted with lemon (Kagzi Kalan),

mango (Amrapali), guava (Lucknow-49, Allahabad *Safeda* and Lalit), *ber* (Banarasi Karaka and Gola) have been grown in current season. For awareness of farmers herbal block has been developed in crop cafeteria which includes medicinal plants of Aloevera, *Ashwagandha, Satavar, Coleus, Giloe, Mushkdana, Sadabahar, Mint, Tulsi (Basil), Lemon grass, Java citronella,* etc.

New initiatives at ATIC

- Drip irrigation system was installed in ATIC crop cafeteria for demonstrating water saving technology to the visiting farmers.
- ATIC conference hall was strengthened for facilitating interaction of farmers with experts.
- Touch Panel Kiosks to access latest IARI technology through computer for visitors were installed in the corridor of ATIC building.
- LED posters having farmer friendly information about the IARI technologies were fixed in the ATIC training hall.

A total number of 39,655 farmers/entrepreneurs, development department officials, students, NGO representatives *etc*., from 17 states of India visited ATIC during the year for farm advisory, diagnostic services, purchase of technological inputs/ products and trainings. A majority of the farmers (85%) visited ATIC to purchase / enquire seeds / varieties and farm publication and others (15%) for agro-advisory services. A majority of them were from Uttar Pradesh (29%) followed by Haryana (22%), Rajasthan (13%), Delhi (12%), Punjab (7%) and others (17%). Besides, 12,273 farmers from 20 states were able to get information on various aspects of agriculture through Pusa *Agricom* (A toll free Help Number-1800-11-8989) Pusa Help-line(011-25841670, 25841039,25846233, 25803600) and Kisan Call Centre 1800-180-1551 (IInd level). Pusa seeds of worth Rs. 73,24,980/**-** and farm publication for Rs. 1,98,840/- have been sold 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 500 farmers and others got farm advisory services through letters/e-mails during the period. The demands of IARI products, technology and services are increasing day by day in the market. Besides farmers, industry has shown a lot of interest in IARI research products. ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators. The feedback strengthened the ATIC activities and provides a ground for need based technologies. The ATIC has also developed functional linkages with various agencies working for the farming community to effectively cater to the information needs of the different stake holders.

Delegates from Ethiopia visiting ATIC

Farmers and farm women from Gujarat visiting ATIC

Pusa Helpline

7.3.8 *Krishi Vigyan Kendra,* Shikohpur, Gurgaon (Haryana)

7.3.8.1 On- farm testing

This activity is mainly focused to test developed technologies which might be helpful to solve the most important and widely spread problems of the groups of farmers in a defined area with their farming system and active participation and management. The major objective of the programme is to provide tailor-made recommendations to the farmers by testing the location specific technologies to solve their field problems.

During the period, 09 On-farm trials were conducted on different field/farm based problems including 2 trials on animal based problems. Details of major field problems based OFTs are given in the following table.

On-farm trails, organized in the farmer's fields

Sl. No.	Name of the On-Farm Testing	No. of Trials
1.	Integrated Nutrient Management (INM) in Wheat	03
2.	Integrated Weed Management (IWM) in Wheat	03
3.	Management of Diamond back moth (DBM) in cauliflower	03
4.	Management of Fusarium wilt in Summer Squash (Chappan Kaddu)	03
5.	Drudgery reduction in farm women (Use of revolving stool during mulching operation)	03
6.	Efficacy of microwave roasting in soybean to improve its digestibility, protein bioavailability and sensory characteristics	03
7.	Management of Nematode in Summer Squash (Chappan Kaddu)	03
8.	Reproductive performance in buffalo	03 (30 Animals)
9.	Evaluation of different drugs on control of ecto-parasites in animals	03 (30Animals)
	Total	**27**

7.3.8.2 Front line demonstrations (FLDs)

FLDs on oilseeds, pulses and cereal crops are playing a key role in transfer and dissemination of the location specific crop technologies in the area. During the period, 250 demonstrations covering 101.80 ha on oilseeds, pulses, cereals and vegetable crops under different schemes were organized.

Results of FLDs organized at the farmers' fields during *Rabi* 2015-16

Name of Programme/ Scheme	Crop	Variety	No of demo	Area (Ha.)	Yield kg/ha				Increasein yield%	B:C ratio
					Demonstrations			Local		
					Max.	Min.	Avg.	Avg.		
FLDs on pulses, cereals and vegetables (Under KVK Scheme)	Mustard	Pusa Vijay	50	20.00	1640	1070	1285	1135 (Krishna)	13.21	2.35
	Wheat	HD-2967	20	8.00	4475	3285	4160	3540 (WH-283)	17.51	3.26
		VL-829	04	0.80	3025	2760	2950 G. Fodder 16500	—	—	3.37
	Barley	BH-393	12	4.80	4385	3415	3825	3355 (BH-902)	14.00	3.38
	Gram	Pusa -372	13	4.00	1245	970	1145	1015 (HC-1)	12.80	2.12
	Carrot	Pusa Rudhira	05	2.00	32600	23800	25350	21500 (Surbhi)	17.91	6.88
	Garden Pea	Arkel	15	6.00	8620	6385	8435	7740 (Jawahar-2)	8.98	4.67
		Total	**119**	**45.60**	—	—	—	—	—	—

Results of FLDs organized at the farmers' field during *Kharif* 2015

Name of Programme/ Scheme	Crop	Variety	No of Demo	Area (Ha)	Yield kg/ha				Increasein yield%	B:C ratio
					Demonstrations			Local		
					Max.	Min.	Avg.	Avg.		
FLDs under KVK scheme	Paddy	PB-1509	28	12.00	4720	3540	4325	3760 (PB-1)	15.03	1.89
	Paddy	CR36	04	1.60	3960	3285	3870	3760 (PB-1)	2.93	1.69
	Pigeon pea	Pusa-992	28	12.00	1875	1640	1735	1560 (Manak)	11.22	6.60
	Moong	Pusa Vishal	05	1.60	805	580	765	New introduction	—	2.96
		MH-421	12	4.80	876	615	835	—	—	3.12
		Total	**77**	**32**	—	—	—	—	—	—
	Vegetables :									
	Bottle gourd	P. Naveen	12	2.00	31275	29425	30225	27640 (Kirti)	9.35	6.25
	Cauliflower	P. Meghna	05	2.00	10485	9430	10320	9535 (Kuwari)	8.23	7.29
		Total	**17**	**4.00**	—	—	—	—	—	—
FLDs under AICRP project	Pearl-millet	Pro-agro -9444	17	10.00	3150	2430	2776	2252	23.27	4.66
	Grand Total	**111**	**46.00**	—	—	—	—	—	—	

7.3.8.3 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies among the farming community the KVK celebrated/organized various extension activities in the villages and at KVK campus. During the period under report 1290 such activities were organized. Details of the extension activities organized during 2015-16 are given in the following table.

Extension activities organized during 2015-16

Sl. No.	Name of the programme	No. of programmes	No. of participants
1.	Field days	19	740
2.	World Food Day	01	55
3.	Women in agriculture day	01	40
4.	Honey day	01	54
5.	Farmers visit at KVK for FAS	—	1446
6.	Field visit of SMSs in farmer's fields	147	3432
7.	Farm Advisory service on telephone	—	3352
8.	Radio & TV talk	21	—
9.	Lectures delivered by SMS of KVK in farmers trainings/ meetings organized by line department/ NGOs	25	4147
10	Method demonstrations	36	166
11.	Kisan Gosthi	01	53
12.	Group meetings/discussions	24	310
13.	Popular articles	03	—
14.	Camp /campaign (Agriculture)	25	1369
15.	Camp /campaign (Animal)	02	352 animals diagnosed and treated
16.	News letter (quarterly)	04	500 copies of each issue were distributed to the farmers
17.	Diagnostic service (Animal) at KVK	12	33 Milk and fecal samples analyzed
18.	Soil & water samples analyzed	1754	1508 (Soil samples) 246 (Water samples)
19.	Exhibitions	03	—
20.	Press releases	21	—
21.	SMSs sent to the farmers through *Kisan* mobile services	43	Sent to 1128 Farmers of the district
	Total	**2143**	—

7.3.9 Transfer of Technologies through IARI Regional Stations

7.3.9.1 Regional Station, Karnal (Haryana)

Seed village programme sponsored by DAC & FW, Ministry of Agriculture and Farmers Welfare, and GOI was continued during *Kharif* 2015 and *Rabi* 2015-16 for farmer-to-farmer horizontal spread of seeds of popular varieties of different crops. In *Kharif* 2015, 38.4 ha area was undertaken for paddy CV PB1509, in *Rabi* 2015-16, 30.0 ha area was taken under wheat HD 3086 and 8.0ha area under *berseem* seed production for increasing the availability of quality seeds in their villages itself. Under Seed Village Programme, resource poor farmers and women farmers were given training at the station as well as at farmer's field on various aspects of quality seed production.

Farmers' meeting. Two farmers' meetings were organized in Village Churni on June 20, 2015 and Badshapur on June 22, 2015 for 'Agro Advisory' to farmers for deficit rain fall during *Kharif* 2015, in which more than hundred farmers and farm women participated.

Beej bikri diwas. A *Beej bikri diwas* was organized on March 22, 2016. *Pusa Beej* of popular varieties of *Basmati* paddy viz., PB 1509, PB 1121 and non-*Basmati* variety Pusa 44 of worth Rs. 22,75,950/- was sold to hundreds of farmers from Haryana, Punjab and Western Uttar Pradesh.

Off campus exhibitions/melas. Station participated in the following *Krishi Mela*-cum-Exhibitions to display the technologies, products and publications of the institute. Stalls exhibited were visited by hundreds of farmers including women farmers. Vegetable kits were also sold to farmers.

- *Krishi Samelan* - cum - Exhibitions at KVK, ICAR-NDRI, Karnal on July 14, 2015.
- *Ganna and Makka Kisan Mela* at CCS HAU RRS, Uchani, Karnal on October 6,2015
- Agri-Tech World: International Exhibition on Agriculture and Horticulture at ICAR-IIW&BR on October 7-9, 2015.
- World Soil Day at KVK, ICAR-NDRI, Karnal on Dec 5,2015
- *Ganna Kisan Mela* at ICAR-SBI, RRS, Karnal on March 3, 2016.
- *Rabi Kisan Mela* at ICAR-CSSRI, Karnal on March 5, 2016.
- Innovative Technology for Onion garlic production and post-harvest management at RRS, Salaru, Karnal on March 9-10, 2016.
- *Pradhan Mantri Phasal Bima Yojana* in ICAR-NDRI, Karnal on March 31, 2016.
- *Mera Gaon Mera Gaurav,* a mega agricultural development programme was launched by ICAR-IARI, Regional Station, Karnal in three clusters of five villages each. Scientists of ICAR-IARI, Regional Station, Karnal visited three clusters separately and interacted with the farmers to improve their productivity by adopting latest scientific interventions. The farmers were provided one page write-up in local language of important agricultural activities to be taken care for different crops.

***'Mera Gaon Mera Gaurav'* programme at village Sirsi, Karnal**

7.3.9.2 Regional Stmation, Indore (MP)

A total of 19 demonstrations of 10 new wheat varieties were conducted in 12.40 ha in 4 villages of Indore and Dhar districts of M.P. using recommended package of practices. Overall average increase in yield was 1.93 t/ha or 63 % in these demonstrations,

compared to 'check' varieties grown with farmers' practices. Best performing varieties were: HD 2987 (Yield- 5.0 t/ha and 108% yield increase over check), DBW110 (Yield- 6.0 t/ha and 100% yield increase over check) and HI 8737 (Yield- 5.6 t/ha and 87% yield increase over check).

7.3.9.3 Regional Station, Pusa (Bihar)

Wheat Front line Demonstrations. To reduce the yield gap between lab-to-land, 14 frontline demonstrations were laid out during the year (2015-16) under report in the village Harpur Bochha (Vidyapati Nagar Block) of Samastipur district of Bihar. The demonstrations conducted with latest variety HD 2967 wheat varieties on the use of bio-fertilizers-*Azatobactor* and PSB (4), zero-tillage technology (4) and new improved wheat variety (6). The performance of different demonstrations conducted was very encouraging. A field day was organized on April 12, 2016 in the village Harpur Bochha (Vidyapati Nagar), the adopted FLD village. About a hundred farmers gathered and participated in the discussions on the performance of the two latest wheat varieties and future plans of diffusion.Frontline demonstrations were also laid out in Mahmadpur village of Muzaffarpur districts of Bihar. The demonstrations were conducted K 1006 and HD 2967 wheat varieties on the use of bio-fertilizers-*Azatobactor* and PSB (4), zero-tillage technology (4) and new improved wheat variety (6).

Varieties (Timely sown):	HD 2967 and K1006
No. of front-line demonstrations:	14
Mean yield:	4,921 and 4.618 (t/ha)
Local check**:**	PBW 343 and HD 2733
Mean yield:	37.14 and 40.34 (qt/ha)
Yield increase:	HD 2967 (21.98 to 28.28 per cent) K 1006 (14.47 to 24.34 per cent)

Outreach Programme. In April 2015, under the IARI Outreach Programme *Kharif, 2015* paddy seed were distributed among nine *KVKs* of Bihar to popularize IARI varieties among the farmers. A paddy trial of three different varieties (Pusa-44, PNR 381 and Pusa Sugandh-5) was given to 270 farmers. The response of farmers was very encouraging for the scented varieties of paddy, especially for Pusa Sugandh- 5. Seed for 30 demonstrations of pigeonpea (var. Pusa-9) was distributed in three districts namely Samastipur, Vaishali and Darbhanga of Bihar. In Rabi, 2015-16 with a goal to popularize IARI Wheat varieties among farmers under the IARI Outreach Programme on "Strengthening of wheat Programme in Eastern India", 540 minikits demonstrations of three timely sown wheat varieties HD-2733, HD-2824 and HD-2967 were laid out in 16 districts of Bihar, one in West Bengal, two in Jharkhand, and two NGOs (*Parivartan, Siwan* and *Gramin Vikash Kendra, Nalanda*). In Soyabean: eighty demonstrations of Soyabean (varieties Pusa 14 and DS 1512) were conducted in Samastipur, Muzaffarpur, Begusarai and East Champaran districts of Bihar.

Minikit wheat demonstration. About 919 minikit demonstrations of nine wheat varieties were laid out in farmers' fields under the close supervision of KVKs in Bihar, Jharkhand and West Bengal in Rabi 2014-15. In Kharif 2015, 270 minikit demonstrations of three varieties of paddy were laid out in farmers' fields in Bihar.

Bihar

Timely sown varieties: HD 2733 (3.384 t/ha) HD 2824 (3.277 t/ha), HD 2967 (3.405 t/ha) CBW 38 (2.907 t/ha) and DPW 621-50 (3.231 t/ha)

Yield increase: 32 to 54 per cent against the state average of 2.206 t/ha

Late sown varieties: HD 2985 (2.816 t/ha), HI 1563 (1.961 t/ha), HW 2045 (2.789 t/ha), and HD 2888 (2.419 t/ha)

Yield increase: 26 to 38 per cent.

West Bengal

Timely sown varieties: HD 2733 (3.624 t/ha), HD 2824 (4.102 t/ha), HD 2967 (3.571 t/ha) and CBW 38 (3.522 t/ha)

Yield increase: -25. to 46 per cent against the state average of 2.8 t/ha

Late sown varieties: HD 2985 (3.394 t/ha), HI 1563 (2.95 t/ha), HW 2045 (3.075 t/ha) and HD 2888 (2.673 t/ha)

Yield increase: 1 to 7 per cent.

Jharkhand

Timely sown varieties: HD 2733 (4.16 t/ha) HD 2824 (3.9 t/ha), HD 2967 (4.18 t/ha) and CBW 38 (3.69 t/ha)

Yield increase: 85 to 127 per cent, against the state average of 1.876 t/ha

Late sown varieties: HD 2985 (3.285 t/ha), HW 2045 (3.1 t/ha) HD 2888 (2.815 t/ha)

Yield increase: 55.56 to 77.78 per cent.

Paddy Demonstrations in *Kharif* 2015

Varieties: Pusa 44 (3.354 t/ha), PNR 381 (2.982 t/ha), and Pusa Sugandha 5 (3.490 t/ha).

Participation in extension activities

- Participation in *Kisan Mela at New IARI Barhi, Hazaribagh, Jharkhand* June 27-28, 2015
- Participated in *Jai Kisan-Jai Vighayan Samaroh (Kisan-Vaighanik Mahasangam)* on December 25, 2015 at Nagar Bhawan, Motihari, East Champaran district, Bihar, organized by IFFCO and ICAR
- Participation in *Krishi Pradarshani Evam Kisan Mela at Parivartan*, Siwan on March 3, 2016
- Participation in *Kisan Mela at IISR Regional center Motipur, Muzaffarpur,* March 5, 2016
- Participation in RAU, *Kisan Mela* on March 5 -7, 2016.

Farmers field day and distribution of mungbean seed minikit at Pusa, Bihar

7.3.9.4 Regional Station, Shimla (HP)

Five front line demonstrations on wheat variety HS 542 and 5 FLD on barley variety BHS 400 were organized in different villages of Himachal Pradesh for popularizing the cultivation of new varieties among the farmers.

Field / farmers' day

- Farmers' field days were organized at Asha Majari and Chalog villages of H.P. Seventy two farmers were educated about new varieties of wheat and barley. Extension folders on wheat and barley were also distributed to them.
- Farmers day organized at Horticultural Research Farm, Dhanda on 18.1.2016 and more than 60 farmers have participated and saplings of different fruit crops viz; apple, pomegranate, kiwi, walnut etc. and extension folders were also distributed.

7.3.9.5 Regional Station, Katrain (Kullu Valley) H.P.

Fifty field demonstrations of the different vegetables had been conducted at the farmer's fields and the varieties/hybrids showed 12-15 percent more yield over check in *Kharif*, 2015. Fifty field demonstrations had been conducted in Rabi 2015-16 and some of crops are in fields. Exhibited different varieties of the vegetables in the Kullu Dussehra from October 22 to 28, 2015 and provided the technical knowledge to the farmers about improved vegetables cultivation practices developed at the station. All the visitors (27 groups of farmers, students, trainees and others) at the station had been attended.

8. EMPOWERMENT AND MAINSTREAMING OF WOMEN

Contribution of rural women to the farm based activities, particularly the animal production and management is widely recognized. They have immense potential to deliver significantly to increase farm output and enhance family income and well-being. Empowerment of rural women through capacity building in farm and non-farm alternative occupations holds a key towards realizing their full potential to realize the intended goals of sustainable food, nutritional and livelihood security. A number of interventions were implemented to address the women empowerment and gender issues for creating awareness about scientific farming, seed production, nutritional security and developing entrepreneurial skills.

8.1 NUTRITION SECURITY THROUGH KITCHEN GARDEN PROGRAMME

Kitchen garden programme *Rabi* 2015-16 for enhancing family nutrition security was in operation in about 56 farm women's families from six villages: Rajpur, Dehuli, Pipri, Misrulia, Dubaha and Naropatti of Sakra block of Muzaffarpur district (Bihar). Farm families were encouraged to grow vegetables in their kitchen gardens. They have grown French beans, cauliflower, carrot, tomato, fenugreek, kasuri methi, mustard *saag*, amaranthus, spinach, peas, and radish. They could get a good supply of vegetables for their home consumption. The farm women were satisfied for their enhanced nutrition levels through the vegetables grown in their own home backyards.

8.2 BIOTECHNOLOGY-LED SOCIO-ECONOMIC EMPOWERMENT OF FARM WOMEN

The project is being implemented in collaboration with two organizations *viz* Deen Dayal Research Institute (DDRI), Chitrakoot and PRDF, Gorakhpur, UP as Non-Government Organization with lead centre at IARI. 22 SHGs of farm women were linked to lead bank of Aligarh district, U.P. where they could save their group contributions. Till March 2016 Rs. 3,62,606/- were saved in the banks. Rural Biotechnological Innovation and Application Unit (RBTIAU) in Karanpur village of Aligarh district, U.P. was established for delivering the farmwomen centered technologies and services. At RBTIAU facilities of a bakery unit, an information kiosk, drudgery reducing implements and tools (wheel hoe) and farm publication are made available. In this centre about 90 capacity building activities, skill and knowledge updation on various issues like mobilization of farm women, SHG process and activities, value addition, seed & safe grain storage, storage grain pests management, seedling raising, nursery raising, use of biopesticide-rhizobium, veterinary camps for livestock health management, household nutrition, crop cultivation methods, fodder production, vegetable production, balanced feed of cattle, management of ecto- and endo-parasites in cattle, deworming in cattle, nutrient management in crops, motivational trainings for entrepreneurship were conducted for farm women. Training on post harvest processing and value addition of fruits and vegetables; preparation of pickles, sauce, *murrabba*; preparation of cookies, bread, bun, cup cakes, and dry flower arrangement to start as enterprise were alos conducted. In all 228 demonstration of *rabi* and *kharif* cereal crops were conducted on the fields to show the yield and economic potential. Backyard nutritional garden was promoted for nutritional sufficiency among farm families. Demonstration of protected cultivation technology (polyhouse and off season vegetable cultivation) were also conduced. Assessment of water quality and suitable crop varieties

i.e., wheat KRL 210, KRL 219, KRL 1-4 and barley as per water quality were demonstrated. Introduction of bio-fertilizers like *Rhizobium* and PSB in moong crop was done. Use of bed planter was also promoted in wheat and cotton crop fields.

8.3 CAPACITY BUILDING OF SHGs FOR GENDER EMPOWERMENT

In the year 2014-15, three Self Help Groups (SHGs) from the different villages were formed. The groups were made to start their own enterprises in three different areas. In 2015-16 the groups have widened their reach and selling their products outside Gurgaon also and have drastically increased their income.

8.3.1 Effectiveness of SHGs in Gender Empowerment

The earnings of SHG women have contributed to their family's income which raised the status of their family in the village. This has ultimately changed the position of women in their family making them able to take part in decision making process. The adoption of entrepreneurial activity by the groups, on one hand helped the women in gaining self-confidence through financial independence and on other hand it has given them recognition in the society by attracting awards and appreciations on district, state and national level. The president of one SHG "Kshitz", Smt. Pooja Sharma has been awarded by Honorable Governor of Haryana, Hon'ble Chief Minister of Haryana and Hon'ble Union Minister of Agriculture & Farmers' Welfare, Shri Radha Mohan Singh in the year 2015-16.

8.3.2 Vocational and Farm Training for Technological Intervention

The KVK, Shikohpur is playing a vital role in empowering rural women of Gurgaon district by organizing various need based self-employment and income generating activities and other extension programmes for creating the awareness about scientific farming and disseminating the technology in wide area. The important programmes and activities organized for rural women during the period (2015-16) are as under: -

Vocational training courses for self-employment and income generation.

- Day longs trainings in villages for updating the farm knowledge/skills.
- Exposure visit of rural women to agriculture fairs and exhibitions.
- Front line demonstration for disseminating improved farm technologies.
- Celebration of "Women in Agriculture Day".
- T.V. talks, advisory services on phone, publication of literature on technical know-how on food processing and dairy management etc.
- Formation of women Self Help Group in villages and motivating them to start their own enterprise and linking them to market.
- In all, 47 programmes were organized through which 564 women of all social classes and income strata were benefited.

The details of income of Self Help Groups

S. No.	Name of SHG	Entrepreneurial activity adopted	Duration	Income generation (Approximate ₹)
1.	Kshitiz	Soy nut, processed soya and pearl-millet flower, pearl-millet *dalia*, maize *dalia* & flour, pearl-millet biscuits, *laddoo* and other savory snacks from soy bean and pearl-millet.	02 Years 06 Months	4,00,000/-
2.	Arzoo	Spices	02 Years 06 Months	16,00,000/-
3.	Prayas	Preserved products of seasonal fruits and vegetables	02 Years	1,50,000/-

A vocational training on "Dress Designing and Tailoring"

A vocational training on "Kitchen Garden"

Activity wise participation of rural women during 2015-16

S. No.	Activity	Duration	No. of programmes/ activities	Number of beneficiaries
A	**Vocational Trainings**			
1.	Establishment of Nutri-farm	1 week	02	30
2.	Dress designing and tailoring	45 days	02	50
3.	Value addition on soybean and pearl-millet	1 week	02	34
4.	Preservation of seasonal fruits and vegetables	1 week	02	21
5.	Participation in other vocational trainings organized	1 week	03	20
	Total	—	**11**	**155**
B	**Agricultural extension and farm advisory**			
1.	Day long trainings (On/off campus)	1 day	21	240
2.	Participation in different field days	1 day	12	117
3.	Celebration of Women in Agriculture day	1 day	01	40
4.	*Kisan Sammelan*	1 day	02	12
	Total		**36**	**409**
	Grand Total (A+B)		47	564

8.4 WOMEN PARTICIPATION IN SEED PRODUCTION

Rural women are playing significant role in agricultural development. Women have proven to be good managers in any kind of activities. Twenty one farm women during *Kharif* 2015 and *Rabi* 2015-16 from different villages of Karnal district, Haryana were selected under seed village scheme. They were given training on various aspects of quality seed production of Paddy cv. Pusa Basmati 1509, Wheat HD 2967/ HD 3086 and *berseem* cv. BL 42. Active participation in the trainings has increased their level of knowledge for quality seed production and storage.

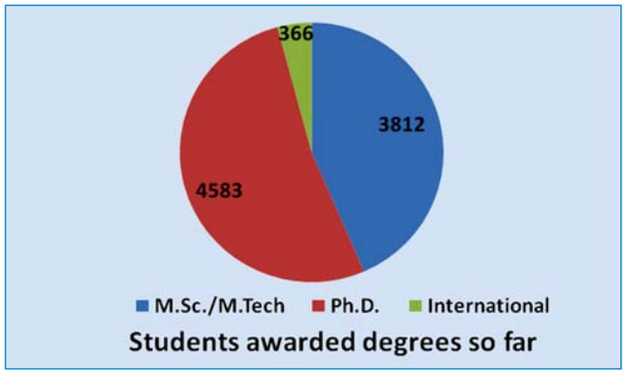
9. POST-GRADUATE EDUCATION AND INFORMATION MANAGEMENT

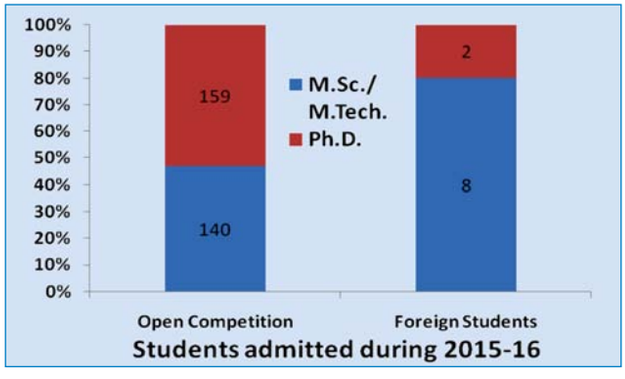
The Post-Graduate School of IARI continues to be the top ranker (AAAA+) among agricultural universities in India and provides leadership in human resource development by awarding Post-Graduate degrees in 26 disciplines. So far, 3780 M.Sc., 32 M.Tech. and 4583 Ph.D. students have been awarded degrees including 366 international students from 48 countries. The Institute has received accreditation from the National Agricultural Education Accreditation Board (NAEAB) of ICAR for a period of five years (2015-20). Accreditation from National Assessment and Accreditation Council (NAAC) of UGC is in progress.

9.1 POST-GRADUATE EDUCATION

9.1.1 Admission during the academic session 2015-16

The PG School continues to be the most sought destination for students in all four streams of admission, namely, open competition, faculty up-gradation, departmental candidates and foreign students. The admission to the Ph.D. programme is based on national level entrance examination conducted at nine different centres of the country, academic track record followed by an interview. While the admission to the M.Sc. programme is based on an All India Entrance Test conducted by the Education Division of the Indian Council of Agricultural Research. The foreign students are admitted through DARE, Ministry of Agriculture and Farmers' Welfare by Board of Studies of respective Division followed by approval of Academic Council and are exempted from the written test and interview. During 2015-16, 133 students (including 4 from physically handicapped and 2 from UPS categories were admitted to M.Sc., 7 to M.Tech. and 159 students (including 3 physically handicapped, 5 under faculty upgradation scheme, 1 departmental Scientific, 5 for CIAE, Bhopal and 16 for IIHR, Bengaluru) to Ph.D. courses. In addition, 10 international students (8 M.Sc. and 2 Ph.D.) were also admitted. Based on the Government of India's conscious decision to establish two IARI like Institution in Assam and Jharkhand, nine students each were admitted to M.Sc. at IARI-Assam and IARI-Jharkhand in 5 disciplines viz., Agronomy, Genetics, Soil Science & Agricultural Chemistry, Vegetable Science and Water Science & Technology during academic year 2015-16.





At present, the total number of students on roll is 877 (252 M.Sc., 15 M.Tech. and 610 Ph.D.) including

35 international students representing 13 foreign countries, namely, Afghanistan, Botswana, Cameroon, Egypt, Ethiopia, Iran, Nepal, Nigeria, Rawanda, Sudan, Syria, Vietnam and Zimbabwe.

9.1.2 Convocation

The 54th Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 5, 2016 with Hon'ble President of India, Shri Pranab Mukherjee as the Chief Guest. Hon'ble Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh presided over the function. Dr. S. Ayyappan, Secretary, DARE & Director General, ICAR, former Directors General of ICAR and Directors and Deans of IARI graced the function. The Chief Guest, Hon'ble President of India presented the medals and awards to the students and faculty. In the convocation address, he emphasized that the globalization of agriculture has increased the prospects for processed food commodities manifold. Our farmers and agri-preneurs must make full use of this opportunity. Increase in investment for agriculture technology development, rural agri-infrastructure, on-farm processing and value addition, and storage facilities are needed. The critical issues that hinder the development of rural agri-businesses need to be addressed. Proliferation of the recently-launched "Start-up India" to the rural sector could provide fillip to the setting up of agro-based enterprises. The "*Mera Gaon Mera Gaurav*" programme of IARI, under which each scientist will adopt a village, should aim at changing agriculture from subsistence to commercial farming. Dr. T. Mohapatra, Director, presented his report on the significant achievements of the Institute during 2015, while the report of the Dean & Joint Director (Education), Dr. R.K. Jain, highlighting the significant achievements in the field of education and training was circulated. Hon'ble Minister of Agriculture and Farmers' Welfare released 15 varieties of different crops. The Annual Report for 2014-15 of the PG School was also released during the Convocation.

Hon'ble President of India, Shri Pranab Mukherjee delivering the 54th Convocation address

During the Convocation, 242 candidates (120 M.Sc., 7 M.Tech. and 115 Ph.D.) were awarded degrees, including 16 (11 M.Sc. and 5 Ph.D.) international students. One student each in M.Tech. (Ms. Supria Priyadarsani, Post-harvest Technology) and Ph.D. (Ms. Saritha M., Microbiology) were awarded the Best Student of the Year Awards. Five students each in M.Sc. and Ph.D. received IARI Merit Medals. Five faculty members of the Institute, namely, Dr. D.R. Biswas (Soil Science and Agricultural Chemistry), Dr. Man Singh (Water Science and Technology), Dr. A. Talukdar (Genetics), Dr. V.K. Sehgal (Agricultural Physics), and Dr. Dinesh Kumar (Agronomy) received the Best Teacher Award - 2015 for their achievements in academics. The XVI Dr. B.P. Pal Medal for the year 2015 was awarded to Dr. Gyanendra Pratap Singh, Principal Scientist, Division of Genetics, IARI, New Delhi for his outstanding research contribution on "Wheat Breeding and Genetics". The XVI Hari Krishna Shastri Memorial Award for 2015 was awarded to Dr. Tirtha Kumar Datta, Principal Scientist, Animal Biotechnology Centre, NDRI, Karnal for his outstanding research contribution in the area of "Animal Biotechnology". The XIX Sukumar Basu Memorial Award for biennium 2013-14 was awarded to Dr. R. Asokan, Principal Scientist, IIHR, Bengaluru for his outstanding research contribution on "Development of Pioneering Molecular Techniques for Pest Management".

9.1.3 Special Lectures

Dr. B.P. Pal Memorial Lecture. The 22nd Dr. B.P. Pal Memorial Lecture was delivered by Prof. C.R.

Babu, Professor Emeritus and Former Pro-Vice Chancellor, University of Delhi on May 26, 2015 on "Biodiversity Parks - An Innovative Model for Conservation of Urban Living, Resources and Enhancement of Quality of Urban Environment". Prof. R.R. Hanchinal, Chairperson, PPV & FRA, presided over the function.

Teachers' Day Lecture. The Teachers' Day Lecture 2015 was delivered on September 4, 2015 by Dr. P.K. Gupta, Hon. Emeritus Professor & INSA Senior Scientist, CCS University, Meerut on "Deteriorating level of teaching: My experiences and thoughts as a teacher". Dr. R.B. Singh, former Director, IARI and Chairman, ASRB, chaired the function.

Lal Bahadur Shastri Memorial Lecture. The 46th Lal Bahadur Shastri Memorial Lecture was delivered by Dr. Soumya Swaminathan, Director General, Indian Council of Medical Research, New Delhi on February 4, 2016 on 'Nutrition and Health Challenges for India and Possible Solutions'. Dr. R.S. Paroda, Chairman, Trust for Advancement of Agricultural Sciences, New Delhi presided over the function.

Dr. Soumya Swaminathan, Secretary, Department of Health Research and Director-General, Indian Council of Medical Research, New Delhi delivering the 46th Lal Bahadur Shastri Memorial Lecture with Dr. R.S. Paroda in Chair

9.1.4 International Recognition

Four courses in Agronomy i.e., Principles and Practices of Weed Management, Water Management, Agronomy of Oilseed Crops and Pulses, and Agronomy of Commercial Crops were taught in Tele-Education mode by IARI faculty to the students of Afghanistan National Agricultural Sciences and Technology University (ANASTU).

9.1.5 Addressing Plagiarism

To maintain academic integrity, 242 student's theses prior to submission were subjected to web-based software "Turnitin" and similarity reports were generated.

9.2 E-GRANTH AND LIBRARY SERVICES

IARI Library is one of the largest and the finest agro-biological libraries in South East Asia housing a total of 3,38,103 publications including books/ monographs, journals, reports, bulletins, post graduate theses and other reference materials, etc. The Library has on its role 2000 members viz., students, scientists and technical staff. It also serves about 2500 visitors every year. The Library functions as the depository of Food and Agricultural Organization (FAO), and Consultant Group of International Agricultural Research (CGIAR) institutes' publications.

9.2.1 Strengthening and Sustainability of E-Granth

In accordance to the ICAR open access policy, it is mandatory to keep a digitized repository of the resources (including thesis) for each Institution. Under the open access policy, an initiative has been taken to extend this facility to others Institutes/SAUs by generating the Communities in the current instance of Krishikosh and create the permission based moderators to manage the information in repository by providing the current Krishikosh repository facilities hosted at ICAR-IARI. The upgradation of Krishikosh from DSpace version 4.2 to new DSpace version 5.5 version to make use of the improved new features in KrishiKosh, IARI has been also initiated.

9.2.2 Acquisition Programme

9.2.2.1 Books

During the period under report, the Library procured 744 publications which includes 175 in Hindi and 133 in English costing ₹6,99,913. The Library also

acquired 201 gift publications and 235 PG students' theses from IARI.

9.2.2.2 Serials

The Library procured 1903 journals/serials through subscription, gifts and exchanges. It subscribed to 116 foreign journals (out of which 30 had online access), 185 Indian journals, 47 Advances & Annual Reviews and 650 newsletters. Exchange relationship was maintained with 65 institutions globally and nationally by sending 152 annual reports, ICAR journals and society publications. A total of 526 publications accessioned. One hundred fifty two annual scientific/technical reports of different institutions and 40 bulletins were received in the Library during the reported period. The expenditure on Serial Acquisition from plan/non plan funds was ₹ 2,02,79,502 for 116 foreign titles and ₹ 15,61,290 for 185 Indian Journals.

9.2.3 Documentation Activities

9.2.3.1 AGRIS Project

IARI Library was declared as an input center for National Agricultural Research Database (NARD) under AGRIS Project. The Library was assigned the job of scanning articles from 10 most important Indian journals. The input was done in ISO format using AGRIN methodology.

9.2.3.2 Developmental news in Agriculture

Fourteen newspapers were scanned and 726 news items pertaining to IARI as well as ICAR were sent to the Directorate, Principal Scientist (PME) and CATAT.

9.2.3.3 Document processing

In all, 1053 documents consisting of 325 books, 202 post-graduate IARI theses, 281 old books, 82 bulletins and 163 Hindi books were processed (classification and cataloguing).

9.2.4 Resource Management

9.2.4.1 Reference, circulation and stack maintenance

Apart from approximately 2000 registered members, the Library served everyday approximately 150 to 200 users, who come from different agricultural universities/ICAR Institutes consulted about 2000 to 2500 documents. During the reported period, 333 new members (34 staff and 290 students) were registered. During the period under report, 1660 publications were issued and 1640 publications returned to its members through "KOHA" library management software. Four hundred twenty two no dues certificates were issued. Membership of DELNET (Developing Library Network) was renewed to provide Inter Library loan (reference services) to scientific community.

9.2.5 CD-Rom workstation

Two prominent international databases on agricultural aspects were subscribed amounting to ₹ 23,00,000 to provide CD-ROM services. Fifteen terminals were provided to users in CD-ROM workstation of the library. These databases are accessible to scientists/students/users of IARI through LAN. In all ₹ 10,500 references were downloaded by the scientists and students of IARI and research scholars from all over India. The cost based references downloaded were 8550 which generated revenues amounting to ₹ 9307.

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 in the form of research papers in peer reviewed journals, books/ book chapters, popular articles, etc. 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 PUBLICATIONS AT A GLANCE

1. Research/Symposia Papers		
a)	Research papers (With international impact factor or NAAS rating 6 and above) published in journals	621
b)	Symposia/conference papers	493
2. Books/Chapters in Books		
a)	Books	37
b)	Chapters in books	297
3. Popular Articles		359

10.2 IN-HOUSE PUBLICATIONS

10.2.1 Regular Publications

- IARI Annual Report 2014-15 (ISSN: 0972-6136)
- IARI NEWS (Quarterly) (ISSN: 0972-6144) - 4 issues
- IARI Current Events (Monthly)-12 issues (Available only on IARI website)

10.2.2 Technical Publications (English)

- Climate Change and Agriculture: Technologies for Enhancing Resilience (ISBN 978-93-83168-22-4)
- Champion Farmers-a Profile (ISBN978-93-83168-23-1)
- Seed Technology Seed Standard and Legal Aspects (TB-ICN: 149/2015)
- Herbarium Cryptogamae Indiae Orientalis (HCIO) and Indian Type Culture Collection (ITCC) (TB-ICN: 150/2015)
- Calendar of Operations for Mango Cultivation (TB-ICN: 151/2015)
- Pusa Mango Hybrids for Higher Income (TB-ICN: 152/2015)
- Entrepreneurship through Establishment of Hi-tech Mango Nursery (TB-ICN: 153/2015)
- A Practical Manual on Approaches for Vegetable Crop Improvement: From Conventional Breeding to Biotechnological Strategies (TB-ICN: 154/2015)
- Compendium of Winter School on Advances in Improvement of Vegetable Crops Using Biotechnological Approaches (TB-ICN: 155/2015)
- Principles and Techniques of Quality Seed Production in Vegetable Crops (TB-ICN: 156/2015)
- Teaching Manual for Hi-tech Vegetable Farming (TB-ICN: 157/2016)
- Soil Health Research and Policies Beyond International Year of Soils - 2015 (TB-ICN: 158/2016)
- Quality Seed Production: A Step Towards Farmer's Entrepreneurship (TB-ICN: 159/2016)

- Production Technology of Flower Crops (TB-ICN: 160/2016)
- Vegetable Hybrids for Nutrition and Profit (TB-ICN: 161/2016)
- Cultivation and Post Harvest Management of Commercially Important Flower Crops (TB-ICN: 162/2016)

10.2.3 fu;fer iqdk'ku ¼fgUnh½

- पूसा सुरभि (वार्षिक) (ISSN: 2348-2656)
- वार्षिक रिपोर्ट 2014–15 (ISSN: 0972-7299)
- पूसा समाचार (त्रैमासिक) (ISSN: 0972-7280)
- प्रसार दूत (त्रैमासिक)
- भा.कृ.अ.सं. सामयिकी (मासिक) (केवल संस्थान की वेबसाइट पर उपलब्ध)

10.2.4 rduhdh iqdk'ku ¼fgUnh½

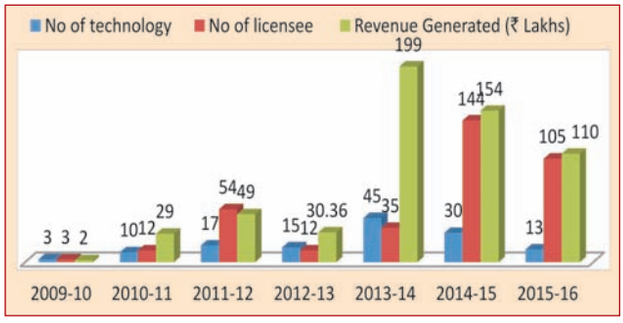
- खाद्य तथा पोषण सुरक्षा हेतु मध्य भारत के लिए गेहूं की उन्नत प्रजातियां (ICN : H-147 /2015)
- आम की बागवानी के लिए मासिक क्रियाओं का कैलेण्डर (ICN: H-148 /2015)
- पूसा आम की संकर प्रजातियां (ICN: H-149 /2015)
- उत्तम बीज की उपलब्धता को बढ़ाती बीज ग्राम योजना (ICN: H-150 /2015)
- आम की हाई–टैक नर्सरी द्वारा उद्यमिता विकास (ICN: H-151 /2015)
- रबी फसलों का बीज उत्पादन (ICN: H-152 /2016)
- उत्तम बीज उत्पादनः कृषक उद्यमशीलता की ओर एक कदम (ICN: H-153 /2016)
- व्यावसायिक पुष्पोत्पादन एवं अलंकृत पौधों का रखरखाव (ICN: H-154 /2016)
- समेकित फसल प्रबंधन एवं बीज उत्पादन तकनीकों पर प्रशिक्षण मैनुअल (ICN: H-155 /2016)

11. IP MANAGEMENT, TECHNOLOGY COMMERCIALIZATION AND AGRIBUSINESS INCUBATION ACTIVITIES

The mission of the Zonal Technology Management and Business Planning and Development (ZTM & BPD) Unit is, *"Translating Agri Research into Farmers' Prosperity"* which is achieved through IP management, technology commercialization and fostering entrepreneurship through business incubation.

11.1 TECHNOLOGY COMMERCIALIZATION

During 2015-16, 13 innovative technologies from North Zone - 1 of ICAR were transferred to 105 industry partners which earned the Institute a revenue of ₹ 105.28 lakhs. Following the success of last year, wheat variety HD 3086 was in great demand and licensed to 83 Industry Partners during the year 2015-16, followed by new entrant in wheat var. HD 3118; rice var. Pusa 1612, mustard var. Pusa Mustard 30; STFR Meter; Biofertilizer technologies; NPK liquid Biofertilizer; VAM Technology; PHT Technologies, Pusa Vita and Pusa Soyanut; vegetable var. bittergourd gyanoecious line and mango vars. Pusa Peetamber and Pusa Pratibha.



Revenue generated through licensing of the technologies during 2009-16

11.2 INTELLECTUAL PROPERTY RIGHTS

Four patent cooperation treaty (PCT) applications, 3 new patent applications with 4 renewals of existing patents were filed, along with 3 responses to First Examination Report (FER) and one each of hearing and amendment. The details are as follows:

IPRs	Application/ registration No.	Innovation/technology/ product/ variety	Date of filing/ registration	Application granted/ registered**
Patent	PCT/IB2015/000433 based on 959/DEL/2014	Nanofabrication process involving clay minerals as receptacles for manufacturing advanced nanomaterials including novel fertilizers	April 1, 2015	PCT filed with respect to existing Indian applications
Patent	PCT/IB2015/000439 based on 989/DEL/2014	Nanofabrication of phosphorus on kaolin mineral receptacles	April 2, 2015	PCT filed with respect to existing Indian applications
Patent	PCT/IB2015/000437 based on 1042/DEL/2014	Beneficiation of phosphate rock for the segregation of phosphorus containing heavy metal free minerals	April 2, 2015	PCT filed with respect to existing Indian applications
Patent	PCT/IB2013/060946	A method for the control of nematodes in plants	June 12, 2015	PCT filed with respect to existing Indian applications
Patent	2395/DEL/2011	Digital soil test and fertilizer recommendation (STFR) meter	May 16, 2015	Amendment filed
Patent	1608/DEL/2015	Device for recommending a crop yield enhancer	June 3, 2015	Filed

Patents	2432/DEL/2015	Plant transformation vector for suppressing MIPS gene expression and method for culturing low phytate soybean	7/8/2015	Provisional application
Patent	3364/DEL/2015	A microbial consortium	October 19, 2015	Filed
Copyright	applied	Online decision support system for soil health assessment		

11.3 AGRIBUSINESS INCUBATION

ZTM & BPD Unit, IARI an Agri Business Incubator incubates new start-up businesses by providing physical space, shared services, business and legal advice and financial and assist them until 'graduation'. This year following activities were under taken.

A. Agribusiness Incubation Programme

During the reported period, physical incubation support was extended to eight (8) start-up companies. Under the virtual incubation support, 3 incubatees were signed MoA for availing the IARI incubation facilities.

B. Ministry of Small and Medium Enterprizes (MSME) Scheme for Business Incubation

Under MSME project, five incubatees received financial grants from MSME under the scheme "Support for Entrepreneurial and Management Development of SMEs through Incubators" through ZTM & BPD Unit. Three incubatees graduated successfully for their initiation as agri-industry.

Company	Incubatee	Project
M/s Jai-Biotech & Research Centre	Mr. Jaideep Pareek	Manufacturing of Bio-fertilizers and Bio- pesticides
M/s Nature's Lap	Ms. Tuba Siddiqui	Utilization of Waste Mango Kernel for Extraction of Rich Mango Kernel Butter oil
M/s Society for Farmer Development	Mr. Bhopinder Mehta	Biscuit Making from Nutritionally Rich Traditional Millets in Combination with Wheat Flour

Agribusiness incubation details

Company	Incubatee	Project	Nature of Incubation
M/s Sickle Innovation	Mr. Nitin	Cotton Harvesting Machine	Physical incubation Supported under MSME
M/s Arpan seed Pvt Ltd	Mr. Raju Ram	Double Mustard: Commercialization of Zero Erucic Acid Mustard (*Brassica juncea*) for Enhancing the Competitiveness of Domestic Edible Oil Industry in India.	Physical incubation Supported under MSME
M/s Unison Agrico	Mr. Abhay Kumar Verma	Instant Millets Mix for Breakfast, Soups, Shake, etc.	Physical incubation Supported under MSME
M/s Enzys Gobindji Biotech Pvt Ltd	Mr. Amit Kumar Roy	Enzys Translational Research and Application Centre (enTRAC)	Physical incubation Supported under MSME
Criyagen	Basavaraj Girennavar	Enterprise on Integrated Nutrient Management (INM) & Integrated Pest Management	Physical incubation
Tripura Bio-tech limited	Mr. K. Phani Raj Kiran	Enterprise on Integrated Nutrient Management	Physical incubation
M/s Vaishnavi Bio-Tech limited	Mr. K. Suryanaryana Murthy	Enterprise on Integrated Nutrient Management	Physical incubation
StellerGene Technologies	Mr. Kapil and Dr. Aparna	Genomic Consultancy & Services Using GWAS and Molecular Makers in Agrigenomic and Humans	Physical incubation
W.S Telematics	Mr. W. Dahyia	Manufacture of STFR Meter	Virtual incubation
Eco Inputs	Mr. Sanjeev Malhan	Manufacturing of Biofertilizers	Virtual incubation
Nature Laps'	Tuba Siddiqui	Utilization of Waste Mango Kernel for Extraction of Rich Mango Kernel Butter and Oil	Virtual Incubation

Subsequently, another batch of 4 incubatees have been selected for grant in aid under the scheme "Support for Entrepreneurial and Management Development of SMEs through Incubators".

C. Marketing and Networking Platform

Launch of *Pusa Krishi Mobile App.* Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh launched mobile app *Pusa Krishi* during *Krishi Unnati Mela* on March 21, 2016 for farmers in order to help them get linked to latest technologies of the institute directly as well as be motivated to becoming entrepreneur farmers. The mobile application has been developed to disseminate information about these technologies to update its various stakeholders. Till date, the App has been downloaded and used by more than 20,000 people in less than 4 months since its launch.

Pusa Krishi App Logo

Launch of *'Pusa Krishi'* mobile app by Hon'ble Union Minister of Agriculture and Farmers' Welfare Shri Radha Mohan Singh during National Agricultural Fair, "*Krishi Unnati Mela*- 2016"

11.4 CORPORATE MEMBERSHIP

One hundred twenty two new corporate members were enrolled, with 88 renewals of existing memberships, raising the corporate membership to a total of 210, and generating a revenue of ₹ 4,08,000 during the year under report.

11.5 HANDHOLDING OF ZONAL ITMUS

- One - to - one interaction with ITMU in-charges as well as with concerned scientists was done regarding technologies ready for commercialization, valuation and IP issues in zonal institutes present in Delhi like NCIPM, NBPGR, NRCSS, CAZRI and DMR.
- Telephonic interaction regarding technologies ready for commercialization, valuation and IP issues of all the zonal institutes was established for providing hand holding for general as well as specific issues.
- Commercialized nano technology basket of CAZRI.

11.6 OTHER ACTIVITIES

A. Marketing and Networking Platforms

International Trade Fair, 2015. ZTM&BPD Unit, ICAR-IARI facilitated and provided space to Ananya Seeds Pvt Ltd and KAD Bioresources Pvt. Ltd, incubatees of IARI, to put up their stalls in the Agriculture Pavillion in 35th India International Trade Fair during November 14 - 27, 2015 to promote and market their products.

National Innovation Foundation Exhibition at Rashtrapati Bhawan. Four incubates of ICAR-IARI (M/s. Unison Agrico, M/s Arpan Seeds, M/s. Kad Bio-resource Pvt. Ltd and M/s. Ananya seeds Pv.t Ltd) to put up stall to showcase their innovative products and technologies at National Innovation Foundation Exhibition at Rashtrapati Bhawan, New Delhi on March, 2016.

National Agricultural Fair "Krishi Unnati Mela - 2016". During National Agriculture Fair, *Krishi Unnati Mela - 2016*, Seven (7) incubatees participated and showcased their products/technologies, services which were of benefit to the farming community as well as other stakeholders of agricultural development at ZTM enclosure. Hon'ble Prime Minister of India, Shri Narendra Modi visited the stall of ZTM&BPD unit, ICAR-IARI and interacted with the incubatees and appreciated the technologies developed by them.

National Agricultural Fair "*Krishi Unnati Mela* - 2016"

B. B2B Meetings

ZTM&BPD Unit organized business meet with M/s Reliance Industries, Mumbai on November 19, 2015 for showcasing ICAR-nano technology basket available for commercialization and seeking avenues for collaboration between IARI and Reliance Industries. In this meet, scientists from IARI, PAU, CAZRI and BITS Pilani showcased their technologies in the field of nano-fertilizer and agricultural chemicals.

B2B Meeting with Indo Gulf Fertilizers at ZTM&BPD unit, IARI was held on February 3, 2016 to showcase the potential technologies of IARI available for licensing.

C. Marketing and Promotion Campaign

During the year 2015-16, eleven e-maketing campaign for technologies of IARI and Zonal Institutes i.e., STFR Meter, Biofertilizer Technology, Biopesticides Technology, Agricultural Chemicals Technology, Nano Fertilizer Technology, Cross Flow Membrane Filtration Assembly for Small Processing Volume, and new Rice, Wheat and Mustard Seed Varieties developed by IARI has been launched.

More than 4000 e-mails despatched to various seed, biofertilizer, biopesticides, chemicals manufacturing and agri-equipments and agricultural machineries manufacturing companies. The campaign received over whelming response from the Industries across India.

Around 600 cold calls were made to various agro-based companies and corporate members for promotion of new technologies developed by IARI, New Delhi.

D. Panel Discussions

Two panel discussions viz., (1) Patenting in Agricultural Biotechnology and Life Forms' and (2) IP and Technology Commercialization – DARE/ ICAR Perspective were organized on July 15, 2015 for the benefit of IARI Scientist and trainees. Practical session on "Prior Art search" and Drafting of Patent Application was conducted during the programme. Field visit of Patent Office, New Delhi, PPVFAR, Science Museum, NASC Complex, IARI fields and Gene Bank of NBPGR, New Delhi and PPVFRA, New Delhi were organized to provide the better understanding of the subject.

E. Industry Partnership Day

On July 29, 2015, ZTM & BPD Unit organized the "Industry Partnership Day", with participation from across small and medium enterprises (SMEs) in North Zone I, working with seeds and/ or breeding materials of the likes. A total 22 Licensing Agreement for only a single technology in one go for Wheat Variety HD 3086 were signed with SMEs after depositing the prescribed licensing fee.

A view of Industry Partnership Day

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, centres, 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 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 the advanced centres of research in other countries, as well as with some of the private seed sector having strong R&D base and expertise in seed quality enhancement.

The Institute has extended liaison with private companies for commercialization of technologies. Commercialization of many IARI technologies with private and public enterprises has taken place.

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 trails 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.

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, European Commission, JAICA, JIRC, JSPS, ACIAR, AVRDC (Taiwan), etc.

The number of externally funded projects in operation during the period from 1.4.2015 to 31.3.2016 are given below:

Name of funding agency	No. of projects
Within India	194
AIREA, Directorate of Horticulture, HPSC&ST, DRDO, MSME, DBT, DST,CMERI, ICAR, CPRI (Mini Mission - HP), CSIR, NCPA, Ministry of Water Resources, Ministry of Environments & Forest (MOFPI), DAC, DFPI&H, NABARD, Indian Meteorological Department (IMD), BARC, MIDH, PPV&FRA, NFBSFARA (ICAR), CRP, etc.	
National Fellow Scheme of ICAR and Niche Area Project	2
Outside India	11
ICARDA, CIMMYT, Harvest Plus Consortium IFPRI, VFRC, IWMI, CIARC, IRRI	

13. AWARDS AND RECOGNITIONS

- The ZTM& BPD Unit, IARI won the Gold in Flame Awards Asia – 2016 under the category "Innovative Farm Model for Farm Profit" for the campaign *"From Lab to Land"* for successful commercialization of inventions from lab to land. The award was conferred by the Hon'ble rural marketing goliaths of Rural Marketing Association of India on March 11, 2016.

Dr. Neeru Bhooshan (third from right) and Dr. Akriti Sharma, ZTM & BPD Unit, IARI receiving RMAI Gold Flame Award Asia-2016

- IARI Regional Station, Karnal, awarded with Centre of Excellence Award in recognition of best performance in Breeder Seed Production under AICRP-NSP (Crops).
- Dr. P. Krishnan, Head, Division of Agricultural Physics received Punjabrao Deshmukh Outstanding Woman Scientist Award by ICAR, New Delhi.
- Dr. Subhash Chander, Professor, Division of Entomology received ICAR Bharat Ratna Dr. C. Subramaniam Award for Outstanding Teachers in Crop & Horticultural Sciences-2014.
- Dr. V.K. Baranwal, Principal Scientist, Division of Plant Pathology was elected NAAS Fellow.
- Dr. K.K. Bandyopadhyay, Principal Scientist, Division of Agricultural Physics was elected NAAS Fellow.
- Drs. R.R. Sharma, V.R. Sagar, Principal Scientists, Food Science and Postharvest Technology received Rajiv Gandhi Rastriya Gyan Vigyan Maolic Pustak Award for the book entitled "*Aadhunik Phal Utpadan*".
- Dr. Ranjan Bhattacharyya, Senior Scientist, CESCRA was elected Fellow of the Royal Geographical Society.
- Dr. Gopala Krishnan S., Senior Scientist, Division of Genetics was elected NAAS Associate 2016.
- Drs. S. Prasad, A.Bhatia and N. Jain, Scientists, CESCRA received ICAR-Dr. Rajendra Prasad Puruskar for Technical Books in Hindi in Agricultural and Allied Sciences on *Paryavaran, Jalvayu Parivartan Avam Krishi.*
- Dr. C. Waghmare, Scientist, Division of Nematology was awarded with Netaji Subhas-ICAR International Fellowships for Doctoral Studies at University of Florida, USA.
- Dr. Sabina Islam, Scientist, Division of Vegetable Science, received Endeavour Research Fellowship Award -2015.
- Dr. Reeta Bhatia Dey, Scientist, Regional Station, Katrain (Kullu Valley) received Endeavor Research Fellowship-2015.

In addition, a large number of our scientists were recognized by their peer groups by electing/ nominating to the various positions in the societies and governmental and inter-governmental committees.

14. BUDGET ESTIMATES

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E.) for the year 2015-16 and Budget Estimates for 2016-17 under Plan

PLAN BUDGET ESTIMATE **₹ in lakhs**

Sl. No.	Name of the Head	B.E. 2015-16	R.E. 2015-16	B.E. 2016-17
1	2	3	4	5
	Grants for creation of Capital Assets (CAPITAL)			
1	Works			
	(A) Land			
	(B) Building			
	i. Office building			100.00
	ii. Residential building		67.00	
	iii. Minors Works			
2	Equipments	50.00	120.00	100.00
3	Information & Technology			
4	Library Books & Journal	250.00	240.00	202.00
5	Vehicles & Vessels			
6	Livestock			
7	Furniture & Fixtures			
8	Others			
A	**Total- CAPITAL (Grants for creation of Capital Assets)**	**300.00**	**427.00**	**402.00**
	Grants in Aid-Salaries (REVENUE)			
1	Establishment Expenses			
	(A) Salary			
	i. Establishment charges			
	ii. Wages			
	iii. Overtime allowance			
	Total-Establishment Expenses (Grants in Aid-Salaries)	**0.00**	**0.00**	**0.00**
	Grants in Aid-General (REVENUE)			
1	Pension & Other Retirement Benefits	0.00	0.00	
2	Traveling Allowance			
	A. Domestic/Transfer T.A.	120.00	120.90	120.00
	B. Foreign T.A			
	Total-Traveling Allowance	120.00	120.90	120.00
3	Research & Opeational Expenses			
	A. Research Expenses	696.00	610.00	615.65
	B. Operational Expenses	435.00	541.00	358.35
	Total Res. & Operational Exp.	1131.00	1151.00	974.00
4	Administrative Expenses			

	A Infrastructure	200.00	227.00	213.00
	B Communication		3.00	5.00
	C Repair & Maintenance			
	i. Equipments, Vehicles & Others	150.00	167.00	133.00
	ii. Office building			
	iii. Residential building			
	iv. Minor Works			
	D Others (exc.TA)	154.00	154.00	230.00
	Total-Administrative Expenses	504.00	551.00	581.00
5	Miscellaneous Expenses			
	A HRD	100.00	35.17	68.00
	B Other Items (fellowships)			
	C Publicity & Exhibitions			
	D Guest House-Maintenance			
	E Other Miscellaneous.			
	Total -Miscellaneous Expenses	100.00	35.10	68.00
	Total Grants in Aid-General	**1855.00**	**1858.00**	**1743.00**
B	**Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)**	**1855.00**	**1858.00**	**1743.00**
	TOTAL (CAPITAL + REVENUE)	**2155.00**	**2285.00**	**2145.00**
*	Tribal Sub Plan Expenditure	135.00	102.00	125.00
*	NEH Expenditure	0.00		20.00
	GRAND TOTAL	**2290.00**	**2387.00**	**2290.00**

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E.) for the year 2015-16 and Budget Estimates for 2016-17 under Non- Plan

NON-PLAN BUDGET ESTIMATES **₹ in lakhs**

Sl. No.	Name of the Head	B.E. 2015-16	RE. 2015-16	B.E. 2016-17
1	2	3	4	5
	Grants for creation of Capital Assets (CAPITAL)			
1	Works			
	(A) Land			
	(B) Building			
	i. Office building			
	ii. Residential building			
	iii. Minors Works			
2	Equipments	50.00	80.00	65.00
3	Information & Technology			8.00
4	Library Books & Journal	5.00	15.00	7.00
5	Vehicles & Vessels			
6	Livestock			1.50
7	Furniture & Fixtures	15.00	50.00	24.00
8	Others			
A	**Total- CAPITAL (Grants for creation of Capital Assets)**	**70.00**	**145.00**	**105.50**
	Grants in Aid-Salaries (REVENUE)			

1	Establishment Expenses			
	(A) Salary			
	i. Establishment charges	15410.00	15922.65	18000.00
	ii. Wages			
	iii. Overtime allowance	4.00	2.50	2.50
	Total-Establishment Expenses (Grants in Aid-Salaries)	**15414.00**	**15925.15**	**18002.50**
	Grants in Aid-General (REVENUE)			
1	Pension & Other Retirement Benefits	10500.00	14400.00	12000.00
2	Traveling Allowance			
	A. Domestic/Transfer T.A.	40.00	45.00	40.00
	B. Foreign T.A			
	Total-Traveling Allowance	40.00	45.00	40.00
3	Research & Opeational Expenses			
	A. Research Expenses	230.00	264.50	252.50
	B. Operational Expenses	280.00	380.50	321.00
	Total Res. & Operational Exp.	510.00	645.00	573.50
4	Administrative Expenses			
	A Infrastructure	1850.00	2000.00	2000.00
	B Communication	50.00	36.00	50.00
	C Repair & Maintenance			
	i. Equipments, Vehicles & Others	175.00	170.50	200.00
	ii. Office building	600.00	1217.00	720.00
	iii. Residential building	450.00	741.00	450.00
	iv. Minor Works	200.00	241.05	250.00
	D Others (exc.TA)	600.00	1254.45	700.00
	Total-Administrative Expenses	3925.00	5660.00	4370.00
5	Miscellaneous Expenses			
	A HRD	6.00	6.50	6.00
	B Other Items (fellowships)	350.00	490.00	500.00
	C Publicity & Exhibitions	20.00	10.00	9.50
	D Guest House-Maintenance	50.00	52.00	70.00
	E Other Miscellaneous.	200.00	268.00	200.00
	Total -Miscellaneous Expenses	626.00	826.50	785.50
	Total Grants in Aid-General	**15601.00**	**21576.50**	**17769.00**
B	**Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)**	**31015.00**	**37501.65**	**35771.50**
	TOTAL (CAPITAL + REVENUE)	**31085.00**	**37646.65**	**35877.00**
	(C) Loan & Advances	60.00	60.00	60.00
	GRAND TOTAL	**31145.00**	**37706.65**	**35937.00**

15. STAFF POSITION

(As on 31.03.2016)

	Category	No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	6	4
2)	Principal Scientist	65	217 (39)
3)	Senior Scientist/Scientist (S.G.)	170	124 (80)
4)	Scientist	337	141 (363)
	Total	**578**	**486** *
B.	**TECHNICAL STAFF**		
1)	Category III	20	15
2)	Category II	292	208
3)	Category I	367	287
4)	Auxiliary	1	1
	Total	**680**	**511**
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	19	17
2)	Group B	275	196
3)	Group C	163	117
	Total	**457**	**330****
D.	**SKILLED SUPPORT STAFF**	**1301**	**846**

Note: * For scientific staff, the figures shown out of parentheses represent the number of scientists working in particular grade (assessment/direct recruitment/induction). The figures shown in the parentheses represent the number of scientists initially appointed by direct recruitment/induction in the grade (i.e., excluding assessment)

** One post held by Smt. Bharti Vikas Zade, ex. CF&AO is included. However, Smt. Zade's deputation tenure was completed on 31/03/2016 and accordingly relieved from this Institute on 31/03/2016. One vacancy is excess filled, i.e., Security Officer.

16. POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLED PERSONS

16.1 POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLED PERSONS

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 are followed.
- Three per cent of the total number 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 2015-16, 4 students in M.Sc. and 3 students in 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 in administrative category as on 31.3.2016 are as follows:

Number of beneficiaries with disability	Total number of beneficiaries	Percentages
9	330	2.72%

17. OFFICIAL LANGUAGE (*RAJ BHASHA)* IMPLEMENTATION

According to Article 343 of the Constitution, Hindi shall be the Official Language (OL) of the Union Government. To implement the objectives in letters and spirit, 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) was constituted by the Institute under the chairmanship of Joint Director (Research) and the Committee ensures compliance of policy and rules of O.L. Act 1963 and O.L. rules of 1976. All the Joint Directors, Head of Divisions and Comptroller are ex-official 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, sub-committees were also constituted in different Divisions, Regional Stations and the Directorate.

17.1.1 Inspection of Progressive Use of Official Language

To achieve the targets fixed in the annual programme of the Department of Official Language. Ministry of Home Affairs, Govt. of India, and as per the recommendations of the Institute Official Language Implementation Committee (OLIC), an OL Inspection Committee was constituted under the Chairmanship of Dr. Indra Mani Mishra, Head, Division of Agricultural Engineering. The Committee inspected the progressive use of OL in all the Divisions, Units and sections of the Directorate. The Committee also visited some of the Regional Stations, namely, Karnal, Pune and Indore, and inspected the progressive use of OL. The Committee gave valuable suggestions for making the desired progress of OL implementation in the concerned Division/Section/Centre, etc. and submitted inspection reports.

17.2 AWARDS AND HONOURS

- The Institute was awarded the Second Prize for doing maximum writing work in Hindi for the year 2014-15 under the ICAR *'Rajarshi Tandon Rajbhasa Puraskar Yojna'*.
- The Institute was also awarded the Second Prize for Institute's Annual *Rajbhasa* Patrika "*Pusa Surbhi*" under *'Ganesh Shankar Vidhyarathi Hindi Krishi Patrika Puraskar Yojna'* of ICAR for the year 2014-15.

17.3 HINDI WORKSHOPS

In order to motivate the staff members in different categories to do maximum work in Hindi, three Hindi Workshops were organized by the Institute head quarter during the year 2015-16.

- First workshop on "*Use of Unicode font and inscript key board in official work"* was organized on April 24-25, 2015 in the Institute Hindi Typing & Training Center for administrative staff of the Institute (Twenty administrative officials participated).
- Second workshop/competition on power point presentation on "GM Crops Still Born" was held on October 6, 2015 for scientists and technical officers of the Institute at CESCRA auditorium. Dr. K.V. Prabhu, Joint Director (Research) inaugurated

the programme. Dr. Girijesh Singh Mehra, Scientist, Division of Agricultural Extension; Dr. Atul Kumar, Senior Scientist, Division of Seed Science & Technology; Dr. Dinesh Kumar Sharma, Principal Scientist, CESCRA; Dr. Harshwardhan Choudhury, Senior Scientist, Division of Vegetable Science; and Dr. Dinesh Kumar, Principal Scientist, Division of Agronomy were awarded first, second, third, fourth & fifth cash prize, of ₹10,000/-, ₹7000/-, ₹5000/-, ₹3000/- and ₹3000/- and certificates, respectively (Twelve scientists and technical officers participated in the workshop/ competition).

- Third workshop was organized on February 19 - 20, 2016 for *Rajbhasha* Nodal Officers to give them knowledge regarding *Rajbhasha Niti* and to fill up the quarterly and Annual Reports (Thirty nodal officers participated).

17.4 AWARD SCHEMES/COMPETITIONS

During the year 2015-16, 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. The following activities were organized :

17.4.1 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 implemented as per the directives of the Department and 10 employees of the Institute were given cash awards for doing their maximum official work in Hindi during the reported period.

17.4.2 *Hindi Vyavahar Pratiyogita*

Hindi Vyavahar Pratiyogita was organized amongst the different Divisions, Regional Stations/Centres, and Sections of Directorate, separately. In the period under report, the Division of Seed Science & Technology and Regional Station, Katrain amongst the Divisions & Regional Stations, and Budget and Compilation amongst the sections were given mobile shield for doing maximum work in Hindi.

17.4.3 *Rajbhasha Patra Vyavahar Pratiyogita*

Rajbhasha Patra Vyavahar Pratiyogita was organized for promoting maximum correspondence in Hindi. The Divisions of Extension & ATIC got first and second prizes, respectively. The prizes carry mobile shields.

17.4.4 Awards for Science Writing in Different Magzines/Papers

A competition for Popular Science Writing was organized for scientists/technical officers of the Institute and winners were awarded first (₹ 7000/-), second (₹ 5000/-) and third (₹ 3000) prizes for their published articles in different journals.

17.4.5 *Pusa Vishisht Hindi Pravakta Puraskar*

Pusa Vishisht Hindi Pravakta Puraskar was given to Dr. Ram Roshan Sharma, Division of Food Science & Postharvest Technology. 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.

17.4.6 Outstanding Nodal Officer Puraskar

For better coordination between Hindi Section and each of the Divisions/Sections/Units and significant progress in official language in the Institute, one Nodel Officer was nominated for each Division/Section/Unit. To motivate the Nodal Officer for their outstanding contribution in Official Language Implementation work in his Division/Section/Unit, a prize of ₹ 5000/- was announced. Shri Ramesh Chandra, ACTO, Division of Extension received the above mentioned prize for year 2014.

17.5 *HINDI CHETNA MAAS*

The Institute celebrated *Hindi Chetna Maas* from September 1 to 30, 2015. Dr. K.V. Prabhu, Joint Director (Research) inaugurated *Hindi Chetna Maas* on September 1, 2015. On this occasion, a debate

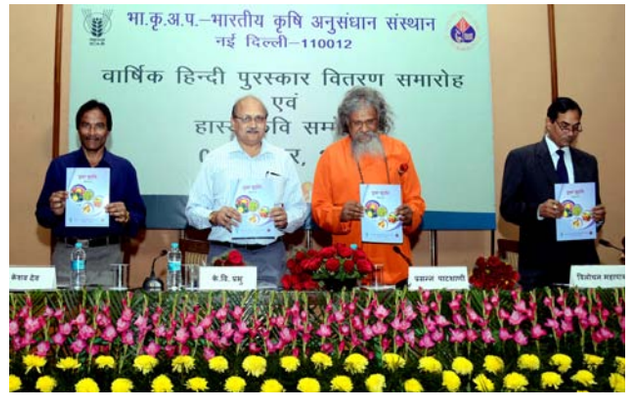
competition was also organized. Shri Anil Kumar Dubey, Ex Director (OL), ICAR and Shri Devendra Upadhyaya, Reporter were invited to judge the competitions. During *Hindi Chetna Maas*, various other Hindi competitions like essay writing, noting & drafting, and quiz, etc. were also organized for all categories of the staff members.

Different Divisions and Regional Stations of the Institute also celebrated Hindi Week/Hindi Day in their respective divisions/regional stations/ establishment during this period. Many competitions were organized to promote the use of Hindi and participants given prizes.

17.5.1 Hindi Annual Prize Distribution Function

The Institute celebrated its Annual Hindi Prize distribution Function on November 7, 2015 at Dr. B.P. Pal Auditorium. Dr. Trilochan Mohapatra, Director, IARI presided over the function, Dr. K.V. Prabhu, Joint Director (Research) and Chairman, Institute Official Language Implementation Committee gave the welcome address. Shri Keshav Dev, Deputy Director (OL) presented the Institute Official Language Progress Report. Dr. Prasanna Kumar Patshani, Hon'ble MP *Lok Sabha* & Convener, Parliamentary Official Language Committee, who was the Chief Guest, released Institute's *Rajbhasha Patrika*, *Pusa Surbhi* and gave away the prizes to the winners of different competitions organized during the year and *Hindi Chetna Maas*. A *Hasya Kavi Sammelan* was also organized on this occasion which brought cheers and smiles to the audience.

Shri Keshav Dev, DD(OL) welcoming Dr. K.V. Prabhu, Joint Director(Research) on the occasion of *Hindi Chetna Maas* function



Dr. Prasanna Kumar Patsani, Hon'ble MP, *Lok Sabha* & Convener, Parliamentary Official Language Committee releasing the Institute's *Rajbhasha Patrika, Pusa Surbhi*

18. TRAINING AND CAPACITY BUILDING

18.1 TRAINING PROGRAMMES

The Institute organizes several national and international short-term training courses (regular, *adhoc* and individual) and refresher courses in specialized areas for the scientists of NAREES under the programmes of "Centres of Excellence" and "Centres of Advanced Studies". In addition, many special training courses were also organized for the benefit of professionals, farmers and extension workers.

Important training programmes organized

Training programme	Dates/Month	No. of trainees
Division of Agricultural Chemicals		
Smart Agro-input Delivery Approaches Based on Hydrogels and Other Polymeric Carriers for Improved Crop Health and Productivity	July 21-30, 2015	17
Division of Agricultural Engineering		
Training Programmes on Agricultural Tools and Machines"	August 4-6, 2015 & August 27-29, 2015	62
Model Training Course on "Improved Agricultural Engineering Technologies for Higher Productivity	March 1-8, 2016	18
Motor Winding for Entrepreneurs	February 15-25, 2016	9
Division of Agricultural Economics		
Quantitative Techniques for Agricultural Policy Research	February 18- March 9, 2016	22
Division of Agricultural Extension		
CAFT on Communication and Management Tools and Approaches for Agricultural Extension	September 2-22, 2015	25
CAFT on Capacity Building for Gender Analysis and Mainstreaming	January 2-22, 2016	22
Training on Zero Tillage and Raised Bed Sowing of Pigeon Pea (at Mumtajpur village)	May, 2015	40
Trainings on Bed Planting System in Pigeon Pea and DSR and SRI in Paddy (at Mumtajpur village)	June, 2015	88
Krishak Gosthis on Contingency Plan for Deficit *Mansoon*	June, 2015	150
Farmers'-Scientists Interaction Meets on Climate Resilient Technologies and Contingency Plan for *Kharif* and two trainings on Direct Seeded Rice (DSR) (Mewat district of Haryana)	June, 2015	100
Trainings on Weed Control, Micronutrient Management and Iron Deficiency in Paddy Crop	July, 2015	95
Training Programme on Pusa Hydrogel and Bio-fertilizer	August, 2015	25
Trainings on Pest and Disease Control	August, 2015	30
Training on Pusa Hydrogel and Bio-fertilisers for Higher Productivity and Water Use Efficiency	September, 2015	22

Training for Insect - pest and Disease Management in *Kharif* Crops	September, 2015	30
Farmers "Scientists Interaction Meet for Water Management as well as Insect-pest Management in *Kharif* Crops	September, 2015	30
Training programmes on Raised Bed, Use of NPK and Mycorhizae, and Conservation Technology (under NICRA Project)	November, 2015	80
Training on Weed Management and Nutrient Management (in NICRA village)	December, 2015	50
Field Visit and *Krishak Sangosthi* (under NICRA project)	January, 2016	50
Four Self Help Groups of Women Mobilized in Project Villages for Entrepreneurship Uptake	February, 2016	4
Field Day on Mustard Crop (Pusa 30) in Lehchora village of Baghpat district (Uttar Pradesh)	March, 2016	100
Scientists and Development Workers Interface on Awareness on Nutrition in Lehchora village of Baghpat district	March, 2016	75
Agricultural Knowledge Management Unit		
Bioinformatics Techniques for Agricultural Data Analysis	January 11-13, 2016	25
Strengthening of E-Granth	February 26-27, 2016	80
Division of Agricultural Physics		
15th EDUSAT based Off "campus Training Programme on Remote Sensing, GIS and GPS	August 10 - November 27, 2015	33
Model Training Course on Participatory GIS for Sustainable Natural Resource Management	February 24 - March 2, 2016	20
Division of Biochemistry		
Plant *Omics*-Emerging Tools and Techniques for Crop Improvement (CAFT)	November 18-December 08, 2015	19
Centre for Environment Science and Climate Resilient Agriculture		
Training on Soilless Cultivation of Vegetable Crops for Urban and Peri-urban Area	January 18, 2016	44
Protected Cultivation of Horticultural Crops	January 27-28, 2016	15
Protected Cultivation as Smart Agriculture	March 31, 2016	80
Division of Food Science and Postharvest Technology		
Development of Functional Food through Extrusion Processing	November 5-7, 2015	15
Advances in Extrusion Processing of Food	December 7-9, 2015	15
Development of Functional Ingredients for Extrusion Processing	January 11-13, 2016	19
Extrusion Processing - Technology and Business Development	February 22-24, 2016	18
Division of Floriculture and Landscaping		
Production Technology of Flower Crops	February 25-29, 2016	54
Floriculture and Landscaping for Livelihood Security	March 20-25, 2016	23
Entrepreneurship Development through Value Addition in Flower Crops	March 14, 2016	50
Division of Genetics		
Genomics and Phenomics Assisted Crop Breeding: Principles and Practices	April 07- 27, 2015	25
State Level Training on *Durum* Wheat Production, Marketing & Consumption	February 22-23, 2016	20
Division of Nematology		
ICAR-Winter School on Designing Modern Crop Pest Combat Strategies with Nematodes and against Nematodes	January 27- February 16, 2016	20

Division of Microbiology		
Training Program on Biofertilizers (VAM production, Compost production, Azotobacter liquid formulation) for Licencees	2015-2016	9
Division of Plant Pathology		
Training on Plant Disease Diagnostics and Management	October 13 - November 02, 2015	23
Training on Functional Analysis of Pathogenicity Genes of Plant Pathogens	January 2 -22, 2016	16
Training programme on ELISA and PCR based Diagnostics at the Referral Centre for Virus Indexing	November 17-21, 2015	9
Division of Soil Science and Agricultural Chemistry		
12th Advanced Level Training on Soil Testing, Plant Analysis and Water Quality Assessment	September 13- October 2, 2015	15
Advanced Tools and Techniques for Analysis of Micro- and Secondary Nutrients and Pollutant Elements	March 3-12, 2016	26
Division of Vegetable Science		
Winter school on Advances in Improvement of Vegetable Crops Using Biotechnological Approaches"	September 18 – October 8, 2015	25
Model Training Course on Entrepreneurship Development to Ensure Quality Vegetable Seed Production for Making the Country Nutritionally Secure"	December 10-17, 2015	25
Vegetable Field Day	January 20, 2016	
Carrot Field Day	February 24, 2016	35
Water Technology Centre		
Precision Farming Technologies (Micro Sprinkler, Drip Irrigation & Fertigation, Poly house, Insect Proof Net House, Nursery Raising, etc.)	7- three days each and 3- one day each	268
Precision Farming Technologies to Improve Crop Production and Water Use Efficiency	36 - Awareness program conducted by PFDC, New Delhi	1246
Pradhan Mantri krishi Sichai Yojna for All India Service Officers	January 12-16, 2016	42
Regional Station, Indore		
PPV & FR Act Awareness Training Programme	January 24, 2015	200
State Level Training on *Durum* Wheat Production, Marketing & Consumption	February 22-23, 2016	20
Regional Station, Pusa, Bihar		
Integrated Crop Management and Seed Production Technique in NEPZ	March 14 -23, 2016	50
Regional Station, Karnal		
Farmers' Training for Members of *Krishi Vistar Avum Mahila Utthan Samiti*, Karnal	September 2, 2015	25
Training on Seed Production of *Rabi* Crops for Progressive Farmers	February 18-20, 2016	20
Training on *Uttam Beej Utpadan: Krishak Udhamseelta Ke Aur Ak Kadam* for Progressive Farmers	March 8-10, 2016	20
Training Programme on *Safalta Ki Kahani – Krishkon Ki Jubani forFarmers*	March 15, 2016	85
Trainings (12) for Farmers under Seed Village Programme during *Kharif* and *Rabi* seasons on Different Aspects of Quality Seed Production	*Kharif* 2015 and *Rabi* 2015-16	191
Regional Station, Katrain		
Emerging Trends in Hybrid Vegetable Seed Production for Temperate Region	May 21-30, 2015	13
Farmers Training Progamme	September 29-30, 2015	25
Farmers Day cum Cabbage Day for Popularization of Cabbage Hybrids Developed at the Station	November 20, 2015	70

Regional Station, Shimla		
Farmers training on Nursery Management of Temperate Fruits	February 2, 2016	
Training on Production and Nursery Management of Temperate Fruits at Katrain	March 11, 2016	
Regional Station, Kalimpong		
Sustainable Production of Darjeeling Mandarin	January 13, 2016	20
Sustainable Production of Large Cardamom	January 15, 2016	20
Zonal Technology Management and Business Planning & Development Unit		
Mango Day	July 15, 2015	65
Intellectual Property Rights in Agriculture	August 12– September 1, 2015	32
Mustard Field Day	February 26, 2016	32

18.1.1 Training Programmes Organized by the Institute's Centre for Agricultural Technology Assessment and Transfer (CATAT)

In all, 19 on-campus training programmes were organized for agriculture officials and progressive farmers of different States. These programmes were attended by 280 participants from Bihar, Gujarat, Assam, Himachal Pradesh, Rajasthan and NCR Delhi. One training programme was also organized by IARI for the representatives of VOs and SAUs/ ICAR partners of collaborative programme.

18.1.2 Trainings for Different Target Groups at Institute's *KVK,* Shikohpur, Gurgoan

Trainings were organized for different target groups at Institute's *KVK,* Shikohpur, Gurgoan to generate the opportunities for income and employment, to provide technical know – how to the practicing farmers and farm women and to update the knowledge of in service personnel.

18.1.3 Other Capacity Building Activities

The Institute's CATAT also conducted several capacity building activities i.e., trainings on application of bio-fertilizers, soil testing and nutrient management, household nutrition, health management of milch cattle and agro-advisory campaign at IARI Model Villages and other locations.

Trainings for different target groups at *KVK,* Shikohpur

Sl. No.	Type of training with target groups	No. of trainings	No. of beneficiaries		
			Male	Female	Total
1.	Vocational trainings for rural youth and girls	20	267	149	416
2.	Day long On/Off campus trainings for practicing farmers and farm women 1. On Campus 2. Off campus	28 47	500 528	02 251	502 779
3.	In-Service (refresher course) trainings for field extension functionaries	08	128	19	147
	Total	**103**	**1423**	**421**	**1844**

19. MISCELLANY

I. Ongoing Projects at IARI as on 31.03.2016

(A)	**In-house Research Projects**	**47**
	School of Crop Improvement	14
	School of Horticulture	09
	School of Crop Protection	08
	School of Natural Resource Management	07
	School of Basic Sciences	02
	School of Social Sciences	07
(B)	**Outreach Programmes**	**10**
(C)	**Flagship Programmes**	**04**

II. Scientific Meetings Organized

a)	Workshops	45
b)	Seminars	19
c)	Summer institutes/Winter school	09
d)	Farmers' day (s)	91
e)	Others	82
	Total	**246**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	216
b)	Scientific meetings	252
c)	Workshops	145
d)	Symposia	121
e)	Others	114
	Total	**848**

Abroad

a)	Seminars	05
b)	Scientific meetings	03
c)	Workshops	09
d)	Symposia	04
e)	Others	08
	Total	**29**

IV. Suggestions Given / Decisions Taken at the Meetings of Senior Management Personnel

Board of Management

- Replacement of equipment approved under EFC by the various Divisions of IARI

Academic Council

- Creation of three new disciplines from the disciplines of Horticulture, namely, Floriculture & Landscape Architecture, Fruit Science and Vegetable Science.
- Extension of the duration of split Ph.D. programme up to 8 years from 6 years.

Research Advisory Committee

1. School of Crop Improvement

- A comprehensive research programme aiming at improving the yield and abiotic stress tolerance in pulses (chickpea / mungbean / pigeon pea / lentil) be taken up. Efforts should be made to identify major QTLs for abiotic stress tolerance and linking these QTLs to genes of interest controlling the traits rather than linked markers loci. There is also a need to broaden the genetic base in pulses through pre-breeding programmes. A close research linkage with ICRISAT / ICARDA is required for this purpose.
- Active collaboration with agronomists is required for breeding wheat varieties for conservation

agriculture. Studies on Karnal bunt in wheat be given a major thrust.

- The transgenic and functional genomics approaches which hold tremendous promises for managing biotic and abiotic stresses should be used in the plant breeding programmes.

2. School of Horticulture

- Heterosis breeding in important vegetable crops be given high priority and molecular basis of heterosis be investigated to enhance the level of heterosis. Ways and means to reduce the pesticide load on vegetable crops be also explored for safe vegetable production.
- Prime importance needs to be given to the development of Hi-tech protected cultivation for vegetable crops (tomato /capsicum / cucumber). Package of practices for these crops should be developed and B: C ratio worked out.
- Major emphasis needs to be given to root stock breeding in mango (for dwarfness / salinity tolerance / drought hardness) and guava (for wilt). Genetics of polyembryony in mango also needs to be investigated.
- Special attention needs to be given to post harvest loss reduction in retail market chain of horticultural crops.

3. School of Natural Resource Management

- Agro-ecology based research including remote sensing, GIS and modeling techniques for vulnerability assessment at regional level be strengthened.
- Appropriate multi-functional farm machinery (for seed placement, fertilizer application, residue / inoculum incorporation and straw collection / chopping) be developed. Commercialization of field machinery and its transfer to farmers be given priority.
- Basic and strategic approaches for enhancing input (water and nutrient) use efficiency be developed and validated.
- Implication of wastewater use on human health be investigated and the wastewater treatment technology of IARI be commercialized.
- Special attention be given to research studies pertaining to improvement of soil health. The soil health cards need to be made relevant and applicable to serve their purpose. It would be most desirable to establish a referral soil testing lab at IARI and strengthen training in the area of soil testing.
- Status of crop residue burning needs to be studied before planting of *Rabi* / *Kharif* crops and efforts intensified on priority to develop and apply the new/improved microbial consortium in rapid *in situ /ex situ* decomposition of crop residue.

4. School of Crop Protection

- Focused work with respect to the use of remote sensing for pest and disease mapping and for evaluating losses at a larger scale required. Work on molecular epidemiology, storage entomology and use of entomopathogenic plant nematodes for pest management be given more emphasis.
- Emerging diseases and diseases of unknown etiology be given special attention for basic and strategic research. Early detection and early warning systems should be targeted under existing theme of management strategies. National pests scenario and paradigm shift in the light of global warming be analyzed and debated at school and institutional level for future line of activities under existing theme.
- Pesticide referral lab established under NATP and accredited should become a national referral lab of the government for fetching more funds for operation / manpower.
- A brainstorming with NBPGR and NBA for facilitating collection and export of genetic resources (insects / seeds, etc.) needed.

5. School of Basic Sciences

- Efficient screening for traits for abiotic stress (salinity /drought/ temperature) tolerance should

be done in representative environment by carefully choosing the parental lines.

- More emphasis should be given to physiological and biochemical basis for efficient translocation processes and genetic manipulation of flowering time in pulses for higher crop productivity.
- The mandate of the basic school may be enlarged to include plant genetic engineering/metabolic pathways and basic research work of other relevant divisions. State of art facilities for studies related to metabolic profiling, proteomics, nucleic acid analysis and genetic transformation; transgenic green house / screen house facilities and also environmental phenotyping facilities (rainout shelters / microplots / climate controlled greenhouses) require to be created for doing good basic research of national importance.

6. School of Social Sciences

- An institutional mechanism for upscaling the IARI Post office model for dissemination of technologies at national level be developed. More focus be laid to extensive demonstration of such technologies in western U.P.
- Major thrust be given to studies pertaining to pulses and oilseeds trade for informed advisories to the Ministry of Commerce, and policy makers. Close research integration with School of NRM is required.

Post Graduate School Activities

- Provision of overseas associateship for capacity building be made. Training of young scientists in selected areas of research specialization be given priority.
- Provision for utilizing HRD funds for Post-Doctoral fellowship and international visits by scientists be made.

Administrative and Financial Activities

- For strengthening of the scientific manpower at the Institute, timely notification of the vacant scientific posts at different levels by IARI and filling up such posts by the council should be accorded high priority.
- The council must finalize the process of technical post recruitment so that sufficient qualified technical manpower is available in the Institute to support the scientific personnel.
- While appreciating the concept of centralized job contract of agricultural operations at IARI for ensuring economy and uniformity of rates, it was suggested that all the agricultural operations taken up at the Institute including regional stations should be listed and man-hours consumed per unit area of each agricultural operation should be worked out. It was also suggested to explore the possibility of getting state govt. schedules of rates for such operation, if any.

General Recommendations

a) Research

- Molecular breeding should become an integral component of research programmes in Horticultural School. A close research linkage with NRCPB is required for this purpose.
- Impact assessment of Green House Gases (GHGs) on agriculture and *vice versa* be brainstormed and a policy brief be brought out, in consultation with the social science group of IARI, for informed advisories to the farmers and appropriate policy making by the policy makers.
- Studies on conservation agriculture be strengthened.
- The school of Basic Sciences should focus on metabolic pathways and biochemical engineering of plant processes. Additional studies under field conditions should be carried out for research work done at pot culture/greenhouse for arriving at meaningful and logical conclusions.
- Establishment of an Accelerated Breeding Centre (ABC) be given priority. A centralized facility including high-throughput genotyping centre, doubled haploid facility, bioinformatics centre, rapid generation advancement facility and transgenic facility for functional validation of cloned genes and transgenic development is needed. The scientific and technical staff for

running these facilities should also be provided adequate training.

- *State of the art* laboratories for seed testing, seed physiology and biochemistry and molecular biology need to be established, accredited and certified.
- Project submission norms be simplified and the concept note to funding agencies be allowed to be submitted at divisional / JD level.
- SoPs / Good laboratory practices be developed and encouraged with special reference to disposal of obsolete chemicals, waste management and effluent discharge.

b) Post-Graduate School

- Provision of a start-up grant for initial settlement and mentoring of newly joined scientists in the Institute be made.
- Intake of Ph.D. students be increased.

c) Administration

- In the wake of cut in administrative personnel sanctioned posts, the Institute must embark upon commensurate automation and computerization. This will hasten the processing of the proposals while bringing in the much needed accountability and transparency in working.

d) Finance

- At the time of calculation of funds allotment/ availability per scientist, administrative expenses like repairs & maintenance of equipment, expenses on electricity, water and other infrastructure should not be accounted for as it gives an inflated picture to the council for non-research purpose.
- The Institute should also closely monitor the progress of various works proposal in respect of IARI - Jharkhand. In case there is any likely savings out of ₹ 15 Cr. (BE 2015-16), the same should be intimated to council but not later than January, 2016.

V. Resource Generation

1) Consultancy & other services

Consultancy services :	₹ 45,49,362
Contract research :	₹ 1,35,97,710
Contract service :	₹ 53,17,057
Training :	₹ 1,06,04,498
Total (A) :	**₹ 3,40,68,627**

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed :	₹ (-) 30,46,729
(b) Commercialization :	₹ 6,98,727
(c) Prototype manufacturing :	₹ 21,01,553
Total (B) :	**₹ (-) 2,46,449**

3) Post Graduate School receipt

Training Programme

(a) Foreigners & Indians :

M.Sc./Ph.D. Programme

(b) Institutional economic fee from foreign scholars under Work Plan : ₹ 45,60,740

(c) Receipt from Registrar (A) Account No. 5432 (9029.201.4314) all fees except institutional economic fee, including sale of information bulletin through D.D. : ₹ 47, 24,270

(d) Cash transferred from Syndicate Bank to Directors Account No. C-49 (9029.305.17) from sale of Information Bulletin through DD : ₹ 18,08,500

(e) 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): ₹ 2,37,435

Total (C) : **₹ 1,13,30,945**

Grand Total (A+B+C) : ₹ 3,40,68,627+ ₹ (-) 2,46,449 + ₹ 1,13,30,945= ₹ 45,153,123

VI. Infrastructural Development

- Office rooms, laboratories and washrooms of WTC building were renovated. Hydro distillation

of mentha oil facility was developed in one of the Lab of Water Technology Centre.

- Strengthening of Divisional Laboratory of Vegetable Science with instruments/ glassware for analysis of plant samples.
- Procured two tractors, mini tractor, crane, power tiller welding machine, etc. at the Division of Agricultural Engineering.
- At Farm Operation Service Unit, Diesel engines for threshers (2), Submersible Pump 15Hp (1), Rotavators (2), Rigid Tyne cultivator(1), CCTV camera facility for security were procured to enhance the capacity of FOSU. Also redevelopment of four tubewells.
- Internal wire fitting in heritage building and temperature and humidity control glass house at the Division of Plant Pathology.
- Procured planetary Ball Mill, Vacuum concentrator, Nitrogen generator at the Division of Agricultural Chemicals.

VII. All India Coordinated Research Projects in Operation during the year April 1, 2015 to March 31, 2016

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 & Pollinators

National Centres Functioning at IARI under All India Coordinated Research Projects

1. All India Network Project on Soil Biodiversity Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen)
2. All India Coordinated Project on Long-term Fertilizer Experiments
3. All India Coordinated Research Project on Soil test Crop Response Correlations
4. All India Coordinated Research Project on Floriculture Improvement
5. All India Network Project on Pesticide Residues
6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture & Agro-based Industries
7. All India Coordinated Research Project on Biological Control of Crop Pests & Weeds
8. All India Coordinated Research Project on Soybean
9. All India Coordinated Research Project on Sub-Tropical Fruits
10. All India Coordinated Research Project on NSP (Crops)
11. All India Coordinated Research Project on Mustard
12. All India Coordinated Research Project on Wheat
13. All India Coordinated Research Project on Rice
14. All India Coordinated Research Project on Pulses
15. All India Coordinated Research Project on Vegetable crops
16. All India Coordinated Research Project on Pearlmillet
17. All India Coordinated Research Project on Whitegrubs & other Soil Arthropods
18. All India Coordinated Research Project on Wheat & Barley Improvement
19. Front Line Demonstration on Pearl Millet – AICRP Pearl Millet under National Food Security Mission (NFSM)
20. Adhoc Cooperating Center of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Indian Institute of Soil Science, Bhopal

VIII. Foreign visitors during April 1, 2015 to March 31, 2016

S. No.	Visitor (s)	Date of visit
1	A 5 - member delegation from Chile	16.04.2015
2	A 10 - member delegation from Ethiopia	21.04.2015
3	A 6 - member delegation from China	05.05.2015
4	A 40 - member delegation from Kenya, Liberia & Malawi	27.07.2015
5	Agricultural Counselors of Foreign Diplomatic Missions based in New Delhi	14.09.2015
6	Ambassadors/High Commissioners of African Countries	15.09.2015
7	ICRISAT's Governing Board members	23.09.2015
8	A delegation from Afghanistan (ICARDA)	28.09.2015
9	A 6 - member EU delegation	08.10.2015
10	Visit of Sr. Editor/Journalists from African countries	28.10.2015
11	A 9 - members delegation from American Council of Education (ACE)	05.11.2015
12	Dr. Kenneth Knox, Chair, Canada Science Technology and Innovation Council, Canada	19.11.2015
13	A 5 - member Chinese delegation led by Ms. Ching Ping, Deputy Director General from Department of Agriculture of Guangdong	14.12.2015
14	A delegation from Afghanistan	21.12.2015
15	Prof. Shmuel Wolf, Dean, Hebrew University of Jerusalem, Israel	14.01.2016
16	A 12 - member delegation from Nepal	15.01.2016
17	A 9 - member delegation led by Mr. Toshiaki Sato, President of Japan Pulse Foundation	08.02.2016
18	His Excellency Mr. Sergo Karapentyan, Minister of Agriculture, Armenia	17.02.2016
19	His Excellency Deputy Agriculture Minister and H.E. Advisor of President along with Senior Policy Makers from Afghanistan	22.03.2016

Dr. T. Mohapatra, director, IARI interacting with the members of American Council of Education

Chinese delegation interacting with IARI team

Appendix 1

Results-Framework Document (RFD) for IARI (2014-15)

Section-1: Vision, Mission, Objectives and Functions

Vision

Generation and extension of innovative technologies to achieve food, nutrition and livelihood security with sustainable agriculture, and economic prosperity along with quality human resource development under dynamic constrained physical and economic environment in the country.

Mission

The primary mission of the Institute is to explore new frontiers of science and knowledge and develop human resource to provide leadership to the country in technology development and policy guidance resulting in a vibrant, responsive and resilient agriculture which must be effectively productive, eco-friendly, sustainable, economically profitable and socially equitable.

Objectives

1. Germplasm enhancement and development of improved cultivars
2. Development and identification of appropriate crop production, protection and value addition technologies
3. Technology dissemination, capacity building and policy research
4. Excellence in human resources development

Functions

To function on the premise that research is the engine of science-led agricultural growth.

To follow the path of scientific research, technology development and extension and human resource development leading to the realization of new paradigms for achieving the congruence among enhanced productivity, sustainability, ecological and environmental security and socio-economic equity.

Section-2: Inter se Priorities among Key Objectives, Success Indicators and Targets

S. No.	Objectives	Weight (%)	Actions	Success Indicators	Unit	Weight (%)	Target/Criteria value				
							Excellent	Very Good	Good	Fair	Poor
							100%	90%	80%	70%	60%
1	Germplasm enhancement and development of improved cultivars	**30**	Evaluation of genetic material	Breeding lines and germplasm evaluated	Number	**5**	30,000	**25,000**	20,000	15,000	10,000
				High performance lines registered/published	Number	**3**	258	**215**	172	129	86
			Development of improved cultivars	Entries contributed to AICRP multi-location trial	Number	**6**	246	**205**	164	123	82
				Varieties identified for release	Number	**6**	22	**18**	14	10	6
			Seed production programme	Breeder seed produced	Weight MT	**5**	600	**500**	400	300	200
				Truthfully labeled seed produced	Weight MT	**3**	630	**525**	420	315	210
				Quality planting material produced	Number	**2**	50,400	**42,000**	33,600	25,200	16,800
2	Development and identification of appropriate crop production, protection and value addition technologies	**25**	Development of technologies for enhancing resource use efficiency	NRM technologies validated/published	Number	**8**	8	**7**	6	5	4
			Development of strategies for biotic/abiotic stress management	Novel molecules, genes and biological formulations developed and or tested	Number	**8**	24	**20**	16	12	8
			Development of technologies for value addition	Novel processes/ products developed for value addition	Number	**5**	6	**5**	4	3	2
			Commercialization of technologies	Technologies commercialized	Number	**4**	14	**12**	10	8	6
3	Technology dissemination, capacity building and policy research	**15**	Field demonstrations and agro-advisories	Field demonstrations conducted and agro-advisories issued	Number	**7**	5,160	**4,300**	3,440	2,580	1,720
			Training of farmers/ Extension officials	Trainings organized	Number	**6**	144	**120**	96	72	48
			Policy analysis	Policy papers published	Number	**2**	3	**2**	1	1	1
4	Excellence in human resources development	**10**	Post Graduate Teaching and AHRD Trainings	Degrees awarded	Number	**5**	216	**180**	144	108	72
				No. of trainings conducted	Number	**5**	38	**32**	26	20	14
*	**Publication/ Documentation**	**5**	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	No.	3	450	**375**	300	225	150
			Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	2	30.06. 2014	02.07. 2014	04.07. 2014	07.07. 2014	09.07. 2014

*	**Fiscal resource management**	2	Utilization of released plan fund	Plan fund utilized	%	2	98	96	94	92	90
*	**Efficient Functioning of the RFD System**	3	Timely submission of Draft RFD for 2 014-2015 for Approval	On-time submission	Date	2	May 15, 2014	May 16, 2014	May 19, 2014	May 20, 2014	May 21, 2014
			Timely submission of Results for 2013-2014	On-time submission	Date	1	May 12014	May 22014	May 52014	May 62014	May 72014
*	**Enhanced Transparency / Improved Service delivery of Ministry /Department**	3	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	2	100	95	90	85	80
			Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	1	100	95	90	85	80
*	**Administrative Reforms**	7	Update organizational strategy to align with revised priorities	Date	Date	2	Nov. 12014	Nov. 22014	Nov. 32014	Nov. 42014	Nov. 52014
			Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC).	% of implementation	%	1	100	90	80	70	60
			Implementation of agreed milestones for ISO 9001	% of implementation	%	2	100	95	90	85	80
			Implementation of agreed milestones of approved Innovation Action Plans (IAPs).	% of implementation	%	2	100	90	80	70	60

Section-3: Trend Values of the Success Indicators

S. No.	Objectives	Actions	Success Indicators	Unit	Actual Value for FY 12/13	Actual Value for FY 13/14	Target Value for FY14/15	Projected Value for FY 15/16	Projected Value for FY 16/17
1	Germplasm enhancement and development of improved cultivars	Evaluation of genetic material	Breeding lines and germplasm evaluated	Number	15000	22495	**25,000**	26,000	27,000
			High performance lines registered/published	Number	203	207	**215**	225	235
		Development of improved cultivars	Entries contributed to AICRP multi-location trial	Number	180	200	**205**	210	215
			Varieties identified for release	Number	20	20	**18**	19	20
		Seed production programme	Breeder seed produced	Weight MT	450	609	**500**	505	510
			Truthfully labeled seed produced	Weight MT	1013	582	**525**	530	535
			Quality planting material produced	Number	65000	46130	**42,000**	43,000	44,000
2	Development and identification of appropriate crop production, protection and value addition technologies	Development of technologies for enhancing resource use efficiency	NRM technologies validated/ published	Number	6	7	**7**	8	9
		Development of strategies for biotic/ abiotic stress management	Novel molecules, genes and biological formulations developed and or tested	Number	16	92	**20**	22	24
		Development of technologies for value addition	Novel processes/ technologies/ products developed for value addition	Number	4	5	**5**	6	7
		Commercialization of technologies	Technologies commercialized	Number	15	41	12	13	14
3	Technology dissemination, capacity building and policy research	Field demonstrations and agro-advisories	Field demonstrations conducted and agro-advisories issued	Number	5000	10657	**4,300**	4,500	4,700
		Training of farmers/ Extension officials	Trainings organized	Number	70	111	**120**	125	130
		Policy analysis	Policy papers published	Number	2	2	**2**	2	2
4	Excellence in human resources development	Post Graduate Teaching and AHRD Trainings	Degrees awarded	Number	208	175	**180**	185	190
			No. of trainings conducted	Number	22	27	**32**	35	38

*Publication/ Documentation	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	Number	423	545	375	390	405
	Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	-	-	02.07. 2014	-	-
*Fiscal resource management	Utilization of released plan fund	Plan fund utilized	%	99.91	98.06	96	96	96
Efficient Functioning of the RFD System	Timely submission of Draft RFD for 2014-2015 for Approval	On-time submission	Date	-	-	May 16, 2014	-	-
	Timely submission of Results for 2013-2014	On-time submission	Date	-	-	May 22014	-	-
*Enhanced Transparency / Improved Service delivery of Ministry/ Department	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	-	-	95	-	-
	Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	-	-	95	-	-
*Administrative Reforms	Update organizational strategy to align with revised priorities	Date	Date	-	-	Nov. 22014	-	-
	Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC)	% of implementation	%	-	-	90	-	-
	Implementation of agreed milestones for ISO 9001	% of implementation	%	-	-	95	-	-
	Implementation of milestones of approved Innovation Action Plans (IAPs)	% of implementation	%	-	-	90	-	-

Section 4 (a): Acronyms

S. No.	Acronym	Description
1.	AICRP	All India Coordinated Research Project
2.	AHRD	Agricultural Human Resource Development
3.	SMS	Short Messages Service
4.	DD	Door Darshan
5.	MT	Metric Tonne
6.	NRM	Natural Resources Management
7.	M.Sc.	Master of Science
8.	Ph.D.	Doctor of Philosophy
9.	IARI	Indian Agricultural Research Institute
10.	ICAR	Indian Council of Agricultural Research
11.	SAUs	State Agricultural Universities
12.	DAC	Department of Agriculture and Cooperation
13.	CGIAR	Consultative Group on International Agricultural Research
14.	APEDA	Agricultural & Processed Food Products Export Development Authority
15.	UPSC	Union Public Service Commission

Section 4(b): Description and definition of success indicators and proposed measurement methodology

S. No.	Success Indicator	Description	Definition	Measurement	General Comments
1	Breeding lines and germplasm evaluated	Source material for the improved varieties to be evaluated	Material generated from the basic germplasm	Number of breeding lines evaluated	It depends on the leadership of scientists associated and collaboration
2	High performance lines registered/ published	Registration/publishing breeding lines for high performance	Breeding lines having traits for high yield and biotic and abiotic stresses that can be exploited for development of improved crop varieties	Number of such lines registered/ published	
3	Entries contributed to AICRP multi-location trial	Breeding lines of field and horticultural crops tested at AICRP multilocational trials against popular cultivated varieties in that region for identification of new varieties for release	Best performing entries are identified as new variety for release	Number of such varieties identified	Number may vary depending upon the material available from the evaluated lines
4	Varieties identified for release	Breeding lines of field and horticultural crops tested at AICRP multilocational trials and identified as new varieties for release during annual workshop	Breeding lines identified for release for superior traits by AICRP Workshop	Number of varieties identified	Number may vary depending upon timely evaluation and fair assessment
5	Breeder seed produced	Produce from nucleus and breeder seed is the starting point in seed chain of producing quality seeds for farmers	Breeder seed is the starting point in seed chain which is multiplied/converted in to foundation/certified seed	Quantity produced (MT)	Quantity may vary as per indent received, availability of land and other resources/ facilities
6	Truthfully labeled seed produced	Truthfully labeled seed are those seeds that are sold to the farmers by showing quality parameter without certification	The seeds which are sold by farmers or companies by showing quality parameter through their label without certification are known as truthful seeds. These seeds don't need permission from government, but seed law regulates the quality parameters mentioned in the label	Quantity produced (MT)	Quantity may vary as per indent received, availability of land and other resources/ facilities
7	Quality planting material produced	Production of quality planting material of fruit crops	Saplings of fruit plants	Number	
8	NRM technologies validated/ published	Validation of technologies that enable crops to use resources efficiently for increasing production	Natural resources are chemical fertilizers, water, and pesticides etc. that are essential for crops to grow	Number	
9	Novel molecules, genes and biological formulations developed and/ or tested	Development and testing of novel molecules, biological formulations and isolation & incorporation of genes for biotic/abiotic stress management	Chemical/biochemical compounds that control insect pests and diseases and increase production. Genes are parts of chromosomes that confer resistance for biotic and abiotic stresses in crop plants	Number	
10	Novel processes/ products developed for value addition	Technologies that add value to agricultural produce	Process by which low cost produce can be converted in high value product	Number	
11	Technologies commercialized	Commercialization of technologies for the benefit of the farmers	Transfer of technology to the stakeholders through commercialization process	Number	
12	Field demonstrations conducted and agro-advisories issued	Trials and demonstrations conducted for technology testing and proving the technology potential production and advisories given to the farmers through direct communication/ DD/Radio/ newspapers/SMSs	On-farm trials aims at testing new technologies under farmers condition and management, by using farmers own practice as control. Frontline demonstration is the field demonstration conducted on farmer's field under the close supervision of scientists. Agro-advisories are issued by various means of communication to the farmers for good agricultural practices, advance forewarnings of weather conditions	Number	Number may vary depending upon the contribution of the volunteer organizations

13	Trainings organized	Capacity building activities related to knowledge and skill improvement/ development programmes conducted for farmers, rural youth and extension personnel	Training is a process of acquisition of new skills, attitude and knowledge in the context of preparing for entry into a vocation or improving productivity in an organization or enterprise	Number	
14	Policy papers published	Policy papers published in peer reviewed journals	The purpose of policy papers is to help the stakeholders, policy makers and planners for bringing out overall changes in agricultural system	Number	Number may vary according to the aptitude of scientists and number of externally funded projects received
15	Degrees awarded	M.Sc. and Ph.D. degrees are awarded to the students	Master and Doctorate degrees	Number	Number may vary based on dedication and withdrawal of students
16	No. of trainings conducted	Advanced AHRD trainings provided to the scientist/researcher of ICAR Institutes/SAUs	A process of acquiring new knowledge for improvement in research, teaching and extension	Number	of trainings may vary as per the availability of fund

Section 5: Specific performance requirements from other departments that are critical for delivering agreed results

Location Type	State	Organisation Type	Organisation Name	Relevant Success Indicator	What is your requirement from this organisation	Justification for this requirement	Please quantify your requirement from this organisation	What happens if your requirement is not met
Central Government		Departments	Department of Agriculture & Cooperation	Breeder seed produced	Indent for quantity of breeder seed	Variety-wise indent for breeder seed	Quantity of breeder seed produced as per indent	Production of less or more quantity of breeder seed

Section 6: Outcome/Impact of activities of Department/Ministry

S. No.	Out Come/Impact	Jointly responsible for influencing this outcome / impact with the following organization(s)/ department (s)/ministry(ies)	Success Indicator	Unit	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
1	Impact on adoption of IARI crop varieties at national and international level	DAC, Planning Commission, Ministry of Environment & Forests, CGIAR Institutes APEDA, Ministry of Commerce, Basmati rice exporting companies	a) Wheat*	%	27.5	23	22	22	23
			b) Rice (Basmati belt)	%	75	76	77	78	79
			c) Share of IARI Basmati rice varieties in export	%	75	75	75	75	77
			d) Mustard*	%	31	35	30	30	32
			e) Pulses*	%	9	9	9	9	10
2	Impact on farmers income/ resources/ employment due to IARI technologies	DAC, Ministry of Panchayati Raj, Ministry of Rural Development and State Governments, SAUs, Volunteer organizations	Increase in farmers income	%	20	22	23	25	27
			Improved rural livelihood and buildup of social capital	Number (Lakhs)	1.1	1.2	1.3	1.4	1.45
			Conservation of resources and environmental quality	%	6	8	9	10	11
3	Achievement of students and faculty at National/ International level	SAUs, CGIAR Institutes, Foreign Universities, UPSC	a) Employments to IARI graduates	%	90	90	90	90	90
			b) Awards & recognitions	Number	86	60	60	60	65

* Percent area estimated based on breeders seed indent

Performance Evaluation Report in respect of RFD 2014-2015 of RSCs i.e. Institutes (April 1, 2014 to March 31, 2015)

Name of the Division: Crop Science

Name of the Institution: ICAR - Indian Agricultural Research Institute

RFD Nodal Officer of the RSC: Dr. I. Sekar, Principal Scientist & In-charge, PME

S. No.	Objective(s)	Weight	Action(s)	Success Indicator(s)	Unit	Weight	Target / Criteria Value					Achieve-ments	Performance		Percent achieve-ments against Target values of 90% Col.	*Reasons for shortfalls or excessive achieve-ments, if appli-cable
							Exce-llent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%		Raw Score	Weighted Score		
1	Germplasm enhancement and development of improved cultivars	30	Evaluation of genetic material	Breeding lines and germplasm evaluated	Number	**5**	30,000	**25,000**	20,000	15,000	10,000	**37753**	**100**	**5**	**151.0**	
				High performance lines registered/published	Number	**3**	258	**215**	172	129	86	**280**	**100**	**3**	**130.2**	
			Development of improved cultivars	Entries contributed to AICRP multi-location trial	Number	**6**	246	**205**	164	123	82	**217**	**92.93**	**5.58**	**105.9**	
				Varieties identified for release	Number	**6**	22	**18**	14	10	6	**19**	**92.5**	**5.55**	**105.6**	
			Seed production programme	Breeder seed produced	Weight MT	**5**	600	**500**	400	300	200	**449**	**84.9**	**4.25**	**89.8**	**A**
				Truthfully labeled seed produced	Weight MT	**3**	630	**525**	420	315	210	**898**	**100**	**3**	**171.0**	**B**
				Quality planting material produced	Number	**2**	50,400	**42,000**	33,600	25,200	16,800	**49483**	**98.91**	**1.98**	**117.8**	
2	Development and identification of appropriate crop production, protection and value addition technologies	**25**	Development of technologies for enhancing resource use efficiency	NRM technologies validated/published	Number	**8**	8	**7**	6	5	4	**11**	**100**	**8**	**157.1**	
			Development of strategies for biotic/ abiotic stress management	Novel molecules, genes and biological formulations developed and or tested	Number	**8**	24	**20**	16	12	8	**33**	**100**	**8**	**165.0**	
			Development of technologies for value addition	Novel processes/ products developed for value addition	Number	**5**	6	**5**	4	3	2	**7**	**100**	**5**	**140.0**	
			Commercialization of technologies	Technologies commercialized	Number	**4**	14	**12**	10	8	6	**30**	**100**	**4**	**250.0**	**C**
3	Technology dissemination, capacity building and policy research	**15**	Field demonstrations and agro-advisories	Field demonstrations conducted and agro-advisories issued	Number	**7**	5,160	**4,300**	3,440	2,580	1,720	**7854**	**100**	**7**	**182.7**	**D**
			Training of farmers/ Extension officials	Trainings organized	Number	**6**	144	**120**	96	72	48	**148**	**100**	**6**	**123.3**	

			Policy analysis	Policy papers published	Number	**2**	3	**2**	1	1	1	**2**	**90**	**1.8**	**100.0**	
4	Excellence in human resources development	**10**	Post Graduate Teaching and AHRD Trainings	Degrees awarded	Number	**5**	216	**180**	144	108	72	**181**	**90.03**	**4.5**	**100.5**	
				No. of trainings conducted	Number	**5**	38	**32**	26	20	14	**36**	**96.67**	**4.83**	**112.5**	
*	Publication/ Documentation	**5**	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	Number	3	450	**375**	300	225	150	**475**	**100**	**3**	**126.7**	
			Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	2	30.06. 2014	**02.07. 2014**	04.07. 2014	07.07. 2014	09.07. 2014	**9.7. 2014**	**60**	**1.2**		
*	Fiscal resource management	**2**	Utilization of released plan fund	Plan fund utilized	%	2	98	**96**	94	92	90	**99.99**	**100**	**2**		
*	Efficient Functioning of the RFD System	**3**	Timely submission of Draft RFD for 2014-2015 for Approval	On-time submission	Date	2	May 15, 2014	**May 16, 2014**	May 19, 2014	May 20, 2014	May 21, 2014	**May 15, 2014**	**100**	**2**		
			Timely submission of Results for 2013-2014	On-time submission	Date	1	May 12014	**May 22014**	May 52014	May 62014	May 72014	**May 2,2014**	**90**	**0.9**		
*	Enhanced Transparency / Improved Service delivery of Ministry/ Department	**3**	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	2	100	**95**	90	85	80	**95**	**90**	**1.8**		
			Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	1	100	**95**	90	85	80	**100**	**100**	**1**		
*	Administrative Reforms	**7**	Update organizational strategy to align with revised priorities	Date	Date	2	Nov. 12014	**Nov. 22014**	Nov. 32014	Nov. 42014	Nov. 52014	**Nov. 12014**	**100**	**2**		
			Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC).	% of implementation	%	1	100	**90**	80	70	60	**100**	**100**	**1**		
			Implementation of agreed milestones for ISO 9001	% of implementation	%	2	100	**95**	90	85	80	**100**	**100**	**2**		
			Implementation of agreed milestones of approved Innovation Action Plans (IAPs).	% of implementation	%	2	100	**90**	80	70	60	**100**	**100**	**2**		

Total Composite Score: 96.39
Rating: Excellent

A. Breeder seed produced was as per the target & allotment received from DAC, Ministry of Agriculture and the target of DAC/Ministry of Agriculture was met.

B. The excess in TL seed production was due to better quality production of TL seed by the production agencies,

C. Commercialization of the technologies is a process which is flexible and hence over achievement.

Due to demand of IARI varieties/technologies from the NGOs and Voluntary Organization for demonstration to the farmers in their respective areas.

Appendix 2

Members of Board of Management of IARI

(As on 31.3.2016)

Chairperson

Dr. Ravinder Kaur
Director (Acting), IARI

Members

Dr. K.V. Prabhu
Joint Director (Research), IARI

Dr. R.K. Jain
Dean & Joint Director (Education), IARI

Dr. J.P. Sharma
Joint Director (Extension), IARI

Dr. Ravinder Kaur
Project Director, WTC

Dr. B.S. Dwivedi
Head, Division of Soil Science & Agricultural Chemistry

Dr. C. Viswanathan
Head, Division of Plant Physiology

Dr. Pritam Kalia
Head (Acting), Division of Vegetable Science

Joint Director (Agriculture)
Govt. of NCT of Delhi

Sh. S.K. Singh
Financial Advisor, ICAR, Krishi Bhawan, New Delhi

Dr. S.K. Malhotra
Agriculture Commissioner
Deptt. of Agril. and Cooperation, Ministry of Agriculture and Farmers Welfare, Krishi Bhawan, New Delhi

Dr. J.S. Chauhan
ADG (FFC), ICAR, Krishi Bhawan, New Delhi

Member-Secretary

Smt. Shashi Prabha Razdan
Registrar & Joint Director (Admn.), IARI

Appendix 3

Members of Research Advisory Committee of IARI

(As on 31.03.2016)

Chairman

Dr. P.L. Gautam
Former DDG (Crop Science), ICAR
& Former Chairperson, PPV&FRA,
New Delhi

Members

Dr. B. Mishra
Former VC,
Sher-e-Kashmir University
of Agricultural, Sciences and
Technology, Jammu.

Dr. S.P. Ghosh,
Former DDG (Hort.), ICAR

Dr. C.L. Acharya
Former Director,
Indian Institute of Soil Science
(ICAR), Bhopal

Dr. R. Khetarpal
Regional Director (South Asia) CABI,
CG Block, NASC Complex,
DPS Marg, New Delhi-110012

Dr. K.R. Koundal,
Former Joint Director (Research),
IARI, New Delhi

Dr. P.K. Joshi
Former Director,
NCAP & NAARM and Director,
South Asia, IFPRI,
South Asia Regional Office,
New Delhi

Dr. J.S. Sandhu
Deputy Director General (Crop
Science), ICAR
Krishi Bhawan, New Delhi-110001

Dr. Ravinder Kaur
Director (Acting), IARI

Member – Secretary

Dr. K.V. Prabhu,
Joint Director (Research), IARI

Appendix 4

Members of Academic Council of IARI

(As on 31.03.2016)

Chairman

Dr. Ravinder Kaur
Director (Acting)
IARI, New Delhi

Vice-Chairman

Dr. R.K. Jain
Dean & Jt. Director (Edn.)
IARI, New Delhi

Members

Dr. N.S. Rathore
Deputy Director General (Edn.),
ICAR

Dr. K.C. Bansal
Director (NBPGR)
New Delhi

Dr. T.R. Sharma
Director (NRCPB)
New Delhi

Dr. U.C. Sud
Director (IASRI)
New Delhi

Dr. O.P. Yadav
Director (IIMR)
New Delhi

Dr. P.K. Mishra
Director, IISWC, Dehradun

Dr. K.K. Singh
Director, CIAE, Bhopal

Dr. M. Anandaraj
Director (Acting), IIHR,
Bengaluru

Dr. K.V. Prabhu
Joint Director (Research)
IARI, New Delhi

Dr. J.P. Sharma
Joint Director (Extension)
IARI, New Delhi

Dr. V.L. Chopra
Former Member,
Planning Commission
A-3/210 A, Janakpuri
New Delhi-110058

Dr. Ajit Varma
Director General
Amity Institute of Microbial
Technology, Amity University
E-3 Block, Fourth Floor, Sector 125,
Noida-201303 (UP)

Dr. C. Ramasamy
Former Vice Chancellor, TNAU
9/12, 5th Cross, Ramalingam
Nagar K.K. Pudur,
Coimbatore-641038 Tamil Nadu

Dr. J.S. Samra
Former CEO, National
Rainfed Area Authority
H. No. 262, First Floor
Sector 33 A, Chandigarh-160020

Dr. Ravinder Kaur
Project Director
Water Technology Centre

Dr. K.M. Manjaiah
Associate Dean, P.G. School

Dr. (Ms.) Irani Mukherjee
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. (Ms.) Pramila Agarwal
Professor, Agricultural Physics

Dr. (Ms.) Seema Jaggi
Professor, Agricultural Statistics

Dr. Y.S. Shivay
Professor, Agronomy

Dr. (Ms.) Archana Sachdev
Professor, Biochemistry

Dr. Anil Rai
Professor, Bioinformatics

Dr. (Ms.) Seema Jaggi
Professor, Computer Application

Dr. Subhash Chander
Professor, Entomology

Dr. H. Pathak
Professor, Environmental Sciences

Dr. S.S. Sindhu
Head & Professor, Floriculture and Landscaping

Dr. S.K. Jha
Professor, Post Harvest Technology

Dr. S.K. Singh
Professor, Fruits and Horticultural Technology

Dr. Vinod
Professor, Genetics

Dr. Sunil Pabbi
Professor, Microbiology

Dr. S.R. Bhat
Professor, Molecular Biology and Biotechnology

Dr. Anil Sirohi
Professor, Nematology

Dr. (Ms.) Rekha Chaudhury
Professor, Plant Genetic Resources

Dr. (Ms.) Pratibha Sharma
Professor, Plant Pathology

Dr. V.P. Singh
Professor, Plant Physiology

Dr. S.K. Jain
Professor, Seed Science & Technology

Dr. R.D. Singh
Professor, Soil Science & Agricultural Chemistry

Dr. T.K. Behera
Professor, Vegetable Science

Dr. Man Singh
Professor, Water Science & Technology

Dr. Anil Sirohi
Master of Halls of Residences

Mr. Sanchal Bilgrami
Comptroller

Dr. B.S. Tomar
Principal Scientist, Seed Science and Technology

Dr. Bhupinder Singh
Principal Scientist, CESCRA

Ms. Usha Khemchandani
Head, IARI Library

Mr. Bikram Jyoti
President, PGSSU

Mr. Abhijit Sarkar
Students' Representative to the Academic Council

Member –Secretary

Ms. Shashi Prabha Razdan
Registrar & Joint Director (Admn.)

Appendix 5

Members of Extension Council of IARI

(As on 12.6.2015)

Chairperson

Dr. Ravinder Kaur
Director (Acting),
IARI, New Delhi

Members

Dr. J.P. Sharma
Joint Director (Extension),
IARI, New Delhi

Ms. Shashi Prabha Razdan,
Joint Director (Admn.),
IARI, New Delhi

Dr. A.K. Singh
Head, Division of Genetics,
IARI, New Delhi

Dr. V.T. Gajbhiye
Head, Division of Agricultural
Chemicals, IARI, New Delhi

Dr. K.S. Rana
Head (Acting),
Division of Agronomy,
IARI, New Delhi

Dr. D.K. Yadava
Head, Division of Seed Sciece
& Technology, IARI,
New Delhi

Dr. Indra Mani
Head, Division of Agril. Engg.,
IARI, New Delhi

Dr. Sanjay Kumar
I/c Seed Production Unit,
IARI, New Delhi

Dr. S.S. Atwal
Head, IARI Regional Station,
Karnal-132001 (Haryana)

Dr. A.P. Saini
Joint Director (Agri.),
Delhi Development Deptt,
11th floor, MSO Building IP estate,
ITO, New Delhi-110002

Dr. K. Ponnusamy
Head, Dairy Extension Division,
NDRI, Karnal-132001(Haryana)

Dr. S.R. Kachru
Director (FI),
Directorate of Extension,
Krishi Vistar Sadan,
IARI Campus, New Delhi

Member-Secretary

Dr. Premlata Singh
Head (Acting), Division of
Agricultural Extension, IARI,
New Delhi

Appendix 6

Members of Executive Council of IARI

(As on 31.03.2015)

Chairperson

Dr. Ravinder Kaur
Director (Acting)

Members

Dr. K. V. Prabhu
Joint Director (Research)

Dr. R. K. Jain
Dean & Joint Director (Education)

Dr. J. P. Sharma
Joint Director (Extension)

Dr. Ravinder Kaur
Project Director, WTC

Head, Division of Microbiology

Dr. A. K. Singh
Head, Division of Genetics

Dr. Pritam Kalia
Head (Acting), Division of Vegetable Science

Head, Division of Entomology

Head, Division of Biochemistry

Head, Division of Agril. Engineering

Project Coordinator, Nematology

Head, Regional Station, Karnal

DDG (CS)
ICAR, Krishi Bhawan
New Delhi

Member – Secretary

Smt. Shashi P. Razdan
Joint Director (Admn.)

Appendix 7

Members of Institute Research Council (IRC)

(As on 31.03.2016)

Chairperson

Director, IARI

Co-chairperson

Joint Director (Research), IARI

Members

Deputy Director General (Crop Science), 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 8

Members of Institute Joint Staff Council (IJSC)

(As on 31.3.2016)

Chairman

Dr. Ravinder Kaur
Director (Acting)

Members (Official Side)

Dr. K.V. Prabhu
Joint Director (Research)

Dr. J.P. Sharma
Joint Director (Extension)

Dr. Alka Singh
Professor,
Agricultural Economics

Dr. Anil Sirohi
Professor, Nematology

Sh. Sanchal Bilgrami
Comptroller

Secretary (Official Side)

Smt. Shasmhi Prabha Razdan
Registrar & Joint Director (Admn.)

Members of Staff Side (Elected)

Sh. Satyendra Kumar
AAO, Division of Vegetable Science

Sh. Yogesh Kumar
Assistant, Division of Plant Pathology

Sh. Radhey Krishn Thakur
UDC, Directorate, IARI

Sh. Raj Kumar
UDC, Directorate

Sh. Veer Pal Singh
Technical Officer, CPCT

Sh. Ganesh Rai
Technical Assistant,
Division of Entomology

Sh. Shrawan Kumar
Technical Assistant, AKMU

Sh. Shiv Kumar Singh
Technical Assistant, Plant Pathology

Sh. Umesh Thakur
Skilled Support Staff,
Audit, Directorate

Sh. Raj Pal
Skilled Support Staff, Directorate

Sh. Shashi Kant Kamat
Skilled Support Staff, Seed Production Unit

Secretary (Staff Side)

Sh. Bijender Kumar,
Skilled Support Staff
CATAT

Appendix 9

Members of Grievance Committee of IARI

(As on 31.3.2016)

Chairman

Dr. J.P. Sharma
Joint Director (Extension)

Members (Official Side)

Dr. V.K. Singh
Head, Agronomy

Smt. Sanjeevan Prakash
CF&AO, Directorate

Sh. A.K. Maithani
Sr. Admn. Officer, Directorate

Members of Staff Side (Elected)

Dr. Jai Prakash
Senior Scientist, Fruits and Horticultural Technology

Sh. Brahm Dutt
Chief Technical Officer, Division of Microbiology

Sh. Pankaj
LDC, Audit, Directorate

Sh. Mohan Lal
Skilled Support Staff, Audit, Directorate

Member-Secretary

Sh. M.K. Chabra
AAO, Division of Agricultural Extension

Appendix 10

Personnel

(As on 31.03.2016)

Directorate

Director (Acting)
Dr. Ravinder Kaur

Joint Director (Research)
Dr. K.V. Prabhu

Dean & Joint Director (Education)
Dr. R.K. Jain

Joint Director (Extension)
Dr. J.P. Sharma

Joint Director (Admn.) & Registrar
Mrs. Shashi Prabha Razdan

Principal Scientist (PME)
Dr. I. Sekar

Incharge, Publication Unit (Eng.)
Dr. S.S. Sindhu

Comptroller
Mr. Sanchal Bilgrami

Chief Administrative Officers
Mr. K.K. Kulshrestha
Mr. P.K. Jain

Agricultural Chemicals

Head (Acting)
Dr. Irani Mukherjee

Professor
Dr. Irani Mukherjee

Network Project Coordinator
Dr. K.K. Sharma

Agricultural Economics

Head (Acting)
Dr. Amit Kar

Professor
Dr. Alka Singh

Agricultural Engineering

Head
Dr. Indra Mani

Professor
Dr. D.K. Singh

Agricultural Extension

Head (Acting)
Dr. Prem Lata Singh

Professor
Dr. Prem Lata Singh

Agricultural Physics

Head
Dr. P. Krishnan

Professor
Dr. Pramila Aggarwal

Agronomy

Head
Dr. V.K. Singh

Professor
Dr. Y.S. Shivay

Biochemistry

Head (Acting)
Dr. Archana Sachdev

Professor
Dr. Archana Sachdev

Entomology

Head
Dr. Chitra Srivastava

Professor
Dr. Subhash Chander

National Fellow
Dr. G.K. Mahapatro

Floriculture and Landscaping

Head
Dr. S.S. Sindhu

Professor
Dr. S.S. Sindhu

Fruits and Horticultural Technology

Head (Acting)
Dr. K. Usha

Professor
Dr. S.K. Singh

Genetics

Head
Dr. A.K. Singh

Professor

Dr. Vinod

Microbiology & CCUBGA

Head

Dr. Annapurna K.

Professor

Dr. Sunil Pabbi

Nematology

Head

Dr. Uma Rao

Professor

Dr. Anil Sirohi

Project Coordinator

Dr. Raman Kumar Wallia

Plant Pathology

Head

Dr. Rashmi Aggarwal

Professor

Dr. Pratibha Sharma

National Fellow

Dr. Rashmi Aggarwal

Plant Physiology

Head

Dr. C. Viswanathan

Professor

Dr. V.P. Singh

Food Science & Post Harvest Technology

Head (Acting)

Dr. Vidya Ram Sagar

Professor

Dr. S.K. Jha

Seed Science and Technology

Head

Dr. D.K. Yadava

Professor

Dr. S.K. Jain

Soil Science and Agricultural Chemistry

Head

Dr. B.S. Dwivedi

Professor

Dr. R.D. Singh

Vegetable Science

Head (Acting)

Dr. Pritam Kalia

Professor

Dr. T.K. Behera

Centre for Environment Science and Climate Resilient Agriculture (CESCRA)*

Head (Acting)

Dr. S.D. Singh

Professor

Dr. Himanshu Pathak

Water Technology Centre

Project Director

Dr. Ravinder Kaur

Professor

Dr. Man Singh

Centre for Agricultural Technology Assessment and Transfer

Incharge

Dr. B.K. Singh

Centre for Protected Cultivation Technology

Incharge

Dr. Neelam Patel

Agricultural Knowledge Management Unit (AKMU)

Incharge

Dr. A.K. Jain

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. Sanjay Kumar

Zonal Technology Management & Business Planning and Development (ZTM & BPD) Unit

Incharge

Dr. Neeru Bhooshan

IARI Library

Incharge (Library Services)

Ms. Usha Khemchandani

IARI Regional Station, Amartara Cottage, Shimla

Head (Acting)

Dr. K.K. Pramanick

IARI Regional Station, Indore

Head

Dr. S.V. Sai Prasad

IARI Regional Station, Kalimpong

Incharge

Dr. Sujit Sarkar

IARI Regional Station, Karnal

Head (Acting)

Dr. V.K. Pandita

IARI Regional Station, Katrain

Head

Dr. Raj Kumar

IARI Regional Station, Pune

Head (Acting)

Dr. S.K. Sharma

IARI Regional Station, Pusa

Head (Acting)

Dr. D.U.M. Rao

IARI Regional Station, Wellington (The Nilgiris)

Head

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. Anjani Kumar

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*Formerly Division of Environmental Sciences and including Nuclear Research Laboratory.