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वार्षिक प्रतिवेदन
Annual Report
2017-18

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कानपुर 208 024

ICAR-Indian Institute of Pulses Research
Kanpur 208 024

With best compliments from

Dr. N.P. Singh
Director

ICAR-Indian Institute of Pulses Research
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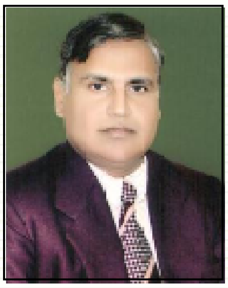
From the Director's Desk



It gives me immense pleasure to present the Annual Report (2017-18) of ICAR-Indian Institute of Pulses Research, Kanpur. I feel it is a privilege to lead a glorious institute like ICAR-IIPR which has made outstanding contributions in the service of the nation in agriculture sector and has set global standards in making pulses accessible and affordable. Despite many impediments and challenges towards scaling pulses production, the country has created a history by record production of pulses to the tune of 24 million tonnes. The present Annual Report of the Institute highlights the significant achievements made under different research, extension and training programmes.

During the year, two new varieties, IPL 220 of lentil and IPFD 2014-3 were released and notified for cultivation in NEPZ and CZ, respectively while lentil varieties, IPL 321 and IPL 315, mungbean varieties IPM 2K14-9 (Varsha) and IPM 302-2 (Kanika) and fieldpea variety IPFD 9-2 were released for notification for winter/spring in Uttar Pradesh. A large number of superior genotypes performed well in AICRP trials including IPC 2012-18 of chickpea, IPM 312-20, IPM 14-7, IPM 512-1 and IPM 410-9 of mungbean; IPL 233, IPL 234 (small seeded), IPL 339 (large seeded) of lentil, and IPF 16-18, IPF 16-13, IPFD 16-4 of fieldpea and were promoted to advanced varietal trial in different zones. For development of new genetic variability, a large scale pre-breeding programme has been initiated in all major pulses which is expected to lead to development of outstanding genotypes having resistance to multiple stresses, wider adaptability and superior yield performance. At the same time, research efforts have again been initiated in environmentally important crop like lathyrus and commercially important like rajmash. Recognizing the nutritional potential of underutilized pulses, breeding programmes have also been initiated in cowpea and horsegram.

Noteworthy progress has been made in genetic transformation of pulses with cry1Ac gene in chickpea and pigeonpea against pod borer. Event selection trial of five transgenic chickpea lines *viz.* IPCa2, IPCa4, IPCT3, IPCT10 and IPCT13 and five pigeonpea lines *viz.* IPCc1, IPCc2, IPPT2, IPPT12 and IPPT18 have been conducted at this Institute strictly adhering to directives provided by Review Committee on Genetic Manipulation and Genetic Engineering Appraisal Committee, ensuring biosafety compliance. Marker assisted breeding has been given impetus and programme on pyramiding multiple race resistance against *Fusarium* wilt in popular chickpea cultivar is on advanced stage. While MABC-developed race 2 resistant chickpea lines are under multilocation evaluation in AICRP trials, JG 16, another popular elite chickpea cultivar is being pyramided for races 1-5 against *Fusarium* wilt. MABC chickpea lines for *hotspot* QTLs introgression in background of DCP92-3 were evaluated for yield under drought conditions wherein yield advantage of MABC line over control was documented.

In Crop Production, whether it is upland or low land based cropping systems, inclusion of pulses invariably improved other critical soil parameters (water-stable aggregate, mean weight diameter, active C-pool, soil organic carbon and C management index) besides improving soil fertility and crop yield. Similarly, pulses did perform well in soybean + pigeonpea – lentil in soybean dominated Central India. As emphasized before, single supplementary life saving irrigation at around 55-60 DAS in lentils proved highly water productive leaving a possibility of further water saving through sprinklers. Regarding foliar supplementation, salicylic acid at 100 ppm or NPK 19:19:19 @ 0.5% at flowering & podding had favourable effect in rainfed condition. Initial trials on organic farming in long duration pigeonpea revealed adequate crop response to it. Five years trial on chickpea in rice fallow condition defined by zero tillage and unpuddled/direct seeding confirmed extended water availability of soil moisture besides scaling crop/water productivity when residues retained up to 30 cm height. New molecules of herbicide showed that clodinafop propargyl + Na-acifluorfen 122.5 g/ha in *Kharif* mungbean and topramezone 20.6 ml/ha in chickpea at 25 DAS are promising.

The need-based water and nutrients requirements of chickpea were worked out based on thermal and fluorescence imaging. Blackgram genotype SPS 29 has been identified as salt tolerant while IPU 99-1709, IPU 2-43, IPU 99-144, BG-367 of blackgram have shown to be potential sources of germplasm having attributes of photothermo-insensitivity. To develop efficient and regulated delivery of weedicides, nano-material based formulations of imazethapyr was prepared. High biological nitrogen fixation lines were identified in lentil genotype IC 428606, IC 428614, IC 429178, IC 428559 and IC 428607. The seed coat colour has been found to be associated with nutritional value of cowpea. The reddish-brown cowpea varieties (GC901 and PL3) have the maximum antioxidant activity.

In crop protection, seven chickpea germplasm *viz*., IC 269484, IC 209404, IC 248151, IC 209414, IC 269590, IC 270228 and IC 305590 were found resistant against wilt disease caused by *Fusarium oxysporum* f.sp. *ciceri*. Out of 1250 pigeonpea lines screened in the wilt sick field at IIPR Research Farm during *Kharif*, 2016-17 for identification of new sources of resistance against *Fusarium udum* (Race-2) causing wilt disease, 20 advanced breeding lines were found resistant. Five lines have been recommended for registration as donors for wilt and four lines for Phytophthora stem blight. Based on reaction of seven differential genotypes of pigeonpea, isolates of *F. udum* were categorized into five distinct races present all over the country. One accession of *Vigna trilobata* (IC 331454) was found highly resistant, whereas one accession of each *V. stipulaceae* (LMR/13-36), *V. trilobata* (TCR-86) and *V. umbellata* (IC 251442) was found resistant. *M. javanica.* Whole genomes of Pigeonpea sterility mosaic virus 1 and Pigeonpea sterility mosaic virus 2 were successfully amplified the target fragment (coat protein gene) and sequenced.

Bioassay of extra cellular metabolites of actinomycetes isolates AIN 10, AIN 12, AIN 16 and AIN 23 showed high insecticidal property as indicated by 80 per cent mortality of second stage larvae of *H. armigera*. One hundred isolates of *Trichoderma* spp. were isolated from rhizosphere of different pulse crops. Based on ITS sequences revealed four different species of *Trichoderma* i.e. *T. harzianum, T. asperellum, T. longibrachiatum* and *T. ressei*. five isolates of *Trichoderma viz*., PPNM-6, IIPR-75, IIPR-68, IIPR-80 and PPIIPR-2 showed maximum antagonistic activity against *Rhizoctonia bataticola.* Fifteen isolates of *Trichoderma* spp. *viz.*, IIPR-2, IIPR-6, IIPR-8, UCK-2, PPF1-1, PPF1-4, SMF, TLKP-1, PPIIPR-2, MLKP-1, TLKP-2, PPKP-1, MLF-2, PPNM-3, and TLF-2 were identified to possess high chitinase activity.

Upliftment of the socio-economic status of the farmers, especially those belonging to selected tribal districts of Madhya Pradesh and Chhattisgarh is one of the focus areas of ongoing extension programmes at IIPR. During 2017-18, 230 *Kharif* technology demonstrations on pigeonpea and urdbean and 340 *R*abi demonstrations on chickpea, fieldpea and lentil were conducted in tribal areas of M.P. and Chhattisgarh in collaboration with KVKs. In addition, 1077 farmers and 173.44 ha area were covered under Farmer FIRST project and all the adopted farmers were registered for Dalhan Sandesh Portal. ICT based interventions have been adopted by this Institute for quick dispersal of IIPR technologies. Voice SMS based advisories service "*Dalhan Sandesh*" was extended to 2839 farmers from Jalaun, Fatehpur, Chitrakoot, Hamirpur, Kanpur Dehat, Ballia, Kanpur Nagar districts of Uttar Pradesh thereby linking experts to farmers directly and 82,886 customized advisories have been sent till date on different pulse crops.

Besides International collaboration with ICRISAT, ICARDA and World Vegetable Centre, the Institute is presently hosting 46 plus externally funded projects in frontiers areas of pulses research from DBT, DST, ICAR National Fund, Bill and Melinda Gates Foundation, ACIAR, UPCAR and many others. The Institute has identified major R&D issues as per the recommendations of the RAC which are being addressed with integration of conventional approaches with cutting edge technologies such as genomics, transgenics, molecular breeding, quality improvement, resource conservation, biotic and abiotic stress management.

The overall growth and development of the Institute was possible with the able guidance, encouragement and continuous support received from Dr. T. Mohapatra, Director General, ICAR and Secretary, DARE, Dr. J.S. Sandhu and Dr Anand Kumar Singh, Deputy Directory Generals (Crop Science), Dr. B.B. Singh and Dr S.K. Chaturvedi, Ex-ADGs (O&P), ICAR, which I acknowledge with sincere gratitude and reverence.

I appreciate the efforts of all the Project Coordinators, Drs. I.P. Singh, G.P. Dixit, Sanjeev Gupta, Shiv Sevak , P.K.Singh and all Heads of Divisions, Drs. Krishna Kumar, Shiv Sevak P.S. Basu, C.S. Praharaj, Rajesh Kumar and (Mrs.) Meenal Rathore for research inputs. I am thankful to the members of Publication Committee, Drs. Krishna Kumar, P.S. Basu, Aditya Pratap, Mohd. Akram, (Mrs.) Meenal Rathore and Rajesh Kumar Srivastava for their praiseworthy efforts in bringing out the Report in time as usual. Last but not the least, I am thankful to all my staff and their families who are supporting and contributing to the progress of the Institute in the service of the nation.

(N.P. Singh)

Contents

Executive Summary

Crop Improvement

- Biofertilized lentil variety IPL 220 having higher concentration of Fe and Zn was released and notified for cultivation in NEPZ. A mottled, tan colour large seeded dwarf fieldpea variety IPED 2014-3 was released for central zone of the country.
- Lentil varieties IPL 321 & IPL 315, mungbean varieties IPM 2K14-9 (Varsha) & IPM 302-2 (Kanika) and fieldpea variety IPFD 9-2 were released for Uttar Pradesh.
- Mungbean varieties IPM 312-20, IPM 409-4, IPM 312-09, lentil variety IPL 225 (small seeded) and fieldpea variety IPF 11-13 were found promising in Uttar Pradesh State Varietal Trials.
- A number of entries performed well in AICRP trials. IPC 2012-18 of chickpea, IPL 233, IPL 234 (small seeded), IPL 339 (large seeded), IPM 312-20, IPM 14-7, IPM 512-1, IPM 410-9 of mungbean IPF 16-18, IPF 16-13, IPFD 16-4 of field-peas were promoted to advanced varietal trials in different zones. Eight entries of chickpea and four each of mungbean, pigeonpea, fieldpea and lentil were evaluated in IVT of AICRP of respective crops.
- Tall and erect lines namely IPC 2014-28, IPC2010-107, IPC 2006-27, IPC 2015-58, IPC 2014-100, IPC 14-10, IPC 2015-54 were found promising and gave yield of more than 20 q/ha.
- Forty three advanced breeding lines having WR 315 (*Fusarium* wilt resistant) and JG 2003-14 (DRR resistant) were evaluated. Lines *viz.,* DR 1541, DR 1505, DR 1540, DR 1501 and DR 1510 were found to be resistant against wilt and IR 1513, DR 1504, DR 1542 and DR 1543 were moderately resistant against DRR.
- Genetic purification of T 39-1 (donor for high protein content) lead to isolation of two genotypes. These genotypes showed semi spreading canopy at vegetative stage. One of these genotypes also possess double pod trait.
- In pigeonpea, a vegetable type genotype IPAV 16-1 having seed weight of 23.65 g/100 seeds and water logging tolerant line IPAC 79 were identified. The line IPAC 66, IPAC 67, IPAC 68 and vegetable type extra large seeded lines IPAV 16-1, IPAV 16-5, IPAV 11b, IPAV 16-17, IPAV 16-22 were found resistant against *Fusarium* wilt disease. In the investigation of genetic diversity and population genetic structure of 41 elite lines of mungbean, STRUCTURE analysis identified three distinct genetic groups and revealed that there was clear improvement in 100 seed wt., pod length, seeds per pod and plant height in elite lines developed after year 2000. The grouping pattern was also supported by the factorial and UPGMA analysis.
- Forty eight fresh crosses in desi chickpea, 12 in *Kabuli* chickpea, 22 in pigeonpea, 16 in lentil, 26 single crosses and 3 two way crosses in mungbean, 15 in urdbean and 23 in rajmash were attempted to widen the genetic base and generate the breeding materials.
- In mungbean, mapping populations 229 $F_{6/7}$ RILs for yellow mosaic disease derived from the crosses IPM 2-14/TMB-37 and 189 $F_{6/7}$ RILs derived from the cross PDM-139/TMB- 37 were maintained. In lentil trait specific RIL mapping populations for early seedling vigour (ILL 7663 × DPL 15) having 160 RILs; root traits (IPL 98/193 × EC 208362) having 200 RILs; earliness (L 4603 x Precoz) having 160 RILs and wilt resistance (PL-02 x Precoz) having 160 RILs have been maintained. In fieldpea also, F_{1s} (220) derived from HFP 4(S) x FC 1 (R) for rust resistance have been harvested for further advancement.
- In chickpea, 400 germplasm and 119 accessions of 6 wild species were maintained, while in pigeonpea, 250 long duration 189 early duration and 57 wild accessions, in lentil 250 accessions, in fieldpea 450 accessions, in mungbean 215 accessions, in urdbean 312 accessions and in Rajmash 510 accessions were rejuvenated and maintained.
- The highest germination percentage (48%) was recorded when seeds of *Kabuli* chickpea variety Kripa was stored in hermetic polythene bags after 20 months of storage and minimum (6%) was recorded in gunny bags. Less than 10% pre-harvest sprouting was noted in thirteen germplasm lines (PLU 662, NO 7668-43, IPU 99-95, IPU 99-247, IPU 8, PLU 302, IPU 99-221, LBG 20, CN 3515, BG 367, PKJU 1, PLU 65, NPU 302) five accessions (IC 276983, IC349701, Trichy local 1, LRM/ 13-33 and LRM/ 13-26) of *Vigna trilobata* and one accession (IC 251440) of *Vigna sublobata* recorded no pod loss due to PHS with 0% fresh seed germination (2.5% in *V. sublobata*).
- The nucleus seed of pigeonpea variety IPA 203, lentil varieties DPL 15, DPL 62, IPL 316, IPL 256, IPL 81, IPL 406 and IPL 220; mungbean varieties Shikha, Virat, Neha, Samrat, IPM 2-3 and IPM 2-14, urdbean varieties IPU 02-3 and IPU 94-1,

fieldpea varieties Adarsh Aman, Vikas, Prakash, IPFD 10-12, IPF 4-9, IPFD 6-3, IPFD 11-5 and IPFD 12-2 and Rajmash varieties PDR 14, Arun, Utkarsh & Amber was produced. A total of638.48 q of breeder of different pulse varieties was produced.

- To pyramid genes for multiple resistance to races 1, 2 3 and 4 of *Fusarium oxysporum* f.sp. *ciceri* causing *Fusarium* wilt in elite chickpea cultivar JG 16, the elite genotypes *viz.,* Vijay and WR 315 were used as the donors for introgressing the genes of interest. The BC_1F_1 progenies of the crosses JG 16 X WR 315 and JG 16 X Vijay were subjected to foreground selection using linked markers and true heterozygotes were identified.
- Eight hybrid entries were selected for testing in trial using two check varieties Pusa 992 and PAU 881. The days to maturity varied from 141 (PAU 881) to 210 days (BDNPH 15-01 and BDNPH 15-02). Concerning yield superiority, four hybrids PAH 3, BDNPH 15-01, IPAH 16-06 and BDNPH 15-02 showed more than 20% yield superiority over the best check *i.e.* Pusa 992.
- Ten pigeonpea lines (AL 15, ICP 7148, AL 201, Pusa 2002-2, MN 5, ICP 88034, ICP 20338, ICP 11255, ICP 20340, PAU 881) are under different stages of CMS conversion. Fresh crosses were attempted to covert ten lines of extra short duration (ICPL 11244, ICPL 11276, ICPL 11279, ICPL 11292, ICPL 11301,ICPL 11326, ICPL 20325, ICPL 20326, ICPL 20327 and ICPL 20329) into male sterile genotypes.
- Twelve F_1 crosses were attempted during 2017-18 with aim to incorporate earliness and high yield. Four crosses involved wild accessions for developing pre-breeding materials viz., UPAS 120/ICP 15685-2 (*C. scaraboides*), UPAS 120/ICP 15763 (*C. sericius*), Pusa 992/ICP 15642 (*C. lineatus*), Pusa 992/ICP 15685-2 (*C. scaraboides*).

Plant Biotechnology

- Conducted event selection trial of five transgenic chickpea lines *viz.* IPCa2, IPCa4, IPCT3, IPCT10 and IPCT13 (Trait: Insect Resistance) at main research farm (Plot No. 5/2) of ICAR-Indian Institute of Pulses Research, Kanpur, strictly adhering to directives provided by Review Committee on Genetic Manipulation [Permit Letter: BT/BS/17/221/2007-PID dtd 15.05.2017] and Genetic Engineering Appraisal Committee [File No. C-12013/5/2016-CS-III], ensuring biosafety compliance (Date of sowing: 18th November, 2017 and date of termination/harvest: 23rd March, 2018).
- Conducted event selection trial of five transgenic pigeonpea lines *viz.* IPCc1, IPCc2, IPPT2, IPPT12 and IPPT18 (Trait: Insect Resistance) at main research farm (Plot No. 5/2) of ICAR-Indian Institute of Pulses Research, Kanpur, strictly adhering to directives provided by Review Committee on Genetic Manipulation [Permit Letter: BT/BS/17/221/2007-PID dtd 15.05.2017 and BT/BS/17/221/2007-PID dtd 22.06.2017] and Genetic Engineering Appraisal Committee [File No. C-12013/4/2016-CS-III], ensuring biosafety compliance (Date of sowing: 14th July, 2017 and date of termination/harvest: 4th April, 2018).
- Transgenic chickpea and pigeonpea lines grown in Event Selection Trial were characterized in terms of trait efficacy, presence of transgene, expression of BT and NPTII protein during vegetative and reproductive stages at various tissues, presence of vector backbone and agronomic characteristics including yield.
- MABC chickpea lines for *hotspot* QTLs introgressed lines in background of DCP 92-3 were evaluated for yield under drought conditions wherein yield advantage of MABC line over control was documented.
- Identified 30 polymorphic SSRs markers between heat tolerant and susceptible chickpea crosses and also identified polymorphism in upstream region of one of the chickpea sucrose synthase gene using agarose gel electrophoresis. Also, 57 microRNA gene based SSR markers have been developed in chickpea and utilized in genetic diversity study of *Cicer* sp.
- Gene based markers (Intron length Polymorphism) (152 nos.) for starch pathway genes in chickpea have been developed.
- A Co-functional network of 14 genes, namely Ca_08086, Ca_19657, Ca_01317, Ca_20172, Ca_12226, Ca_15326, Ca_04218, Ca_07256, Ca_14620, Ca_12474, Ca_11595, Ca_15291, Ca_11762 and Ca_03543 was identified. The role of the network gene modules in plant fungal interactions has been further explored by studying their expression pattern in transcriptome studies of chickpea– *Fusarium* interactions available in public domain.
- The cry_1Ac and cry_2Aa genes have been cloned downstream of the modified pod specific promoter along with terminator sequences and their orientation has been confirmed. cry_2Aa gene cassette has been sub-cloned into the marker free binary vector and sub-cloning of cry_1Ac gene cassette is in progress.
- Of the different explants tried for regeneration, double cotyledonary node with extended hypocotyl was identified to regenerate clearly

visible and longer shoots in greengram cultivars Samrat and SML668.

- The desired gene(s) *tma 12* and *nptII* have been independently subcloned into pRI201AN vector to develop two - vector system for future co transformation attempts and development of marker free transgenic plants. The independent constructs have been confirmed by restriction digestion and sequencing.
- Full gene structure of grasspea oxalyl CoA synthetase gene has been identified.
- Phenotyping for wilt resistance is ongoing and isolated DNA from F_2s derived from Bahar (S) and KPL 43 (R) cross for genotyping with polymorphic SSRs is planned.

Crop Production

- The effect of different rice based crop rotation on *Kharif* rice yield was prominent after 13 years of crop rotation with the highest rice yield under rice-wheat-mungbean. Pulse inclusive rotations improved the water-stable macro-aggregate (WSMA) in both surface (0-0.2) and subsurface (0.2-0.4) soil depths. Pulse inclusive rotations led to higher ($p<0.05$) aggregate ratio (AR), mean weight diameter (MWD), and geometric mean diameter (GMD) over RW rotation, being the highest in RWMb rotation. The higher active C-pool (8.5-18.1%), SOC (5.9-16.8%), and C management index (5.2-7.3%) were observed in pulse inclusive rotations.
- The yield of cereal crops (maize, *bajra*, and wheat) was registered higher under RDF. In contrast, the performance of pulse crops was better under INM. However, the highest grain yield of maize/*bajra* and wheat (6.3 t/ha) was recorded under MWMb system with the application of inorganic fertilizer. Based on the system productivity, MWMb rotation had the highest pigeonpea equivalent yield, while among the nutrient management practices, the system productivity (PEY) was found in the order of RDF > INM > CT.
- The MWMb and PW cropping systems and INM resulted in higher mean weight diameter (MWD) in surface soil. Also, adoption of INM caused higher macro-aggregate over balanced RDF.
- Estimation of soil P mineralizing enzymes under pigeonpea-wheat system suggested that the highest acid phosphatase and alkaline phosphatase activity (g p-nitrophenol/g soil) noticed at harvesting stage both in pigeonpea and wheat.
- On intercropping with diverse crops/seasons/productivity, a three years study concluded that significantly higher total productivity and returns were observed with soybean + pigeonpea – lentil in Bhopal and adjoining regions of M.P. in Central India.
- Following appropriate land configuration (broad bed and furrow, BBF) in the heavy soils of Central India, productivity of soybean could be further enhanced with BBF (*vis-à-vis* flat planting). Supplementary irrigation once to lentil at flowering could be economical in absence of rainfall during *rabi* season. Similarly, seed priming (for 4 hours) in lentil was useful under rainfed condition.
- Ammonium molybdate at 1 g/kg seed treatment + 25 kg $ZnSO_4$ ha^{-1} should be fertilized to soybean in soybean-chickpea system in Central India. Addition of 5 t FYM/ha could be best for Central Zone condition for soybean-chickpea system.
- On sprinkler irrigation combined with improved agro-techniques, it was concluded that row spacing of 22.5 cm was optimum over both farmers' practices of 30 cm and narrow spacing of 15 cm). Sprinkler irrigation in late evening hours was useful due to 32% less water use, 70% higher water use efficiency (WUE), 70% higher water productivity (WP), increased net return of ₹ 10106 and BCR by 0.13 over flood irrigation applied by farmers.
- Effect of hydrogel at 2.5-5 kg/ha were not pertinent in chickpea 'JG 16' while it was apparent with nutrient solution of urea/NPK spray and salicylic acid or thiourea spray. Maximum yield was obtained however with salicylic acid at 100 ppm followed by NPK (19:19:19) at 0.5% applied at both flower initiation and pod development stages.
- Long duration pigeonpea yields a maximum of 19.5 q/ha under organic cultivation which was comparable to that of chemical farming. The study also revealed that pulses (pigeonpea) responded well to organics more than inorganic ones. If seeds are not a constraint, row spacing of 75 × 20 cm could give additional yield in this long duration pigeonpea, especially in alluvial soils.
- In a long term conservation agriculture (CA) study, higher system productivities in terms of chickpea equivalent yield (CEY) was recorded in zero-tillage (5.9%), residue retention (9.5%) and in rice-chickpea-mungbean cropping system (56.4%) over conventional tillage, no residue and rice-wheat, respectively. Further, 79.9% improvement in system productivity along with similar trend in economics and sustainability were recorded in CA over conventional practices.
- Improvement in soil physical, biological, and

chemical properties was also recorded under CA over conventional practice. Soil aggregation and C-pool also showed positive improvement under CA.

- Among the different mungbean cultivar, the sequence for grain yield under CA was Virat (IPM 205-7) > Samrat > IPM 2-3 > HUM 16 > IPM 2-14.
- Changes in rhizospheric soil properties varied largely with different urdbean genotypes. Genotype MASH 1 had higher rhizospheric alteration, which was attributed to higher above ground biomass and root growth attributes. The changes in soil available-P, available-S and pH ranges from 0.3–33.0%, 0.2–9.4%, 0.1–4.1%, respectively.
- Significant response of chickpea crop to supplemental N application at nodule degeneration stage was observed. An additional yield of 417 kg/ha could be achieved with application of 25 kg N/ha. The increased yield with application of N was attributed to increase in leaf weight, grain filling, and test weight.
- The grain yield of Rajmash (*Rabi* Rajmash in Northern Plain Zone) increased significantly up to N rate of 120 kg/ha.
- Based on system productivity 33 kg P to rice and 11 kg P to lentil had the higher system productivity [rice equivalent yield (REY) 9.6 t/ha] closely followed by the treatment 16.5 kg P to rice and 5.5 kg P to lentil with rice residue and PSB (REY 9.5 t/ha). The grain yield of lentil crop was found higher after DSR than SRI and PTR plots.
- Unpuddled rice/direct seeded rice, foliar nutrition of micronutrients and 2% urea in combination could be suggested for achieving higher yield in chickpea under rice fallows.
- Appropriate crop management practices amalgamated with RCTs (retention of 30 cm rice stubbles, zero tillage and appropriate rice establishment method viz., unpuddled transplanting/direct seeding) could play a key role in scaling crop productivity in rice fallow.
- Butachlor 1.25 kg/ha or pendimethalin 1 kg/ha followed by (fb) bispyribac-Na 20 g/ha in rice and pendimethalin 1 kg/ha fb quizalofop-p-ethyl 100 g/ha in chickpea had significantly higher weed control efficiency and grain yield over others.
- Clodinafop propargyl + Na-acifluorfen 122.5 g a.i./ha in *Kharif* mungbean and topramezone 20.6 ml/ha in chickpea had minimum phyto-toxicity and higher weed control efficiency in mungbean and chickpea under alluvial soil.
- Substantial improvement in system productivity in terms of chickpea equivalent yield (45.33 q/ha) were observed under maize+urdbean intercropping system. Further, application of CFG4 to chickpea recorded highest CEY (50.52 q/ha).
- Application of 125% dose of CFG being on par with 150% CFG, statistically enhanced nodulation in mungbean, urdbean and chickpea over RDF applied through straight fertilizers (RDF-SF) and control. Customized fertilizers give higher productivity and nutrient use efficiency over straight fertilizers.
- Application of Matar formula (13.3:20:10:8.3:1.3; N:P:K:S:Zn); a locally prepared fertilizer formulation to field pea genotypes (Aman, IPFD 10-12, IPF 4-9, Prakash and Vikas) recorded higher grain yield (11-28%) farmers practice and RDF through straight fertilizers.
- Foliar spray of multi-nutrient supplement to chickpea enhanced grain yield (17.6 q/ha) of chickpea to the tune of 12.3 per cent higher over foliar spray of urea (2% solution). Further, yield increment due to foliar spray of multi-nutrient supplement was higher in JG 16 compared with local.
- Seed coating of chickpea using zinc oxide upto 7.5% by seed weight, enhanced seed yield by 16.7% in HC5 and 14.7% in JG 17 over no coating or control. Similarly, yield increment due to seed coating with zinc oxide upto 7.5% also observed to the tune of 19.9 and 17.4% in IPFD 11-05 and IPFD 11-10, respectively. Moreover, seed coating of chickpea and fieldpea with ZnO upto 7.5% had no toxicity and mortality effect.
- Among various chickpea genotypes, IPC 10-142, IPC 11-85 and HC 5 are having branch angle above 60° with more than 30 cm podding height and are suitable to mechanical harvesting including combine harvester. Further, these chickpea genotypes IPC 10-142, IPC 11-85 and HC 5 recorded poding height of 46.52, 38.38 and 36.87 cm, respectively.

Crop Protection

- Seven chickpea germplasm lines *viz.*, IC 269484, IC 209404, IC 248151, IC 209414, IC 269590, IC 270228 and IC 305590 were found resistant against wilt disease caused by *Fusarium oxysporum* f.sp. *ciceri*.
- Of the 349 accessions of chickpea screened against *Ascochyta* blight, three accessions *viz.*, IC 2792, IC 117744 and IC 305587 showed resistant reaction, whereas 15 accessions showed moderately resistant reaction.

- Among 150 genotypes/cultivars screened against *Ascochyta* blight, genotypes PBG 5, HC 1, GNG 1958, GNG 1581, ILC 482, ILC 3279 were found resistant.
- Six accessions of wild chickpea *viz.*, ILWC 182, ILWC 188, ILWC 185, ICC 17151, ILWC 31 and ICC 17207 were found resistant against *Botrytis* grey mold caused by *Botrytis cinerea* under laboratory/ green house conditions, whereas 19 accessions showed moderately resistant reaction.
- Four fungicides- captan, chlorothalonil, bitertenal, and carbendazim at 500 ppm were found effective against *A. rabiei* whereas carbendazim and captan at 500 ppm concentration were most promising against *B. cinerea*.
- Of the 106 isolates of *Trichoderma* spp. recovered from the rhizospheric soils of pulses and oilseed crops, 5 isolates of *Trichoderma viz.*, PPNM-6, IIPR-75, IIPR-68, IIPR-80 and PPIIPR-2 showed maximum antagonistic activity against *Rhizoctonia bataticola*.
- Eight isolates of *Trichoderma* spp., IIPRCK-2, UCK-2, KB-PP, CH-CK-1, IIPR-74, IIPR-59, PPF2-1 and IIPR-81 were found tolerant to high salt (NaCl) concentration (10%) whereas IIPR-74 and IIPR-59 identified heat tolerant (40°C).
- Fifteen isolates of *Trichoderma* spp. *viz.,* IIPR-2, IIPR-6, IIPR-8, UCK-2, PPF1-1, PPF1-4, SMF, TLKP-1, PPIIPR-2, MLKP-1, TLKP-2, PPKP-1, MLF-2, PPNM-3 and TLF-2 were identified to possess high chitinase activity.
- A total of 1250 pigeonpea lines were screened in the wilt sick field at IIPR Research Farm during *Kharif*, 2016-17 for identification of new sources of resistance against *Fusarium udum* (Race-2) causing wilt disease of pigeonpea. Pigeonpea variety, Bahar used as susceptible check showed 100% mortality.
- Twenty advanced breeding lines *viz*. IPAC-66, IPCA-67, IPAC-68, IPA10W-2-9, IPA10W-14, IPA10W-3-8, IPA10W-12, IPA10W-18, IPA10W1-8, IPA10W 20-2, IPA10W 20-4, IPA10W 2-0-1, IPA10W 4-10, IPAc-68-6, IPA 16-6, IPA 16-2, IPA 17-1, IPA 17-2, IPA 17-4 and IPA 17-5 were found resistant against wilt disease caused by *Fusarium udum*.
- Eighteen lines of vegetable type pigeonpea (IPAV 16-3, IPAV 16-4, IPAV 16-10, IPAV 16-11C, IPAV 16-12, IPAV 16-12-2, IPAV 16-17E, IPAV 16-18A, IPAV 16-19 B-1, IPAV 16-19B-3, IPAV 16-19B-4, IPAV-16-21, IPAV-16-22, IPAV 16-22-1, IPAV 16-22A, IPAV 16-22B, IPAV 16-24 and IPAV 16-22C) were found resistant against wilt.
- Out of 31 genotypes received from ICRISAT, 7 (ICPWS-1618, ICPWS-1619, ICPWS-1620, ICPWS-1627, ICPWS-1615, ICPWS-17 and ICPWS-1611) were recorded as resistant with 0-10% wilt incidence.
- Twelve pigeonpea genotypes (DPPA 85-3, DPPA 85-5, DPPA 85-7, DPPA 85-8, DPPA 85-11, DPPA 85-12, DPPA 85-13, DPPA85-14, DPPA 85-16, IPA-38, IPA 16F and IPA 15F) were found resistant to wilt disease caused by *F. udum*.
- Reaction of 29 genotypes of pigeonpea *viz.* KPL 44, ICP 8862, KPL 49, IPA 38A, IPA 38B, GPS 33, BSMR 736, BSMR 853, KPBR 80-2-1, PI 397430, KPL 43, IPA 40, Sujatha, ICP 8858, IC 8859, Banda Palera, BWR 377, ICP 89046, ICP 93812, ICP 89048, ICP 89049, ICP 14722, ICP 9174, ICP 93011, AWR 74/15, JAW 5-6A, BDN 1, BDN 2, ICP 8863 used as donors for wilt resistance indicated stability of resistance.
- A total of 79 wild accessions of different species of *Cajanus* (*C. scarabaeoides*, *C. platycarpus*, *C. cajanifolius*, *C. lineatus*, *C. sericeus*, *C. volublis*, *C. albicans* and *C. viscibo*) and five species belonging to *Rhynchosia* (*R. aurea*, *R. bracteata*, *R. rothii*, *R. rufescens* and *R. minima*) were screened for resistance against wilt pathogen, *Fusarium udum*.
- Twenty wild accessions of different species of *Cajanus* and *Rhynchosia* were identified as resistant to wilt disease caused by *F. udum*.
- Based on reaction of seven differential genotypes of pigeonpea, isolates of *F. udum* were categorized into five distinct races.
- Eleven pigeonpea genotypes *viz.*, IPAC-79, IPAPB 7-2-1-7, IPAPB-7-2-1, KPBR-80-2-1, IPAC-3, IPAC-2, IPA15-01, IPAC 68-4, IPA 15-07, IPA16E-7 and AL-201-A were identified as resistant against *Phytophthora* stem blight (PSB) showing disease incidence between 5.4-10 per cent.
- Seven genotypes of mungbean (IPM 302-2, IPM 410-3, IPM 205-7, IPM 312-19K, IPM 02-03, IPM 312-90K and IPM 312-17) showed resistance against yellow mosaic disease caused by MYMIV for third consecutive year.
- Based on results of three consecutive years, fourteen urd bean genotypes (IPU 13-6, IPU 12-19, IPU 13-3, IPU 11-2, IPU 13-11, IPU 13-5, IPU 11-6, IPU 09-13, IPU 2-33, IPU 13-9, IPU 9-26, IPU 01-117, IPU 99-1 and IPU 96-6) were identified as resistant against MYMIV.
- More than 70% plant mortality in lentil wilt sick was recorded in wilt susceptible genotypes of lentil, namely K 75, Sehore 74-3 and L 9-12. The plot may now be used for phenotyping lentil

genotypes against wilt disease.

- Rajmash genotypes *viz.* EC-150250, GPR-203, EC-541703, EC-400414, BD-9116291, IC 84607 and EC-31084 showed resistant reaction against *Bean common mosaic virus* both under field as well as artificial sap inoculations.
- In reverse transcriptase PCR, three pairs of primers successfully amplified the desired fragments of CpMMV from crinkle affected leaves of urdbean.
- Whole genomes of Pigeonpea sterility mosaic virus 1 and Pigeonpea sterility mosaic virus 2 were assembled from the deep sequencing data.
- Of the four pairs of primers tested, only one primer pair- PSMV-cpf-*5'*ATGCCTCCAAAGATGCCA TCT3'/ PSMV-cpr- 5'TTACTCCTTTAAAG ATTTCAAAG3' successfully amplified the target fragment (coat protein gene) of PPSMV 1.
- Bioassay of extra cellular metabolites (ECM) of actinomycetes isolates AIN 10, AIN 12, AIN 16 and AIN 23 showed high insecticidal property as indicated by 80 per cent mortality of second stage larvae of *H. armigera*.
- Forty one genotypes/lines of pigeonpea, 69 of chickpea, 18 of mungbean, 15 of urdbean, 29 of lentil and 19 of fieldpea and 28 accessions of wild relative of *Vigna* were evaluated for resistance against root knot nematode, *M. javanica*. One pigeonpea genotype (ICP 15-701) was found highly resistant whereas nine genotypes namely, DPPA-85-12, DPPA-85-8, DPPA-85-1, DPPA-85-13, GRG-177, PA 440, PA414, PA 291, AKTM 1012 were resistant. Two lines of chickpea (GLK 28127 and GNG 2281), one line of lentil (LL 1397) and one of fieldpea (Pant P 250) were found resistant.
- One accession of *Vigna trilobata* (IC 331454) was found highly resistant, whereas one accession of each *V. stipulaceae* (LMR 13-36), *V. trilobata* (TCR 86) and *V. umbellata* (IC 251442) was found resistant to *M. javanica.*
- Grain yield and protein contents of grains were reduced with the increase in the inoculum level of *H. cajani* in urdbean variety Uttara.
- *Heterodera cajani* cysts stored in dry and moist soil were found to lose viability after four years of storage as indicated by the absence of hatching in cysts stored in dry and moist soil kept in net house and lab.
- Application of neem cake @ 1000 kg/ha significantly reduced cysts population in urdbean.
- In cropping sequence trial, the cyst population in the soil was reduced by 47.8% after linseed.
- Of the 21 isolates of *Trichoderma* spp. tested against *Meloidogyne* spp., isolates T 1, T 13, T 17 and T 21 were found best in reducing egg hatching compared to control and isolates T 1, T 5, T 9 and T 21 were best in causing higher juvenile mortality compared to control.
- Two isolates of *Paecilomyces lilacinus* were isolated and tested against *Meloidogyne* for their biocontrol potential. Both the isolates were found potential in reducing egg hatching and causing higher juvenile mortality compared to control.
- Out of 150 soil samples collected from different places of Uttar Pradesh, only 12 samples yielded entomopathogenic nematodes. Based on morphological and pathological characters, the EPNs from 11 samples were identified as *Steinernema* and one sample yielded *Heterorhabditis.*
- Of the 350 PGPR isolates recovered from rhizospheric soil of pulses and other crops, 270 isolates were screened. Thirty five isolates showed positive chitinolytic activity and 50 isolates showed positive phosphate solubilisation. Two isolates *viz.* IIPRSBLN-7 and IIPRBTCP-14 were found to have both phosphate solubilisation as well as chitinolytic activity. Majority of chitinase producing PGPR isolates were obtained from chickpea rhizosphere.
- One hundred isolates of *Trichoderma* spp. were isolated from rhizosphere of different pulse crops. Based on ITS sequences revealed four different species of *Trichoderma i.e. T. harzianum, T. asperellum, T. longibrachiatum* and *T. ressei.*
- Out of 30 PGPRs (*Pseudomonas* and *Bacillus* sp.) isolated from rhizospheric soil of pulses, 9 isolates were highly antagonistic against *F. udum*.
- Out of 44 isolates belonging to different species of *Trichoderma, viz. T. asperellum, T. harzianum, T. longibrachiatum* and *T. ressei*, one isolate of *T. harzianum* (T 8) was found tolerant to high tempearature (40^{0}C) and high salt (10%).
- Using specific primers in PCR, involvement of MYMIV was confirmed in yellow mosaic disease affected samples of mungbean from Pantnagar, Kanpur and New Delhi. One sample from New Delhi, however, showed association of MYMV. Yellow mosaic affected mungbean samples from Vamban revealed association of MYMV, whereas yellow mosaic affected samples of horsegram from Coimbatore had infection of HgYMV.
- Both components of (DNA A and DNA B) of MYMIV, MYMV and HgYMV genomes have been cloned, sequenced and characterized for developing infectious clones.
- A total of 77 root knot nematode infected

rhizospheresoil and plant samples were colected. Out of which, three samples from Varanasi and two samples from Salem were found having bacterial attachments on juveniles (of root knot nematodes).

Basic Science

- Based on the physiological constraints limiting pulse productivity, various strategies were made to mitigate abiotic stresses, identification of promising donors for developing tolerant varieties, agrotechniques for enhanced seed germination, minimizing photo-thermoinsensitivity and deciphering biochemical mechanisms of heat tolerance.
- The non-invasive techniques were standardized for assessing physiological efficiency of chickpea based on thermal imaging, leaf pigments and gaseous exchange measured through Infra red gas analyzer. The data will be useful to assess need-based water and nutrient requirement of pulses.
- About 50 prospective lentil germplasm lines were identified as putative heat tolerant under field screening based on podding efficiency and grain filling which needs further confirmation.
- Urdbean genotype SPS 29 appeared to be relatively tolerant to salt stress based on the least leaf necrosis at higher level of salinity 5EC and maintaining higher photosynthetic activity.
- The osmopriming with KNO_3 and Ca $(NO_3)_2$ were found to be more effective in enhancing seed germination, seedling vigour and photosynthesis.
- The urdbean genotypes IPU 99-1709, IPU 2-43, Uttara, IPU 99-144, BG 367 and PLU 703 were early type in both Kanpur and Dharwad and flower initiation did not vary much in two locations indicating their photoinsensitivity across the locations.
- Antioxidant defence mechanisms were higher in heat tolerant chickpea ICCV 92944 as compared to sensitive lines ICC 10685 as tolerant lines showed higher activities of peroxidise and superoxide dismutase. Two types of new peptides (about 100 kDa and 65 kDa) were induced in both heat tolerant and heat susceptible genotypes after subjecting the plants to heat stress at vegetative stage when compared to the control.
- Nutritional and phyto-chemical profile of cowpea (*Vigna unguiculata*) and fieldpea (*Pisum sativum*) with emphasis on their bioavailability and health promoting properties were assessed in diverse cowpea and fieldpea germplasm.
- The fieldpea varieties with reddish brown seed coat (EC 328758 and IPFD 2014-2) have the highest antioxidant activity.
- The reddish-brown cowpea varieties (GC 901 and PL3) have the maximum antioxidant activity. The cowpea has much higher antioxidant activity than fieldpea.
- Germplasm of major pulses are screened for BNF traits and for revealing diversity of associated rhizobia.
- Mungbean genotypes via MG-34, MG-4 and MG-50 recorded high nodule fresh weight (>200 mg) and no reduction in nodule biomass due to low available soil-P.
- Urdbean genotypes U 11, U 17, U 23 U 26 and U 95 have been found to be high nodulators.
- Lentil genotype IC-428606, IC-428614, IC-429178, IC-428559 and IC- 428607 were identified as potential genotypes for high biological nitrogen fixation.
- Initiatives have been taken to develop nano-material based microencapsulated formulation for weed control in pulse crops.
- To develop nano-material based formulations of imazethapyr certain clay materials and wood powder converted to > 60% of particles to their nano-range size.
- The residual values for Imazethapyr and pendemethalin herbicides were far less than the prescribed MRL values of the herbicides (0.1 mg/g) based on the LCMS test.
- Under externally funded project on Rhizosphere microbiome for improving symbiotic nitrogen fixation and yield of lentil, based on Transmission Electron Microscopy (TEM) study, elongated bacteroids were found in root nodules of *L. culinaris*, while Y shaped bacteroids reported to have high nitrogen fixing ability were found in *L. ervoides.*
- Under NICRA project, water-logging resistant pigeonpea genotype IPAC 79 was identified based on high survival rate >80% after 3 days of submergence and this line was submitted for registration. In mungbean , 17 resilient lines were identified out of 260 germplasm tested. Phenotyping of root traits in lentil e.g. root length was done using mapping population P1 ((IPL98/193) that showed variation from 12 to 67 cm. RIL RT-58 had vigorous root system.

Social Science

- Total 230 *Kharif* technology demonstrations on pigeonpea and urdbean were conducted in tribal areas of M.P. and Chhattisgarh States in collaboration of KVKs coming under ICAR-ATARI, Jabalpur. The highest yield (1250 kg per ha) of urdbean was recorded in Dhar district of M.P. by cultivating PU-31 variety of urdbean and maximum increase 32.00%. Similarly in pigeonpea, LRG-41, JKM 1892, JT 501 planted in KVK Kabirdham, Jhabua, Dindori and Badwani, the maximum yield of 1500 kg/ha was recorded and increase 17.64 yield over local check.

- Total 340 *Rabi* demonstrations were conducted on chickpea, fieldpea and lentil by KVKs of Kanker, Kabirdham, Balrampur, Dantewada Baster under Chhattisgarh, KVK Dindori, Badwani, Dhar, Jhabua and Shahdol and KVK Kargil, Zanskar and Leh under Jammu & Kashmir in tribal areas. The average yield of chickpea was recorded as 12.15 q/ha and increase in yield was 38.41% in comparison to local variety yield.
- The project envisages developing digital platforms for sharing knowledge resources related to pulse production technologies to pulse farmers, extension personnel and other stakeholders. Under the project, knowledge modules related to production and protection of pigeonpea and mungbean crops have been prepared for use in digital platforms.
- Farmers' information use pattern related to agricultural technologies was recorded. Among the interpersonal sources, majority of the farmers used fellow farmers (64%) and input dealers (58%), while formal sources of information were used to lesser extent. With regards to use of print and ICT based information sources, television followed by newspaper was used by majority.
- Crop profile contents on production statistics, tradestatistics, price statistics, Minimum Support Price (MSP), Crop Calendar, FLD's, BSP's, *Mandi* prices, Govt. schemes, seed information, ITK's, postharvest management, feedback etc. have been collected for the current year. All the contents have been compiled, validated, analysed and stored in digital format.
- The production of pulses during 2017-18 was estimated at 23.95 million tonnes which was higher by 0.82 million tonnes than the last year's (2016-17) record production of 23.13 million tonnes and was higher than the five years' average production by 5.10 million tonnes (an increase of 27%).
- The exponential growth rate in production of pulses for last ten years (2008-09 to 2017-18) was found to be at 4.45% (significant at 1% level) with an Instability Index of 9.05%.
- As per the time-series analysis, the exponential growth rates in MSP during the last ten years (2007-08 to 2017-18) for pigeonpea, moongbean, urdbean, chickpea and lentil were 11.34, 9.24, 9.4, 10.86 and 9.43% in terms of nominal prices and 6.64, 4.62, 4.77, 6.17 and 4.81% in terms of real prices.
- As per the time-series analysis of data collected from Central Statistics Office, Ministry of Statistics and Programme Implementation and Office of the Economic Adviser, Ministry of Commerce & Industry, both in terms of wholesale price Index (WPI) and consumer price index (CPI) based measures, price indices of pulses were on the decline since the peak during 2016. Inflation in pulses in percentage terms were negative since December 2016 in case of CPI based measure and since February, 2017 in case of WPI based measure.
- Taking into consideration of genotype x environment interaction (GEI) effect in Multi-environmental trials, AMMI based selection index has been used to rank the genotypes, as it captures a large portion of the GEI sum of squares. This index is the weightage of stability and yield component and higher the index value better is the genotypes.
- Total 1077 farmers and 173.44 ha area have been covered under Farmer FIRST project. Total 274 farmers were provided hybrid seed of vegetable crops covering 10.93 ha area for additional income and employment. Total 47 farmers were provided hybrid seed by covering 8 ha area under maize. Total 273 farmers were provided improved seed of urdbean and covering 62 ha area. Total 277 farmers were provided improved seed of urdbean and covering 73 ha area. Total 41 farmers applied imidaclorpid control of aphid. Total 65 farmers applied indoxacarb for control of pod borer. One hundred farmers applied micronutrients for wheat & chickpea. All the adopted farmers have been registered for *Dalhan Sandesh* Portal.
- Total 82 farmers and 23.50 ha area covered. Scented variety of rice as critical input was provided to the farmers for enhancing production and income in project area. The recorded yield under farmer field was 42.50 q/ha for Pusa Sugandga 4 variety and 48.40 q/ha for Pant 12 variety. The average net return obtained was ₹ 35,460 and ₹ 36,910 in comparisons to local yield.
- Altogether 71 farmers were provided 1600 poultry chicks breed namely CARI Nirbhik, Shyama and Devendra brought from ICAR-CARI, Izzatnagar, Bareilly for increasing income employment and

nutrition. Farmers rearing 15-20 birds were getting net income ₹ 1,010.00 per month and 60 hours employment per month. Similarly, farmers rearing 25-50 birds were getting ₹ 5,110.00 and 90 hours employment per month and farmers rearing at large scale between 55-110 poultry birds were getting ₹ 12,680.00 and 120 hours employment per month. Provided 15 goats to rural poor women farmers for increasing their income and nutritional security.

- During 2016-17, 27 farmers produced about 17,063 kg seed of high yielding, disease resistant improved varieties of pigeonpea (IPA 203) and fieldpea (Var. Aman, IPFD 10-12, Prakash and IPF 4-9) crops and collectively earned a gross income of ₹ 6,76,396/-. During the year 2017-18, the two registered groups of partner farmers in Silhara and Salempur villages of Kanpur Dehat district were technological empowered to initiate seed production of an about 15 ha of area of fieldpea (var. Aman, IPFD 10-12, Prakash) by 15 partner farmers in project villages.

- Voice SMS based advisories service "*Dalhan Sandesh*" of ICAR-IIPR, Kanpur has been extended under the project to 2,839 farmers from Jalaun, Fatehpur, Chitrakoot, Hamirpur, Kanpur Dehat, Balia, Kanpur Nagar districts of Uttar Pradesh State thereby linking experts to farmers directly. A total of 82,886 customized advisories were sent till date on pulse crops on chickpea, pigeonpea, mungbean, urdbean and lentil production technologies. The economics of voice based advisories was worked out to be ₹ 1.8 per crop per farmer.

- To strengthen existing seed delivery system for ensuring the availability of quality chickpea seed to farmers of Hamirpur, Chitrakoot and Banda district of Bundelkhand region of Uttar Pradesh, on-farm interventions were carried out in 8 villages under Tropical legumes-III project. These interventions included 70 participatory on farm demonstrations of 0.4 ha each on recommended high yielding and diseases resistant chickpea varieties (*Desi*: RVG 203, *Kabuli*: Shubhra, Ujjawal).

- Partner farmers registered a yield advantage of 4 q/ha from the demonstration plots as compared to the control plots. Partner farmers were mobilized to Four Seed Growers' Groups in project villages. During 2016-17, partner farmers in the groups produced 5,602 kg seed and during 2017-18, 26 ha of area in the project district is registered for foundation seed production for chickpea and partner farmers are expected to produce about 33,100 kg of chickpea seed.

About the Institute

Pulses continue to be an important ingredient of human diet specially, the large vegetarian population in the country. In the era of Green Revolution with major focus on staple food like rice and wheat, pulses were relegated to the marginal lands with least of inputs. This coupled with the increasing population resulted in reducing *per capita* availability of pulses to the masses. To enhance the productivity of the existing varieties by improved production technologies, besides breeding for high yielding varieties of different pulse crops become the prime concern. To take up the cause, All India Coordinated Pulses Improvement Project (AICPIP) was started in 1966 at the Indian Agricultural Research Institute (IARI), New Delhi. Later in 1978, its headquarters was shifted to the then Regional Station of IARI at Kanpur under the name of Project Directorate (Pulses). It was further elevated as Directorate of Pulses Research (DPR) in 1984 and became an independent entity under the direct control of ICAR. In 1993 the DPR was upgraded and elevated to the status of Indian Institute of Pulses Research, and simultaneously, AICPIP was trifurcated into three coordinated projects on chickpea, pigeonpea and MULLaRP (mungbean, urdbean, lentil, lathyrus, rajmash and pea) to provide focused attention on each crop. Since then, the Institute is playing a key role in strengthening the nutritional security and sustenance of soil health. Besides generating basic knowledge and material, other activities of the Institute include development of appropriate crop production and protection technologies, production and supply of nucleus and breeder seeds of improved varieties, demonstration and transfer of technologies, and strategic coordination of pulses research through wide network of testing centers across the country.

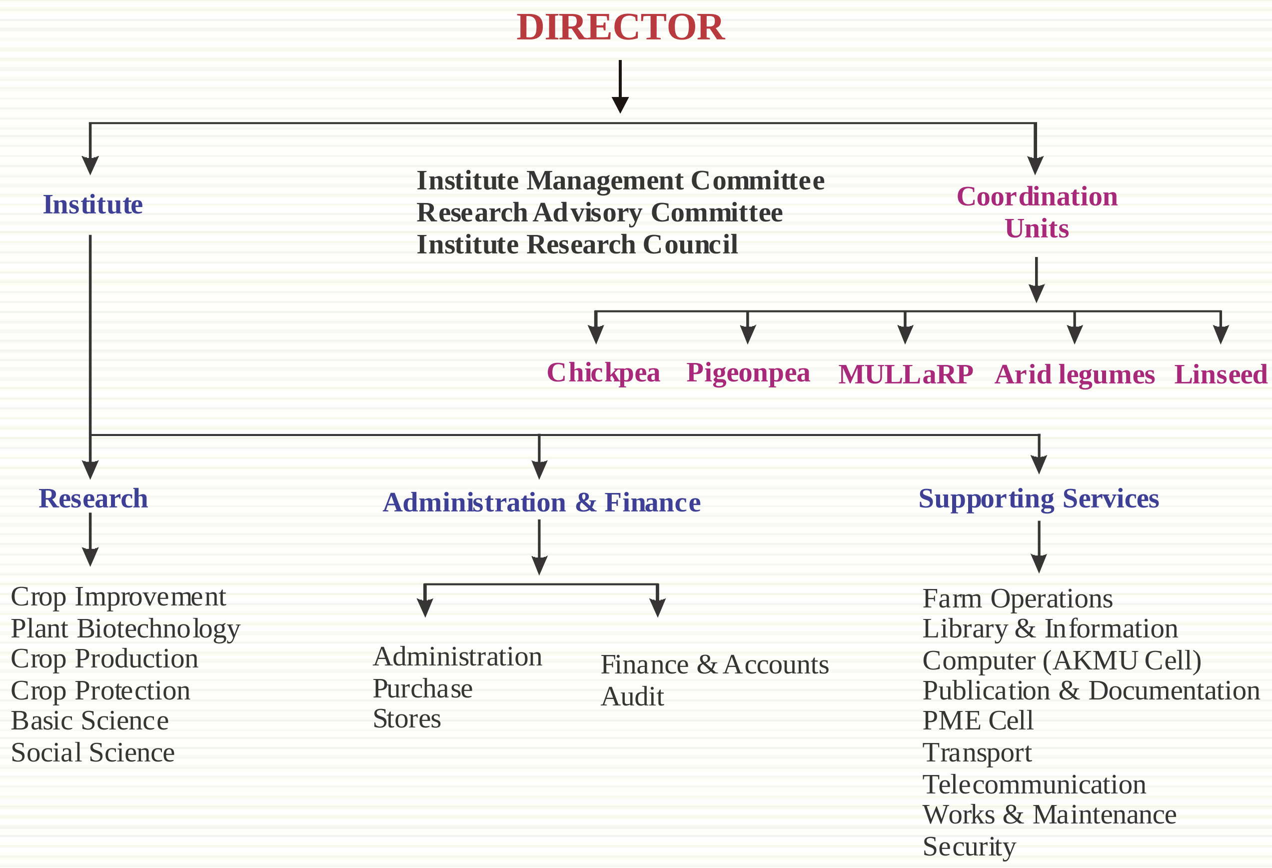
The Institute is located at Kanpur, Uttar Pradesh at $26^0 27'$N latitude, $80^0 14'$E longitude and 152.4 meter above the mean sea level. It is situated on Grand Trunk Road, 12 km from Kanpur Central Railway Station towards New Delhi.

The overall climate varies from semi-arid to arid. The summers are very hot and winters are cool and dry. The monthly weather data for the year revealed that the mean monthly maximum temperature varied from 19.2^{o}C to 41.7^{o}C and the minimum temperature from 3.4^{0}C to 26.8^{o}C. The relative humidity varied from 15.7% to 99.00%.

Multi-disciplinary research of both applied and basic nature is conducted under six divisions namely, Crop Improvement, Plant Biotechnology, Crop Production, Crop Protection, Basic Science and Social Science. For region specific and strategic research, the Institute has one Regional Centre *cum* Off-Season Nursery at Dharwad in Karnataka and one Regional Station at Bhopal in Madhya Pradesh. To cater to the needs of the Institute's activities and mandate, service units such as Farm Management, Library & Informatics, ARIS Cell, Hindi Cell, Art & Reprography and Publication & Documentation are in place.

The Institute has a well developed 84 ha research farm at its headquarters, Kanpur. Physical Containment Facility has been created for advancing generation of the transgenic plants and further validation of the transgenic lines. A post-entry quarantine facility is also in place to intercept seed borne virus from imported seeds. In addition, screening facilities against major diseases of pulse crops have been developed. Rain-out shelter to screen genotypes against drought, well-equipped laboratories of biotechnology, molecular biology, biochemistry, physiology, pathology, bio-control, soil chemistry, medium-term germplasm storage and weather observatory provide necessary infrastructures for R & D activities. The computer cell provides facilities for data base management, documentation, and statistical analyses. The library houses exhaustive literature on pulse crops besides CAB abstracting on CD ROM. The museum depicts pulse technologies developed by the Institute. The Institute has sanctioned strength of 88 scientists, 63 technical, 27 administrative and 51 supporting personnel.

Organizational Set-up



Staff Strength

As on 31.3.2018

Category	Sanctioned	In position	Vacant
RMP	01	01	0
Scientist	88	74	14
Technical	63	48	15
Administrative	27	24	03
Supporting	51	33	18

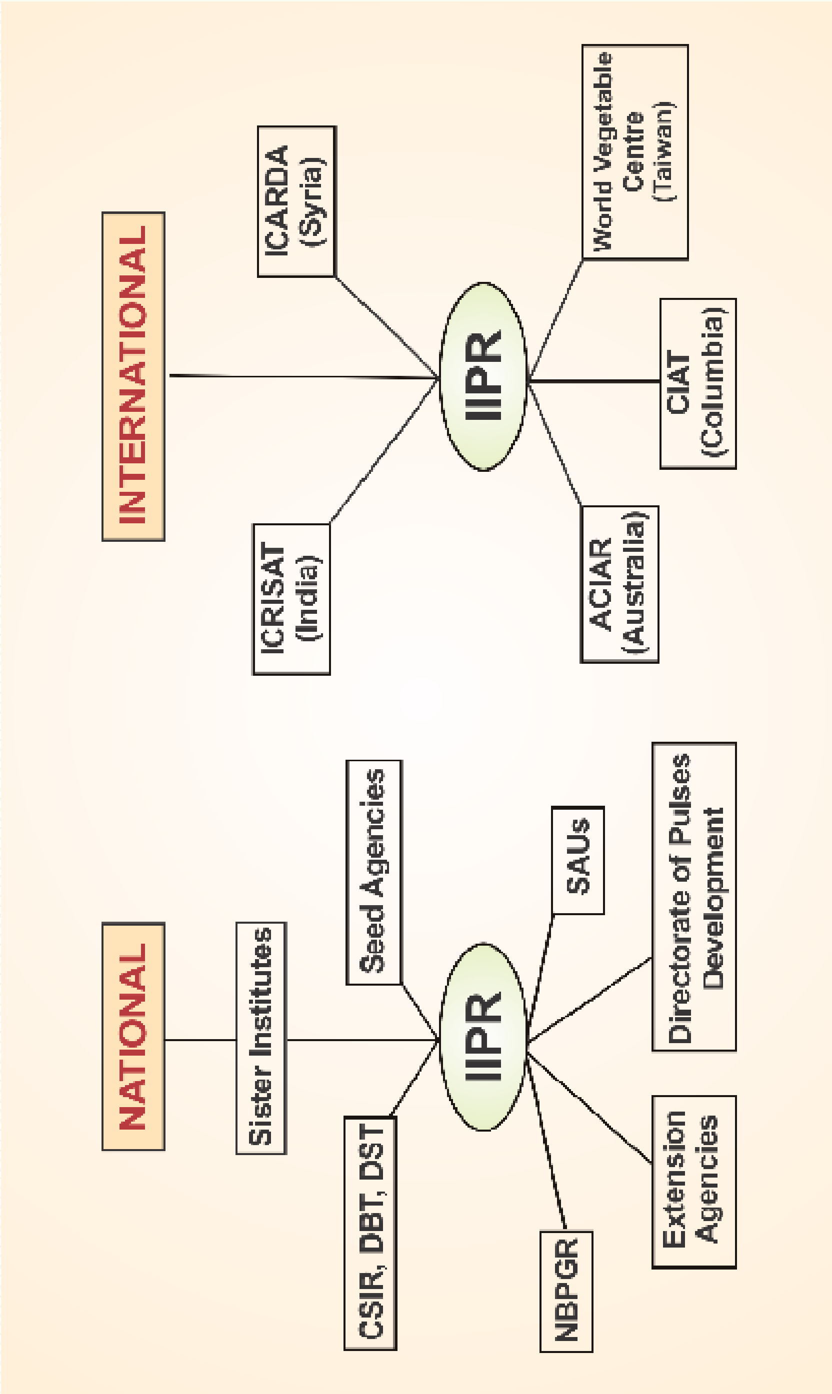
Mandate

- Basic and strategic research on pulses to improve productivity and quality
- To provide equitable access to information, knowledge and genetic material to develop improved technology and enhance pulse production
- Planning, coordination and monitoring of applied research on national and regional issues through All India Coordinated Projects
- Dissemination of technology and capacity building.

Major Research Programmes

- Genetic Enhancement for Yield and Quality
- Biotechnological Interventions
- Plant Genetic Resources : Collection, evaluation and conservation
- Cropping Systems Research
- Integrated Nutrients Management
- Integrated Pest Management
- Physiological Studies
- On-farm Research and Informatics
- Post-harvest Technology

Linkage and Collaborations



Financial Statement

Statement of Receipt and Expenditure for the Financial Year 2017-18

			₹ in lakh
A.	**Receipt**		2901.10
B.	**Expenditure**		
	Plan		2901.09
C.	**Pension and other retirement benefits**		148.00
D.	**AICRP**		
	Chickpea		
	a.	Coordination Unit	9.70
	b.	Grant-in-aid	1080.30
	Pigeonpea		
	a.	Coordination Unit	3.88
	b.	Grant-in-aid	901.12
	MULLaRP		
	a.	Coordination Unit	6.89
	b.	Grant-in-aid	1174.01
	AINPAL		
	a.	Coordination Unit	12.55
	b.	Grant-in-aid	268.04

Status of Implementation of SFC 2017-20 Three Year Plan (Up to 31.03.2018)

(₹ in lakh)

Head	Approved outlay (R.E.)	Expenditure 2017-18
A. Recurring		
Pay & Allowances/Wages & Pension	2172.25	2172.25
TA	25.00	25.00
HRD	9.56	9.56
Contingency	596.09	596.09
Total	**2802.90**	**2802.89**
B. Non-Recurring		
Equipment, Information Technology & Furniture & Fixture	6.88	6.88
Works	73.85	73.85
Library	0.11	0.11
Total	**80.84**	**80.84**
C. TSP	17.36	17.36
D. Total (A+B+C)	**2901.10**	**2901.09**

Crop Improvement

Project 1: Genetic enhancement of pulses for grain yield, quality and multiple stresses resistance

Chickpea

Performance of breeding lines in AICRP trials: IPC 2012-108 was promoted to AVT 1- *desi* trial for its possible release under normal sown condition in NEPZ. Ten IPC elite breeding lines (timely sown: IPC 2010-142, IPC 201-14, IPC 2010-72, IPC 2011-142, IPC 2012-31; Late sown: IPC 2007-28, IPC 2010-62; *Kabuli*: IPCK 2009-165, IPCK 2010-124, IPCK 2011-179) are in Uttar Pradesh State Adaptation Trials at different stages. Eight new IPC entries are being evaluated in IVT trials under AICRP on Chickpea. Proposal for identification of *desi* chickpea variety IPC 2010-62 was submitted, although, it could not be identified.

Generation of breeding materials: Forty eight crosses (32 in main season and 16 in off-season) were attempted to generate breeding material. Out of these, 32 fresh crosses were made successfully during main season involving 3 accessions (ILWC 21, ILWC 81, ILWC 256) of wild *Cicer* spp. to broaden the genetic base using JAKI 9218 as agronomic base. *Ascochyta* blight resistant, tall and erect *kabuli* line, ILC 3279, was utilized in hybridization to develop *kabuli* chickpea and HC 5 and IPC 2006-11 for developing *desi* varieties for mechanical harvesting. Prominent donors for transferring tolerance to high temperature (JG 14), post emergence herbicide (ICC 1205) and salinity (CSG 8962) were also utilized in hybridization. Sixteen new crosses were attempted during off-season at ICAR-IIPR, RC, Dharwad involving high yielding agronomic bases (JG 11, NBeG 47, GNG 1581, IPC 2006-11, IPC 2010-134, CSG 8962) and donors having large seed, drought tolerance, salinity tolerance, high grain protein content and wilt resistance.

Segregating material/generation advancement: Thirty seven crosses made during 2016-17 were advanced and F_2 seeds harvested. These crosses were made to generate breeding material to incorporate diseases resistance, combine heat and drought tolerance, broadening the genetic base and enhancing seed protein content. Thirty three crosses involving two wild *Cicer reticulatum* accessions, tall and erect plant types, wilt resistant, heat tolerant and post emergence herbicide tolerant donors attempted during 2016-17 were advanced. Seventeen F_2 were grown and desirable single plant selections were made. Two thousand one hundred seventy one single plant selections (SPS) in various segregating generations (F_2: 662 SPS; F_3: 657 SPS; F_4: 396 SPS; F_5: 563 SPS; F_6: 256 SPS; F_7: 63 SPS) were grown for further advancement and desirable types plant selection were made. Similarly, 391 progeny bulks (*desi* and *kabuli*) from different generations were evaluated in different preliminary trials.

Evaluation of elite breeding lines: More than 276 elite breeding lines of *desi* and *kabuli* chickpea were evaluated under irrigated and late sown condition at ICAR-IIPR, Kanpur. Besides, 20 elite breeding lines were also evaluated at ICAR-IIPR Regional Research Centre cum Off Season Nursery, Dharwad and ICAR-IIPR, RS, Phanda (Bhopal).

Station trial 1: Three station trials having 27 pre-breeding lines in each were evaluated alongwith three checks (DCP 92-3, JG 16, Pusa 547) under timely sown conditions at New Research Campus. The lines surpassing in grain yield to the best check (JG 16) were IPC 2015-48 (2655 kg/ha) and IPC 2006-126 (2761 kg/ha).

Station trial 2: Under normal sown conditions, 27 breeding lines were evaluated along with three checks for grain yield and other traits at New Research Campus. Genotypes viz., IPC 2014-171 (2071 kg/ha), IPC 2015-24 (2021 kg/ha), IPC 2012-108 (2011 kg/ha), IPC 2014-39 (1800 kg/ha), IPC 2014-51 (1783 kg/ha) performed better than the best check, KWR 108 (994 kg/ha).

Station trial 3: Two station trials having 27 breeding lines were conducted at Main Campus. In first trial, IPC 2011-28 (2916 kg/ha), IPC 2008-92 (2911 kg/ha), IPC 2015-183 (2861 kg/ha), IPC 2008-83 (2850 kg/ha), IPC 2010-72 (2821 kg/ha) surpassed the best check DCP 92-3 (2795 kg/ha) in grain yield. In other trial, our 27 breeding lines, two lines (IPC 2007-13:2621 kg/ha and IPC 2009-21:2905 kg/ha) exhibited higher yield than the best check KPG 59 (2561 kg/ha).

Station trial 4: In *kabuli* chickpea, two station trials each having 30 elite breeding lines were conducted at Main Campus. In the first trial, IPCK 2013-163 (1786, 48.71); IPCK 2012-143 (1771, 39.44); IPCK 2015-241 (853, 41.89) registered higher grain yield than the best check Pusa Chamatkar (1508 kg/ha, 28.6 g 100-seed weight) with desired seed size. In other trial, IPCK 2014-

128 (2388, 41.57) exhibited higher grain yield than the best check.

Evaluation of tall and erect breeding lines (suited to mechanical harvesting) in yield trials

Out of 54 tall and erect genotypes (>60° branch angle), IPC 2014-28 (85 cm, 2821 kg/ha); IPC 2010-107 (76 cm, 2586 kg/ha); IPC 2006-27 (89 cm, 2553 kg/ha); IPC 2015-58 (86 cm, 2446 kg/ha); IPC 2014-100 (80 cm, 2375 kg/ha); IPC 2014-10 (91 cm, 2370 kg/ha), IPC 2015-54 (74 cm, 2071 kg/ha); IPC 2015-165 (73 cm, 2000 kg/ha); IPC 2014-143 (75 cm, 1778 kg/ha); IPC 2015-123 (64 cm, 1741 kg/ha); IPC 2014-167 (67 cm, 1619 kg/ha); IPC 2015-116 (69 cm, 1544 kg/ha) performed well. All of these genotypes were tall with erect plant type and were free from lodging. These are being evaluated for yield and other traits during 2017-18.

Phenotyping against biotic and abiotic stresses

***Fusarium* wilt disease:** Out of 227 IPC2016 series lines (35 *kabuli* & 192 *desi*) screened against *Fusarium* wilt, 36 lines exhibited resistance (1 *kabuli*-IPC 2016-138 and 35 *desi*) while 33 lines (24 *desi* and 9 *kabuli*) exhibited moderate resistance to *Fusarium* wilt in sick plot which is predominantly developed for race 2 of the pathogen. Under AICRP – Pathology programme, 9 elite breeding lines (3 *kabuli*: IPCK 2012-29, IPCK 2006-56, IPCK 2009-165; and 6 *desi*: IPC 2010-134, , IPC 2012-98, IPC 2008-69, IPC 2013-33, IPC 2008-11, IPC 2007-28) exhibited resistance/ moderate resistance against different chickpea diseases. Out of these, IPCK 2010-134 and IPC 2007-28 and IPC 2008-69 exhibited stable resistance over two years against *Fusarium* wilt in multi location screening under AICRP on Chickpea.

Dry root rot disease: Against dry root rot, elite breeding lines viz., IPC 2012-98, IPC 2013-33, IPC 2011-85 and IPC2010-219 exhibited moderate resistance in first year screening under AICRP on Chickpea.

Screening against post emergence herbicide: Sixty two germplasm accessions and elite breeding lines including 26 promising and 36 new lines were phenotyped using post emergence herbicide Imazethapyr @ 100 g/ ha. Only two lines *viz.,* ICCV 11116 and ST-3-D-2 exhibited stable tolerance against the targeted herbicide. Both lines exhibited stable reaction against Imazethapyr during 2017-18 as well indicating their potential for utilization in breeding programme and identification of gene(s)/QTLs controlling herbicide tolerance in chickpea.

Development of chickpea varieties tolerant to heat stress

Generation advancement of the following contrasting crosses was done. Various physiological and yield related parameters were recorded for the individuals of ICC92944 x JG315 (F_3) cross under late sown condition in field.

KWR 108 × JG315 (heat sensitive × heat sensitive) (F_3)

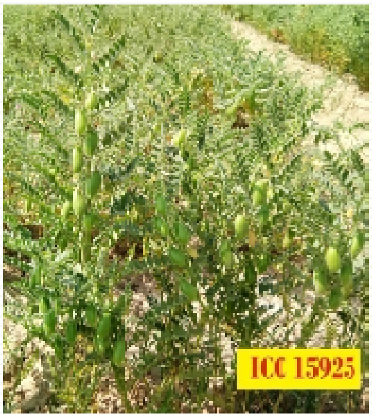
JG11 × ICC1205 (Heat tolerant × heat tolerant) (F_3)

JG130 × ICC92944 (Heat tolerant × heat tolerant) F_3

ICC92944 × JG315 (Heat tolerant × heat sensitive) (F_3)

Mapping population developed through SSD method for heat and drought tolerance

1. DCP 92-3 × ICC 92944 (F_4 206), 2. DCP 92-3 × ICC1205 (F_4 165), 3. DCP 92-3 × ICC 96030 (F_4 150), 4. DCP 92-3 × ICC 4958 (F_4 168), 5. ICC 4958 × ICC 92944 (F_4 145), 6. ICC 92944 × JG 315 (F_3 145), 7. JG 11× ICC 1205 (F_3 151), 8. ICC 92944 × JG 130 (F_3 148).



Breeding for higher yield and enhanced resistance against abiotic stress in chickpea

A new set of crosses have been attempted for various abiotic stress relevant traits: JG 11 × JG 62, JG 62 × JG 11, ICC 92944 × JG 11 (heat tolerance), HC 5 × ICC 92944 (heat tolerance), ICC 1205 × JG 16 (heat tolerance), ICC 96030 × JG 11, ICC 1356 × ICC 92944 (heat tolerance), JG 11 × ICC 96029, DCP 92-3 × HC 5, ICC 96030 × JG 11, JG 16 × ILC 583, KWR 108 × ILC 583, ICC 07110 × ILC 3518 (heat tolerance). Four promising genotypes IPC 11-1-39, IPC 11-6-9, IPC 11-9-18, ICC 15925, ICC 15894 were selected based on their high pods/plant and yield/plant performance under late sown condition.

Besides, 76 advanced breeding lines were sown under late sown (17th January 2017) condition for screening against heat. Variations were observed for pod setting/ seed setting efficiency under heat stress period (>35°C T^{max}) and plot yield. 14 lines namely IPC 2015-112, IPC 2015-185, IPC 2014-112, IPC 2015-19, IPC 2015-147, IPC 2015-149, IPC 2015-151, IPC 2015-153, IPC 2015-95, IPC 2015-120, IPC 2015-196, IPC 2015-37, IPC 2015-183, IPC 2007-56 have been identified possessing heat tolerance. These lines are being phenotyped during 2018 under field conditions by sowing on 16th January 2018.

Breeding for yield enhancement in *kabuli* chickpea suitable for different ecologies

Evaluation of *kabuli* chickpea germplasm and elite lines

Forty *kabuli* chickpea germplasm were raised during *rabi* 2017-48 at ICAR-IIPR, Main Campus for characterization of morphological traits such as foliage colour, leaf shape, leaf size, pod size, days to 50% flowering, plant height (cm), number of pod per peduncle, number of seed per pod, grain yield, seed size, seed colour, seed shape and 100-seed weight.

Hybridization, generation and evaluation of breeding lines

For development of genetically improved breeding lines of *kabuli* chickpea for grain yield and seed size and broadening genetic base of existing cultivars and restructuring plant type for suitability to mechanical harvesting, twelve crosses *viz.,* (IPCK 2002-29 / IPCK 02, IPCK 2002-29 / Phule G 0517, IPCK 2002-29 / IPCK 2006-78, IPCK 2002-29 / KAK 2, IPCK 2002-29 / AP 04, IPCK 2002-29 / MNK 1, IPCK 02 / AP 04, IPCK 02 / JGK 1, IPCK 02 / IPCK 2009-165, IPCK 2002-29 / IPCK 2009-165, IPCK 02 / IPCK 2011-179 and IPCK 2002-29 / IPCK 2011-179) were made during *rabi* 2017-18. The F_1s are being raised during off-season at ICAR-IIPR, Regional Centre, Dharwad, (Karnataka) for advancement.

ICVT trials

Two ICVT trials (ICVT-*desi* and ICVT-*kabuli*) received from ICRISAT, Hyderabad having 20 entries including two checks (JG 16 and DCP 92-3 under *desi* and Vihar and Ujjawal under *kabuli*) were raised in RBD with two replications ICAR-IIPR, Kanpur. Data on days to flower initiation, days to 50% flowering, plant height, days to first pod initiation, days to maturity, plot yield and 100 seed weight were recorded.

Combining *Fusarium* Wilt and Dry Root-rot Resistance in Chickpea by Integrated Breeding Approach

Identification of Donor Parents

Forty three advanced breeding lines with WR 315 (*Fusarium* wilt resistant) and JG 2003-14-16 (Dry root rot resistant) as one of the parent were evaluated for dual resistance against *Fusarium* wilt and dry root rot in sick plot. These lines were screened for *Fusarium* wilt resistance at wilt sick plot (predominantly race 2) at ICAR-IIPR, Kanpur and dry root rot resistance at hot spot location at Rajasthan Agricultural Research Institute, Durgapura. Six lines *viz.,* DR1541, DR1542, DR1505, DR1540, DR1501 and DR1510 were found to be resistant and other six namely DR1512, DR1502, DR1508, DR1532, DR1504 and DR1511 were moderately resistant to *Fusarium* wilt. Four lines *viz.,* DR1513, DR1504, DR1542 and DR1543 were found to be moderately resistant against dry root rot.

Generation of Breeding Material

Seventeen fresh crosses using the parents possessing stable resistance against dry root rot and *Fusarium* wilt *viz.* IPC 2010-134 x JG 24, GNG 1958 x IPC 2005-28, IPC 2010-134 x CSJ 556, IPC 2010-134 x DKG 964, IPC 2010-134 x (IPC 2006-88 x ILWC 179), GNG 1958 x JSC 37, GNG 1958 x IPC 2007-28, GNG 1958 x GNG 2226, GNG 1958 x DKG 964, JG 37 x NBeG 47, IPCK 2002-29 x IPCK 2006-78, JAKI 9218 x Pant G 5, JG 14 x JSC 37, RSG 931 x IPC 2008-69, JG 14 x ILWC 21, RSG 931 x ILWC 21 and CSJ 515 x IPC 2008-69 were made. Besides, a set of crosses *viz.,* JSC 37 x IPC 2005-28, JSC 37 x BG 212, JSC 37 x JG 62, IPC 2005-28 x BG 212, IPC 2005-28 x JG 62 and BG 212 x JG 62 were also made to elucidate the genetics of dry root rot resistance. Fresh crosses were made to develop new mapping population for dry root rot namely IPC 2005-28 x BG 212 and IPC 2005-28 x JG 62.

Generation advancement

Fourteen crosses namely, GNG 1958 x IPC 2007-28, GNG 1958 x IPC 2008-103, GNG 1958 x IPC 2005-28, GNG 1958 x JG 14, IPCK 2002-29 x IPCK 2006-78, GNG 2226 x JSC 37, IPC 2010-134 x JSC 37, JG 16 x DKG 964, IPC 2005-28 x BG 212, IPC 2005-28 x JG 62, JG 35 x JG 3-14-16, JG 37 x Phule G 06102, JG 315 x JG 3-14-16 and IPC 2010-134 x JG 14 were advanced to F_2 stage. Three hundred seventeen single plant selections were done among six crosses namely, JG 16 x BG 212, JG 16 x JG 2003-14-16, JG16 x IPC 2005-64, JG 16 x IPC 2005-28, IPCK 2004-29 x IPCK 2012-258 and JAKI 9218 x IPC 2005-24 for advancement to F_3.

Enhancement of protein content in chickpea

Acclimatization and pre-breeding genetic purification of the reported donor T39-1 for high seed protein content lead to isolation of two variant lines from the base landrace population (Fig. 1). The variant lines had semi spreading canopy at vegetative/

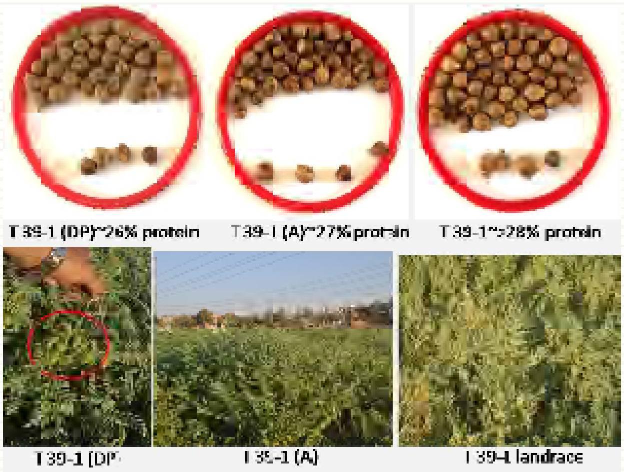


Fig. 1 : High protein line T39-1 and its two variants (A and DP). Abbreviation: DP- Double podded.

podding stages with respect to spreading type canopy of the base population. One of these lines was observed to have double poding trait with seed setting, over the years and across locations. All the three lines (two variants and the original landrace type) are blue flowered and did not show any phenological variation for two consecutive years. T39-1 (ICC 5912) has been reported for heat susceptibility which is a major hurdle in crossing, but those isolates had better heat tolerance (filled/unfilled pod ratio). Regarding seed protein content, the landrace with spreading canopy had the highest protein (>28%), whereas the variants had protein content ~26%.

Three crosses were made involving parents rich in protein (>27%), namely, T39-1, T1-A, P3318. F_2 seeds from the single plants of the contrasting cross IPC2004-98 x T39-1 (F_2 size = 280) were constituted into families and significant variation in protein content was observed between them. F_3 (size = 320) of the population were grown and wide variation was apparent with respect to plant architecture and podding behavior. Phenological variants were handled separately. Two other F_2 crosses, namely, T39-1 x ICC 4958 and JG 16 x T39-1 were duly advanced to next generation through kernel selection. T39-1, being heat susceptible, has poor seed setting. However, in the segregating generations of crosses using T39-1 as donor in improved agronomic backgrounds, seed setting could be improved considerably.

A panel of 78 germplasm accessions constituted from the IIPR genebank based on nearness in kernel traits and flower colour of reported high protein donor lines (T39-1, T1-A) was evaluated in the field for the second year and eight potential high protein lines which were found promising are to be validated. Multiple trait selection and Euclidean clustering (with phenological attributes, plot yield, hundred seed weight and seed protein content data of one season) showed co-clustering of the high protein lines, which indicate potential of correlated selection of indirect selection to enhance seed protein content (Fig. 2).

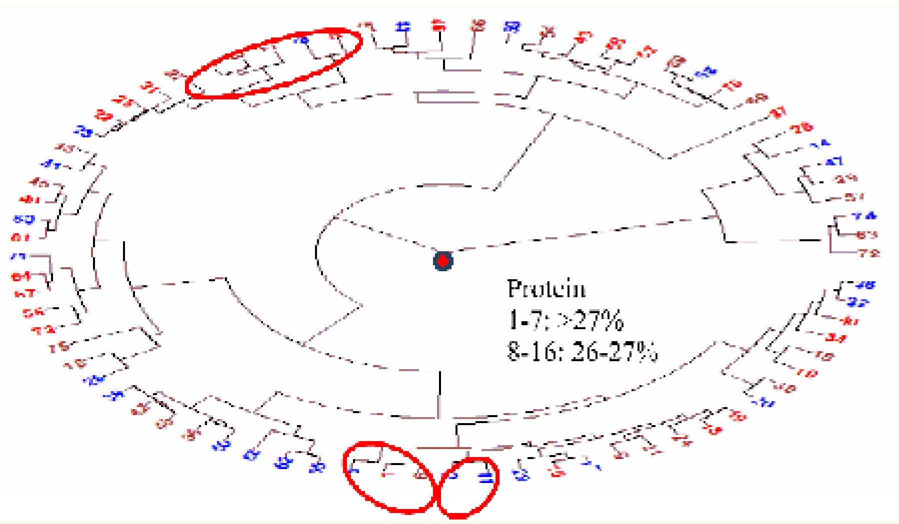


Fig. 2 : Euclidean clustering of 78 germplasm accessions considering phenological attributes, plot yield, hundred seed weight and seed protein content. Accessions: 1 (ICC9914), 2 (ICC10242), 3 (ICC10491), 4 (ICC10036), 5 (ICC4683), 6 (ICC4568), 7 (ICC9553), 8 (ICC10500), 9 (ICC10268), 10 (ICC8470), 11 (ICC2112), 12 (ICC10587), 13 (ICC4945), 14 (ICC1486), 15 (ICC2003), 16 (ICC2091).

Pigeonpea

Promising pigeonpea lines for cultivation in UP state

Proposal for IPA 206 has been submitted for its possible release for cultivation in UP state. The genotype has yielded 1063 kg/ha in State Adaptive Trial conducted during 2012-17 with distinct yield superiority over the check Bahar (934 kg/ha), NDA 1 (938 kg/ha) and NDA 2 (912 kg/ha). Potential yield of IPA 206 was found to be 2490 kg/ha at IIPR, Kanpur. The variety is resistant to wilt and has medium sized seed (12.71 g/1000 seeds) with oval shape, smooth and black coloured seed coat.

Performance of breeding lines in AICRP trials

The entries *viz.*, IIPA 2014-2 (Pusa 9/ Kudrat), IPA 2014-4a (MAL13/Kudrat), IPA 2015-2 (MAL 13/ NA 1) and IPA 2015-19 (Ranchi local/UPAS 120) are proposed for IVT under AICRP during 2017-18. The variety IPA 9-1 is in AVT-2 under state adaptive trial and IPA 13-1 in AVT for state adaptive trial during 2017-18.

Station trials (ST)

A station trial comprising 24 entries, 12 entries in each ST were conducted with three checks (Bahar, NDA 1 and IPA 203) in three replications during *kharif* 2017-18 at IIPR main farm. The entries include IPA 13-1, IPA 14-6, IPA 14-7, IPA 15-1, IPA 15-19, IPA 15-2, IPA 16-13, IPA 16-18, IPA 16-22, IPA 16-6, IPA 16-7, IPA 2014-2, IPA 2014-4A, IPA 206, IPA 9-1, IPAM 16-1, IPAM 16-2, IPAM 16-3, IPAM 16-6, IPA 17-1, IPA 17-2, IPA 17-3, IPA 17-4 and IPA 17-5.

AICRP (Pigeonpea) nominated entries IPA 2015-19 (left) & IPA 2014-4A (right)

Screening against wilt

A set of 450 single plant selection progenies of different advanced generations were screened against wilt and 46 resistant SPS were taken in F_5 out of 124 SPS, 54 SPS in F_6 out of 203 SPS and 48 resistant SPS in F_7 out of 123 SPS under wilt sick field condition of ICAR-IIPR, Kanpur.

Generation of breeding materials

Eighteen late & 12 early crosses of F_1s were developed during 2017-18. Different segregating and advanced generations were advanced *viz.,* 47 F_1s and 3 BC_2F_1 were advanced to F_2 and BC_2F_2 respectively. Single plant selections were made in 18 F_3 crosses (1008 SPS), 23 F_4 crosses (506 SPS), 19 F_5 crosses (123 SPS), 13 F_6 crosses (85 SPS) and 17 F_7 crosses (123 SPS). A set of 58 parents was maintained through single plant selection. Sixty eight genotypes were identified as extra large seeded for vegetable type breeding purpose from germplasm nursery (Fig. 3).

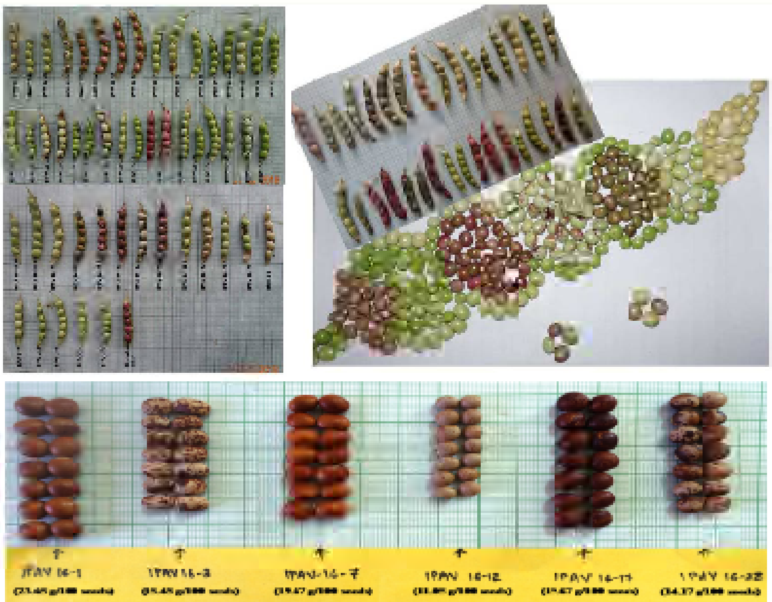


Fig. 3 : Visual variation for pod size and dry seed size and colour among vegetable type genotypes

Identification of an extra-large seeded genotype IPAV 16-1 in pigeonpea

Ninety six pigeonpea genotypes were examined for genetic variability in 100-seed weight (g). The highest seed weight (23.65 g/100-seeds) was recorded for the genotype IPAV 16-1 followed by IPAV 16-21 (19.75 g), IPAV16-15 (19.71 g), IPAV 16-7 (19.67 g), IPAV 16-11 (19.40 g) and IPAV 16-17 (19.05 g). The identified extra large seeded IPAV 16-1 genotype has an immense potential to use as a donor for improving seed weight in pigeonpea.

Pre-breeding

Two species of *Cajanus viz. C. scarabeoides* and *C. platycarpus* belonging to primary and secondary genepool were used in crosses for the introgression of useful alleles in to the cultivated pigeonpea. The cross between *C. cajan* and C. *platycarpus* was not successful, therefore, bridge cross was attempted between *C. scarabeoides* and *C. platycarpus* with the aim to cross the hybrid with cultivated pigeonpea. Several *Phythopthora* stem blight tolerant and *Fusarium* wilt tolerant large seeded *C. cajan* lines were crossed with *C. scarabeoides* for utilizing the resistance genes from *scarabeoides* and also to widen the genetic base of the breeding population.

The BC_1F_6 and F_7 populations derived from crosses, namely Early three (determinate, early and pod bearing in cluster) x *C. scarabeoides* (ICP15685), UPAS 120 x *C. scarabeoides* (ICP 15761), IPAC 64 x *C. cajanifolius* (ICP 15629) were advanced to the next generation. The derivatives of wild crosses were advanced to F_7 generation. The selfed progenies of the cross derivatives among selected F_3's plants between the adapted lines and the F_3 derivatives of *Cajanas scarabeoides* namely, NDA-1 x WDN 100, Pusa 2001 x Bennur local, IPAC-79 x WD-5, Maruti x WD-5-1, Maruti x WDN 100, WDBCU-5-2 x WDBCU-5-1were advanced to the next generation. Selections were made from the F_5 derivatives of *C. scarabeoides* (IPAC 8 x WDN2-258, ICP 88039 x IPAC 3, ICP 88039 x WD 3, WDN1-95 x IPAC 3, IPAC 79 x WD 4, IPAC 79 x WD 5, IPAC 79 x WD 3, IPAC 70-1 x WDN2-288) for advancing them to F_6.

Validation of *Fusarium* wilt resistant lines

Several *Fusarium* wilt resistant pigeonpea genotypes have been developed either through crossing and selection or through selection from the composite population screened in the wilt sick plot in the pre-breeding project. These lines have originated from diverse genetic background involving multiple parents. The *Fusarium* wilt resistant alleles were funneled from BSMR 736, BSMR 853, WRP 1, TS3R, Banda Local, IPA 8F, C 11, KPL 44, KPL 43, ICPL 8863 and local accessions from Korba. Multiple crosses using multiple parents were used to generate the segregating populations. Some of the highly resistant genotypes derived from the multiple crosses were channeled into composite population for deriving further batches of resistant lines possibly with diverse allelic composition. The initial batch of resistant line was derived from the two way or three way crosses. Rigorous selection procedure was followed and all the segregating materials were selected and advanced in the wilt sick plot of IIPR. The homozygous lines were also tested in the wilt sick plot for at least two years. In 2017-18, these wilt resistant lines were validated in the replicated trial in wilt sick plot of IIPR, Kanpur. IPAC 66, IPAC 67, IPAC 68, IPA 10W12, IPA 10W1-8, IPA 20-2 showed average disease score of 6.2; 2.9, 4.1, 5.0, 6.5 and 8.3, respectively whereas, the adjoining checkplanted at regular interval was severely diseased (% infection). In addition, five lines *viz.* IPA 10W4-10, IPA10W16, IPA10W18, IPA10W20-1 and IPA 10W20-3 derived from multiple crosses and homogeneous for morphological trait segregated for resistance in the progeny population of at least 40 plants. A minimum of five resistant plants were tagged for testing the homogeneity of resistance in the next generation. The lines *viz.* IPAC 66, IPAC 67, IPAC 68 showed negligible disease score for past five years. Five late maturing and extra large seeded lines viz., IPAV 16-1, IPAV 16-5, IPAV 16-11b, IPAV 16-17 and IPAV 16-22 have recorded resistance reaction against wilt for past three years.

Water-logging tolerance in pigeonpea

Pigeonpea experiences excess moisture at seedling stage and sometimes subjected to flooding during rainy season in low lying areas. Even 3 to 4 days continuous submergence leads to hypoxia and sustains injury to roots and eventually plant dies. IPAC 79 is a water logging tolerant line of pigeonpea. It was tested for water logging tolerance for four years in replicated trials conducted at IIPR, Kanpur in 2011-12, 2012-13, 2013-14 and 2017-18.

IPAC 79 (Fig. 4) is a long duration pigeonpea advance line derived from the cross between Bennur Local x BRG 2. It was tolerant to 96 hours of water logging initiated at 20 days seedling stage. It showed 53.8% survival as compared to 0.6 % survival in water logging sensitive line ICPL 7035. In addition to water

Fig. 4 : The genotype IPAC 79 showing tolerance to water-logging at field condition.

logging tolerance, it was also resistant to Phytopthora stem blight, an important soil borne disease of pigeonpea. It is a tall, erect and compact and late maturing genotype with purple pigmentation on the stem. It bears streaked and diffused red flowers and purple sticky pods with dark purple seed coat and test weight of about 12 g. It can also withstand moderate degree of terminal heat. It is an improved genotype (20 q/ha) but statistically inferior than the national check Baharin grain yielding ability (24.6 q/ha) in replicated trials conducted at IIPR, Kanpur during 2013-14.

After multiple cycles of water logging, the chlorophyll content of IPAC 79 remained less affected (18% reduction) even after 4th cycle of stress as compared to other entries. Simultaneously leaf nitrogen balance index (NBI) declined to the extent of 50% in sensitive genotype ICPL 7035 whereas, only 20% reduction recorded in tolerant genotype IPAC 79. The root capacitance dropped from 0.86 nf to 0.61 nf in IPAC 79 after exposure to water logging whereas, the root capacitance declined (1.02 nf to 0.2 nf) drastically in the sensitive genotype ICPL 7035 indicating irreversible damage of roots due to stress affecting absorption of minerals and other nutrients from soil. Water logging induced accumulation of leaf anthocyanin was negligible in IPAC 79 as compared to sensitive genotypes. Apart from water logging tolerance and Phytopthora resistance, IPAC 79 is an improved genotype that showed good general combining ability in crosses with wild derivatives of *Cajanus scarabeiodes*.

Identification of *Phythopthora* stem blight tolerant lines

The advanced generation wild derivatives of *C. scarabeoides* were screened against *Phythopthora* stem blight (PSB) in the sick plot for the identification PSB resistant genotypes. The frequency of PSB resistance alleles are more in the late maturing genotypes, therefore, due emphasis was given to identify the PSB genotypes that matures early. Among the wild derivatives, two lines namely, IPAWD 28-1 and IPAC 2 exhibited resistance against PSB. One early genotype IPAB 10-9 was also resistant to PSB. A few materials derived from various cross combinations segregating for PSB resistance were selected and advanced to next generation for selection of homozygous resistant lines.

Screening of genotypes for high temperature tolerance

A set of 150 lines were screened for high temperature tolerance at Bhopal during the period under report. Forty putatively tolerant lines are being rescreened at Kanpur under the rainout shelter. Five plants were randomly selected from each line and de-podded in February. Observations were recorded on reproductive phenology, pollen germination at high temperature, pod length, seeds per pod, pods per plant and 100-seed weight of normal and de-podded plants. Observations on pollen germination indicated that IPAHT 47 has reproductive superiority at high temperature.

Screening of genotypes for drought tolerance

Pigeonpea genotypes were screened in rainfed situation at multi-location and a few lines that were consistently performing better under rainfed condition were selected for validation. During the period under report, IPAD 4 and IPAD 5 were the best performers. In 2017-18, a set of 19 lines including drought susceptible genotypes, were raised in the rain out shelter for generating the physiological data. The physiological data will be correlated with the agronomic data from multi-location trial.

Genetic improvement of yield and disease resistance in medium duration pigeonpea

Populations derived from crosses, namely ICP 12195 x VKS 11/24-2, IPA 9F x ICP 12195, VKS 11/24-2 x Bahar, IPAC 67 x IPAC 68, IPAC 68 x Bahar, IPAC 79 x WRP 1, ICPL 20135 x Bahar, ICPL 20135 x IPAC 72, IPAC 66 x IPA 8F, Maruti x IPAC 68, Maruti x IPAC 66, Maruti x IPAC 67, IPAC 79 x IPAAC 70, Bahar x IPAC 79, IPAC 24 x IPAC 72, ICP 10958 x IPAC 70, IPA 8F x Bahar, IPA 8F x 56/2010, IPAC 70 x IPA 8F, SEL 14 x IPA 8F, IPA 7F x IPA 8F, UPAS 120 x ICPL 88039, ICP 7366 x ICP 7148, IPAC 24 x IPAC 64, IPAC 66 x IPAC 67 were advanced to BC_1F_7 and F_9. The F_6's derived through intercrossing of TTB 7, IPAC 80, IPAC 79, BSMR 853, IPA 8F and JKM 189 were advanced to F_7 generation. The BC_1F_5 and F_6 generations of [IPAC 79 x IPAC 80, JAP 10-50 x IPA 203, Maruti x IPA 8F, NA 1 x (ICPL 87154), IPAC 80 x (ICPL 87154), IPAC 79 x (ICPL 87154), Prabhat x IPAC 64 , LRG 30 x Dholi Local, ICP 970 x JAP 10-52, Bahar x Maruti, NDA 1 x IPA 8F, NDA 1 x IPAC 68] were advanced.

Short duration pigeonpea

Evaluation of genotypes in station trial

In station trial, 10 entries including three check varieties *i.e.* Pusa 992, PAU 881 and ICPL 88039 were evaluated. Two entries, IPA 17E-03 and IPA 17-01 showed 35% and 33% superiority, respectively over the best check (Pusa 992).

Generation of new breeding material

Twenty two crosses were attempted to generate fresh breeding material. However, seeds could be obtained from 20 crosses. Early and extra early duration genotypes were used as donors in these crossing programmes.

List of the new F_1 crosses in pigeonpea (early duration) could be obtained

1	Bahar × ICPL 11326
2	Bahar × ICPL 20326
3	Bahar × ICPL 11279
4	NA 1 × ICPL 11326
5	NA 1 × ICPL 20329
6	UPAS 120 × ICPL 11326
7	UPAS 120 × ICPL 20326
8	UPAS 120 × ICPL 11276
9	CORG 9701 × ICPL 11244
10	CORG 9701 × ICPL 20327
11	CORG 9701 × ICPL 20325
12	PA 406 × ICPL 11276
13	PA 406 × ICPL 20325
14	PA 414 × ICPL 20329
15	PA 414 × ICPL 11301
16	CO 6 × ICPL 11292
17	Asha × ICPL 11244
18	Asha × ICPL 20327
19	Asha × ICPL 11301
20	Asha × ICPL 11279

Generation advancement

Single plant selections were carried out in different segregating generations. These included 382 SPS from F_2 (66 crosses), 119 SPS from F_3 (20 crosses), 89 SPS from F_4 (seven crosses), 52 SPS from F_5 (four crosses), 88 SPS from F_6 (three crosses), 23 SPS from F7 (two crosses) and 46 SPS from four crosses in F_8 generation.

Lentil

Varieties developed

IPL 220: The biofortified lentil variety (IPL 220) having high concentration of Fe (73-114 mg/kg) and Zn (51-63 mg/kg) in seeds has been released and notified for cultivation in NEPZ. It is developed through hybridization following pedigree method of selection from a three way crosse [(DPL 44 x DPL 62) x DPL 58]. It has average yield of 1378 kg/ha with a yield superiority of 8.93% and 11.13% over the check varieties, HUL 57 and KLS-218 in NEPZ, respectively. It is small seeded variety (2.4 g/100-seeds), has brown seeds with orange cotyledons. It is resistance to major diseases like rust, *Fusarium* wilt and stemphylium blight (emerging disease of the proposed zone).

IPL 321: Lentil variety IPL 321 derived from a cross K 75 × DPL 62 has been identified for notification in UP under normal sown conditions. Its average yield is 12.74 q/ha. This large seeded variety showed high resistance to wilt, rust and Ascochyta blight.

IPL 315: Lentil variety IPL 315 derived from a cross PL 4 × DPL 62 has been identified for notification in UP under normal sown conditions. It has wider adaptability with average yield of 1235 kg/ha in Uttar Pradesh. This large seeded variety (2.9 g/100-seed weight) has brown, attractive seeds with orange cotyledons and has resistance to rust and tolerance to wilt.

Performance of breeding lines in AICRP trials

Seven entries were evaluated in AICRP trials during 2016-17. Three entries including two small seeded IPL 233 and IPL 234 and one large seeded IPL 339 have been promoted to AVT -1 for NHZ and CZ, respectively.

Entry	Yield (kg/ha)	Promoted to	Zone
IPL 234 (small seeded)	1056 (18.8%)	AVT-1	NHZ
IPL 233 (small seeded)	976 (9.8%)	AVT-1	NHZ
IPL 339 (large seeded)	1581 (8.2 %)	AVT-1	CZ

Thirteen entries (IPLS 221, IPLS 225, IPLS 227, IPLS 228, IPLS 231, IPLS 232, IPLB 325, IPLB 329, IPLB 330, IPLB 331, IPLB 335, IPLB 338 and IPL 534) are being evaluated in UP State Adaptive Trials. Among these entries, IPLS 231, IPLS 232, IPL 338 and IPL 534 entries have been promoted for second year evaluation. Small seeded lentil variety IPL 225 having average yield 10.27 q/ha has been recommended for identification and release for cultivation in Uttar Pradesh.

Evaluation of promising breeding lines

During 2017-18, two station trials with 15 entries each and one preliminary yield trial with 60 entries were conducted at main and new research farms in order to evaluate the performance of the entries in ST-I at main farm, IPL-121802, IPL-161361, IPL-131173, IPL-141583 recorded higher yield (14.24 q/ha to 15.00 q/ha) over the check, IPL 220. The entry IPL-141583 gave the highest yield (15.00 q/ha) with 14.18% yield advantage over the best check variety (DPL 62). This entry also showed the high biomass and 111 days maturity. In ST-II, IPL-10834, IPL-151161 and IPL-151023 entries recorded higher yield (14.88 q/ha to 15.71 q/ha) over the best check IPL 534. The entry IPL-151023 gave the highest yield (15.71 q/ha) with 52.1% yield advantage over the best check IPL 534. This entry also matured at the earliest (109 days) in comparison to other entries. In PYT, six entries (IPL-171365, IPL-151302, IPL-161426, IPL-171364, IPL-161464, IPL-171408) were promising over the checks for further evaluation in station trial. These entries yielded 14.3 – 16.00 q /ha. A station trial of 15 entries having large seed size (>2.5 g/ 100 seeds) and PYT comprising of 60 entries along with the checks IPL 316 and DPL 62 was conducted at RS-IIPR, Bhopal.

Generation of breeding material

During *Rabi* season 2017-18, 16 crosses (DPL 62 x B-77; IPL 220 x B-77; IPL 534 x B-77; IPL 406 x B-77; DPL 62 x 2K/303; IPL 220 x 2K/303; IPL 321 x 2K/303; IPL 406 x 2K/303; IPL 534 x 2K/303; IPL 406 x SLL-OPFL; IPL 316 x SLL-OPFL; IPL 406 x ILWL 92; IPL 341 x IPL 538; IPL 342 x IPL 539; IPL 538 x IPL 341; IPL 539 x IPL 342) were attempted among the elite breeding lines having earliness, high biomass and wider adaptability. Besides, 12 fresh crosses were attempted under the national crossing programme by using PL316 and 12 different donors including ILWLS 118, IPL 321, LL1114, PL 7, DPL 58, ILL 7663; LL 699; RVL 16-4; PL-1; PL 2; DPL -62 and LL 1161.

F_{1s} seeds were grown from seven crosses (IPL 316 x DPL 58, IPL 321 x ILWL 77; IPL 321 x ILWL 63; IPL 220 x ILWL 63; IPL 230 x IPL 534; IPL 233 x IPL 534; IPL 339 x IPL 316). Ten F_1 plants were generated from these crosses and only six plants were identified as true hybrids. Also, BC_2F_1 seeds from two crosses (IPL 6002 x DPL 58 x DPL 58 and ILWL 118 x IPL 220 x IPL 220) were raised during this year and BC_2F_2 seeds were harvested from 36 plants. Single plant selection (SPS) was made from 22F_2 (263 SPS), 50F_3 (546 SPS), 35F_4 (260SPS);and 13F_5 (149 SPS) and bulked 120 progenies of 23F_6 were bulked for yield evaluation.

Development and maintenance of mapping populations

Trait specific RIL mapping populations for early seedling vigor (ILL 7663 × DPL 15) having 160 RILs;

root traits (IPL 98/193 × EC 208362) having 200 RILs; Earliness (L 4603 x Precoz) having 160 RILs and wilt resistance (PL-02 x Precoz) having160 RILs have been maintained.

ICARDA nurseries

Three ICARDA nurseries for earliness (LIEN-E-2018), pre-breeding (LIPBN-2018) and mechanical harvesting (LIEN-MH-2018) traits comprising 36, 9 and 36 entries, respectively were evaluated at IIPR New Research Farm. Among these entries, three entries namely 36201, 36220 and 36234 have been identified as useful donors for mechanical harvesting, while one entry 33235 has been identified for mechanical harvesting from LIEN-E- 2018 nursery for earliness.

Mungbean

New varieties developed

IPM 2K14-9 (Varsha): This variety has been developed following pedigree method of breeding from the cross EC998885/PDM 139. It was tested in UP State Adaptive Trials during *Kharif* season for three years (2014-16) and outperformed the best check variety, IPM 02-3 showing a yield superiority of >35%. It has been identified and approved by the State variety Release Committee for *Kharif* cultivation in Uttar Pradesh.

IPM 302-2 (Kanika): Another superior genotype, IPM 302-2, developed from the cross PM 4/EC398897 was also identified as a promising genotype for cultivation during Spring and *Kharif* seasons in U.P. State on the basis of its consistently superior performance over three years. It outperformed the best check, IPM 02-3 by showing yield superiority of 27%. This variety has been approved for release by the State Variety Release Committee for *Kharif* cultivation in Uttar Pradesh.

IPM 312-20: Developed from the cross, IPM 03-1/SPS 5, this genotype exhibited >12% superiority over the best check cultivar, Pant Mung 6 in the North Hill Zone (NHZ) of the country. Therefore, this identification proposal has been invited which will be considered during *Kharif* AICRP Group Meet 2018. Likewise, this variety exhibited >18% superiority over the best check, IPM 99-125 in U.P. State Adaptive Trials also during last three years. Therefore, it has also been identified for cultivation during Spring season in Uttar Pradesh and proposal has been invited which is being submitted.

IPM 409-4: The genotype IPM 409-4, developed from the cross, PDM 288/IPM 03-1, performed consistently better over the best check, IPM 99-125 in U.P. State Adaptive Trials during Spring (2015-17) yielding >9% better over the best check. Therefore, identification proposal of this variety has been invited for release during Spring season in Uttar Pradesh.

IPM 312-09: Developed form the cross, IPM 03-1/SPS 5, this genotype also performed consistently superior in U.P. State Adaptive Trials during Spring season. This variety has been identified for release during Summer season in Uttar Pradesh.

Evaluation of elite breeding lines

During Spring 2017, one demonstration, one station trial (ST) and one preliminary yield trial (PYT) were conducted. Station trials comprising of 24 entries including four checks was conducted. Three entries *viz.,* IPM 312-394-1 (972 kg/ha), IPM 9901-6-1 (953 kg/ha) and IPM 14-46-7 (912 kg/ha) outperformed the best check, IPM 410-3 (872 kg/ha). The PYT was conducted with 48 entries including five checks and the entries IPM 610-2-4 (1834 kg/ha), IPM 604-1-1 (1612 kg./ha), IPM 604-1-2 and IPM 101-102 (M X U) (1530 kg/ha each) and IPM 204-212 (M XU) 1473 kg/ha) outyielded the best check IPM 2-3 (1418 kg/ha).

During Summer 2018, one demonstration (12 entries), 1 station trial (24 entries) and 1 preliminary yield trial (PYT) (48 entries) were conducted. In station trial comprising 24 entries including four checks, three entries *viz.* IPM 14-106, IPM 312-394-1 and IPM 14-22 outperformded the best check, IPM 2-3.

During *Kharif* 2017, one demonstration, two ST and two PYT were conducted. Data were recorded in ST ad PYT on days to flowering, days to maturity, seed yield/plot and disease incidence. ST I the yield data could not be recorded as the grain was spoiled due to excess terminal rains and therefore, the trial was considered as vitiated. In ST II, the genotype IPM 701-704 (MXU) (1274 kg/ha) recorded the highest yield followed by IPM 101-102 (MXU) (1238 kg/ha) and IPM 14-9 (999.60 kg/ha) as compared to the best check, PDM 139 (916 kg/ha). Two PYTs were conducted with 48 entries each including six checks. While the trials were in excellent condition before maturity, terminal rains spoiled the grain quality and hence, both these trials were also considered as vitiated and will be repeated again during *Kharif* 2018.

RC, Dharwad: One s tation trial of mungbean comprising 20 entries was conducted during *Kharif* 2017-18. The genotype IPM-410-3 (1678 kg/ha) recorded the highest seed yield followed by IPM 312-394-3 (1609 kg/ha), IPM 2-3 (1569 kg/ha) and IPM 2-14 (1510 kg/ha). The entries IPM 312-394-1 (57 days) and IPM 312-394-3 (59 days) were the earliest to mature. During Spring Summer 2018, two station trials of mungbean comprising 24 genotypes each are being conducted for their evaluation for yield and related traits.

Evaluation of promising genotypes in AICRP trials: Two mungbean genotypes *viz.,* IPM 312-19 and IPM 312-20 performed significantly better than the best check during *Kharif* season and were promoted to AVT 2 in the North Hill Zone of the country. Among these, IPM 312-20 recorded >12% yield superiority over the best check, Pant Mung 6 in *Kharif* season in NHZ and therefore, its identification proposal will be submitted to Varietal Identification Committee. Likewise, genotype IPM 14-7 was promoted to AVT 1 in the same zone. In Spring season, genotypes IPM 512-1 and IPM 410-9 were promoted to AVT 1 in NEPZ as well as NWPZ.

Four new genotypes viz., IPM 512-1 and IPM 410-9 (*Kharif* season), IPM 208-1 (Spring season) and IPM 06-05-1 (Summer season) were nominated for multilocation evaluation at IVT stage in AICRP, MULLaRP during 2017-18. In U.P. State Adaptive Trials, the genotypes, IPM 410-9, IPM 512-1 and IPM 312-19 performed significantly better than the best check cultivars and entered into second year of multilocation testing during Spring/Summer/*Kharif* seasons. Three new genotypes *viz.,* IPM 312-4, IPM 5-17 and IPM 9901-8 were nominated afresh for multilocation evaluation during 2017-18.

Development of new breeding materials and their generation advancement

Intra-specific crosses

During *Kharif* 2017, 11 new intra-specific cross combinations were made between elite mungbean cultivars (IPM 02-3, IPM 02-14, IPM 410-3 and IPM 205-7) and identified donor lines including IC 251446, LGG 460, MH 421 and SML 1815.

Two-way crosses: Thirty two-way cross combinations were also attempted in an order to develop more diverse genetic material in mungbean. In all these crosses, sufficient quantity of F_1 seed was obtained.

S. No.	Name of the Cross
1.	(IPM 99-125/TCR-7)//(IPM 99-125 / PRR 2008-2)
2.	(IPM 409-4/IPM 2-3) //(PDM-139 / IPM 410-3)
3.	(IPM 99-125 / TCR-7)//(IPM 2-3 / TCR-188)
4.	(IPM 99-125 / PRR 2008-2)//(IPM 410-3 / IPM 96-2)
5.	(PDM-139 / IPM 410-3)//(IPM 409-4 / IPM 2-3)
6.	(PDM-139 / TCR-385)//(IPM 410-3 / IPM 2-3)
7.	(PDM-139 / TCR-385)// (IPM 2-3 / TCR-7)
8.	(IPM 2-3 / TCR-7) //(IPM 410-3 / IPM 96-2)
9.	(IPM 99-125 / IPM 2-3) // (IPM 99-125 / PRR 2008-2)
10.	(IPM 99-125 / TCR 218) // (IPM 205-7 / IPM 94-1)
11.	(IPM 410-3 /TCR-262) // (IPM 205-7 / PDM-139)
12.	(IPM 205-7 / PDM-139) //(IPM 410-3 / SML 1815)
13.	(IPM 205-7 / PDM-139) // (IPM 410-3 / LGG-460)
14.	(IPM 410-3 /TCR-262) // (IPM 205-7 / SML 1815)
15.	(IPM 205-7 / IPM 94-1) // (IPM 410-3 / SML 1815)
16.	(IPM 205-7 / PDM-139) // (IPM 410-3 / LGG-460)
17.	(IPM 99-125/ IPM 94-1) // (IPM 99-125 / TCR-218)
18.	(IPM 410-3 / LGG-460) // (IPM 410-3 /TCR-262)
19.	(IPM 410-3 / LGG-460) // (IPM 205-7 / PDM-139)
20.	(IPM 2-14 / VBG 04-003) // (IPM 2-3 / LGG-460)
21.	(IPM 410-3 / SML 1815) // (IPM 205-7 / IPM 94-1)
22.	(IPM 99-125 / PDM-139) // (IPM 410-3 / LGG-460)
23.	(IPM 2-3 / TCR-188) // (IPM 99-125 / PRR 2008-2)
24.	(IPM 205-7 / MH-421) // (IPM 2-3 / TCR-7)
25.	(IPM 2-3 / TCR-188) // (PDM-139 / TCR-385)
26.	(IPM 2-3 / TCR-7) // (IPM 205-7 / MH-421)
27.	(IPM 410-3 / IPM 2-3) // (PDM-139 / TCR-188)
28.	(IPM 2-3 / PRR 2008-2) // (IPM 2-14 / VBG 04-003)
29.	(IPM 2-3 / LGG-460) // (IPM 2-14 / VBG 04-008)
30.	(IPM 410-3 / IPM 96-2) // (IPM 2-3 / TCR-7)

Advancement of breeding materials: In advanced breeding material, 42 superior fixed lines were isolated. Besides this, 438 single plant selections from different segregating generations in mungbean x mungbean and mungbean x urdbean crosses were also made.

Development and maintenance of mapping populations

For maintenance of mapping populations, 229 $F_{6/7}$ RILs for yellow mosaic disease derived from the crosses IPM 2-14/TMB-37 and 189 $F_{6/7}$ RILs derived from the cross PDM-139/TMB- 37 were maintained. These mapping populations were also characterized for agronomic traits. Trait-specific mapping populations for seed size, days to flowering and days to maturity are also being developed which are at early (F_2/F_3) stage.

Improvement in Indian mungbean breeding programme as revealed by genome-wide mapped microsatellite markers

Genetic diversity and the population genetic structure of forty-one elite lines of mungbean developed in Indian mungbean breeding programme during three decades were investigated using 80 mapped microsatellite markers. Six hundred ninety six alleles were detected among the 41 lines with an average of 8.68 alleles per locus. Gene diversity ranged between 0.93-0.05 with mean of 0.68, and polymorphic information content ranged between 0.92-0.05, with mean of 0.66. Out of 80 microsatellites, 51 were found highly polymorphic with >0.60 PIC value and these were noticed as most informative. As a result of STRUCTURE analysis, three distinct genetic groups were identified and revealed that breeding programme led to a clear-cut improvement in 100-seed weight, pod length, seeds per pod and plant height in elite lines developed after year 2000 (Fig. 5). The grouping pattern was also supported by the factorial and UPGMA analysis.

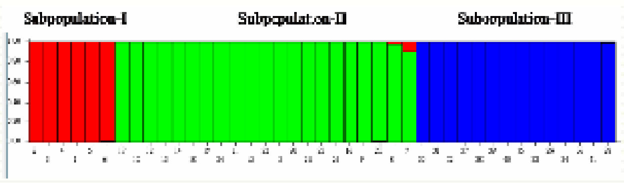


Fig. 5 : Population genetic structure of 41 mungbean elite lines based on 80 SSR markers using the admixture model. Groups for each panel are represented by different colors

Identification of QTLs associated with MYMIV resistance and association mapping for days to first flower in mungbean

Marker-trait association of a selected panel of 127 mungbean genotypes was established for yellow mosaic disease (YMD) caused by MYMIV. Virus-specific primer pairs, AC/AV-abut and BC/BV-abut confirmed the role of MYMIV in disease development. Out of 256 microsatellite markers, 31 polymorphic microsatellites were located on four linkage groups (LGs) *viz.* LG2, LG4, LG6 and LG9. These markers were used to identify the novel QTLs associated with MYMIV. The model-based population structure analysis resulted in formation of five distinct genetic subpopulations. Subpopulation-wise polymorphic information content (PIC) ranged between 0.58-0.67, indicating ample amount of variation at genome level. The subpopulation-V had maximum 149 alleles with an average of 6.58 alleles per locus. In the study, 17 microsatellite markers were detected as associated with MYMIV resistance. Two specific regions close to CEDG293 and cp1038 associated with MYMIV resistance were detected in the study. These microsatellite loci located on chromosome 2 and 6 may prove useful in marker assisted mungbean improvement programme for MYMIV resistance.

For another trait, i.e. days to first flower, marker-trait association studies was completed in another set of 96 mungbean/*Vigna* accessions. Markers X87 and VR015 were found associated with days to first flower and pod length.

Urdbean

Hybridization and advancing of segregating generations

Generation of breeding materials: Fifteen crosses were successfully attempted involving diverse breeding lines or parents. The crosses are: PLU272xIPU02-43, KVK-PxIPU02-43, Mash114x Mash1008, PU31 x LBG685 x Lalitpur local, Mash114xTU103, T-9 x IPU02-43, Mash1108 x Uttara, Mash114 x PU11-14, Lalitpur local x IPU02-43, Lalitpur local x IPU11-2, Uttara x PLU272, Mash114 x IPU02-43, Mash114 x LBG623, IPU02-43 x T-9 and PLU59 x IPU02-43.

Advancement of segregating generations:

Twenty breeding lines and segregating generations (F_2-F_8) were advanced as following :

Generation	Families	Crosses	SPS made
F_8	15	03	100 + 03 bulks
F_5	20	20	200 + 20 bulks
F_4	45	09	140 + 09 bulks
F_3	79	13	200 + 13 bulks
F_2	-	20	20 bulks

Promotion of entries in state varietal trials

IPU 11-2, an entry with sufficient yield advantage was identified for release in Uttar Pradesh.

Station trial

In station trials, three entries out of 20 entries, IPU 11-6 (956 kg/ha), IPU 13-9 (950 kg/ha) and IPU 12-5 (971 kg/ha) were promising compared to the check.

Biofortification for quality traits in urdbean (*Vigna mungo* L. Hepper) and Fe metabolism related genes' expression analysis in lentil

A set of 100 urdbean genotypes grown in augmented design in NRF and Main Farm of IIPR were harvested and grounded into seed powder and tested for seed iron and zinc concentrations using atomic absorption spectrophotometer (AAS). The Fe concentration ranged from 8-285 mg/kg with an average value of 99 mg/kg. In case of zinc, average estimated value was 32 mg/kg and it ranged from 0.45-134 mg/kg among the tested urdbean genotypes.

Fieldpea

Variety released and notified

IPFD 2014-2: Developed a mottled (violet) tan colour and bold seeded dwarf fieldpea variety using IPFD 99-13 and P 1297-97 as parents. It exhibited the average yield potential of 2270 kg/ha in Central Zone with more than 26% superiority over the best check 'Vikas'. It is resistant to powdery mildew in proposed zone

and matures in 102 days. It is moderately resistant to *Ascochyta* blight, pod borer, aphid and leaf miner. This variety has been released and notified for central zone comprising states of Madhya Pradesh, Chhattisgarh, Maharashtra and part of Rajasthan.

Generation of breeding material: Thirty fresh crosses were attempted during *Rabi* 2017-18 involving different donors possessing specific traits *viz.,* large seed size, number of seeds per pods, pod length, number of pod, earliness, powdery mildew resistance and rust tolerance.

Evaluation of advance breeding lines: In station trial for dwarf genotypes, 13 genotypes were evaluated along with three checks. Among these, IPFD 18-2 (3773 kg/ha) and IPFD18-11 (3481kg/ha) were found promising as compared to the best check, IPFD 12-2 (3410 kg/ha). In another station trial, 15 tall genotypes were evaluated along with three checks. Among these, genotypes IPF 2018-17 (3012 kg/ha) and IPF 2018-20 (2783 kg/ha) were found to be superior as compared to the best check, IPFD 10-12 (2720 kg/ha). In preliminary yield trial (PYT), 26 tall and 18 dwarf entries were evaluated with three checks.

Selections of promising genotypes from segregating population: Twenty five crosses were raised in F_1 generation. From the segregating generations, single plants were selected on the basis of earliness, seed size, pod length, yield per plant and resistance to powdery mildew and rust. Total 220 single plants from 24 crosses in F_2, 220 single plants from the progenies of 22 crosses in F_3 and 250 single plants from the 25 F_4 generations were selected. In F_5 and F_6 generation 433 and 168 bulk single lines were evaluated, respectively.

Development of mapping population: 220 SPS from FS population derived from HFP 4(S) x FC1(R) for rust resistance have been harvested for further advancement.

Promising entries in AICRP trials: One tall fieldpea entry IPF 16-18 was promoted to AVT-1 in North Eastern Plain Zone (NEPZ) and North Hill Zone (NHZ). Another tall type entry IPF 16-13 was promoted to AVT-1 in NEPZ. Likewise, one dwarf entry IPFD 16-4 was promoted to AVT-1 for Central zone (CZ). Four new entries *viz.,* IPF 17-18, IPF 17-19, IPFD 17-2 and IPFD 17-6 are being evaluated in IVT.

Promising genotypes in UP State coordinated trials

IPF 11-13: The performance of this genotype was found promising over the popular check variety Rachna in

Uttar Pradesh State Varietal Trial over three years (2014-17). Identification proposal will be submitted soon. In state adaptive trials, four entries have been promoted and two new entries were submitted this year.

Herbicide tolerant genotypes: Based on last two years screening, a set of fifteen genotypes comprising highly tolerant, tolerant, moderately tolerant, sensitive and highly sensitive genotypes was examined in larger plot for resistance against popular post-emergence herbicide, 'metribuzin', @ 500 g/ha. The plants were scored for herbicide toxicity on three different stages *viz.,* 15 days after spray (DAS), 30 DAS and 60 DAS on a scale of 1-5. Based on scoring for visual appearance and toxicity on plants, only one genotype P-637 was found tolerant (Fig. 6). The Institute Germplasm and Genotypes Identification Committee (GGIC) also visited field and they were satisfied with the performance of genotype (Fig. 7). This genotypes consistently witnessed tolerance for metribuzin @ 500 g/ha during previous two years screening also. Therefore, this genotype can be utilized as donor to accelerate breeding programme and development of herbicide (metribuzin) tolerance variety.

Fig. 6 : Herbicide **tolerant genotype (P-637)**

Fig. 7 : GGI Committee visit

Screening for rust resistance

Rust is one of the most important biotic stresses of fieldpea which is caused by *Uromyces fabae* and occurs at flowering and fruiting stage of the crops (Fig. 8). During *Rabi* 2017-18, F_5 populations of 43 crosses of fieldpea was screened for rust resistance under natural field condition. Total 439 single plant progenies along with three checks were evaluated for identification of resistant sources for rust under natural field conditions during *Rabi* season 2017-18. Data of rust severity were recorded using 0-5 disease rating scale. Five random plants were selected in each progeny for field observation. Out of 433 progeny evaluated, 301 progenies showed resistance, 6 were moderately resistant, 61 were susceptible and 65 showed highly susceptible reaction against *Uromyces fabae*. 176 advanced breeding lines out of 174 F_6 segregating populations were also evaluated. 141 lines exhibited resistant reaction, 8 were moderately resistant, 15 were susceptible and 10 were highly susceptible against *U. fabae*. These resistant lines could be used for further fieldpea resistance breeding programme.

Fig. 8 : (a) aecial and (b) uredial pustules on lower surface of leaves after disease incidence

Screening of fieldpea for high temperature tolerance

Total 151 genotypes comprising advanced breeding lines, released varieties and germplasm accessions were planted at three different dates of sowing *viz.,* 15.11.17 (I), 30.11.17 (II) and 15.12.17 (III) to expose the genotypes against different temperatures regimes. The main objective is to identify stable and high temperature tolerant genotypes of fieldpea. Different morpho-physiological observation like days to flowering, no. of pods/plant, no. of seeds/pod, primary branches, Ist pod bearing node, plant height, days to maturity, yield/plant, plot yield, NBI, flavonoids and chlorophyll content are recorded and are being analyzed.

Rajmash

Screening of rajmash germplasm for cold tolerance

The objectives of this study was to screen the seedling emergence and the phenotypic response of rajmash germplasm under different temperature regimes under field conditions to display stress-tolerant genotypes with good agronomic performances and yield potential. Eighty genotypes including three susceptible checks *viz.,* IC382691, IC 417353, IC341404 were evaluated in RCBD design with two replications against cold stress under field condition. The data recorded on various morpho-physiological traits and all the traits displayed significant differences among genotypes. Based on the phonological data some of the promising genotypes were found highly tolerant to cold *viz.,* EC 15, GPR 203, GPR 204, IC 392636, IC 391488, NO 3160A, BLF 101, ET 4515, ET 8415, ET 8416, EC 500232, IC 361279, IC 356063 and IC 340947. The highly sensitive genotypes were IC391531, IC340828, IC340865, IC337290, IC341404, EC400445, EC400361, IC 360857, IC 382691 and IC 417353. Consistent comparable results were observed in natural field condition since from last two years of field evaluation.

Rajmash seedling died due to cold stress and leaf damage scale for cold stress screening

Evaluation of germplasm

Five hundred germplasm accessions were evaluated for morphological and agronomic traits in augmented design at main research station, IIPR, Kanpur. All the germplasm accessions showed wide range of variation for the traits studied. The analysis of variance revealed significant differences for the characters indicating wide variation among the genotypes. Superior germplasm accessions were identified for various traits *viz.,* early flowering: (EC 94456, IC 41665, IC 41668 and IC 41669); early

Character	Promising accessions
Early flowering (< 50 days)	IC340877, IC341197, IC340928
Late flowering (76-100 days)	IC341435, EC150250
No. of primary branches (>3)	EC400414, EC564797, EC150250
Pod length (>10 cm)	EC500232, ET4515
No. of seeds per pod (> 5)	IC41668, EC500232, BLF101
Vegetable type	IC405545, IC405546, IC341435
Dual purpose type	GPR204
Resistance to BCMV	EC15, BLF101, C500232, ET8415
Upright branching	BLF101, EC500232, EC125715
Large seed type	IC340902
Purple Stem anthocyanin	IC341389, IC341406, EC150250
Circular seed type	EC400414

maturity: (IC 41674, IC 43572, IC47642 and IC 199183); long pods: (EC 106613, EC 128569, IC 42378, IC 43556, IC 43557, IC 43564, IC 381103, IC 405506); vegetable type: (IC 405545, IC 405546, IC 448956, IC 448994 and IC 43556). These genotypes could be utilized in breeding programme for the improvement of specific traits.

Generation of breeding material

Two thousand crosses were attempted using 20 donor parents in for improvement of specific traits such as cold tolerance, BCMV disease resistance, dual purpose type (both grain and vegetable type) and higher seed yield. Only 34 crosses were successful.

Screening of germplasm aganist BCMV disease resistance

Three hundred germplasm acessions were screened against BCMV disease under natural field condition utilizing three suscptible checks *viz.,* IC 341338, IC 341339 and IC 383620. Based on the per cent disease incidence, the genotypes were categarized as highly tolerent : (EC 15, IC 356063, IC 340947, BLF

101, EC 500407, IC 391488, NO 3160A, ET 84490, GPR 203, EC 564797, IC 341435, GPR 203, IC 341408, IC 391377 and IC 356005); moderately tolerent: (IC 383566, IC 360859, IC 382655, IC 419886, IC 340938, IC 341407, IC 340961 and IC 340901) sucessptible : (IC 356064, IC 419787, IC 340911, IC 341381, IC 382674) and highly sucessptible: IC 341338, IC 341339, IC 341340, IC 430037, IC 341386, IC 341395, IC 360865, IC 356057A IC 356057B, IC 422005, IC 419817, IC 338701, IC 341346 and IC 383620.

Pre-breeding, Germplasm Management, (Evaluation and Rejuvenation) and Pre-breeding

Chickpea

Maintenance of germplasm lines: Four hundred chickpea germplasm accessions were rejuvenated. Seventy five selected accessions were evaluated under timely sown condition. Among those, fifteen accessions (ICC15898, ICC 15910, ICC10136, ICC 10641, ICC 15015, ICC 11447, ICC 15879, ICC14245, ICC 15911, ICC 15896, DKG 21204, DKG 21193, ICC 15900, DKG 21178 and DKG 21191) were identified with better source:sink relation and plot yield. A set of 177 accessions were evaluated under late sown condition. Twelve accessions, namely, ICC 16684, ICC 14778, ICC 251813, ICC 14866, ICC 1882, ICC 15847, ICC 15921, JG 2001-115, RSG 945, ICC 15119, ICC14729 and ICC 07102 were found to be promising with respect to yield and phenological attributes. Based on performance and yield across two years, 28 promising accessions were evaluated for yield and phenological attributes under timely sown condition. Potential lines with high plot yield were ICC 15185, ICC 1708, ICC 9553, ICC 15088, ICC 15850 and ICC 10261. All of them had a plot yield higher than 1.5 kg from plot size of 6sq.m. (>2500 kg/ha).

Maintenance of wild *Cicer* species: One hundred nineteen accessions belonging to six wild Cicer species were sown in Wide Hybridization Garden. Three inter-specific crosses made during 2016-17 are being advanced.

Pigeonpea

Germplasm rejuvenation

Pigeonpea genetic resource comprising of 1000 long duration, 380 early maturing and 112 wild genotypes belonging to Gene Pool-2 and 3 are being maintained at ICAR-IIPR gene bank. During 2017-18, 250, 189 and 57 long duration, early duration and wild accessions were rejuvenated, respectively. Fifteen late maturing trait specific accessions were selected for using in breeding programme.

Wilt sick field with distinct resistant and susceptible symptom

Screening wild accessions against wilt resistance

A set of 57 wild accessions was screened against *variant-2* of *Fusarium udum* in wilt sick field, and disease reaction was recorded.

Lentil

Total 450 accessions of active germplasm including a diverse set of 94 local accessions; 87 ICARDA minicore; 100 accessions of Mediterranean landraces and a population of 96 accessions received from Kota were evaluated and maintained.

Pre-breeding materials

The pre-breeding lines generated from cultivated x wild crosses were maintained. 405 pre-breeding lines from five crosses including DPL 58 x ILWL 118 (120 lines), DPL58 x ILWL 248 (45 lines), ILWL 366 x DPL 58 (90 lines), ILWL 425 x DPL 62 (90 lines), ILWL 189 x DPL 62 (60 lines) derived from crosses of improved lines (*L. culinaris*) and accessions of wild species (*L. orientalis*) were raised and evaluated for yield and other traits. Besides, 133 single plants were selected in F_4 from 32 wide crosses for advancing to next generation.

Mungbean

During *Kharif* 2017, 514 germplasm accessions were rejuvenated from medium term storage. 215 active germplasm lines were also maintained and evaluated for different morphological traits. Simultaneously, a minicore set of mungbean lines comprising 296 accessions was raised in two replications during Summer as well as *Kharif* seasons at ICAR-IIPR, Kanpur and during *Kharif* season at RS, Dharwad. Data were recorded on 14 morpho-physiological parameters besides yellow mosaic disease. The seeds of minicore accessions were also multiplied for conducting replicated trials during ensuing seasons.

Among wild *Vigna*, 107 accessions including *Vigna radiata* (11); *V. trilobata* (19) ; *Vigna mungo* (10); *V. umbellata* (16) ; *V. sublobata* (5) ; *V. aconitifolia* (8) ; *V. sylvestris* (5) ; *V. stipulaceae* (2) ; *V. radiata* var. *setulosa* (2); *V. hainiana* (4) ; *V. trinernia* var. *bournei* (3) ; *V. glabrescens* (1) ; *V. pilosa* (3) ; *V. trinernia* (1) ; *V. dalzelliana* (3) ; *V. unguiculata* (4) ; *V. vexillata* (1) ; *V. khandalensis* (1) were maintained during *Kharif* 2017. These were also evaluated for 34 morpho-physiological traits following IBPGR descriptors.

Prebreeding and distant hybridization: A large scale pre-breeding and distant hybridization programme has been initiated in mungbean to introgress desirable genes from wild *Vigna* accessions. 107 Asiatic *Vigna* accessions were evaluated on 34 morphological traits over the last 3-4 years besides their molecular characterization for identification of usable and inter-crossable wild accessions. On the basis of this information, donors were identified in Asiatic *Vigna* and 26 new cross combinations were attempted to generate F_1 seeds. Successful crosses were made between the elite mungbean lines (IPM 02-3, IPM 02-14, IPM 410-3 and IPM 205-7) and 10 wild *Vigna* accessions (VBG 04-003, TCR 93, *V. umbellata* (PRR 2008-2), TCR 88, VBG 04-008, TCR 89, TCR 20, *V. glabrescens*, *V. sylvestris* (IC277036), and *V. sylvestris* (IC 277039). Good quantity of F_1 seeds was obtained from all these crosses.

Intra-specific crosses	
1. IPM 2-14 / LGG-460	8. IPM 2-14 / TCR-88
2. IPM 2-14 / MH-421	9. IPM 2-14 / VBG 04-003
3. IPM 2-14 / SML 1815	10. IPM 2-14 / PRR 2008-2
4. IPM 2-3 / SML-1815	11. IPM 2-14 / TCR 94
5. IPM 2-3 / MH-421	12. IPM 2-14 / TCR-89
6. IPM 2-3 / RMG-1028	13. IPM 2-14 / *V. umbellata*
7. IPM 410-3 / LGG 460	14. IPM 2-14 / *V. glabrescens*
8. IPM 410-3 / MH-421	15. IPM 2-3 / TCR-88
9. IPM 205-7 / LGG-460	16. IPM 2-3 / PRR 2008-2
10. IPM 205-7 / MH-421	17. IPM 2-3 / VBG 04-003
11. IPM 205-7 / SML 1815	18. IPM 2-3 / LGG-460
Inter-specific crosses	19. IPM 2-3 / VBG 04-008
1. IPM 205-7/VBG 04-003	20. IPM 2-3 / TCR-94
2. IPM 205-7/ IC 251446	21. IPM 2-3 / *V. umbellata*
3. IPM 205-7 / PRR 2008-2	22. IPM 410-3 / VBG 04-003
4. IPM 205-7 / TCR 88	23. IPM 410-3 / VBG 04-00
5. IPM 205-7 / VBG 04-008	24. IPM 205-7 / TCR-20
6. IPM 205-7 / TCR 89	25. IPM 205-7 / *V. umbellata*
7. IPM 205-7 / TCR	26. IPM 2-14 / VBG 04-008

Field view of germplasm accessions of fieldpea

Urdbean

Plant genetic resource management and its utilization through pre-breeding

Under the pre-breeding activity, few inter-specific crosses *viz.,* IPU11-2 x *Vignasylvestris*, IPU02-43 x *V. sublobata*, IPU02-43 x *V. umbellata,* IPU11-2 x *V. umbellata*, KS-1x *V. sublobata*, KS-1 x *V. umbellata*, IPU02-43 x Pant M-6 (*V. radiata*) and DPU88-31 x LBG685 x *V. umbellata* were attempted. In addition to this, 312 germplasm lines were rejuvenated and their flowering data and disease reaction for YMV were recorded.

Fieldpea

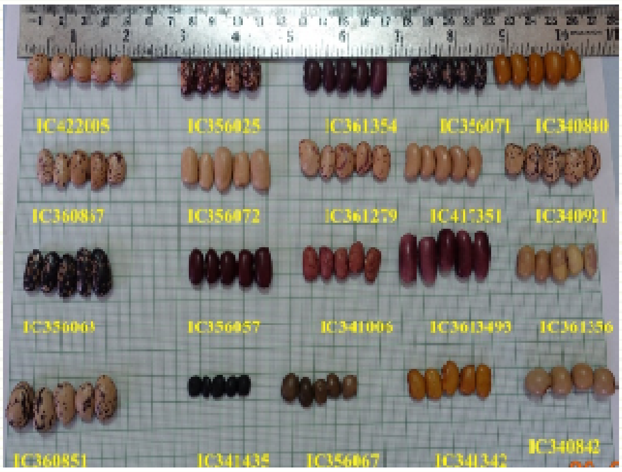
Germplasm rejuvenation: Nine hundred fifty accession of fieldpea germplasm rejuvenated.

Germplasm evaluation: Two hundred accessions of fieldpea received from ICAR-NBPGR were evaluated for different traits like days to 50% flowering, anthocynin, leaf size, foliage color, leaf axil color, plant height, petal color, pod no./axil, pod curvature, pod beak, pod color, pod/plant, pod length, no. of seeds/ pod and days to maturity. The other post harvesting data *viz.*, seed colour, seed shape 100-seed weight and yield/plant are being recorded.

Rajmash

Seventy two rajmash germplasm including three cultivated varieties (Baspa, Kailash and Triloki) were procured from NBPGR-RS, Shimla, Himachal Pradesh.

In addition, 510 germplasm accessions of rajmash were rejuvenated and maintained at ICAR-IIPR, Kanpur. Most of these accessions have been procured from ICAR-NBPGR national genebank regional station *viz.,* Bhowali and Shimla.



Larger Variation for seed colour, size and shape

Seed production and quality enhancement in pulses

Longevity in *kabuli* chickpea *cv.* Kripa

Kripa seeds were stored in jute gunny bag, hermetic polyethylene bag, silo and conventional polypropylene sacks for nearly two years and tested for seed quality parameters on periodical intervals. Seeds stored in jute gunny bag recorded only 6% germination, while seeds in hermetic polyethylene bag, silo and conventional polypropylene sack recorded 48, 36 and 20% germination, respectively after 20 months of storage (Fig. 9). The Kripa seeds had an initial germination of 80%.

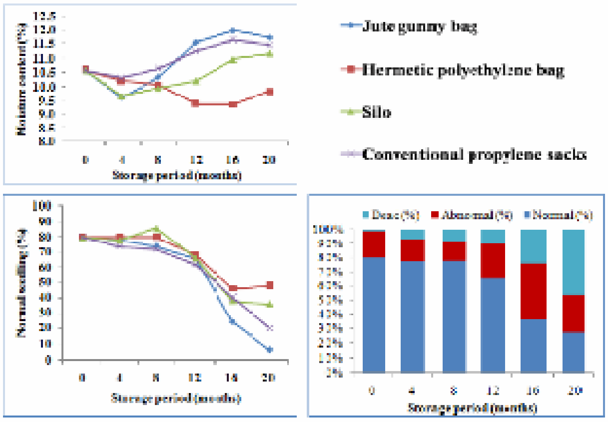
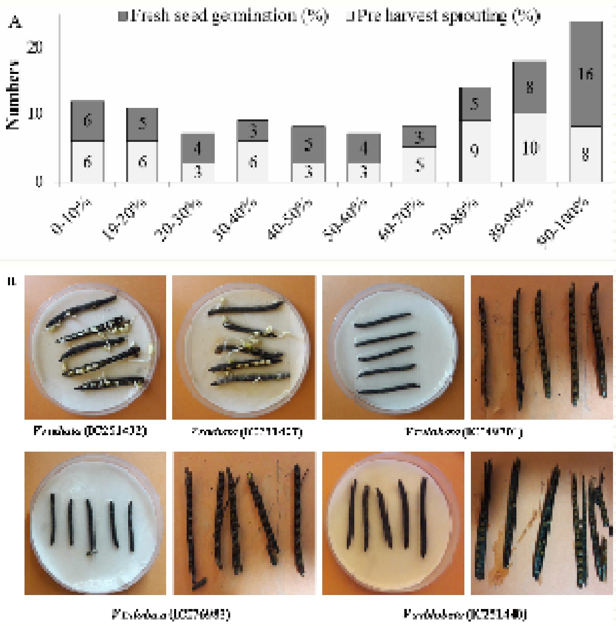


Fig. 9 : Changes in moisture content and normal seedlings with storage

Identification of PHS tolerant genotypes in *Vigna species*

One hundred and forty urdbean genotypes (99 germplasm and 41 varieties) and 59 wild accessions of 11 different *Vigna* species were screened for the level of variation in pre harvest sprouting (PHS). Seed germination inside pod was used as a measure of PHS. PHS among 140 urdbean genotypes ranged between 2.86-93.81%. Thirteen germplasm lines (PLU 662, NO 7668-43, IPU 99-95, IPU 99-247, IPU 8, PLU 302, IPU 99-221, LBG 20, CN 3515, BG 367, PKJU 1, PLU 65, NPU 302) had PHS value of less than 10%. Among 59 wild *Vigna* accessions, PHS value ranged between 0-100%, with a mean of 55.86%. Five accessions (IC 276983, IC 349701, Trichy local 1, LRM/ 13-33 and LRM/ 13-26) of *Vigna trilobata* and one accession (IC 251440) of *Vigna sublobata* recorded no pod loss due to PHS with 0% fresh seed germination (2.5% in *V. sublobata*).



Variation in PHS (%) and FSG (%) in wild *Vigna* accessions

Nucleus Seed Production and Maintenance Breeding

In pigeonpea, nucleus seed of IPA203 was produced in isolation at New Research Campus and 58 parents have been maintained through single plant selection.

In lentil, 140 kg nucleus seed of seven released varieties (IPL 81, IPl 406, DPL 15 and DPL 62, IPL 316, IPL 526 and IPL 220) was produced and 2800 single plants of above varieties were selected for nucleus seed production during next year.

During the year 2017-18, 180 kg nucleus seed of six mungbean varieties (IPM 410-3 (Shikha), IPM 205-7 (Virat), IPM 99-125 (Meha), PDM 139 (Samrat), IPM 2-3 and IPM 2-14 was produced. More than 3000 single plant selections of 8 released varieties (including Kanika and Varsha) were also taken during *Kharif* 2017 for growing single plant progeny rows for producing nucleus seed.

Twenty kg nucleus seed of IPU 02-43 and 25 kg of IPU 94-1 was produced in urdbean.

The nucleus seed of Institute developed fieldpea varieties *viz.*, Adarsh, Aman, Vikas, Prakash, IPFD 10-12, IPF 4-9, IPFD 6-3, IPFD 11-5 and IPFD 12-2 of fieldpea was produced.

Breeder Seed Production

During 2017-18, 638.48 q breeder seed of different pulse varieties was produced :

Crop	Variety	BSP (q)
Chickpea	Subhra, Ujjawal, JG 14, RVG 202, RVG 203	206.51
Fieldpea	Prakash, Vikash, IPFD 10-12, Aman, Adarsh, IPFD 4-9, IPFD 6-2, IPFD 11-5, IPFD 12-2	175.35
Mungbean	Samrat, Meha, IPM 2-3, IPM 2-14, Virat, Sikha	88.05
Pigeonpea	IPA 203, TJT 501	79.75
Lentil	IPL 316, IPL 406, IPL 526	48.66
Urdbean	Uttara, IPU 2-43	34.20
Rajmash	Utkarsh	3.96
Horsegram	CRIDA 18A	2.00
	Total	**638.48**

200.70 kg nucleus seed of four released varieties of Rajmash *i.e.* PDR 14 (42 kg), Arun (62.36 kg), Utkarsh (58.36 kg) and Amber (38 kg) was produced.

Externally Funded Projects

Development of molecular marker (SSR) resource putatively linked to heat tolerance in chickpea

Phenotypic data for various heat tolerance related traits were recorded in 160 chickpea genotypes under normal and late sown conditions. The DNA of these genotypes were isolated and genotyping (through SSR markers) of these genotypes is under progress for GWAS study for investigating MTA for heat relevant traits.

Generation advancement of genetic material

Crosses in F_1 generation: JG11 × JG62, JG62 × JG11, ICC92944 × JG11, HC5 × ICC92944, ICC1205 × JG16, ICC96030 × JG11, ICC1356 × ICC92944, JG11 × ICC96029, DCP92-3 × HC5, ICC96030 × JG11, JG16 × ILC583, KWR 108 × ILC583, ICC07110 × ILC3518.

Crosses in F_2 generation: KWR108 × JG315 (F_2), JG130 × ICC92944 (F_2), JG11 × ICC1205 (F_2), ICC92944 × JG315).

Crosses in F_3 generation: Digvijay × IPC2004-54 (F_3), GNG1581 × ICC4958 (F_3), JAKI9218 × IPC2004-52, JG16 × ICC4958 (F_3), Digvijay × ICC4958 (F_3), JG 16 × IPC2004-98 (F_3).

Crosses in F_4: HC5 × JG16, JGK1 × JG16.

Crosses in F_5 generation: JG11 × ICC4958 (F_5), JG16 × ICC 4958 (F_5), KWR 108 × ILC3279 (F_5), DP92-3 × ILC 3279 (F_5), ICC92944 × ILC3279 (F_5), KWR108 × ICCV96030 (F_5), FLIP03-100 × ICC4958 (F_5), JGK1 × ICC4958 (F_5), JG315 × IPC2004 -52 (F_5), ICC1205 × JG03-14-16 (F_5).

Crosses in F_7 and F_8 generation: IPC06-11 × ICC96030 (F_7), T39-1 × ICC 96030 (F_7), IPC09-50 × BPM (F_7), IPC09-50 × IPC09-88 (F_8).

Phenotyping for root traits in lentil

A mapping population comprising 200 RILs derived from a cross IPL 98/193 (long root) x EC208362 (shortroot) was phenotyped in PVC tubes for root traits (Fig. 10). Observations were recorded after 60 days of sowing. Root length was 46.3 in IPL 98/193 and 15.0 cm in EC 208362. While it ranged from 11.8 cm to 67.6 cm in RIL mapping population. The shoot length was 17.0 cm in IPL 98/193 and it was 13.0 cm in EC 208362. However, it was ranged from 4.7 cm to 21.5 cm in in RIL mapping population. This mapping population was also evaluated for phenotypic traits and RILs having long roots showed good podding at Bhopal location.

CRP on molecular breeding for improvement of tolerance to biotic and abiotic stresses, yield and quality traits in crops: Chickpea

This project was undertaken with an objective to pyramid genes for multiple resistance to races 1, 2 3 and 4 of *Fusarium oxysporum* f.sp. *ciceri* causing Fusarium wilt in elite chickpea cultivar JG 16. The elite genotypes *viz.,* Vijay and WR 315 were used as the donors for introgressing the genes of interest. The BC_1F_1 progenies of the crosses JG 16 X WR 315 and JG 16 X Vijay were subjected to foreground selection using linked markers and true heterozygotes were identified. These were subjected to second round of backcrossing. Likewise the F_1 X F_1 intercrossed progenies of the crosses JG 16 X WR 315 and JG 16 X Vijay were also subjected to marker analysis using foreground markers and the true heterozygotes were backcrossed in an effort to pyramid multiple race resistance against *Fusarium* wilt. The identified markers *viz.,* TAA60, TA194, GA16, TA59 for race 1, TR19, TA110, TS47, TA37 for race 2, TR 19, TAA60, TA194, GA16 for race 3, TR19, GA16, TA59 for race 4 were used for foreground selection in the backcross progenies. In another priogramme on marker assisted breeding for drought tolerance, 03 true heterozygotes in the BC_1F_1 progeny and 12 F_1s were backcrossed with JG 16. In all crosses, the fresh F_1 seeds were also crossed with recurrent parent JG 16, to develop backcross progenies which will be subjected to foreground selection.

CRP on Hybrid pigeonpea

Wide hybridization and CMS diversification

One F_2 population comprising 150 individuals derived from the population ICPL 20340 (*C. cajan*) × *Cajanus scarabaeoides* (ICP 15739) was grown. Only one partial sterile plant was observed in the population. Ten pigeonpea lines (AL 15, ICP 7148, AL 201, Pusa 2002-2, MN 5, ICP 88034, ICP 20338, ICP 11255, ICP 20340, PAU 881) are under different stages of CMS conversion. Fresh crosses were attempted to

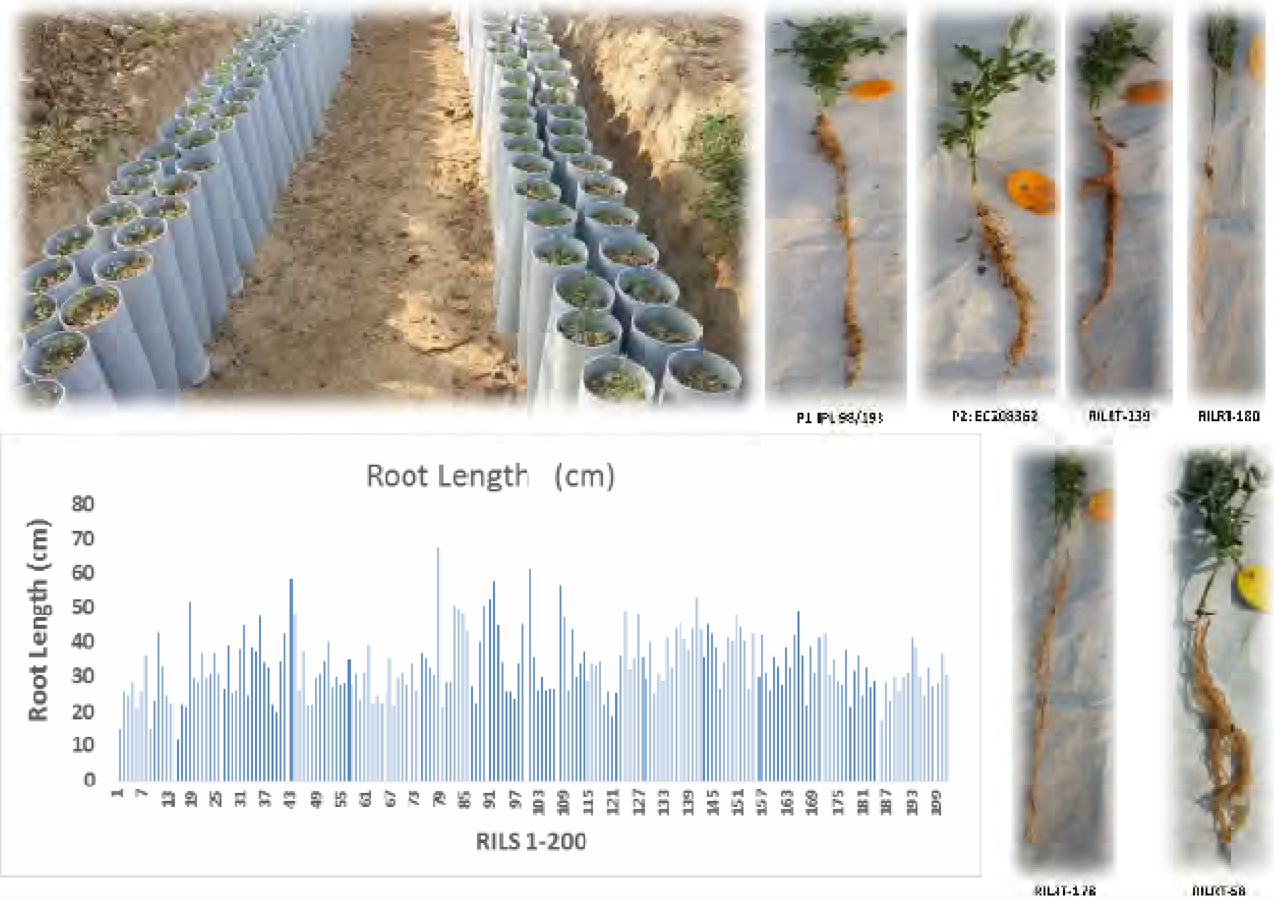


Fig. 10 : Variation in root length in 200 RILs

covert ten extra short duration lines (ICPL 11244, ICPL 11276, ICPL 11279, ICPL 11292, ICPL 11301, ICPL 11326, ICPL 20325, ICPL 20326, ICPL 20327 and ICPL 20329) into male sterile genotypes.

Development and evaluation of early maturing CMS hybrids

Eight hybrid entries were selected for testing in trial using two check varieties, Pusa 992 and PAU 881. The days to maturity varied from 141 (PAU 881) to 210 days (BDNPH 15-01 and BDNPH 15-02). Concerning yield superiority, four hybrids, PAH 3, BDNPH 15-01, IPAH 16-06 and BDNPH 15-02 showed > 20% yield superiority over the best check *i.e.* Pusa 992. Further, 62 A × R combinations were evaluated for fertility restoration and yield. The fertility restoration ranged from 66% (GT 33A X CO2R) to 100% in these experimental hybrids. Twenty two cross combinations showed complete fertility restoration. Based on yield, superior cross combinations (A × R) were identified, which included CORG 990047 AX CO 2R, PA163A X CO 2R and ICPA 2039 X CO 2R. In parallel, 117 new cross combinations were made for their evaluation in this *Kharif* season.

Maintenance of A, B and R lines

Twenty sterile (A) lines, cognate maintainer (B) lines and 80 restorer (R) lines are being maintained.

CRP on Agro-biodiversity: Pigeonpea (Characterization of germplasm)

Four hundred pigeonpea germplasm received from ICAR-NBPGR were sown in Augmented Design with 3 national checks and a local check for characterization of the germplasm. Observations are being recorded on descriptors and a few agronomic traits. The yield attributes were also recorded.

Genomic data analysis for identification of economically important markers and viral diagnostics in pulses

A comparative transcriptome analysis of young floral buds from the CMS line (ICPL 88039A) carrying A2 cytoplasm and its cognate maintainer line (ICPL 88039B) was conducted. The digital gene expression (DGE) analysis revealed a set of 311 genes that showed differential expression between ICPL 88039A and ICPL 88039B. Of these 311 DEGs, 17 genes showed down-regulation while 214 remained up-regulated in ICPL 88039B as compared to the CMS line. Based on GO and KEGG analyses, we could potentially associate CMS in pigeonpea with genes and transcription factors involved in important bioprocesses including "ATP production" and "Pollen development and pollen tube growth". Importantly, four DEGs namely Probable methyltransferase 18 (PMT18), Pollen-specific leucine-rich repeat extension 3 (PSL3), Sucrose transport SUC8-like (SUC8), Lascorbate oxidase homolog (L-AOH) were selected for validation of DGE results from flower bud tissue. Flower bud tissue of ICPL 88039A was taken as control. The ratio of Log2 fold change in RNAseq and qPCR RNA seq data showed a close agreement with these four genes showing upregulation in both datasets. In parallel, the transcriptome assembly for genetic variants was mined. We found a total of 17,787 and 72 simple sequence repeat (SSR) markers from de novo transcriptome assembly and DEGs, respectively. We successfully designed 12056 primers from de novo assembly. We also constructed a gene regulatory network using 308 DEGs. A total of 30 hub genes were obtained and their role in plant reproductive development has been well established in other crops. Our study constitutes the first report on candidate genes and gene regulatory networks associated with CMS trait in pigeonpea.

In order to investigate Fusarium wilt response in pigeonpea, transcriptome profiling was performed with root samples under different time frames and RNAs were harvested for downstream library preparation for Illumina HiSeq2500. The basic analysis included mining DEGs, transcription factors (TF), gene regulatory network depicting hub genes along with discovery of SSR-FDM, genic SNPs, lncRNA and Indels etc. DEGs included a total of 4,133 up-regulated and 4,249 down-regulated genes. We have selected top 10 up regulated and 10 down regulated differential expressed genes based on the experimental fold change value after normalization and p-value for further quantitative analysis. Functional annotation of the sequence was carried out using Blast2GO. Blastx results showed the homologous sequences present in protein database corresponding to the query sequences. These sequences were further categorized into gene ontology categories *viz.,* molecular function, biological process and cellular components.

Widening the genetic base in pigeonpea [*Cajanu cajan* (L.) Millsp.] through pre-breeding efforts for developing next generation wilt resistant and photoinsensitive early genotypes

Evaluation of genotypes for earliness and yield

During *Kharif* 2017, a set of 161 early maturing genotypes were evaluated by planting at three different sowing dates with two checks (UPAS 120 and Pusa 992) for earliness yield and yield attributing traits and photo-insensitive reaction. Among all genotypes, 26 lines (ICPL-11263, ICPL-11255, ICPL-20338, ICPL-11254, ICPL-11265, ICPL-11274, ICPL-11256, ICPL-20340, ICPL-11260, ICPL-11276, ICPL-20333, ICPL-11270, ICPL-11253, ICPL-11258, ICPL-11265, ICPL-11298, ICPL-11326, ICPL-11301, ICPL-11306, ICPL-11303, ICPL-11292, ICPL-11264, ICPL-1134, ICPL-20328, ICPL-11333, ICPL-11254) were recorded as early flowering and maturing (120 days).

Sixteen genotypes (ICPL-11263, ICPL-11255, ICPL-11259, ICPL-20338, ICPL-20340, ICPL-20336, ICPL-11251, ICPL-11258, ICPL-11260, ICPL-11265, ICPL-11254, ICPL-11274, ICPL-87, ICPL-84031, SKNP-0516 and GAUT-86-25) were reported as wilt resistant.

Generation of breeding material

Twelve F_1 crosses were attempted during 2017-18 aiming to incorporate earliness and high yield. Four crosses involved wild accessions for developing pre-breeding materials *viz.,* UPAS 120/ICP 15685-2 (*C. scaraboides*), UPAS 120/ICP 15763 (*C. sericius*), Pusa 992/ICP 15642 (*C. lineatus*), Pusa 992/ICP 15685-2 (*C. scaraboides*).

International mungbean improvement network (ACIAR-Australia)

Replicated trial of mungbean minicore collection (MCC) comprising 296 was conducted to evaluate the MCC and multiply its seeds simultaneously. Another trial was conducted at ICAR-RS, Dharwad (Karnataka) during *Kharif* 2017 to evaluate the MCC and multiply its seeds. Among the 296 MCC accessions, two did not germinate at ICAR-IIPR. At Dharwad, all entries germinated well. Most of the MCC entries were found susceptible to yellow mosaic disease. Only 5 accessions *viz.,* VI004957AG, VI004934AG, VI004973B-BLM, VI004937AG and VI002190BG were found highly resistant 55DAS while 47 were resistant at both the locations. While no other major disease was recorded, a few accessions in the initial screening were found desirable for yield traits. When pooled from both locations, (Kanpur and Dharwad) sufficient seed was harvested in 285 minicore accessions while seed could not be harvested in 11 accessions. A set of 10 Indian mungbean varieties was sent to ICAR-NBPGR along with all necessary documents for its onward dispatch to AVRDC as per provision in the project. The seed has been received at World Veg, Taiwan. Total genomic DNA was also extracted from all minicore accessions. Its quantification and quality check was completed.

Development of lentil cultivar with high concentration of iron and zinc (HarvestPlus program-ICARDA)

- Biofortified lentil variety IPL 220 having high concentration of Fe (73-114 mg/kg) and Zn (51-63 mg/kg) has been released for cultivation in NEPZ.
- Analyzed the Fe and Zn content of 100 accessions of lentil including lentil varieties and entries that being evaluated in PYT and Station trail. The range of Fe varied from 50.7 ppm (IPL141685) to 248.5 ppm (IPL 230) while Zn ranged from 34.1 ppm (IPL 14147) to 67.3 ppm (IPL 325).
- A BC_2F_5 population of >500 individuals derived from the cross IPL 220 x ILWL 118 were grown for identification markers associated with QTL controlling Fe and Zn concentration in lentil. The 20 single plant progenies are being utilized for SNP genotyping and phenotyping with Fe and Zn concentration for identification of genomic regions associated with molecular markers.
- One hundred forty five single plants were selected from 5 crosses in F_2 (IPL 220 x IPL 328, IPL 534 x IPL 220, IPL 220 x IPL 248, IPL 328 x IPL 534, IPL 316 x IPL 2200 and advanced this year for developing the fixed lines.
- Fe and Zn concentration was analyzed in 30 entries evaluated in PYT and AICRP trials. In these entries, Fe was ranged from 15.4 to 149.0 ppm, while concentration of Zn was 24.4 to 79.2 ppm.
- Fifteen entries were grown is station trial at ICAR-IIPR, RS, Bhopal and ICAR-IIPR, Kanpur. The seeds of these entries were analyzed for Fe and Zn concentration. The Zn concentration ranged between 14.4 and 63.2 mg/kg at IIPR-RS, Bhopal and from 20.0 to 54.8 mg/kg at ICAR-IIPR, Kanpur, while range of Fe concentration was from 10.8 to 81.6 mg/kg at IIPR-RS, Bhopal and 39.1 to 103.8 mg/kg at ICAR-IIPR, Kanpur. These results showed significant genetic variability for Fe and Zn concentration in studied breeding lines. However, genotype × year interaction effects were found significantly high for both Fe and Zn.
- Fe and Zn concentration in the seeds of 15 entries of station trial-2 grown at ICAR-IIPR, RS, Bhopal was analysed and Zn concentration in the seeds of their entries ranged between 14.4 and 44.0 mg/kg, while Fe concentration between 17.0 and 93.0 mg/kg. These results are needed to validate.

Harnessing favourable QTL for yield contributing traits from wild and exotic germplasm of lentil using AB-QTL analysis (DBT–funded)

Yield Traits: Developed BC_2F_2 population of >1500 plants from cross IPL 220 x ILWL118 (*L. orientalis*) for yield traits. The individual plant progenies of BC_2F_2 populations are being phenotyped for agronomic traits and a wide range of variation for flowering time (55-85 days), plant height (20-60 cm), primary branches (2-5), secondary branches (8-58), pods/plant (8-393), and yield per plant (2.4 to 14.4 g) was observed among this population.

Early growth vigor trait: Developed 17 BC_2F_1 (out of 22 seeds) plant progenies from [(*i.e.* IPL 220 (small seeded) × ILL 6002 (exotic line), while 6 BC_2F_1 (out of 24 seeds) plant progenies were developed from another cross DPL 58 (large seed) × ILL 6002 (exotic line)]. These progenies are being selfed during current *Rabi* season (2017-18) for generating BC_2F_2 populations.

Genotyping: Thirty samples of these populations are being sequenced for studying the marker-trait analysis through bulk segregant analysis (BSA).

Characterization, mapping and transcriptome analysis of seed protein, β-carotene and mineral contents in chickpea (*Cicer arietinum* L.)

Standardization of the protocol (regarding sample preparation) for total protein detection (*Kjeldahl* method) in the reported accessions with high (>27%) and low (<17%) protein content showed decorticated kernels producing repeatable results with respect to whole grains. Validation for seed protein content across the seasons (*rabi* and *kharif*) and locations (Kanpur and Dharwad) in contrasting accessions showed high protein in T 39-1, T1-A, P3318 and low protein in NEC755, P 3719. However, reported low protein lines (NEC755, P 3719) showed up to 21% total protein under Kanpur condition (with respect to reported 15-17% in ICRISAT, Hyderabad).

During main season and off-season, four contrasting crosses were attempted and hybridity of F_1 seeds were confirmed based on kernel characteristics. Accessions T39-1 and T1-A were used as donors and NEC 755, ICC 4958, CSG 8962 were taken as recipients.

A diverse panel of 140 genotypes constituted at ICAR-IIPR, Kanpur has been phenotyped for total protein content and three breeding lines, namely, IPC 2010-72, IPC 2008-103, IPC 2005-28 were identified with total protein ~27%, which might be potential donor lines. Random heterozygous F_2 plants from three contrasting crosses (JAKI 9218 x T39-1, DCP 92-3 x T39-1 and ICC 4958 x T39-1) were selected and families were constituted from the different types of kernels harvested from the single plant. Total protein content of those families was observed to be differing significantly and even transgression was observed. This observation indicated that segregating populations might be handled based on family constituted on the basis of kernel characteristics from the seeds harvested from the single plants. During *Rabi* 2017-18, a diverse panel of four hundred accessions constituted at ICAR-IARI was evaluated under field conditions in Kanpur and are being phenotyped for total protein content.

Enhancing breeder seed production

During 2017-18, 12 BSP centers have additionally produced 4862 quintals of breeder seed of different pulse varieties against the target of 978 q.

Crop	Target (q)	Production (q)
Chickpea	235	3241
Lentil	166	205
Fieldpea	68	190
Mungbean	195	374
Urdbean	166	304
Pigeonpea	123	548
Total	**978**	**4862**

Creation of seed hub

During 2017-18, 150 seed hubs located throughout India produced 1,06,387.64 q quality seed against the target of 84,770 q.

International collaboration

International Collaboration has been established with, AVRDC, Taiwan; BARI, Bangladesh; ACIAR, Australia and DAR, Myanmar, funded by ACIAR, Australia through International Mungbean Improvement Network.

Crop	Target (q)	Production (q)
Mungbean	18610	18719.05
Urdbean	11550	14332.11
Pigeonpea	15300	17216.18
Chickpea	25300	37772.9
Lentil	8350	11079.2
Fieldpea	4410	4604.5
Mothbean	100	205
Cowpea	650	1020
Horsegram	300	425
Rajmash	100	592
Lathyrus	100	421.7
Total	**84,770**	**1,06,387.64**

Projects completed

1. Genetic improvement for yield and multiple stresses in lentil (institute).
2. Genetic resources management in lentil.
3. Harnessing favorable QTL for yield contributing traits from wild and exotic germplasm of lentil using AB-QTL analysis (DBT funded).
4. Improving seed quality of major pulses.

Plant Biotechnology

Genomics enabled pulses crop improvement

Marker assisted gene introgression for drought tolerance in elite chickpea

A "*QTL-hotspot*" containing two sub regions "*QTL-hotspot*_a" and "*QTL-hotspot*_b" having functional implication for drought stress tolerance in chickpea was transferred through marker assisted backcrossing (MABC) approach from the donor parent ICC 4958, the drought tolerant genotype, into the elite genetic background of DCP 92-3. In this perspective, 21 BC_3F_4 lines were selected based on foreground marker analysis (TA170, NCPGR 21 and TR 11) as well as phenotypic observation of recurrent parent traits. The recovery of recurrent parent genome in these selected lines was analyzed with 40 SSR markers representing all the linkage groups. Background analysis revealed that the extent of recurrent parent genome recovery ranged from 65.40% to 85.3% (Fig. 11). Yield evaluation under drought conditions of 3 MABC chickpea lines for *hotspot* QTLs introgressed lines in background of DCP 92-3 was done and yield advantage of MABC line over control was seen. Attempts were also made to introgress *hotspot* QTLs in other elite chickpea line i.e. background of KWR 108 and GNG 1581.

Molecular dissection of response to terminal heat in chickpea

In effort to map the QTL(s) responsible for heat stress tolerance in chickpea and to identify differentially expressed transcripts during heat stress, different F_2 mapping populations were generated and are being evaluated for heat stress in late sown conditions and will be utilized for mapping QTLs. The list of crosses and their population size and stages are listed in Table 1. The F_2 population consisting 320 individuals derived from Pant G 114 (Heat susceptible)

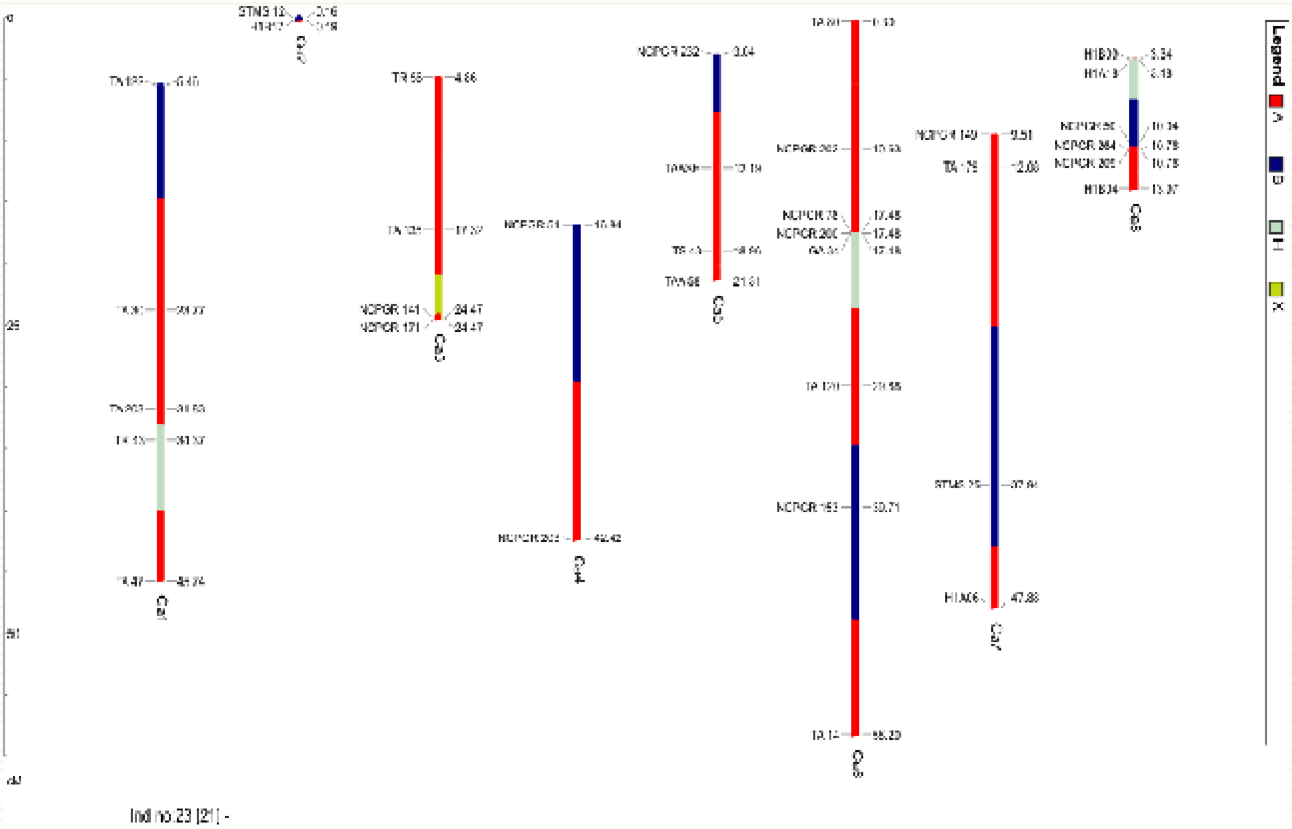


Fig. 11 : Recovery of recurrent genome in L-22-2 introgressed line of DCP 92-3 for enhanced drought stress tolerance

Table 1: Chickpea mapping populations segregating for heat stress

S. No.	Cross	Population stage	Population size
1	BG 256 x EC 556270	F_3	240
2	Pant G 114 x ICC 15614	F_3	320
3	BG 256 x ICC 12155	F_3	160
4	ICCV 2 x ICC 9942	F_3	190
5	ICCV 2 x ICC 12155	F_3	195
6	DCP 92-3 x ICC 4958	F_7	225
7	ICC 5912 x ICC 10685	F_1 to F_2 stage	200

and ICC15614 (Heat Tolerant) cross were evaluated for heat stress in pot condition (Fig. 12). Heat stress was given by sowing during 2nd week of January that exposes the plant to heat stress during flowing time in the month of March 2nd week where temperature will be beyond 33°C (Fig. 13). Six different F_2 populations are being evaluated for heat stress in field condition with sowing of January 20th, 2018 (Table 2) and observation all yet to be recorded for different parameters like number of filled pods, per cent pod set and yield per plant. Mapping will be carried out using phenotypic and geneotypic data of segregating populations. In the process of analyzing polymorphism in sucrose synthase coding genes of chickpea, we could identify polymorphism in upstream region of one of the sucrose synthase gene using agarose gel electrophoresis (Fig. 13) and this polymorphism has to be validated by sequencing the PCR amplicons and the process is underway. Apart from this, 57 microRNA gene based SSRs in chickpea were developed using draft genome sequence of chickpea and utilized in genetic diversity study of *Cicer* sp (Fig. 14).

Fig. 12 : F_2 segregants of Pant G 114 and ICC 15614 cross under high temperature regime in pot condition

Table 2: Chickpea mapping populations tested for heat stress during 2017-18

S. No.	Cross	Population stage	Population size (Individuals)
1	BG 256 x EC 556270	F_2	252
2	Pant G 114 x ICC 15614	F_2	320
3	BG 256 x ICC 12155	F_2	225
4	ICCV 2 x ICC 9942	F_2	182
5	ICCV 2 x ICC 12155	F_2	260
6	DCP 92-3 x ICC 4958	F_7	225
7	Vishal x ICC 1205	F_2	200

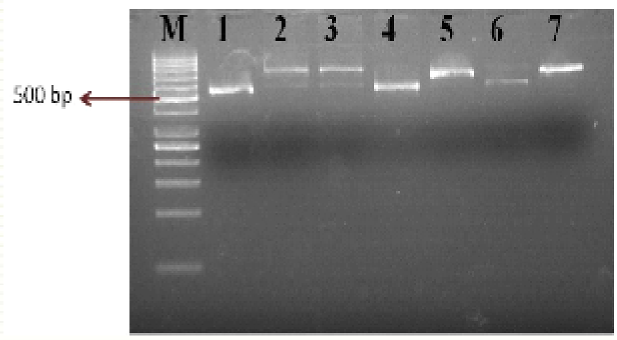


Fig. 13 : Polymorphism in upstream region of one of the sucrose synthase gene in chickpea. M-50bp ladder, 1-BG256; 2-EC60098; 3-EC600100; 4-ICC17123; 5-ILWC207; 6-ICC17177; 7-ILWC212

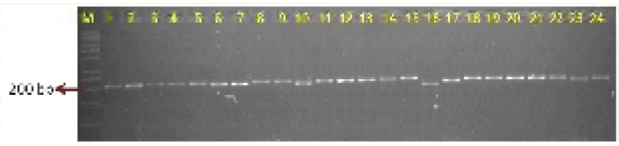


Fig. 14 : Polymorphic pattern of MicroRNA SSRs in *Cicer* sps. M: 50 bp ladder; Amplicon size ~210-220 bp

Molecular insight into *Fusarium*-chickpea interaction

Towards understanding the molecular mechanisms in chickpea-*Fusarium* interactions, a systems biology approach was adopted. Based on earlier lab finding, a multi-stress responsive WRKY transcription factors was reported, we derived the coexpressed genes and their functional networks. Co-functional network of 14 genes, namely Ca_08086, Ca_19657, Ca_01317, Ca_20172, Ca_12226, Ca_15326, Ca_04218, Ca_07256, Ca_14620, Ca_12474, Ca_11595, Ca_15291, Ca_11762 and Ca_03543 were identified (Fig. 15). Evidence of a possible linkage between the roles of the network genes operating in plant-fungal interactions has been derived from GO ontology based functional annotation studies. Firstly BLAST2GO analysis of the network genes revealed transport, establishment of localization involving in biological

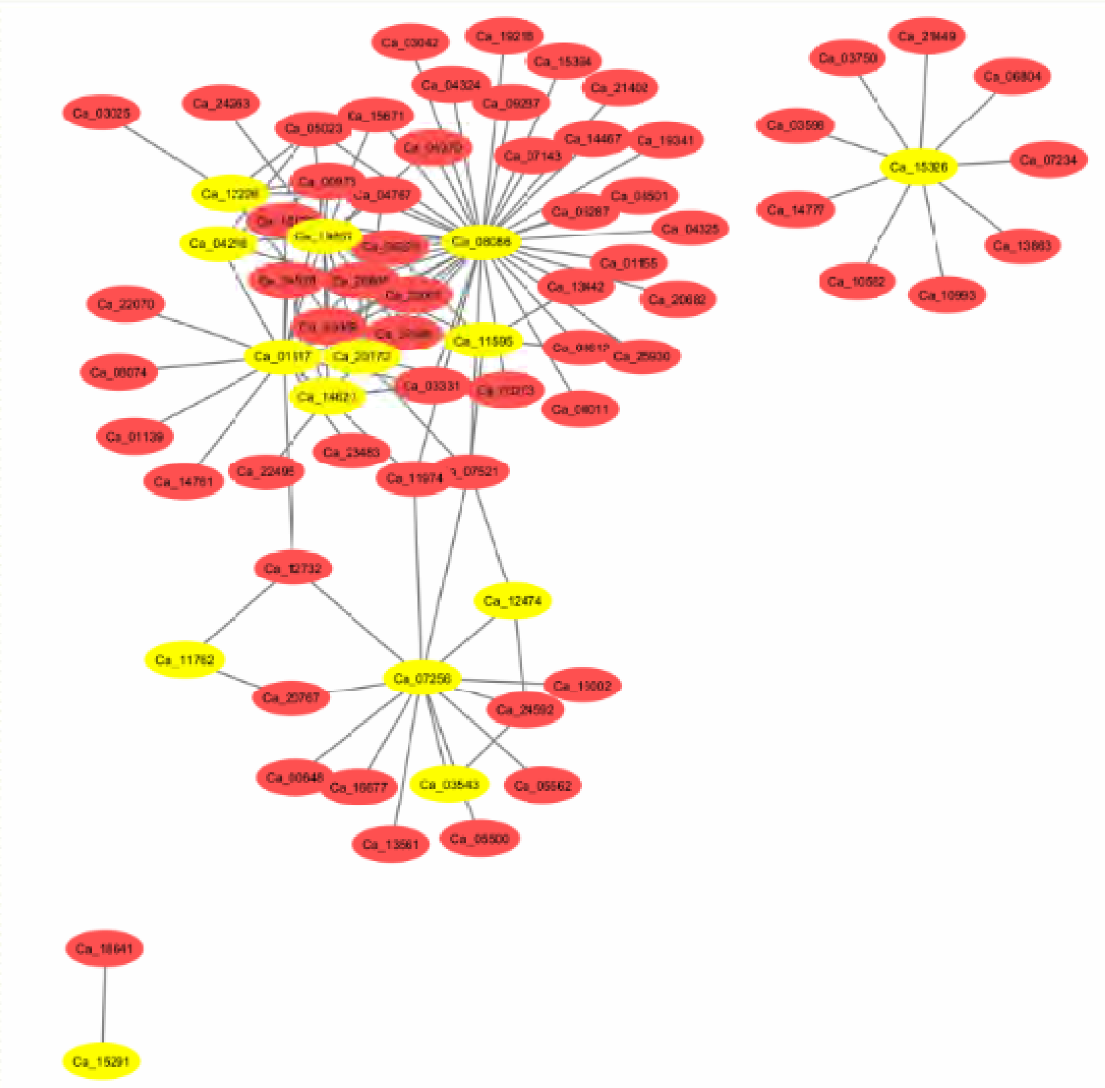


Fig. 15 : Gene Coexpression Network (GCN) diagrame of the co-expressed genes common to chickpea and *Arabidopsis*

process (GO: 0006810) (GO: 0051234) (GO: 0051179) (GO: 0008150). Car_WRKY TF ortholog in *Arabidopsis* has been predicted to be involved in callose deposition, a mechanism predominantly adopted by plants during wounding and other biotic stress conditions. Functional enrichment analysis of the WRKY48, bZIP60 and CZF were found to be responsive to chitin (GO: 0010200). Presence of chitin is a common feature in fungi, and indicating the probable role of the network genes in fungal infections. The role of the network gene modules in plant fungal interactions has been further explored by studying their expression pattern in transcriptome studies of chickpea–*Fusarium* interactions available in public domain. Contrasting expression pattern of all the 14 network genes in resistant and susceptible chickpea cultivars suggested their association with resistance mechanisms. Further, none of the coding transcripts of the identified gene modules was found to be targets for reported chickpea miRNAs. This minimizes the possibilities of miRNA mediated translational inhibition of the transcripts of the network genes. Therefore, any alterations in the expression level can be solely attributed to be stress responsive. Thus, 14 network genes can be regarded as pathway reporter genes for resistance towards *Fusarium* in chickpea.

Further, two of the network genes: WRKY TF and CSE (Caeffoyl Shikimate Esterase) were also found to be acting as Hub genes. Allele mining of the both the candidate genes have been donein chickpea genotypes with phenotypic data for wilt.

Each gene corresponds to a node. Each co-expression network corresponds to an adjacency matrix. The adjacency matrix encodes the connection strength between each pair of nodes (genes).The adjacency matrix was calculated based on absolute value of Pearson correlation coefficient.

Trait mapping for developing plant ideotype in pigeonpea

The project was formulated for trait mapping in pigeonpea through marker trait association analysis in the germplasmfor various ideotype component traits such as plant height, determinate and indeterminate growth habit, days to flowering and maturity, cleistogamy nature of flowering, seed size and number of seeds per pod. For this, the panel with 95 diverse pigeonpea genotypes were constituted and the mapping panel is being evaluated in ICAR-IIPR field during 2nd consecutive year for various plant ideotype component traits including plant height, days to 50% flowering, days to maturity, number of primary branches, determinacy and cleistogamy (Fig. 16).

The panel was genotyped with 25 SSRs (Fig. 17) and will be genotyped with more SSRs and then trait linked markers for different plant ideotype traits will be identified.

Fig. 16 : Field view of pigeonpea mapping panel for plant ideotype trait mapping. A: Plant stand at 50 days after sowing; B: Plant stand at 80 days after sowing; C: Plant stand at reproductive stage

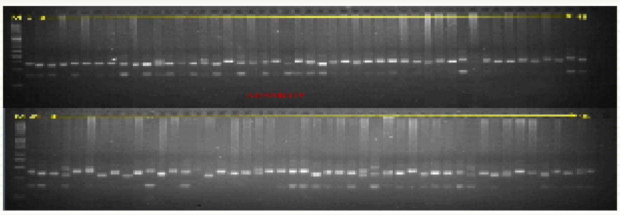


Fig. 17 : Allelic pattern at AHSSR119 marker locus in 95 pigeonpea genotypes. M: 50bp ladder; 1 to 95: different pigeonpea accession

Transgenic Technology for Genetic Improvement in Pulses

Genetic engineering for development of pod borer resistant chickpea using multigene approach

The aim of the project is to develop transgenic chickpea expressing insecticidal genes using novel approaches. Under the project, development of marker free, multigene constructs bearing cryIAc and cry2Aa genes regulated by pod specific promoter has been taken up. In this direction, a highly pod specific *msg* promoter from soybean reported by Stromvick *et al.* (1999) has been isolated from Indian genotypes of soybean. However the restriction analysis of the amplified promoter revealed the presence of unwanted restriction sites making it unfit for development of multigene constructs. Therefore, for the ease of cloning, the undesired restriction sites present innately in the native promoter have been eliminated by site directed mutagenesis using 60bp long PCR primers. Further as a strategy for enhanced expression of insecticidal genes in tissue specific manner, a 36 nucleotide plant viral untranslated region (UTR) of the 5′ region of the Alfalfa Mosaic Virus (AMV) coat protein was incorporated for imparting stability to mRNA and translational enhancement. In addition, for enhancing efficiency of ribosome binding, a poly A-tract consisting of ten Adenine residues was also incorporated. These additional DNA elements will confer stability and enhance the transcriptional and translational efficiency. The resultant 1.285 kb pod specific promoter has been cloned in pUC57 vector and confirmed by restriction analysis and by sequencing. The pUC57 vector construct bearing modified promoter can be deployed for high level tissue specific gene expression of cis/trans genes along with chosen terminator in chickpea. This technology can also be deployed for transgene expression in soybean and other legumes as well. Further, cryIAc and cry2Aa genes have been cloned downstream of the modified pod specific promoter along with terminator sequences and their orientation has been confirmed. Finally, cry2Aa gene cassette has been sub-cloned into the marker free binary vector and sub-cloning of cryIAc gene cassette is in progress.

In addition, *MADS* box transcription factors, known to be involved in flower pod development have been studied in detail in quest of novel pod specific promoters. Genome wide identification and gene duplication analysis of 83 MADS box encoding genes has been done (Fig. 18). Phylogenetic foot printing of the promoters revealed the presence of conserved non coding sequences not only upstream but also in intragenic regions, providing insights into the complex gene regulatory mechanisms of pod development in chickpea.

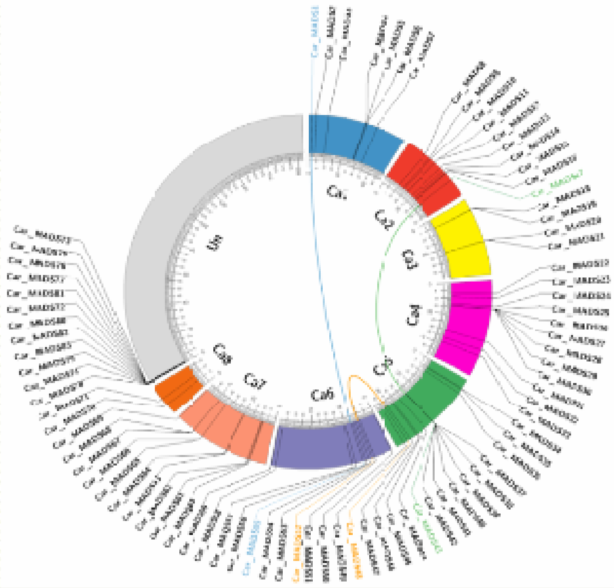


Fig. 18 : Genome wide identification and gene duplication analysis of MADS box genes in chickpea. Genes are represented as Car_MADS1-83. Chromosomes are represented as Ca_1- Ca_8 & Un(scaffold). Duplicated genes are connected with colored lines.

Development of whitefly tolerant genetically transformed mungbean (*Vigna radiata*)

Yellow Mosaic Disease (YMD) is the most destructive disease in mungbean caused by a begamovirus and is transmitted by whiteflies, *(Bemisia tabaci* Genn). It leads to severe yield reduction in the pulse. Management of the disease is largely dependent on use of resistance cultivars, cultural practices and incessant use of insecticides that has rendered many whitefly populations tolerant to insecticides. As a result, the disease is still prevalent. Vector management is a feasible option but functional breeding lines that confer tolerance/resistance against whiteflies are not available. The tma12 gene is known to impart tolerance to whitefly infestations by hindering development of whitefly nymphs into adults. Hence, genetic transformation of greengram using *tma12* for tolerance to whitefly infestations and to minimise public and regulatory concerns related to antibiotic resistance genes in developed transgenic crops, development of marker free transgenics was proposed (Fig. 19).

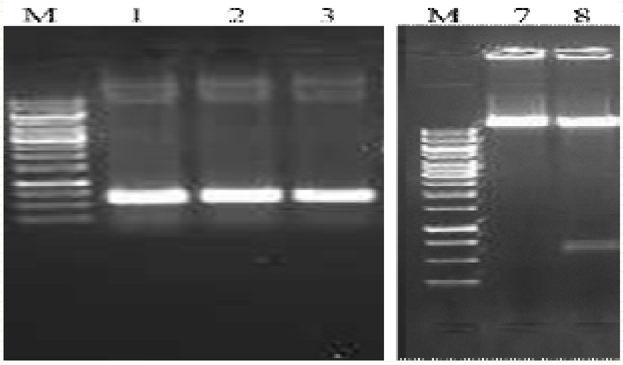


Fig. 19 : M is 1 kb marker; 1, 2 ,3 show amplification of tma12 gene (582 bp) from obtained transformed colonies; 7 is modified prI201 An vector; 8 is restriction digestion of gene expression cassette having tma 12 with Nde ! and Sal !

The two vector strategy was opted and pRI201AN vector was modified to eliminate the preexisting nptII gene expression cassette by restriction digestion and act as cloning vector. *Tma12* was subcloned into MCS of this vector (Fig. 20). The colonies obtained on kanamycin selection media were confirmed by restriction digestion, colony PCR and sequencing. The modified pRI201AN vector can be used as marker free gene expression vector. Modified pRI201AN vector harbouring *tma12* under the control of constitutive CaMV35ES promoter will be used along with prior developed modified pRI201AN vector with *nptII* gene expression cassette in co-transformation studies for the development of marker free transgenic plants.

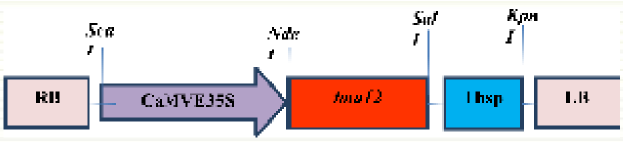


Fig. 20 : Gene expression cassette for *tma12*

The *in vitro* regeneration protocol in mungbean was assessed in varying phytohormone combinations using different explants e,g primary leaf, hypocotyl, single cotyledonary node, double cotyledonary node (DCN) and embryonic axis in the cv. Samrat. Observations revealed that five days old double cotyledonary node (DCN) with elongated hypocotyl region responded better in comparison to DCN of same age. The response was better in context of length and number of regenerated shoots in MSB5 supplemented with 1 mg/LBAP. Similar observations were recorded in the cv. SML 668 (Fig. 21). Reproducibility of screened in media composition and protocol is being assessed.

Fig. 21 : ***In vitro*** **regeneration in cv. SML 668 using modified DCNs with BAP supplement**

Development of regeneration and transformation protocol in grasspea (*Lathyrus sativus* L.)

Grasspea (*Lathyrus sativus*) is an important pulse crop.However, presence of neurotoxin β-ODAP in seeds and other plant parts renders grasspea unfit for consumption. One of the potential approaches to reduce β-ODAP content is by down-regulating/ knocking down ODAP biosynthesis pathway related genes by genetic engineering/genome editing technology. For harnessing the potential of the technology, an *in vitro* regeneration system amenable to genetic transformation as well target gene for modification is pre-requisite. Initial, regeneration studies on two genotypes of grasspea (cv. Pusa 24 and Mahateowra) indicated high responsiveness to regeneration. Notably, embryonic axis explant was found highly responsive to *in vitro* regeneration in terms of *de novo* regeneration of multiple shoots. Therefore, embryonic axis explant was selected for *Agrobacterium*-mediated transformation in two grasspea genotypes *viz.* Pusa 24 (ODAP-0.25%) and Mahateowra (ODAP-0.05%), the best representative of high and low ODAP content, respectively. pCAMBIA 2301 binary vector carrying *nptII* as selectable marker and *gus* reporter gene interrupted by intron (to ensure its expression only in plant) was mobilized into Agrobacterium (LBA4404) by freeze thaw method. For establishingan efficient *in vitro* genetic transformation system, first step is to determine the sensitivity of explant for kanamycin. About 40 to 46 embryonic explants of each variety were inoculated in MS media supplemented with different concentrations of kanamycin (0, 50, 100, 125 and 150 mg/L). After 15 days of inoculation, it was found that about 92.6% of explant gets bleached and multiple shooting is completely inhibited at 150 mg/L (Fig. 22) kanamycin whereas in Mahateowra about 95% explants gets bleached and only 2.5% explants responded for multiple shooting at 125 mg/L kanamycin. Although bleaching was initiated in Pusa 24 at 100 mg/L kanamycin and Mahateowra at 50 mg/L kanamycin. However, to avoid selection escape and chimerism, we selected 150 mg/L kanamycin for Pusa 24 and 125 mg/L for Mahateowra for selection of transformants.

Second step was to test whether selected grasspea genotypes were favourable for *Agrobacterium*-infection and tissue regeneration. For this, embryonic axis explant of Pusa 24 and Mahateowra were infected with *Agrobacterium* strains LBA 4404 and EHA 105. Both the genotypes were found highly responsive for LBA 4404 infection than EHA 105 as assessed by transient GUS expression (Table 3). Majority of explants exhibited GUS expression in the swollen embryonic axis region (Fig. 23): the region from where multiple shoots arises under the influence of BAP. Further, we tested the effect of *Agrobacterium* on multiple shoot regeneration. About 16 embryonic axis explants (cv-P 24) were infected with *Agrobacterium* (LBA 4404) and co-cultivated for two days in shoot induction media supplemented with 200 M Acetosyringone. After co-cultivation, explants were washed with 500 mg/L cefataxime to remove Agrobacteria and inoculated in shoot induction media for 15 days. A control was run

Fig. 22 : Effect of various concentration of kanamycin on embryonic axis explants (cv P 24). C: Control without kanamycin, 50K: 50 mg/L kanamycin, 100K: 100 mg/L kanamycin, 125K: 125 mg/L kanamycin, 150K: 150 mg/L kanamycin

parallel to experiment where no *Agrobacterium* infection was given. After 15 days of inoculation, we observed that *Agrobacterium* infection didn't interfere with plant regeneration (Fig. 24).

Table 3 : Comparison of transient GUS expression induced by Agrobacterium LBA4404 and EHA105

Genotype	Agrobacte-rium Strain	No of explants inoculated	% of explant showing GUS expression
Pusa 24	EHA 105	49	24.4%
Mahateowra	EHA 105	66	42.4%
Pusa 24	LBA 4404	30	90%
Mahateowra	LBA 4404	30	87%

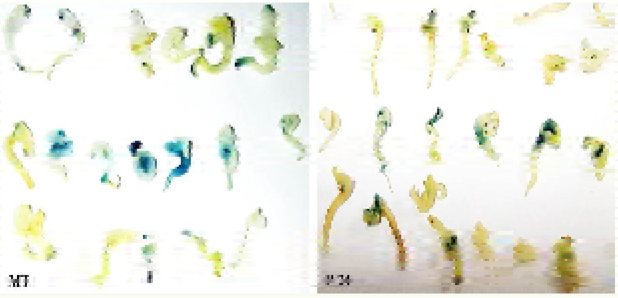


Fig. 23 : Transient GUS expression of embryonic axis explant infected with LBA4404.MT: Mahateowra, P-24: Pusa 24

Fig. 24 : Effect of Agrobacteria on multiple shoot regeneration. a. Explant without Agrobacterium infection, b. Explant with infection

Further, to identify gene for ODAP manipulation, we targeted the gene encoding Oxalyl CoA synthetase enzyme. Full length transcript of Oxalyl CoA synthetase enzyme in grasspea was identified based on sequence information in homologous species, publically available transcriptome of grasspea and through PCR. Based on full length transcript sequence information of grasspea oxalyl CoA synthetase, we designed six overlapping set of primers so that it covers whole sequence of transcript. When these primers set were used in PCR using grasspea genomic DNA (cv. Pusa 24) as template and resulting PCR products were sequenced and aligned with the transcript sequence, it gave clear cut information on presence of intron and exon of the gene. Using this approach, we have identified full structure of grasspea oxalyl CoA synthetase gene (Fig. 25).

Eco-friendly management of spotted pod borer *Maruca vitrata* Fabricius in short duration pigeonpea

Legume pod borer, *Maruca vitrata* is a serious pest in pigeonpea, hence, fifty pigeonpea genotypes were screened in field. Among them, ICPL 87 had recorded highest mean per cent pod damage (64.29) and JA 4 had recorded lowest per cent pod damage (13.56). Among the seven different border crops deployed for management of *M. vitrata*, sorghum has recorded the lowest mean *Maruca* larva/plant (1.17) whereas highest was recorded from sole crop (8.81) [Fig. 26]. Sorghum as border crop with the pigeonpea has recorded highest population of *Coccinella septum punctata* (1.36/plant) and *Cheilomenes sexmaculata* (1.32/plant) while sole crop has recorded lowest population of *C. sexmaculata* (0.09/plant) and sole crop has recorded the lowest population of *C. septumpunctata* (0.11/plant). The average yield was also highest from sorghum (3.47 kg/35 m^2) whereas the lowest from sole crop (2.18 kg/30 m^2). Thus, the sorghum as border crop has recorded the lowest spotted pod borer population in pigeonpea ICPL 67B from 41st to 47th SMW.

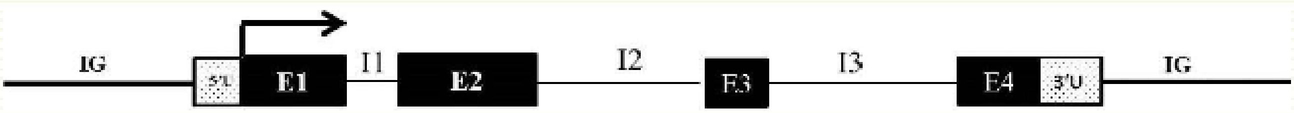


Fig. 25 : Structure of Oxalyl CoA synthetase gene. E1, E2, E3 and E4 are exon 1,2, 3, 4 respectively, I1, I2, I3 indicates intron 1,2,3. IG denotes Intergenic region. 5^{1}U and 3^{1}U indicates 5^1 and 3^1 UTR, respectively

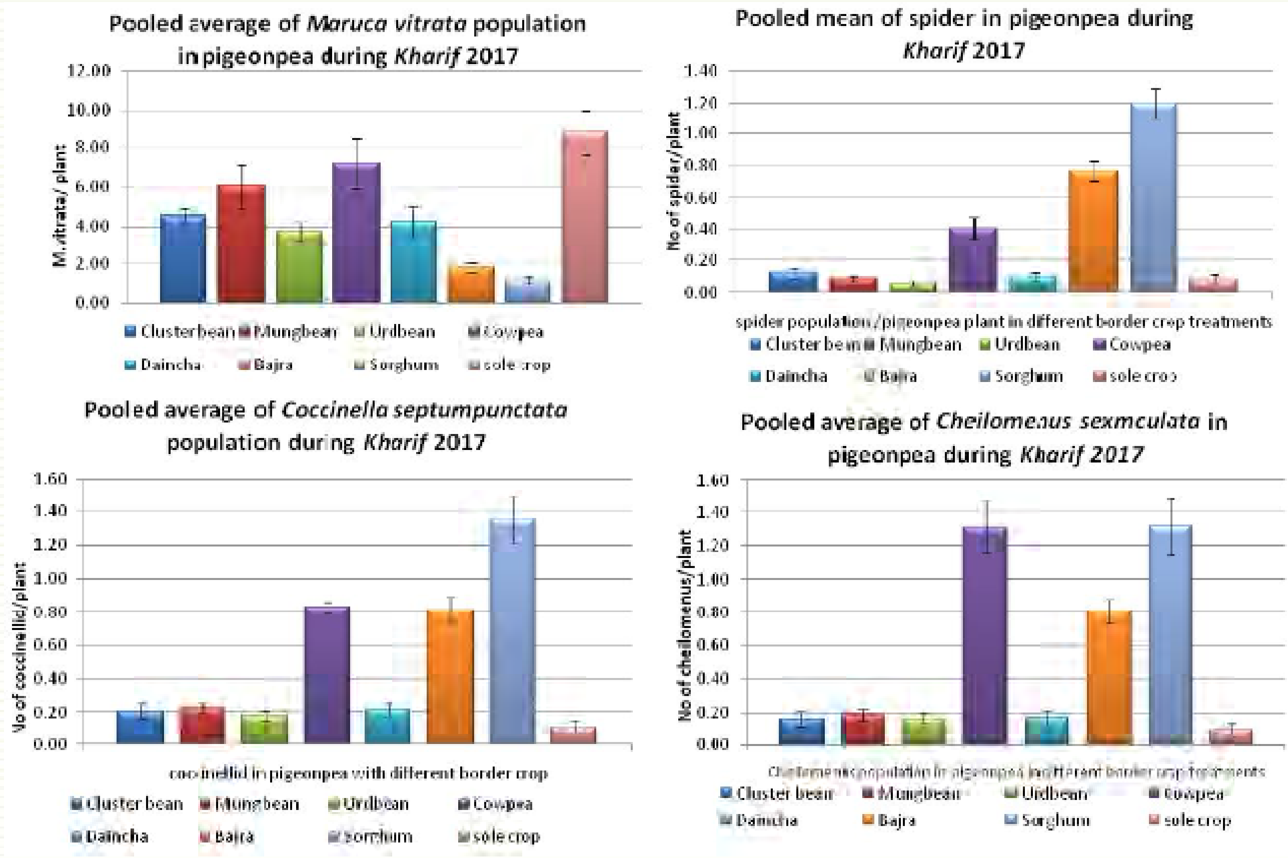


Fig. 26 : Mean population of *Marucavitrata* and its natural enemies

Externally Funded Projects

Incentivizing Research in Agriculture

Molecular approaches for mapping of novel gene(s)/ QTL(s) for resistance/ tolerance to salinity stress in chickpea

Identification of salt induced candidates modulating genes through RNASeq-approaches

High salinity, a global threat to agricultural production, is a multicomponent stress under the control of multitudes of genes and gene networks. The ionic and osmotic imbalance arises from NaCl-induced reduction of the solute potential of the soil solution, which in turn reduces the hydraulic conductance and hence, water and solute uptake by plants. It is a combination of these effects that leads to remodulating the whole gene network and regulatory mechanism. In order to understand the molecular mechanism and gene network, whole transcriptome analysis was done in two contrasting chickpea genotypes ICCV 10 (R) and ICC 4463 (S) exposed under different salt concentration. In these studies, approximately 178,323, 816 paired-end reads were generated from four samples and assembled using reference based assembly using CLC Genomic Workbench 9.0. We report 3,982 differentially expressed genes (DEGs), of which gene grouping under energy metabolism, ROS scavenging and defence, protein translation, processing and degradation, cell wall-related, hormone related, signal transduction, Amino acid metabolism and transcription factor family (Fig. 27). There is also significant alterations in transporter transcript level (Cation/H+ exchanger, H+ transporter, vacular transporter, inorganic phosphate trasporter etc.) key players during salinity stress play important role during plant salinity stress.

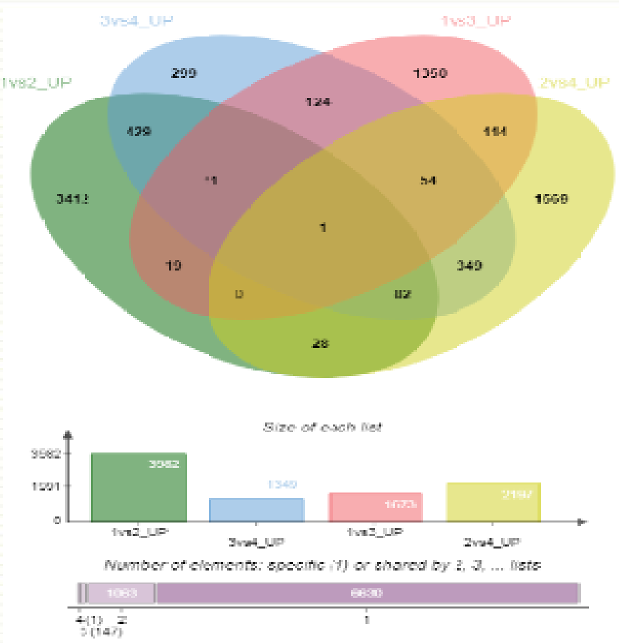


Fig. 27 : Differential Expressed gene (DEG) induced under ICCV 10 (Tolerant) and ICC 4463 (Susceptible), in different combinations

QTL mapping for salinity stress tolerance

Towards mapping the QTLs, RIL population comprising 212 population size was genotyped with chickpea SNPs array comprising of 50K SNPs spread across the genome. With this, 5000 polymorphic SNPs were found for QTL analysis. In the preliminary linkage map analysis, approxesimatly 3,000 SNPs were anchored in 8 linkage group covering 1,300cM. However, it is further being analysed to do the trait mapping. The field phenotypic evaluation of F_7 population of salinity stress at ICAR-IIPR, Kanpur; ICAR-CSSRI, Karnal, PAU, Ludhiana and ICAR-IARI, New Delhi is being carried out. In order to validate the result obtained under field conditions, genotypes having contrasting phenotypes for salinity stress were screened under *in vitro* conditions.

In planta screening for tissue specific Na^+ sequestration in roots in complementation with photochemical quenching: linking salinity stress tolerance in chickpea

The hydroponics screening method for salt tolerance in chickpea was developed (Fig. 28). The methodology used germinated seedling to place onto the hydroponic apparatus to analyze the movements of the soluble Na^+ and Cl^- ions. The method is simple, cheap, fast, clear result, high throughput, low cost, easy handling and short time consuming that allows the

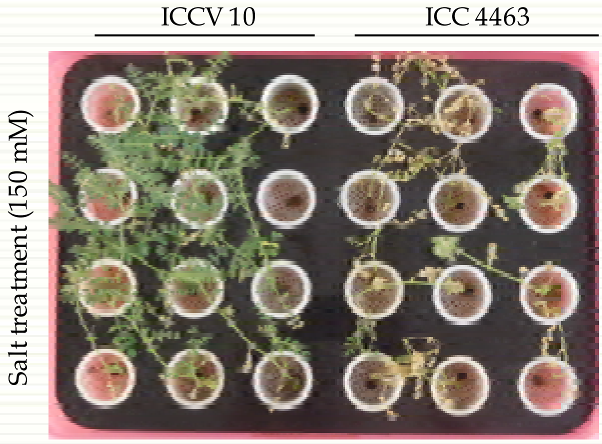


Fig. 28 : Hydroponic Screening of ICCV 10 (Tolerant) and ICC 4463 (Susceptible), under *in-vitro* conditions 150 mM supplemented with full strength of hogland solution

screening of several populations seedlings within 20-25 days (Fig. 29). For analysis, the movements of Na^+ ions through the apoplastic movements or vacuolar translocation through CoroNa dyes, which intercalates to the Na^+ and gives fluorescent signaling under exposing at excitation energy and visualize under confocal microscope of different root growing tips. In planta methods of analyzing the tissue specific Na^+ sequestration gives the information about the basic tolerance mechanism in chickpea under salinity.

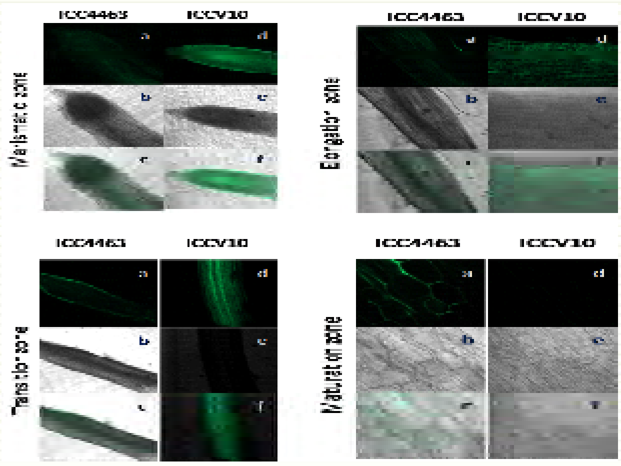


Fig. 29 : Confocal microscopy screening of ICCV 10 (Tolerant) and ICC 4463 (Susceptible), under *in-vitro* conditions 150 mM supplemented with full strength of hogland solution

Functional genomics in chickpea (NPFFGM)

The mapping population consisting of 250 individuals derived from WR 315 x JG 62 crosses was advanced to F_8 generation. Parental polymorphism study of 300 SSR markers were employed to study parental polymorphism. Out of the total SSR markers screened, 47 were found to be polymorphic. The population is being screened against foc race-2 in sick plotcondition, and disease incidenceis being recorded. Validation of *Fusarium* wilt stress induced transcript based markers in chickpea genotypes is in progress. Screening and validation of newly synthesized five *Fusarium* wilt specific chickpea transcript markers in 14 chickpea genotypes set through polyacrylamide gel electrophoresis. Among five, one marker was found to be polymorphic. The PCR result showed presence of two alleles within the set. The sequences of these amplified alleles are being analyzed, to detect association with the *Fusarium* race specific reaction.

Genetic mapping of *Fusarium* wilt (FW) and sterility mosaic disease (SMD) in pigeonpea (NPFFGM)

The project targets genetic mapping for *Fusarium* wilt (FW) and sterility mosaic disease (SMD) for which genetic analysis and mapping for FW and SMD resistance using F_2s derived from Bahar (s) and KPL 43 (R) and Maruti (S) and Bahar (R), respectively was planned. To map resistance genes against FW (variant 2), two mappingapproaches -genetic linkage mapping and genome wideassociation mappingare beingused. Association analysis with 89 diverse pigeonpea genotypes revealed seven putatively associated SSR markers with FW resistance. Preliminary genetic analysis from screening of biparental population developed from Bahar (S) x KPL 43 (R), revealed the involvement of two (or more) recessive genes (1:15) for resistance to variant 2 in KPL43. Through BSA analysis, HASSR8, HASSR58 and HASSR121 found to belinked with FW resistance. Presently, all the seven SSR markers identified through association analysis and BSA markers are being used to re-validate in advanced generations of $F_{2:3}$mapping population of Bahar and KPL 43 cross is in a processes of phenotyping for *Fusarium* wilt incidence in ICAR-IIPR wilt sick plot. The genomic DNA was isolated from F_2 samples and confirmation of already identified linked markers using F_2 population will be carried out with F_2 genotypic and F_3 phenotypic data. To study the genetics and map the resistance loci for SMD in pigeonpea, the generation of F_2 mapping population using Maruti (SMD susceptible) and Bahar (SMD resistance) genotypes is in progress. This year sufficient putative crossed F_1 seeds (30 seeds) were harvested from Maruti and Bahar cross and true F_1 will be identified and advanced to F_2 in the coming season. The F_2 population will be utilized for studying genetic and molecular basis of SMD resistance in pigeonpea. Out of 250 SSRs screened for polymorphism between Maruti and Bahar, 30 SSRs (12%) found to be polymorphic between two parents and more markers will be screened in coming days (Fig. 30).

Transgenic development in chickpea and pigeonpea (NPFGGM)

The project envisages development of transgenic chickpea and pigeonpea for gram pod borer resistance employing domain shuffled Bt-*cry1Aabc* gene. Two transgenic chickpea lines (IPCa2, IPCa4) and two pigeonpea lines (IPCc1, IPCc2) were evaluated for trait efficacy in confined field conditions at main research farm (Plot No. 5/2) of ICAR-Indian Institute of Pulses Research, Kanpur, based on guidelines provided by Review Committee on Genetic Manipulation [Permit Letter: BT/BS/17/221/2007-PID dtd 15.05.2017 and BT/BS/17/221/2007-PID dtd 22.06.2017 (Pigeonpea) and BT/BS/17/221/2007-PID dtd 15.05.2017 (chickpea)] and Genetic Engineering Appraisal Committee [File No. C-12013/4/2016-CS-III (pigeonpea) and C-12013/5/2016-CS-III (chickpea)].

Event Selection Trial of chickpea was undertaken to identify best transgenic chickpea event based on

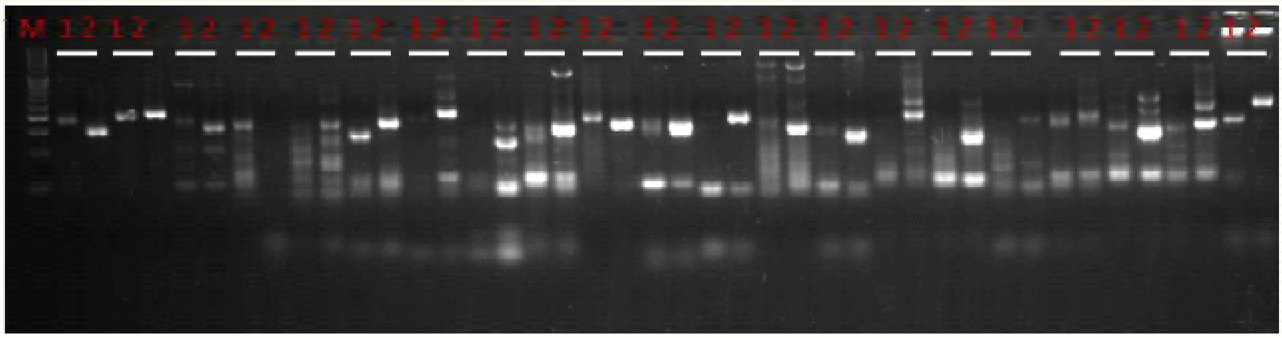


Fig. 30 : Screening of polymorphic SSRs between Maruti and Bahar pigeonpea genotypes. M: 50 bp ladder; 1: Maruti 2: Bahar

Fig. 31 : Event Selection Trial at Main Research Farm, ICAR Indian Institute of Pulses Research, Kanpur A. Five transgenic pigeonpea lines (under 40 um mesh net) and B. Five transgenic chickpea lines

efficacy of engineered trait (insect resistance), agronomic performance and expression of Bt protein (Fig. 31). The experiment was laid under Randomized Complete Block Design (RCBD) with four checks: DCP 92-3 (Control), JAKI 9218 (National check), GCP 105 (Zonal Check) and KWR 108 (Local Check). An area of 10 m isolation distance was maintained along all four sides of the trial. The trial was conducted for a period of 4 months and five days (Date of sowing: 18th November, 2017 and date of termination/harvest: 23rd March, 2018). During the trial, for agronomic evaluation, notified DUS characters of transgenic chickpea lines were compared with control, DCP 92-3 and documented. PCR analyses of chickpea lines using gene specific and nptII indicated presence of transgene and quantitative ELISA indicated expression of BT and NPTII protein in leaf, seeds, pod wall. Data compilation and report preparation are in progress.

Similarly, Event Selection Trial of pigeonpea was undertaken to identify best transgenic pigeonpea event based on efficacy of engineered trait (insect resistance), agronomic performance and expression of Bt protein (Fig. 31). The experiment was laid under Randomized Complete Block Design (RCBD) with four checks: Asha/ICPL 87119 (control), IP 203 (National check), MAL 13 (Zonal Check) and NDA 1 (Local Check). Since pigeonpea is cross pollinated (insect mediated, outcrossing upto 30%), the trial area was covered with 40 um mesh net to meet isolation distance criteria. During the trial, for agronomic evaluation, notified DUS characters of transgenic pigeonpea lines were compared with control, Asha and documented. PCR analyses of chickpea lines using gene specific and nptII indicated presence of transgene and quantitative ELISA indicated expression of BT and NPTII protein in leaf, seeds, pod wall. Data compilation and report preparation are in progress. The trial was conducted for a period of 8 months and 20 days (Date of sowing: 14th July, 2017 and date of termination/harvest: 4th April, 2018).

Identification and characterization of gram pod borer resistant transgenic chickpea and pigeonpea for confined field trial (Period: February, 2018 – March, 2018)(NASF)

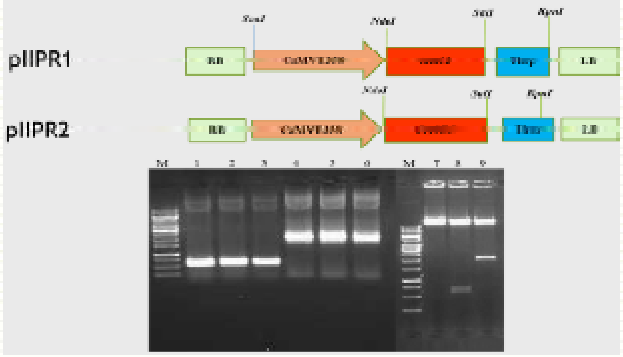
The project envisages identification and characterization of transgenic chickpea and pigeonpea for gram pod borer resistance employing *Bt-cry1Ac* gene. Three transgenic chickpea lines (IPCT 3, IPCT 10 and IPCT 13) and three pigeonpea lines (IPPT 2, IPPT 12 and IPPT 18) were evaluated for trait efficacy in confined field conditions at main research farm (Plot No. 5/2) of ICAR-Indian Institute of Pulses Research, Kanpur, along with cry1Aabc lines generated from NPFGGM Project. Besides agronomic evaluation based on DUS characters, molecular characterization of transgenic lines in terms of zygosity status, presence of vector backbone using oligos designed from vector backbone (pBinAR), flanking sequence analysis using Thermal Asymmetric Inter Laced PCR (TAIL-PCR) and expression profiling of BT and NPTII protein is being carried out. Data compilation and report preparation are in progress.

Development of *Bemisia tabaci* (whitefly) and *Spodoptera litura* resistant marker free transgenic blackgram expressing tma 12 and cry1Ec insecticidal protein(s) (DST_SERB)

The insect pests *Spodoptera litura* and virus transmitting whitefly (*Bemisia tabaci*) cause great yield loss in blackgram. With no effective natural germplasm available to confer tolerance to these pests, genetic engineering of blackgram using the insecticidal genes cry1Ec and tma12 was opted to develop marker free transgenic blackgram tolerant to infestation of whitefly and/or *Spodoptera*. To minimize the use of antibiotic resistant genes as selectable marker, marker free gene expression cassettes were developed with *Tma12* and *CryIEC* genes cloned under constitutive promoter CaMVE35S in pRI201AN vector for co-transformation studies using two vector system (Fig. 32).

The pRI201AN vector was modified by eliminating *nptII* gene expression cassette through restriction digestion that gave bands of DNA fragments ~8640 bp and ~1792 bp. The desired vector DNA fragment 8640 bp was eluted and purified from gel, staggered ends were made blunt using T4 DNA polymerase and phosphate group was added using T4 polynucleotide kinase. The vector backbone was ligated overnight and product transformed into *E. Coli*, plated on Luria Agar media with kanamycin as selection agent. The obtained transformed colonies were confirmed by performing colony PCR and recombinant clones were confirmed by restriction digestion. Clones were further confirmed by DNA sequencing. Modified pRI201AN was developed and served as a vector for cloning of *Tma12* and *CryIEC* genes. The cry1 Ec gene was subcloned into the modified pRI201AN vector.

Modified pRI201AN vector harbouring marker free gene expression cassette expressing *Tma12/CryIEC*



M is 1 Kb marker; 1,2 and 3 shows amplification of *Tma12* gene (582 bp) from obtained transformed colonies. 4,5 and 6 shows amplification of *CryIEC* gene (1.9 Kb) from obtained transformed colonies. 7 is modified pR1201AN vector, 8 shows restriction digestion of gene expression cassette expressing *Tma12* with *NdeI* and *SalI*, 9 shows restriction digestion of gene expression cassette expressing *CryIEC* with *NdeI* and *SalI*.

Fig. 32 : Development of gene expression cassette harboring both *tma12* and *cry1Ec* under control of constitutive promoter CaMV35ES is under progress

Characterization and development of bio-pesticide from native microbes for the management of Bihar hairy caterpillar in pulse crop (UPCAR)

Two bioagents, one baculovirus (SpobNPV) and *Bacillus thuringiensis* were identified and characterized for management of Bihar Hairy

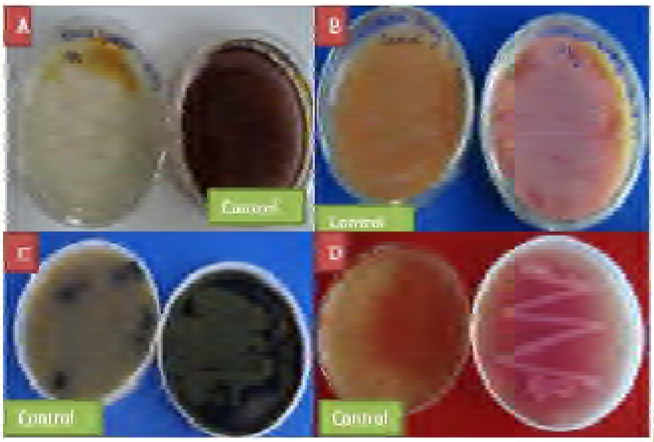


Fig. 33: Ak2.IIPR biochemical characterization

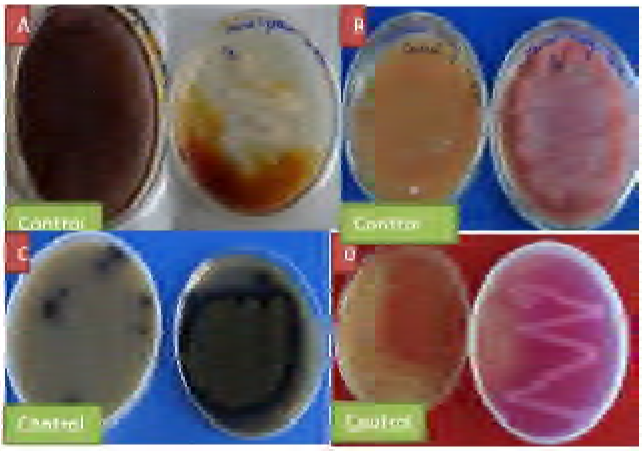


Fig. 34: F8.IIPR biochemical characterization

A- Starch hydrolysis; B- Lecithinase test; C-Esculin hydrolsis test; D- Urease test

Caterpillar (BHC), *Spilosoma obliqua* Walker. Twelve Bt isolates were identified and characterized using morphological growth parameters, Biochemical tests *viz.*, Lecithinase, esculin hydrolysis, casein, starch hydrolysis, catalase, urease (Fig. 33 & 34), physiological tests (growth in different concentration of Nacl& different temperature), motility and protein crystal staining. The vip gene of F8.IIPR, F6.IIPR, Ak2.IIPR, F1.IIPR & F5.IIPR was amplified using Vip3Aa primer and first 3 isolates sequence was submitted to NCBI (MF143591, MF143590 and MF143589). The partial sequence of16srRNA gene of 63 isolates was submitted to NCBI (KU601952 to KU601947 and KX661358 to KX661354). Biosynthesis of silver nanoparticles using Bt isolate AK2.IIPR was done and its bioefficacy is tested against *Spodoptera litura* and *Helicoverpa armigera*. The per cent mortality in *S. litura* and *H. armigera* was the highest (100 & 90.91) for silver nano formulation compared to spore crystal mixture of AK2.IIPR (76.92 & 72.73) and Btkurstaki z-52 (61.46 & 54.55) (Fig. 35).

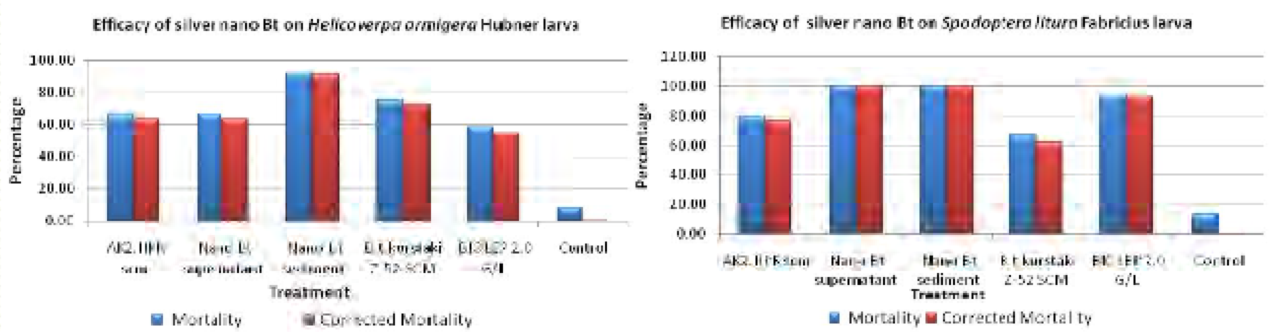


Fig. 35 : Bioefficacy of Silver nanoBt formulation

Crop Production

Long-term soil fertility and cropping system

Rice based cropping systems

Four rice-based cropping systems *viz.,* rice-wheat (R-W), rice-chickpea (R-C), rice-wheat-mungbean (R-W-Mb), and rice-chickpea-rice-wheat (R-C-R-W) were evaluated at three fertilizer management systems *viz.,* control (CT), integrated nutrient management (INM, crop residues + biofertilizers *viz., Rhizobium* for pulses and phosphate solubilising bacteria for cereals + farmyard manure at 5t/ha + 50% NPK) and inorganic fertilizers (RDF, recommended dose of N, P, K, S, Zn and B). Rice (Pant Dhan 12) was transplanted on first week of July, while, wheat (PBW 343) and chickpea (KWR 108) were sown on mid-November. Following the same trend like previous years RWMb system had the higher system productivity. The effect of different crop rotation on *Kharif* rice yield was prominent after 13 years of crop rotation. Rice yield was higher in R-W-Mb system followed by R-W-R-C and the lowest yield was in conventional R-W system. Pulse inclusive rotations improved the water-stable macro-aggregate (WSMA) in both surface (0-0.2) and subsurface (0.2-0.4) soil depths (Fig. 36). In surface soil, the WSMA was the highest in RWMb (64.8%) followed by R-C (57.0%) and found the least in R-W (49.9%). Pulse inclusive rotations led to higher ($p<0.05$) aggregate ratio (AR), mean weight diameter (MWD), and geometric mean diameter (GMD) over R-W rotation, being the highest in RWMb rotation. The higher active C-pool (8.5-18.1%), SOC (5.9-16.8%), and C management index (5.2-7.3%) were observed in pulse inclusive rotations and found in the order of RWMb > RC e” RWRC > RW.

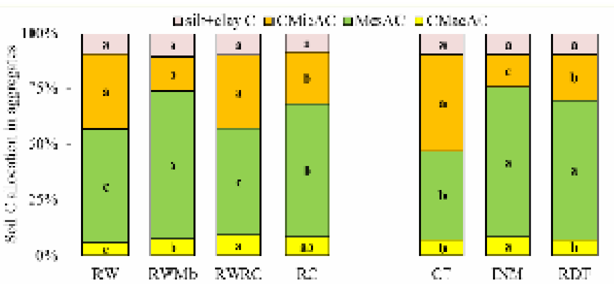


Fig. 36 : Allocation of SOC in different aggregate size classes under different treatments at surface (0-0.2 m) depth. CMacAC = coarse macro-aggregated C (>2 mm); MesAC = meso-aggregated C (0.25-2 mm); CMicAC = coarse micro-aggregated C (0.053-0.25 mm); = silt + clay C (<0.053 mm). Between the columns different lowercase letters are significantly different at Pd”0.05.

Maize and bajra based cropping systems

Four cropping sequences, each maize-based *viz.,* maize-wheat (MW), maize-wheat-mungbean (MWMb), maize-wheat-maize-chickpea (MWMC) and pigeonpea-wheat (PW) and *bajra*-based *viz., bajra*-wheat (BW), *bajra*-wheat-mungbean (BWMb), *bajra*-wheat-*bajra*-chickpea (BWBC) and pigeonpea-wheat (PW) were evaluated at three nutrient management practices *viz.,* control (CT), integrated nutrient management-INM (crop residues + bio-fertilizers *viz., Rhizobium* for pulses and phosphate solubilising bacteria for cereals + farmyard manure at 5 t/ha + 50% NPK) and inorganic fertilizers (RDF, recommended dose of N, P, K,S, Zn, and B). The cultivars sown during the year 2016-2017 were DKC 8144 (maize hybrid), Proagro 9450 (bajra hybrid), UPAS 120 (pigeonpea), HD 2967 (wheat), JG 16 (chickpea) and IPM 02-3 (mungbean).

In the experiment, the yield of cereal crops (maize, *bajra* and wheat) was registered higher under RDF. In contrast, the performance of pulse crops was better under INM. The highest grain yield of maize (6.1 t/ha) and wheat (6.3 t/ha) was recorded under MWMb system with the application of inorganic fertilizer (Table 4). Similarly, the highest grain yield of *bajra* (4.2 t/ha) and wheat (6.4 t/ha) was recorded under BWMb cropping system with the application of RDF (Table 5). Based on the system productivity, MWMb rotation had the highest pigeonpea equivalent yield and registered the least under PW rotation. Among the nutrient management practices, the system productivity (PEY) was found in the order of RDF > INM > CT.

The MWMb and PW cropping systems and INM resulted in higher mean weight diameter (MWD) in surface soil. The PW and MWMb systems recorded significantly higher macro-aggregate over MW in surface soil. Also, adoption of INM caused higher macro-aggregate over balanced RDF. PW system and INM accumulated significantly higher macro-aggregate and micro-aggregate associated C over MW in surface soil (Fig. 37). Estimation of soil P mineralizing enzymes under pigeonpea-wheat system suggested that highest acid phosphatase and alkaline

Table 4 : Long-term effect of crop rotation and nutrient management practices on grain yield (kg/ha) of component crops in upland maize based system

Treatment		Maize	Pigeonpea	Wheat	Chickpea	Mungbean
Maize-wheat (MW)	Control	1333	-	1790	-	-
	Inorganic	5210	-	5857	-	-
	INM	4333	-	4752	-	-
Maize-wheat-mungbean (MWMb)	Control	1657	-	1924	-	705
	Inorganic	6124	-	6314	-	1029
	INM	4886	-	4990	-	1143
Maize-wheat-maize-chickpea (MWMC) (2 year rotation)	Control	1505	-	-	1762	-
	Inorganic	5610	-	-	2057	-
	INM	4352	-	-	2210	-
Pigeonpea-wheat (PW)	Control	-	867	1524	-	-
	Inorganic	-	1105	4457	-	-
	INM	-	1552	3952	-	-

phosphatase activity (g p-nitrophenol/g soil) noticed at harvesting stage both in pigeonpea and wheat. Pigeonpea-wheat cropping systems and INM recorded higher weed emergence in surface soil in both surface and sub-surface soil depth other cropping *Cyperus rotundus, Phyllanthus niruri* and *Coronopus didymus* were more pre-dominant (Fig. 38).

Table 5 : Long-term effect of crop rotation and nutrient management practices on grain yield (kg/ha) of component crops in upland *bajra* based systems

Treatment		*Bajra*	Pigeonpea	Wheat	Chickpea	Mungbean
Bajra-wheat	Control	2171	-	1829	-	-
	Inorganic	3657	-	5981	-	-
	INM	2933	-	4790	-	-
Bajra-wheat-mungbean	Control	2590	-	1962	-	752
	Inorganic	4171	-	6419	-	1114
	INM	3371	-	5076	-	1190
Bajra-wheat-*bajra*-chickpea (2 year rotation)	Control	2495	-	-	1810	-
	Inorganic	3790	-	-	2190	-
	INM	3067	-	-	2238	-
Pigeonpea-wheat	Control	-	867	1524	-	-
	Inorganic	-	1105	4457	-	-
	INM	-	1552	3952	-	-

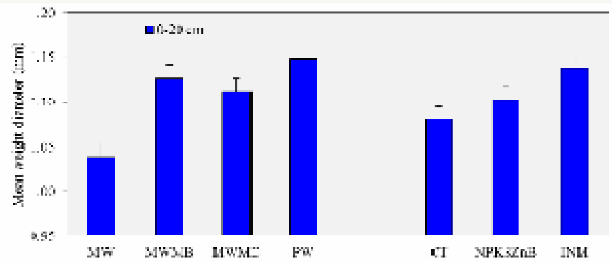


Fig. 37 : Mean weight diameter of soil aggregates as influenced by crop rotation and nutrient management practices

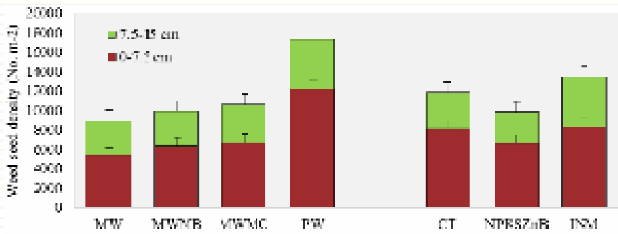


Fig. 38 : Changes in total weed seed bank density with long term practice of difftent crop rotation and nutrient management practices

Nutrient management

Screening of pulse genotypes for improved rhizospheric properties in mild-alkaline soil

Understanding rhizospheric soil properties of pulse crops is important for selecting efficient genotypes, which have higher nutrient acquisition potential through alteration of rhizospheric soil environment. Therefore, the rhizospheric alteration in thirty genotypes of urdbean, thirty fieldpea genotypes, and fifteen (including F_1 hybrid, released variety, and testing lines) pigeonpea genotypes were assessed in mild–alkaline (~8.1) soil. Results demonstrated that changes in rhizospheric properties in winter pulses was much prominent than *Kharif* crops (pigeonpea and urdbean). The rhizospheric alteration of different urdbean genotypes varied largely. The genotypes (IPU 2–43 × BG 4008) and MASH1 had higher rhizospheric alteration (soil available-P, soil available-S and pH), which was attributed to higher aboveground biomass and root growth attributes. The changes in soil available P, available S and pH ranges from 0.3–33.0%, 0.2–9.4%, 0.1–4.1%, respectively. For pigeonpea, not much variation was observed among the hybrids, released variety and genotypes. However, significant variation in different cultivars was apparent (Fig. 39).

Effect of supplemental application of nitrogen under terminal nodule degeneration phases in chickpea

In chickpea, nodule starts degeneration after flowering stage, therefore, it is anticipated that biological N–fixation, which is the primary source of N in chickpea, may limits crop potential productivity. Significant response of chickpea crop to supplemental N application at nodule degeneration stage was observed. An additional yield of 417 kg/ha could be achieved with application of 25 kg N/ha. The increased yield with application of N was attributed to increase in leaf weight, grain filling, and test weight (Fig. 40).

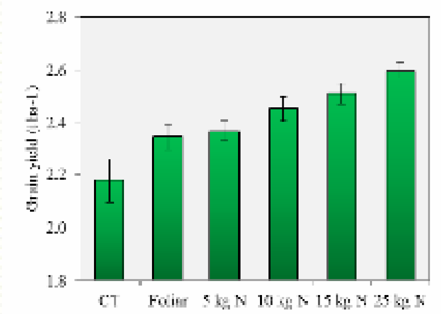


Fig. 40 : Effect of N supplementation at nodule degeneration stage on grain yield of chickpea

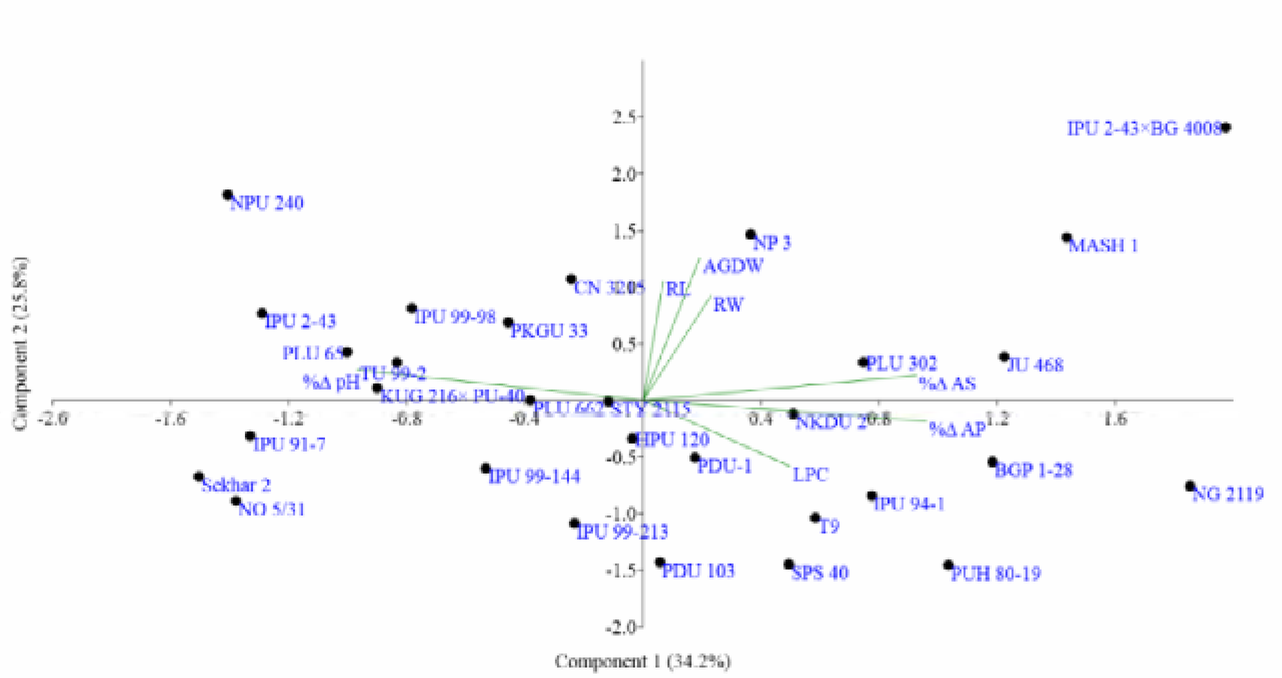


Fig. 39 : Scatter plot of different urdbean genotypes on principal component analysis computed based on rhizospheric alteration in pH, soil available P, soil available S, and plant growth attributes [*AGDW* aboveground dry weight, *RL* root length, *RW* root weight]

Physical fractionation of nodules and its relation with crop growth in chickpea

Variable growth pattern of nodules and its position on root likely to have a relation with plant growth in legumes. Here, we fractionated nodules based on their size [large (> 7 mm), medium (2–7 mm) and small sized nodule (<2 mm)] and its position (primary or lateral root) on roots in chickpea plant (n = 100) primarily to characterize the efficient nodules and also to study their relationship with plant growth attributes. The large sized nodule (LSN) mainly developed on primary roots (56.69%) as compared to lateral roots (11.89%). Number of LSN had a significant positive relation with plant growth attributes, while medium (MSN) and small sized nodule (SSN) exhibited no correlation with plant growth attributes. The fresh weight of LSN of primary root had a strong influence on leaf, stem, aboveground total, and root biomass accumulation. However, others (MSN and SSN) remain non–significant. The multiple regressions likewise confirmed that only number and fresh weight of LSN directly influenced the plant biomass accumulation (leaf, stem, and root). Nodule development on primary root had inhibitory effect on lateral root nodulation. Thus, size fraction of the nodule and its position in root could be used as an important observation in agronomic studies to best relate the nodulation with plant growth attributes.

Optimization of fertilizer N rate in *Rabi* season rajmash

Six graded dose of N (0, 30, 60, 90, 120, and 150 kg/ha) was applied to optimize the fertilizer N requirement of *Rabi* season rajmash in Indo–Gangetic plains. The yield of rajmash increased significantly up to N rate of 120 kg/ha. Maximum grain yield was registered in fertilizer N rate at 120 kg/ha, which was 93% higher over N control. The SPAD value reading was almost comparable across the fertilizer N treatments during January, which may be due to drastic fall in temperature that might have influenced crop N acquisition (Fig. 41).

(a) (b)

Fig. 41 : Crop growth of rajmash in the treatment N control (a) and N at 120 kg/ha (b)

Assessment of soil–plant P dynamics in aerobic rice–lentil

A field experiment was conducted to optimize the seasonal fertilizer P rate in aerobic rice-lentil production systems. Treatments comprised of two rice production systems *viz.*, direct seeded rice (DSR) and system of rice intensification (SRI) and seven system–based seasonal fertilizer P application rates. One additional treatment *i.e.* puddled transplanted rice (PTR) with recommended P rate to rice and lentil was also evaluated. The second year data revealed that the response of rice crop to P management was prominent in aerobic rice–based production system (up to 15.8% yield enhancement). Based on system productivity 33 kg P to rice and 11 kg P to lentil had the higher system productivity [rice equivalent yield (REY) 9621 kg/ha] closely followed by the treatment 16.5 kg P to rice and 5.5 kg P to lentil with rice residue and PSB (REY 9.5 t/ha). The grain yield of lentil crop was found higher after DSR than SRI and PTR plots (Fig. 42 & 43). Irrespective of P management treatments, the SPAD reading data demonstrated that rice crop faced N stress under DSR system, as compared to SRI system during anthesis.

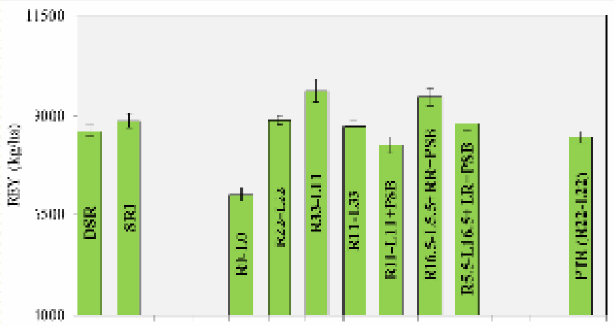


Fig. 42 : Effect of crop establishment and P management practices on REY in rice-lentil

Fig. 43 : Higher crop growth of rice and lentil under crop (16.5 kg P to rice and 5.5 kg P to lentil with rice residue and PSB)

Organic cultivation of pulses

A field experiment was initiated during *Kharif* season of 2017-18 to develop package of practice for pulses grown under organic cultivation. To begin with

Table 6 : Growth and yield performance of pigeonpea 'IPA 203' under organic cultivation

Variety	Grain yield (kg/ha)	Straw yield (kg/ha)	Total harvest biomass (kg/ha)	Harvest index (%)
(A) Package of practice				
Organic	1952	4710	6662	29.1
Inorganic	1685	3429	5114	32.9
SEm (±)	157	227	368	1.03
CD (0.05)	NS	784	1274	3.56
(B) Row Spacing (cm) standardization				
90 x 20	1673	3882	5556	30.3
75 x 20	1964	4256	6220	31.7
SEm (±)	157	227	368	1.03
CD (0.05)	NS	NS	NS	NS
Interaction (A x B)				
Organic x90 cm	1821	4487	6308	28.7
Organic x 75cm	2082	4933	7015	29.6
Inorganic x 90 cm	1525	3278	4803	31.9
Inorganic x 75cm	1845	3580	5425	33.8
SEm (±)	222	321	521	1.46
CD (0.05)	NS	1109	1802	5.04
Analysis made on factorial RBD.				

organic cultivation, long duration pigeonpea 'IPA203' was chosen. Initially, two cultivation packages were taken up involving organic and inorganic as main factor. For other factor, two row spacing were selected *viz.*, 90×20 cm (55,555 plants/ha) and 75 × 20 cm (66,666 plants/ha) in order optimize plant population under the agro-ecosystem including the existing soil and climatic condition). Under organic packages, nutrients are supplemented with FYM only along with need based plant protection against pests and diseases were made with organic origin. No chemical was applied to these plots either through soil or by foliar application. In inorganic package, nutrients were applied through chemical fertilizers and crop was protected from sucking pests/pod bore through conventional plant protection chemicals. The crop performance was good as it yields a maximum of 19.5 q/ha under organic cultivation (Fig. 44, Table 6), which was comparable to that of chemical farming. The study also revealed that pulses responded to organics more than inorganic ones. Here in this case, pigeonpea can be grown successfully with organic packages. As a result of significantly higher biomass in organic package, harvest index (29.1%) was comparatively lowered under it (over inorganic package, 32.9%). On the contrary, row spacing did not influence grain yield, straw yield, total biomass in pigeonpea although higher yields and biomass were realized at narrow row spacing of 75 × 20 cm. From the data, it was also

Fig. 44 : Performance of pigeonpea 'IPA 203' under organic package

evident that additional 20% in plant population could result in 3 q/ha bonus yield (17.4%). Therefore, if seeds are not a constraint, row spacing of 75 × 20 cm could give additional yield.

Enhancing Resource use Effciency

Enhancing RUE in pulse based cropping system in Central India (Soybean + pulse intercropping)

With an objective of scaling crop performance against abiotic stress in presence of ponding of water during monsoon season and heavy soil condition, an investigation was carried out at ICAR-IIPR, Regional Centre, Bhopal on soybean-lentil system (Table). Five different intercrops *viz.*, short duration pigeonpea 'TJT 501', maize 'RASI 4242', sorghum 'Colonel 6363', urdbean 'IPU 2-43' and sesame 'G-2' were grown in soybean 'JS 20-29' in 2:2 replacement series both under flat bed and broad bed furrow (BBF) land configurations. These crops were followed by lentil 'IPL 316' during *Rabi* with or without supplementary irrigation. Three years study concluded that soybean was compatible with short duration pigeonpea as the slow growth of pigeonpea during initial period facilitated soybean growth as a parallel inter-cropping. After maturity of soybean (90 days), pigeonpea occupied the total space (Fig. 45 & 46) and in fact, performed as a pure or mono-crop and gave higher soybean equivalent yield in comparison to other intercropping situation. Later, lentil grown during *Rabi* adds to the total yield and economics.

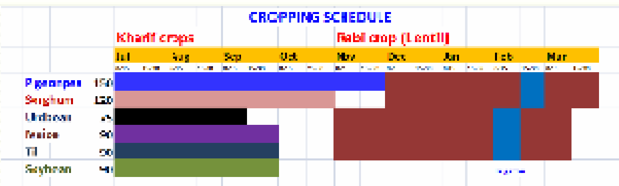


Fig. 45 : A proposed cropping scheme encompassing *Kharif* crops (soybean + intercrop) and *Rabi* crop (lentil) with crop duration in days (supplementary irrigation to lentil only in case of need)

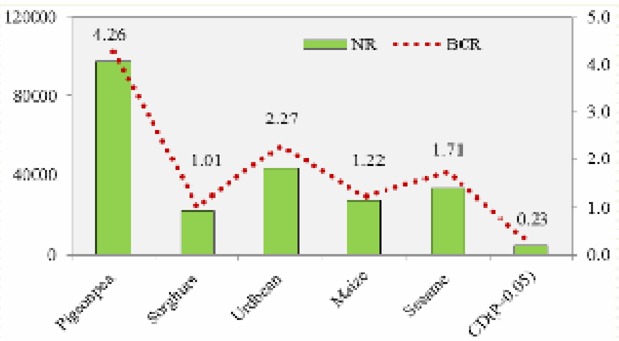


Fig. 46 : Economics of soybean + pigeonpea-lentil in Central India (NR: Net return in ₹/ha-yr)

The following conclusions were drawn from the study conducted during the last three years study (2014-17, pooled data).

- On intercropping with diverse pulses/cereal/oilseed crops in terms of total system productivity for both *Kharif* + *Rabi* (soybean +intercrop-lentil), a three years study concluded that significantly higher total productivities and returns were observed with soybean + pigeonpea - lentil followed by soybean + urdbean - lentil in Central India.
- Following appropriate land configuration (broad bed and furrow, BBF) in the heavy soils of Central India, soybean productivity could be enhanced when it was planted under BBF (*vis-à-vis* flat planting) as the former (BBF) proved its superiority over flat planting. Supplementary irrigation once to lentil could be useful in absence of rainfall during *Rabi* season (reproductive stage of lentil).
- Seed priming (for 4 hours) was useful under rainfed condition for *rabi* sowing after soybean. In addition, when it is combined with mulch, it had additional advantages in terms of moisture conservation and extended water availability to *Rabi* crop, besides grain yield.
- Ammonium molybdate @ 1 g/kg seed treatment + 25 kg $ZnSO_4$/ha should be fertilized to soybean in soybean-chickpea system in Central India. Addition of 5 t FYM/ha could be the best for Central Zone condition for a soybean-chickpea system.

Enhancing productivity in diverse pulses based cropping systems through improved nutrient management in Peninsular India

A field experiment was conducted during 2017-2018 at IIPR Regional Research Centre, Dharwad consisting of two cropping systems *viz.*, 1) maize (NK 4250) – chickpea (JG 11) and 2) soybean (DSB 21) - chickpea, two conservation practices *viz*; 1) conventional system 2) conservation system i.e., (mulching with maize straw); h three fertilizer application practices *viz.,* 1) Control 2) 100% RPP to *Kharif* and *Rabi* crop (100-100), and 3) 100% RPP to *Kharif* and 50% RPP to *Rabi* crop (100-50). The results relieved that chickpea equivalent yield (CEY) of maize-chickpea was 1.5 t/ha and that of soybean-chickpea

Table 7 : Effect of cropping systems and fertilizer application on chickpea equivalent yield

Cropping system	CEY (kg/ha)
1. Maize -chickpea	14834
2. Soybean- chickpea	8550
CD (5%)	790
Conservation practice	
1. Conservation(M+)	12399
2. Conventional (M-)	10586
CD (5%)	260
Fertilizer application	
1. Control	6874
2. 100-100	8650
3. 100-50	7460
CD (5%)	150

system was 0.85 t / ha. There was 17% increase in CEY in conservation practice as compared to conventional system (Table 7, Fig. 47). Among the fertilizer treatments, 100-100 recorded the highest CEY (8.7 t / ha).

Fig. 47 : Pulses based cropping systems under different treatments

Effect of liquid and carrier based bio-fertilizers on urdbean

An experiment was conducted at IIPR Regional Centre, Dharwad, to study the performance of carrier based and liquid inoculants of bio-fertilizers along with different doses of RDF and its effect on soil properties in urdbean (Fig. 48). The experiment revealed that 125% RDF + *Rhizobium* + PSB, liquid based) performed better when compared to other treatments, with respect to growth, effective root nodules per plant (35), dry matter production at harvest (20.1 g/plant), number of pods per plant (30.1), test weight (5.4 g), seed yield (1020 kg/ha), enzyme activity peak flowering stage and nutrient uptake.

Fig. 48 : Effect of liquid bio-ferilizers in urdbean

Water Management

Tillage × sprinkler irrigation in lentil

A field experiment was carried out during *Rabi* 2017-18 in 'IPL316' lentil to study the effect of irrigation (sprinkler irrigation *vis-à-vis* normal flood irrigation at critical stages of branch and pod development) coupled with diverse tillage options (conventional, reduced and zero tillage) on crop performance, water use and efficiency of applied inputs. The study showed that tillage options despite their inherent differences in terms of time and frequency of tillage could not influence grain and straw yield of the crop (Table 8). Yet, irrigation scheduling based on sprinkler irrigation did. Quite evidently, the growing season receives very little rain and was in fact climatologically scanty so far amount of precipitation occurred in *Rabi* season is concerned. It amounted to 8.2 mm of total rainfall from only 1 rainy day (received on 24th January 2018) as against 117 mm evaporation cumulated over the season (Mid-Nov 2016 to Mid-March 2017). Following intervention of irrigation scheduling and recharge of soil moisture storage, normal crop yield was also harvested (with average of 1500 kg grain yield/ha).

The study revealed that reduced or zero tillage (RT or ZT) had an edge over conventional tillage options in grain yield of lentil. This was confirmed from higher total biomass yield accrued from the former two treatments. However, other yield traits and growth attributes in lentil 'IPL 316' were not influenced by different tillage treatments carried out during *Rabi*, 2017-18 (Table 5). Irrigation scheduling, on the contrary, significantly influenced grain yield and its attributes and crop growth/development. Significantly higher grain yield was recorded with sprinkler irrigations applied at either branch or both at branch and pod development. This was again confirmed from higher values of related attributes *viz.*, straw yield, total biomass, pods/plant and grain weight/plant. As a result of these, harvest index was higher under sprinkler irrigation applied at either stages or both the stages. Therefore, the study concludes that with sprinkler irrigation at branch and podding, there was higher grain production (132%), biomass yield (145%), pods/plant (122%) and grain weight/plant (101%) under sprinkler irrigation applied at both branch and pod development in comparison to rainfed cultivation (Table 5). Thus, there was increase in crop productivity (due to water saving as a result of sprinkler irrigation) following optimum irrigation scheduling through sprinkler irrigation at branch and pod development over that in flood irrigation.

Effect of sprinkler irrigation and row spacing in mungbean

A field study cum large plot on-station field demonstration was carried out involving two popular

Table 8 : Effect of tillage and sprinkler irrigation at critical stages on chickpea grain yield and its yield attributes

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	HI (%)	Total harvest biomass (kg/ha)	Seed Index (g)	Seeds /pod	Pods/ plant	Grain wt./ plant (g)
Tillage								
ZT	1518	2886	35.1	4404	2.93	1.86	66.2	2.75
RT	1665	3032	36.0	4697	2.88	1.86	67.6	2.89
CT	1370	2858	32.8	4227	2.86	1.88	67.1	2.89
SEm+	57.4	71.0	1.05	87.8	0.07	0.06	3.7	0.18
C.D. (0.05)	NS	NS	NS	354.8	NS	NS	NS	NS
Sprinkler Irrigation								
Ibr (SPR)	1613	2970	35.2	4583	2.96	1.81	68.8	2.98
Ipod (SPR)	1352	2361	36.5	3713	2.88	1.89	65.4	2.43
Ibr+pod (SPR)	1769	3298	35.4	5067	2.93	1.81	71.7	3.02
Ibr (NOR)	1440	2739	34.5	4179	2.79	1.84	67.0	2.88
Ipod (NOR)	1259	2251	36.5	3510	2.97	1.90	53.3	2.38
Ibr+pod (NOR)	1671	3935	29.7	5606	2.80	1.94	75.6	3.36
SEm+	62.7	143	1.2	176	0.06	0.05	4.4	0.21
C.D. (0.05)	182	415	3.5	510	NS	NS	12.8	0.62
Interaction was not significant.								
Rainfed crop	764	1301	37.0	2065	2.82	1.83	32.3	1.50

varieties (Samrat and IPM 02-3) and five agro-technologies involving row spacing at 15 cm, 22.5 cm and 30 cm (farmers' practice) combined with sprinkler/flood irrigation with the aim of refining the optimum row spacing and sprinkler irrigation need of mungbean for enhancing crop productivity and profitability. The intra-row distance was maintained at 10 cm. This was studied in the backdrop of summer rains, if any, so as quantify the irrigation water use and its efficiency in the crop of summer mungbean. A row spacing of 22.5 cm, irrespective of normal or paired row, produced around 300 kg additional grain yield per hectare over farmers' practice (30 cm row spacing). Most evidently, sprinkler irrigation combined with 22.5 × 10 cm row spacing had yielded the highest grain yield which was closely followed by narrow row spacing of 15 cm × 10 cm combined with flood irrigation (Table 9, Fig. 49). Paired row (15-30 cm × 10 cm) could not establish its superiority over normal spacing (22.5 cm × 10 cm) as evident during existing hot and humid condition of EGPZ. Thus, the study established the role of regulated sprinkler irrigation as per crop need over

Table 9 : Growth and yield performance of spring planted mungbean under various agro-techniques

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Total biomass at harvest (kg/ha)
Variety			
Samrat	1245	2110	3355
IPM 02-3	1034	1760	2794
SEm (±)	38.0	54.5	117
CD (0.05)	203	276	389
Irrigation x Row spacing			
Sprinkler + RS (22.5 × 10 cm)	1225	2077	3302
Flood + RS (22.5 × 10 cm)	1154	1959	3113
Flood + PR (15-30 × 10cm)	1135	1927	3062
Flood + NR (15 × 10 cm)	1210	2054	3264
Flood + FP (30 ×10 cm)	974	1659	2633
SEm (±)	21.5	47.5	67.6
CD (0.05)	63.9	115	167
RS: Row spacing; NR: Narrow row spacing; FP: Farmers' practice; Interaction effect was not significant			

Fig. 49 : Performance of mungbean under overhead sprinklers versus flood irrigation (left 'IPM 02-3' and right 'Samrat')

the prevailing practice of flood irrigation. Similarly, the current investigation showed the optimum plant population maintained at 22.5 × 10 cm over both narrow (15 × 10 cm) and wide plant population (30 × 10 cm). Similar trend was evident in the case for straw, total biomass and other yield attributes.

The effect of overhead sprinkler irrigation + improved agro-techniques (paired row, narrow row spacing with sprinkler irrigation) concluded that

- A row spacing of 22.5 cm was optimum over farmers' practices of 30 cm row spacing for April sown crop.
- 15 cm row spacing is not the optimum both on economics and yield.
- Sprinkler irrigation was useful as it consumed 31.9% less water use, 69.7% higher WUE, 69.8% higher WP, increased net return of ₹ 10,106 and BCR by 0.13 over flood irrigation applied by farmers.

Enhancing nutrient and WUE of chickpea with hydrogel

A field experiment was initiated during 2017-2018 to study the effect on enhancing nutrient and water use efficiency of chickpea through hydrogel under rainfed/limited irrigated situation. Three hydrogel application levels *viz.*, 0, 2.5 and 5 kg/ha in main plot, and five foliar application of chemicals/nutrients such as water spray (control), 2% urea, Thiourea 500 ppm, Salicylic acid at 100 ppm and NPK (19:19:19) at 0.5% at both flower initiation and pod development stages in sub plot, were replicated thrice in a split plot design. During 2017-18, improvement in chickpea yield and its attributes were not pertinent following application of hydrogel (without or with it at its variable rates). However, the improvement in chickpea grain yield was apparent following application of either nutrient solution (urea versus NPK spray) or growth chemicals (salicylic acid or thiourea spray) at the given concentration. Maximum yield was obtained however with salicylic acid at 100 ppm followed by NPK (19:19:19) at 0.5% applied at both flower initiation and pod development stages (Table 10). Similar was the effect of these applied at both the above stages on other yield and growth attributes.

Table 10 : Effect of hydrogel on chickpea yield, yield attributes and growth characters

Treatment	Grain yield (kg/ha)	Total yield (kg/ha)	Straw yield (kg/ha)	HI (%)	Seed Index (g)	Pods/ Plant	Seeds /Pods	Grain wt. (g)
Hydrogel (kg/ha)								
0	1531	3117	1586	50.1	17.9	48.1	1.35	8.94
2.5	1597	3214	1617	50.2	18.0	50.9	1.30	9.59
5.0	1606	3406	1799	47.0	18.0	52.1	1.28	10.14
SEM (±)	51.0	118.3	74.9	0.74	0.21	1.8	0.04	0.49
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Foliar spray at branch and podding								
Water	1349	2847	1499	48.0	17.4	43.5	1.21	8.35
Urea (2%)	1649	2223	1573	51.5	18.3	49.8	1.38	9.75
NPK (0.5%) 19:19:19	1715	3565	1850	48.1	17.6	53.7	1.24	9.89
SA (100 PPM)	1729	3583	1855	48.5	17.9	54.1	1.34	10.25
Thiourea (500 PPM)	1448	3009	1561	49.3	18.5	50.7	1.37	9.55
SEM (±)	99.3	192	150	2.9	0.32	2.4	0.05	0.40
CD (0.05)	291.4	564	NS	NS	NS	6.9	NS	1.17
Interaction was not significant								

Weed management

Weed management in pulses through post-emergence (POE) herbicides

Mungbean

Field experiment was conducted on activities of some post-emergence herbicides (POE) *viz.* topramezone, tembotrione, imazethapyr + imazamox, oxyfluorfen, fenoxaprop-p-ethyl, and clodinafop-propaygyl + Na- acifluorfen to assess their phytotoxicity and efficacy on mungbean. The weed phytotoxicity symptoms due to application of oxyfluorfen 150 g a.i./ha, topramezone 20.6 g a.i./ha and clodinafop propargyl + Na-acifluorfen 122.5 g a.i./ ha were started next day after application (DAA) of these herbicide. The herbicide oxyfluorfen 150 g a.i./ ha, topramezone 20.6 g a.i./ha and tembotrione 100 g a.i./ha showed higher phytotoxicity in mungbean at 7, 15 and 25 days after herbicide application (DAA). However, other herbicides did not show any phytoxicity on mungbean in terms of leaf burning. The population and dry weight of broad-leaved, narrow-leaved and total was significantly reduced with application of clodinafop propargyl + Na- acifluorfen 122.5 g a.i./ha and and oxyfluorfen 150 g a.i./ha at 35 DAS and at harvest and they were at par with pendimethalin 1.0 kg a.i./ha *fb* imazethapyr 100 g a.i./ha. At the entire crop growth stages *i.e.* at 35 DAS at harvest, clodinafop propargyl + Na-acifluorfen 122.5 g a.i./ha, and oxyfluorfen 150 g a.i./ha recorded higher WCE than the remaining weed control practice (Fig. 50).

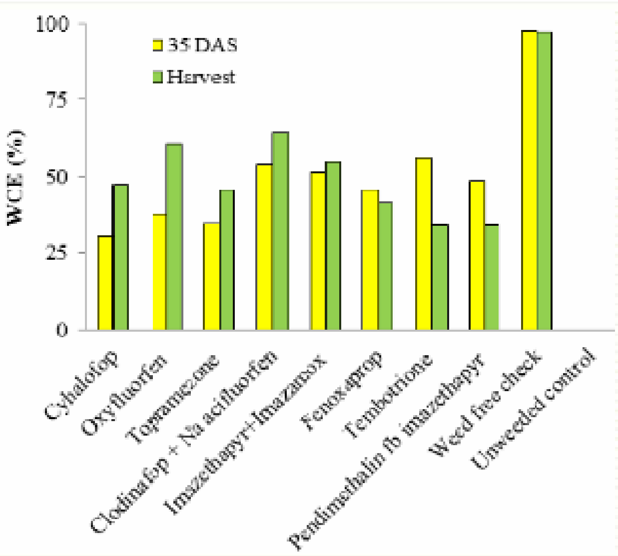


Fig. 50 : Weed control efficiency (%) of different POE herbicides in mungbean

Among the herbicidal treatments, the lowest number of nodules/plant was recorded in oxyfluorfen 150 g a.i./ha. However, among herbicidal treatments, clodinafop propargyl + Na-acifluorfen 122.5 g a.i./ha and pendimethalin 1 kg a.i./ha *fb* imazethapyr 100 g a.i./ha attained significantly higher nodule dry matter accumulation over other herbicides. These herbicides also recorded significantly higher mungbean grain yield over other herbicides. The highest yield was obtained in weed free check (860 kg/ha). Because of higher grain yield in clodinafop propargyl + Na-acifluorfen 122.5 g a.i./ha and pendimethalin 1.0 kg a.i./ha *fb* imazethapyr 100 g a.i./ha, they recoded lower weed index over rest of the herbicide treatments.

Chickpea

Performance of some new post-emergence herbicides was also evaluated to assess their efficacy and phytotoxicity in chickpea. Major weed flora observed in chickpea included broad-leaved weeds *viz. Coronopus didymus*, *Convolvulus arvensis*, *Chenopodium album*, *Chenopodium murale*, *Fumaria parviflora*, *Anagallis arvensis*, *Spergula arvensis*, *Medicago denticulata* and *Vicia hirsuta* and narrow-leaved like *Asphodelus tenuifolius* and *Phalaris minor*.

Post-emergent herbicides had phytotoxicity on chickpea after exposure on the foliage. The crop recovery duration varied with herbicides. The phytotoxicity of tembotrione 100 g a.i./ha and halosulfuron methyl 70 g a.i./ha were prominent immediately after application and extended up to 30 days after application (DAA) of herbicides. On the other, phytotoxicity of imazethapyr and imazethapyr + imazamox were prolonged and recovery was poor. The phytotoxicity of topramezone 20.6 g a.i./ha was minimal on chickpea and crop recovered quickly. Whereas, it had higher phytotoxicity on weeds.

All weed control treatments recorded significantly lesser weed population and dry matter of weeds than unweeded control. Among the herbicides, topramezone 20.6 g a.i./ha, and pendimethalin 1.0 kg a.i./ha *fb* quizalofop- ethyl 100 g a.i./ha were promising and it has an edge over other for reduction in weed population and dry weight of broad-leaved and narrow-leaved weeds. The weed control efficiency (WCE) was higher in topramezone 20.6 g a.i./ha and pendimethalin 1.0 kg a.i./ha a *fb* quizalofop- ethyl 100 g a.i./ha over other herbicides (Fig. 51). The data pertaining to number of nodules/plant showed that all the herbicidal treatments reduced the number of nodules/plant than weed free check. Among the

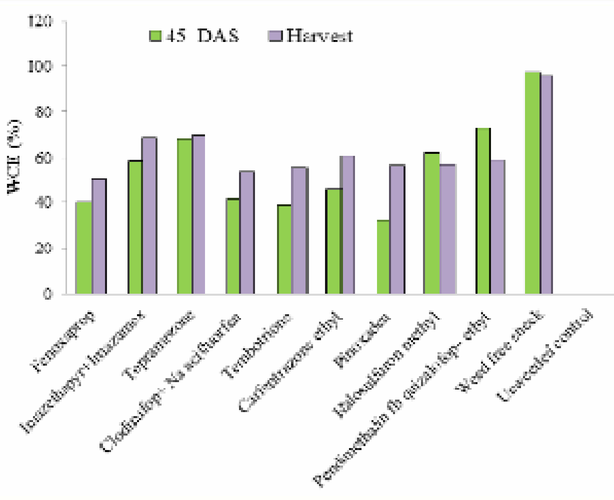


Fig. 51: Weed control efficiency (%) in chickpea at different growth stages

herbicidal treatments, the lowest number of nodules/ plant was recorded in tembotrione 100 g a.i./ha. However, among herbicidal treatments topramezone 20.6 g a.i./ha and pendimethalin 1.0 kg a.i./ha *fb* quizalofop- ethyl 100 g a.i./ha attained significantly higher nodule dry matter accumulation over other herbicides. Topramezone 20.6 g a.i./ha recorded significantly higher chickpea grain yield over other herbicides (Fig. 52). The highest yield was obtained in weed free check (1437 kg/ha) followed by topramezone 20.6 g a.i./ha (1265 kg/ha). Because of higher grain yield in topramezone 20.6 g a.i./ha and pendimethalin 1.0 kg a.i./ha *fb* quizalofop- ethyl 100 g a.i./ha, they recorded lower weed index over rest of the herbicide treatments.

Fig. 52: Performance of chickpea under topramezone 20.6 ml a.i./ha vis-à-vis weedy check

Resource conservation technology

Conservation tillage and residue management in pulse based system

A field experiment was initiated during 2009 to study the effect of resource conservation technology in pulse based cropping system. Two tillage practices (zero tillage, ZT and conventional tillage, CT) in main plot, three cropping systems (rice–wheat, rice–chickpea, rice–chickpea–mungbean) in sub plot and two residue management practices (residue retention and residue removal) in sub–sub plot were replicated thrice in a split–split plot design. From 2015 onward, ½ dose of P and no K were applied to *Rabi* and summer crops under CA (ZT + residue retention in rice–wheat–mungbean).

The improvement in rice yield followed the sequence of ZT (4510 kg/ha) > CT (4308 kg/ha), residue retention (4570 kg/ha) > no residue (4248 kg/ha) and in RWMb (4617 kg/ha) > RC (4413 kg/ha) > RW (4196 kg/ha) in 2016 (Fig. 53). The same trend was observed in case of *Rabi* crop. The higher system productivity in terms of chickpea equivalent yield (CEY) was recorded in ZT (5.9%), residue retention (9.5%) and in rice–chickpea–mungbean (56.4%) over CT, no residue and rice–wheat cropping system. Net returns and B:C ratio were also higher in rice–chickpea–mungbean cropping system (₹ 1,22,204/ha and 2.34, respectively) and least under rice–chickpea (₹ 60,626/ha and 1.87, respectively). Similarly, sustainability index was also higher in rice–chickpea–mungbean (0.73) and residue incorporation (0.56) over rice–wheat and no–residue.

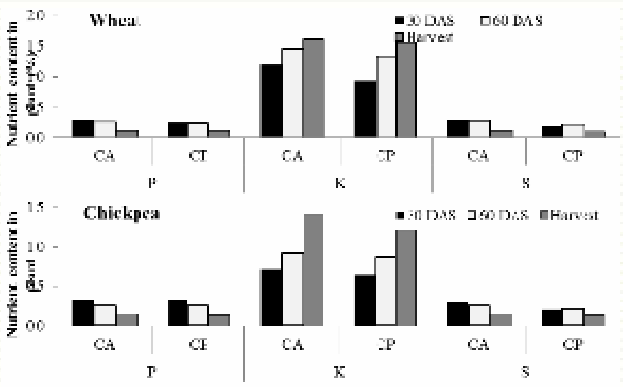


Fig 53 : Phosphorus, potassium and sulphur dynamics in wheat and chickpea under CA and conventional practice

The conservation agriculture practices *i.e.* rice–wheat–mungbean with crop residue addition and zero tillage reduced the bulk density and particle density over rice–wheat under conventional practices. Whereas, rice–wheat–mungbean with crop residue addition and zero tillage increased water holding capacity and volume expansion over rice–wheat without residue addition and under CT. Similarly, ZT with crop residues and R–W–Mb recorded higher macro–aggregate in surface (0–20 cm) and sub–surface (20–

40 cm) soil whereas, continuous rice–wheat caused reduction macro–aggregate.

The tillage, residue, and cropping systems had significant effect on soil available P, K, S, Zn and Fe over the years. In general, the ZT with residue addition and rice–wheat–mungbean cropping systems significantly enhanced the available P, K, S, Zn and Fe over the years over CT, no–residue and rice–wheat. Continuous adoption of CA in R–W–Mb system led to significant enhancement in non–labile C in surface soil causing higher sequestration of C in soil over rice–wheat system in CT without residues.

Weeds seed bank study revealed that RC cropping system led to higher weed emergence in surface soil over rice–wheat because more accumulation of weed seeds. The ZT had higher weed emergence in surface soil; however, in sub–surface soil the trend was *vice–versa*.

Performance of summer mungbean under conservation agriculture in rice–wheat cropping system in IGP

A field experiment was started during 2015 to assess the performance of summer mungbean under conservation agriculture in rice–wheat system. The study was conducted under split plot design with three replications. Main plot consist of three rice residue management practices *viz.,* 30 cm stubble, burning of 30 cm stubble and no residue; 2 tillage practices for summer mungbean in sub–plots *viz.,* zero tillage and conventional tillage and 5 mungbean varieties in sub–sub–plots *viz.,* IPM 2–3 (60 days); IPM 2–14 (65 days); HUM 16 (58–60 days); Samrat (55–58 days); IPM 205–7 (50–52 days).

The residue management treatment and tillage practices were at par for the mungbean yield. Among the different mungbean cultivar, the sequence for grain yield was IPM 205–7 (1369 kg/ha) > Samrat (1198 kg/ha) > IPM 2–3 (1182 kg/ha) > HUM 16 (1144 kg/ha) > IPM 2–14 (1095 kg/ha). The residue management was also at par for mungbean nodulation. However, ZT + wheat stubble increased the nodulation in mungbean. The cultivar, IPM 2–14 led to higher mungbean nodule formation over rest of the cultivar. When grain yield is concerned for rice and wheat, the tillage management (CT and ZT) could not make significant impact on grain yield. However, residue addition significantly improved the rice and wheat grain yield over no–residue and residue burning (Fig. 54).

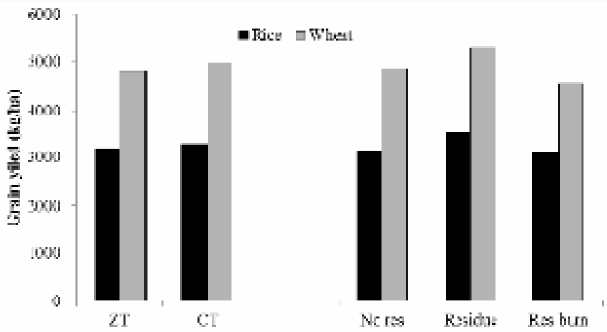


Fig. 54 : Performance of rice and wheat under different management practices

Pulses in upland cropping systems under CA practices

A field experiment was conducted during 2016–2017 to design a cropping system with higher system productivity and resource–use efficiency. The system productivity in terms of chickpea equivalent yield showed that April planted pigeonpea (UPAS 120) + summer mungbean (1:3) – wheat (5,550 kg/ha), maize – wheat – mungbean (4,831 kg/ha), early pigeonpea (UPAS 120) + urdbean – wheat (Unnat Halna) (4,823 kg/ha) and early pigeonpea (UPAS 120) – wheat (Unnat Halna) (4,417 kg/ha) recorded higher system productivity over other cropping systems. The intercropping based cropping systems recorded higher grain yield over sole cropping for pigeonpea–wheat cropping system. The maize–wheat cropping system recorded lower system productivity over pigeonpea–wheat based cropping systems. The maize–wheat cropping system was at par with maize – chickpea + mustard (6:2) for system productivity.

Weed management strategies for enhancing productivity and sustainability of pulses systems

A field experiment was conducted to monitor the weed dynamics and integrated weed management, crop productivity, soil physio-chemical, and biological properties in rice-chickpea cropping system under conventional and conservation agriculture practices. Four tillage cum crop establishment methods *viz.,* (i) puddled transplanted rice (PTR) – conventional tilled (CT) chickpea (PTR-CTC), (ii) PTR – zero tilled (ZT) chickpea (residue retention in chickpea) (PTR-ZTC), (iii) ZT dry seeded rice – ZT chickpea (residue retention in both crops) (ZTDSR-ZTC), (iv) CT dry seeded rice – CT chickpea (CTDSR-CTC) and three weed control practices as sub plots were laid out in split plot design with three replications. The weed control practices in rice crop consisting of (i) butachlor 1.25 kg a.i./ha or pendimethalin 1 kg a.i./ha followed by bispyribac sodium 20 g a.i./ha, (ii) butachlor 1.25 kg a.i./ha or pendimethalin 1 kg a.i./ha followed by almix 4 g a.i./ha, (iii) butachlor 1.25 kg a.i./ha or pendimethalin 1 kg a.i./ha followed by 1 hand weeding, whereas, in chickpea comprising of (i) pendimethalin 1 kg a.i./ha followed by quizalofop ethyl 100 g a.i./ha, (ii) oxyfluorfen 150 g a.i./ha followed by propaquizafop 100 g a.i./ha, (iii) pendimethalin 1 kg a.i./ha followed by 1 hand weeding and weedy check.

In case of rice, CTDSR-CTC system resulted in significantly higher weed density (10/m^2) and dry weight (6.5 g/m^2) at 45 days after sowing over PTR-CTC and ZTDSR-ZTC systems. Among weed control practices in rice, butachlor 1.25 kg a.i./ha or pendimethalin 1 kg a.i./ha followed by bispyribac-Na 20 g a.i./ha at 20 DAS recorded significantly lowest weed density (7.3/m^2) and dry weight (5.0 g/m^2) over weedy check. In chickpea, ZT with rice residues retention (PTR-ZTC and ZTDSR-ZTC systems) recorded lower weeds density and dry weight over CT-chickpea. In chickpea, pendimethalin 1 kg a.i./ha followed by quizalofop-p-ethyl 100 g a.i./ha recorded significantly lowest weed density and dry weight.

The grain yield of rice was higher in PTR system over CTDSR and ZTDSR system. However, ZTDSR-ZTC system recorded significantly higher chickpea grain yield over other practices (Table 8). The system productivity in terms of chickpea equivalent yield followed the sequence of PTR-CTC (4.42 t/ha) > PTR-ZTC (4.28 t/ha) > ZTDSR-ZTC (4.21 t/ha) > CTDSR-CTC (4.16 t/ha). The chickpea growth parameter like, plant dry weight, nodule growth and rhizospheric properties were higher in ZT with residues over CT without residues. The ZT with crop residues retention recorded higher soil moisture over CT in surface soil.

Table 11 : Rice and chickpea productivities in different tillage and weeds management practices

Treatment	Yield of rice (t/ha)	Yield of chickpea (t/ha)
Crop establishment practices		
PTR-CTC	4.92	2.35
PTR-ZTC	5.13	2.13
ZTDSR-ZTC	4.45	2.54
CTDSR-CTC	4.18	2.40
CD (P=0.05)	0.34	0.18
Weed control practices		
Rice: Buta./PMT fb Bis.; Chickpea: PMT fb Quizal.	5.04	2.37
Rice: Buta./PMT fb Almix; Chickpea: Oxyf. fb Propaquiz.	4.33	2.36
Rice: Buta./PMT fb HW; Chickpea: PMT fb HW	4.63	2.34
CD (P=0.05)	0.29	NS

Physical and engineering properties of different varieties of chickpea relevant to design of planter

Physical and engineering properties of different varieties of chickpea (Fig. 55) namely, JG–16, HC–5, KWR–108, IPC–4–1, IPC–5–62, DCP–92–3, IPC–4–98 and JG–14 had been studied for the determination of parameters for the design of planter. Different apparatus (Fig. 56) had been fabricated and standard procedures were followed to measure different physical and engineering properties. Different varieties had been collected from the Crop Improvement Division of ICAR–IIPR, Kanpur which had moisture content of 10 to 11.4% for different varieties. Different parameters like length, breadth, thickness, geometric mean diameter, sphericity, bulk density, true density, angle of repose, coefficient of static friction were calculated using different apparatus.

Fig. 55: Different varieties of chickpea taken for study

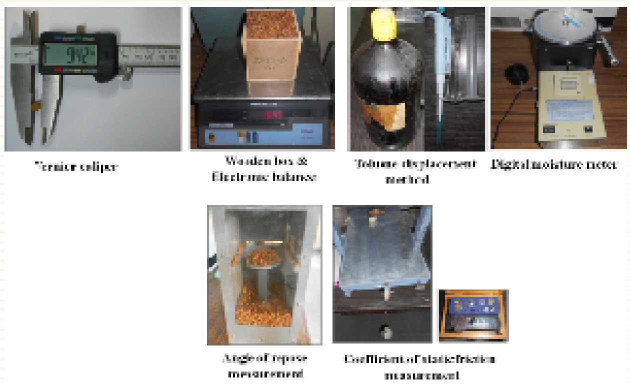


Fig. 56: Different apparatus used for the measurement

No load and preliminary testing of experimental *dal mill* for Pigeonpea (UPAS 120)

No load testing of experimental dal mill had been done, rpm was measured using contact type tachometer and power consumption, current and voltage by using power clamp (Table 12 & 13).

Table 12 : Measurement of rpm using contact type tachometer

S.No.	Motor rpm	Rotor rpm
1.	1480	748
2.	1482	748
3.	1482	749

Table 13 : Measurement of power consumption, current, and voltage at no load using power clamp

	Power (kW)	Power factor (pf)	Current (A)	Frequency, (Hz)	Voltage (V)	Frequency, (Hz)
1.	0.44	0.465	4.6	50	237.2	49.9
2.	0.43	0.367	4.6	49.7	237.4	49.9
3.	0.42	0.368	4.6	50.3	236.9	49.9

Preliminary testing of experimental *dal mill* was conducted without pre–treatment for pigeonpea (UPAS 120) on single pass (Table 14) and second pass (Table 15).

Table 14 : Preliminary testing of experimental *dal mill* for pigeonpea (UPAS 120) without pre–treatment on single pass

S. No.	Pitted sample weight (g)	Whole undehusked grain (g)	Whole dehusked grain (g)	Splitted undehusked grain (g)	Splitted dehusked grain (g)	Husk (g)
1	100	29.4	12.2	40.2	14.2	4.0
2	100	29.7	16.5	37.7	12.8	3.3
3	100	30.6	17.3	39.7	10.7	1.7

Table 15 : Preliminary testing of experimental *dal mill* for pigeonpea (UPAS 120) without pre–treatment on second pass

S. No.	Pitted sample weight (g)	Whole undehusked grain (g)	Whole dehusked grain (g)	Splitted undehusked grain (g)	Splitted dehusked grain (g)	Husk (g)
1	100	1.0	22.8	14.9	57.0	4.3
2	100	1.1	35.6	12.7	47.6	3.0
3	100	1.3	29.3	14.1	49.7	5.6

Evaluating next generation fertilizers in maize-chickpea

A field experiment was carried out to in *Typic Ustochrept* soil of Kanpur to evaluate the influence of intercropping and different blend of fertilizers including customized fertilizers in maize-chickpea cropping sequence. The treatment comprising of intercropping (Sole maize, maize+urdbean and maize+soybean) allotted to main plot and varying blend of fertilizers (RDF_1, RDF_2, RDF_3, CFG_1, CFG_2, CFG_3, CFG_4 and control) kept in sub-plots under split plot design and replicated thrice. Under this study, the crop of urdbean and soybean were intercropped with maize and fertilizers were applied as per the recommendation of the main crop *i.e.* maize. No additional fertilizers were added to the intercrop or component crop *i.e.* urdbean and soybean.

Inclusion of urdbean as intercrop with maize recorded marked improvement in maize grain yield over sole maize and maize+soybean. This showed that intercropping of urdbean with maize as pulse crop had no deleterious effect on yield of maize, although it improves the grain yield of maize also. However, higher chickpea yield was observed when sown under the treatment sole maize in succession. The intercrop of both urdbean and soybean gave additional yield. Moreover, application of maize formula (6:5.4:10:6.0:1.0:0.6:0.2); a locally prepared fertilizer formulation to maize recorded higher grain yield over rest of the fertilizer options (straight fertilizers, customized fertilizers etc.). Further, application of customized fertilizers gave higher grain yield over straight fertilizers. Similarly, marked improvement in grain yield of urdbean and soybean also noticed due to application of CFG_4 over rest of the fertilizer management options. When chickpea was grown in succession and applied with chickpea formula (5.5:4.6:4.5:8.3:1.4:0.8:0.08:0.034) being par with RDF_2 but better over other fertilizer management options.

The crops of maize and chickpea were grown in succession on same raised bed, no tillage operations were done. Only raised beds were reshaped just before the sowing of maize in *Kharif* and chickpea in *Rabi*. Substantial improvement in system productivity in terms of maize equivalent yield (65.39 q/ha) and chickpea equivalent yield (45.33 q/ha)were observed under maize+urdbean intercropping system. Further, application of CFG_4 to maize and chickpea recorded highest MEY (79.19 q/ha) and CEY (50.52 q/ha) (Fig. 57). This indicated that applying balanced nutrients in desired amount in accordance with the demand of crop had marked influence on grain yield.

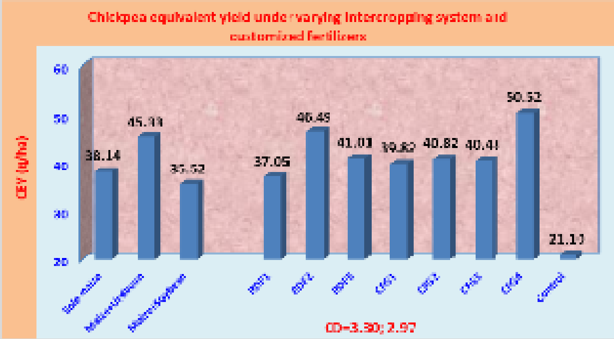


Fig. 57 : Chickpea equivalent yield under varying intercropping system and customized fertilizers

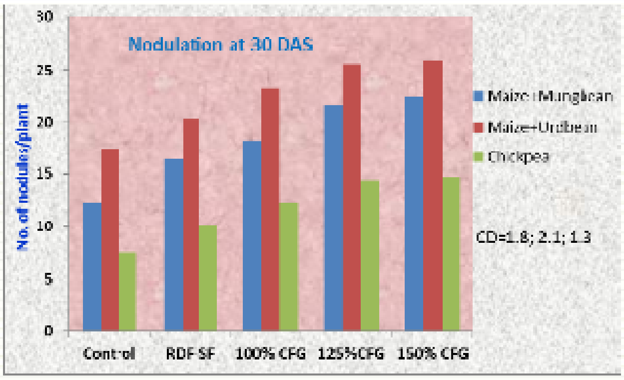


Fig. 58 : Nodulation at 30 dAS

Optimizing customized fertilizers in maize-chickpea

A field experiment was conducted to optimize the quantity of maize formula (6:5.4:10:6.0:1.0:0.6:0.2) and chickpea formula (5.5:4.6:4.5:8.3:1.4:0.8:0.08:0.034); locally prepared customized fertilizer formulations applied to maize and chickpea, respectively, in succession. During *Kharif* season, intercropping (Sole maize, maize+mungbean and maize+urdbean) systems were allotted to main plot and varying doses of maize/chickpea formula (Control, RDF through SF, 75% of CFG, 100% of CFG, 125% of CFG and 150% of CFG) kept in sub-plots under split plot design and replicated thrice. Under this experiment, the crop of mungbean and urdbean were intercropped with maize and customized fertilizer formulations were applied as per the treatment to the main crop *i.e.* maize. No surpluscustomized fertilizer formulations were added to the intercrop or component crop *i.e.* mungbean and urdbean.The results revealed that application of customized fertilizer grade (CFG) to mungbean, urdbean and chickpea enhanced nodule number at 30 DAS significantly over no fertilizer (=control) and RDF applied through straight fertilizers. Application of 125% dose of CFG being on par with 150% CFG, statistically enhanced nodulation in mungbean, urdbean and chickpea over RDF applied through straight fertilizers (RDF-SF) and control. This might be attributed to continuous supply of all desired nutrients to the plants as per need in slow release matrix. Application of 125% CFG recorded 21.6, 25.6 and 14.4 nodules/plant in mungbean, urdbean and chickpea, respectively. However, under control treatment, 12.3, 17.5 and 7.5 nodules/plant was recorded. This indicated that customized fertilizer formulations could be a better option to realize higher nodulation in pulses over straight fertilizers.

On-farm trials on customized fertilizers

An On-farm trial (OFT) was conducted in Karchalpur village (26°09' N Latitude and 80°31' E Longitude) of Fatehpur district to evaluate performance customized fertilizers on productivity of fieldpea genotypes. Under the OFT, five genotypes of fieldpea (Aman, IPFD 10-12, IPF 4-9, Prakash and Vikas) were evaluated for grain yield enhancement under varying nutrient management strategies (Farmers practice of nutrient management, RDF through straight fertilizers and customized fertilizer). The findings reveal that application of Matar formula (13.3:20:10:8.3:1.3; N:P:K:S:Zn); a locally prepared fertilizer formulation to field pea genotypes recorded higher grain yield over rest of the nutrient management options (Farmers practice and RDF through straight fertilizers). All the fieldpea genotypes responded well and out yielded due to application of *Matar* formula. The yield increment observed from 11-28 per cent due to application of *Matar* formula over farmers practice of nutrient management.

To evaluate performance of varying foliar spray on productivity of chickpea genotypes under rainfed conditions of Fatehpur, Uttar Pradesh. Under the OFT, two genotypes of chickpea (JG 16 and Local) were evaluated for grain yield enhancement under varying foliar spray options (Foliar spray of urea; foliar spray of Zn, Fe; foliar spray of urea, Zn, Fe and foliar spray of multi-nutrient supplement). Foliar spray of multi-nutrient supplement to chickpea (17.6 q/ha) enhanced grain yield of chickpea to the tune of 12.3 per cent higher over foliar spray of urea (2% solution). Further, yield increment due to foliar spray of multi-nutrient supplement was higher in JG 16 compared with local. It reflected that multi-nutrient deficiency is more prevalent in the locality, because of that reason responses were greater under multi-nutrient supplement spray. Further, combined spray of urea (2%

NH_2CONH_2), zinc (0.5% $ZnSO_4$) and iron (0.3% $FeSO_4$) had no toxicity effect on chickpea and significantly enhanced grain yield over urea or zinc+iron spray, individually.

Micronutrient fortification of pulses

Experiments were conducted on *Typic Ustochrept* soil of Kanpur to evaluate approaches of agronomic biofortification (=ferti-fortification) of pulses. The results indicated that seed coating of chickpea cultivars (HC 5 and JG16) with different levels of zinc (0.0 to 7.5% ZnO by seed weight) enhanced grain yield significantly (Fig. 59). Seed coating of chickpea using zinc oxide upto 7.5% by seed weight, enhanced seed yield by 16.7% in HC5 and 14.7% in JG 17 over no coating or control. Higher responses were observed in HC 5 compared with JG 16; this might be due to genetic makeup of the cultivar. Moreover, no toxicity symptoms were noticed in both the cultivars upto 7.5% level of seed coating. Similar studies were also conducted under pots in net house to corroborate the findings. The yield increment trend was found similar under both the conditions of field and pot.

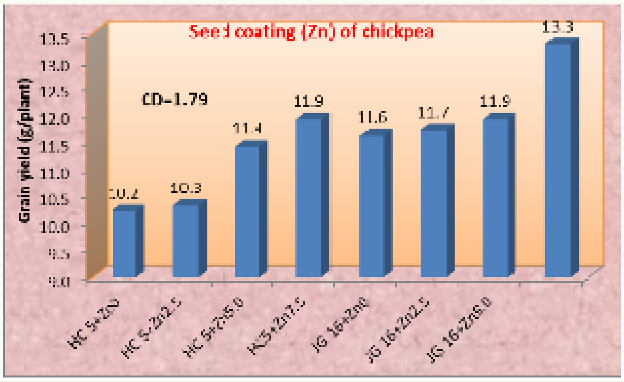


Fig. 59 : Seed coating (Zn) of chickpea

Similarly, seed coating of fieldpea genotypes (IPFD 11-5 and IPFD 11-10) with zinc oxide (0-7.5% by seed weight) also enhanced seed yield significantly (Fig. 60). The yield increment due to seed coating with zinc oxide upto 7.5% observed to the tune of 19.9 and 17.4% in IPFD 11-05 and IPFD 11-10, respectively. Moreover, seed coating of fieldpea with ZnO upto 7.5% had no toxicity and mortality effect on fieldpea, however, it boosted the seed germination rate and stand establishment. It opens up the scope for evaluating higher level of seed coating with zinc oxide. Further, significantly highest grain yield/plant of fieldpea was observed in IPFD 11-5 (16.9 g/plant) and IPFD 11-10 (18.9 g/plant) at the application rate of 7.5% seed coating.

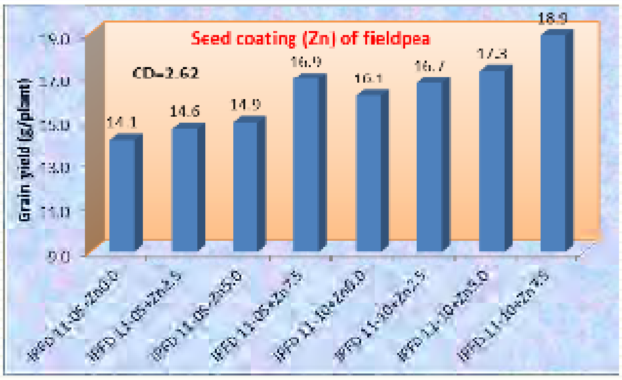


Fig. 60 : Seed coating (Zn) of fieldpea

Mechanical harvesting of chickpea

Field experiment was conducted with the objective to determine the optimum plant geometry and genotype for mechanical harvesting of chickpea with higher productivity. In the experiment, five chickpea genotypes (HC 5, IPC 10-62, IPC 10-142, IPC 08-11 and IPC 11-85) were evaluated under two crop geometry (30×10 cm and 22.5×10 cm) for suitability to combine harvesting and higher yield. The results revealed that growing of chickpea IPC 10-142 attained the highest poding height (46.52 cm) under the crop geometry of 22.5×10 cm followed by IPC 11-85 (38.38 cm) at the same crop geometry of 22.5×10 cm (Fig. 61). Moreover, IPC 10-62 and IPC 08-11 are having branch angle less than 60° whereas, IPC 10-142, IPC 11-85 and HC 5 are having branch angle more than 60°. This indicated that the genotypes having branch angle above 60° (IPC 10-142, IPC 11-85 and HC 5) are suitable to mechanical harvesting including combine harvester. Likely, successful demonstration of combine harvesting of chickpea HC 5 at ICAR-IIPR, Kanpur also witnessed suitability of mechanical harvesting with combine harvester. Combine harvesting of chickpea also notices lower shattering losses compared with manual harvesting. Likewise, threshing efficiency was also comparable.

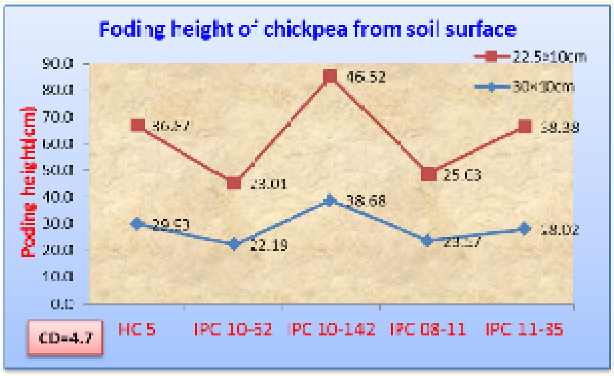


Fig. 61 : Foding height of chickpea from soil surface

Externally Funded Project

Mitigating abiotic stresses and enhancing resource-use efficiency in pulses in rice fallows through innovative resource conservation practices

The findings revealed the followings:

- Unpuddled rice/direct seeded rice, foliar nutrition of micronutrients and 2% urea in combination could be suggested for achieving higher yield in chickpea under rice fallows.
- Life saving irrigation and foliar application of micronutrients could be advocated under rainfed condition for realizing higher grain yield of chickpea.
- Appropriate crop management practices amalgamated with RCTs (retention of 30 cm rice stubbles, zero tillage and appropriate rice establishment method *viz.,* unpuddled transplanting/direct seeding) could play a key role in scaling crop productivity in rice fallow.

The recommendations emerged out of this five years trial are as under:

- Depending on agro-ecological situation, rice + pulse relay cropping or rice fallow pulse system are dominant and adopted.
- For both the systems, suitable varieties of rice (110-120 days) and lentil, lathyrus, chickpea and urdbean having early high vigour for rice fallows are to be taken up.
- Rice stubble retention (20-30 cm) is suitable for conserving soil moisture and higher productivity in rice + pulse relay cropping system.
- Sowing of pulses with conservation tillage (zero tillage coupled with rice residue mulch/stubbles) under rice – pulse sequential cropping is advantageous.
- Paired rows planting (22.5 cm x 45 cm) of chickpea could give additional yield (5-10%).
- Foliar application of 2% urea / DAP (in T.N.) at flowering and 10 days thereafter in pulses could be advocated for alleviating N stress and enhancing seed yield under rice fallow.
- Application of quizalofop-p-ethyl @ 100 g/ha post-emergence is recommended to control rice ratoons at 2-3 leaves stage (suitable variety can replace herbicides).
- Two prototypes of manual operated single row ZT Drill for sowing of pulses under rice fallows of heavy and medium textured soils.

Crop Protection

DISEASES

Wilt of Chickpea

Host plant resistance

Wilt disease caused by *Fusarium oxysporum* f.sp. *ciceri* is the most important biological constraint to chickpea production in the country. Two hundred forty nine germplasm lines from ICAR-NBPGR, New Delhi were screened against wilt caused by *F. oxysporum* f.sp. *ciceri* in the wilt sick field which had a high level of sickness as indicated by 100% plant mortality in the susceptible check, JG 62. Seven germplasm lines *viz.*, IC 269484, IC 209404, IC 248151, IC 209414, IC 269590, IC 270228 and IC 305590 showed resistant reaction.

Four hundred twenty mapping populations from different crosses for resistance against *Fusarium* wilt has been screened.

A total of 306 AICRP lines were screened against *Fusarium* wilt of chickpea under wilt sick field of IIPR, Kanpur.

Ascochyta blight of chickpea

Host plant resistance

Two hundred forty nine accessions of chickpea obtained from ICAR-NBPGR, New Delhi were screened against *Ascochyta rabiei* under laboratory/green house conditions. Only three accessions *viz.,* IC 2792, IC 117744 and IC 305587 showed resistant reaction whereas 15 accession *viz.,* IC 269261, IC 2094, IC 2792, IC 83129, IC 248149, IC 209465, IC 275691, IC 209530, IC412984, IC327482, EC 223067, IC 248149, IC 203080, IC 83129 and IC 24185 showed moderately resistant reaction. Rest of the accessions showed susceptible reaction.

A collection of 150 cultivars/genotypes was also screened. Genotypes, PBG 5, HC 1, GNG 1958, GNG 1581, ILC 482, ILC 3279 showed resistant reaction.

Diversity in *Ascochyta rabiei*

Twenty five isolates of *Ascochyta rabiei* collected from major chickpea growing regions of Ludhiana, Bathinda, Jalandhar and Gurdaspur districts of Punjab, Samba and Jammu, Katra regions of Jammu and Kashmir and GBPUAT, Pantnagar, Udham Singh Nagar district of Uttarakhand. All isolates were found pathogenic on chickpea.

Botrytis grey mold of chickpea

Host plant resistance

One hundred fifty accessions of wild chickpea were screened against *Botrytis* grey mold caused by *Botrytis cinerea* under laboratory/ green house conditions following cut twig technique. Of 150 accessions, only six *viz.,* ILWC 182, ILWC 188, ILWC 185, ICC 17151, ILWC 31and ICC 17207 showed resistant reaction whereas viz., C-105, ILWC 110, ILWC 30, ILWC 38, ILWC 115, ILWC 95, ILWC 211, ILWC 256, ILWC 273, ILWC 274, ILWC 278, ILWC 283, ILWC 50, ILWC 44, ICC 17152, ICC 17155, ILWC 212, ICC 182 and C 106 showed moderately resistant reaction. Remaining accessions showed susceptible reaction.

Diversity in *Botrytis cinerea*

Twenty eight isolates of *Botrytis cinerea* collected from Ludhiana, Jalandhar and Gurdaspur districts of Punjab, Udham Singh Nagar and Nainital districts of Uttarakhand and Bareilly district of Uttar Pradesh. All isolates were found pathogenic on chickpea. Microscopic observations revealed high variability among the isolates with respect to mycelia character, conidial size, sclerotial size, arrangement of sclerotia, presence and absence of sclerotia on culture media.

Evaluation of fungicide against Ascochyta blight and Botrytis gray mold

Efficacy of five fungicides, captan, chlorothalonil, bitertenal, copper oxychloride and carbendazim at different concentrations (100, 200 and 500 ppm) was evaluated against *Ascochyta rabiei* and *Botrytis cinerea* using poisoned food technique. Observations recorded on the inhibition of fungal growth indicated that carbendazim, bitertenal, captan and chlorothalonil are effective against *A. rabiei* whereas carbendazim and captan at 500 ppm concentration are most promising against *B. cinerea*.

Isolation of phylloplane microbes and their evaluation against *Botrytis cinerea* and *Ascochyta rabiei* under *in vitro*

In order to exploit phylloplane microflora against two foliar pathogens infecting chickpea *viz., Botrytis cinerea* and *Ascochyta rabiei*, 25 bacterial and 12 fungal isolates were recovered from chickpea phylloplane. Evaluation of these microbes against *Botrytis cinerea* and *Ascochyta rabiei* is in progress.

Identification of multi-trait *Trichoderma* sp. for the management of dry root rot of chickpea

A total of 106 isolates of *Trichoderma* spp. recovered from the rhizospheric soils of pulses and oilseed crops growing in Kanpur Dehat, Kanpur Nagar, Banda and Chitrakoot were characterized for their antagonistic activity against dry root rot pathogen, *Rhizoctonia bataticola* under *in vitro* condition by dual culture technique. Isolates were also evaluated for their chitonolytic activity, tolerance to high salt levels and high temperature.

Results of dual culture recorded after 7 days of inoculation revealed maximum growth inhibition by five *Trichoderma* isolates *viz.*, PPNM-6, IIPR-75, IIPR-68, IIPR-80 and PPIIPR-2 (Fig. 62).

Salt tolerance: Effect of NaCl on growth of *Trichoderma* spp. was studied by exposing isolates at 5% and 10% salt conc. amended in PDA. Out of 88, all isolates were grown at 5% whereas 56 grown at 10%, IIPRCK-2, UCK-2, KB-PP, CH-CK-1, IIPR-74, IIPR-59, PPF2-1and IIPR-81 showed maximum radial growth after 5 days of incubation period.

Heat tolerance: To investigate heat tolerance of *Trichoderma* isolates, 5 mm diameter plugs placed from 4-day-old cultures on PDA and each plug was placed in the centre of a plate containing PDA and incubated for 5 days at 35°C and 40°C. Out of 88 *Trichoderma* isolates screened for heat tolerance, eight isolates *viz*, IIPR-74, IIPR-59, IIPR-76, IIPR-79, IIPR-88, IIPR-78, IIPR-81 and IIPR-83 showed maximum radial growth at 35°C after 5 days of incubation period whereas only 2 isolates IIPR-74 and IIPR-59 could grow at 40°C temperature (Fig. 63).

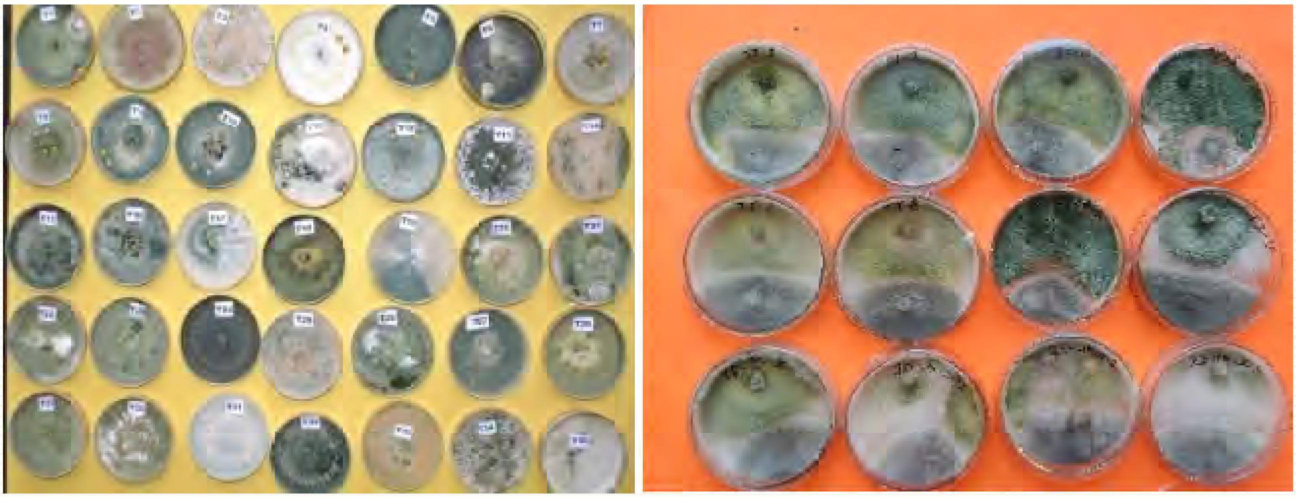


Fig. 62 : Population diversity of *Trichoderma* and their dual culture against *R. bataticola*

Fig. 63 : Characterization of *Trichoderma* isolates to abiotic (Salt and temperature tolerance) stress

Fig. 64 : Chitinolytic Activity

Out of 106 *Trichoderma* isolates, 57 isolates were tested for chitinase activity after 7 days of incubation in the colloidal chitin supplemented agar medium Fig. 64). Fifteen isolates, *i.e* IIPR-2, IIPR-6, IIPR-8, UCK-2, PPF1-1, PPF1-4, SMF, TLKP-1, PPIIPR-2, MLKP-1, TLKP-2, PPKP-1, MLF-2, PPNM-3 and TLF-2 gave rapid and the highest response in colloidal chitin and represented high chitinase activity.

Multi-trait *Trichoderma* spp. showing higher *in vitro* inhibition, heat tolerance, salt tolerance and chitinolytic activity will be exploited for biocontrol potential against root rot diseases of chickpea caused by *Rhizoctonia bataticola*. This study aims to identify salt tolerant and heat tolerant *Trichoderma* spp. and elucidation of mechanism of multi-trait *Trichoderma* spp. which could be utilized for management of diseases caused by fungi and bacteria causing severe losses to pulse crops.

Wilt of pigeonpea

Host plant resistance

A total of 1250 pigeonpea lines were screened in the wilt sick field at IIPR Research Farm during *Kharif*, 2016-17 for identification of new sources of resistance against *Fusarium udum* (Race-2) causing wilt disease of pigeonpea Fig. 65). Pigeonpea variety, Bahar used as susceptible check showed 100% mortality.

Of the five hundred advanced breeding lines, 20 (IPAC-66, IPCA-67, IPAC-68, IPA10W-2-9, IPA10W-14, IPA10W-3-8, IPA10W-12, IPA10W-18, IPA10W1-8, IPA10W 20-2, IPA10W 20-4, IPA10W 2-0-1, IPA10W 4-10, IPAc-68-6, IPA16-6, IPA16-2, IPA17-1, IPA 17-2, IPA 17-4 and IPA 17-5) showed resistant reaction against wilt disease incidence up to 10.0 per cent as against 100% in susceptible check, Bahar.

Out of 60 vegetable type pigeonpea lines evaluated, 18 (IPAV 16-3, IPAV 16-4, IPAV 16-10, IPAV 16-11C, IPAV 16-12, IPAV 16-12-2, IPAV 16-17E, IPAV 16-18A, IPAV 16-19 B-1, IPAV 16-19B-3, IPAV 16-19B-4, IPAV-16-21, IPAV-16-22, IPAV 16-22-1, IPAV 16-22A, IPAV 16-22B, IPAV 16-24 and IPAV 16-22C) were found resistant (0-10% wilt incidence).

Out of 31 genotypes received from ICRISAT, seven (ICPWS-1618, ICPWS-1619, ICPWS-1620, ICPWS-1627, ICPWS-1615, ICPWS-17 and ICPWS-1611) were recorded as resistant with 0-10% wilt incidence.

Fig. 65 : View of the wilt sick plot maintained at IIPR with wilt susceptible and resistant genotypes

Among 84 genotypes received from AICRP-Pigenpea, eight (D-3, D-4, D-6, D-9, PHY-5, PHY-8, IVTM-3 and IVTM-4) were found resistant with wilt incidence 0-10%.

Twelve (DPPA85- 3, DPPA85-5, DPPA 85-7, DPPA 85-8, DPPA85-11, DPPA 85-12, DPPA85-13, DPPA 85-14, DPPA 85-16 and IPA-38, IPA 16F, and IPA15F) of 30 IIPR promising pigeonpea lines exhibited resistant reaction.

Reaction of 29 genotypes of pigeonpea *viz.* KPL 44, ICP 8862, KPL 49, IPA 38A, IPA 38B, GPS 33, BSMR 736, BSMR 853, KPBR 80-2-1, PI 397430, KPL 43, IPA 40, Sujatha, ICP 8858, IC 8859, Banda Palera, BWR 377, ICP 89046, ICP 93812, ICP 89048, ICP 89049, ICP 14722, ICP 9174, ICP 93011, AWR 74/15, JAW 5-6A, BDN 1, BDN 2 and ICP 8863 used as donors for wilt resistance in breeding programme was monitored in the wilt sick plot. Observations on their reaction against wilt disease indicated stability of resistance.

A total of 79 wild accessions of different species of *Cajanus* (*C. scarabaeoides, C. platycarpus, C. cajanifolius, C. lineatus, C. sericeus, C. volublis, C. albicans* and *C. viscibo*) and five species belonging to *Rhynchosia* (*R. aurea, R. bracteata, R. rothii, R. rufescens* and *R. minima*) were screened for resistance against wilt pathogen, *Fusarium udum* (Fig. 66). Of the seventy nine accessions, 20 were found resistant, while the remaining accessions showed moderately resistant reaction. The wilt resistant accessions will be subject to screening again before recommending their use in pigeonpea breeding programmes.

Races in *Fusarium udum* causing wilt of pigeonpea (*Cajanus cajan* L.) in India

Fifty isolates of *Fusarium udum* selected from a large number of isolates collected from pigeonpea growing areas of the country were subjected to pathogenicity on a set of seven pigeonpea genotypes

Fig. 66 : (a) Wild pigeonpea accessions grown at IIPR, Research Farm (b) resistant and susceptible wild accessions

Fig. 67 : Pathogenic reaction of *F. udum* on differential genotypes and race specific screening facilities at IIPR, Kanpur

as differentials (Bahar, C 11, ICP 8863, ICP 7035, BDN 1, KPL 44 and ICP 9174) for three years (Fig. 67). Based on reaction of differential genotypes, these 50 isolates were categorized in to 5 distinct races. Most of the isolates (18) resembled race 2 followed by race 1 (14) and race 3 (8), respectively. Six isolates resembled race 4, whereas four isolate belonged to race 5. Race 1 and 2 appear to be relatively predominant. This study will help in developing race specific wilt resistant lines/ cultivars of pigeonpea.

Phytophthora stem blight

Host plant resistance

Two hundred fifty five early and medium duration pigeonpea lines were screened against Phytophthora stem blight (PSB) in a sick field (Fig. 68(a)). UPAS 120 and ICP 7119 was sown as check after every two rows of test entry. PSB incidence ranged between 5.4 to 100% in different genotypes. Based on the mean disease incidence of the three replications, 11 pigeonpea lines *viz.*, IPAC 79, IPAPB 7-2-1-7, IPAPB 7-2-1, KPBR 80-2-1, IPAC 3, IPAC 2, IPA 15-01, IPAC 68-4, IPA 15-07, IPA 16E-7 and AL 201-A) were identified as resistant showing disease incidence between 5.4-10 per cent Fig. 68(b)).

Yellow mosaic disease of mungbean and urdbean

Host plant resistance

One hundred ten genotypes of mungbean and 85 of urdbean were screened during *Kharif* 2017 against yellow mosaic disease. Based on results of three consecutive years, seven mungbean genotypes (IPM 302-2, IPM 410-3, IPM 205-7, IPM 312-19K, IPM 02-03, IPM 312-90K and IPM 312-17) and fourteen urdbean genotypes (IPU 13-6, IPU 12-19, IPU 13-3, IPU 11-2, IPU 13-11, IPU 13-5, IPU 11-6, IPU 09-13, IPU 2-33, IPU 13-9, IPU 9-26, IPU 01-117, IPU 99-1 and IPU 96-6) are categorized as resistant against MYMIV. The identity of virus causing yellow mosaic disease in the mungbean and urdbean genotypes grown at Kanpur was confirmed as MYMIV by using the specific primer.

Lentil

Development of wilt sick plot

Wilt sick plot is required for screening genotypes against wilt disease caused by *F. oxysporum* f.sp. *lentis* (Fig. 69). Three wilt susceptible genotypes of lentil, namely K 75, Sehore 74-3 and L 9-12 were grown in the field being developed as wilt sick plot on November 2, 2017. Culture of *F. oxysporum* f.sp. *lentis* multiplied on broken lentil seeds and straw was added to the field before sowing. Observations on wilt development were recorded. In all the three genotypes, wilt incidence recorded was >70%. The plot may now be used for phenotyping lentil genotypes against wilt disease.

Fig. 69 : A view of lentil wilt sick plot

Fig. 68 : (a) View of *Phytophthora* stem blight sick field (b) Identified potential donors

Management of lentil wilt through *Trichoderma* sp and bacteria

Twenty isolates of *Trichoderma* spp. and 10 isolates of PGPRs (*Pseudomonas* and *Bacillus*) were isolated from lentil rhizosphere from Kanpur Dehat, Hamirpur, Banda and Chitrakoot districts (Fig. 70) and evaluated against *Fusarium oxysporum* f.sp *lentis* using dual culture technique under *in vitro* condition for their antagonistic potential (Fig. 71).

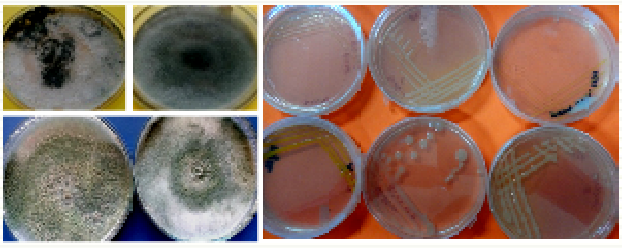


Fig. 70 : *Trichoderma* and PGPRs isolated from lentil rhizosphere

Fig. 71 : Antagonistic activity of *Trichoderma* spp. isolates and bacteria against *F. oxysporum lentis*

Out of 20 isolates of *Trichoderma* spp. evaluated, isolates IIPRT 15 appeared most effective and indicated by maximum inhibition of mycelia growth (79.45%) growth of *F. oxysporum lentis* and was followed by T 31 (69.78%). Among 10 PGPRs evaluated, isolates PGPRs 14 had highest antagonistic potential.

Rajmash

Bean common mosaic virus (BCMV)

Three hundred rajmash germplasms were screened against Bean Common Mosaic Virus under field conditions as well as by artificial sap inoculation. Genotypes, EC 150250, GPR 203, EC 541703, EC400414, BD 9116291, IC 84607 and EC 31084 showed resistant reaction both under field as well as artificial sap inoculations.

INSECTS

Development of microencapsulated formulation of HearNPV to improve its photostability

Five isolates of *Helicoverpa armigera Nucleopolyhedrovirus* (Hear NPV 1, -2, -4, -5 and -6) were mass cultured on host insect, *Helicoverpa armigera* (Hubner) larvae. Semi-purified POB's (Polyhedral Occlusion Bodies) of all the isolates were extracted and preserved at 4°C for further study (Fig. 72).

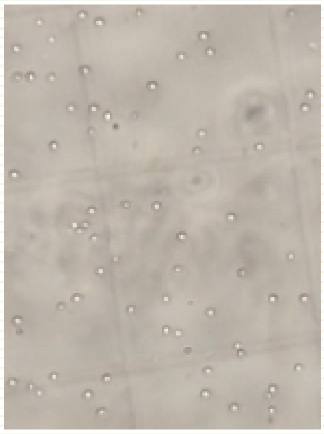


Fig. 72 : Polyhedral Occlusion Bodies (POB's) of HearNPV

Pathogenic potential of HearNPV isolates was evaluated on 6 days old larvae of its host insect, *H. armigera* using semi-purified viral suspension by diet surface contamination technique. The LC50 value of the isolates ranged from 2.70×10^4 POB's/ml to 3.03×10^4 POB's/ml. However, there was no significant difference in virulence among the isolates as reflected by overlapping 95% fiducial limits of LC50 values.

Harnessing the bio-compounds of actinomycetes against *Helicoverpa armigera*

Continuing the search for the actinomyces producing insecticidal compounds, 36 actinomycetes cultures (Fig. 73) were isolated during 2017-18 from different agro-rhizospheric soils, river/pond bank soils and Farmyard Manure (FYM) samples collected from Fatehpur, Sitapur and Auraiya districts of Uttar Pradesh. These isolates have been tentatively given identity numbers as AIN 24, 26, …..59. Currently, 59 cultures (AIN 1-AIN 59) are being maintained in the laboratory (Table 16).

Extra Cellular Metabolites (ECM) of actinomycetes released into broth were evaluated for

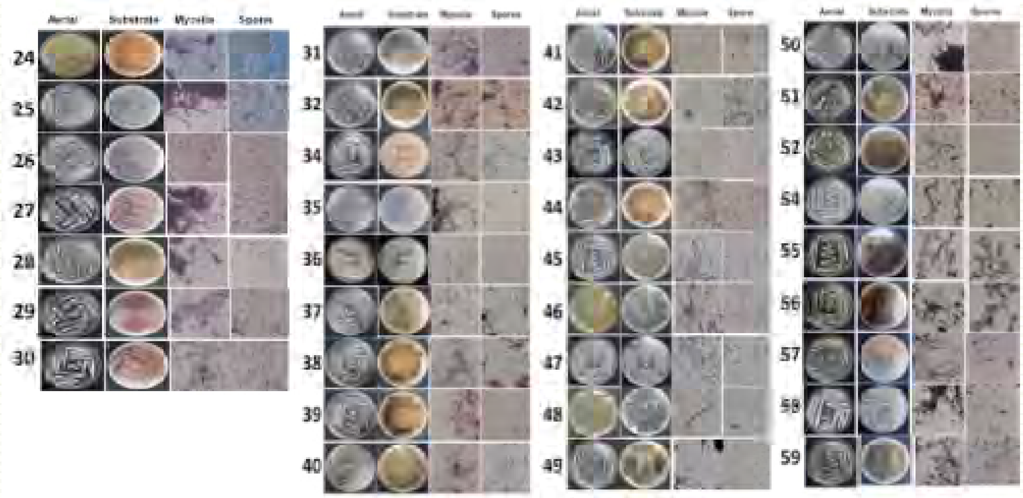


Fig. 73 : Cultural and morphological characters of isolated actinomycetes cultures

Table 16 : Location, enviromental feature and mycelial colour of isolated actinomycetes

AIN no.	Location	Environmental feature	Colour	
			Aerial mycelia	Substarte mycelia
24	Khajuha	Chickpea rhizosphere	Yellowish-Green	Orange
25	Korsam-Alipur	FYM sample	Grey	Creamiest-White
26	Korsam-Alipur	Chickpea rhizosphere	Whitish-Maroon	Maroon
27	Korsam-Alipur	Chickpea rhizosphere	White	Orange
28	Korsam-Alipur	Chickpea rhizosphere	Grey	Brown
29	Korsam-Alipur	Chickpea rhizosphere	White	Orange
30	Korsam-Alipur	Tomato rhizosphere	White	Orange
31	Korsam-Alipur	Onion rhizosphere	Whitish-Green	Brownish-White
32	Korsam-Alipur	Onion rhizosphere	Brownish-White	Brown
33	Korsam-Alipur	Onion rhizosphere	Orange	Orange
34	Khajuha	Sugarcane rhizosphere	White	Orange
35	Tenduli Bindki Kohana	Pond bank soil	Whitish-Maroon	Maroon
36	Birpur	Pigeonpea rhizosphere	Creamiest-White	Creamiest-White
37	Chakbirpur	Oat rhizosphere	Grey	Brownish-Green
38	Chakbirpur	Oat rhizosphere	Grey	Brownish-Green
39	Shambhura	Tomato rhizosphere	Whitish-Grey	Brownish
40	Shambhura	Tomato rhizosphere	Grey	Brownish-Green
41	Chhapa	Cabbage rhizosphere	Grey	Browniush-Green
42	Navinagar	Pigeonpea rhizosphere	Grey	Brown
43	Rihur	Banana rhizosphere	White	Creamiest-White
44	Rihur	Banana rhizosphere	Grey	Brown
45	Bharonpur	Mustard rhizosphere	Greyish-White	Brown
46	Chak-Kuber	Pigeonpea rhizosphere	Brownish-Green	Dark Green
47	Bharonpur	Mustard rhizosphere	Creamiest-White	Whitish-Brown
48	Bharonpur	Mustard rhizosphere	Brownish-Green	Dark Green
49	Chak-Kuber	Sweet Potato rhizosphere	Creamiest-White	Dark Brown
50	Bharonpur	Wheat rhizosphere	Yellowish-White	Yellow
51	Shankarpur	Brinjal rhizosphere	Grey	Dark Green
52	Harshankarpur Diwar	Chickpea rhizosphere	Grey	Dark Green
53	Harshankarpur Diwar	Chickpea rhizosphere	White	Brown
54	Harshankarpur Diwar	Chickpea rhizosphere	Creamiest-White	Creamiest-White
55	Harshankarpur Diwar	Chickpea rhizosphere	Grey	Dark Green
56	Harshankarpur Diwar	Chickpea rhizosphere	Grey	Dark Green
57	Harshankarpur Diwar	Chickpea rhizosphere	White	Brown
58	Harshankarpur Diwar	Chickpea rhizosphere	White	Creamiest-White
59	Harshankarpur Diwar	Chickpea rhizosphere	Grey	Dark Green

their insecticidal property against second stage larvae of *H. armigera*. Bioassay of ECM from 32 actinomycetes cultures revealed larval mortality in the range of 20 - 80% (Fig.74, Table 17). Among different actinomycetes isolates, AIN 10, AIN 12, AIN 16 and AIN 23 showed 80 per cent larval mortality.

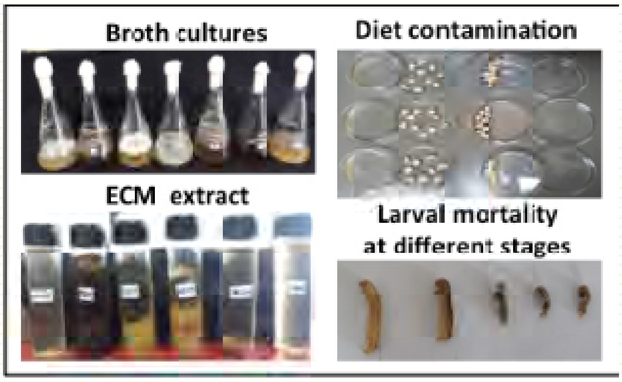


Fig. 74 : Actinomycetes cultures on broth, ECM extract and bioassay

Table 17 : Grouping of Actinomycetes isolates based on per cent larval mortality

Larval Mortality (%)	Actinomycetes Isolate Number (AIN)
70-80	5,10,12,16,21,23,31,32
50-69	4,6,7,9,11,13,14,20,26,27,28,29,34
30-49	3,22,25,37,30,41
10-29	24,35,36,38,40

NEMATODES

Screening for resistance against root-knot nematode, *Meloidogyne javanica*

Forty one genotypes/lines of pigeonpea, 69 of chickpea, 18 of mungbean, 15 of urdbean, 29 of lentil, 19 of fieldpea and 28 accessions of wild relative of *Vigna* were evaluated for resistance against *M. javanica*.

In case of pigeonpea, one genotype (ICP 15-701) was found highly resistant whereas nine genotypes (DPPA85-12, DPPA 85-8, DPPA 85-1, DPPA 85-13, GRG 177, PA 440, PA 414, PA 291, AKTM 1012) were resistant. Two lines of chickpea, GLK 28127 and GNG 2281 were found resistant and five *viz.*, IPC 2011-141, GJG 1320, NBCG 807, NBCG 732 and KWR 108 were moderately resistant. None of the urdbean and mungbean lines was resistant; one line of mungbean (VGG 10-008), however, showed moderately resistant reaction. One line of lentil (LL 1397) and one of field pea (Pant P 250) were found resistant whereas 13 lines of lentil *viz.*, VL 126, LL 1320, NDL 14-12, L 475, 1LL 1370, PL 406, PL 063, DPL 15, PL 024, LL 1373, PL 221, L 4769, IPL 406 and two lines of fieldpea (HFP 9907, IPFD 2014-2) were moderately resistant. Among accessions of wild relatives of *Vigna*, one accession of *Vigna trilobata* (IC 331454) was highly resistant, one each of *V. stipulaceae* (LMR/13-36), *V. trilobata* (TCR-86) and *V. umbellata* (IC 251442) were resistant and one of *V. stipulaceae* (LMR/13-38) and two of *V. trilobata* (JAP/10-5, JAP/10-9) were moderately resistant.

Effect of *Heterodera cajani* infestation on yield and protein content of urdbean

Urdbean variety, Uttara was grown in cemented pots (2′x3′) containing sterilised soil artificially infested with three levels of *H. cajani* inoculum *i.e.* T_1: 60 thousand eggs/juveniles, T_2: 90 thousand eggs/juveniles and T_3: 120 thousand eggs/juveniles. Each treatment was replicated thrice along with un-inoculated check.

Observations on grain yield recorded after 2½ months of sowing revealed that the *H. cajani* reduced grain yield at all the levels of infestation and the extent of reduction increased with the increase in inoculum level. Maximum grain yield was recorded as 67 g/per pot in un-inoculated check followed by 62.7 g, 49.3 g and 15 g per pot infested with inoculum level of 60, 90 and 120 thousand eggs/juveniles, respectively. Similarly, total protein in grains estimated using Lowry's method revealed maximum protein (33.4%) in grains harvested from un-inoculated pots followed by 32.0% and 30.3% in grains harvested from pots inoculated with 60 and 90 thousand eggs/juveniles, respectively. Protein content in the grains from pots infested with highest level of inoculums (1.2 lakh eggs/juveniles per pot) was minimum *i.e.* 26.1% (Fig. 75).

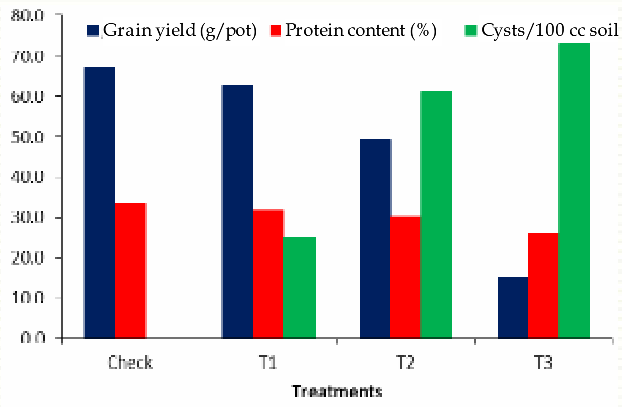


Fig. 75 : Effect of *Heterodera cajani* infestation on the grain yield and total protein of urdbean

Survival of eggs/juveniles of *Heterodera cajani* in brown cysts

Cysts were extracted from moist and dry soil stored in laboratory and net house for 48 months. The filled and empty cysts were counted. Five filled cysts were kept in root extract of urdbean for hatching in small petri plates and replicated thrice. There was no hatching from the cysts even after a month. This indicated that eggs did not survive after four years of storage in dry and moist soil kept in net house and laboratory conditions. Data made it clear that the eggs of *Heterodera cajani* could survive in brown cysts for three years. Crop rotation with non host crops, therefore, needs to be followed for two to three years for reducing cysts population in fields.

Management of *Heterodera cajani* by using *neem* products, *Trichoderma* and nematicides

Effect of eight treatments including inoculated and un-inoculated controls (Table 18) was evaluated against *Heterodera cajani* infecting urdbean. Experiment was conducted in plastic pots of 8 inch diameter containing *Heterodera cajani* infested soil at a level of 6 eggs/juveniles/cc soil. Each treatment was replicated thrice. Three seeds of urdbean variety, Uttara were sown in each pot; however, two plants were maintained after germination. After 45 days of sowing, data was recorded on the shoot length, fresh and dry weight of shoot and root, and number of cysts per 100 cc soil.

All the treatments, improved plant growth parameters and reduced the cyst population significantly as compared to inoculated check. Maximum shoot length (25.3 cm) and fresh shoot weight (22.25 g) were in neem cake treatment. Dry shoot weight was maximum (4.91 g) in neem seed powder treatment whereas maximum fresh and dry root weight 5.77 g and 1.09 g was recorded in seed treatment with carbosulfan. Cysts reduced drastically in all treatments except seed treatment with *T. harzianum*. Minimum cysts 3 cysts/100 cc soil were recorded treatment where *T. harzianum* was applied in soil with FYM (Table 1).

Effect of different cropping sequences on the population dynamics of *Heterodera cajani*

Experiment was conducted in cemented pots of size 2'x3' containing sterilized soil made infested by adding pigeonpea cyst nematode, *H. cajani* and allowing their multiplication by growing urdbean variety, Uttara. The cropping sequences (CS) selected were CS_1: Urdbean – chickpea – maize – sorghum – chickpea – maize – urdbean; CS_2: Urdbean–linseed-pearlmillet-urdbean-linseed-pearlmillet-urdbean; CS_3: Urdbean – wheat – mungbean-urdbean- wheat – mungbean – urdbean and CS_4: Long duration pigeonpea followed by long duration pigeonpea (Fig. 76). Before starting cropping sequences, average cyst population was recorded as 10, 23, 15 and 6 cysts per 100 cc soil in cropping sequence 1, 2, 3 and 4, respectively. The crops grown were chickpea, linseed, wheat and pigeonpea. After the harvest of *Rabi* crops cyst population was estimated which was 13, 12, 15 and 52 cysts/100 cc soil in chickpea, linseed, wheat and pigeonpea, respectively. Per cent change in cyst population in one season was 30% increase in chickpea, no change in wheat, 47.8% decrease in linseed and 766.7% increase in pigeonpea (Table 19). In summer, different crops as per cropping sequences were followed.

Table 19 : Cysts population before sowing and after harvesting of *Rabi* crops and pigeonpea

Cropping sequence	Crop	No. of cysts/100 cc soil		% change
		Before sowing	After harvest	
CS 1	Chickpea	10	13	30.0
CS 2	Linseed	23	12	-47.8
CS 3	Wheat	15	15	0.0
CS 4	Pigeonpea	6	52	766.7

Table 18 : Effect of treatments on plant growth parameters and cyst population

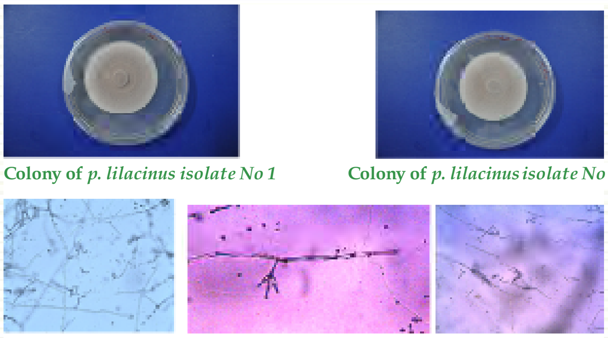
Treatments	Shoot Length (cm)	Shoot wt. (g)	Dry shoot wt. (g)	Root wt. (g)	Dry root wt. (g)	No. of cysts/ 100 cc soil
T1: Carbofuran 3G 1.5 kg ai/ha	21.5[a]	20.14[ab]	4.03[ab]	3.96[a]	0.95[a]	8[a]
T2: Seed treatment with Carbosulfan 25 EC@ 0.1% v/w	21.8[ab]	20.55[ab]	3.70[ab]	5.77[a]	1.09[a]	5[a]
T3: *T. harzianum* @1 kg in 1 qFYM/ha	21.3[a]	18.57[ab]	3.17[bc]	4.18[a]	0.83[a]	3[a]
T4: Neem cake@ 1000 kg/ha	25.3[b]	22.25[a]	3.97[ab]	5.06[a]	0.98[a]	8[a]
T5: NSP @ 100 kg/ha	24.6[ab]	21.71[a]	4.91[a]	4.47[a]	0.90[a]	6[a]
T6: Seed treatment with *H. harzianum* @5 g/kg seed	21.6[a]	16.32[b]	2.97[bc]	4.32[a]	0.90[a]	37[b]
T7: Inoculated check	14.1[c]	10.34[c]	2.02[c]	2.43[b]	0.57[b]	54[c]
T8: Uninoculated check	21.6[ab]	20.14[ab]	4.60[a]	4.68[a]	1.27[a]	-
CD at 5%	3.8	5.29	1.40	2.41	0.49	8

Fig. 76 : Crops grown during *Kharif* (A) and *Rabi* (B)

Potential of fungal bio-agents for the management of parasitic nematodes in pulses

Twenty one isolates of *Trichoderma* spp. were isolated and tested against *Meloidogyne* spp. for their efficacy. Isolate no. T1, T13, T17 and T21 were best in reducing egg hatching compared to control and isolates T1, T5, T9 and T21 were the best in causing higher juvenile mortality compared to control.

Two isolates of *Paecilomyces lilacinus* were isolated and tested against *Meloidogyne* for their biocontrol potential. Both the isolates were found more potential in reducing egg hatching and causing higher juvenile mortality compared to control.



Colony of *p. lilacinus isolate No 1* Colony of *p. lilacinus isolate No 2*

mycelium Phialides and conidiospore

Characterization of entomopathogenic nematodes (EPNs)

In order to exploit entomopathogenic nematodes for the management of gram pod borer, a survey was conducted to isolate EPNs from various agricultural fields at different geographical locations in Uttar Pradesh. A total of 150 soil samples (approximately 500 g) from rhizosphere of different crop were collected from Kanpur Dehat, Kanpur Nagar, Fatehapur, Mallapura, Bhawanipur, Gharkatara, Taranpur, Dudhiyapur, and Sitapur KVK (Fig. 77). Each soil sample was a composite soil sample of 6-8 randomly collected subsamples at a depth of 0- 15 cm from an area of about 25 m^2 with the help of hand shovel. Samples were brought to the laboratory and baited with last instar larvae of *Galleria mellonella* and incubated at 25+2°C in B.O.D. incubator (Fig. 78). Four to five days after incubation, the dead larvae were collected and incubated again for 7-10 days for EPN multiplication inside the dead cadaver. The infected cadaver were then kept on White's trap for emergence of nematodes. Out of 150 soil samples, only 12 samples yielded entomopathogenic nematodes (Table 20). Based on morphological and pathological characters the EPNs from 11 samples were identified as *Steinernema* and one sample yielded *Heterorhabditis.* These are being sub-cultured on larvae of *G. mellonella* to get large number of pure populations of entomopathogenic nematodes for further studies.

Fig. 77 : Survey and collection of soil samples

Table 20: Details of entomopathogenic nematodes isolates collected from different locations

Isolate code	Geographical origin	Habitat/ Crops	GPS coordinates		EPN Species	Soil texture
			Longitude (N)	Latitude (E)		
IIPR1	Main Farm, IIPR, Kanpur	Chickpea	26°48.89'	080°27.383'	*Steinernema siamkayai*	Sandy loam
IIPR2	NRF, IIPR, Kanpur	Fieldpea	26°52.24'	080°24.981	*Steinernema siamkayai*	Sandy clay
IIPR3	Vegetable Farm, CSAUAT, Kanpur	Fieldpea	26°49.802'	080°27.179	*Steinernema siamkayai*	Sandy loam
IIPR4	Mallapura	Cowpea	27°31.329'	080°48.720'	*Steinernema thermaphilum*	Sandy loam
IIPR5	Bhawanipur	Banana	26°29.629'	080°16.398'	*Steinernema thermaphilum*	Clay soil
IIPR6	Gharkatara	Cowpea	27°44.383'	080°33.305'	*Steinernema thermaphilum*	Sandy loam
IIPR7	Taranpur	Banana	26°41.444'	080°10.418	*Steinernema abbasi*	Sandy clay
IIPR8	Dudhiyapur	Mungbean	27°29.965'	080°53.109'	*Steinernema abbasi*	Sandy loam
IIPR9	KVK, Sitapur	Cowpea	27°28.762'	080°53.119	*Steinernema abbasi*	Sandy loam
IIPR10	Korsam - Alipur	FYM	26°05.443'	080°34.437'	*Steinernema abbasi*	-
IIPR11	Roshanai - Fatehpur	Brinjal	26°41'444'	80°10'.418'	*Steinernema sp*	Clay soil
IIPR12	Vegatable Farm, CSAUAT, Kanpur	Tomato	26°49.616'	80°27.590'	*Heterorhabditis sp*	Sandy loam

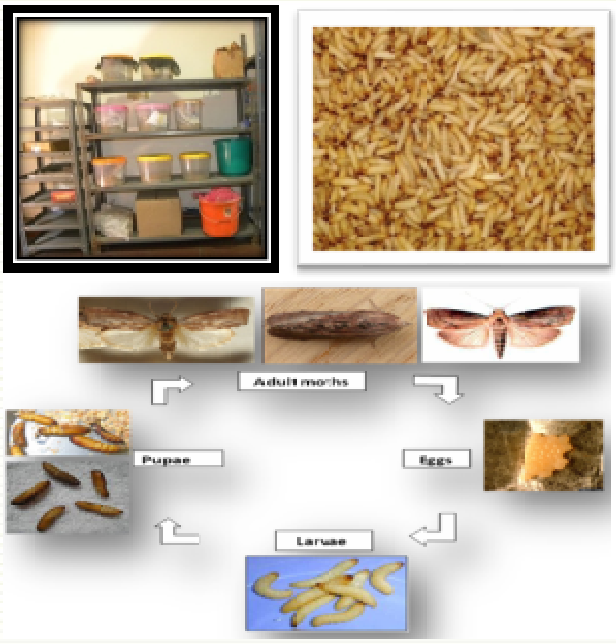


Fig. 78 : Host insect culture (*Galleria mellonila*)

Externally Funded Projects

Identification of potential Plant Growth Promoting Rhizobacteria's (PGPRs) against *Fusarium* wilt and dry root rot for enhancing chickpea productivity

Of the three hundred fifty PGPR isolates recovered from rhizospheric soil of chickpea, pigeonpea, lentil, egg plant, tomato and potato collected from different districts of UP, 270 isolates were screened *in-vitro* for their chitinolytic activity on minimal salt medium and phosphate solubilisation on Pikovskaya's agar medium. Thirty five isolates showed positive chitinolytic activity, out of which five isolates *viz.* IIPRSBLN-7, IIPRSACP-8, IIPRSRCP-21, IIPRSRCP-4 and IIPRBHWT-6 were more effective chitin utilizers. Similarly, 50 isolates showed positive phosphate solubilisation. The phosphate solubilisation by PGPR has normally been observed between 72 to 96 hrs after inoculation. Our results revealed that few isolates are able to produce clear zone of phosphate solubilisation within 48 hrs indicating high potential for phosphate solubilisation and making it available to the plants. Similarly, chitinase activity is visible during 48-72 hrs whereas rhizosphere PGPR isolates showed clear zones of chitin degradation within 24 hrs. Two isolates *viz.* IIPRSBLN-7 and IIPRBTCP-14 were found to have both phosphate solubilisation as well as chitinolytic activity. Majority of chitinase producing PGPR isolates were obtained from chickpea rhizosphere (Table 21)

Development of microbial based formulations and their consortia for management of pigeonpea wilt disease

Identification and characterization of potential *Trichoderma* and PGPRs

One hundred isolates of *Trichoderma* spp. were isolated from rhizosphere of different pulse crops from Kanpur Dehat, Hamairpur, Fatehpur, Banda and Chitrakoot districts. All isolates were primarily characterized on the basis of morphological and cultural characters (Fig. 79). Molecular characterization based on ITS sequences revealed four different species of *Trichoderma i.e. T. harzianum, T. asperellum, T. longibrachiatum* and *T. ressei* (Fig. 80).

Table 21 : Promising PGPR isolates showing chitinolytic and phosphate solubilising activity

Sl. No.	Chitinolytic isolates	P solubilisers	Sl. No.	Chitinolytic isolates	P solubilisers
1	IIPRSHCP-18	IIPRBHWT-22	19	IIPRHMCP-23	IIPRBAFP-11
2	IIPRSACP-10	IIPRBHWT-23	20	IIPRJHCP-14	IIPRSACP-9
3	IIPRSHCP-2	IIPRBHWT-24	21	IIPRBHWT-6	IIPRSACP-11
4	IIPRBTCP-9	IIPRBHWT-25	22	IIPRCKPP-9	IIPRARCP-12
5	IIPRBTCP-11	IIPRCKPP-11	23	IIPRSHTO-1	IIPRSRCP-5
6	IIPRBTCP-14*	IIPRCKPP-12	24	IIPRSHEP-1	IIPRSRCP-6
7	IIPRBTCP-16	IIPRCKPP-13	25	IIPRSHEP-6	IIPRSHCP-19
8	IIPRBTCP-20	IIPRCKPP-14	26	IIPRHSCP-7	IIPRSHCP-20
9	IIPRBTCP-21	IIPRSHEP-8	27	IIPRSBLN-6*	IIPRSBLN-6*
10	IIPRKUCP-6	IIPRSHEP-9	28	IIPRSBLN-7	IIPRSBLN-7
11	IIPRKUCP-12	IIPRSHEP-10	29	IIPRSACP-3	IIPRBTCP-5
12	IIPRKUCP-16	IIPRSHEP-11	30	IIPRSACP-8	IIPRBTCP-6
13	IIPRKUCP-17	IIPRHSCP-12	31	IIPRSRCP-1	IIPRBTCP-7
14	IIPRHMCP-4	IIPRHSCP-13	32	IIPRSRCP-15	IIPRBTCP-15
15	IIPRHMCP-5	IIPRHSCP14	33	IIPRSRCP-18	IIPRBTCP-14*
16	IIPRHMCP-7	IIPRBAFP-8	34	IIPRSRCP-21	IIPRBTCP-19
17	IIPRHMCP-9	IIPRBAFP-9	35	IIPRSRCP-4	IIPRBTCP-23
18	IIPRHMCP-22	IIPRBAFP-10	36		IIPRBTCP-24

* Isolates showing both chitinolytic and phosphate solubilising activity

(a) (b) (c)

Fig. 79 : (a) Colony morphology of PGPR isolates (b) Phosphate solubilisation (c) Chitinolytic activity

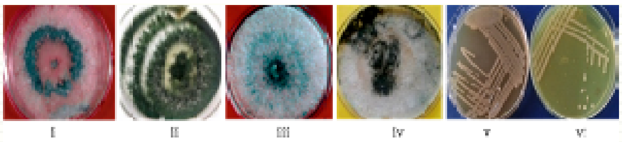


Fig. 80 : Diversity of *Trichoderma* spp., (i) *Trichoderma harzianum*, (ii) *T. asperellum*, (iii) *T. longibrachiatum*, (iv) *T. reesei* and (v & vi) PGPRs collected from rhizosphere of pulse crops

Of the 100 isolates evaluated for their antagonistic activity against *Fusarium udum,* isolates IIPRTh-1, IIPRTh-14, IIPRTh-31 and IIPRTh-7 inhibited maximum mycelia growth of *F. udum* i.e. 78.9%, 75.6%, 75.0% and 70.08%, respectively. *Trichoderma* isolates T31, T30, T32, T16, T38, T28 and T21 were promising in enhancing the plant growth parameters *viz.,* shoot length and root length and reducing the wilt incidence in pigeonpea. 20 isolates (T7, T31, T30, T32, T35, T9, T17, T16, T41, T42, T34, T21, T38, T40, T39, T10, T1, T26, T14 and T15) of *Trichoderma* showed high chitinase activity on chitinase detection media (Fig.81).

Out of 30 PGPRs (*Pseudomonas* and *Bacillus* sp.) isolated from rhizospheric soil of pulses, 9 isolates i.e. PGPRs 2, PGPRs14, PGPRs10, PGPRs15, PGPRs4, PGPRs14, PGPRs8, PGPRs11 and PGPRs 28 were highly antagonistic against *F. udum* (Fig. 82).

Identification of high temperature and salt tolerant isolates of *Trichoderma* spp.

In order to identify isolates with tolerance to high temperature, pH and salt level, 44 isolates belonging to different species of *Trichoderma, viz. T. asperellum, T. harzianum, T. longibrachiatum* and *T. ressei* were

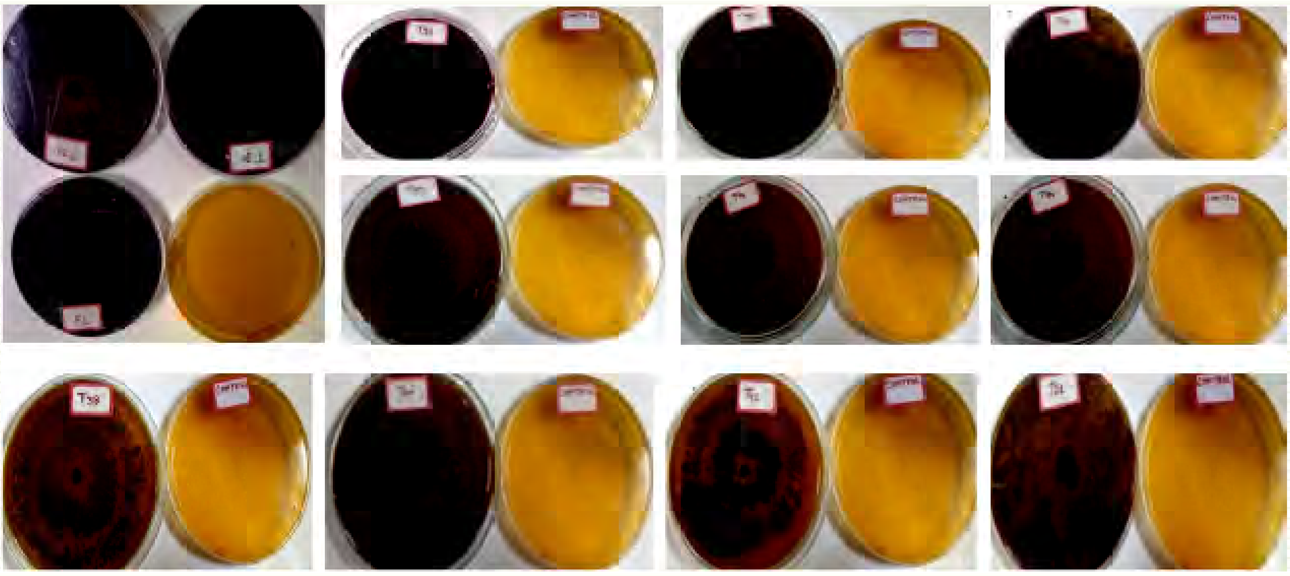


Fig. 81 : Chitinase activity observed after 5 days of inoculation in Chitinase Detection Media supplemented with colloidal chitin

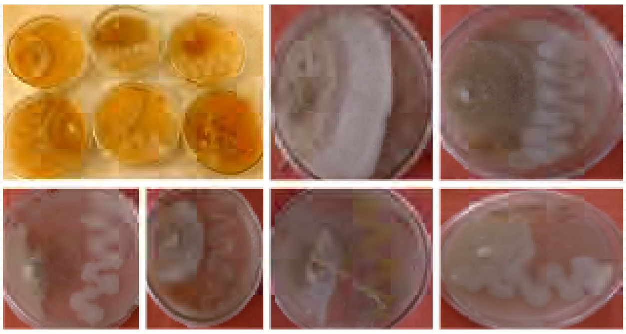


Fig. 82 : Antagonistic activity of PGPR isolates against *F. udum*

subjected to different tempeartures (35^{0}C, 40^{0}C and 45^{0}C), pH (5, 8, 9 & 10) and salt (2%, 4%, 6%, 8% & 10%) regimes under *in vitro* conditions. One isolate of *T. harzianum* (T8) was found tolerant to high tempearature (40^{0}C) and high salt (10%).

Transcriptome dynamics in host-viruses interaction to identify multi-virus resistant genotypes in mungbean

Development of infectious clones of YMD causing viruses

Mungbean/horsegram plants showing typical yellow mosaic symptoms were collected/procured from Kanpur, Bangalore, Vamban, Coimbatore, Delhi and Pantanagr. Total DNA from the collected plant samples of mungbean/horsegram (leaves) was successfully isolated using Plant Rneasy Mini Kit. Twenty nine samples of mungbean were tested in PCR for the detection of YMD causing viruses using specific primers (Fig. 83). Samples collected from Kanpur, Pantnagar and Delhi were found positive with MYMIV and both DNA fragments were detected except one sample from Delhi in which, MYMV was detected. Samples from Vamban showed the infection of MYMV and both DNA molecules were present. Samples of hosregram (n=2) were found positive with HgYMV (Table 22).

Table 22 : List of the samples collected and test for the presence of YMD causing viruses

Crop	Location	No. of samples	No. of samples found positive in PCR					
			MYMIV		MYMV		HgYMV	
			DNA A	DNA B	DNA A	DNA B	DNA A	DNA B
Mungbean	Kanpur	10	7	7	-	-	-	-
	Vamban	4	-	-	4	4	-	-
	Delhi	12	8	8	1	1	-	-
	Pantnagar	3	3	3	-	-	-	-
Horsegram	Coimbatore	4	-	-	-	-	2	2

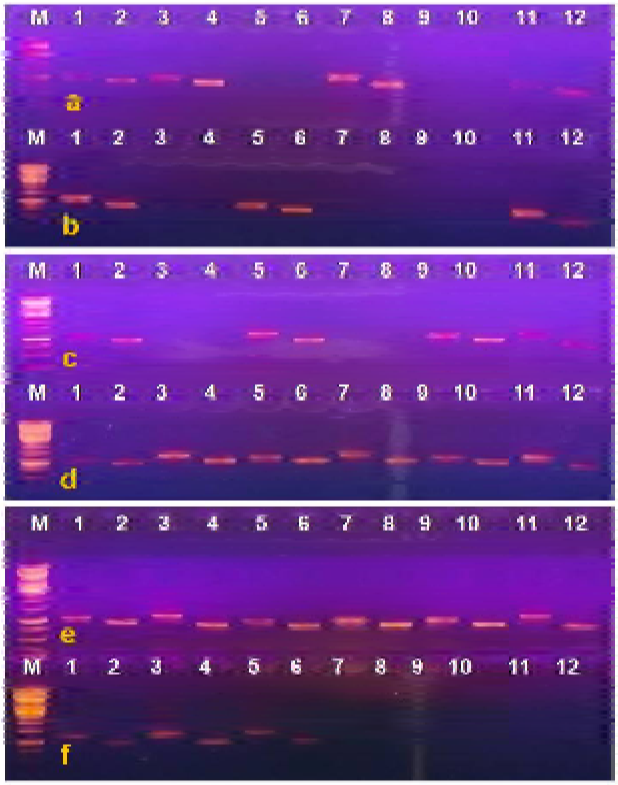


Fig. 83 : Detection of MYMIV/MYMV/HgYMV in mungbean and horsegram sample. M=1 kg DNA ladder (Fermentas). The expected size DNA fragments to be amplified for DNA-A is 1.0 kb and for DNA-B is 0.9 kb. Samples and primers details are in Table 1

Four samples of munbean from Kanpur, two each of mungbean and horsegram from Vamban and Coimbatore were subjected to RCA to obtain the full length DNA fragments of MYMIV/ MYMV/ HgYMV. The analysis of RCA products digested with different restriction enzymes and observed in 1% agarose gel revealed the presence of expected size (2.7kb) DNA fragments (Fig. 84). These fragments were successfully ligated with pJET/1.2 cloning vector and sequenced. The full length DNA-A and DNA-B of MYMIV were assembled. The blastn results of DNA-A revealed that it had maximum 98% identity with DNA-A of many isolates of MYMIV (NCBI Accession No. AY269992, FM208846 etc.). Similarly, the blastn results of DNA-B revealed that it had maximum 99% identity with DNA-B of MYMIV (NCBI Accession No. AY049771, JN543396). The full length DNA-A and DNA-B of the mungbean samples collected from Vamban were assembled. The blastn results of DNA-A revealed that it had maximum 98% identity with the DNA-A of MYMV (NCBI Accession No. KC911721, DQ400848 etc.). Similarly, the blastn results of DNA-B revealed that it had maximum 97% identity with the DNA-B of many isolates of MYMV (NCBI Accession No.AJ439057, AJ132574, DQ865202, KC911724, KC911731, DQ400849, AJ439059 and KC911727). The fragments obtained from horsegram sample were successfully purified from gel and ligated with pJET/1.2 cloning vector. The full length DNA-A and DNA-B were assembled. The blastn results of DNA-A revealed that it had maximum 99% identity with the DNA-A of HgYMV isolates (NCBI Accession Nos. AM932427, KC019306, KP752088, AJ627904) and DNA-B had maximum 98% nucleotide identity with the DNA-B of HgYMV (NCBI Accession Nos. KC019307 and AM932428). Hence, in blastn, full length DNA-A of each virus (MYMIV/MYMV/HgYMV) species (under study) had 97-99% nucleotide identity with DNA-A of respective virus species, much higher than the species demarcation limit of 91% for begomoviruses. It indicated that these viruses are the isolates of MYMIV/MYMV/HgYMV.

DNA-A and DNA-B sequences of each virus isolates (MYMIV/MYMV/HgYMV) were used to prepare a restriction map for the selection of appropriate restriction enzymes for further linearization of these DNA molecules so that they may be ligated with binary vector (pRI-201) also linearized with the same restriction enzymes.

The gel analysis of RCA products from one of the horsegram samples digested with NdeI (restriction enzyme) revealed the presence of 2.7 kb DNA fragments (Fig. 85a). The pRI201 (binary vector) was linearized with NdeI. Both (linearized horsegram DNA and pRI201) the gel purified fragments were

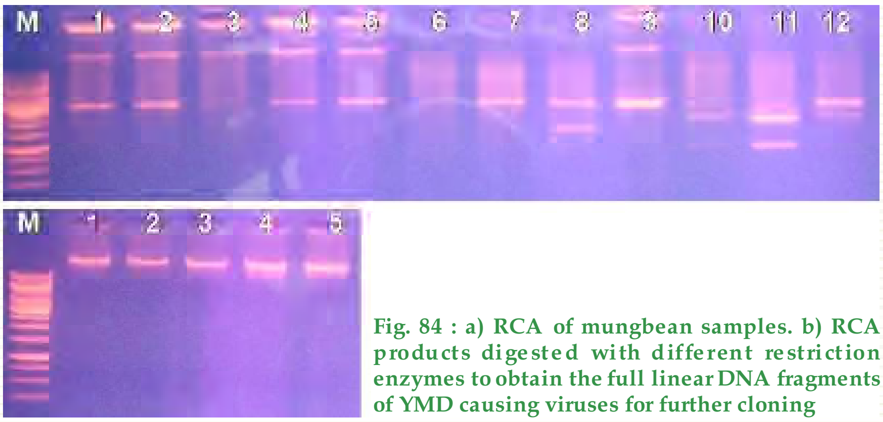
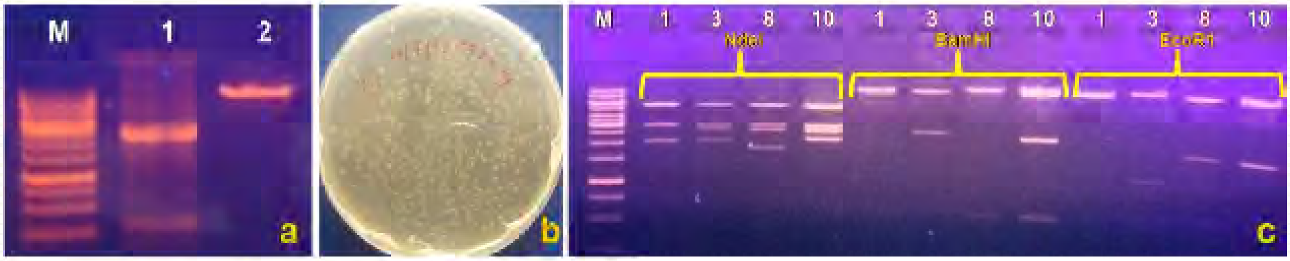


Fig. 84 : a) RCA of mungbean samples. b) RCA products digested with different restriction enzymes to obtain the full linear DNA fragments of YMD causing viruses for further cloning



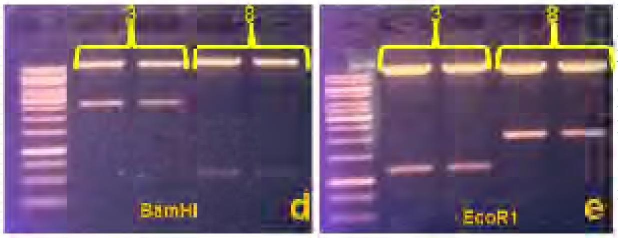


Fig. 85: Development of infectious clone of HgYMV. a) Lane 1=RCA product of HgYMV digested with NdeI, Lane 2=pRI1201 linearized with NdeI; b) transformed clones of pRI201+HgYMV; c) Selectoin of recombinants clones (colony on 1, 3, 8 & 10) digested with NdeI, BamH1 and EcoR1; d) colony no. 3 and 8 digested with BamH1 indicated the direction of the insert; e) colony 3 & 8 digested with EcoR1 again indicated the same direction of the insert and also confirming the type of DNA molecule inserted (this will help in inserting one more full or partial DNA molecule of the same).

successfully ligated and transformed into the *E coli* (DH5á) (Fig. 85b). To select the transformed clones, ten colonies were tested in PCR using primer specific to amplify the DNA-A and DNA-B fragment of HgYMV. All the colonies were found positive with DNA-B only. From them, 4 colonies (colony no. 1, 3, 8, and 10) were grown overnight in nutrient broth and the plasmids were successfully isolated. The plasmids of these colonies were further subjected for restriction digestion to ascertain the insert (Fig. 85c). The gel analysis revealed that the different restriction enzymes released different sizes of DNA fragments from each colony. However, colonies no. 3 and 8 have the similar restriction profile. These colonies were further tested to know the orientation of the insert so that the one more molecule (full or partial) be ligated in the same clone. We found that colony number 3 has the HgYMV-DNA-B in 5′ direction of the insert and colony number 8 has the same insert in 3′ direction (Fig. 85c & 85d). The ligation of targeted DNA inserts with pRI201 is under process.

Nematophagous Bacteria: Identification and profiling of host specificity of *Pasteuria penetrans* infecting *Meloidogyne* spp. in pulses

Surveys werecarried out in places falling in three agro climatic zones *viz.,* Middle Gangetic Plains (Varanasi, Uttar Pradesh), Upper Gangetic Plains (Sitapur, Uttar Pradesh) and Southern Plateau and Hills (Salem, Tamil Nadu) to collect soil and plant samples from the root knot nematode infected area. A total of 77 root knot nematode infected rhizosphere soil and plant samples (30 from Varanasi, 35 from Sitapur and 12 from Salem) were collected. Out of 77 samples observed, three samples from Varanasi and two samples from Salem were having bacterial attachments on juveniles. These infected juveniles were immediately inoculated separately on susceptible plant host for host- parasite life cycle completion which is necessary for bacterial spore multiplication.

Basic Science

Management and analysis of production constraints in pulses as influenced by different abiotic stresses and photothermoperiods

Physiological assessment of effects of various abiotic stresses on chickpea based on crop sensors and imaging and mitigation through foliar nutrition and growth stimulants

An experiment conducted on chickpea using variety JG 14 , showed that photosynthetic electron transport rate (ETR) was maximum at 25^0C (Fig. 86 A) with increasing irradiance levels. However, photosynthetic rates in response to increasing PAR demonstrated a broad temperature range 20 to 40^0C (Fig. 86B). Despite decrease in the stomatal conductance (Fig. 87C), the transpiration rates increased at high temperature 40^0C. The results showed higher transpiratory water loss when subjected to high temperatures (Fig. 87D) and this led to decrease in the water use efficiency of the crop. At low temperature of (10^0C), the gaseous exchange including carbon fixation and transpiration were more affected than photosynthetic light reaction. Light compensation point was much higher at high temperature (40^0C) than the lower temperatures indicating poor utilization of light at lower irradiance levels (Fig. 86B). The light compensation point is defined as the level of PAR irradiance at which carbon fixation stops and CO_2 is released in process of respiration. The results indicated that under moderate light intensity of about 1000 mol favours more photosynthetic carbon gain. As high temperature and high light intensity often are superimposed each other, hence to achieve higher carbon gain, more demand of irrigation is required at high temperature. Thermal images were correlated with canopy temperature and transpiration. The image based techniques thus discriminate chickpea varieties in their ability to sustain lower canopy temperature under drought. Thermal images of three chickpea genotypes have been shown in the Fig. 88. Out of three rows of different chickpea varieties, one row ICC 4958 showed low average canopy temperature and also more green canopy as compared to rest of the two varieties under similar level of soil moisture. The thermal image-based technique, therefore, could be useful to detect physiological efficiency of crop under stress environment. The lower canopy temperature could be associated with deep roots or plant having vigorous root system to extract water from soil and allowing more transpiration, preventing desiccation and keeping canopy temperature cool under stress. Another device green seeker enables recording of NDVI (Normalized deviation vegetation index) which is useful to assess the physiological efficiency of plant both under stressed and non-stressed conditions. Table 23 showed the

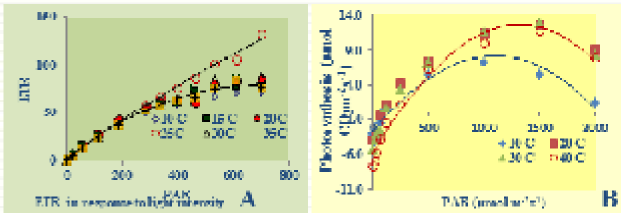


Fig. 86 : Light response of photosynthetic ETR (A) and photosynthesis in chickpea variety JG 14

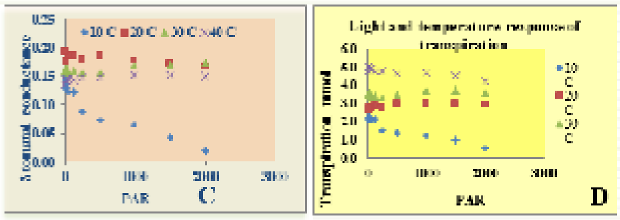


Fig. 87 : Light and temperature response of stomatal conductance and transpiration in chickpea variety JG 14

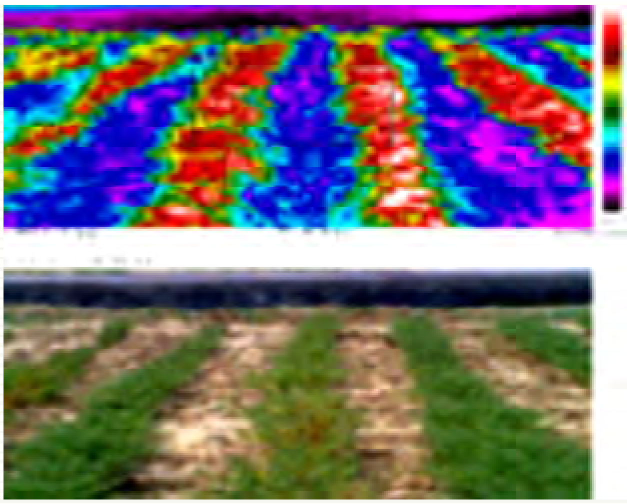


Fig. 88 : Thermal images of three chickpea varieties grown under water deficit condition

NDVI values of chickpea varieties at podding stage under rainfed conditions. The genotypes maintaining higher NDVI values at this stage were more physiologically efficient and high yielding types as compared to remaining varieties having lower NDVI values. Most of the early maturing varieties showed lower NDVI values as they complete their life cycle faster and are subjected to senescence early, hence, NDVI also appeared to be related with leaf senescence and chlorophyll degradation.

Identification and physiological characterisation of high-temperature and drought tolerant genotypes of lentil (*Lens culinaris* Medik.) for improving productivity and resilience

A field experiment was conducted with 250 germplasm lines/variety including check for their screening to heat tolerance. Crop was sown during *Rabi* season (2017-18) in two different sets as normal (10th November 2017) and late sown (9th January 2018) for phenotyping and screening for heat tolerance (Fig. 89). Data on crop phenology, growth parameters, yield and yield attributes were recorded for all the genotypes. Most of the germplasm lines/varieties performed better under normal sown condition compared to late sown crop. Out of 250 germplasm lines screened, >50 germplasm lines could perform better and maintained good crop vigour, flowering, pod formation and grain filling under high temperature (>30 ^{0}C). However, 158 germplasm lines/varieties could flower but failed to set pods under similar climatic conditions. It was observed that pod formation, pod development and grain filling rate are the most important parameters which was severely affected when temperature increased beyond 30^{0}C (Fig. 90). Based on comparative performance of germplasm in terms of pod formation (Nos.), pod development and grain filling (%), 50 nos. of prospective germplasm lines were identified for their further screening for heat tolerance.

Fig. 89 : Phenotyping and germplasm screening for heat tolerance in lentil (DSC 0204)

Fig. 90 : Pod formation and grain filling in lentil genotype IG 2507 under high temperature (>30^{0}C)

Table 23 : Germplasm screening for heat tolerance in lentil

Genotype	High NDVI	Genotype	Low NDVI
ICC 12916	0.72	RSG 11	0.51
ICC 15868	0.71	KPG 59	0.50
ICC 14880	0.70	JG 14	0.50
RSG 896	0.67	Radey	0.49
Pusa 209	0.67	Virat	0.49
JG 12	0.66	GNG 146	0.49
HC 1	0.66	JAKI 9218	0.46
ICCV 37	0.65	RSG 895	0.46
CSJ 515	0.64	ICCV 96030	0.44
RSG 974	0.64	GNG 1292	0.44
JGG 1	0.62	IPC 94-94	0.44
PG 5	0.61	CSJ 140	0.43
ICC 4958	0.61	PDG 3	0.41
L 551	0.61	BG 276	0.36
PDC 84-16	0.60	JG 16	0.33
GCP 101	0.60	RSG 959	0.30

Physiological basis of salt tolerance in urdbean

In order to assess the sensitivity of urdbean genotypes to salinity, graded solution of sodium chloride having 0EC (control without NaCl), 3EC and 5EC were applied at regular intervals to thoroughly washed sand filled in different pots (Fig. 91). Five urdbean genotypes such as SPS 29, NDU 1, Pant U 30, Pant U 40 and PLU 158 were subjected to different levels of salinity.

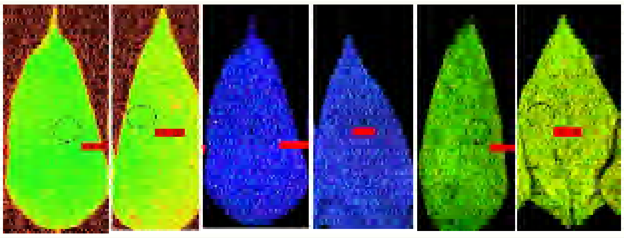


Fig. 91 : Photosynthetc images :Fm: 0EC (L)-5EC(R) ; Fv/ Fm: 0EC (L)-5EC(R) ; NPQ: 0EC (L)-5EC(R)

subjected to 3 EC while rest of the genotypes showed significant reduction in the ETR at the same level of salinity stress (Fig. 91). The results showed positive association of higher flavnols in SPS-29 maintaining higher photosynthetic electron transport rates under salinity stress. Based on the phenotypic expression and enhanced epidermal flavnols leading to maintain optimum photosynthetic activity under salinity stress, the urdbean genotype SPS 29 appeared to be relatively tolerant to salt stress over rest of the genotypes.

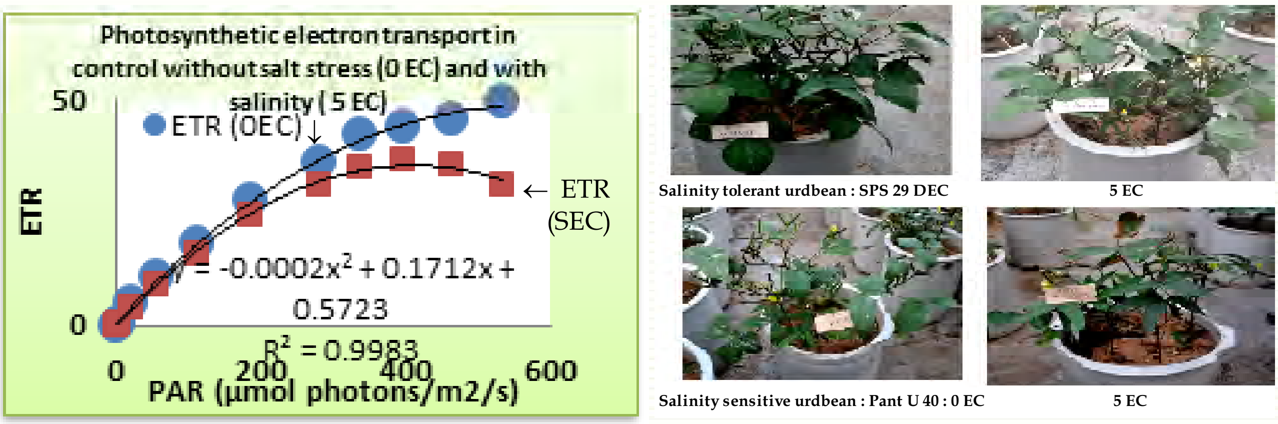


Fig. 92 : Light response of photosynthetic electron transport rate (left) and salinity effects in tolerant (SPS 29) and sensitive (Pant U 40) urdbean lines (right)

Table 24 : Leaf pigments and polyphenols in control 0 EC) and saline stress (5 EC) in different urdbean genotypes

Genotype	NBI (0 EC)	NBI (5 EC)	Chl (0 EC)	Chl (5 EC)	Flav (0 EC)	Flav (5 EC)
SPS 29	39.40	31.03	35.22	31.53	0.96	1.45
NDU 1	29.23	25.37	27.30	29.87	1.06	1.18
Pant U 30	27.57	23.00	25.28	23.87	1.10	0.56
Pant U 40	26.50	22.67	24.58	30.90	1.35	0.67
PLU 158	28.57	26.53	27.55	32.27	1.12	0.78
NBI: Nitrogen balance index ; Chl: Chlorophyll index						
Flav : Flavnols						

Retarded growth, smaller leaves, increased succulence of leaves, and necrosis were the typical visible symptoms developed in salinity affected most of the urdbean genotypes except SPS 29 (Fig. 92). The leaf chlorophyll, nitrogen balance index (NBI) decreased in all the test genotypes at 5EC salinity level, however, the genotype SPS 29 had shown significant accumulation of epidermal flavnols over control without salinity (Table 24). The epidermal flavnols are the polyphenols having protective role under salinity stress against damage caused by free radicals generated during salinity stress, particularly under high irradiance levels. The photosynthetic electron transport rate (ETR) remained unaffected at high photosynthetic active radiation e.g. 700 mol photons $m^{-2}s^{-1}$or significantly increased in SPS 29 when

Seed quality enhancement through osmo-priming in chickpea crop under normal and water deficit conditions

An experiment was conducted under laboratory as well as in plastic pots of 10 kg capacity with 5 seed osmo-priming level, two varieties of chickpea (Ujjawal and JG 14) and two moisture levels (Normal at field capacity and water deficit at half of the field capacity) during *Rabi* season 2017-18 to study the influence of seed osmo-priming with inorganic salts on seed quality, enzyme activity, growth, crop efficiency, grain yield and storability under normal and water deficit conditions. The observations on seed quality parameters included per cent germination, rate of germination, seedling length and dry weight, field emergence, vigour index I &II just after start of germination and up to 7th days as per ISTA procedure. Growth parameters including leaf area, plant height and photosynthetic rate, Stomatal conductance, transpiration rate, chlorophyll, NBI, flavnols and anthocyanin were measured at pod formation stage. On the basis of observations recorded during Ist year, it may be concluded that osmo-priming of one year old chickpea seeds with 0.2% solution of KNO_3, $MgSO_4$, $Ca(NO_3)_2$ and tap water for 06 hours considerably enhanced the germination, speed of germination, seedling length and weight, field emergence and vigour index I & II in both the varieties under normal and water deficit conditions over their respective controls. Amongst, the priming agents used KNO_3 performed better than $MgSO_4$, $Ca(NO_3)_2$ and tap water in respect to enhance seed quality (Fig. 93). However, per cent improvement was higher in water deficit condition than normal moisture conition. Variety Ujjawal responded better than JG 14 under both the conditions (Fig. 94 & 95). Osmo-priming with different inorganic salts and tap water also showed the positive response

Fig. 93 : The effect of KNO_3 priming on seedling growth in chickpea varieties Ujjawal and JG 14

Fig. 94 : The effect of KNO_3 priming on field emergence in Ujjawal under normal and water deficit

Fig. 95: The effect of KNO_3 priming on field emergence in JG 14 under normal and water deficit

in terms of increase in stomatal conductance, photosynthetic rate and transpiration rate in both the varieties under normal and water deficit condition. The osmopriming with KNO_3 and $Ca(NO_3)_2$ were found to be more effective in enhancing the above parameters over rest of the priming treatments. Varieties did not show any definite trend for these characters. Nitrogen balance index (NBI) increased with osmo-priming treatments but the magnitude of increase was more with KNO_3 followed by $MgSO_4$, $Ca(NO_3)_2$ and tap water and variety Ujjawal showed higher NBI over JG 14. Similarly chlorophyll and flavnols showed enhancement with KNO_3, $MgSO_4$, $Ca(NO_3)_2$ and tap water priming but priming with $MgSO_4$ under drought showed the highest chlorophyll and flavnols in both the varieties. Anthocyanin was accumulated in leaves of chickpea plants primed with KNO_3, $MgSO_4$ and

Table 25 : Characteristics features of urdbean genotypes

Character	Range of expression	Entries name
Plant height	Minimum	IPU 99-179, IPU 2-43, NO 7668-43, Uttara, PDU 3, PLU 429
	Maximum	PLU 65, PGRU 95018, NO 5131, IPU 99-31, TU 99/20-293, STY 2868, NKGH 31
Initiation of flowering	Earliest	T 9 (35), BG 367(35), IPU 99-179(36), IPU 2-43 (36) and IPU 99-144 (36)
	Late	CH 35-15a (52), UH 85-15(51), IPU 99-115(50) and HPU 120(50)
Initiation of 1st poding	Earliest	IPU 99-213(39), BG 367(38), IPU 99-179 (40) and IPU 99-144(40)
	Late	IPU 99-115 (57), NO 7668-43(58), IPU 2K-22(56) and IPU 94-2 (55)
50 % flowering	Earliest	JU 78-27(43), IPU 91-7(44), Uttara (45) and PKGU 1 (44)
	Late	IPU 99-233 (62), IPU 90-32 (58), GU 28(57) and PLU 703 (53)
50% poding	Earliest	IPU 2-24(54), IPU 99-144 (54), V 3108 (55) and Shekhar (54)
	Late	IC 43647(65), NPV 94-10 (63) IPU 99-232 (63) and IPU 2K-1 (64)
Yield genotypes	High- 9.12-14.1 (g/3 plant)	PGRU 95014, PLU 662, PGRU 99028, BG 367, IC 165111, IPU 99218, IPU 99-79, UH 80-25, LBG 20, Mash 01, IC 50748, IPU 90233, IPU 99-232, PGRU 95014, NPU 94-10, IPU2K-99-197, IPU 2-43
	Low-3.03-5.4 (g/3 plant)	GG 9120, STY 2868, IC 43647, PLU 703, IPU 99-144, STY 2834, PDU 2E, NO 5/31, PLU 302, YU 99-2, IPU 99-247
Same yield at Kanpur & Dharwad	7-8 (g/3 plant)	IPU 99-179, PKGU 1, PU 30, IC 82-19, Marsh 01
IPU 99-18 and IPU 99-14 – No flowering and poding was observed		

$Ca(NO_3)_2$ salts and it was higher under water deficit conditions than normal.

Strategies for improving yield stability in urdbean through photothermo-insensitivity

A field experiment was conducted using 100 selected urdbean genotypes. These genotypes were planted in augmented design in field under irrigated conditions at Kanpur on July 7, 2017 and Dharwadon November 27, 2017 and February 14, 2018. Phenological observations were recorded such as 1st flowering, 50% flowering, 1st podding, 50% podding, and maturity. The genotypes IPU 99-123 (39 Days) and BG 367 (38 Days) showed early flower and pod initiation during *Rabi* season. The genotypes, IPU 99-1709, IPU 2-43, Uttara, IPU 99-144, BG 367 and PLU 703 were early typein both Kanpur and Dharwad. While no flowering was observed in the genotypes, IPU 99-18 and IPU 99-141 (Table 25).

Biochemical basis of heat tolerance in chickpea

A study was initiated to know the biochemical difference between heat tolerant (ICC 92944) and heat susceptible (ICC 10685) genotypes of chickpea at vegetative stage under normal as well as heat treatment condition. Among the antioxidant enzymes, superoxide dismutase (SOD) and peroxidase activity were estimated. The SOD activity was found more in tolerant genotype (ICC 92944) as compared to susceptible genotype (ICC 10685). After exposure to heat stress, the SOD activity decreased in both the genotypes when compared to their respective control (Fig. 96). Peroxidase activity was observed more in tolerant genotype (ICC 92944) as compared to susceptible genotype (ICC 10685). After exposure to heat stress, peroxidase activity increased in both the genotypes when compared to their respective control (Fig. 5.11). The MSI was found more in tolerant genotype (ICC 92944) as compared to susceptible genotype (ICC 10685), however, under heat stress, the MSI decreased in both the genotypes when compared to their respective control (Fig. 95). The total chlorophyll, chlorophyll 'a', chlorophyll 'b' and ratio of chlorophyll 'a' and 'b' were found to be higher in heat tolerant genotype (ICC 92944) compared to the heat susceptible one (ICC 10685). However, after subjecting the plants to heat stress, the total chlorophyll, chlorophyll 'a', chlorophyll 'b' and ratio of chlorophyll 'a' and 'b' decreased when compared to their respective control. In heat tolerant genotype, the decrease in the ratio of chlorophyll 'a' and 'b' under heat stress was less as compared to susceptible genotype.

Effect of heat stress on protein profile in the leaves of chickpea genotypes at vegetative stage was observed. No difference was found in band pattern of ICC 92944 (heat tolerant genotype) and ICC 10685 (heat susceptible genotype) with respect to protein profile. Two types of new peptides (about 100 kDa and 65 kDa) were induced in both heat tolerant and heat susceptible genotypes after subjecting the plants to heat stress at vegetative stage when compared to the control (Fig. 97).

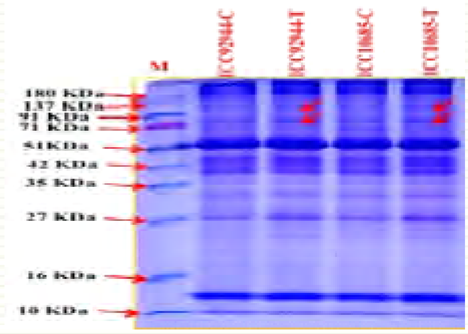


Fig. 97 : Effect of heat treatment on protein profile using SDS-PAGE analysis

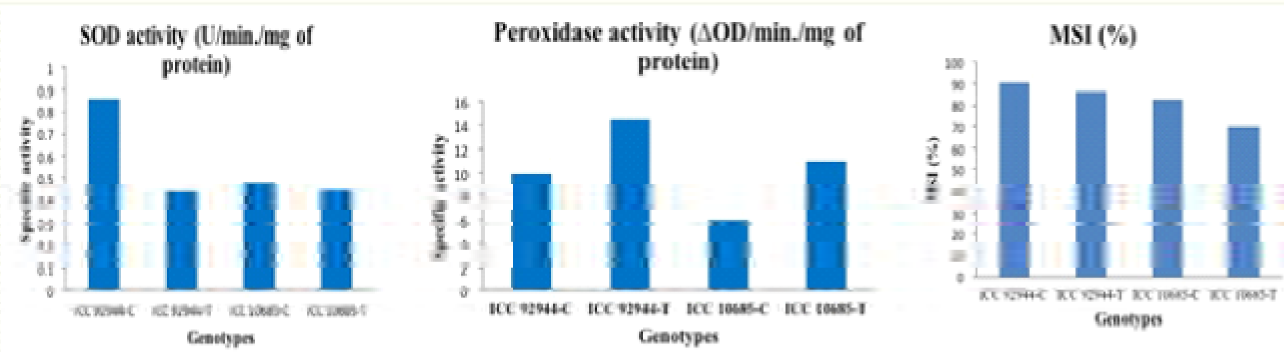


Fig. 96 : Effect of heat treatment on SOD (Left), peroxidase activity (middle) and Membrane stability index (MSI) (right)

Nutritional and phyto-chemical profile of cowpea and field pea with emphasis on their bioavailability and health promoting properties

The antioxidant activity of fifteen diverse varieties/genotypes of fieldpea (*Pisum sativum*) and twelve varieties of cowpea (*Vigna unguiculata*) varying in the colour of their seed coat was estimated using the ferric reducing antioxidant power (FRAP) assay. The antioxidant activity in the fifteen varieties/genotypes of pea ranged from 0.81 m moles $FeSO_4.7H_2O$ equivalent/100 g seed in the green seeded variety IPF 12-20 to 7.84 m moles $FeSO_4.7H_2O$ equivalent/100 g seed in the reddish-brown seeded variety EC 328758 (Fig. 98). It was observed that among all the varieties, the green seeded varieties (IPFD 10-12, IPF 16-13 and IPF12-20) have the least antioxidant activity, the yellow seeded varieties (IPF 5-19, IPF 1-10, Azad P-3 and P 489) had comparatively better antioxidant activity followed by the black variety (P 1586) and the varieties with reddish brown seed coat (EC 328758 and IPFD 2014-2) have the highest antioxidant activity.

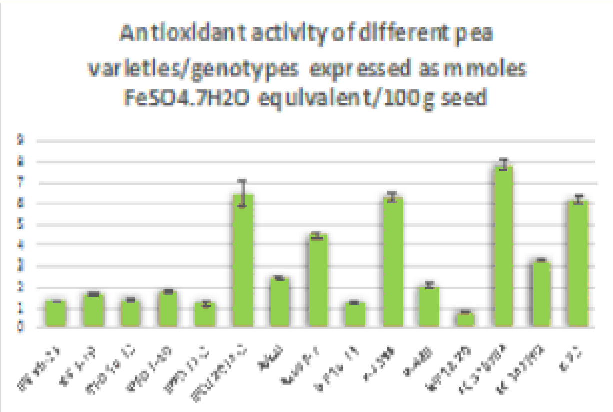


Fig. 98 : The total antioxidant activity in terms of reducing power (FRAP) of different pea varieties

It was observed that cowpea has much higher antioxidant activity as compared to pea and the values for antioxidant activity ranged from 1.99 mmoles $FeSO_4.7H_2O$ equivalent/100g seed in the yellowish white seeded variety RC 101 to 13.86 mmoles $FeSO_4.7H_2O$ equivalent/100 g seed in the reddish-brown variety GC 901 (Fig. 99). Among all the twelve varieties that were tested, the yellowish white seeded cowpea varieties (RC 101 and TCS 160) have the least antioxidant activity followed by the brown and mosaic patterned varieties while the reddish-brown varieties (GC 901 and PL 3) have the maximum antioxidant activity.

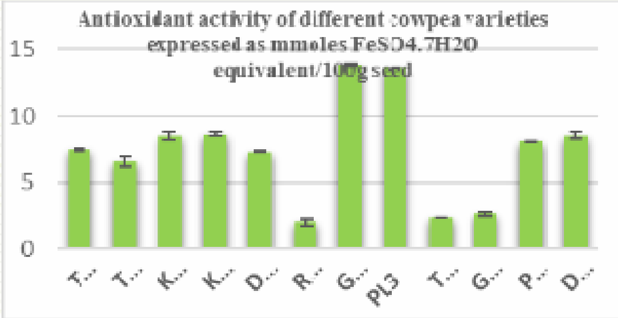


Fig. 99 : The total antioxidant activity in terms of reducing power (FRAP) of different cowpea varieties

Harnessing symbiotic efficiency of germplasm of major pulses for improving biological nitrogen fixation

Symbiotic nitrogen fixation is a signature feature of legumes. Host specificity of legume-rhizobia symbiosis is determined by the signal exchange between the partners. Due to poor genetic divergence, Indian varieties of specific pulse crop can trap only few similar kinds of rhizobia even at different agro-eco zones. If we introduce variations at signaling process by using distantly related host genotypes, it is possible to reveal higher diversity of host specific rhizobia that may also differ functionally. Variation for a trait in plant genetic resources provides the basis and the raw material that plays a fundamental role in crop improvement programme. Still now, limited germplasm sets of pulses have been screened for SNF and resulted in identification of a number of germplasm accessions that fix more atmospheric N_2 compared to others under similar conditions. By considering above issues, germplasm of major pulses are screened for BNF traits and for revealing diversity of associated rhizobia. Only 17% of tested mungbean germplasm lines recorded nodule fresh weight more than 200 mg/plant at 45 DAS in P-deficient condition. Nearly 63% of tested mungbean genotypes recorded poor nodulation (<100 mg/plant). Mungbean genotypes via MG 34, MG 4 and MG 50 recorded high nodule fresh weight (>200 mg) and no reduction in nodule biomass due to low available soil-P (Fig. 100).

Hundred different genotypes of urdbean were screened for nodulation and biological nitrogen fixation (BNF) under two different P-status of soil, Normal (20 kg P/ha) and low (0 kg P/ha). Observations on BNF traits like nodulation number, plant fresh weight and dry weight were taken on two weeks after sowing to identify early nodulating genotypes. Isolation and purification of rhizobia from 100 different

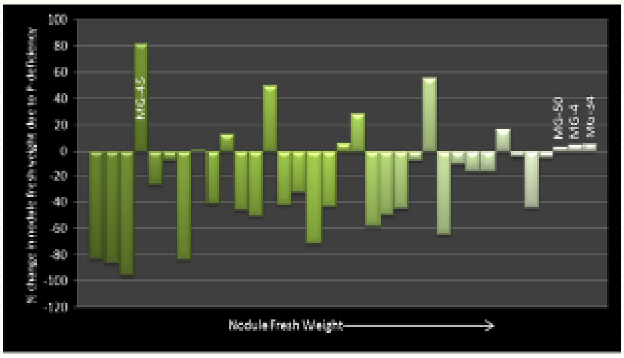


Fig. 100: Effect of soil P-deficiency on nodule fresh weight of mungbean germplasm

genotypes of urdbean was done. Nodule number varied from 6 to 23. Urdbean genotype U 11, U 17, U 23, U 26, U 95 are some of the high nodulators.

Normal P	Low P
Excellent Nodulator (>20 nodules): U 11, U 17, U 23, U 26, U 70, U 84, U 94, U 95	U 9, U 10, U 53, U 68, U 83
Good Nodulator (>15 nodules): U 5, U 68, U 91, U 93, U 96	U 5, U 51, U 61, U 65, U 70, U 75, U 85, U 91, U 93, U 96
Poor Nodulator (<8 nodules): U 2, U 19, U 42, U 48, U 79, U 88	U 2, U 13, U 19, U 25, U 46, U 71, U 79

Interactive effect of lentil genotypes-rhizobium on biological nitrogen fixation

One hundred twenty lentil genotypes consisting of 108 germplasm lines and 12 varietal checks were screened for high nodulation and biological nitrogen fixation. Lentil genotypes were grouped into three categories based on the days to 50% flowering, early (<65 days to 50% flowering); medium (65-75 day to 50% flowering) and late (>75 days to 50% flowering). Early genotypes showed the highest nodulation and biomass accumulation at flowering and podding stage, respectively. The medium and late flowering germplasm showed the highest nodulation at 45 days after sowing and the highest biomass accumulation at flowering stage (Table 26, Fig. 101). Positive correlation was recorded among nodule number, shoot dry weight and nodule specific weight at vegetative stage and between shoot dry weight and nodule specific weight at 50% flowering stage. Lentil genotype IC 428606, IC 428614, IC 429178, IC 428559 and IC 428607 were identified as potential genotypes for high biological nitrogen fixation whereas IPL 316 was identified as high nodulator. The lentil nodulating rhizobia were isolated and their purity was confirmed through plant infection test, out of total isolates, 92 were found positive for *Rhizobium*. PCR amplified 16S rDNA region was digested with restriction enzymes *Bsu*RI, *Hpa*II and *Rsa*I, which produced polymorphic banding pattern on the gel (Fig. 102). Based on 16S rDNA-RFLP

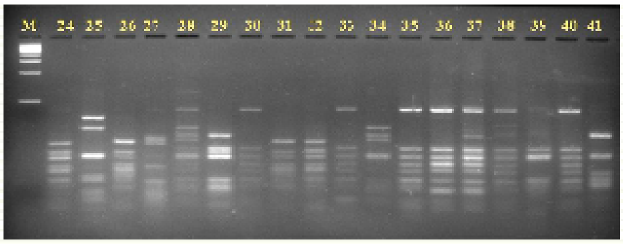


Fig.102: RFLP profile of 16S rDNA PCR products digested with the combination of restriction enzymes *Hpa* III, *Bsu*RI and *Rsa*I

Table 26 : Range of nodule numbers per plant, shoot dry weight and nodule specific weight in three groups of lentil germplasm

Growth stage	<65 days			65-75 days			>75 days		
	NN	SDW	NSW	NN	SDW	NSW	NN	SDW	NSW
Vegetative	1-4	0.13-1.4	0.42-4.88	1-6	0.20-1.7	0.44-5.8	1-13	0.15-1.1	0.44-5.14
50% flowering	1-7	0.4-2.7	0.35-4.79	1-4	0.6-6.4	0.5-12.7	1-5	0.9-7.3	0.6-8.5
Pod formation	1-2	1.1-7.1	1.19-4.9	1-2	0.75-11.5	0.63-9.8	1-4	0.6-10.1	0.83-5.9

NN- Nodule numbers, SDW- Shoot dry weight (g/ five plants), NSW- Nodule specific weight (mg/ nodule)

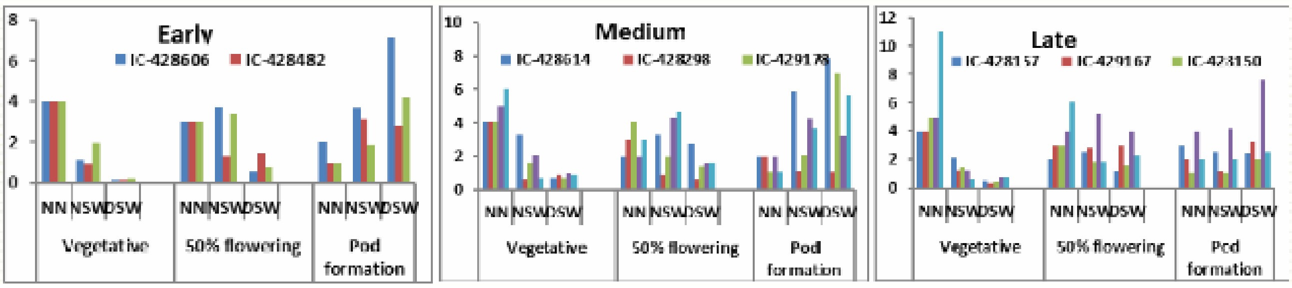


Fig. 101 : Distribution of BNF associated traits in early, medium and late lentil germplasm

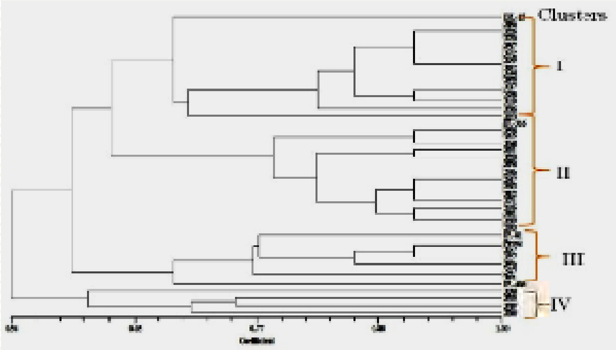


Fig.103: Phylogenetic relationship based on 16S rRNA-RFLP of lentil nodulating rhizobial isolates

pattern (Fig. 103), the rhizobial isolates were divided in to four major clusters. Cluster IV was very specific and consisted of isolates from lentil genotypes which require 65-75 days to 50% flowering. Cluster II was the biggest cluster formed from 8 restriction groups and they contained isolates from the genotypes requiring 65-75 and more than 75 days to 50% flowering.

Development of nano-material based microencapsulated formulation of imazethapyr for weed control in pulse crops and minimizes residue dynamics to the environment

Nano material based formulations: To develop nano-material based formulations of imazethapyr certain clay materials and wood powder were successfully converted to more than 60% of particles to their nano-range size by following frequent grinding and sedimentation techniques. Approximately 500 g of nano-range materials of three clay based materials *viz.,* $Mg_3Si_4O_{10}(OH)_2$: $(OH_2)_4$ $(OH)_2(Mg_5Si_8O_{20}.4H_2O)$: $[(Mg, Al, Fe)_3(OH)_2/(Si_3Al)O_{10}$ Mg_2^+ $(H_2O)_4]$: and wood powder were recovered by processing nearly 1.5 kg of fine powder of each materials. The analysis of nano range materials for their Particle size distribution, Surface topology, sizes and shapes etc is in progress at CIRCOT, Mumbai. After proper analysis micro encapsulated and other kind of formulations of imazethapyr will be developed and evaluated for their bioactivity against major weeds of pulse crops and release kinetics with the help of IARI and NPL New Delhi.

Persistence and degradation of post-emergence herbicides in soil, plant and seeds of summer and *Kharif* pulse crops

Herbicide residue study: Persistence and degradation studies of two post-emergence *viz.,* Imazethapyr and Pendimethalin herbicides were taken during kharif in mungbean field. Soil samples were collected at different interval of times and processed for extraction and cleanup and subsequently analyzed at DWSR, Jabalpur via LCMS. The observed residual values were found in range of 0.0047 to 0.00011 mg/g soil between intervals of 2 hr-45 days of spray for imazethapyr and 0.091 to 0.052 mg/g soil for pendimethalin. The observed residual values for both for both of the herbicides were far less than the prescribed MRL values of the herbicides (0.1 mg/g). details are given below in Table 27. Seed and straw of crop was found free of residues of both of the herbicides.

Externally Funded Projects

Rhizosphere microbiome for improving symbiotic nitrogen fixation and yield of lentil in North Eastern States of India (DBT)

A survey was made during July 12-17, 2017 and collected six field soil samples from Tripura state and one from rice fallow field of Silchar. These soil samples along with a set of soil samples collected by Partner Institute Assam University, Silchar were transported to ICAR-IIPR, Kanpur and used for trapping rhizobia with lentil variety DPL 65 during *Rabi* 2017-18. Root nodules were developed in lentil plants grown on 25

Table 27 : Residue value of imazethapyr and pendmethalin

Sampling at time	Residue level of herbicides at max 230					
	Soil sample imazethapyr		Soil sample pendimethalin		Straw and grain at harvest	
	Peak area	residue (mg/g)	Peak area	Residue (g/g)	Peak area	Residue (g/g)
2 hr.	65578	0.0047	95381	0.091		
5 days	53615	0.0035	92615	0.078		
15	48931	0.0027	89721	0.079		
25	42429	0.0023	74539	0.065		
35	39942	0.0015	69732	0.057		
45	35337	0.0011	63421	0.053	ND	ND
	MRL value for both of the herbicides = 0.1 mg/kg seed					

soil samples only. One hundred and twenty rhizobial isolates obtained from those root nodules were used for further confirmation and diversity analysis. Plant genotypes with contrasting BNF potential have to be identified in order to link the changes in microbial community of nodule/rhizosphere with BNF potential as proposed in the project. Hence, fifty lentil genotypes belong to four different wild species of lentil via. *Lens ervoides, L. nigricans, and L. orientalis* were screened under pot conditions. Same set of lentil genotypes were grown in research field strips having contrasting phosphorous availability at New Research Campus, IIPR, Kanpur. Two lentil genotypes (G-Code 7 and 8) recorded the profuse vegetative growth in low-P soil. It indicated that nutrient uptake efficiency/symbiotic efficiency may be higher in those genotypes. Rhizosphere soil and plant tissues of selected wild lentil genotypes serve as study material for understanding role of microbiome on symbiotic efficiency for nitrogen fixation. A total of 269 lentil associated bacteria (LaB) were isolated from above three wild species of lentil via. *Lens ervoides, L. nigricans,* and *L. orientalis.* As the nodule efficiency is determined by the bacteroid morphotypes, root nodules of *Lens culinaris* and *Lens ervoides* were subjected to Transmission Electron Microscopy (TEM) (Fig. 104). Unmodified as well as elongated bacteroids are found in root nodules of *L. culinaris*, while Y shapes bacteroids reported to have high nitrogen fixing ability are found in *L. ervoides* (Fig. 105).

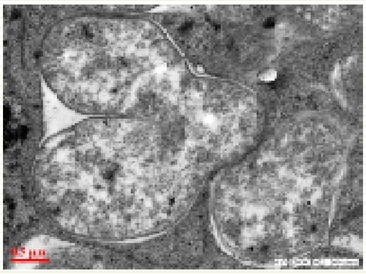


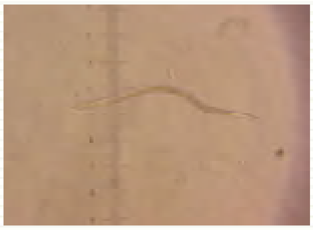
Fig.104: Transmission electron micrograph show

National innovations on climate resilient agriculture (NICRA)

Based on revival efficiency of seedlings after detrimental temperature shock and TTC test, two urdbean genotypes TPU 4 and GU 1 have been identified as heat tolerant. Sensitivity of lentil plants during reproductive period under the high temperature was assessed and genotypes were classified as (a) sensitive, (b) highly sensitive, (c) tolerant and (d) highly tolerant. Phenotyping of root traits *e.g.* root length was done using mapping population P1 ((IPL 98/193) that

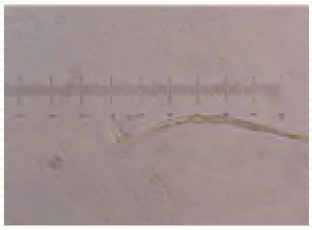
A. Spore encumbered juvenile (isolate 1)

B. Spore encumbered juvenile (isolate 2)



C. Spore encumbered juvenile (isllate 3)

D. Spore encumbered juvenile (isolate 4)



D. Spore encumbered juvenile (isolate 5)

Fig.105: Spore encumbered juvenile (isllate 1-5)

showed variation from 12 to 67 cm. RIL RT-58 had vigorous root system. Water-logging resistant line in pigeonpea genotype IPAC 79 was identified based on high survival rate >80% after three days of submergence. This genotype was characterized by formation of aerial roots at basal region during submergence enabling plant to receive air and sustain root respiration partially while roots subjected to submergent condition. In mungbean, 260 germplasm (indigenous & exotic) were screened for identification of resilient lines. 17 lines were identified. 7 fresh crosses generated utilizing already identified resilient lines (NICRA phase I) for generation of breeding materials. 8 breeding lines developed during NICRA phase I advanced to F_{5-6} generation through single plant selection. 230 F_6 RILs derived from the cross IPM 2-14 x TMB 37 and 196 F_6 RILs derived from the cross PDM 139 x TMB 37 maintained. Panel of 384 SSR markers screened on identified resilient lines, 133 (34.63%) SSRs found polymorphic. These will be utilized for genotyping of resilient lines.

Social Science

Increasing pulses production for food, nutritional security and rural livelihoods of tribal farming community through demonstration and training (Tribal sub-plan scheme)

The project has been implemented in 10 selected tribal dominated districts of M.P., Chhattisgarh and Jammu & Kashmir to bring change in all-round socio-economic development in a time bound manner. Community oriented and resource based technological supports have been provided with active involvement, cooperation and collaboration of concerned KVK of district and ICAR-Agricultural Technology Research Application Institute, Zone IX Jabalpur, Madhya Pradesh. Altogether 570 demonstrations have been conducted in tribal areas for the nutritional security and economic development during 2017-18.

Total 230 *Kharif* demonstrations on pigeonpea and urdbean (Fig. 106) were conducted in M.P. and Chhattisgarh states. The demonstrations were conducted by the KVKs in tribal areas by covering urdbean. The highest yield of urdbean was recorded 1250 kg per ha in Dhar district of M.P. by cultivating PU 31 variety of urdbean and maximum increase 32.00%. Similarly in pigeonpea, LRG 41, JKM 1892 and JT 501 planted in KVK, Kabirdham, Jhabua, Dindori and Badwani. The maximum yield was recorded 1500 kg/ha and increase 17.64 yield over local check.

Fig. 106 : Demonstration plot of urdbean

Fig. 107 : Demonstration plot of chickpea

Total 340 *Rabi* demonstrations were conducted on chickpea, fieldpea and lentil by KVKs of Kanker, Kabirdham, Balrampur, Dantewada Baster comes under Chhattisgarh, KVK Dindori, Badwani, Dhar, Jhabua and Shahdol and KVK Kargil, Zanskar and Leh comes under Jammu & Kashmir (Fig. 107). The chickpea varieties like JAKI 9218, JG 14, JG 130 were included for demonstrations under TSP programme. The maximum yield was obtained by JG 130 and JAKI 9218 varieties of chickpea in Shahdol M.P. and Dhar, M.P. area and per cent of increase in yield was 32.30 and 38.10, respectively. The lentil variety IPL 316 was provided to the farmers under demonstration. The maximum increase in yield was obtained 32.81% in Shahol district of M.P. Similarity, fieldpea variety, Paras provided to the farmers and found highest yield 1105 kg/ha in Kanker, Chhattisgarh with increase 28.27%.

Fig.108: Information source use pattern for agricultural related information from interpersonal sources (N= 300)

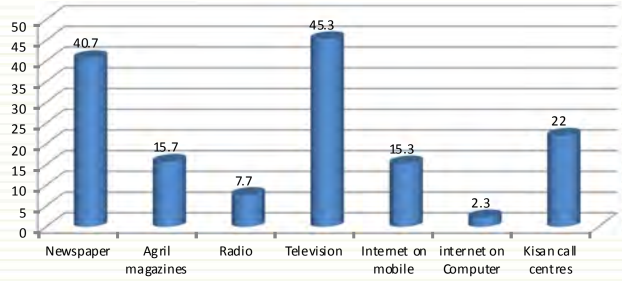


Fig.109: Information source use pattern for agricultural related information from print and ICT based information sources (N= 300)

Development and validation of digital platforms for dissemination of information on pulse production technologies

The project envisages developing digital platforms for sharing knowledge resources related to pulse production technologies to pulse farmers, extension personnel and other stakeholders. Under the project, knowledge modules related to production and protection of pigeonpea and mungbean crops have been prepared for use in digital platforms.

Farmers' information use pattern related to agricultural technologies was recorded. Among the interpersonal sources, majority of the farmers used fellow farmers (64%) and input dealers (58%), while formal sources of information were used to lesser extent (Fig. 108 & 109). With regards to use of print and ICT based information sources, television followed by newspaper was used by majority.

Development of web-based commodity profile for chickpea and pigeonpea

Crop profile contents on production statistics, trade statistics, price statistics, minimum support price (MSP), crop calendar, FLD's, BSP's, mandi prices, Govt. schemes, seed information, ITK's, post-harvest management, feedback etc., have been collected for the current year. All the contents have been compiled, validated, analysed and stored in digital format. An user-friendly data structure has been designed and shared for web-based platform. Commodity Profile for Pulses (CPP Portal) has been developed and linked with the contents (Fig. 110). It is a web-based information portal which provides the information needs of farmers, researchers, exporters

Fig.110: Commodity Profile for Pulses (CPP) Portal

and policy makers. This portal will also serve as an information highway for sharing pulse crops knowledge through latest IT tools including mobile technology.

Farm-retail price behaviour and transmission in Indian pulses market

The production of pulses during 2017-18 was estimated at23.95 million tonnes which was higher by 0.82 million tonnes than the last year's (2016-17) record production of 23.13 million tonnes (Fig. 111) and was higher than the five years' average production by 5.10 million tonnes (an increase of 27%). The exponential growth rate in production of pulses for last ten years (2008-09 to 2017-18) was found to be at 4.45% *** (significant at 1% level) with an Instability Index of 9.05%.

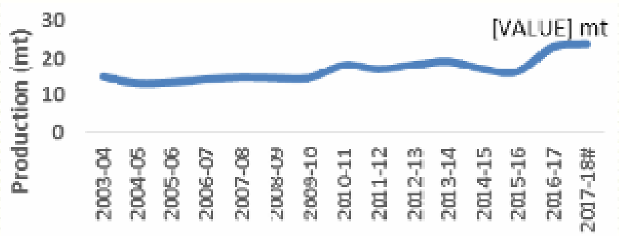


Fig. 111 : Production of pulses in India

This year, Minimum Support Price (MSP) of pigenpea was increased by 7.9% (from ₹ 5,050 per quintal to ₹ 5,450 per quintal), moong by 6.7% (from ₹ 5,225 per quintal to ₹ 5,575 per quintal), urad by 8% (from ₹ 5,000 per quintal to ₹ 5,400 per quintal), chickpea by 10% (from ₹ 4,000 per quintal to ₹ 4,400 per quintal) and lentil by 7.6% (from ₹ 3,950 per quintal to ₹ 4,250 per quintal). As per the time-series analysis, the exponential growth rates in MSP during the last ten years (2007-08 to 2017-18) for pigeonpea, moong, urad, chickpea and lentil were 11.34%, 9.24%, 9.4%, 10.86% and 9.43% in terms of nominal prices and 6.64%, 4.62%, 4.77%, 6.17% and 4.81% in terms of real prices (Table 28, Fig. 112 & 113).

Table 28 : Exponential growth rates (%) in Minimum Support Prices of Pulses (2008-09 to 2017-18)

Season	Pulses	MSP (Nominal)	MSP (Real)
Kharif	Pigeonpea	11.34 ***	6.64 ***
	Mung	9.24 ***	4.62 ***
	Urd	9.4 ***	4.77 ***
Rabi	Chickpea	10.86 ***	6.17 ***
	Lentil	9.43 ***	4.81 ***

*** Significant at 1% level.

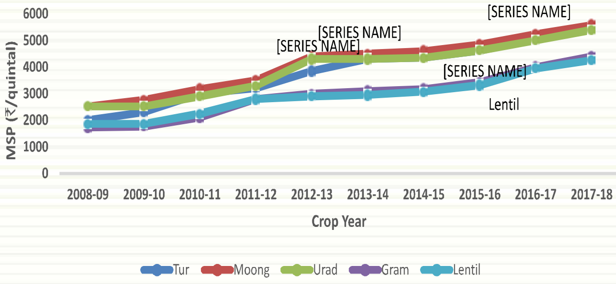


Fig.112: Minimum support prices of pulses-nominal prices

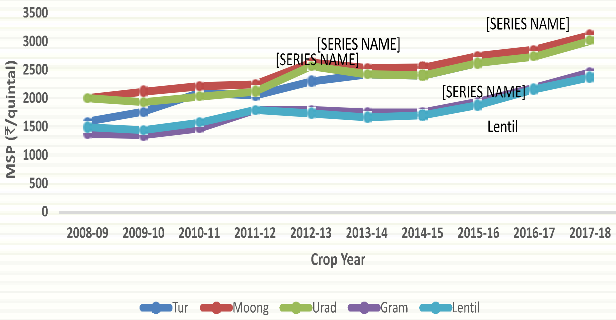


Fig.113: Minimum support prices of pulses-real prices (2011-12=100)

Trade policies of pulses were changed this year. Prohibition on export of all types of pulses were removed while import duties were imposed on peas (50%), chickpea (40%), lentil (30%) and pigeonpea (10%) and quantitative restrictions were imposed on imports of urad, moong and pigeonpea this year. Further, the procurement of 20 lakh tonnes pulses was the highest ever procurement of pulses. As per the time-series analysis of data collected from Central Statistics Office, Ministry of Statistics and Programme Implementation and Office of the Economic Adviser, Ministry of Commerce & Industry, both in terms of Wholesale Price Index (WPI) and Consumer Price Index (CPI) based measures, price indices of pulses were on the decline since the peak during 2016 (Fig. 114). Inflation in pulses in percentage terms were negative since December, 2016 in case of CPI based measure

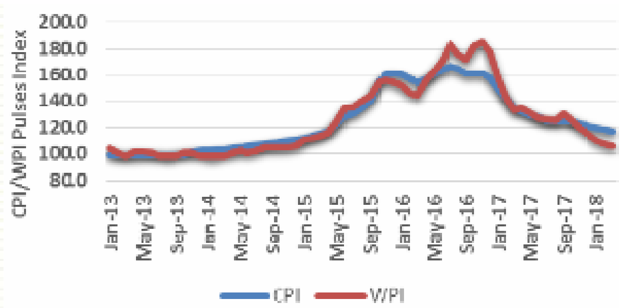


Fig.114: WPI and CPI based pulses indices (Base 2013=100) in India

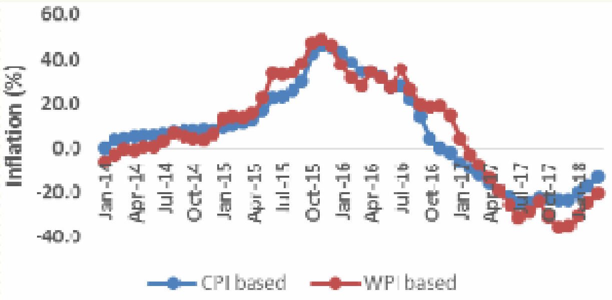


Fig. 115 : Inflation in pulses (%) in India

and since February, 2017 in case of WPI based measure (Fig. 115).

Assessing suitability of chickpea genotypes in multi-environment testing

Taking into consideration of genotype x environment interaction (GEI) effect in multi-environmental trials, genotypes should be selected on the basis of both average yield and stability component rather than only on the basis of average yield. In this regard, AMMI based selection index has been used to rank the genotypes, as it captures a large portion of the GEI sum of squares. This index is the weightage of stability and yield component and higher the index value better is the genotypes. The index of 41 initial varietal trial (IVT) of *desi* chickpea genotypes were calculated with two different weight of yield (50% and 75%) and stability component (50% and 25%), which were evaluated at five effective locations viz, Hisar, Pantnagar, Sriganganar, New Delhi, and Ludhiana representing the North West Plain Zone of All India Coordinated Research Project on Chickpea Program during 2016-17. Ranking of genotypes are done based on two different weight of stability and yield component. Genotype BAUG108 with 7.6530 index value was found the best genotype followed by genotype KGD 99-4 with index value 3.3082 and genotype RVSSG 42 with index value 2.9427 when alpha = 1 i.e. stabaility component w2 = 0.5 and yield component w1 = 0.5. When alpha = 0.33 i.e. stability component w2 = 0.25 and yield component w1 = 0.75, genotype BAUG 108 with 3.1097 index value was found the best genotype followed by genotype KGD 99-4 with index value 1.8051 and genotype CSJ 907 with index value 1.6731. Hence, these genotypes may be used by the chickpea breeder for developing high yield and stable chickpea lines on AMMI based simultaneous selection for yield and stability.

A study on farmers adoption behaviour towards sustainable pulse production practices in Bundelkhand region of Uttar Pradesh

This project was taken up to understand the adoption behavior of various category of farmers in pulse production in order to come out with future plan for effective dissemination. Under this project, two districts were selected for study and data collection i.e, Hamirpur and Banda districts of Bundhelkhand region of Uttar Pradesh. Review work of the project work has been done from various sources of literature and available records regarding study area and research variables. The schedule has been prepared for measurement of independent and dependent variables along with development of scales for adoption behaviour. Secondary basic information has been collected and further major data collection will be done with subsequent data analysis and report writing.

Externally Funded Projects

Integrated approaches for food, nutrition and livelihood security of rural household in Fatehpur district of Uttar Pradesh – Farmer FIRST Project

The Farmer FIRST project has been implemented in three villages namely Karchalpur, Kharouli and Mirai of Devmai block of Fatehpur district during the period 2017-18. Different interventions related to pulses, cereal, horticulture and livestock, barseem implemented in participatory mode in project area to enhance the productivity, production, income and over all development of farming community. The results are presented intervention wise below:

Pulse based demonstration for increasing production and income: Summer mungbean and urdbean interventions were implemented in project area by covering 550 farmer for additional income and to generate additional employment during season in village itself. The average yield of mungbean recorded 9.50 q/ha and urdbean 8.35q/ha. Income gained ₹ 19,310/ha and ₹ 15,440/ha mungbean and urdbean employment per day (Fig. 116). Similarly, demonstration as chickpea were also conducted in project area by covering 71 farmers to solve the problem of wilt disease and pod bores. The critical inputs seed, insecticide were provided. The average yield recorded 26.80 q/ha and income gained by ₹ 83,545/ha (Table 29).

Table 29 : Economics of pulses crops under Farmer FIRST Project

Sl. No.	Name of crop	Variety	Yield (q/ha)	Yield increase over local (%)	Cost of cultivation (₹)	Gross income (₹)	Net return (₹)	B:C ratio
1	Mungbean	IPM 2-14	9.50	20.25	14890	34200	19310	2.29
		Local variety	7.90	_	13450	28440	14990	2.11
2	Urdbean	IPU 2-43	8.35	16.78	13785	29225	15440	2.12
		Local variety	7.15	_	11990	25025	13035	2.08
3	Chickpea	JG 16	26.80	18.44	29015	112560	83545	3.87
		Local variety	22.55	_	29090	95220	70330	3.27

Rate per q of Mungbean – ₹ 3,600, Urdbean – ₹ 3,500 and Chickpea – ₹ 4,200.

Cereal based demonstration for increasing production and income

Demonstration on rice were conducted in project area to enhance the food security and enhance income of the farmers through introduction of new varieties of rice. Total 82 farmers and 23.50 ha area covered. Scented variety of rice as critical input was provided to the farmers for enhancing production and income in project area. The recorded yield under farmer field was 42.50 q/ha Pusa Sugandga-4 variety and 48.40 q/ha Pant-12 variety. The average net return obtained ₹ 35,460 and ₹ 36,910 in comparisons to local yield (Fig. 117, Table 30).

Economics of wheat crop under Farmer FIRST Project

Farmers were provided critical input to conduct the demonstration on wheat to enhance yield and Food Security through high yielding varieties K 1006 and K 9423. The variety K 1006 is rich in zinc content which

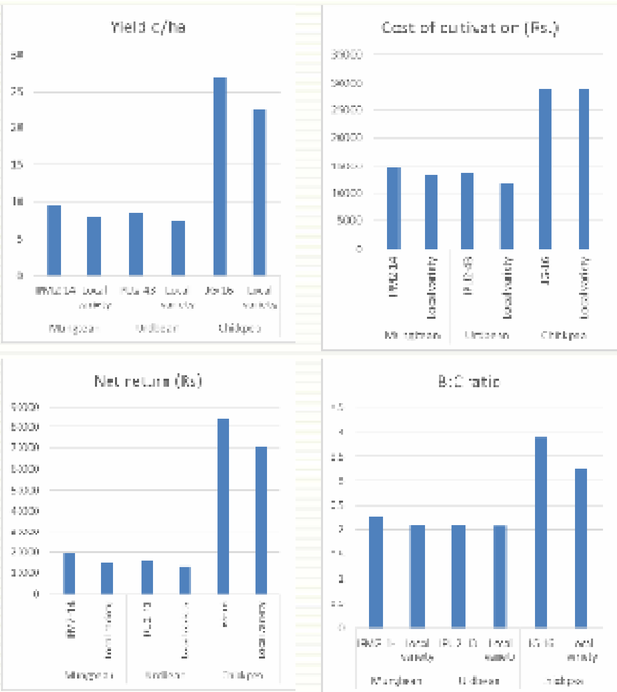


Fig.116: Economics of pulse crops under Farmer FIRST Project

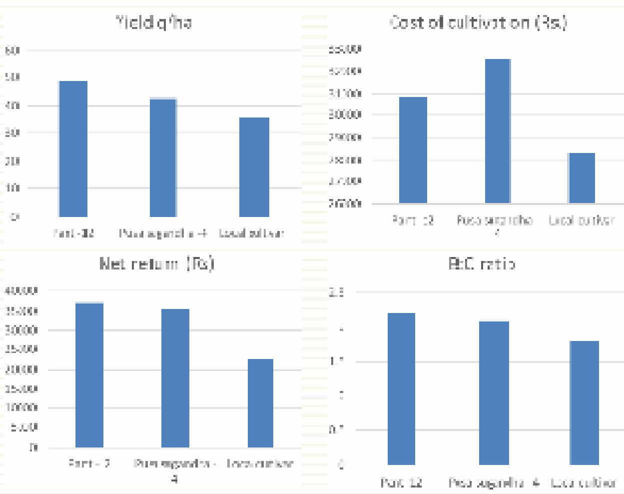


Fig.117: Economics of rice crop under Farmer FIRST Project

Table 30 : Economics of rice crop under Farmer FIRST Project

Sl. No.	Variety	Yield q/ha	Yield increase over local (%)	Cost of cultivation (₹)	Gross income (₹)	Net return (₹)	B:C ratio
1	Pant -12	48.40	25.71%	30850	67760	36910	2.19
2	Pusa Sugandha - 4	42.50	16.85%	32540	68000	35460	2.08
3	Local cultivar	36.20		28302	50680	22378	1.79

B:C Ratio = Gross return/Cost of cultivation Rate per q – Pusa Sugandha-4 ₹ 1,600/ q Pant-12 and local variety-₹ 1,400/q is suitable for children and old people 2017. Total 74 farmers are covered. K1006 variety of wheat are timely sown variety which is suitable for these area. The average yield recorded of K1006 and K9423 variety of wheat is 54.65 q/ha and 38.3 q/ha, respectively. The average net income gained by farmer is timely sown variety and late sown variety ₹ 60,333/ha and ₹ 34,801/ha, respectively (Fig. 118, Table 31).

Vegetable based demonstration for higher return and nutrition: Demonstration of high yield variety/ hybrid of summer season vegetable in project area which is utilized the fallow field in summer season for obtaining the additional income and to generate the employment of rural youth and women.

Okra: The farmer were provided seed as critical input for conducting the demonstrations of summer okra to regular income and nutritional value. The average income ₹ 1,69,120 /ha was recorded (Fig. 118). Total no. of 32 demonstrations of okra conducted by covering 8.50 ha area. This has become a source of income in off season.

Bottle gourd: The farmers were provided critical input for conducting the demonstrations of summer bottle gourd for additional income after harvesting of wheat, mustard and potato. Farmers gained ₹ 1,13,588 /ha income. Total 23 demonstrations on bottle gourd were conducted in 5.0 ha area (Table 32).

Sponge gourd: The farmers were provided hybrid seed of sponge guard as critical input for conducting the demonstrations of summer sponge gourd to additional and nutritional value and the average ₹ 1,13,013 /ha

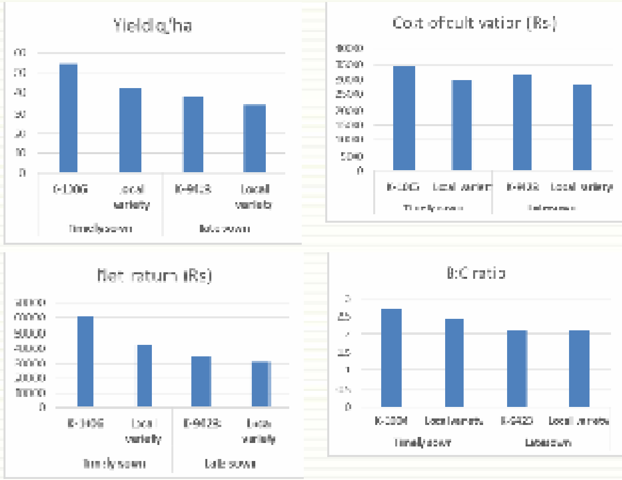


Fig.118: Economics of Wheat crop under Farmer FIRST Project

income (Fig. 119). Total 21 demonstrations of the sponge gourd were conducted in summer season on 4.50 ha. Thus farmers gained net return ₹ 11,303/ha (Table 32).

Pumpkin: The farmer were provided hybrid seed as critical input for conducting the demonstrations of summer pumpkin to used are fallow land and nutritional value and farmers gained average ₹ 79,350/ ha income (Fig. 119). Total 20 demonstrations of the pumpkin were conducted on 4.50 ha area (Table 32).

Poultry units were established in project area to demonstrate the survivability, income and employment for rural youths and women farmers. Altogether 71 farmers were provided 1600 poultry chicks breed namely CARI Nirbhik, Shyama and Devendra brought from CARI, Izatnagar, Bareilly for increasing income

Table 31 : Economics of timely and late sown wheat

Sl. No.	Time of sowing	Variety	Yield (q/ha)	Yield increase over local (%)	Cost of cultivation (₹)	Gross income (₹)	Net return (₹)	B:C ratio
1	Timely sown	K 1006	54.65	29.80	34485	94818	60333	2.74
		Local variety	42.10	_	29650	73044	43394	2.46
2	Late sown	K 9423	38.30	11.01%	31650	66451	34801	2.09
		Local variety	34.50	_	28310	59858	31548	2.11

Rate ₹/q - ₹ 1,735

Table 32 : Economics of vegetable crops

Sl. No.	Name of crop	Variety	Yield (q/ha)	Yield increase over local (%)	Cost of cultivation (₹)	Gross income (₹)	Net return (₹)	B:C ratio
1	Okra	Samrat F1	80.00	14.28	70880	240000	169120	3.38
		Local variety	70	_	68765	210000	141235	3.05
2	Bottle gourd	Hybrid	71.60	30.41	65537	179125	113588	2.71
		Local variety	54.90	_	61545	137250	75705	2.22
3	Sponge gourd	Hybrid	88.50	23.43	63987	177000	113013	2.76
		Local variety	71.70		60638	143400	82762	2.36
	Pumpkin	Hybrid	74.50	24.58	62200	141550	79350	2.25
		Local variety	59.80	_	58638	113620	54982	1.93

Rate ₹/q – Okra - ₹ 3,000, Bottle gourd - ₹ 2,500, Sponge gourd - ₹ 2,000 and Pumpkin - ₹ 1,900

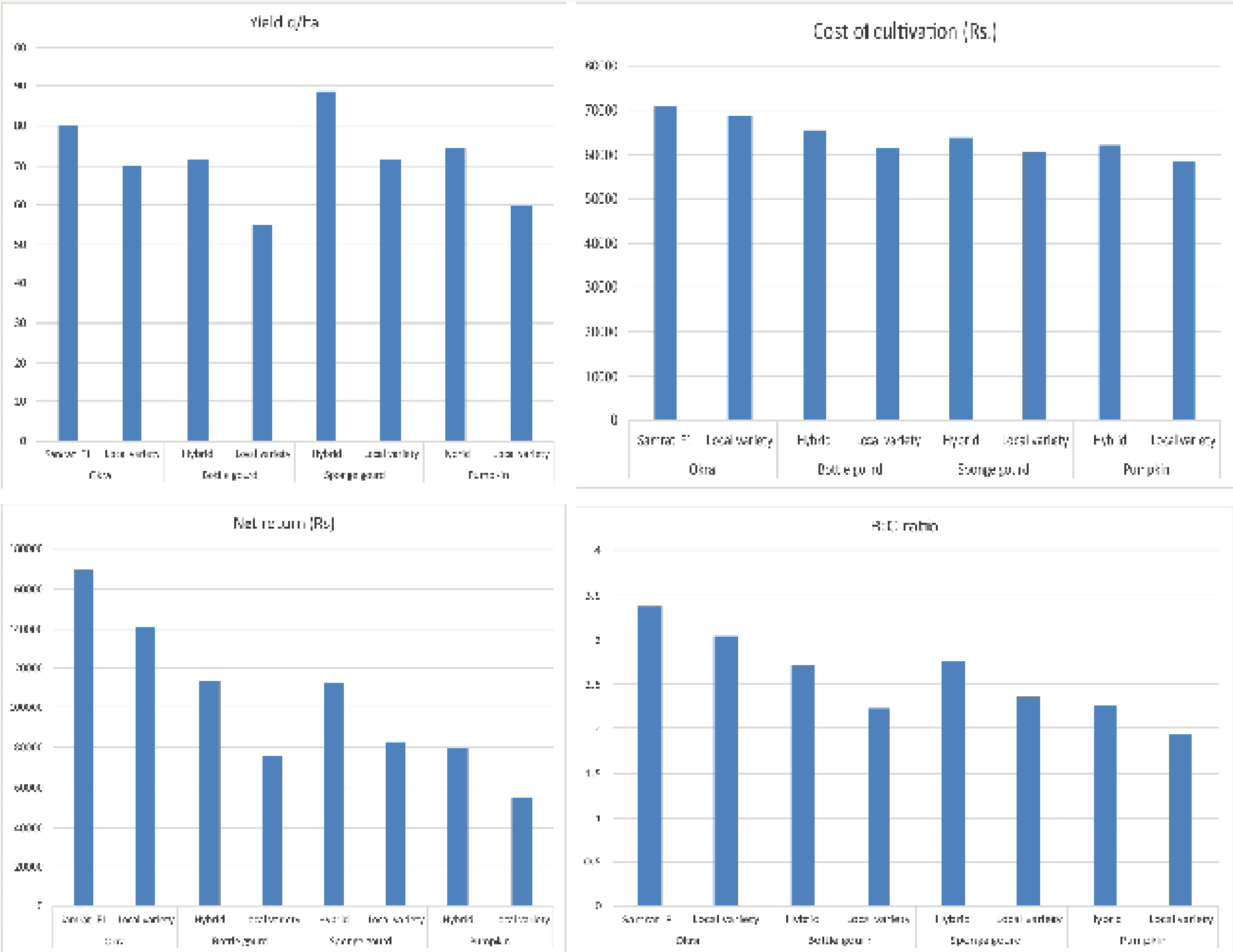


Fig. 119: Economics of vegetable crops under Farmer FIRST Project

employment and nutrition. Farmers rearing 15-20 birds were getting net income ₹ 1,010.00 per month and 60 hours employment per month. Similarly farmers rearing 25-50 birds were getting ₹ 5,110.00 and 90 hours employment per month and farmers rearing at large scale between 55-110 poultry birds were getting ₹ 12,680.00 and 120 hours employment per month (Table 33).

Table 33 : Poultry based demonstration for income, employment and nutritional security

Sl.No.	Particular	Category of poultry rear farmer Dual purpose breed		
		15-20 poultry	25-50 poultry	55-110 poultry
1.	Number of farmers	51	15	5
2.	Egg laying start	After 5th month	5-5.6 month	5-5.6 month
3.	Number of egg / month / poultry	22	22	22
4.	Rate per egg	10-15	10-15	10-15
5.	Rate of meat (₹/kg)	500-600	500-600	500-600
6.	Work done in poultry farm per day	1-2 hr	2-3 hr	3-4 hr
7.	Feeding calculation after grazing	1350 (90 kg * ₹ 15)	2700 (180 kg*15)	6075 (405*15)
8.	Health	100	500	2000
9.	Labour charge per month	1500	2250	3000
10.	Total expenditure	2950	5450	11075
11.	Gross income	3960	10560	23760
12.	Net income	1010	5110	12680

Total 9 combination of crop and vegetable wee implemented in project area and it was found that Cereal + pulse +vegetable + poultry farming system has given maximum income ₹ 3,45,789.00 followed by Cereal + vegetable + poultry farming system ₹ 2,94,580.00 and Rice + okra farming system ₹ 2,52,972.00 (Table 34).

Table 34 : Integrated farming system module Total number of farmer covered - 1898

Sl. No.	IFS module	Number of farmers	Per cent of farmer	Cropping intensity	Cost of cultivation (₹)	Income (₹)	Rank
1	Rice + chickpea	879	46.31	200	39160.00	144723.00	
2	Rice + wheat + mungbean	648	34.14	300	55520.00	136680.00	
2	Rice + okra	215	11.32	200	53025.00	252972.00	III
4	Chickpea + pumpkin	351	18.49	200	57215.00	202255.00	
5	Cereal + pulse + poultry	50	2.63	200	85890.00	250147.00	
6	Cereal + vegetable + poultry	41	2.16	200	114786.00	294580.00	II
7	Live stock + poultry	34	1.79	-	74580.00	84850.00	
8	Cereal + pulse + vegetable + poultry	21	1.10	300	127458.00	345789.00	I
9	Poultry + vegetable	10	0.52	100	54178.00	88147.00	

Socio-Economic and technological empowerment of pulses growers of Jalaun and Kanpur dehat district of Uttar Pradesh

Four project villages ie., Salempur and Silhara of Kanpur Dehat and Barai and Sohrapur of Jalaun district, were developed as model Pulse villages in pulse growing regions of Jalaun and Kanpur Dehat district. These model pulse villages were envisaged to serve as knowledge diffusion centres for pulse cultivation technologies in the area. The project utilized a three pronged strategy for technological empowerment with regard to pulse production technologies by involving farmers, farm women and village youth as partners in the project during 2015 to 2018. The three targeted groups were involved in project activities as per their participation in pulse production activities.

Entrepreneurship development in seed production

For purpose of encouraging entrepreneurship among partner farmers and farm youth as well as for enhancing the availability of quality seed of improved pulse varieties, pulse growing farmers and farm youth were mobilized for seed production technologies of pulse crops. During 2016-17, 27 farmers produced about 17063 kg seed of high yielding, disease resistant improved varieties of pigeonpea (IPA 203) and fieldpea (Var. Aman, IPFD 10-12, Prakash and IPF 4-9) crops and collectively earned a gross income of ₹ 6,76,396/-. During the year 2017-18, the two registered groups of partner farmers in Silhara and Salempur villages of Kanpur Dehat district were technological empowered to initiate seed production of in about 15 ha of area of field pea (var. Aman, IPFD 10-12, Prakash) by 15 partner farmers in project villages. The societies have produced about 160 q of seed and are currently linked to The farmers' societies were supported for building up linkages with Uttar Pradesh Seed Certification Agency and ICAR-IIPR, Kanpur for seed production and marketing, respectively. The seed societies contributed towards improving village level farmers' access to quality seed as well as towards strengthening the formal seed system of pulse crops at the regional level.

Capacity enhancement programmes

In addition, need based crop specific two on farm capacity enhancement programmes for 82 partner farmers and farm women from targeted project villages were organized which included on station and trainings. These programmes covered aspects like seed production technology, pulse production technology, seed treatment, post-harvest handling and value addition of pulses. A total of 70 women farmers were capacitated for improved pulse storage technologies for safe storage of pulses in a specially designed training programme, wherein they were also made aware about the importance of pulses in the nutritional security of farm families.

Farmer to farmer exchange of seed

For achieving a greater diffusion of improved varieties of pulse crops as well as other production technologies among farmers through social networks, farmer to farmer extension was encouraged among the farmers in the region. The documentation of the horizontal spread of fieldpea seed (var. Prakash) was studied and it was recorded that the partner farmers strengthened the informal seed system by diffusion of 23.14q of seed that was sufficient for sowing in 23.14

ha of area in 17 villages spread within a radius of 35 kilometres. Participating farmers earned incremental returns of about ₹ 27,000/- collectively.

The project villages are being recognized as local hubs of improved seed of pulse crops in the region. In addition, partner farmers are being recognized as importance source of information on improved technologies for pulse production in the model villages developed under the project.

Harnessing modern communication technologies for sharing of available knowledge resources with pulse growing farmers of Uttar Pradesh

Voice SMS based advisories service "*Dalhan Sandesh*" of ICAR-IIPR, Kanpur has been extended under the project to 2839 farmers from Jalaun, Fatehpur, Chitrakoot, Hamirpur, Kanpur Dehat, Balia, Kanpur Nagar districts of Uttar Pradesh state thereby linking experts to farmers directly. A total of 82,886 customized advisories were sent till date on pulse crops on chickpea, pigeonpea, mungbean, urdbean and lentil production technologies. The economics of voice based advisories was worked out to be ₹ 1.8 per crop per farmer.

Farmers perceived Dalhan Sandesh Service was studied and it was recorded that with regard to aspects like credibility of message and ease in comprehension, it was found most appropriate (Table 35).

Farmers members of "Barapur Beej Vikas Sansthan" in Kanpur Dehat district, were capacitated to take up seed production of pigeon pea (var. IPA 203) and chickpea (var. Ujjawal) in 5 ha and 2.5 ha, respectively during 2016-17. The farmers produced about 7,482 kg of seed and earned collective gross economic advantage of ₹ 613450/-. During 2017-18, the farmers' society has been facilitated for chickpea seed production (var. Ujjawal) in 3 ha area and are

Table 35 : Perceptions of partner farmers about *Dalhan* Sandesh Service (N = 300)

Item	Score	Weighted score
Timeliness of message	225	10.63
Compatibility to local conditions	230	10.86
Frequency of message	208	9.83
Comprehensive Content	197	9.31
Easy to comprehend	255	12.05
Delivered systematically	238	11.24
Credibility of message	271	12.80
Language simple and convincing	243	11.48
Usability of the message	250	11.81

expected to contribute about 8,000 kg of seed to formal seed system.

Tropical Legumes III "Improving Livelihoods for Smallholder Farmers: Enhanced Grain Legume Productivity and Production in Sub-Saharan Africa and South Asia"

To strengthen existing seed delivery system for ensuring the availability of quality chickpea seed to farmers of Hamirpur, Chitrakoot and Banda districts of Bundelkhand region of Uttar Pradesh, on-farm interventions were carried out in 8 villages under Tropical legumes-III project during 2017-18. These interventions included 70 participatory on farm demonstrations of 0.4 ha each on recommended high yielding and diseases resistant chickpea varieties (*Desi*: RVG 203, *Kabuli*: Shubhra, Ujjawal). Partner farmers registered a yield advantage of 4 q/ha from the demonstration plots as compared to the control plots. Partner farmers were mobilized to Four Seed Growers' Groups in project villages. During 2016-17, partner farmers in the groups produced 5602 kg seed and during 2017-18, 26 ha of area in the project district is registered for foundation seed production for chickpea and partner farmers are expected to produce about 33,100 kg of chickpea seed.

For identification of farmer-preferred varieties of chickpea crop and traits, a total of 30 Farmer Participatory Varietal Selection (FPVS) trials were conducted with inclusion of chickpea varieties Shubhra, Ujjawal, RVG 202 along with four state level released varieties *viz.,* IPC 2006-77, IPC 2005-62, IPC 2004-98 and IPC 2004-1 in the identified project villages. For ensuring rapid diffusion of quality seed of chickpea varieties among the farming community, 263 farmers of the project villages were provided 6 to 8 kg seed of recommended chickpea varieties (Shubhra, Ujjawal, RVG 202, JG 16) for covering 0.25 acre each. Farmer participatory seed production through four farmers registered societies formed under the project was taken up in 26 ha of area in the project villages. A total of 69.2 q quality seed of improved chickpea varieties was infused into the seed system of targeted districts covering an area of 77.5 hectares. Partner farmers were assisted in developing linkages with Uttar Pradesh Seed Certification Agency and ICAR-IIPR seed hubs. For enhancing the capacities of partner farmers, three on-farm training programmes were conducted in the project villages during February 2018 involving 117 farmers. In addition, women specific capacity enhancement programme was conducted involving 50 farm women from project villages of Hamirpur district on 13th February 2018. For purpose of sharing of experiences of on-farm interventions, a Farmer-Scientist Interaction meet was organized on 25th February 2018 involving 101 farmers. Farmers perceived the introduced varieties to be better in terms of plant vigour, branching, flowering, podding and they showed keen interest in expansion of chickpea cultivation.

Development of pulses based bio-village sustainable models through action research for livelihood security under different agro-ecosystems in Uttar Pradesh

The two villages *i.e.,* Benipur and Kucharam as selected earlier were continued except village Nagla added in Shahjahanpur. Two farmers society *"Benipur Swami Vivekananda Seva Samiti*" at Shahjahanpur and "*Maa Durga Krishak Seva Samiti*" in Chitrakoot were formed and registered under Society Registration Act 21, 1860. The demonstrations cum seed production on *Rabi* pulses i.e. Chickpea (var. JG 14, JG 16), Lentil (var. IPL 316) were organized with 55 farmers in 15.0 ha where area was registered with State Seed Certification Agency. The biopesticide as spinosod 45 SC (0.4 ml/liter of water) was applied in chickpea against *Helicoverpa*. Farmers appreciated the impact of the insecticide over those were under practice. Further, the demonstrations on spring/summer pulses 2018 *i.e.* Mungbean (var. IPM 02-3), Urdbean (IPU 2-43) were organized with 27 farmers in 8.0 hectare area. A pulse crop cafeteria at KVK, Sahjahanpur and Chitrakoot was maintained where 26 cultivars of chickpea, fieldpea and lentil were assessed. The earthworm spp. *Esenia fetida* was supplied (58 kg) to 29 farmers for vermi-composting. Variuos size and shapes structures were made as vermicompost units. The waste decomposer a (formulation of fungus prepared from cow dung) developed by National Bio-fertilizer Development Centre (NBDC) was demonstrated with 40 farmers. ''Pusa Compost Inoculants' also procured for demonstrations. One IIPR mini *dal mill* was supplied for processing and employment generation and demonstrated among farmers. Two training program for 70 farmers of two days each were organized at KVK, Shahjahanpur and Chitrakoot where 15 resource persons had imparted knowledge and skill oriented training. The farmers were empowered on various project activities through organizing farmers-scientists' interaction meetings in adopted villages. The regular meetings by project staff were conducted and messages communicated to farmers. The local heaps farm yard manure (FYM) as available in village were enriched it helps the sanitation of village too. Farmers were sensitizes and motivated for pit method of compost making and organic pulse production.

Development of pulse based model village for sustainable rural livelihood in central zone of Uttar Pradesh

The primary data were collected form 55 stakeholders. The area under various crops in *Kharif, Rabi* and *Zaid* season under exiting crops was worked out and benefit cost ratio (BCR) of crops grown under each of season was studied. Though the economic concerns are important behind cultivation of any crop but there are several other factors those taken into considerations by the farmers. Therefore, various other reasons those favour and non-favour the adoption of various crops under each season were studied to know the decision making of farmers for adoption of crops. The functional linkages and coordination with line department was made to promote pulse crops under various schemes. One Farmers society i.e *'K.P. Welfare Society'* No. 1463/2017-18 registered under 1860 Act of Society Registration. Frontline demonstration (13) on chickpea var. JG 16 was organised. The distribution of area under *Kharif* crops (Fig. 120) showed that ash gourd, maize, chili, paddy, long duration pigeonpea sorghum, urdbean, early pigeonepa, sorghum occupied 42, 18, 12, 10, 7, 4, 2, 2 per cent area in adopted village.

The distribution of area under *Rabi* crops (Fig. 121) showed that wheat occupied 80% area in *Rabi* season followed by chickpea (8%), rapeseed (4%), potato (3%), vegetables (2%) and mustard (2%).

The distribution of area under zaid crops (Fig. 122) showed that majority (75%) area was fallow during *zaid* season (Fig. 122) and mungbean occupied maximum (16%) land followed by urdbean (3%), sugarcane (2%) and vegetables (2%) etc.

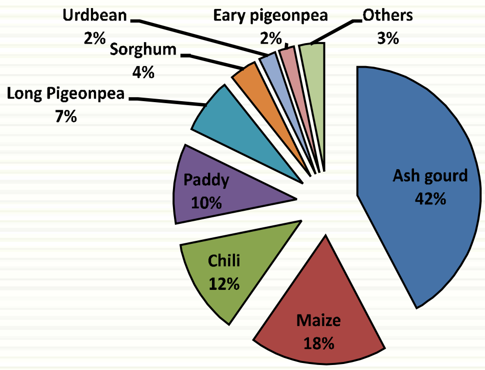


Fig. 120: Distribution of area under *Kharif* crops

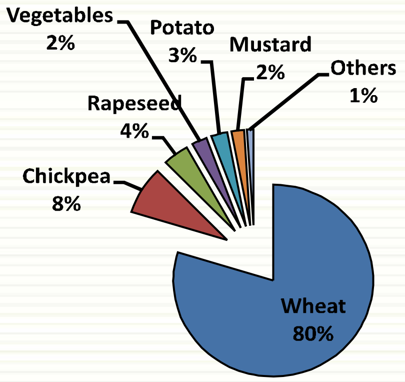


Fig. 121: Distribution of area under *Rabi* crops

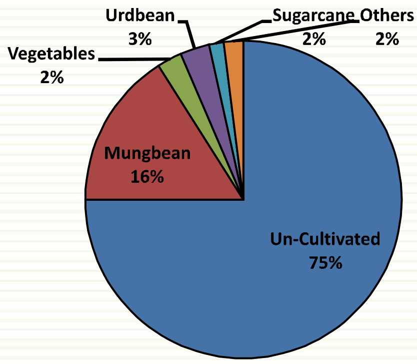


Fig. 122: Distribution of area under *Zaid* crops

Participation in training/meeting/ workshop, etc.

- Dr. Rajesh Kumar, Head, Div. of Social Scinces attended Training workshop "Methodological framework for implementation of FFP" at CISH, Lucknow on 4th October, 2017.
- Attended Training workshop "Methodological framework for implementation of FFP" at CISH, Lucknow on 4th October, 2017.
- Attended National Conference on "Farmers Centric Agri-innovation for Sustainable Development during 24-25 March 2017 at CSAUA&T, Kanpur.
- Attended **International Conference on *"Sustainability of Smallholder Agriculture in Developing Countries under Changing Climatic Scenario*** scheduled to be held during February 14–17, 2018 at CSAUA&T, Kanpur, India-**reg.**
- Attended Regional (North-III) Workshop on Institutional Digital Repository for NDL Project held on June 2-3, 2017 at main library, IIT-BHU, Varanasi.
- Attended training programme on "Scaling water productivity and resource conservation in Upland field crops ensuring More crop per drop" from 06-26 september 2017 at ICAR-IIPR, Kanpur.
- Attended National Symposium on Pulses for Nutritional Security and Agricultural Sustainability at ICAR-IIPR, Kanpur

II) Any other (Please specify)

Prepared movie on "one documentary film (4 minute) on "*Improved planting techniques of kharif pulse crops"* was prepared.

Mera Gaon Mera Gaurav (My Village My Pride)

Mera Gaon Mera Gaurav was has been implemented in villages of Fatehpur, Kanpur Dehat and Kanpur Nagar districts. The demonstrations on chickpea, fieldpea, pigeonpea, mungbean and urdbean have been conducted for additional income and employment to the rural youths and women which were especially paid attention. Interactive meetings were organized with farmers, communicated pulse messages, received feedback on various aspects, distributed extension literature, observe crops in fields. Majority of farmers have been registered for 'Dalhan Sandesh' to get time to time latest information about agriculture and livestock. Farmers were providing seed of vegetable and maize for additional income and employment during slack period. *Kisan Sewa Samiti* has been formed to facilitate the marketing and quality seed availability in souring villages. The linkages have been developed with the different government and non-government agencies to help the farmers. Farmers were given training on crop and live stock to upgrade their skill for doubling the income. One 'Field Day' was organized to create the awareness among the farmers about the pulses. The Farmer-Scientist Interaction was organized to expose about new technologies of pulses. Awareness was created among the farmers about of quality seed and harmful effect of insecticide. Farmers were also provided regularly about the livestock management by organizing training-cum-interaction meeting.

Regional Station, Bhopal

Research achievements

1. Grasspea (*Lathyrus sativus* L.)

(A) Plant genetic resources (Rejuvenation and Characterization)

Total 532 genotypes, from Bhopal (380) and Kanpur (292) centres, were multiplied and evaluated for descriptor based agro-economic traits. Besides, purification of genotypes was carried out by growing single plant progenies under pollen control conditions.

Table 36 : Genetic variation for various quantitative traits in grasspea

S. No.	Character	Range Min-max	Promising genotypes
1	Plant height (cm)	36.2-92.8	RLK-1233(92.8 cm)
2	Days to maturity	110-135	IC 296745A and RLK 195 (110)
3	Primary branches / plant	2 - 5	VKS1/127(5)
4	Pods per plant	7- 11	EC-329738 (11)
5	No. of seeds /plant	11- 28	JBT-38/48 (28)
6	Seeds/ pod	1-8	JBT-38/48
7	Biological yield (g)	7.8- 115.2	VKS/SSC/4/14 (115.2 g)
8	Grain yield / plant (g)	0.36-20.04	JBT-38/48 (20.04 g)
9	100 seed weight (g)	0.8- 15.1	Sel 471 (15.1g)
10	Plot yield (g)	2.4- 716.2	DC-241 (716.2 g)

Table 37 : Unique genotypes identified in grasspea

S.No.	Traits	Genotypes
1.	Large size and white colour seeds	Sel 471, Bio R 239, Bio R 219
2.	Green mosaic seed	RLK 195
3.	Low ODAP (0.01-0.04)	Sel 471, Bio R 239, Bio R 219

Wide magnitude of variability was observed for major qualitative (flower colour, leaf shape and size, seed colour, seed shape) and quantitative (maturity duration, seed size, no. of pods per plant, no. of branches per plant, no. of seeds per pod and plant height).ODAP analysis for these genotypes is underway (Table 36 and 37).

(B) Mutation breeding

A wide magnitude of variation was observed in M_2 generation of gamma irradiated Grasspea. Following mutagenic treatments, chlorophyll mutations (albino, xantha, chlorina and chlorinate) were observed in all the three treatments and varieties (Fig. 123). Chimeras, Leaf curling and twisting were also noticed in few plants. Seeds were collected from matant lines to advance M_3 generation. In general, it was observed that Mahatewda (0.4 Kgy) showed

Grasspea purification, multiplication and evaluation under pollen control conditions under nylon net house

(a) (b) (c)

Broader leaves, green seeds (b) and large seeded (c) Grasspea genotypes

Albino Albino Xantha Chlorina Chlorinata

Fig. 123 : M_2 plants showing variability for chlorophyll pigmentation (spectrum)

maximum variation/sensitivity as highest chlorophyll mutations (albino, xantho, chlorine and chlorinate) were observed with this genotype followed by Ratan at highest doses (0.4 Kgy). of gamma rays .

(C) Crossing programme

F_1's from crosses attempted during previous year were grown and found intermediate between two parents. Seeds were collected to grow F_2 generation.

Table 38 : Selection of mutants under different treatments

No.	Variety	Doses (kgy)	Mutants (no)
1.	Ratan	0.3	8
		0.4	39
2.	Mahatewda	0.3	07
		0.4	47
3.	Prateek	0.3	2
		0.4	17

Table 39 : Inter-varietal crosses in grasspea

S.No.	Crosses	No. Pollinations made	No. of Seed set
1.	Ratan x Mahateora	87	14
2.	Mahateora x Ratan	52	21

New crosses were also attempted between Ratan and Mahateora in both the directions using male as well as female parents (Table 38 and 39).

2. Chickpea (*Cicer arietinum* L.)

(A) Plant genetic resources (Rejuvenation and Characterization)

Total 2262 germplasm lines including 1015 new set of genotypes collected from NBPGR, and already existing 1247 genotypes including 64 breeding lines from ICRISAT were further multiplied and evaluated for descriptor based agro-economic traits during *rabi* 2017-18. High magnitude of variability was observed among the genotypes. Promising genotypes were identified for further validation. Few trait specific genotypes were identified as unique genotypes for further utilization in various breeding programmes (Fig. 124).

(1) Chickpea core germplasm (NBPGR)

Chickpea core collections were characterized and promising genotypes were identified (Table 40, 41 & 42; Fig. 125 & 126).

Table 40 : Variability among the germplasm lines of NBPGR Core set

S.N.	Character	Range	Promising genotypes
		Min-Max	
1	Days to 50% flowering	40-94	IC 305602 (40 d), IC 52174 (43d)
2	Days to maturity	100-142	EC 267504 (100 d), EC 407911 (100 d), IC 554984 (101d), IC 468644 (101d), IC 272224 (102 d), IC 244372, IC 269583 (102d)
3	Branches/plant	2 -6	IC 350844 (6), IC 118913 (5), IC 209552 (5), IC 270867 (5), IC 272252 (5)
4	Plant height (cm)	28-100	IC-408212 (100cm)
5	100 seed weight (g)	6 - 45	IC 299218 (44.80)
6	Pods per plant	24-75	EC 555720 (75)
7	No. of seeds/plant	25 -122	EC 555720 (122)
8	No. of seeds/pod	1-3	EC 555720
9	Biological yield(g)	14.86 -287.08	ICC 2367 (287.08 g)
10	Seed yield(g)/ plant	6.46 – 179.74	EC 555720
11	Harvest index (%)	14.36 – 99.90	IC 512070

(a) Angular double podding (b) Normal podding (c) Compact podding (d) distant podding

Fig. 124 (a-d) : Variability for podding behaviour in chickpea

Table 41 : Variability among the ICRISAT breeding lines (64)

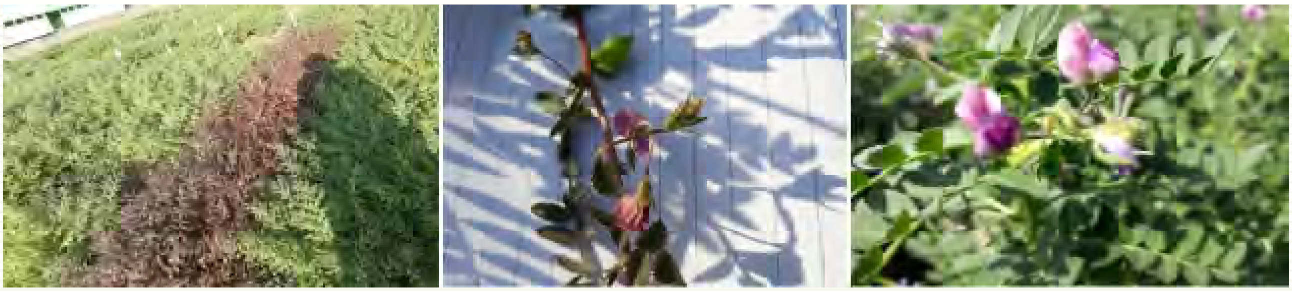
S.N.	Character	Range Min-max	Promising genotypes
1	Days to 50% flowering	34-44	PAO8016R (34 d), PAO8116R (34 d), PAO3716R (34 d)
2	Days to maturity (d)	95-112	POA8016R(95 d), PAO3216R(95 d), PAO3416R(95 d), PAO3616R(95 d)
3	Primary branches / plant	1-7	PAO3216R (7), PAO3416R (6)
4	Plant height (cm)	32.5-75	PAO8016R (75)
5	100 seed weight (g)	12-44	PAO8016R (44g)
6	Pods per plant	47-96	PAO3716R (96)
7	No. of seeds /plant	42-162	PAO3716R (162)
8	No. of seeds /pod	1-3	PAO3716R
9	Biological yield (g)	16.9-253.25	PAO8016R (253.25g), PAO3716R (133.5g)
10	Seed yield / plant (g)	13.26 - 80.02	PAO3716R (80.02 g), PAO3716R (70.76 g)
11	Harvest index (%)	11.65-156.74	PAO8016R (156.74%)

(a) Leaf variant of PAO 8016R (b) High no. of primary branching (PAO3216R)

Fig. 125 : Variants identified in ICRISAT breeding lines

Table 42 : Trait specific chickpea genotypes identified for utilization in breeding programme

S.N.	Traits	Genotypes
1.	Early maturity (d)	EC-267504 (100 d), EC-407911 (100 d), IC-554984 (101d), IC 468644 (101d), IC-272224 (102 d), IC-244372, IC 269583 (102d)
2.	Mechanical harvesting	**IC-408212 (100cm),** IC-267159, IC-118913, IC-244174, IC-382406, IC-348481, IC-83999, IC 244325, IC 83992, IC 84028, IC 84005, IC 84030, IC 83011, IC 294173, IC 84003, IC 244340, IC 118913, IC 244174
3.	Multiple flowers / pods with high anthocyanine content	**IC 395468**
4.	High anthocyanine content	IC 244384, IC 393468, IC-270969
5.	Flattened stem	**IC 424391**, IC 83743, IC 244613 and IC 83745
6.	Gigas leaf / pod variant	EC 267494
7.	Multi-pinnate types	IC 270944, IC-328146, IC 328746, IC 270344
8.	Compact leaf types	IC 248076, 116483, IC 428043, IC 365603, IC 3056033, IC 116343
9.	Simple leaf types	IC 551991, IC 244181, IC 275224, IC 328034, IC 486882, IC 487344, IC 84021, EC 547382, IC 481344, IC 82021, IC 834021, IC 486882, IC 551991, IC 328034, IC 468764, IC 275224



(a) High anthocyanine content (b) 3-5 flowers/peduncle (c) 3 flowers/peduncle

(d) Flattened stem (e) Simple leaf (f) Mmultipinnate leaf (g) Compact leaf

Fig. 126 : Variation in core and collections from NBPGR, New Delhi

Pre breeding and wild genera / species

Vigna: 18 wild accessions of 09 wild species are being maintained in wild pulse garden (Fig. 127).

Pigeonpea: Total 29 breeding lines generated from twenty parental genotypes including F_1, F_2, F_3, F_4 and F_5 generations were grown during *Kharif* 2017. All the lines showed variability for various agro-economic

Fig. 127 : *Wild* sp. of pulses grown in pre-breeding garden

traits. These were harvested separately to advance further.

NICRA: Experiments on chickpea and lentil for drought and heat tolerance were conducted and data supplied to concerned scientists at IIPR, Kanpur headquarters (Fig. 128).

Results revealed that application of 5 t/ha FYM to soybean recorded significantly higher growth parameter, yield attributing character and yield of soybean and its residual effect also significant on succeeding chickpea crop over no FYM. Further higher seed yield of soybean was recorded when soybean was

(a) Lentil mapping populations (b) Chickpea early sowing (c) Chickpea late sowing

Fig. 128 (a-c) : NICRA experiments conducted at IIPR, RS, Bhopal

Station trials: Three station trials were conducted

1. **Lentil:** 45 lines were grown and evaluated for grain yield in three replications for Central region. IPL-161435 gave highest yield (1.300 Kg / 8.4 m2) followed by IPL-161441 (1.140 Kg / 8.4 m2), IPL-11718 (1.102 Kg/ 8.4 m2) and performed better than check IPL 316.
2. **Chickpea:** 29 lines in three replications were grown and evaluated for grain yield for Central region. It was found that IPC 16-165 (3.25 Kg / 6m2), IPC 16-200 (3.05 Kg / 6m2), IPC 16-14 (2.65 Kg / 6m2) performed better than checks i,e, JG 16 and JG 14.
3. **Urdbean:** 18 lines in three replications were grown and evaluated for grain yield for Central region. It was reported that IPU 13-7 (250.5g / m2), IPU 11-6 (266.3 g / 6 m2), IPU 10-33 (181.3 g /6 m2), IPU 12-5 (204.3 g / 6 m2), IPU 12-4 (203.7 g/ 6 m2) performed better than checks i,e, Uttara and IPU 2-43.

Enhancing Productivity and Nutrient Use Efficiency through Micronutrient Management in Soybean – Chickpea System in Central India

An field experiment was carried out at IIPR, Regional station, Phanda, Bhopal to alleviate the micronutrient stress in soybean-chickpea system. The objective was increase the productivity, nutrient use efficiency and total farm income through FYM and micronutrient management in vertisols of Central India.

fertilized with ammonium molybdate 1 g/ kg seed treatment + 0.5 % foliar spray of $ZnSo_4$ over rest of treatments except ammonium molybdate 1 g/kg seed treatment + 25 kg/ha $ZnSo_4$ and ammonium molybdate 1 kg/ha soil application + 25 kg/ha $ZnSo_4$. However, residual effect of ammonium molybdate 1 kg/ha soil application + 25 kg/ha $ZnSo_4$ recorded significantly higher yield attributing character and yield of succeeding chickpea crop but remained on par with ammonium molybdate 1 g/kg seed treatment + 25 kg/ ha $ZnSo_4$ and ammonium molybdate 1 g/ kg seed treatment + 0.5 %.foliar spray of $ZnSo_{4.}$

It is evident from the results that application of 5 t/ha FYM recorded significantly higher soybean equivalent yield (3488 kg/ha) in soybean-chickpea system over no FYM application (Table 43 & Fig. 129). Further, application of ammonium molybdate 1 kg/ha

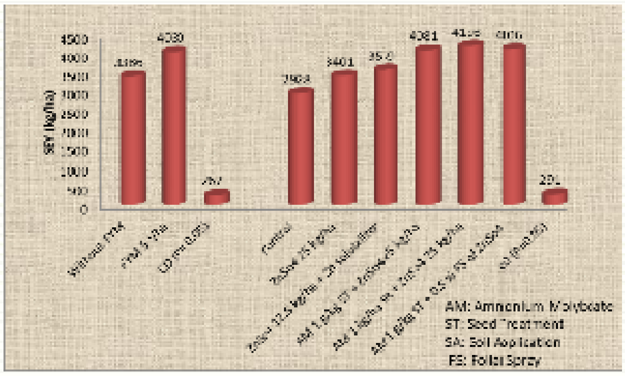


Fig.129: System productivity (SEY) under varying levels of FYM and micronutrient management

Table 43 : Effect of FYM and micronutrient management on seed, haulm biological yield and harvest index of soybean and chickpea

Treatment	Soybean				Chickpea			
	Grain yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Grain yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
FYM								
Without FYM	820	1630	2450	34	1675	1666	3341	50
FYM 5 t/ha	1096	2085	3181	35	1922	1865	3786	51
CD (P= 0.05)	237	65	283	NS	202	121	322	NS
Micronutrient management								
Control	701	1284	1985	35	1454	1464	2918	50
$ZnSo_4$ 25 kg/ha	889	1669	2558	35	1641	1663	3304	50
$ZnSo_4$ 12.5 kg/ha + Zn solubilizer	923	1709	2632	35	1721	1722	3444	50
Ammonium molibdate 1 g/kg seed treatment + $ZnSo_4$ 25 kg/ha	1045	2107	3152	33	1982	1914	3896	51
Ammonium molibdate 1 kg soil application + $ZnSo_4$ 25 kg/ha	1085	2159	3244	34	2032	1948	3980	51
Ammonium molibdate 1 g/kg seed treatment + 0.5 % foliar spray of $ZnSo_4$	1104	2218	3322	33	1960	1881	3841	51
CD (P=0.05)	111	373	369	NS	184	181	265	NS

soil application + 25 kg/ha $ZnSo_4$ fetched significantly higher system productivity (3648 kg/ha) in terms of soybean equivalent yield over preceded levels. However, it was remained statistically identical with ammonium molybdate 1 g/kg seed treatment + 25 kg/ha $ZnSo_4$ and ammonium molybdate 1 g/kg seed treatment + 0.5 % foliar spray of $ZnSo_4$.

Seed production and quality enhancement in pulses

Sub-Project Objective: To enhance field emergence of extra large seeded *kabuli* chickpea

A collaborative experiment was conducted at IIPR, RS, Phanda, Bhopal (field study) & IIPR, Kanpur (physiological and biochemical analysis) to check the efficacy of different seed priming agents on improving field emergence and yield of extra large seeded kabuli chickpea *cv* Kripa. Priming in general improved the field emergence of kabuli chickpea especially with hydro-priming and osmotic priming with polyethylene glycol @ -1.0 MPa. Primed seeds have high seed vigour at field conditions than control. Plot yield is also higher in primed seeds than control, highest in PEG-1.0Mpa followed by hydropriming. Laboratory germination percent was improved by all the priming treatments but most of all by PEG -1.0Mpa and hydro-priming respectively. SDS PAGE profiling indicated the differential expression of proteins with seed priming. Notably, protein of 89 kDa was expressed in all the priming treatments except for control (Fig. 130). Similarly, proteins of 20 and 25 kDa were expressed in seeds primed with PEG, mannitol, salicylic acid and hydro-priming, while a 12 kDa protein was induced only by hydro-priming. In general, the band intensity as well as the number of proteins induced by seed priming increased over control. The sugar content of the seed (total, reducing and non-reducing) was significantly affected by different seed priming treatments. The highest contents of total (11.16 mg g^{-1} fresh weight) and reducing sugars (8.22 mg g^{-1} fresh weight) were recorded in the seeds primed with PEG - 1.5 Mpa for 24 h. The electrical conductivity of seed leachate was significantly affected by seed priming

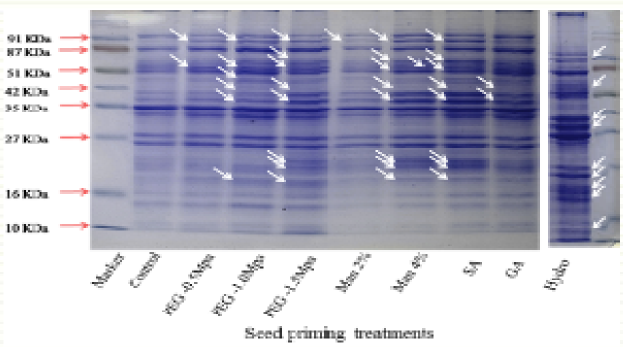


Fig.130: Electrophoresis pattern and molecular weight of expressed protein

treatments; control recorded the highest value and lowest in salicylic acid. It is evident that priming process leads to repair mechanism of membrane, enhancing its stability as primed seeds recorded low electrical conductivity of seed leachate than unprimed control.

Breeder Seed Production at Bhopal

The following breeder seed production program was taken up under Additional Breeder seed production programme of DAC. The production was better for each crop and variety as compared to given target (Table 44 & 45).

Table 44 : Breeder seed (ABSP) production in Kharif 2017 at IIPR, RS, Bhopal

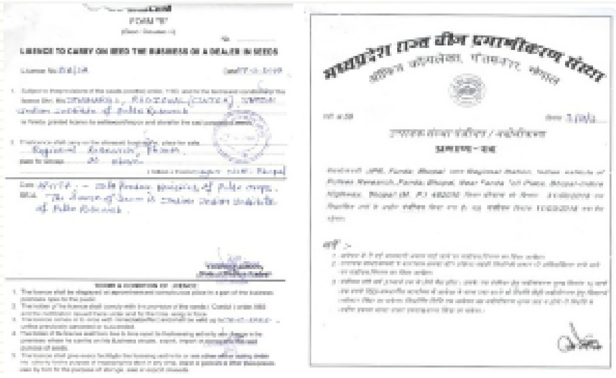
Crop	Target	Variety	Year of release	Production (q)	Surplus/ deficit (q)
Pigeonpea	20.00	TIJ 501	2009	45.00	+ 23.00
Urdbean	15.00	IPU 2-43	2009	22.00	+ 22.00
Mungbean	20.00	IPM 2-3	2009	15.00	
		Virat	2016	5.00	
		Sikha	2016	5.00	
Total				25.00	+ 5.00

Table 45 : Breeder seed (ABSP) production during Rabi 2017-18 at IIPR, RS, Bhopal

Crop	Target (q)	Variety	Year of release	Production (q)	Surplus or deficit (q)
Chickpea	20.00	JG 14	2009	05.00	
		RVG 202	2012	104.00	
		RVG 203	2012	39.00	
		Shubhra	2009	06.00	
Total	**20.00**			**154.00**	**+ 134.00**
Lentil	28.00	IPL 316	2016	40.00	+ 12.00

Seed Hub

Seed hub program of DAC & FW is operational at Bhopal station with the licence for seed business and registered at MPSSCA, Bhopal for quality seed certification. Quality seeds were produced more than the given target with the farmer's participatory seed approach under seed hub project funded and continuously monitored by DAC, Govt. of India (Table 46).

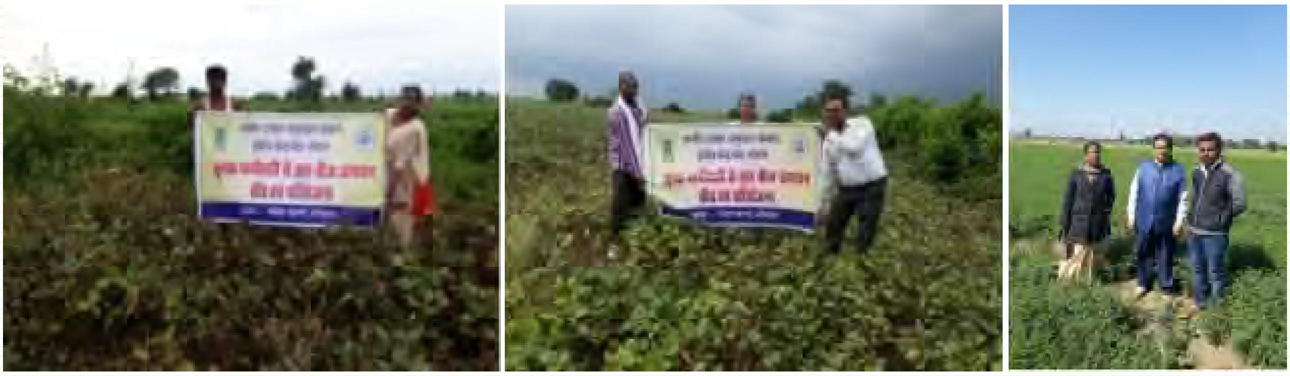


Licence to carry on seed business and registration with M.P. seed certification agency

Table 46 : Quality Seed Production under seed hub Seed Hub) at IIPR, Regional Station, Bhopal

Crop	Production (q)	Varieties taken
Mungbean	84.72	IPM 2-3, IPM 2-14, Samrat
Urdbean	52.47	IPU 2-43, Uttara
Chickpea	460.00	RVG 202, RVG 203, Subhra, JG 14
Lentil	70.00	IPL 316
Fieldpea	210.00	Aman, IPFD 10-12, IPF 4-9, Prakash
Pigeonpea	360.00	IPA 203, TJT 501
Total	1237.19	On against target of 100 Q.

Breeder seed monitoring by NSC and M.P. State seed certification officers



Monitoring of seed prog. (Storage structures) under EBSP & Seed Hub by DAC / DPD, Bhopal

Technology demonstration

Pulse technology demonstration during *Kharif, Rabi* and zaid has been conducted to popularize the best available technology for farmers of Madhya Pradesh

Frontline Demonstration

I. **Transfer of technology:** New varieties with full package of practices of chickpea, pigeonpea, lentil, mungbean and urdbean has been given to farmers. Besides advice and continuous visits have been arranged to nearby villages in Bhopal and Sehore districts. We have visited number of farmers in Phanda village and they have initiated growing *kharif* pulses instead of soybean.

II. **Education and training:** Mentoring trainees through MANAGE, Hyderabad by conducting Certified Farm Advisory program Module - III.

Chickpea verity RVG 202 grown with amla (*Emalia officinalis*) tree as an intercrop

New initiative for summer mung demonstration at the Research Station

Table 47 : FLD on chickpea and Lentil conducted at IIPR, RS, Bhopal

S.N.	Village	Name of farmer	Area (ha)	Veriety	Improved var. yield (q/ha)	Farmer's variety (local) yield (q/ha)
1	Fanda Kala	Lakhan singh	1	Shubhra	18 .0 q	12.5
2	Fanda Kala	Kumer Singh	1	RVG-202	21.3 q	11.2
3	Fanda Kala	Uday Singh	1	RVG-203	19.1 q	14.0
4	Fanda Kala	Ram Singh	1	JG-14	20.4 q	11.3
5	Fanda Kala	Mukesh Mewada	1	RVG 202	21.59 q	11.1
FLD on lentil conducted at IIPR, RS, Bhopal						
1	Bhensaya Nagin	Raghuveer Singh	1	IPL-316	15.5 q	12.3
2	Khamaliya	Bhojraj Singh	1	IPL-316	19.17 q	13.8
3	Amlaha	Suneel Verma	1	IPL-316	16.45 q	11.7
4	Jamni	Ramlal Nagar	1	IPL-316	15.0 q	11.1
5	Fanda Kala	Mukesh	1	IPL-316	17.0 q	12.0

III. Visits of dignitaries

Officer's visits

1. Director, IIPR visited and monitored research activities (Field IRC on 09.02.2018) at station
2. Dr.N.P. Singh, Director, NIABSM, Baramati, Pune visited station on 29.08.2017 and appreciated our efforts
3. Dr Ashok Kumar, Principal Scientist & Head, Germplasm Evaluation Division, NBPGR, visited chickpea field during crop season
4. Former chairman with Director, Geologists and hydrologists, CGWB, Bhopal, Govt. of India visited Research Station.

Farmers visit

Developmental activities

1. Culverts (03)
2. Chain link fencing (Total area closed)
3. WBM and CC road
4. One new pond have been developed (80×50 m)
5. One pond deepening was done (80×50 m)
6. Threshing floor (113×93 ft)
7. Storage (2 unit) and processing unit (01)
8. Approach road to seeds stores constructed
9. Two tractors purchased
10. Movable mini sprinkler kit (04 sets) has been procured to ensure *rabi* crops irrigation at station
11. Boundary wall painted with apple green and lemon shades of Narolac paints
12. Lease line (10 mbps) and internet system with EPABX of BSNL has been setup
13. Irrigation channels are being constructed
14. Fields are being levelled by JCB
15. Plantations have been done
16. Heavy racks for seed storage purpose have been purchased
17. Purchase and installation of Sprinkler irrigation system is under process
18. Purchase and installation of seed processing machine is under process
19. Online UPS procured to avoid power interruption in official works
20. Constriction of office building, equipment shed and labour shed is under process.

Table 48 : Farmers visited under Mukhyamantri khet tirth yojana of Govt. of M.P.

S.No.	Place	No. of farmer's	Date
1.	Shujalpur	12	08/06/17
2.	Shajapur	09	08/06/17
3.	Kalapipal	08	03/01/18
4.	Vidisha	40	04/01/18
5.	Barwani	45	10/02/18
6.	Agarmalwa	65	12/02/18
7.	Agarmalwa	30	17/02/18

Table 49 : Students visited under excursion tour

S.No.	Place	No. of students	Date
1.	S.R.K. Univ.	60	14/09/18
2.	Manage Students	25	12/12/17

Monitoring of chickpea core set of germplasm at IIPR, RS, Bhopal

Farmers visit

IIPR-Regional Research Centre (RRC) *cum* Off-Season Nursery, Dharwad, Karnataka

Crop Improvement

Plant genetic resources management and its utilization through pre-breeding

Mungbean and urdbean

- Total 296 accessions of mungbean-mini-core collected from world vegetable centre, Hyderabad were rejuvenated and evaluated for different traits during kharif, 2017-18, at IIPR-Regional Research Centre, Dharwad. The entry VI003440 (55 days) was the earliest to mature followed by VI005066AGM (57 days) and VI001728AG (59 days).
- Total 175 accessions of urdbean germplasm were rejuvenated and evaluated for various traits during both kharif and rabi 2017-18. The entries NO-5131 (63 days) and NG-2119 (64 days) were the earliest to mature followed by VH-99-149 (67 days).


Evaluation and rejuvenation of mungbean and urdbean germplasm

Management of plant genetic resources and genetic enhancement for grain yield and resistance to multiple diseases in cowpea and horsegram

Cowpea

- Total 110 accessions of cowpea germplasm were rejuvenated and evaluated for different morphological traits during kharif/rabi 2017-18. Wide range of variations was observed for pod length, flower color, seed coat color and seed size. The entries such as PL-4 (76 days), CPP-6 (76 days) and CPP-16 (76 days), were the earliest to mature followed by CPP-1 (77 days).
- **Generation of breeding materials**: Five Fresh crosses were made involving donor lines for earliness, large seed size and resistance to powdery mildew and YMV disease with DC-47-1, Goa cowpea-3, CO-2, DC-15 and CO-7. Seven crosses from different generations (F_2-F_3) were advanced. Individual plant selections were made based on their superiority for yield and disease resistance traits.

Horsegram

- Total 120 accessions of horsegram germplasm were rejuvenated and evaluated for different morphological traits during rabi 2017-18. Wide range of variations was observed for different morphological traits. The entries such as GPM-5 (80 days), GPM-171 (80 days) and TCR-1700 (81 days) were the earliest to mature followed by AK-42 (81 days) and GPM-63 (83 days). While, the entries such as GPM-33 (98 days), GPM-50 (97 days), GPM-49 (96 days) and TCR-1799 (96 days) took more number of days to mature.


Evaluation of cowpea and horsegram germplasm

- **Generation of breeding materials**: Five Fresh crosses were made (CRIDA 18 R X VLG-48, VLG-15 X VLG-10, CRIDA-18R X VLG-15, CRIDA18R X VLG-10, VLG-19 X VLG-10) involving donor lines with earliness, high biomass and resistance to powdery mildew disease . Six crosses from different generations (F_1-F_2 & F_2-F_3) were advanced. Individual plant selections were made based on their superiority for yield and disease resistance traits.

Genetic enhancement of pulse crops for yield, stability and quality

Station trials of mungbean and urdbean

Station trial of mungbean comprises 20 entries were evaluated during kharif season. The entries such as IPM-312-394-1 (57) and IPM-312-394-3 (59) were the earliest to mature. The genotype, IPM-410-3 (1659

Kg/ha) was recorded highest seed yield followed by IPM-312-394-3 (1592 Kg/ha).

Evaluation of advance breeding lines of mungbean

Station trial of urdbean comprises 18 entries were evaluated during kharif season-2017-18. The genotypes, IPU-177 (1329 Kg/ha) and IPU-13-1 (1205 Kg/ha) were produced higher yield compared to check variety-IPU-2-43 (1150 Kg/ha).

Station trials of chickpea (*desi* and *Kabuli*)

Station trials of chickpea (2 Desi + 1 Kabuli) were conducted under rain fed conditions during the *rabi* season 2017-18.

In chickpea (desi) station trial-I (23 entries including 3 checks, Tall plant types) the genotype, IPC-2014-143 (92 days) was the earliest to mature followed by IPC-2014-171 (93 days) and JG-11 (94 days). The genotypes, IPC-2014-171 (1260 kg/ha), IPC-2015-50 (1207 kg/ha) and IPC-2014-167 (1180 Kg/ha) produced higher yield over the best check JG-11 (910 kg/ha).

In chickpea (desi) station trial-II (45 entries including 3 checks), the genotype IPC-2016-127 (91 days) and IPC-2016-238 (92 days) were the earliest to mature compared to check, JG-16 (95 days). The genotypes such as IPC-2016-224 (1070 Kg/ha) and IPC-2016-227 (902 Kg/ha) were produced higher seed yield over the check JG-16 (850 Kg/ha). Most of the entries revealed highly susceptible reaction to rust disease under field conditions, however, entries such as IPC-2016-197, IPC-2016-231, IPC-2016-15 and IPC-2016-227 were found to be moderately resistant to rust disease under field condition.

In Chickpea (kabuli) station trial-III (33 entries including 3 checks), the genotype, IPCK-2015-265 (95 days) was the earliest to mature followed by IPCK-2015-111 (96 days). IPCK-2014-137 (1168 kg/ha) and IPCK-2014-26 (1095 kg/ha) produced higher yield compared to check varieties-IPCK-2002-29 (1040 kg/ha) and KAK-2 (920 Kg/ha). Most of the entries produced lower yield due to severe incidence of chickpea rust during crop growth period.

Station trials of chickpea (Desi and Kabuli) advance breeding lines

Generation of breeding materials

Mungbean and urdbean

Fresh crosses were attempted in mungbean (IPM-2-14 x TCR-188) and urdbean (PGRU-95016 x TCR-188). 18 F_5 and 12 F_2 s populations of urdbean have been sown for generation advancement and made single plant selection during *kharif.*

Chickpea rust disease severity in station trials (desi and kabuli)

Chickpea

Segregating populations of chickpea (F_{6-7}) (JG 11 × ICC 13124, JG 11 × WR 315, BGD 103 × ICC-13124 and BGD 103 × WR-315) and selections from ICRISAT chickpea breeding materials were sown for generation advancement and made promising individual plant selections during *rabi,*

Entries in State MLT

Two promising entries of mungbean (IPM-14-28 and IPM-406-1) and urdbean (IPU-11-2, IPU-12-30) were entered in state multi-location trials and were evaluated under different agro-climatic zones of Karnataka.

Off-season generation advancement of pulses

Chickpea and lentil

During the year, 2017-18 segregating materials for generation advancement were received from 8 centers of AICRP on chickpea such as Banswara (28 lines), Sehore (50 lines), Rahuri (15 lines), Ludhiana (568 lines), Junagarh (14 lines), Sriganganagar (8 lines), Coimbatore (20 lines) and Hisar (10 lines). Chickpea (F_2 & Mapping populations) and lentil (106 lines) were received from IIPR, Kanpur. The generation advancement was performed at the IIPR RRC *cum* Off-Season Nursery, Dharwad during the *Kharif* 2017-18 and advanced breeding materials were sent to the respective centers. Fresh crosses were also successfully attempted in chickpea during off-season.

Generation advancement of chickpea and lentil during off-season

Breeder / TL seed production

During *kharif*, breeder seed of mungbean cv. IPM 2-14 (200 kg) and urdbean cv. IPU-2-43 (250 kg) were produced under rain fed condition on about 3 ha area.

During *rabi*, breeder seed production of Kabuli chickpea varieties such as (IPCK 2002-29 and IPCK-2004-29) were undertaken on more than 3.0 acres and produced sum total seed yield of about 290 kg. TL seed production of chickpea variety-JG-11 was done on about 1 acre and produced seed yield was about 200 Kg. In horsegram variety-CRIDA-18 was produced TL seed of about 200 Kg.

Crop Production

Enhancing productivity in diverse pulses based cropping systems through improved nutrient management in Peninsular India

A Field experiment was conducted during 2017-18 at IIPR Regional research centre, Dharwad consisting of two cropping systems *viz.,* 1) Maize (NK 4250) –Chickpea(JG 11) and 2) Soybean(DSB 21) - Chickpea, two conservation practices *viz.;* 1) conventional system 2) conservation system i.e., (mulching with maize straw); h three Fertilizer

Table 50 : Chickpea equivalent yield

Cropping system	CEY (kg/ha)
1. Maize –chickpea	14834.5
2. Soybean- chickpea	8550
Cd (5%)	790
Conservation practice	
1. Conservation(M+)	12399
2. Conventional (M-)	10586
Cd (5%)	260
Fertilizer application	
1. Control	6874
2. 100-100	8650
3. 100-50	7460
Cd (5%)	150

Deputy Director of Agriculture, Dharwad monitored the breeder seed plots of mungbean and chickpea application practices *viz.,* 1) Control 2) 100% RPP to Kharif and Rabi crop (100-100) and3) 100% RPP to kharif and 50% RPP to Rabi crop (100-50) .The results relieved that chickpea equivalent yield of maize-chickpea was 14834.5 kg/ha and that of soybean-chickpea system was 8550 kg/ha. There was 17% increase in CEY in conservation practice as compared to conventional system. In fertilizer treatments, 100-100 recorded highest CEY (8650 kg/ha) (Table 50).

Pulses based cropping systems

Effect of liquid and carrier based bio-fertilizers on urdbean

An experiment was conducted at IIPR Regional Centre, Dharwad, to study the performance of carrier based and liquid inoculants of bio-fertilizers along with different doses of RDF and its effect on soil properties in urdbean. The experiment was a randomized complete block design with thirteen treatments and threereplication, The experiment revealed that, T_{12} (125 % RDF + *Rhizoium* + PSB, liquid based) performed better when compared to other treatments, with respect

Liquid bio-ferilizer experiment in urdbean

to growth, effective root nodules per plant (35), dry matter production at harvest (20.1 g/plant), Number of pods per plant (30.1), test weight (5.4g), Seed yield (1020 kg ha^{1}), enzyme activity peak flowering stage and nutrient uptake.

Crop Protection

Establishment of nursery for screening of pigeonpea sterility mosaic disease

Pigeonpea sterility mosaic disease (PSMD) caused by *Pigeonpea Sterility Mosaic Virus* (*PPSMV*),a species of the genus *Emaravirus* is an important constraint for pigeonpea production in Southern and North Eastern Plains of India. Pigeonpea sterility mosaic disease nursery was established at ICAR-IIPR, Regional Research Center, Dharwad, Karnataka to screen and identify the resistance sources. Initially, during Kharif season 2016 a susceptible check of pigeonpea (ICP 8863) was planted and ratooned during summer season 2017 to get natural infection of SMD. Later, the infector rows of ICP 8863 were planted in first fortnight of July, 2017 and leaf stapling technique was adopted to spread the disease in infector rows. The average disease incidencein the infector rows was 92.59 percent. Thus, the established nursery will be of great value for searching resistant sources in pigeonpea against sterility mosaic disease.

SMD infected plant

Infector Row

PSMD Nursery

Screening of pigeonpea genotypes against sterility mosaic disease

During *kharif* season, 22 pigeonpea wilt resistant entries were screened with leaf stapling technique. Among which five entries namely, P479, ICP70-35, DPPA 85-1, P96169B and DPPA85-8 were found resistant, Five entries were moderately resistant viz., KPL44, IPA8F, Bahar, PH1063 and ICP2014-4A and remaining 12 genotypes were found susceptible. The disease incidence among genotypes was ranged between 0 to 94.1 percent. The average disease incidence in the infector rows was 92.59 percent.

Screening of horsegram (*Macrotyloma uniflorum*) genotypes against powdery mildew caused by *Erysiphe polygoni*

Twenty two entries were screened for powdery mildew resistance. Percent disease index was ranged between 4.4 to 100%. Disease development was very high with 100 percent PDI in susceptible check (Crida-18R). Among which, Two entries were found resistant namely, TCR1771 and TCR1825. Two entries were found moderately resistant namely, TCR1805 and TCR1729. Remaining genotypes were reported to be moderately susceptible to highly susceptible.

Screening of cowpea (*Vigna unguiculata*) genotypes against powdery mildew caused by *Erysiphe polygoni*

Twenty cowpea entries including AICRP were screened against powdery mildew. Percent Disease index (PDI) among genotypes was ranged between 0-88.8%. Out of 20 genotypes, One entry CPP14 was found immune. Three entries namely, DC47, Co-4 and CPP4 were found moderately resistant with PDI of 10-25%. Remaining17 lines were reported to be moderately susceptible to highly susceptible

Evaluation of fungicides against chickpea rust

Efficacy of five fungicides namely, Difenconazole (0.1%), Propiconazole (0.1%), Corbendazim+Mancozeb (0.2%), Thiophanate methyl (0.1%) and Tebuconazole (0.1%) was evaluated against rust disease under field conditions. The rust disease incidence was 100% and severity was 98.66 %. Tebuconozole found effective with 29.1 percent reduction over control followed by Defenconozole (27%).







Severe outbreak of rust *Uromyces ciceris arietini* in chickpea

Heavy incidence and severity of chickpea disease was observed at IIPR-regional research centre and farmer's fields. The planting of chickpea was done on second fortnight of October 2017 and the disease appearance was observed during first fortnight of December 2017. Based on visual symptoms the disease was identified as rust, which is caused by *Uromyces ciceris arietini*. The leaves were covered with brown concentric pustules later stages they coalesce to form bigger pustules. Morphology of the spore was studied to confirm the disease. Globose to subglobose shaped with echinulations and cinnamon coloured uredospores were observed. A total 70 entries were observed for rust incidence and severity. The disease incidence was 100% and severity ranged between 76 to 100%.


Incidence of insect pests in different pulses crops and arid legume

Field trials were conducted during Kharif and Rabi season 2017-18 to record the incidence of insect pests in different pulses crops at RRC, Dharwad. Pod borer *Maruca vitrata* was found to be a major borer pest on pulses. During Kharif, the per cent pod damage in mung (cv. IPM 2-14) was 24.87 and 41.30 and 42.40 in cowpea varieties DC-15 and DC-47, respectively. Whereas, during Rabi season the percent pod damage in cowpea was 24.90 and 27.50 in DC-15 and DC-47, respectively. The percent borer damage in Rabi season was somewhat lower as compared to Kharif season. Black aphid (*Aphis cariccivora*) was major sucking pests occurring in large colonies on stem, flowers and pods of the crop. During Kharif season the scale of black aphid was 9 in mung and cowpea, whereas in Rabi season, it was 5 and 7 scale in DC 15 and DC 47 of cowpea varieties, respectively. Cowpea thrips, Bhiar hairy caterpillar were other minor insect pests observed in cowpea.

Pod damage by *M. vitrata* on mungbean

***M. vitrata* feeding flower buds**

Black aphids on mungbean

Black aphids on cowpea

***Spilosoma* sp. on cowpea**

Developmental activities


Installed Cemented Rings

Laboratory cum office building works in progress


Visit of Dr. N.P. Singh (Director, IIPR, Kanpur) and Dr. Masood Ali (Ex. Director, IIPR)

All India Coordinated Research Projects

CHICKPEA

Varieties released and notified

Meera (GNG 2171): The *desi* type chickpea variety developed from the cross GNG 663 X BG 1044 is suitable for timely sown irrigated conditions of NWPZ. It has an average yield of 2014 kg/ha and has significant yield superiority over the check varieties. GNG 2171 is tolerant to *Fusarium* wilt disease and has yellow coloured seed of size 15.9 gm/100-seed. The variety has been released and notified for NWPZ comprising the states of Punjab, Haryana, Western U.P., Jammu & Kashmir, Delhi, Northern Rajasthan, Himachal Pradesh and Uttarakhand.

Gujarat Gram 5 (GJG 0809): This variety has been developed from the cross GJG 9707 X IPC 97-7 and released and notified for NHZ comprising of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and NEH region. Its average yield is 15-16 q/ha. It matures in 157 to 160 days in NHZ. It has attractive brown colour seed and medium seed size and semi erect growth habit. It is also moderately resistant to wilt, stunt & root and tolerance to Ascochyta blight. The variety has been identified for release in NHZ comprising of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and North Eastern Hill Regions.

Promising entries

The following entries out yielded the best check variety by more than 5% in different trials:

Pre-breeding

Total one hundred and forty five germplasm accessions including primitive landraces possessing specific traits were maintained at IIPR, Kanpur. Forty six accessions of *C. reticulatum*; 38 of *C. judaicum*; 17 of *C. pinnatifidum*; 5 of *C. echinospermum*; 3 of *C. cuneatum* and 2 of *C. yamashitae* could be maintained in wide hybridization garden. Accessions ILWC 115 and ILWC 21 confirmed presence of heat tolerance with pod setting at >35°C. Fresh crosses were developed in *kabuli* chickpea utilizing accessions ICC 14194 and ILC 3279. Trait specific stocks at different segregating generations derived out of pre-breeding programme in *kabuli* were duly maintained and evaluated. Number of segregating populations of *kabuli* chickpea in different generations and consequent germplasm accessions utilized (in parentheses) are

Trial	Zone	Promising entries (kg/ha)
AVT-2 (*Desi*)	NEPZ	GNG 2264 (1638), [KWR 108 (1399) (ch)]
IVT (*Desi*)	NWPZ	H 13-36 (3327), [GNG 1958 (3145) (ch)]
	NEPZ	KGD 13-36 (1814), DC 16-2 (1756), BRC 1 (1751), RG 2011-02 (1656), CSJ 907 (1648), H 13-36 (1626), H 12-63 (1623), GL 13001 (1614), RKG 13-380 (1610). BG 3075 (1596), CSJ 866 (1578), RKG 13-75 (1571), BAUG 108 (1554), AKG 1303 (1536), Phule G 0819 (1536), IPC 12-108 (1529), CSJ 1416 (1519), NDG 15-6 (1516), NBeG 776 (1502), BG 3076 (1494), Phule G 0818 (1470), GNG 2325 (1463), [GCP 105 (1390) (ch)]
	WCZ	Phule G 0818 (2706), AKG 1303 (2610), [JG 16 (2466) (ch)]
	SZ	PBG 503 (1847), NBeG 738 (1825), CSJ 907 (1747), [JG 11 (1650) (ch)]
AVT -2 (Late sown)	NWPZ	GNG 2261 (2384), [GNG 2144 (2315) (ch)]
AVT-1 (Late sown)	NWPZ	H 12-55 (2572), GNG 2299 (2519), [Pusa 547 (2327) (ch)]
	NEPZ	GNG 2299 (1402), [KPG 59 (1304) (ch)]
IVT (Late sown)	NEPZ	RKG 13-515-1 (1851), NBeG 806 (1817), H 12-29 (1596), [Pant G 186 (1504) (ch)]
	ECZ	RKG 13-515-1 (1683), [JSC 56 (1547) (ch)]
IVT (Rainfed)	WCZ	CSJ 824 (2236), [Vijay (2080) (ch)]
	SZ	NBeG 779 (1778), GAG 1423 (1746), [JAKI 9218 (1649) (ch)]
AVT-2 (*Kabuli*)	NWPZ	GNG 2285 (2585), RVSSG 30 (2482), [GNG 1969 (2268) (ch)]
	WCZ	RVSSG 30 (1841), RVSSG 24 (1826), [BGD 128 (1721) (ch)]
IVT (*Kabuli*)	SZ	NBeG 440 (1780), [PG 95311 (1727) (ch)]
IVT (ELSK)	-	GLK 14311 (1860), [PKV 4 (1727) (ch)]
IVT(Mechanical Harvesting)	NWPZ	H 13-09 (2767(, [GNG 1581 (2554) (ch)]
	CZ	RVSSG 8102 (2692), JG 2016-24 (2491), [JG 16 (2323) (ch)]
AVT-1 (DTIL)	-	MABC-WR-SA 1 (2099), NBeG 506 (2065), [Annegiri (1928) (ch)]

Values in parenthesis are grain yield in kg/ha mentioned hereby: Four F_7 populations (ILWC 21, PG 95333, PG 0517); 7 F_6 populations (Gokce, GL 88341, ICC17109, ILWC 21, ILC 3886); 2 F_5 populations (ILWC 245);7 F_4 populations (ICC 14778, ILWC148, ILWC179, ILWC21, ICC 188, ILC 351, ICC 14778);5 F_4 populations (ILC 327, ILWC 21, ILWC 179, ILC 593, ILWC 148); 3 F_2 populations (ICC 14778, ILWC115, ILWC 21).

National Crossing Programme

In order to develop a pool of segregating materials, station and national crossing programme were organized at AICRP-Chickpea centres. Centres attempted 414 crosses as per need of the region under national (88 crosses) and station (326 crosses) crossing programme. Crosses were made under national crossing programme at ARS, Sriganganagar (4); PAU, Ludhiana (4); RARI, Durgapura (20), ARS, Badnapur (2);PDKV, Akola (2); CCSHAU, Hisar (4); MPKV, Rahuri (7); GBPUA&T, Pantnagar (2); RAK COA, Sehore (4); JAU, Junagadh (5); ARS, Indore (4); JNKVV, Jabalpur (6); IGKVV, Raipur (4); NDUA&T, Faizabad (2); RARS, Nandyal (4); TCA, Dholi (2); UAS, Dharwad (5); ARS, Banswara (2); ARS, Kota (4) and BAU, Ranchi (1). The seeds of these crosses will beadvanced and segregating material will be shared among various centres for further selection.

Off-Season Nursery

Segregating materials of chickpea for generation advancement during off season were received from 10 different centres of AICRP *viz*. Rahuri, Ludhiana, Sriganganagar, Kota, Sehore, Junagadh, Jabalpur, Coimbatore, Durgapura and Hisar. Breeding materials of chickpea were duly advanced to next generation at Dharwad. Eleven new crosses were developed during the off season and twenty four F_2 populations were advanced to next generation. PAU, Ludhiana advanced 568 F_3/F_4 lines from various crosses at IIPR, off-season Research Station, Dharwad. At PAU off-season Research Station, Keylong (H.P.), two sets of RILs (one with 140 lines and another of 200 lines) are being advanced. In addition, eight backcrosses and 25 elite parental lines are grown for attempting off-season crosses. Chemically (EMS) induced breeding material in M_2 generation is also being advanced at Keylong.

Genetic resource management

Total 17,488 germplasm accessions were maintained at 20 centres. These accessions were evaluated for morphological traits and are being maintained.

Breeder seed production

Total 11664.89 q of breeder seed of 68 chickpea varieties was produced against DAC indent of 10119.41q including the carry over seed of indented varieties available with seed producing centres.

Crop Production

Agronomy

- Experiments revealed the superiority of Broad Bed Furrow (BBF) with one row of compatible intercrop planted in furrows. This has been confirmed in terms of chickpea equivalent yield (CEY) along with favourable economics at Dharwad (with wheat), Rahuri (with mustard) and Kalaburagi (Gulbarga) (with safflower).
- Studies on critical stage specific supplementary irrigation in chickpea showed that single supplementary irrigations especially at pod development at Rahuri, two irrigations each at branching and pod development at both Dharwad and Kalaburagi were found optimum. However at Kota, sprinkler irrigation schedule at 0.6 IW/CPE (at par with 0.8 IW/CPE) coinciding with the above critical stages resulted in higher grain yield in chickpea.
- Residue retention had resulted in significantly higher productivity in comparison to control plots (without retention) at two locations viz., Shillongani and Kalaburagi, while the effect was not evident at Nandyal.
- On a strategic season-long weed control programme involving combination of pre- and post- emergence broad spectrum herbicides, pre-emergence application of Pendimethalin 38.7 CS or 30 EC at 1 kg/ha PE combined with onehoeing at 30-35 DAS was superior at Ranchi, Banswara, Raipur and Kalyani (where, the latter treatment with 30 EC was the best). At Dharwad, however, Oxyflurofen 23.5% at 0.5 kg/ha, PE was the best.
- Studies on tillage practices influencing crop establishment and productivity of chickpea in rice fallows revealed that conventional tillage followed by line sowing of chickpea was efficient at Ranchi; while relay cropping of chickpea in rice yielded the highest at Shillongani and Kalyani. At Raipur, zero tillage followed by line

sowing of chickpea is advocated.

- Studying suitability of differentrice establishment practices following selection of appropriate varieties in both rice and chickpea, it revealed that unpuddled or direct seeded rice could not influence chickpea yield. However, short duration rice (130 days maturity) and local suited variety of chickpea (Indira chana 1) were better adopted at Raipur.
- With an objective of enhancing productivity in rice fallows through chickpea based mixed cropping system at Imphal (Manipur), it was observed that chickpea 'JG 16' + linseed 'Meera' sown at 75:25 proportion was the best compatible intercropping system at the location. Chickpea grain yield was enhanced significantly with timely planting after harvest of medium duration rice variety.
- Biofortification of Zn and Fe in chickpea through agronomic intervention could bea possible reality in coming times. Invariably, there was a significant difference in nutrient (Zn & Fe) content in seed among different varieties grown at different locations of the country. In most of the trials, combined application of RDF along with Zn and Fe (0.5% Zn+ 0.1% Fe) as foliar sprays at critical stages was effective for biofortification at most of the centres viz., Ludhiana, Pantnagar, Samba, Rahuri, Badnapur, Durgapura, Dharwad, Raipurand Kalaburagi. At Sehore and Junagadh, application of RDF along with $ZnSO_4$ at 25 kg/ ha to soil was beneficial.

Plant Physiology

- Critical daylength for chickpea was worked out to be 11 hour based on experimental trial conducted at five locations *e.g.* Dharwad, Jabalpur, Kota, Ludhiana and Kalyani. The results indicated that chickpea shifts to flowering and reproductive phase when daylength exceeds above 11h.
- Three contrasting environments were identified for chickpea. High yielding locations (Jabalpur and Kota are the places having daylength below 11 h during winter months (Dec-Jan) and this non-inductive conditions along with prevailing mean max/min temperature 30/12 C amazingly favours growth of biomass and producing high yield.
- All the chickpea high yielding locations have essentially 2 months non-inductive conditions <11 h daylength and minimum temperature below 15°C during early vegetative phase to accumulate as much as biomass.
- Under rainfed , a number of potential genotypes have been identified that were characterized by high photosynthetic rates, chlorophyll and NDVI (Normalized Difference Vegetation Index) which was an indication of higher physiological efficiency under limiting moisture condition. These genotypes were Pusa 244, BGD 75, ICCV 96030, JG 12, RSG896, SAKI 9516, ICC 4958, GNG 1488, JG 16, BGD 103, PBG 5 and ICCV 92944.
- Among 30 genotypes tested under late sown conditions, ICCV 92944 showed the highest level of tolerance with heat susceptibility index (HSI) of 0.004 and did not show any reduction in the yield in late sown crop as compared to its normal sown counterpart . Other heat tolerant genotypes having low HSI were PDG 4, Dohad yellow, GNG 663, and RSG 896 . These heat tolerant genotypes repeatedly showing better performance across diverse locations when exposed to high temperature.
- Few promising heat tolerant lines such as Dohad yellow, ICCV 92944, Vaibhav, PDG 4, GPF 2 and BGD 72 showed higher flexibility in increasing the foliar resistance when exposed to high temperature. Dohad Yellow ranked top as heat tolerant genotype having 68% pollen germination followed by ICCV 92944 with 66% and GNG 663 (55%). The same genotypes showed heat tolerance under both the experimental sites Jabalpur and Ludhiana.
- The treatment salicylic acid (SA) along with nutrient (Pulse Magic) increased grain yield and harvest index. The salicylic acid@ 500 nmole was found very effective for enhancing photosynthesis, stomatal conductance, chlorophyll and water-use efficiency in chickpea varieties JG 11 and JG 14. The foliar spray of SA and pulse Magic played a crucial role in mitigating abiotic stresses.

Microbiology

- Fifteen new isolates of mesorhizobia, nodulating chickpea were isolated at Ludhiana centre. Mesorhizobial isolates were screened for plant growth promoting traits and plant infectivity test.

Of 15 *Mesorhizobium* isolates, 5 mesorhizobia LGR-2, LGR-3, LGR-4, LGR- 5 and LGR-12 were identified as best strains for IAA, siderophore, 1-Aminocyclopropane carboxylase deaminase and HCN production, and plant infectivity test.

- Out of 4 new isolates of mesorhizobia tested at Sehore centre, all the new strains were equally effective for symbiotic traits and yield with local isolates RVSRG119 (reference) strain of *Mesorhizobium*.
- Total 277 isolates of endophytic bacteria were made from chickpea nodules and root samples collected at Ludhiana, Pantnagar, Delhi and Hisar. All the isolates were screened for plant growth promoting traits (P-solubilization, IAA and siderphore production). Seven endophytic bacterial isolates [PNE-10(*Bacillus cereus* NCBI Accession No. KR868766) and PNE-12 (*Bacillus aerophilus* NCBI Accession No. KP642129) from Pantnagar, HNE-1(*Pseudomonas flourescens*) and HNE-2(*Bacillus bromophilus*) from Hisar, LNE-1 (*Pseudomonas aeruoginasa*), LRE-1 (*Pseudomonas flourescens* NCBI Accession No.KR303708 from Ludhiana) and DNE-1 (*Enterobacter* sp.) from Delhi were identified with multifunctional traits and also characterized molecularly by 16S rRNA technique.
- Multilocation testing of six elite *Mesorhizobium* strains at five different centres showed that strain LGR-14-2 from Ludhiana and CH 1233 (reference, Hisar) outyielded all other strains with an increase of 17% followed by GBR 13-21 (Kalaburgi) 16.6% and LGR 14-1 (Ludhiana) 16.1% over control. Reference strain F-75 from Delhi increased grain yield by 12% over control.
- Root and nodule endophytic bacteria were used as inoculants at 5 locations as consortium biofertilizer along with *Mesorhizobium* sp. Nodule endophytic strain PNE 10 (Pantnagar) along with *Mesorhizobium* (CH1233), CNE-1(Hisar) + *Mesorhizobium* (CH1233), PNE-12(Pantnagar) + *Mesorhizobium* (CH1233) and LRE-2(Ludhiana) + *Mesorhizobium* (CH1233) enhanced chickpea yield with range of 10.8-11.9% over the control and seem to be better inoculants than PGPR. Maximum dehydrogenase activity of soil was recorded in dual inoculation of *Mesorhizobium*+nodule endophytic bacteria treatments.

Crop Protection

Plant Pathology

- **Wilt:** *Desi* chickpea entries GNG 1320, GNG 2300, H 12-26, GCP 101, GNG 1581, BG 3076, Phule G 0818, BG 3068, GL 12003, IPC 2010-134, IPC 12-49, IPC 2012-98, PG 0104, IPC 2013-33,RVG 203, GJG 1316, GJG 2346, AKG 1216 and NBeG were resistant to moderately resistant at > 4 locations across the zones. In *kabuli* types HK 1309, HK 13-114, GLK 28127 and CSJK 126 were resistant to moderately resistant at > 7 locations across the zones. In extra large seeded *kabuli* types (ELSK) NBeG 458, NBeG 731, RVSSG 37, Phule G 0517 and HK 14-25 were resistant to moderately resistant at > 4 locations across the zones. In MH trial Phule G 08108, RCBM, JG 2016-24, BG 3062, BG 3082, CSJ 1005 were resistant to moderately resistant at > 7 locations across the zones. In DTIL, MABC-WR-SA 2 was resistant to moderately resistant at 6 locations across the zones.
- **Dry Root Rot (DRR):** Entries JG 2016-44, BRC 1, GNG 2261, BG 7078, CSJ 824, GJG 1421 were found resistant to moderately resistant at 2 or more locations. In MH Phule G 0818 and BG 3062 were resistant to moderately resistant at2 or more locations
- In national nurseries genotypes like IPC 12-98, GJG 1320, Phule G 13107, GJG 1316, IPC 17-28, JG 74315-2, CSJ96, JG 24, Phule G0405 and Phule G 12110 were resistant to moderately resistant at 6 or more than 6 locations. For dry root rot entry CSJ 592 was moderately resistant at all the locations.
- Resistance to was confirmed in genotypes like H 10 -01, GNG 2263, Phule G 408, JGG 1209, GJG 1010, GJG 922, SCGPWR 4, SCGPWR 32, IPC 2008-69, GNG 1581, Phule G 12110, IPC 2008-11, IPCK06-56, GLK 08-104 and SCGPWR 28 against wilt.
- Effect of climatic changes on occurrence of different diseases of chickpea was studied at seven locations. Higher wilt incidence was noted in mid to late November sown crop in NWPZ and NEPZ. In CZ, higher wilt incidence was observed in October sown crop. Dry root rot and Collar rot were higher in early sown crop at IIPR Kanpur, while in SZ, DRR was more in late sown crop.

Entries with stable resistance for more than 2 years (No. of years given in parentheses) against major diseases:

Disease	Entries
Wilt	SCGP-WR 28 (4), BCP 60 (2), GJG 0814 (4), IPCK 10-134 (2), IPC 07-28 (2), GJG 0921 (4), GJG 1010 (2), SCGP-WR 32 (3), GJG 904 (4), IPC 08-69 (3), CSJ 96 (2)
DRR	JG 24 (3)

- Genotype identified as multiple resistant : Wilt/ DRR-Phule G 0818, GNG 2207.

Entomology

- Seven experiments were taken in entomology and successfully implemented. A large number of entries were screened in IVT, AVT-1, AVT-2 and Ent 02 trials and despite considerable variation across locations in the incidence of pod borer and the reaction of the genotypes, none of the entries were observed to be truly resistant to pod borer.
- In NWPZ, the incidence of pod borer ranged from 9.33-64.47% at Ludhiana, 7.82-55.91% at Hisar, 0.00-5.49% at Ganganagar, 16.67-100% at Pantnagar and 6.35-28.21% at Durgapura.
- In NEPZ, comparatively low incidence of pod borer were recorded, which ranged from 6.00-32.80% at Faizabad, 0.57-17.41% at Banda, 2.80-23.60% at Dholi and 5.46-27.40% at Shillongani.
- In CZ, the incidence of pod borer damage ranged from 3.02-14.46% at Badanapur, 5.65-39.84% at Rahuri, 4.66 -20.20% at Junagadh, 3.00-6.19% at Sehore and 8.10-29.15% at Jabalpur.
- In SZ, comparatively low incidence of pod borer were recorded, which ranged from 0.00-18.88% at Nandyal and 11.00-50.55% at Kalaburgai. The maximum yield of 1750 kg and 2044.50 kg/ha, respectively was recorded at Nandyal and Kalaburagi.
- The incidence of insect pests of chickpea and their natural enemies throughout cropping period was observed in early, timely and late sown crop conditions. The damage done by pod borer was the lowest in timely sown crop and it has recorded comparatively lower pod damage and higher yield than both early and late sown conditions. However at Badnapur and Durgapura, early sown crop has recorded less pod damage and higher grain yield.
- Avoidable yield losses in chickpea against pod borer, *H. armigera* were recorded to be 3.25 to 66.17% in all the zones.
- In phenology based application of selective insecticides/biopesticides combinations against *H. armigera*, the first spray of Profenophos 50 EC @ 650 g.a.i./ha + Emmamectin benzoate 5 SG @ 11 g.a.i./ha+ Spinosad @ 73 g a.i./ha as subsequent second and third spray was observed as the best treatment for the control of pod borer damage and gave maximum yield in NWPZ and NEPZ. However, in SZ and CZ sequential spray of Profenophos 50 EC 650 g a.i./ha followed by HaNPV (2 x 10^9 POBs) @ 250 ml/ha followed by Spinosad 45 SC @ 73 g a.i./ha was observed as best treatment against pod borer.

Frontline Demonstrations

- Three hundred and seventy two demonstrations were conducted on package technology. By applying package technology, 1601 kg/ha of yield was obtained against 1294 kg/ha by farmer's practice. Increase in grain yield was 23.8 per cent.
- Sixty demonstrations were conducted on package technology in rice fallow. The overall mean grain yield of package technology in rice fallows was 1476 kg/ha and mean yield of local practice was 1133 kg/ha. The per cent increase in grain yield was 30.4%.
- Thirteen demonstrations were conducted on Insect Pest management technology. The overall mean grain yield by applying IPM was 2024 kg/ ha and mean yield of local practice was 1722 kg/ ha. The per cent increase in grain yield was 17.5%. Besides, five demonstrations were conducted on application of micronutrients like molybdenum and sulphur. The overall mean grain yield of demonstrations with application of micro-nutrients was 1036 kg/ha and mean yield without micronutrient application was 860 kg/ ha. The per cent increase in grain yield was 19.3%.
- Four hundred and one demonstrations were conducted under Tribal Sub plan in tribal areas which gave an average yield of 1319 kg/ha which was 29.3% higher than yield obtained through traditional practices and varieties.

PIGEONPEA

Crop Improvement

Promising Entries

In All India Coordinated Pigeonpea Varietal Evaluation Programme (2017-18), nine trials viz., IVT (Extra early 115-120 days) in NWPZ, NEPZ and NEHZ; IVT (Early:121-150 days) in NWPZ, NEPZ, SZ, CZ and NEHZ; AVT-1 (Early:121-150 days)in NWPZ, IVT (Mid-early: 151-165 days) in CZ and SZ; AVT-1 (Mid early:151-165 days); IVT (Medium: 166-185 days) in CZ and SZ; AVT-1 (Medium:166-185 days) in CZ and SZ; IVT (Late: >200 days) in NEPZ and AVT 1+2 (Late > 200 days) in NEPZ were executed at 132 locations of five zones.. Under these trials, a total of 87 genotypes were evaluated along with suitable checks and promising genotypes observed under these trials are mentioned in the summary table given here under:

Genetic Resources

Five thousand seven hundred twelve germplasm accessions including cultivated and wild species were maintained at 22 centers. Out of these, 331 are new collections including cultivated and wild species through exploration and procurement. Evaluation of 1050 germplasm lines were carried out at different centres for yield and yield components, disease

Trial	Zone	Test Entries	Grain yield (kg/ha)		Days to 50% flowering	Days to maturity	100 seed wt.(g)
			Zonal mean	% increase over check			
IVT (Extra early 115-120 days)	**NWPZ**	PADT 16	1369	9.17	65	120	6.71
		AL 1992	1404	11.96	76	126	7.95
IVT (Early; 121-150 days)	**NWPZ**	RKPV 413-02	1508	8.64	92	152	8.36
		PA 477	1468	5.76	92	151	7.75
		Pusa 2017-1	1465	5.54	85	132	7.64
AVT-1 (Early:121-150 days)	**NWPZ**	PA 421	1701	10.67	98	152	7.48
IVT (Mid-early: 151-165 days)	**CZ**	AKTE 12-04	2063	5.20	114	167	9.34
		WRGE 122	2067	5.40	111	163	10.28
		KRG 33	2083	6.22	113	162	10.20
	SZ	AKTE 12-04	1873	5.69	115	171	9.70
		WRGE 121	1969	11.11	108	165	10.42
		WRGE 122	1968	11.06	114	164	10.33
		KRG 33	1910	7.78	105	164	11.05
AVT-1 (Mid early:161-165 days)	**SZ**	WRGE 93	1945	9.76	115	173	10.32
	CZ	GRG 152	2165	20.14	115	171	10.75
IVT (Medium: 166-185 days)	**CZ**	GJP 1606	2038	9.22	123	177	10.97
		RPS 2008-5	2056	10.18	117	175	10.20
	SZ	PT 0723-1-2-3	1568	6.23	119	176	11.27
		TRG 87	1569	6.30	122	182	11.70
		RPS 2008-5	1647	11.58	115	168	10.88
AVT-1 (Medium:166-185 days)	**CZ**	RKPV 527-01	2116	7.30	108	169	9.88
	SZ	RVSA 16-1	1628	10.89	120	173	10.98
		TDRG58	1561	6.33	115	169	10.19
		LRG 133-33	1627	10.83	118	173	10.36
		MPV 106	1546	5.31	121	174	11.41
AVT-2 (Medium: 166-185 days)	**SZ**	CRG 2012-25	1636	11.44	122	175	9.66
IVT (Late; >200 days)	**NEPZ**	KA 16-5	2118	5.26	180	255	11.62
		IPA 15-2	2153	7.00	178	255	9.84
		Pusa 172	2765	37.42	176	253	12.62
		Pusa 171	2198	9.24	177	256	12.10
		KA 16-1	2313	14.96	178	255	11.76
AVT-1 (Late; >200 days)	**NEPZ**	Pusa 163	2382	15.12	182	253	11.13
		Pusa 151	2351	13.62	179	257	11.45
AVT-2 (Late; >200 days)	**NEPZ**	DA 15-1	2277	10.05	182	257	10.32

resistance, drought tolerance and morphological characters. Out of these accessions, 171 lines were utilized in breeding programme for transferring the desired traits in the best agronomic bases. Under pre breeding programme, 97 crosses were attempted involving agronomic bases, landraces, different accessions of wild species and African materials/ derivatives which were supplied from ICRISAT.

Breeding materials

In order to develop pool of segregating material, station and national crossing programme was organized at AICRP-Pigeonpea centres. Two hundred eighty five crosses were attempted and seeds were harvested from all these crosses at different centres as per need of the region under national and station crossing programme. Under national crossing programme, 88 crosses were developed at various centres namely Akola (04), Badnapur (04), Bangalore (04), Coimbatore (09), Dholi (04), Gulbarga (09), Hisar (02), Junagadh (05), Kanpur (02), Kota (02), Lam (02), Ludhiana (02), Nagaland (04), Pantnagar (02), Rahuri (04), Raipur (02), Ranchi (04), S K Nagar (0-4), Sehore (04), Tripura (03), Vamban (04), Varanasi (04), and Warangal (04) attempted crosses under national crossing programme. The seeds of these crosses will be advanced and segregating material will be shared among various centres for varietal development.

Breeder Seed Production

For crop season 2017-18, indent of 350.86 q of pigeonpea breeder seed was received for 56 varieties/ hybrids from DAC. Against this indent, allocation was done for 437.83 q and a total of 735.45 q of breeder seed was produced at different centres.

Crop Production

Agronomy

Cropping system

- At Sehore, among different varieties of pigeonpea tried with soybean intercropping system, pigeonpea equivalent yield was not significant with varieties like PAU 881, AL 201, UPAS-120 and CORG-9701 in soybean intercropping system (1:6) but significantly superior over 2:4 ratio.
- At Rahuri, two years study revealed that pigeonpea (AL 201) + soybean (2:4) intercropping based sequential cropping system with wheat has recorded significantly higher pigeonpea grain equivalent yield (3958 kg/ha), gross monetary returns (₹ 1,99,861/ha), net monetary returns (₹ 1,08,850/ha) and highest B:C ratio (2:2) and system productivity of 10.84 kg/ha/day.

Irrigation management

- Drip irrigation at 75% pan evaporation level recorded the highest grain yield of pigeonpea and it was at par with 50% pan evaporation at wider spacing of 120 x 30 cm at Badnapur.
- At Rahuri, drip irrigation at 50% pan evaporation at wider spacing of 120 x 60 cm recorded significantly higher pigeonpea grain yield, gross monetary returns, higher net monetary returns and benefit cost ratio.
- At Gulbarga centre, drip irrigation at 100% PE recorded significantly higher pigeonpea grain yield and it was at par with 75% PE with a wider spacing of 120 x 60 cm.

Drought mitigation

- At Bengaluru and Vamban centres, Pusa hydrogel at 2.5 kg/ha + Mulching with organic residue at 5 tonnes/ha recorded significantly higher pigeonpea grain yield but it was at par with Vermicompost at 2.5 tonnes/ha + Pusa hydrogel at 2.5 kg/ha.
- Whereas at Gulbarga centre, the pigeonpea grain yield was significantly higher at seed hardening with $CaCl_2$ + Pusa hydrogel but was on par with vermicompost + Pusa hydrogel and was also on par with Pusa hydrogel + mulching compared to other treatments.
- At Badnapur and Chitrakoot centres, Pusa hydrogel at 2.5 kg/ha + Mulching with organic residue at 5 tonnes/ha recorded significantly higher pigeonpea grain yield but it was at par with vermicompost at 2.5 tonnes/ha + Pusa hydrogel at 2.5 kg/ha.
- At Rahuri, pigeonpea grain yield was significantly superior at seed hardening with $CaCl_2$ at 2% + Pusa hydrogel at 2.5kg/ha and it was at par with vermicompost at 2.5 t/ha + Pusa hydrogel at 2.5 kg/ha.

Nutrient and pest management

- At Rahuri, RDF + multinutrient spray of 2 ml/ liter + Indoxacarb spray at 50% flowering + one systemic insecticide 15 days after first spray produced significantly higher pigeonpea grain yield (2158.3 kg/ha), gross monetary returns (₹ 92,236/ha), net monetary returns (₹ 40,636/ ha) and B:C ratio (1.8) than other treatments.

- At Junagadh, Chitrakoot and Badnapur centres significantly higher pigeonpea grain yield was recorded with RDF with 1% urea spray + 0.25% $ZnSO_4$ + 0.25% borax spray at 50% flowering + Indoxacarb spray at 50% flowering + one systemic insecticide at 15 days after first spray.
- At Berhampur, application of 0.5% borax at 50% flowering stage recorded higher grain yield of pigeonpea (1666.64 kg/ha), which was closely followed by pesticide application (1647 kg/ha) and multi-micronutrient spray (1580 kg/ha).
- At Kota centre, application of recommended dose of fertilizer followed by foliar spray of multi micronutrient at 50 % flowering indoxacarb 15.8 EC at 15 days later recorded maximum and significantly higher grain yield (1638 kg/ha), net returns (₹ 66,239/ha) and B: C ratio (2.87).
- At Kanpur centre, significantly higher grain yield (2820 kg/ha) was recorded with RDF + multinutrient spay of 2 ml/liter of water + Indoxacarb at flowering + one systemic insecticide 15 days after first spray.
- At Tripura centre, RDF + multinutrient spray @ 2 ml/liter + Indoxacarb spray at 50% flowering + one systemic insecticide 15 days after first spray produced significantly higher pigeonpea grain yield (571 kg/ha), over other treatments. At Nagaland centre RDF+ 0.5% borax spray at 50% flowering recorded significantly higher grain yield compared to other treatments.
- At Dholi centre foliar application of multi micronutrient @ 2 ml/liter of water together with RDF and two sprays of insecticides *i.e.* indoxacarb at flowering followed by profenofos 15 days after first spray produced maximum grain yield (2145 kg/ha).

Compatibility of insecticides with plant growth regulators

- At S.K. Nagar, pooled data of three years (2015 to 2017) revealed that tank mix application of Indoxacarb 15.8 EC with TNAU pulse wonder @ 5 kg/ha at flowering stage followed by application of Ryanaxipyr 18.5 EC after 15 days has registered significantly higher pigeonpea grain yield (1697 kg/ha), net returns (₹ 88,628) and B:C ratio (2.43) and remained at par with spraying of [(Rynaxipyr18.5 EC + pulse wonder) at flowering and by spray of Indoxacarb 15.8 EC at 15 days later.
- At Bengaluru, mean data of three years (2015 to 2017) revealed that tank mix application of Indoxacarb 15.8 EC with TNAU pulse wonder @ 5 kg/ha at flowering stage followed by application of Ryanaxipyr 18.5 EC after 15 days later has registered significantly higher pigeonpea grain yield, net returns and B: C ratio and remained at par with spraying of[(Rynaxipyr 18.5 EC + pulse wonder) at flowering and by spray of Indoxacarb (15.8 EC) at 15 days later.
- At Kanpur, significantly higher grain yield (2872 kg/ha) was obtained with spraying of tank mix application of Rynaxipyr 18.5 EC + NAA at flowering and spray of Indoxacarb (15.8 EC) at 15 days later).

Effect of nipping and spacing

- At Bengaluru centre significantly higher grain yield was obtained with the spacing of 90 cm x 30 cm. Nipping practices did not differ significantly.
- At Lam centre, crop geometry of 180 cm × 30 cm recorded significantly higher grain yield of pigeonpea but remained at par with 150 cm × 30 cm spacing. Significantly higher grain yield of pigeonpea was registered with nipping at 45 DAS (1443 kg/ha).
- At Warangal, the crop geometry of 180 cm × 30 cm recorded higher grain yield of pigeonpea and remained at par with 150 cm × 30 cm spacing. Significantly higher grain yield was registered with nipping at 45 DAS (1443 kg/ha).
- At Badnapur, nipping at 45 DAS recorded significantly higher grain yield (1368 kg/ha). Spacing of 90 x 30 cm recorded significantly higher seed (1542 kg/ha).
- At Rahuri , nipping at 45 DAS treatment produced significantly higher pigeonpea grain yield (2268 kg/ha), gross monetary returns (₹ 1,24,240/ha), net monetary returns (₹ 73,265/ ha) and B:C ratio (2.4) Sowing of pigeonpea at 180 x 30 cm produced significantly the highest pigeonpea grain yield (2449 kg/ha).
- At Berhampur (O), 120 x 30 cm was found the most suitable and recorded the highest yield (1702 kg/ha). Nipping at 45 DAS increased no. of branching, no. of pod per plant and the grain yield (1502 kg/ha).
- At Dholi, nipping at 60 DAS recorded significantly higher grain yield (1717 kg/ha). The crop seeded at 90 x 30 cm produced the maximum grain yield (1772 kg/ha).

Microbiology

- To study the temperature tolerance of newly isolated *Rhizobium* strains of pigeonpea, an experiment was conducted in the six different centres *viz.,* Akola, Coimbatore Kalaburagi, Ludhiana, Vamban and Varanasi. Fifty three pigeonpea rhizobial strains were isolated from all the centres. At Coimbatore, out of the four *Rhizobium* isolates, CoR2 is most suited for growth at higher temperature. At Kalaburagi, 25 new rhizobial isolates were isolated from pigeonpea nodules and screening process is under progress. At Ludhiana, 5 pigeonpea *Rhizobium* isolates P-6, P-9, P-30, P-31 and P-32 were found to exhibit growth at 35 and 40 C. At Vamban, out of five *Rhizobium* isolates, VPR 3 was observed as thermo tolerant followed by VPR 4. Whereas at Varanasi, out of the 14 isolates only six were able to grow at higher temperature.

- The experiment was conducted to assess the performance of pigeonpea rhizobial strains under different agro-ecological conditions, six efficient rhizobial strains developed at various locations *viz.;* Akola, Kalaburagi and Varanasi were used. At Akola, among the different *Rhizobium* strains GAKPR showed higher nodulation and grain yield followed by GRR 12-21 whereas at Coimbatore and Kalaburagi, nodulation and grain yield were recorded the highest in the *Rhizobium* strains GRR 12-21 and GRR 15-21. The *Rhizobium* strain RA 15-18 enhanced the nodulation followed by GRR 12-21, whereas the highest grain yield was noticed with GRR 12-21 at Varanasi.
- The experiment was carried out at different locations *viz.,* Coimbatore, Kalaburagi, Ludhiana and Varanasi, to evaluate the endophytic rhizobacteria for improving the yield of pigeonpea. Among the different endophytic rhizobacteria, PNE-12, PKE-8, PLE-5 and POE-7 along with *Rhizobium* increased the nodulation and grain yield of Pigeonpea at locations *viz.,* Coimbatore, Kalaburagi, Ludhiana and Varanasi, respectively.
- To test the efficacy of six nutrient mobilizing rhizobacteria along with local best strains of *Rhizobium* for improving the pigeonpea productivity, the experiment was carried out at Akola, Coimbatore, Kalaburagi and Vamban. At Akola and Coimbatore, among different nutrient mobilizing rhizobacteria, GNm-11 and CNm along with *Rhizobium* performed better with respect to nodulation and yield respectively. Both at Kalaburagi and Vamban, nutrient mobilizing rhizobacteria VNm enhanced nodulation and grain yield of pigeonpea.
- To evaluate the plant growth promoting rhizobacteria for improving the efficiency of *Rhizobium* inoculants, the experiment was implemented using six efficient plant growth promoting rhizobacterial strains obtained from different centers *viz.,* Coimbatore, Ludhiana and Kalaburagi. The PGPR strain GPGR-25 in combination with *Rhizobium* performed better with respect to nodulation and grain yield at Kalaburagi. At Vamban, the PGPR strain GPGR-25 enhanced the nodulation, whereas grain yield was maximum with strain LP-13.

Crop Protection

Plant Pathology

A. Host Plant resistance

A. Wilt: The entries IBTDRG 1, IBTDRG 2, IBTDRG 3, PT 0723-1-2-3, GRG 152, MAL 45, CORG 93, TDRG 58, MPV 106, LRG 223, KRG 33, BDN 2014, BDN 2014-1, TRG 87, GJP 1606, TDRG 59, MAL 13, MAL 49, DA 15-1, IPA 2014-4A, BRG 5, BSMR 736, BSMR 853, KPL 44, IPA 8F, CRG 2015 and BDN 711 were found the most promising and exhibited R to MR reaction to wilt in more than 50% of locations tested. ICRISAT genotypes *viz.,* ICPWS 1602, ICPWS 1603, ICPWS 1605, ICPWS 1607, ICPWS 1608, ICPWS 16, ICPWS 1613, ICPWS 1615-ICPWS 1618, ICPWS 1622-ICPWS 1627-showed resistant reaction to wilt in 5-9 locations, out of 9 locations tested.

B. Sterility mosaic: The entries MAL 45, PUSA 151, BDN 711, MAL 13, DA15-1, IPA 2014-4A, IPA 20-14-2, IPA 15-19, KPL 43, ICPWS 1604, ICPWS 1608, ICPWS 1611, ICPWS 1615, ICPWS 1617, ICPWS 1618, ICPWS 1619, ICPWS1622, ICPWS 1624 and ICPWS 1628 were showed resistant reaction in 50 per cent of the locations tested.

***C. Phytophthora* stem blight**: Five entries *viz.,* PA421, CRG 2012-25, IBTDRG 2, PT 0704-1-2 and BDN 2014-1 were recorded resistant reaction at two centres out of 4 centres tested.

D. Macrophomina stem Blight: Three entries *viz.,* BDN 2, RVSA 16-1, GJP 1606, WRG 122, BAUPP 15-21, PT 0704-1-2 and IPA 20-14-2 recorded resistant reaction in one location out of 2 locations tested. Whereas MAL 48 and KRG 33 showed moderately resistant reaction at both Coimbatore and Varanasi.

E. Leaf spot: Seven entries namely, KPL 44, IPA 20-14-2, KA 16-5, IBTDRG 1, IPA 17B-10, BDN 711, KRG 33, TDRG 58, Pusa 153, BDN 2 and one hybrid ICPH 2700 showed resistant reaction at Coimbatore.

Epidemiology

A. Epidemiology of sterility mosaic disease: Effect of dates of sowing on the incidence of pigeonpea sterility mosaic disease and its vector *A.Cajani* was conducted at Badnapur, Bengaluru, Coimbatore, Dholi, Rahuri and Junagadh. Last week of November to first week of December is favorable period for the incidence of SMD under Coimbatore condition. Early sown crop registered faster development of the disease compared with the late sown crop at Bengaluru, Rahuri. At Dholi, Coimbatore and Junagadh, late sown crop registered faster development of the disease as compared to early sown crop.

B. Epidemiology of Macrophomina stem canker: In summer season, the disease incidence reached up to 30 per cent and only 12 per cent incidence was observed during *Kharif* season. During summer, the atmospheric temperature and soil temperature was positive correlated with *Macrophomina* blight incidence with the correlation coefficient of 0.967 and 0.997 respectively. Relatively humidity was negatively correlated with the disease incidence with the correlation coefficient of - 0.223.

C. Epidemiology of Powdery Mildew: Powdery mildew of pigeonpea incited by *Leveillula taurica* is one of the severe foliar diseases in pigeonpea. For studying epidemiology of powdery mildew, sowing was taken on 07.8.2017 with the variety Co 5. The crop was maintained with the standard package of practices. The incidence of powdery mildew was recorded at 15 days interval starting from the disease appearance. Powdery mildew incidence was negatively correlated with temperature with the correlation coefficient of - 0.375 and positively correlated with the RH with the correlation coefficient of 0.258. The rate of spread of the disease was more (0.997) at 75 DAS.

III. Monitoring of race of *Fusarium udum*: The reaction on pigeonpea host differentials in wilt sick plot at 5 locations across the zones indicated the existence of variability in *Fusarium udum* population across centres tested.

IV. Variability study in pigeonpea sterility mosaic virus: The study indicated the existence of variability in the pigeonpea sterility mosaic virus present in Badnapur, Bangalore, Coimbatore, ICRISAT, Rahuri and Varanasi on the basis of pigeonpea host differential reaction to virus at these centres.

V. Management of Pigeonpea sterility mosaic virus disease: Two sprays of Fenpyroximate @ 1 ml/l first spray at 25 DAS and second spray at 45 DAS was found effective in reducing the incidence of SMD and increasing the grain yield at Bengaluru and Coimbatore. Whereas two sprays of Fenazoquin @ 1 ml/l first spray at 25 DAS and second spray at 45 DAS were found effective in reducing the incidence of SMD and increasing the grain yield was recorded at Bharuch and vamban.

VI. Survey and surveillance studies: Wilt, sterility mosaic Phytophthora stem blight and dry root rot were major diseases of pigeonpea across the locations during the year 2017-18. The status of wilt ranged from 0-90 per cent in SZ, 0-53 in CZ, 5-10 per cent in NEPZ whereas 10 to 15% in NWPZ and 0-16 per cent in Hill zone. The status of sterility mosaic disease ranged from 3-5 per cent in NEPZ, 9-1- per cent in NWPZ, 0-51 per cent in CZ and up to 50 per cent incidence in SZ. Phytophthora stem blight incidence of 11-16% per cent recorded in NWPZ, 0 to 20 per cent in CZ and 10 to 45 per cent incidence of Phytophthora stem blight in SZ and 10-31 % PSB was recorded in HZ (Nagaland) for the first time. The incidence of *Macrophomina* up to 25 per cent was recorded in SZ and CZ. Phyllody incidence up to 15 per cent was observed in SZ (Bangalore). *Cercospora* and *Alternaria* blight (20-50%) were observed in NEPZ and SZ. Yellow mosaic virus disease incidence of 3-15 per cent was also recorded at Coimbatore during 2017-18.Further Collar rot and leaf spot were recorded for the first time in Nagaland (NEHZ).

Entomology

- Under preliminary screening, out of 366 germplasm lines, twenty three, thirteen and thirty two entries showed low pod damage due to gram pod borer (0.0-17.0%), spotted pod borer and pod fly, respectively.
- Under advanced varietal trial (AVT 1), at NWPZ under Early maturity group, ASJ 1009; at CZ under Mid early group GRG 152; at CZ under medium maturity group MPV 106 and RKPV 527-01; at SZ under medium maturity group RVSA 16-1 and CRG 2012-25 (AVT 2 entry); at NEPZ under late maturity group Pusa 163 at Varanasi and MAL 45 at Dholi were most promising with low pod damage and high yield.
- Under advanced varietal trial (AVT 2), at NEPZ under late maturity group, Pusa 153 at Varanasi and MA 6 at Dholi were the most promising with low pod borer and pod fly damage.
- Under advanced material trial (AMT), at CZ, ICPHaRL 4985-10, ICPHaRL 4985-11, ICP 49114, ICP 11957, LRG 105, V 127 and CO (Rg) 9900134;

and at SZ, ICPHaRL 4985-10, ICP 49114, BRG 10-2, V 127 and Gulyal local (Red) with low pod borer and pod fly damage were most promising and can be utilized in further breeding programme.

- Under screening of hybrids, GRPH 3477, ICPH 7933, ICPH 2671, PHP 145 and IPH 15-03 were most promising with low pod borer and pod fly damage. The hybrids, ICPH 7933 and ICPH 3492; and LRG 52 recorded the highest yield.
- Under sequential application of insecticides, spraying of chlorantraniliprole 18.5 SC @ 30 g a.i/ha (0.3 ml/l), followed by flubendiamide 480 SC @ 30 g a.i/ha (0.2 ml/l) and dimethoate 30 EC @ 300 g a.i/ha (2.0 ml/l) at 10 days interval starting from flower bud initiation stage was very effective against pod borers and sucking pest with more yield and high cost benefit ratio.
- Against blister beetles, Lambda-Cyhalothrin 5 EC @ 25 g a.i / ha (1.0 ml/l) was found very effective with higher no. of pods/plant and grain yield.
- Against pod sucking bugs, acephate 75 SP @ 750 g a.i/ha (2.0 g/l), fipronil 80 WG @ 50 g a.i/ha (0.125 g/l) and deltamethrin 2.8 EC @ 12.5 g a.i/ha (0.9 ml/l) performed well and the results are to be further confirmed.
- Under monitoring of pod borers, in CZ, peak adult population of *H. armigera* and *M. vitrata* was observed during 46 - 52 and 43-44 SMW, respectively.
- In SZ, peak adult population of *H. armigera* was observed during 40 - 43 and 49 - 52 SMW. The larval population of *H. armigera* was more during 43-46 and 49-52 SMW. Similarly, the larval population of *M. vitrata* was more during 49 SMW.
- In NWPZ, the peak *H. armigera* adult population was observed during 34-43 SMW, whereas the larval population was peak during 44 SMW. The adult and larval population of *M. vitrata* was peak during 42 and 40-41 SMW, respectively.
- In NEPZ, the adults of *H. armigera* started appearing from 3rd SMW and reached peak in 12-13 SMW.
- In NEHZ, *M. vitrata* webs were more during 43 SMW. Incidence of *M. vitrata* and *H. armigera* was positively correlated with Maximum Temperature, Min. Temperature & Relative Humidity 1; and negatively correlated with RH II & RF.
- Surveys conducted in different farmers fields indicated that pod damage due to *H. armigera*, *M. vitrata* and podfly ranged between 0.0 – 18.8%, 0.7 – 24.4% and 5.3 – 46.8% (Varanasi), respectively. At Coimbatore, *Helicoverpa* and *Maruca* damage was recorded up to 62 and 90%, respectively. Pod sucking bug, *Clavigralla gibbosa* was appeared as a major sucking pest causing up to 29.0% seed damage in Ludhiana.

Nematology

- Two genotypes, DA 15-1 and IPA -15-19 gave moderately resistant reaction at three locations out of four locations against *Meloidogyne incognita.*
- Four genotypes, PA 421, PA 414, Pusa 153 and WRGE 93 were observed moderately resistant against *M. incognita* at two locations out of four test locations.
- Two genotypes, PA 421 and PA 414 were found moderately resistant against *M. javanica* at both the test locations.

4. Frontline demonstrations

- During 2017-18, frontline demonstration on pigeonpea was organized in 321 (ha) area on five components *viz.*, Intercropping with soybean, transplanting, IPM, planting on ridges and package technology (integration of all the components) against 342 (ha) demonstrations allocated and results of all 321 (ha) demonstrations were received.
- Intercropping of pigeonpea with soybean (2:4) resulted 32.3% more grain yield than farmers practice (Sole crop) with 40.9% higher net return in 48 (ha) demonstrations.
- Transplanting of pigeonpea resulted 62.56% more grain yield than normal sowing with 72.5% higher net return in 5 (ha) demonstrations.
- Insect (pod borers) management was found most beneficial and recorded 18.5% higher grain yields with 22.8% higher net return in 15 (ha) demonstrations.
- Planting on ridges recorded 19.8% higher grain yield as compared to flat sowing in 13 (ha) demonstrations.
- Integration of all components of production technology enhanced the productivity of pigeonpea by 26.9% with 40.02%, higher net return in 240 (ha) demonstrations.

MULLaRP

New Varieties

Mungbean

KM 2328: This is an early flowering, semi-erect and determinate variety of mungbean developed by CSAUA&T, Kanpur. It is resistant to Yellow mosaic virus and Cercospora leaf spots. The average yield is 8-11 q/ha. The maturity period is 60-62 days. It is suitable for Uttar Pradesh State.

GAM 5: This variety is developed by AAU, Model Farm, Vadodara (Gujarat). The average yield under normal condition is 1811 kg/ha. The plant growth habit is semi erect type. The maturity period is 60-65 days and suitable for *Kharif* and summer cultivation for Gujarat State.

Pusa 1431 : This variety is developed by ICAR-IARI, New Delhi for spring season (irrigated) for National Capital Region of Delhi including Delhi and adjoining areas in the state of Haryana, Rajasthan and U.P. It showed multiple resistances to MYMV, Cercospora leaf spots (CLS), anthracnose, web blight and urdbean leaf crinkles (ULCV). It is suitable for early planting after harvest of mustard and potato in spring season. The maturity range is 66-70 days.

RUPOHI (SGC 16): Rupohi variety of mungbean is resistant to cercospora leaf spot (CLS) and Yellow mosaic virus (YMV) diseases. Moderately resistant to web blight, pod borer, aphids, leaf roller and store pests. The maturity range is 65-70 days. The grain yield is 12-13 q/ha. This variety developed AAU, Shillongani for all zones of Assam.

Urdbean

KKM 1 : This variety is developed by Agricultural College and Research Institute, Killikulam (TNAU). The average yield is 607 kg/ha. This variety is erect and determinate plant type with lanceolate leaf, yellow colour flower, hairy pods with dull black coloured seeds. The maturity period is 65-70 days. It is suitable for cultivation in Tamil Nadu State.

ADT 6 : This variety developed by TNAU, Aduthurai. The average yield under normal conditions is 741 kg/ha. It is moderately resistant to leaf crinkle virus and powdery mildew diseases. The maturity period is 65-70 days. It is suitable for cultivation in Tamil Nadu State.

VBN 8 : This is semi-erect and determinate variety of urdbean with broad to narrow lanceolate terminal leaflet. The average yield is 1329 kg/ha. The maturity period is 65-75 days. This variety is developed by NPRC, Vamban for summer irrigated condition of SZ.

Lentil

L 4717 (Pusa Ageti Masoor): An extra early lentil variety L 4717 derived from the ILL 7617 x 91516 was released and notified for Central Zone comprising states of Madhya Pradesh, Chhattisgarh, Maharashtra and the southern Rajasthan. It is resistant to wilt and Ascochyta blight.

IPL 526: A medium large seeded variety of lentil IPL 526 derived from DPL 62 x DPL 58 was released and notified for Uttar Pradesh. It is tolerant to rust and wilt.

Pant L 9 (PL 098): A small seeded lentil Pant L 9 derived from a cross Pant L 5 x IPL 105 was released and notified for Uttarakhand. It is resistant to rust, wilt and Ascochyta blight diseases.

RLG 5 (Keshwanand Masoor 1): A small seeded lentil variety RLG 5 was released and notified for Rajasthan. It is moderately resistant to root knot nematode.

Fieldpea

IPFD 12-2: The dwarf fieldpea variety IPFD 12-2 derived from HUDP 15 x EC 342002 is resistant to powdery mildew hence released and notified for Central Zone comprising state of Madhya Pradesh, Chhattisgarh, Gujarat and Southern Rajasthan.

IPFD 11-5: The dwarf fieldpea variety IPFD 11-5 derived from (DDR 16 x HUDP 7) x DDR 16 was released and notified for Central Zone comprising state of Madhya Pradesh, Chhattisgarh, Gujarat and Southern Rajasthan.

Pant P 155: The dwarf fieldpea Pant P 155 derived from Pant P 13 x DDR 27 was released and notified for Uttarakhand. It is resistant to rust and powdery mildew diseases.

RFP 4 (Keshwanand Matar 1): A medium large seeded fieldpea derived from Bonneville x NPL was released and notified for Rajasthan. It is moderately resistant to powdery mildew and rust.

IPFD 6-3: It is dwarf and tendril type fieldpea derived from KPMRD 389 x HUDP 7 was released and notified for Uttar Pradesh. It is resistant to powdery mildew and moderately resistant to rust.

Crop Improvement

Pre breeding and distant hybridization

A large scale preebreeding and distant hybridization programme has been initiated in mungbean to introgress desirable genes from wild *Vigna* accessions. 107 Asiatic *Vigna* accessions were evaluated on 34 morphological traits over the last 3-4 years besides their molecular characterization for identification of usable and intercrossable wild accessions. On the basis of this information, 26 new cross combinations were attempted at IIPR to generate F_1 seeds. Successful crosses were made between the elite mungbean lines (IPM 02-3, IPM 02-14, IPM410-3 and IPM205-7) and 10 wild *Vigna* accessions (VBG 04-003, TCR 93, *V. umbellata* (PRR 2008-2), TCR 88, VBG 04-008, TCR 89, TCR 20, *V. glabrescens*, *V. sylvestris* (IC277036), and *V. sylvestris* (IC 277039). At Badnapur, progenies of cross BMG 75-1(Mungbean) x BWU-9 (*V. sylvestris*) having long pod and urdbean type were utilized as a donor with mungbean as female and progenies having mungbean type are utilized as a donor with urdbean as a female parent. The object of making these crosses is to increase the pod length of urdbean.

Ninety seven single plants were selected 6 F_2 population from the crosses (ILWL 118 x IPL 220, ILWL 97 x IPL 99/209 x ILWL 97, DPL 58 x ILWL 248, IPL 406 x ILWL 118 x IPL 406, IPL 220 x ILWL 248 x IPL 220 and IPL 220x ILWL 145 x IPL 220). F_3 populations were grown from 15 crosses involving accessions of wild species *Lens orientalis* as [ILWL 145, ILWL 248, ILWL 118, ILWL 97, ILWL 208, IG 135355, IG 136667 ILWL 324, ILWL 401). Total 87 single plants were selected from these crosses for advancing to next generation.

Total 291 single plant progenies were selected from 4 F_5 crosses (66: ILWL-425 × DPL-62, 11: ILWL-366 × DPL-58, 45: DPL-58 × ILWL-248, 91: DPL-62 × ILWL-189). Eighty F_6 single plant progenies were bulked from a cross made between cultivated (DPL 58) and *Lens orientalis* (ILWL 118) species. Seven promising single plant progenies were bulked from a cross DPL 58 x ILWL 248 for evaluating them next year in PYT.

Mutation Breeding

A collaborative research programme at four AICRP on MULLaRP centres *viz.*, Dharwad, Coimbatore, Kota and Port Blair with technical guidance of BARC, Bombay on mutation breeding was started from *Kharif* 2017 to breaking yield plateau in urdbean. At Coimbatore, two YMV susceptible varieties of urdbean *viz.,* PU 1 and CO 6 were irradiated with gamma ray dose of 200 Gy, 300 Gy and 400 Gy. The M_1 plants were raised during *Rabi* 2017-18. In each treatment, 200 plants were selected and will be forwarded to M_2 generation. The M_2 generation will be raised during summer 2018 to select YMV resistant plants. In mungbean during *Rabi* 2017-18, at Berhampur 297 plants were selected in M_4 generation for M_5 generation from five mutation materials (Pusa 9531 350GY, Pusa 9531 400 GY, Pusa 1333 350 GY, MH 421 350 GY and MH 318 350 gy). In mungbean fourteen mutant lines of SML 668 and TMB 37, resistant to MYMV were bulked and are being tested in multi-location yield trials during *Kharif* 2018. Mutation breeding was undertaken at PAU, Ludhiana for MYMV resistance and early maturity. Some other desirable mutants were also identified.

Bio-fortification

A set of 100 urdbean genotypes grown in augmented design in NRF and Main Farm of IIPR were harvested and grounded into seed powder and tested for seed iron and zinc concentrations using atomic absorption spectrophotometer (AAS). The Fe concentration ranged from 8-285 mg/kg with an average value of 99 mg/kg. In case of zinc average estimated value was 32 mg/kg and it ranged from 0.45-134 mg/kg among the tested urdbean genotypes.

National Crossing Programme

In order to develop pool of segregating material, a national crossing programme was organized at 16 centres for Mungbean and 12 centres for Urdbean. A total of 247 crosses were attempted in mungbean. Similarly, 176 new crosses were attempted in urdbean. The seed of these crosses will be advanced and segregating material will be shared among various centres for varietal development. Ten centres, each for lentil and fieldpea and one centres for lathyrus were also involved for developing 167 crosses in lentil at IARI, New Delhi (65); ARS, Kota (3); ARS, Sehore (21); CSAUAT, Kanpur (13); GBPUAT, Pantnagar (13); IIPR, Kanpur (10); BAU, Ranchi (5); RARS, Sagar (19); and RARI, Durgapura (5); IGKV, Raipur. Similarly, a 138 new crosses were attempted in fieldpea at CSAUA&T, Kanpur (14); RARS, Sagar (13); IIPR, Kanpur (25); CCS HAU, Hisar (14); GBPUAT, Pantnagar (07); IGKVV, Raipur (45); RARI, Durgapura (05); BAU, Ranchi (3); BHU, Varanasi (06) and ARS, Shillongani (6). In lathyrus, IGKV, Raipur attempted only 35 crosses. The seed of these crosses will be advanced and segregating material will be shared among various centres for varietal development.

Breeding for heat tolerance

At IIPR, Kanpur, 11 genotypes including 6 tolerant and 5 sensitive genotypes identified under field conditions were genotyped with functional markers. These functional markers developed from intron spanning regions and genes encoding heat-sock proteins. Total 23 functional markers generated 77 loci with a range of 1-13 loci per marker. The genotypic data generated from these markers was used to construct the UPGMA based dendogram. The tolerant and sensitive genotypes were clearly clustered in separate groups.

Molecular breeding in lentil

Marker-trait association of a selected panel of 127 mungbean genotypes was established by IIPR, Kanpur for yellow mosaic disease (YMD) caused by MYMIV. Virus-specific primer pairs, AC/AV-abut and BC/BV-abut confirmed the role of MYMIV in disease development. Out of 256 microsatellite markers, 31 polymorphic microsatellites were located on four linkage groups (LGs) viz. LG2, LG4, LG6 and LG9. These markers were used to identify the novel QTLs associated with MYMIV. The model-based population structure analysis resulted in formation of five distinct genetic subpopulations. Subpopulation-wise polymorphic information content (PIC) ranged between 0.58-0.67, indicating ample amount of variation at genome level. The subpopulation-V had maximum 149 alleles with an average of 6.58 alleles per locus. In the study, 17 microsatellite markers were detected as associated with MYMIV resistance. Two specific regions close to CEDG293 and cp1038 associated with MYMIV resistance were detected in the study. These microsatellite loci located on chromosome 2 and 6 may prove useful in marker assisted mungbean improvement programme for MYMIV resistance.

For assessing the breeding progress of Indian mungbean breeding programme, genetic diversity and the population genetic structure of forty-one elite lines of mungbean developed in during three decades were investigated using 80 mapped microsatellite markers. 696 alleles were detected among the 41 lines with an average of 8.68 alleles per locus. Gene diversity ranged between 0.93-0.05 with mean of 0.68, and polymorphic information content ranged between 0.92 and 0.05, with mean of 0.66. Out of 80 microsatellites, 51 were found highly polymorphic with >0.60 PIC value and these were noticed as most informative. As a result of STRUCTURE analysis, three distinct genetic groups were identified and revealed that breeding programme led to a clear-cut improvement in 100-seed weight, pod length, seeds per pod and plant height in elite lines developed after year 2000. The grouping pattern was also supported by the factorial and UPGMA analysis.

Molecular breeding programme in lentil is under way at ICAR-IIPR, Kanpur, ICAR-IARI, New Delhi and PAU, Ludhiana. Trait specific mapping populations for early seedling vigor (ILL 7663 × DPL 15) having 160 F_5 SPS and root traits (IPL 98/193 × EC 208362) having 160 F_5 SPS have been advanced to F_6 generation following single pod descent method. In addition to this, 5 RILs derived from a cross IPL 98/193 × EC 208362 were selected for evaluating their yield potential. In association studies conducted at Kanpur, a diverse panel of lentil germplasm consisting of 96 accessions was used (i) to study flowering time over environments and (ii) to identify simple sequence repeat markers associated with flowering time through association mapping. This study identified QTLs for flowering time that explained high phenotypic variation across the environments or in a particular environment. Thirteen SSR markers showed significant association with flowering time were derived from express tag sites (ESTs) of lentil and explained high phenotypic variation compared to genomic SSR markers. Hence, these markers can be used as functional markers in lentil breeding programme for developing short duration cultivars.

The efforts have also been made for developing the intron spanning markers in lentil. This leads to development of 1600 intron spanning as new markers in lentil. A set of 84 intron spanning markers were tested for their polymorphism among 32 accessions of lentil. Out of these 84 SSR markers, 24 intron spanning markers (28.6%) showed polymorphism. Thus compared to SSR markers, these markers showed higher polymorphism. These markers will be utilized in genotyping of AB QTL populations.

Herbicide tolerance in fieldpea

Based on last year preliminary screening at ICAR-IIPR, Kanpur a set of eighty five genotypes was made comprised of highly tolerant, tolerant, moderately tolerant, sensitive and highly sensitive genotypes. Given diverse set evaluated for resistance against popular post-emergence herbicide metribuzin @ 500 g/ha. The plants were scored for herbicide toxicity on three different stages like 15 days after spray(DAS), 30 DAS and 60 DAS on a scale of 1–5. The results of experiment revealed that there was huge amount of genetic variation for tolerance against metribuzin. The behaviour of genotypes varied for visual appearance and toxicity during different interval after spray. After 30 days of spray, many genotypes showed tolerance in visual appearance but based on final scoring after 60 days for visual appearance and toxicity on plants only one genotype P-637 found tolerant. This genotypes during preliminary screening also expressed tolerance for metribuzin @ 500g/ha. Therefore, after further confirmation in larger area this genotype could be utilized as donor to accelerate breeding programme.

Genetic Resources

During *Rabi* 2016-17, total 4591 cultivated accessions of lentil gemplasm were maintained by 12 AICRP centres *viz.*, ARS, Kota; RARS JNKV, Sagar; IGKV, Raipur; BAU, Ranchi; CSAU&T, Kanpur; NDUAT, Faizabad; CCSHAU, Hisar; ICAR-IARI, New Delhi; ICAR-IIPR, Kanpur; RARI, Durgapura; Srinagar and RARS, Shillongani. Twelve AICRP centres *viz.,* ARS, Kota; BAU, Ranchi; NDUAT, Faizabad; BHU, Varanasi; CCSHAU, Hisar; ICAR-IIPR, Kanpur; JNKV, Sagar; S.K. Nagar, RARI, Durgapura; IGKV, Raipur; Srinagar and RARS, Shillongani maintained a total of 1218 accessions of fieldpea. In lathyrus, 2426 accessions of lathyrus germplasm were maintained by three AICRP centres *viz.*, IGKV, Raipur, IIPR Regional Station, Bhopal and AAU, Shillongani. A total of 943 accessions of rajmash germplasm were maintained at BHU, Varanasi, S.K. Nagar and IIPR, Kanpur. A total of 339 accessions of six wild species (*Lens orientalis* and *L. odemensis, L. nigricans, L. erevoides* and *L. tomentosus, L. lamottei*) and 90 accessions of Mediterranean landraces were grown and maintained at ICAR-IIPR, Kanpur. A total of 5502 germplasm lines of mungbean and 2556 of urdbean were maintained at different centres. A large number of accessions of 18 wild *Vigna* species are also maintained at different centres.

Breeder Seed Production

In mungbean, the total breeder seed production was 911.55 q against the indent of 969.95 q for 53 indented varieties. In urdbean, the breeder seed production was 364.22 q against the indent of 451.75 q for 46 indented varieties. The breeder seed production programme has been taken up in lentil and fieldpea. In lentil, the breeder seed production was 534.53 q for 38 varieties. Similarly, a total of 777.30 q breeder seed of 25 varieties of fieldpea was also produced. Besides, breeder seeds of lathyrus (166 q) and rajmash (14.40 q) were also produced.

Agronomy

Mungbean

- Mungbean genotype IPM 312-20 with wider spacing (45 x 10 cm) exhibited higher grain yield (1082 kg/ha) followed by IPM 312-19 (1013 kg/ha) at Imphal.
- Pre-emergence application of pendimethalin 30 EC + imazethapyr 2 EC (ready mix) @ 0.75 kg/ha found effective for controlling weeds and higher grain yield with monetary return at Coimbatore, Durgapura, Imphal, Lam and Ludhiana.
- Post emergence application of clodinafop propargyl 8 % + aciflourfen sodium 16.5 % (ready mix) @ 125-187.5 g/ha at 15-20 DAS was found effective for controlling weeds and obtained higher grain yield with monetary return at Badnapur, Chitrakoot, Jodhpur, Kota and Mohanpur.
- Foliar spray of Urea 2% + salicylic acid 75 ppm at flower initiation or NPK (18/19:18/19:18/19) 2% spray at flower initiation or TNAU pulse wonder 5 kg/ha spray at flower initiation proved better for higher grain yield.

Urdbean

- Urdbean variety Uttara sown with normal spacing (30 x 10 cm) has exhibited higher grain yield (1172 kg/ha) at Imphal.
- Post emergence application of clodinafop propargyl 8% + aciflourfen sodium 16.5% (ready mix) @ 125-187.5 g/ha at 15-20 DAS was found promising herbicide for controlling weeds and produced higher grain yield at Kota, Dholi, Keonjhar, Mohanpur, Raipur, SK Nagar.
- Preemergence application of pendimethalin 30 EC + imazethapyr 2 EC (ready mix) @ 0.75 kg/ha was also found better for controlling weeds and higher grain yield at Berhampore, Pantnagar, Imphal, Vamban and Lam.
- Foliar spray of urea 2% + salicylic acid 75 ppm or NPK (18/19:18/19:18/19) 2% or salicylic acid 75 ppm at flower initiation and 7 days after 1st spray or TNAU pulse wonder 5 kg/ha spray at flower initiation proved effective for higher grain yield and monetary return.
- Application of 100% recommended dose of fertilizer (18-25 N:40-50 P_2O_5: 20-25 K_2O: 20 S kg/ha) along with 5 tonne FYM/ha and seed inoculation with either LMn16 or *rhizobium* was found better for higher grain yield.

Lentil

- Drilling of hydrogel 2.5-5.0 kg/ha before sowing and supplementing with foliar nutrients either NPK (19:19:19) 0.5 % or salicylic acid 75 ppm at flower initiation and pod development stage was found effective for enhancing grain yield and economics of lentil.
- Seed priming of lentil and effective post-emergence application of quizalofop ethyl 5 EC @ 60 g/ha at 25-30 DAS and subsequently foliar spray of NPK (19:19:19) 0.5% at pre flowering and pod initiation was found best management practice for enhancing grain yield of lentil under rice fallow situation.
- Zero tillage (direct sown) with crop residue (30 cm) at Raipur whereas, conventional tillage practice (2 harrowing + planking) with crop residue (30 cm) at Dholi and Varanasi was found better for higher lentil yield under rice-lentil cropping system.
- Application of recommended dose of fertilizer (RDF) 20-17-16-20 kg NPKS/ha along either seed treatment with 1-2 g ZnO + 1-2 g $FeSO_4$ or foliar application of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$ + seed inoculation with bfr LNm43a was found effective for enhancing grain yield of lentil.
- Lentil AVT_2 genotype LL 1320 (825 kg/ha) and VL 148 (823 kg/ha) at Almora and Imphal (NHZ) and L 4727 (1434 kg/ha), RKL 14-20 (1238 kg/ha) and RVL 13-5 (1154 kg/ha) at Kota, Raipur and Sehore (CZ) sown with seed rate (50 kg/ha) were found promising genotypes for higher grain yield.

Fieldpea

- Fieldpea AVT_2 genotype Pant P 250 (1688 kg/ha) and IPFD 2014-2 (1458 kg/ha) at Durgapura, Hisar and Pantnagar (NWPZ) and Pant P 243 (2055 kg/ha), IPFD 2014-2 (2048 kg/ha) and IPFD 2014-11 (2043 kg/ha) at SK Nagar, Raipur and Kota (CZ) with higher seed rate 100 kg seed/ha were found promising genotype for higher grain yield.
- Application of 100% recommended dose of fertilizer (RDF) 20-17-16-20-5 kg NPKSZn/ha and seed inoculation with *rhizobium* + *PSB* + *PGPR (RB-2)* + 1.0 g ammonium molybdate/kg seed and two times foliar spray of NPK (19:19:19) 0.5% at pre flowering and pod initiation gave higher grain yield (1650-1800 kg/ha) of fieldpea at NWPZ, NEPZ and CZ.

Lathyrus

- Lathyrus seed treated with sodium molybdate @ 0.5 g/kg seed and two times foliar spray of NPK (19:19:19) @ 0.5% at branching and 15 days after 1st spray harvest gave higher grain yield (1600-1700 kg/ha) under rice-utera lathyrus system.
- AVT_2 genotype BK 14-1 and DLY 13-7 with higher seed rate 50 kg seed/ha were found promising genotype for higher grain yield (1900-2100 kg/ha) of lathyrus.

Microbiology

- Mungbean *Rhizobium* isolates HUMR-13, HURM-15 and HUMR-16 (Varanasi) and CoGR2, CoGR3 and CoGR4 (Coimbatore) showed nodulation at higher temperatures.
- Plant growth promoting rhizobacterium MMC33 expressed P & Zn solubilization at 40^{0}C.
- Under multi-location testing, COG-15 (Coimbatore) and MOR-1 (Varanasi) consistently out-performed other strains with respect to symbiotic parameters and yield.
- Endophyte MOE5 (Varanasi) + *Rhizobium* was found to be the best over three years of testing both for symbiotic interaction and yield in mungbean.
- In lentil, twenty two new low-temperature tolerant *Rhizobium* isolates have been identified. Nutrient mobilizers LNm-1 (Ludhiana) and PNm-1 (Pantnagar) outperformed all other strains for the third consecutive year in terms of symbiotic parameters and yield.
- PGPRs LLAcc-3 (Ludhiana) and IIPRAcc-1 (Kanpur) were found promising for lentil and fieldpea.

Plant Pathology

Mungbean

- PM 14-11 and MH 2-15 showed multiple resistance to MYMV, root rot, urd leaf crinkle and leaf curl during *Kharif* and CoGG 13-39 and OBGG-58 showed multiple resistance to MYMV, leaf curl, leaf crinkle, and stem necrosis during *Rabi*.
- Seed treatment with imidacloprid 5 g/kg seed followed by foliar spray of hexconazole 0.1% on initial appearance of disease was highly effective against foliar fungal diseases.
- Entries SML 2236 and SML 1899 showed highly resistant reaction to MYMV in national genetic nursery.

Urdbean

- Entries LBG 888, PU 14-19 and Shekhar 3 showed multiple resistance to MYMV, leaf crinkle and leaf curl during *Kharif*.
- All the entries showed multiple resistance to MYMV, leaf crinkle and stem necrosis during *Rabi*. Seed treatment with imidacloprid 5 g/kg seed followed by foliar spray of hexconazole 0.1% on initial appearance of disease was highly effective against foliar fungal diseases.

Lentil

- Entries VL 148, IPL 230 and VL 527 showed multiple resistance to rust and Ascochyta blight at all the locations. Entries VL 148, LL 1370, PL 224, PL 221 and IPL 221 were found resistant to wilt.
- Fungicides amistar, propiconazole and tebuconazole were effective for lowering the disease severity of rust and increasing the yield.

Fieldpea

- Pant P 347 and Pant P 354 showed resistant reaction to rust while RFP 2011-3, Pant P 243, HFP 1315, HUTP 1602, Pant P 353, Pant P 355, KPMR 748, Pant P 250, IPFD 2014-2, Pant P 343, VL 65, KPMR 940, RFP 10-05 and RFP 2010-2 were showed resistant reaction to powdery mildew.

Identification of Yellow mosaic viruses

- MYMV DNA-B and MYMIV DNA-A were present in all the samples of urdbean and mungbean received from nine locations.

Nematology

- PM 14-3 was moderately resistant against *M. javanica* at two locations, out of four locations while KM 2241 was moderately resistant against *M. incognita* at three locations, out of four locations.
- Four entries COGG 0912, Pant M6, IPM 312-19 and MGG 387 were moderately resistant against *M. incognita* at two locations out of four locations.
- Intercropping of mungbean with clusterbean reduced the nematode population and gave more net income compared to mungbean alone in root knot nematode infested field.
- VBG 12-034 gave moderately resistant reaction against *M. javanica* at two out of four locations and IPU 243 was found moderately resistant at three locations out of four locations against *M. incognita*.
- Four lentil entries PL 4, L 4076, RKL 14-20 and IPL 336 gave moderately resistant reaction against *Meloidogyne incognita* at RAU, Pusa and Kanpur and NDL 14-12, LL 1370, PL 406, RKL 14-20 and PL 024 were found moderately resistant to *M. javanica* at two locations of Durgapura and Kanpur.
- Combination of seed treatment with carbosulfan 25 EC @ 0.1% v/w and neem cake @ 500 kg/ha or neem seed powder @ 50 kg/ha is effective in reducing the nematode population and increasing the yield of fieldpea.

Entomology

Mungbean (*Kharif*)

- In advance stage screening, entry ML 2236 and ML 2056 were identified promising against whitefly and Jassid at Ludhiana. The entries SML 1811, ML 2027 found promising against whitefly and aphid and ML 613 found promising against pod borer at Berhampur.
- For control of sucking insect-pests, Diafenthiuron 50 WP @ 312 g a.i./ha was found effective with least infestation of insect pests and high crop yield. The next best treatment was Seed treatment with Thiomethoxam 35 FS (3 g/kg seed) + foliar application of Thiomethoxam 25 WG @ 25 g a.i./ha.
- Compatibility of insecticides with fungicide for management of insect-pests indicate that the treatment with Thiomethoxam 25 WG (0.3 g/l) + propiconazole 25 EC (1.0 ml/l) were effective in reducing the sucking pests and diseases and the application of Spinosad 45 SC + propiconazole 25 EC (0.6 ml + 1 ml/l) were found quite effective against pod borer complex.
- The IPM modules comprises seed treatment, tall growing millet crop @ 2 thick row around the field as barrier crop, monitoring with yellow sticky trap @ 50 per ha, NSKE 5% spray on appearance of whitefly on sticky trap and need based application of the insecticides in rotation diafenthiuron 50 WP @ 312.5 ai per ha/trizophos 40 EC @ 400 g ai/ha/acetamiprid 20 SP @ 20 g ai/ha at 10 days intervals found effective in reducing insect-pests incidence, more yield and good net return.

Mungbean (*Rabi*)

- The entries CO 6, MGG 385, Pusa 9072 and VGG

15-030 found promising against sucking insect pests and pod borer at Lam, Coimbatore and Berhampur.

Urdbean (*Kharif*)

- In advance stage screening, entries KUG 675 and KUG 725 found promising at Ludhiana, Pantnagar and Faizabad.
- For control of sucking insect-pests, Diafenthiuron 50 WP@ 312 g a.i./ha was found effective against sucking pests. The next best treatments was Spiromesifen 240 SC @ 150 g a.i./ha.
- Compatibility of insecticides with fungicide for management of insect-pests indicate that the Thiomethoxam 25 WG (0.3 g/l)+ propiconazole 25 EC (1.0 ml/l) were effective in reducing the sucking pests and diseases. The next best treatment was application of Spinosad 45 SC + propiconazole 25 EC (0.6 ml + 1 ml/l).

Urdbean (*Rabi*)

- The urdbean genotype were tested at Berhampur and Lam against sucking insect pests and pod borer. The entries VBG 13-003VBG 12-111,VBG 14-016 and MBG-1050 were found promising against aphid and entries COBG 13-08, VBG 12-034 and OBG 41 were found promising against whitefly at Berhampur. The entries DKU 118 and IPU 027 found promising at Lam.

Lentil

- The studies on estimation of crop losses due to insect pests ranged from 8.04 to 31.95% at Ludhiana, 18.4 to 51.0% at Pantnagar, 13.97 to 32.6% at Durgapura, 7.5 to 39.6% at Mohanpur and 11.1 to 23.3% at Faizabad.
- Evaluation of IPM modules indicated that module comprises seed treatments, intercrop with mustard, NSKE 5% spray at 40 DAS followed by spray of either indoxacarb @ 50 g a.i./ha or rynaxypyr @ 20 g a.i./ha or spinosad 45 SC@ 73 g a.i./ha at 50% flowering stage increased in yield and reduced the insect incidences and gave maximum cost-benefit ratio.

Fieldpea

- Evaluation of newer insecticides against pod borer complex indicated that application of Rynaxypyr 18.5 SC @ 25 g a.i./ha, Indoxacarb 14.5 SC@ 60 g a.i./ha and Emamectin benzoate @ 10 g a.i./ha were observed most effective.
- Management of black cutworm *Agrotis ipsilon* at Shillongani indicated that 32.1% in increase in yield by adopting IPM practices *viz.,* application of mustard cake at the time of sowing, seed treatments, mulching with rice straw after sowing and spray of Chlopyriphos during night.

Rajmash

- The leaf minor damage in rajmash at Varanasi ranged from 6.25 to 10.98% and pod borer 3.1 to 10.7%. The entries RE 15-1, HURP 15,Haland 84 and HUR 202 were found promising.

Frontline Demonstrations

Mungbean

- Package technology in *Kharif* witnessed 23 per cent higher grain yield and 26 per cent increment in net returns over local farmers practices.
- In *rice-fallow*, package technology depicted 15 per cent higher grain yield and 26 per cent increase in terms of net economic benefit over local varieties.
- Adopting package technology in *Rabi* accomplished 49 per cent increase in grain yield along with 73 per cent monetary advantage.

Urdbean

- Package technology in *Kharif* depicted 33 per cent higher grain yield and 44 per cent increase in terms of monetary benefit over local practices.
- In *Rabi* urdbean, 31 per cent yield advantage was obtained and 43 per cent increase in net returns through package technology adoption.
- In rice-fallow, package technology depicted 14 per cent increase in grain yield and 25 per cent raise in terms of net returns over local practices.
- Adoption of post-emergence herbicide increase in yield recorded to be 30 per cent and in term of monetary advantage, there was 29 per cent gain.

Lentil and Fieldpea

- A total of 173 frontline demonstrations were conducted with full technology packages in lentil and fieldpea which exhibited 31% and 30% increase in yield, respectively. With the adoption of improved technologies, there was net monetary benefit of 32% and 35% in lentil and fieldpea cultivation, respectively.

NETWORK PROJECT ON ARID LEGUMES

Crop Improvement

Variety released

- **RMO 2251 (Marudhar) RMO 225-1-6:** This variety has been developed through mutation of RMO 225 and identified for moth growing areas, erect stem with 3-5 branches. Fodder remains green up to maturity, early maturing (63-67 days). Average yield is 5-6 q/ha. Average incidence of YMV and moderately resistant to leaf crinkle virus in field condition.
- **RGS 3:** This variety has been developed from the cross RGC 936 x RGC 1002 and identified for cluster bean growing areas during summer. It is early maturing, highly and heavy moderately resistance against major diseases and pests of guar. It is branched, medium tall, semi erect indeterminate plant type. It matures in 91 days. It's average yield is 1277 kg/ha.

Varieties identified

- **KBC-9:** This variety has been developed from the cross Arka garima x VS-389 and identified for the southern states. The plant type is bushy and erect and seeds are (11.53 g/100-seed) large and light brown in colour. It matures in 80-85 days. It's average yield is 1100-1200 kg/ha. It is resistant to dry root rot and colour rot and moderately resistant to yellow mosaic virus.
- **TC 901:** This variety is mutant of EC 394763 and identified for the northern part of the country for summer season. Plant is semi-determinate in growth habit, broad leaves and pods with thin pod wall. It matures in 69-75 days. The 100-seed weight is 11.4 g. It's average yield is 900-1000 kg/ha and resistant to cowpea mosaic virus and leaf crinkle.

Promising Entries

- Based on yield data, the following entries out yielded the best check by more than 5%. The mean yield (kg/ha) of promising entries as well as check has been indicate in parenthesis.

Breeder Seed Production

In case of four arid legume crops, BSP indent of 505.89 q was received and 288.28q of breeder seed was produced. Crop wise scenario of breeder seed production is given below:

- In guar, 288.9 q of breeder seed was produced against the DAC indent of 227.33 q of 15 varieties.
- In cowpea, an indent of 41.5 q of 13 varieties was received and 144.17 q of breeder seed was produced.
- In mothbean, DAC indent of 61.77 q of 4 varieties was received and 65.75 q of breeder seed was produced.
- In horsegram, indent of 16.9 q of 7 varieties was received. Total 21.07 q of Breeder seed was produced.

Production Technologies

In experiment "Effect of foliar nutrition on productivity of summer cowpea", results revealed that the differences in seed yield were found non-significant due to various treatments. Among different treatments, application of KNO_3 @ 2% spray at flower initiation and pod initiation gave maximum seed yield (2359 kg/ha) over all the treatments.

In experiment "Enhancing resources use efficiency and productivity of cowpea," results indicated that the differences in seed yield were found significant due to different treatments. Treatment T_9 i.e. Crop residue retention @ 3 t/ha was recorded significantly higher seed yield (1421 kg/ha) over rest of the treatments and was at par with treatment T_7, T_8, T_4, T_3, T_5 and T_1.

In experiment "Enhancing resources use efficiency and productivity of clusterbean," results showed that the application of RDF with FYM @ 2.5 t/ha gave significantly higher seed yield (1178 kg/ha), net monetary return (`47507/-ha) and BCR (3.75) over all the treatments but was at par with reducing 25% plant population (by increased plant intra-row spacing) and crop residue retention @ 3 t/ha.

Crop	Trial	Zone	Genotypes (Mean yield)
Cowpea	AVT-2	South	KBC 9 (977), PTB 1 (971), KBC 8 (944), KBC 7 (941), DC 16 (927)
Guar	AVT-1 + IVT	North	RGr 16-2 (1023)
	AVT-1 + IVT	South	RGr 16-7 (792), RGr 16-2 (715), GAUG 1304 (753)

Experiment "Integrated weed control in Cowpea" was conducted at SDAU S.K. Nagar, RSKVV, Gwalior, and ARS, Pattambi with following treatments

At S.K. Nagar, results indicated that the differences in seed yield were found significant due to different treatments. Treatment T_8 *i.e.* Weed free check recorded significantly higher seed yield (1410 kg/ha) over rest of the treatments and at was par with treatment T_5 (Pendimethalin @ 0.75 kg a.i./ha as PE + one inter-cultivation at 20-25 DAS), T_6 (Pendimethalin @ 0.75 kg a.i. / ha as PE + imazethapyr @ 40 g a.i./ha at 2-3 leaf stage of weeds) and T_1 (one intercultivation at 20-25 DAS) recorded seed yield (1309, 1299 and 1244, respectively).

Weed control efficiency was recorded the highest in treatment T_8 (100 %) followed by T_5 (83.55 %) and T_1 (81.27 %).

At RSKVV, Gwaior, results showed that application of Pendimethalin @ 0.75 kg a.i./ha as PE + one Interculture at 20-25 DAS gavesignificantly higher seed yield (1975 kg/ha), net monetary return (₹ 1,03,477/ha) and BCR (6.37) over all the treatments. The significantly lowest seed yield (721 kg/ha) was noted in Weedy check (No weeding) treatment.

ARS, Pattambi recommended post emergence application of Imazethapyr + Imazamox @ 40 g/ha at 3-4 leaf stage (or) application of Imazethapyr @ 40 g/ha at 3-4 leaf stage can control grassy as well as broad leaved weeds.

Experiment "Integrated weed control in Cluster bean" was conducted at RARI, Durgapura; CCSHAU, Hisar; ARS, Hanumangarh and RRS, Bhatinda with following treatments.

At RARI, Durgapura; results revealed that pre emergence application of Pendimethalin @0.75 kg a.i./ha PE + one Intercultivation at 20-25 DAS resulted in seed yield (7.69 q/ha) and stover yield (21.11 q/ha) was statistically significantly superior over T1, T2, T3, T4 and weedy check and at par with T5 and T6 treatments of weed management. At ARS, Bhatinda, all the treatments gave more yield than the weedy check (613.9 kg/ha). The highest yield of 1549.3 kg/ha was obtained in weed free check. Treatment T5 that was pre-emergence application of Pendimethalin and post-emergence application of Imazethapyr gave 1423.4 kg/ha. At CCSHAU, Hisar; results revealed that the highest seed and straw yield were recorded with treatment T_{10} (weed free check) which was on par with T_3 (Imazethapyr @ 40 g a.i./ha at 2-3 leaf stage of weeds), T_7 (Pendimethalin @ 0.75 kg a.i./ha as PRE + 1 Intercultivation at 20-25 DAS), T_8 (Pendimethalin @ 0.75 kg a.i./ha as PRE + Imazethapyr @ 40 g a.i./ha at 2-3 leaf stage of weeds) and T_9 [Pendimethalin @ 0.75 kg a.i./ha as PRE + {Imazethapyr + Imazamox @ 40g a.i./ha at 2-3 leaf stage of weeds (improved practice)}]. Maximum net returns (₹ 27,508/ha) and BC ratio (2.22) were recorded with T_3 (Imazethapyr @40 g a.i./ha at 2-3 leaf stage of weeds) followed by T_9 and T_8. At ARS, Hanumangarh; the highest yield of 1146 kg/ha was obtained in T7 (Pendimethalin @0.75 kg a.i./ha as PE + Imazethapyr +Imazamox @ 40 g a.i./ha at 2-3 leaf stage of weeds) which was significantly higher than the yield of weedy check (547 kg/ha).

Plant Pathology

Evaluation of genotypes of arid legumes under different coordinated trials against important diseases

Clusterbean

At ARS, Bikaner; out of 14 genotypes, 12 were observed susceptible to highly susceptible against bacterial blight. The minimum disease intensity (20.00%) was recorded in X-10 and GAUG-1304 at Bikaner centre and 2.67% in RGr-16-10, CAZG-15-3 and CAZG-15-4 at S.K. Nagar centre.

Root rot incidence was also observed at ARS, Bikaner and found that the disease incidence was very less (0.00 to 25.71%). The maximum root rot incidence was recorded in GAUG-1305 (25.71%) followed by RGr-16-3 (22.50%) and minimum disease incidence was recorded in RGr-16-10, X-10, RGr-16-4 and CAZG-15-3 (0.00%).

At ARS, Durgapura; three genotypes HG 2-20 (ch), CAZG 15-3, RGC 1066 (ch) and RGr 16-3 showed highly resistant reaction and four genotypes RGr 16-10, RGr 16-7, CAZG 15-4 and RGr 16-2 showed resistant reaction.

Cowpea

At Bikaner centre, the highest disease incidence of root rot/web blight was observed in GC-1304 (75.00%) which showed highly susceptible reaction. However, it was observed that cowpea entries, DC 7-15 (AVT 1) and CPD 229 were found free (0.00%) from the disease.

At S.K. Nagar, all genotype were found to be highly resistant to resistant against the root rot/web blight disease of cowpea, the minimum incidence was recorded in VCP 12- 007 (0.33%), however, it was maximum (6.00%) in the cowpea entry GC-1203.

At ARS, Durgapura; out of 11 genotypes, two entries, CPD 229 and GC 1203 were found highly resistant, four entries *i.e.* DC 7-15 (AVT 1), CPD 240, TC 161, GC 1304 found resistant, entries VCP 12-007, VCP 09-019 gave moderately resistant reaction.

Horsegram

At S.K. Nagar, it was observed that all the genotypes were highly resistant to resistant against Cercospora leaf spot disease where the disease intensity ranged between 1.33 to 9.67%. Only two entries i.e. BSP 15-2 (AVT-1) and BSP 16-1 were shown maximum disease intensity (9.67%) and shown resistant reaction.

At Pattambi, dry root rot disease intensity was recorded from 0.00 to 50.00% in different entries of horsegram. The entries i.e. VLG 42, CRHG 19 (ch) and VLG 43 were found free from the disease.

Management of bacterial blight of clusterbean under epiphytotic conditions:

The experiment was conducted at different locations *i.e.* Bikaner, Durgapura, S.K. Nagar and Hanumangarh during three years.

At Bikaner, it was observed that all the treatments were found superior over control in reducing the disease severity and increasing the grain yield on the basis of three year pooled data. The minimum disease intensity (14.83%) and higher grain yield of 11.18 q/ha was recorded with treatment streptocycline 500 ppm (SS) + streptocycline (250 ppm) + copper oxychloride (0.2%) with 2 sprays at 15 days interval. It was followed by streptocycline 500 ppm (SS) and 2 spray of copper hydroxide (0.2%) at 15 days interval where 17.33% disease intensity and 10.45 q/ha of grain yield was recorded.

At S.K. Nagar, seed socking (SS) with Streptocycline 500 ppm + streptocycline (250 ppm) + copper oxychloride (0.2%) 2 sprays at 15 days interval was found most effective among all treatments tested with minimum disease intensity (7.44%) and a higher grain yield of 5.06 q/ha.

At Durgapura, all the treatments were found to be superior over control in reducing disease intensity (21.93%) was recorded in seed soaking with streptocycline 500 ppm for one hour with two spray of copper hydroxide (0.2%) followed by seed soaking with 500 ppm with two spray of streptocycline 250 ppm + copper oxychloride (0.2%). These treatments also showed maximum yield *i.e.* 6.12 q/ha and 5.20 q/ha, respectively, on three years mean basis.

At Hanumangarh, result revealed that significantly less 4.61 % PDI of bacterial blight of clusterbean and significantly higher grain yield of 12.24 q/ha was recorded in the treatment streptocycline 500 ppm (SS) + streptocycline (250 ppm) + copper oxychloride (0.2%) 2 sprays at 15 days interval.

Management of root rot of mothbean through local isolated bioagents under epiphytotic conditions

This experiment was conducted for three years during *Kharif* season. Results showed that all treatments were found effective against root rot disease of mothbean over control. Treatment combination, *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) + soil application of *T. harzianum* + *P. fluorescens* (1.25 +1.25 kg in 50 kg FYM for each/ha.) was found the most effective among all treatments tested with disease incidence (21.78%) was recorded. Maximum seed yield (10.56 kg/ha.) was also recorded in this treatment. Treatment *T. harzianum* seed treatment (8 gm/kg seed) + soil application of *T. harzianum* (2.5 kg in 100 kg FYM/ha.) was also found effective against the root rot disease severity. Seed treatment with *P. fluorescens* (8 gm/kg seed) alone found the least effective against the disease on the three pooled basis.

Management of root rot of cowpea

An experiment on management of root rot of cowpea was conducted for three years during *Kharif* season at S.K. Nagar centre. Results revealed that all treatments were found effective against disease incidence. Seed treatment with carbendazim 50% WP (2 gm/kg seed) and soil application of *Trichoderma harzianum* @ 1.5 kg/ha, which is a combination of treatments was recorded as the most effective against disease incidence (2.33%) and grain yield (5.49 q/ha).

Management of root rot of cowpea through local isolated bio-agents

At S.K. Nagar centre, this experiment was conducted for three years during *Kharif* season. Results showed that all treatments were found effective against disease incidence. Treatment *T. harzianum* seed treatment (8 gm/kg seed) + Soil application of *T. harzianum* (2.5 kg in 100 kg FYM/ha) was found the most effective among all treatments tested with disease incidence (2.11%) was recorded. Maximum seed yield (5.92 q/ha) was also recorded in this treatment. Treatment combination *T. harzianum + P. fluorescens* seed treatment (4+4 gm/kg seed) + soil application of *T. harzianum + P. fluorescens* (1.25 +1.25 kg in 50 kg FYM for each / ha) was also found effective against disease severity on the basis of three years mean data.

Entomology

Evaluation of genotypes in coordinated varietal trials

Cowpea

At Bikaner centre, the minimum incidence of leaf hopper was observed in CPD-240 (1.2 leaf hopper/leaf) followed by GC-1304 (1.4 leaf hopper /leaf) and RC-101 (1.4 leaf hopper/leaf), however, in case of whitefly, it was minimum in CPD-240 (1.00 whitefly/leaf) followed by GC-3 (1.2 whitefly/leaf) and RC-101 (1.2 whitefly /leaf).

At S.K. Nagar, the incidence of pod borer was minimum in RC-101 (8.38%) followed by KBC-10 (8.59%) and CPD-240 (8.61%). Rest of the entries showed the average incidence. As regard to leafhopper incidence, it was minimum in entry GC-3 (0.66 leaf hopper/leaf) followed by GC-1304 in which leaf hopper population was 0.75/leaf. However, whitefly population was minimum in GC-1304 (0.72 whitefly/leaf) followed by RC-101 (0.93 whitefly/leaf) and KBC-10 (0.95 whitefly/leaf).

Clusterbean (Guar)

At Bikaner centre, the data revealed that the leafhopper population was minimum in RGr 16-7 (1.2 leafhopper/leaf) followed by HG-563 (1.4 leafhopper/leaf) and X-10 (1.4 leafhopper/leaf). However, the whitefly population was minimum in RGr 16-7 (1.00 whitefly/leaf) followed by RGr 16-4 (1.3 whitefly/leaf) and X-10 (1.4 whitefly/leaf).

At S.K. Nagar, minimum population of leafhopper was observed in RGr 16-7 (0.71 leaf hopper/leaf) followed by X-10 (0.75 leaf hopper/leaf) and CAZG 15-4 (0.87 leaf hopper/leaf)). However, whitefly population was minimum in RGr 16-7 (0.72 whitefly/leaf) followed by X-10 (0.90 whitefly/leaf) and RGr 16-3 (1.05 whitefly/leaf) and HG-563 (1.05 whitefly/leaf).

Horsegram

At S.K. Nagar centre, the data revealed that the entry BSP 15-2 had minimum incidence of leaf hopper and whitefly (0.71 and 0.72 /leaf) followed by BSP-15-1 (0.78 and 0.76 /leaf) and CRHG-19 (0.80 and 0.81/leaf), respectively.

Management of cowpea aphid

At Pattambi, the pooled data of three years revealed that the minimum population of aphid (0.89 aphid per leaf) and maximum yield of cowpea (1197.05 kg/ha) was recorded in the treatment of Dinotefuran @ 0.4g/ litre spray after 48 hrs of application followed by Ethiprole+ Imidacloprid @ 0.3g/litre spray in which aphid population were 3.56 aphid per leaf and yield was (1170.94 kg/ha).

Pest management in clusterbean during *Kharif*

At Bikaner, among all the treatments combined treatment T_7 (T_3 +T_6- i.e., Seed soaking for 1 hrs with Streptocycline @ 500 ppm + seed dressing with Carbendazim @ 2g/kg seeds, Seed treatment with Fipronil 5% SC @ 4 ml/kg seeds, foliar spray with Streptocycline @ 250 ppm + copper oxycloride @ 0.2 % and foliar spray with Thiamethoxam 25 WG @ 0.3g/litre followed by Acetamiprid 20 SP @ 0.2g/litre at 15 days interval) was found the most effective against bacterial leaf blight (disease intensity 11.98 %) and root rot (disease incidence 7.00%) and insect pests (whitefly population 0.70 /leaf and leaf hopper population 0.71/leaf). Maximum seed yield (18.05 q/ha) was also recorded in this integrated treatment.

At Durgapura, Seed soaking with streptocycline @ 500 ppm + seed dressing with carbendandazim + seed treatment with fipronil 5% SC @ 4 ml/kg seed and foliar spray with streptocycline @ 250 ppm + copper oxychloride @ 0.2 % + foliar spray with Thiamethoxam 25 WG @ 0.3 g/litre followed by spray of Acetamiprid 20 SP @ 0.2 g /litre at 15 days interval showed minimum incidence of aphid (0.71 aphid/leaf) & Jassids (0.80 jassid/leaf) and minimum Bacterial leaf blight infection (9.76%) as compared to all other treatments and this treatment also showed maximum grain yield i.e. 10.28 q/ha.

At S.K. Nagar, results revealed that minimum incidence and intensity of bacterial blight (7.67 & 4.33%) , root rot incidence (1.0%), white fly 0.50 /leaf and leaf hopper 0.42/leaf was recorded in the treatment of seed soaking with streptocycline @ 500 ppm + seed dressing with carbendandazim @ 2 g/kg seed + seed treatment with fipronil 5% SC @ 4 ml/kg seed and foliar spray with streptocycline@250 ppm + copper oxychloride @ 0.2% + foliar spray with thiamethoxam 25 WG @ 0.3 g/litre followed by spray of acetamiprid 20 SP @ 0.2 g /litre at 15 days interval and this treatment also gave the highest grain yield of clusterbean (12.10 q/ha). The incidence of whitefly appears on clusterbean crop in the last week of August (Maximum intensity in third week of September: 6-7 whitefly/leaf), however, leaf hopper appears on the crop in the first week of September (Maximum intensity in third week of September: 5-6 leaf hopper/leaf).

Management of sucking pests of mothbean

At Bikaner, minimum population of whitefly (0.48) and leaf hopper (0.64) was recorded in the treatment of seed treatment with Imidacloprid 600 FS @ 5 ml/kg of seed+ foliar spray with Thiamethoxam 25 WG @ 0.3 g/litre and this treatment also gave maximum yield (11.73 q/ha) followed by Seed treatment with Fipronil 5% SC @ 4 ml/kg of seed + foliar spray with Acetamiprid 20 SP @ 0.2 g/litre in which the whitefly and leafhopper population was 0.52 and 0.76/leaf, respectively and yield was 11.48 q/ha.

Quality Characters

Guar

- Mean value of carbohydrate content was maximum in the national check RGC 1066 (45.02%).
- Maximum mean endosperm content was observed in national check RGC 1066 (42.63%).
- Mean protein content was maximum in CAZG 15-3 (32.61%).
- Maximum mean gum content was observed in national check RGC 1066 (31.63%).
- Maximum mean viscosity was observed in national check RGC 1066 (3546cp).

Cowpea

- Mean value of protein content was maximum in the national check RC 101 (31.09%).
- Minimum tannin content was observed in the national check PL 3 (0.296 mg/g).
- Trypsin inhibitor activity was minimum in DC 7-15 (AVT-I) 1573(TUI/g).
- Phytic acid content was minimum in VCP 12-007 (6.36 mg/g).

Mothbean

- Mean protein content was maximum in the RMO 3-570 (24.32%).
- Mean minimum tannin content was observed in the RMO 3-570 (0.445 mg/g).
- Trypsin inhibitor activity was minimum in RMO 225 (36 TUI/g).
- Phytic acid content was minimum in RMO 4-1-6-09 (5.45 mg/g).

Frontline Demonstrations

Cowpea

Ninety four frontline demonstrations were allotted to five centres. Forty two demonstrations were organized by five centres. Overall mean yield of high yielding varieties with improved technology was 1084 kg/ha and yield of local practices was 564 kg/ha. 92.2 per cent increase in yield was recorded in demonstrations.

In Karnataka, UAS, Bangalore conducted 15 demonstrations on farmer's field to demonstrate the production potential of variety PHG 9. The mean yield of demonstration plots was 258 kg/ha. The average yield obtained in control plots was 208 kg/ha and in this way, increase in yield of 24.3 per cent was recorded.

In Kerala, ARS, Pattambi, organized two demonstrations by providing the seed of horsegram variety, CRHG 9. This variety gave average yield of 1950 kg/ha.

In Rajasthan, ARS Bhilwara conducted five demonstrations by providing the seed of variety AK 42. This variety gave an average yield of 415 kg/ha which was 84.4% higher than the yield of local variety 225 kg/ha.

Tribal Sub Plan

For upliftment of tribal population of country, Govt. of India formulated the tribal sub plan and separate budget was allotted during financial year 2016-17. AINRP on Arid Legumes organized the demonstrations by providing the seed of high yielding varieties of cowpea, guar and horsegram and technical knowhow to raise the crops. Under tribal sub plan, total 219 demonstrations were conducted by three centres *i.e.* RARI, Durgapura; ARS, Bhilwara and ARS, Bilaspur on three arid legumes crops *i.e.* cowpea, guar and horsegram. The per cent increase in the yield was 16 to 84.6.

Transfer of Technology

For effective dissemination of new pulse production technologies among farmers and other stakeholders, following trainings and other extension activities were organized during 2017-18:

Activity	Duration	No. of participants	Participants
Hi-Tech Pulse Production Technology	21-25 August, 2017	35	Extension officials of stets department SMS, TA of U.P.
Module-II Certified Farm Advisor MANAGE training programme	03-17 October, 2017	07	ADA, SMS of different states
Model Training Course	13-20 November, 2017	19	Joint Director (Agriculture) Deputy Director (Agriculture) Distt. Agril. Officers of different states
Training for Dal Millers of Maharashtra	11-12 December, 2017	05	Dal Millers of Maharashtra
MANAGE training programme	05-14 February, 2018	22	DDA, ADA, SDO, BTM. SMS TA, of different states
Training of farmers			
Other States	19-21 September, 2017	31	Farmers of Pusa, Bihar
	26-28 September, 2017	25	Farmers of Sitamadhi, Bihar
	18-19 December, 2017	23	Farmers of Dumka, Jharkhand
	16-19 January, 2018	48	Farmers of Ranchi, Jharkhand
	05-08 February, 2018	21	Farmers of Girideeh, Jharkhand
	21-24 February, 2018	47	Farmers of Dhanbad, Jharkhand
	06-09 March, 2018	24	Farmers of Gadhwa, Jharkhand
	20-23 March 2018	26	Farmers of Ranchi, Jharkhand
Uttar Pradesh	07-09 June, 2017	30	Farmers of Jaloun, U.P.
	22-24 June, 2017	25	Farmers of Kannauj, U.P.
	27 June, 2017	45	Farmers of Kanpur Dehat, U.P.
	27-28 June, 2017	11	Farmers of Kannauj, U.P.
	30 August, 2017	42	Farmers of Kanpur Dehat, U.P.
	23-25 October, 2017	19	Farmers of Hardoi, U.P.
	21-22 February, 2018	18	Farmers of Fatehpur, U.P.
	9 August, 2017	136	Farmers of Fatehpur, U.P. (Under Farmer FIRST Project)
	5 September, 2017	50	Farmers of Fatehpur U.P. (Under Farmer FIRST Project)
	5 December, 2017	60	Farmers of Fatehpur, U.P. (Under Farmer FIRST Project)
	10 January, 2017	50	Farmers of Fatehpur, U.P. (Under Farmer FIRST Project)

Field Day Organized/Farmer-Scientist Meeting			
Activity	**Duration**	**No. of participants (Approx.)**	**Participants**
Kisan Mela-2018 & Farmer-Scientist Interface organized at IIPR, Kanpur	17th March, 2018	1000	Farmers, Entrepreneurs, Extension Personnel
Chickpea and Pigeonpea Field Day at Village Karchalpur, Fatehpur under Farmer FIRST project	22 March, 2018	150	Farmers of Fatehpur, U.P.
Participation in Agril. Exhibition & Kisan Mela			
"Krishi Kalyan Mela held at Motihari, Bihar on the occasion of Champaran Satyagrah Shatabdi Samaroh	13-19 April, 2017	2150	Farmers, Entrepreneurs, Extension Personnel
Agricultural Exhibition cum Seminar was held at Pandit Deen Dayal Upadhyaya Dham, Mathura.	22-25 September, 2017	1890	Farmers, Entrepreneurs, Extension Personnel
Agricultural Exhibition in World Food India-2017, New Delhi	03-05 November, 2017	2000	Farmers, Entrepreneurs, Extension Personnel
Kisan Mela and Agriculture Technology Showcasing, at ICAR-CISH, Rahmankheda Lucknow	30th November, 2017	800	Farmers, Entrepreneurs, Extension Personnel
Exhibition on the occasion of UP Diwas organized by State Agriculture Department U.P.	24th January, 2018	650	Farmers, Entrepreneurs, Extension Personnel
AGRIEXPO 2018 organzied during International Conference on "Sustainability of Smallholder Agriculture in Developing Countries under Changing Climatic Scenario" scheduled at CSAUA&T, Kanpur, India-reg	February 14–17, 2018	800	Farmers, Entrepreneurs, Extension Personnel
Krishi Unnati Mela 2018 scheduled to be held at IARI, New Delhi-reg.	March 16–18, 2018	5200	Farmers, Entrepreneurs, Extension Personnel
"Regional Agricultural Fair for Northern Region" at IIVR, Varanasi	February 23–25, 2018	1500	Farmers, Entrepreneurs, Extension Personnel

Activity	Duration	No. of participants (Approx.)	Participants
Exposure visit at IIPR, Kanpur	04/06/2017	30	Farmers of Bhind, M.P.
	05/06/2017	19	Farmers of Hardoi, U.P.
	15/06/2017	46	Farmers of Raibareli, U.P.
	22/06/2017	18	Farmers of Jaloun, U.P.
	26/06/2017	48	Farmers of Unnao, U.P.
	29/06/2017	35	Farmers of Hamirpur, U.P.
	26/08/2017	37	Farmers of Unnao, U.P.
	25/09/2017	50	Farmers of Hamirpur, U.P.
	26/09/2017	38	Farmers of Mau, U.P.
	27/09/2017	21	Farmers of Gorakhpur, U.P.
	06/10/2017	20	Farmers of Urai, U.P.
	10/10/2017	42	Farmers of Kanpur Dehat, U.P.
	11/10/2017	40	Farmers of Karouli Rajasthan
	12/10/2017	32	Farmers of Anooppur
	13/10/2010	23	Farmers from Katni, Madhya Pradesh
	13/10/2017	90	Farmers from Reewa, Madhya Pradesh
	29/11/2017	36	Farmers from Guna, M.P.
	22/12/2017	51	Farmers from Satna, M.P.
	29/12/2017	14	Farmers from Katni, M.P.
	10/01/2018	50	Farmers from Bhind, M.P.
	10/01/2018	24	Farmers from Katni, M.P.
	11/01/2018	17	Farmers from Vidisha, M.P.
	20/01/2018	34	Farmers from Shahdol M.P.
	07/02/2018	56	Farmers from Damoh, M.P.
	07/02/2018	12	Farmers from Vidisha, M.P.
	09/02/2018	12	Farmers from Jabalpur, M.P.
	10/02/2018	70	Farmers from Muraina, M.P.
	13/02/2018	12	Farmers from Vidisha, M.P.
	16/02/2018	70	Farmers from Guna, M.P.
	11/03/2018	81	Farmers from Muraina, M.P.
	12/03/2018	40	Farmers from Lodhipur, Shahjahanpur
	13/03/2018	20	Farmers from Shahjahanpur U.P.
	13/03/2018	23	Farmers from Jabalpur, M.P.
	20/03/2018	50	Farmers from Varanasi, U.P.
	22/03/2018	150	Farmers from Kanpur, U.P.
	23/03/2018	45	Farmers from Muraina, M.P.
	25/03/2018	55	Farmers from Satna, M.P.
	28/03/2018	25	Farmers from Gwaliar, M.P.

- One documentary film (4 minute) on "*Improved planting techniques of kharif pulse crops*" was prepared.

Participation in *Kisan Mela*

Scientists of the centre participated in the *"Krishimela"* at Dharwad and Bijapur, organized by UAS, Dharwad during September, 2017 and Janauary, 2018 and displayed seed samples of IIPR released varieties and various charts related to crop production and plant protection measures in pulse crops. Scientists of RRC attended chickpea field day on 6th Feb. 2018 organized by University of Agricultural Sciences at Dharwad.

Conduct of FLDs and visits to farmer's fields

Five FLDs were conducted on Chickpea (JG-11) in different farmer's fields in Narendra, Amargol, Byahatti,Kundgol of Dharwad and Naregal of Gadag district during rabi-season and visited pulse growing farmers fields of Dharwad, Belgaum and Bijapur district during *kharif/rabi* and interacted with them.


Participation in *Kisan Mela* at Dharwad and Bijapur


Farmers Field Visits

Publications

Research Papers

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शेखर सुधांशु, कुमारी, चंचिला, रुपेश रंजन, कुमार, मनीष एवं कुमार, योगेश (2017). छोटे रोमंथी पशु पालन से महिलाओं का सशक्तिकरण. कृषि विज्ञान केंद्र, कोडरमा (भा.कृ.अनु.प.–राष्ट्रीय चावल अनुसन्धान संस्थान, कटक–केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीक बुलेटिन सीरीज 3. पृष्ठ संख्याः 120.

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कुमार, योगेश, रंजन, रुपेश, कुमार, मनीष, शेखर, सुधांशु एवं मैती, डी (2017). वर्षाश्रित क्षेत्रों में सीधी बुआई विधि द्वारा धान की खेती. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः सुधांशु शेखर, चंचिला कुमारी, रुपेश रंजन, मनीष कुमार एवं योगेश कुमार). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.–राष्ट्रीय चावल अनुसन्धान संस्थान–केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 8–13.

कुमार, योगेश, मंडल, एन पी, कुमारी, चंचिला, शेख, सुधांशु र एवं मैती, डी (2017). विभिन्न फसलों के बीज उत्पादन के सिद्धांत एवं उनकी तकनीक. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः शेखर, सुधांशु, कुमारी, चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.–राष्ट्रीय चावल अनुसन्धान संस्थान–केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 21–26.

कुमार, योगेश, कुमार, मनीष, रंजन, रुपेश एवं राघव, दुष्यंत (2017). झारखण्ड में मक्का की वैज्ञानिक खेती. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः शेखर, सुधांशु, कुमारी, चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार, योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.–राष्ट्रीय चावल अनुसन्धान संस्थान–केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 27–34.

कुमार, योगेश, शेखर, सुधांशु, रंजन, रुपेश एवं कुमारी, चंचिला (2017). झारखण्ड में अरहर की उन्नत खेती. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः शेखर, सुधांशु, कुमारी, चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार, योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.–राष्ट्रीय चावल अनुसन्धान संस्थान–केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 35–39.

कुमार, मनीष, कुमार, योगेश, रंजन, रुपेश एवं शेखर, सुधांशु (2017). झारखण्ड में गेंहू की वैज्ञानिक खेती. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः शेखर, सुधांशु, कुमारी, चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार, योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.–राष्ट्रीय चावल अनुसन्धान संस्थान–केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान

केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 40—47.

कुमार, योगेश, शेखर, सुधांशु, कुमार, मनीष एवं रंजन, रुपेश (2017). झारखण्ड में चना की वैज्ञानिक खेती. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः शेखर, सुधांशु, कुमारी, चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार, योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.—राष्ट्रीय चावल अनुसन्धान संस्थान—केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 48—54.

कुमार, धनंजय, कुमार, योगेश, शेखर, सुधांशु, रंजन, रुपेश एवं शुक्ला, प्रतीक (2017). चारा उत्पादन की वैज्ञानिक विधि. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीकी (सम्पादनः शेखर, सुधांशु, कुमारी, चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार, योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.—राष्ट्रीय चावल अनुसन्धान संस्थान—केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 87—91.

शेखर, सुधांशु, रंजन, रुपेश, कुमारी, चंचिला, कुमार, मनीष एवं कुमार, योगेश (2017). दुधारू गाय में उत्पादन तथा खनिज एवं विटामिन अल्पता सम्बन्धी रोग. In: पठारी क्षेत्र में आधुनिक कृषि एवं पशु पालन की तकनीक (सम्पादनः शेखर, सुधांशु, कुमारी चंचिला, रंजन, रुपेश, कुमार, मनीष एवं कुमार, योगेश). कृषि विज्ञान केंद्र कोडरमा (भा.कृ.अनु.प.—राष्ट्रीय चावल अनुसन्धान संस्थान—केन्द्रीय वर्षाश्रित उपराऊँ भूमि चावल अनुसंधान केन्द्र, हजारीबाग) द्वारा प्रकाशित तकनीकी बुलेटिन 2: 125—128.

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Agarwal, D.K., Katiyar, P.K., Uday Bhaskar, K., Sripathy, K.V., Pal, Govind, Vijayakumar, H.P., Jeevan Kumar, S.P., Boraih, K.M., Ramesh, K.V., Bhojraja Niak K and Lamichaney, Amrit (2017) Innovative approaches of PPP in pulses seed production. *In*: Abstract book of National Symposium on Pulses for Nutritional Security and Agricultural Sustainability held at ICAR-IIPR, Kanpur during December 02-04, 2017. pp. 48-51.

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Singh, U., Kumar, R., Praharaj, C.S., Purushottam and Mishra, R.K. (2017) *Basantkalin Urd Evam Greeshmakalin Moong Ki Unnat Kheti*. ICAR-

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Singh, U., Kumar, R., Praharaj, C.S., Purushottam, Bhatt, S. and Kumar, K.R. (2017) *Kisano Ki Aay Badhane Hetu Gehun Ki Unnat Kheti*. ICAR-Indian Institute of Pulses Research, Kanpur, Ext. Folder Pub. No. 3/2017. Pp.1-8.

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Tiwari, T.N., Tiwari, A.K., Singh, A.N., Agarwal, D.K. and Rajendra Prasad, S. (2017) *Beejon Kee Gunvatta, Utpaadakta Evam Suraksha Banaye Rakhne Hetu Takniki Sanstutiyan.*

Tiwari, T.N., Kumar, Madan, Ramesh, K.V., Jeevan Kumar, S.P., Tiwari, A.K. and Agarwal, D.K. (2017) *Uttar Pradesh Ke Liye Sarson Kee Anukool Prajatiyan Evam Sankar Kismein.*

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Pal, G., Kumar, M., Jeevan Kumar, S.P. and Tiwari, T.N. (2017) *Gunvattayukt Beej Kee Aavashyaktaein Evam Shreniyan.*

Kumar, M., Tiwari, T.N., Ramesh, K.V., Pandey, N. And Agarwal, D.K. (2017) *Sookshmjeevon Dwara Beejon Ka Jaivik Upchaar.*

Tiwari, T.N., Tiwari, A.K., Kumar, M., and Agarwal, D.K. (2017) *Uttar Pradesh Hetu Upyukt Gehoon, Chana Evam Sarson Kee Prajatiyan.*

Pandey, N., Kumar, A., Jamali, N., Kumar, M., Tiwari, T.N., Ramesh, K.V. and Agarwal, D.K. (2017) *Sookshmjeevon Ka Rahasymayi Sansaar; Krishi Ka Adhaar.*

Copyrights/Trademark

- Registered Copyright of software "IRS-MULLaRP" (Diary No. 10085/2016-CO/L)
- Filed Copyright of software "Germplasm Information System for Pulse Crops" (Diary No. 13833/2017-CO/L).

Institute Publications

i. Annual Report 2016-17

ii. *Varshik Prativedan* (Annual Report - Hindi) 2016-17

iii. Pulses Newsletter Vol. 28, Nos. 1, 2, 3 and 4.

iv. Rajbhasha Patrika – *Dalhan Alok*, 2017.

v. *Dalhan Prodyogiki Hastantaran me Prasar Taknikon ke Safal Prayog.*

vi. *Kisano ki Aay Badhane hetu Gehun kee Unnat Kheti.*

vii. *Kisano ki aay Badhane hetu Basant Kaleen Urd evam Greeshmkaleen Mung kee Unnat Kheti.*

viii. *Agrotechnologies for Pulses in Rice Fallows.*

ix. Enhansing Nutrient use efficiency through next gen. fertilizers in field crops.

x. Practical Manual-Chemical analysis of Soil and Plant Samples.

xi. *Dalhani fasalon me Kherpatwar Prabandhan.*

Folders

i. Brochure on 'Enhancing Breeder Seed Production for Increasing Indigenous Production of Pulses in India.

ii. (a) Folder on *Chanamitra* Application.

(b) Folder on *Dalhan Gyan Manch.*

iii. *Chana ki Fasal me Ekitrit Rog evam Keet Prabandhan.*

iv. *Bundelkhand me Chana Utpadan kee Karya Pradaliyan.*

Training and Capacity Building

Deputation Abroad

Dr. N.P. Singh, Dr. Aditya Pratap and Dr. Sanjeev Gupta visited Bangladesh Agricultural Research Institute, Joydebpur, Dhaka, Bangladesh on May 30-31, 2017 to participate in the Annual Planning-cum-Review Meeting of the 'International Mungbean Improve-ment Network' funded by the Australian Centre for International Agricultural Research. In this meeting, the progresses of the project during the initial year as well as technical programme for the next year were discussed.

Dr. Krishna Kumar, Head, Crop Protection Division, deputed for delivering a talk on "Exploration and exploitation of plant growth-promoting and antagonistic microbes for crop health management in India" during 5th Asian Plant Growth-Promoting Rhizobacteria International Conference for Sustainable Agriculture 2017 at Bogor, Indonesia from July 16-19, 2017.

Dr. Aditya Pratap visited WorldVeg, Tainan, Taiwan between Nov., 14-24, 2017 to attend a training programme on 'Molecular breeding in mungbean'. During this visit, Dr. Pratap also interacted with the Scientists and Staff of WorldVeg and delivered a seminar on 'Pulses improvement programme in India'.

Dr. Alok Das, Scientist, Division of Plant Biotechnology was deputed to attend a Workshop at Bangladesh Agricultural Research Institute (BARI) on Biosafety as resource person. He delivered a presentation on Biosafety Issues at Dhaka on 26th July, 2017.

Dr. S.K. Chaturvedi, Principal Scientist, Division of Crop Improvement visited Tanzania as Member of Delegation led by Joint Secretary, Ministry of External Affairs. To discuss "Bilateral cooperation if field of agriculture especially in pulses" during 8-16 July 2017.

Dr. S.K. Chaturvedi, Principal Scientist, Division of Crop Improvement visited Kenya As Expert & Principal Investigator of TL-III to attend Seed System Strategy Development Workshop, Nairobi, Kenya during 29-11-2017 to 2-12-2017.

Dr. Aditya Pratap visited BARI, Dhaka, Bangladesh to participate in annual planning-cum-review meeting of the International Mungbean Improvement Network.

Dr. Aditya Pratap visited WorldVeg (AVRDC) Taiwan w.e.f. Nov. 14-25, 2017 to attend training programme on 'Mungbean Molecular Breeding'.

Trainings attended

- Dr.Sanjay M. Bandi attended the ICAR sponsored Short Course (10 days) on "Nanotechnological approaches in Pest and Disease Management" held at ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru during 15 to 24 November, 2017.
- Dr. Neetu Singh Kushwah attended six days training on "Genome sequencing: Methods and Applications" held at ICAR-NBFGR, Lucknow on March 12-17, 2018.
- Dr. Neetu Singh Kushwah attended National Conference on "Innovative Farming for Food and Livelihood security in changing Climate" held at BCKV, Kalyani, West Bengal.
- Dr. Neetu Singh Kushwah visited ICAR-Central Institute for Cotton Research, Nagpur to get acquainted with confined field trials on cotton from June 21-22, 2017
- Dr. Shanmugavadivel attended Workshop on Breeding Management System for data migration at IIPR from 15th-18th Nov 2017.
- Mr. Sudhir Kumar attended Professional Attachment Training" for 3 months (17th Nov. 2017 to 16th Feb. 2018) at ICRISAT, Hyderabad.
- Dr. Alok Das attended Training Workshop on Biosafety as resource person to deliver a presentation on Biosafety Issues at Bangladesh Agricultural Research Institute (BARI), Dhaka, Bangladesh on 26 July, 2017.
- Dr. Alok Das attended IBO Update for ICAR-Indian Institute of Pulses Research, Kanpur, Institutional Biosafety Officer Training Workshop: Auditing Contained Research Facilities on September 10, 2017 in Bangalore, India.

- Dr. Aravinda K Konda attended the workshop, "Essential programming for Life scientists", at IIT, Hyderabad during July 13-15, 2017.
- Dr AK Srivastava attended training programme on "Advanced Experimental Designs and Statistical Analysis for Breeding and Agronomic Trials" organized by ICARDA w.e.f. Oct. 23 to Nov. 3, 2017 at ICAR-IASRI, New Delhi.
- Dr Basavraja T attended five days International Mungbean Improvement Project (IMIN) workshop on plant breeding database and statistics organized by AVRDC-IMIN project partners at AVRDC-ICRISAT Campus, Hyderabad during October 23 -27, 2017.
- Dr Basavraja T attended one day Germplasm field day on *Kharif* oilseeds and pulses (Mungbean and Urdbean) at ICAR-NBPGR, Isspur farm, New Delhi on October 5, 2017.
- Dr. Amrit Lamichaney participated in three days training on TOT on Skill Development organized by ASCI at RVSKVV, Gwalior during December 11-13, 2017.
- Dr Aditya Pratap attended national consultation on bioresources for sustainable development held at Institute of Life Sciences, Bhubaneswar, Odisha, on July 31-August 2, 2017.
- Dr. DS Gupta attended CAFT training of 21 days on "Application of OMICS Tools and Techniques for Agricultural Germplasm Improvement" at ICAR-IASRI, New Delhi from Feb. 9, 2018 to March 1, 2018.
- Dr AK Parihar attended Group Meet on Mungbean, Urdbean, Cowpea and Guar for spring, summer & rice fallow cultivation at RVSKVV, Gwalior, during November 10-11, 2017.
- Dr. Jitendra Kumar attended Review Meeting of Foreign aided Projects, held on June 22, 2017 at ICAR, Krishi Bhawan New Delhi
- Dr. Jitendra Kumar attended Annual Review & Planning Meeting of DAC-ICAR-ICARDA on Pre-breeding in lentil and chickpea held at NASC, Pusa Campus, New Delhi on July 4, 2017.
- Dr. C.P. Nath, Scientist attended the International Centre for Agricultural Research in the Dry Areas (ICARDA) funded training programme on "Advanced experimental designs and statistical analysis for breeding and agronomic trials" organized by ICARDA w.e.f. October 23, 2017 to November 3, 2017 at IASRI, New Delhi.
- Dr. C.P. Nath, Scientist participated in the ICAR-sponsored short course on "Enhancing nutrient use efficiency though next generation fertilizers in field crops" from November 21-30, 2017 at ICAR-Indian Institute of Pulses Research, Kanpur, U.P.
- Mr. K K Hazra, Scientist participated in the ICAR-sponsored short course on "Enhancing nutrient use efficiency though next generation fertilizers in field crops" from November 21-30, 2017 at ICAR-Indian Institute of Pulses Research, Kanpur, U.P.
- Dr. PR Sabale attended the Refresher course on innovative strategies for diagnosis and management of plant diseases at UAS, Dharwad from 8th to 28th Dec. 2017
- Dr. Revanappa attended the training programme on plant breeding data base and statistics from Oct, 23-27, 2017 held at world vegetable centre, South Asia office, ICRISAT campus, Hyderabad.
- Dr. M H Kodandaram, Principal Scientist acted as Resource Person in a training programme on "Innovative approaches in pest management through bio-rationals against biotic and abiotic stress of major fields crops under climate resilient agriculture" held from 5-19th Feb., 2018 at UAS Dharwad.
- Dr. Revanappa and Dr.P.R. Saabale attended the Group Meet for All India Coordinated Research Project on MULLaRP, and Arid legumes held at G. B. Pant University of Agriculture & Technology, Pantanagar
- The scientists of IIPR, RRC are involved in PG Teaching & Research Guidance at University of Agricultural Sciences at Dharwad.

Symposiums/Seminars

- Dr. Revanappa, Dr. PR Sabale and Dr. M.H. Kodandaram participated in the National symposium on *Pulses* for nutritional security and agricultural sustainability held at Kanpur from 2-4th Dec. 2017.
- Dr. Revanappa, participated in National conference on Genetics and Cytogenetics held at UAS, Dharwad held from 1–2, Feb. 2018.

Awards and Recognitions

Dr. N.P. Singh, Director, ICAR-IIPR, was awarded with *Dr. Dharmpal Singh Lifetime Achievement Puraskar* by U.P. Academy of Agricultural Sciences, Lucknow. The award was presented to Dr. Singh by Hon'ble Governor of Uttar Pradesh Shri Ram Naik on June 14, 2017, in the presence of Drs. Mangala Rai and Panjab Singh, both former DG, ICAR and other dignitaries. Dr. Singh has been awarded for his notable contributions in over all agricultural development in Uttar Pradesh.

"Chaudhari Devi Lal Outstanding All India Coordinated Research Project Award 2016" to the AICRP on Chickpea

Recognizing its pioneering role in promoting chickpea research in the country, the Indian Council of Agricultural Research has conferred the prestigious **"Chaudhari Devi Lal Outstanding All India Coordinated Research Project Award 2016"** to the AICRP on Chickpea on July 16, 2017.

Indian Council of Agricultural Research

Certificate

CHAUDHARY DEVI LAL OUTSTANDING ALL INDIA COORDINATED RESEARCH PROJECT AWARD 2016

is presented to

All India Coordinated Research Project on Chickpea

ICAR-Indian Institute of Pulses Research

Kanpur, Uttar Pradesh

- Dr. Uma Sah, Pr. Scientist received *Dr. Ram Pratap Singh Vishisht Krishi Vaigyanik Puraskar* in Agricultural extension management category for the year 2016 from Uttar Pradesh Academy of Agricultural Sciences at Lucknow. The award was given by Hon'ble Agriculture Minister, Uttar Pradesh, Shri Surya Pratap Sahi in presence of Hon'ble Governor, Uttar Pradesh, Shri Ram Naik on June 14, 2017 during National Seminar on "Agriculture Research and Education in Relation to Development of Integrated Agriculture: Challenges & Solutions" held at ICAR-Indian Institute of Sugarcane Research (IISR), Lucknow.

- Dr. Chandra Mohan Singh, Young Scientist (SERB-DST), Crop Improvement Division, got "Award for Distinguished Research in International Arena" in recognition of his global achievement in the field of agricultural research in National Seminar on "New Paradigm of Strengthening Agricultural Education in India – A Critical Overview" held at ICAR- Indian Institute of Sugarcane Research, Lucknow by Agrigate Foundation on April 17, 2017.
- Dr. Shanmugavadivel, Scientist was awarded the Young scientist Award for contribution in the field

of Agricultural Biotechnology given by Society by Scientific Development in Agriculture and Technology, Meerut, UP on December 2017.

- Dr Ummed Singh, Senior Scientist was honoured with 'Distinguished Scientist Award' by Society for Bioresource and Stress Management, Kolkata in the Third International Conference on 'Bioresource and Stress Management' held at State Institute of Agriculture Management (SIAM), Jaipur, Rajasthan during November 08-11, 2017.
- Dr Abhishek Bohra has been awarded with ISPRD Young Scientist award-2017 to recognize his contribution in the area of legume genetics and breeding. Noteworthy achievements of his research work include large-scale DNA markers in pigeonpea and chickpea, first SSR-based genetic map of pigeonpea, first high-density genetic linkage map of chickpea. Concerning trait mapping, he was involved in the studies that reported a set of QTLs/marker-trait associations governing resistance to sterility mosaic diseases (SMD), Fusarium wilt and fertility restoration in pigeonpea. His significant contribution also involves discovery of a QTL "hot spot" region in chickpea controlling a range of drought tolerance related traits.

- Dr Ummed Singh, Senior Scientist was honoured with 'Distinguished Scientist Award' by Society for Bioresource and Stress Management, Kolkata in the Third International Conference on

'Bioresource and Stress Management' held at State Institute of Agriculture Management (SIAM), Jaipur, Rajasthan during November 08-11, 2017.

Dr. C.S. Praharaj, PS & Head was conferred with Best Scientist Award 2017 (Senior Category) for Outstanding Contribution in Agricultural Research and Development by ICAR-Indian Institute of Pulses Research, Kanpur on Institution Foundation Day held on Sept. 5, 2017.

- Dr Abhishek Bohra received **IIPR's Best Scientist Award** for the year 2017 in the young scientist category.
- **Best Scientist Award in Senior Scientist** Category by ICAR-National Rice Research Institute, Cuttack on 23.04.2017 during 71st Institute Foundation Day and *Dhan Diwas* at Cuttack, Odisha.
- Mr. Uday Jha was awarded with Young Scientist Award during Third International Conference on Bioresource and Stress management, held during Nov. 8-11, 2017 at Jaipur, Rajasthan, India.
- Dr. C.P. Nath received "The Indian Science Congress Association (ISCA) Young Scientist Award" for 2017-18 in the Section of Agriculture and Forestry Sciences on March 20, 2018 in the Manipur University, Imphal.

Dr. Bansa Singh was elected as President of Nematological Society of India, Division of Nematology, IARI, New Delhi for the period of 2018-19. Nematological Society of India was established in 1969 and started publication of Indian journal of Nematology in 1971. This society is also member of International Federation of Nematology Societies.

- Dr. Jitendra Kumar received Bioved Fellowship Award 2018 on the occasion of "20th Indian Agricultural Scientists and Farmers' Congress on "Recent Need based and Eco-Friendly Technologies for Doubling Farmers' Income" during Feb. 17-18, 2018, Bioved Research Institute of Agriculture, Technology & Sciences, Sringverpur, Allahabad in the auditorium of Bioved Krishi Prodyogiki Gram, Moharab, Allahabad.

- Drs. Jitendra Kumar, Mr. Uday Jha, Dr. AK Parihar, Dr. Ummed Singh and Dr. Alok Das received ISPRD fellowship Award 2017, on the occasion of National Symposium held on Pulses for Nutritional Security and Agriculture Sustainability (PulSym 2017) during December 2-4, 2017, IIPR.
- Dr C.S. Praharaj, PS & Head was nominated as Editor-in-Chief for the Journal of Food Legumes published by ISPRD, ICAR-IIPR, Kanpur for 2017-20.
- Dr. Alok Das was elected as Member, International Society of Root Research, Germany (ID: 589)
- Dr. Alok Das was elected as Member, International Society of Biosafety Research, Washington DC (ID: 2018-016-01)
- Dr. C.P. Nath was recognized as a "Member of the International Soil Tillage Research Organization (ISTRO)" in the year 2017.
- Dr. Neetu Singh Kushwah, Scientist was awarded best Innovative Research Paper Award entitled "Isolation, cloning and characterization of promoter of Rubisco Small Subunit 2B (rbcs2b) gene of Arabidopsisthaliana during '1st Farm Innovation Congress-2018' and National Conference on 'Innovative Farming for Food and Livelihood security in changing Climate' held on 12th-13th January, 2018 at BCKV, Kalyani, West Bengal.
- Best Oral Presentation Award: Paper entitled 'Exploitation of *Trichoderma* and PGPRs for Management of Wilt of Major Pulse Crops', authored by Mishra, R.K., Monika Mishra, Naimuddin, and Krishna Kumar and presented by R.K. Mishra was adjudged as best oral presentation in National Symposium on "Doubling Farmers' Income and Farm Profitability by 2022" held at Dr. BBAU, Lucknow organized by RASSA on Oct. 28-29, 2017.
- Poster of the paper entitled 'Development of Whitefly and Defoliator Resistant Marker free Black gram (*Vigna mungo*)' authored by Paras, P; Meenal Rathore and N.P. Singh presented in NCPP 2017 Emerging Role of Plant Physiology for Food Security and Climate Resilient Agriculture" (Ref PB46) held at IGKV, Raipur from Nov. 23-25, 2017 was adjudged for the Best Poster Award.
- Paper entitled 'Identification of New Donors for Phytophthora Stem Blight (PSB) in Short and Medium Duration Pigeonpea' authored by R.K.Mishra, Naimuddin, Monika Mishra, Abhishek Bohra, Satheesh Naik SJ, Krishna Kumar, D. Dutta, F. Singh and I.P. Singh was awarded Best Poster Award during National Symposium on 'Pulses for Nutritional Security and Agricultural Sustainability (Pulsym2017)' held at ICAR-IIPR, Kanpur on Dec. 2-4, 2017.
- Drs. Satheesh Naik SJ, Amrit Lamichaney, Kiran Gandhi B, Abhishek Bohra, Dibendu Datta, Mishra RK, Farindra Singh, Singh IP and Singh NP received Best Poster Award for the poster of the paper entitled "Identification of tolerant genotypes against pulse beetle in pigeonpea (*Cajanus cajan* (L.) Millisp.)" during National Symposium on Pulses for Nutritional Security and Agricultural Sustainability held at ICAR-IIPR, Kanpur during December 02-04, 2017.
- Dr AK Parihar received 'Best Poster Award' for abstract entitled "Pulses outlook: trend, market and policy initiatives" at National Symposium on Pulses for Nutritional Security and Agricultural Sustainability organized during Dec. 2-4, 2017 by ISPRD and ICAR-IIPR in collaboration with ICAR, New Delhi.
- Dr. C.P. Nath was awarded the Best Poster Award in 'PulSym2017' (National Symposium on Pulses for Nutritional Security and Agricultural Sustainability) held during December 2-4, 2017, organized by Indian Society of Pulses Research and Development (ISPRD) and ICAR-Indian Institute of Pulses Research in collaboration with Indian Council of Agricultural Research at ICAR-Indian Institute of Pulses Research, Kanpur.
- Dr C.S. Praharaj, PS & Head was nominated as a Member of Institute Management Committee of ICAR-Indian Institute of Seed Science, Mau, Uttar Pradesh for a period of 3 years with effect from 23.02.2018 to 22.02.2021.
- Dr. Krishna Kumar as a Mentor guided Dr. N. Amaresan, Assistant Professor, C.G. Bhakta Institute of Biotechnology, Uka Tarsadia University, Bardoli, Dist-Surat, Gujarat for -INSA-Visiting Scientist Fellowship (October 2017-Novermber 2017).
- Dr. Alok Das, Scientist, Division of Plant Biotechnology was nominated Institute Scientist for Science India Portal (https://scienceindia.in/).
- Dr C.S.Praharaj, PS and Head was Course Director for ICAR sponsored Summer School on "Scaling Water Productivity and Resource Conservation in Upland Field Crops Ensuring More Crop per Drop" held during Sept 6-26, 2017 at ICAR-Indian Institute of Pulses Research, Kanpur. He was also Course Coordinator in ICAR sponsored Short Course on "Enhancing Nutrient Use Efficiency through Next Generation Fertilizers in Field Crops" held at IIPR, Kanpur during Nov 21-30, 2017.

On-going Research Projects

S No.	IIPR Code	Project name	Sub-project		PI	Co-PI	Period
1.	CRSCIIPRSIL 201700100140	**Genetic enhancement of pulse crops for yield, stability and quality.** Coordinator: Dr. Shiv Sewak					2017-20
			Chickpea	Breeding for yield enhancement in *desi* chickpea	Dr. S. K. Chaturvedi	Dr. Yogesh Kumar	
				Breeding for higher yield and enhance resistance against abiotic resistance in chickpea	Dr. A.K. Srivastava	Dr. U.C. Jha Dr. L. Manjunath	
				Breeding for high yield and enhance resistance against abiotic stresses resistance in chickpea	Dr. U.C. Jha	Dr. Archana Singh-(Bhopal)	
				Improving seed protein content in chickpea	Dr. B. Mondal	Mr. Vaibhav Kumar	
				Breeding for yield enhancement in *kabuli* chickpea suitable for different ecologies	Dr. Yogesh Kumar	Dr. S. K. Chaturvedi Dr. B. Mondal Dr. L. Manjunath	
			Pigeonpea	Early maturing pigeonpea	Dr. Dibendu Datta	Dr. Abhishek. Bohra	
				Medium duration	Dr. Archana Singh (Bhopal)	Dr. P.K. Katiyar	
				Long duration	Dr. Satheesh Naik, SJ	Dr. Farindra Singh	
			Mungbean	Mungbean component	Dr. Aditya Pratap,	Dr. T. Basavraj Dr. Revenappa-(Dharwad)	
			Urdbean	Sub-component 1	Dr. P.K. Katiyar	Dr. Debjyoti Sen Gupta Dr. Revenappa-(Dharwad) Dr. Archana Singh (Bhopal)	
				Sub-component 2: Bio-fortification for quality traits in urdbean (*Vigna mungo* L. Hepper) and Fe metabolism related genes' expression in lenlil (*Lens culineris* Medik.)	Dr. Debjyoti Sen Gupta	Dr. Ummed Singh	
			Lentil		Dr. Jitendra Kumar	Dr. Debjyoti Sen Gupta	
			Fieldpea		Dr. A.K. Parihar	Dr. R. K. Mishra	
			Rajmash		Dr. T. Basavraj	Dr. L. Manjunath	

S No.	IIPR Code	Project name	Sub-project		PI	Co-PI	Period
2.	CRSCIIPRSIL 201700200141	**Plant Genetic Resources Management and its utilization through pre-breeding. Coordinator: Dr. Farindra Singh**					2017-20
			Urdbean			Dr. P.K. Katiyar Dr. Debjyoti Sen Gupta	
			Pigeonpea			Dr. Dibendu Datta Dr. Satheesh Naik SJ	
			Mungbean			Dr. Aditya Pratap	
			Lentil			Dr. Jitendra Kumar	
			Chickpea (Bhopal)			Dr. Archana Singh	
			Fieldpea			Dr. A. K. Parihar	
			Chickpea			Dr. B. Mondal	
			Urdbean & Mungbean (Dharwad)			Dr. Revenappa B	
			Rajmash			Dr. Basavaraja T	
			Horsegram & Cowpea	PGR Management and genetic enhancement for grain yield and resistant to multiple diseases	Dr. Revenappa-Dharwad		2015-20
			Lathyrus	PGR Management and improvement of grasspea for low ODAP	Dr. Archana Singh (IIPR RS, Bhopal)	Dr. Neetu Singh Kushwah	2015-20
3.	CRSCIIPRSIL 201700300142	**Seed Production and Quality enhancement** **Coordinator: Dr. P.K. Katiyar**					2017-20
				SP 1: To study the effect of climatic variable (rainfall and elevated CO_2	Dr. A. Lamichaney	Dr. P.K. Katiyar Dr. Kalpana Tiwari Mr. Alok Kumar	
				SP 2: To enhance field emergence of extra large seeded *kabuli* chickpea	Mr. Alok Kumar	Dr. A. Lamichaney Dr. P.K. Katiyar	
4	CRSCIIPRSIL 201700400143	**Genomics enabled Pulse improvement** **Co-ordinator : Dr. K.R. Soren**					2017-20
			SP 1: Marker-assisted gene pyramiding for pod borer resistance and drought tolerance in elite chickpea		Dr. K.R. Soren	Dr. Alok Das Dr. Shanmugavadivel P. S. Dr. Sujayanand, G.K. Dr. Biswajit Mondal	June 2014 to May 2019
			SP 2: Molecular dissection of response to terminal heat in chickpea		Dr. Shanmugavadivel P. S	Dr. K.R. Soren Dr. S. K. Chaturvedi	Nov. 2014 to May 2019
			SP 3: Trait mapping for developing plant ideotype in pigeonpea.		Dr. Shanmugavadivel P. S	Dr. Abhishek Bohra Dr. Satheesh Naik SJ	July 2016 to June 2019

S No.	IIPR Code	Project name	Sub-project	PI	Co-PI	Period
5.	CRSCIIPRSIL 201700500144	**Transgenic technology for crop improvement** **Coordinator : Dr. Meenal Rathore**				2017-20
			SP 1: Genetic engineering for development of pod borer resistant chickpea using multigene approach	Mr. K. Aravind Kumar	Dr. Alok Das Dr. Sujayananad G.K	2015-20
			SP 2: Development of regeneration and transformation protocol in grasspea (*Lathyrus sativus*).	Dr. Neetu Singh Kushwah	Dr. Alok Das Dr. Archana Singh Dr. Shanmugavadivel P. S	2017-20
			SP 3: Development of whitefly tolerant genetically transformed green gram (*Vigna rediata*)	Dr. Meenal Rathore	Dr. Alok Das Dr. Neetu Singh Kushwah	2017-20
6.	CRSCIIPRSIL 201700600145	**Development of resource-use efficient agro-technologies involving pulses and its cropping systems under diversified agro-ecologies** **Coordinator :Dr. C.S. Praharaj**				**2017-20**
			SP 1: Long-term effect of pulses in cropping systems on soil health and crop productivity in Indo-Gangetic plains	Dr. C.S. Praharaj	Dr. Narendra Kumar Dr. Ummed Singh Mr. K.K. Hazra Dr. C. P. Nath Dr. R. K. Mishra	
			SP 2: Soil-plant-nutrient dynamics for efficient nutrient management in pulses (Assessment of soil plant nutrient dynamics for strategic nutrient management in pulse based cropping system)	Mr. K. K. Hazra	Dr. Ummed Singh Dr. C. P. Nath	2015-18
			SP 3: Evolving strategic nutrient supply for higher productivity in pulses systems	Dr. Ummed Singh		
			SP 4: Precision irrigation scheduling for higher water productivity in pulses-based cropping systems	Dr. CS Praharaj	Ummed Singh, Ram Lal Jat	
			SP 5: Scaling productivity and nutrient use efficiency in pulses-based cropping systems in Central India (Improving productivity and nutrient use efficiency through micronutrient management in soybean – chickpea cropping system in Central India)	Dr. R. L. Jat	Dr. C.S. Praharaj	2016-19
			SP 6: Enhancing productivity in diverse pulses based cropping systems through improved nutrient management in Peninsular India	Dr. M.S. Venkatesh	Dr (Mrs) Ganajakshi Math, Professsor (Agron), UAS Dharwad	2017-2020
			SP 7: Development of climate resilient RCTs for pulses-based cropping systems	Dr. Narendra Kumar	Dr. CP Nath, Dr. Lalit Kumar Dr. D N Borase Dr. RP Dubey (DWR, Jabalpur)	
			SP 8: Weed management strategies for enhancing productivity and sustainability of pulses systems (Weed management in rice–chickpea cropping system under conservation practices 2016-21)	Dr. C P Nath,	Dr. Narendra Kumar	
			SP 9: Farm mechanization suitable for pulses	Er. Man Mohan Deo	Dr. Prasoon Verma, Dr. C. S. Praharaj	

S No.	IIPR Code	Project name	Sub-project	PI	Co-PI	Period
7.	**CRSCIIPRSIL 201700700146**		**Post harvest management of pulses, value addition and by-product utilization. Coordinator ; Dr. Prasoon Verma**			**2017-20**
			SP 1: Determination of milling characteristics for pulse cultivars	Dr. Prasoon Verma	Er. Man Mohan Deo	
	CRSCIIPRSIL 201600500129		**SP 2:** Enhancing efficiency of abrasive dehusking unit of IIPR Mini *Dal* Mil for different Pulses.	Dr. Prasoon Verma	Er. Man Mohan Deo	Oct. 2016 to Sept. 2019
8.	**CRSCIIPRSIL 201700800147**	**Characterization of pest and pathogens and host plant resistance in pulses PI : Dr. Naimuddin**				**2017-20**
			Chickpea		Dr. Manjunatha, L., Dr. Bansa Singh, Dr. Devendrappa M	
			Lentil		Dr. Naimuddin, Dr. Mohd. Akram, Dr. Bansa Singh, Dr. Devendrappa M	
			Mungbean and Urdbean		Dr. Mohd. Akram, Dr. Naimuddin, Dr. Bansa Singh, Dr. Devendrappa M	
			Pigeonpea		Dr. R.K. Mishra, Dr. Naimuddin, Dr. Sabaale, P.R., Dr. Mohd.Akram	
			Cowpea and Horsegram (Dharwad centre)		Dr. Sabaale, P.R., Dr. Mohd.Akram	
9.	**CRSCIIPRSIL 201700900148**	Bio-intensive management of major pest and pathogens of pulse crops **PI : Dr. Krishna Kumar**				**2017-20**
			Bio-intensive management of major diseases of pigeonpea	Dr. R.K. Mishra	Dr. Naimuddin	June 2014 to May 2019
			Potentials of fungal bio-agents for management of parasitic nematodes of pulses	Dr, R. Jagadeeswaran	Dr. Bansa Singh	June 2014 to May 2019
			Development of multi-trait *Trichoderma* sp. formulation for the management of dry root rots of chickpea	Dr. Krishna Kumar	Dr. Manjunatha L., Dr. R. K. Mishra	July 2016 to June 2019
			Development of micro-encapsulated formulation of *Helicoverpa armigera* NPV (HaNPV) to improve its photostability	Dr. Sanjay Bandi	Dr. S. K. Singh, Dr. Lalit Kumar	July 2016 to June 2019
			Management of major foliar diseases of chickpea through host resistance and phylloplane microbes	Dr Manjunatha, L.	Dr. Krishna Kumar	June 2016 to June 2019
			Harnessing the bio-compounds of actinomycetes against *Helicoverpa armigera*	Dr. Kiran Gandhi B.	Dr. Krishna Kumar , Dr. Lalit Kumar, Dr. D. N. Borse	Oct. 2016 to June 2019
			Characterization and enhancement of shelf life of entomo-pathogenic nematodes (EPNs) for management of *Helicoverpa armigera* in chickpea	Mr. Devindrappa M	Dr. Krishna Kumar Dr. Sanjay Bandi	July 2016 to June 2019

S No.	IIPR Code	Project name	Sub-project	PI	Co-PI	Period
10	CRSCIIPRSIL 201701000149	**Management and analysis of production constraints in pulses as influenced by different abiotic stresses and photo-thermoperiods Coordinator: Dr. P. S. Basu**				2017-20
			SP 1: Development of diagnostic model to identify stress tolerant genotypes based on non-invasive monitoring of nutrient & water status dependent crop spectral indices of chickpea	Dr. P. S. Basu		
	CRSCIIPRSIL 201402200116		**SP 2:** Biochemical basis of heat tolerance in chickpea (*Cicer arietinum* L.) (Old Project - Biochemical characterization of Heat Shock Proteins (HSPs) and antioxidative defense mechanism in chickpea genotypes. 2014-17)	Mr. Vaibhav Kumar		2017-2020
			SP 3: Strategies for improving yield stability in Urdbean through photothermo –insensitivity	Dr. Vijay Laxmi	Dr. D. P. Patel	2017-2020
			SP 4: Identification and physiological characteristic of high-temperature and drought tolerant genotypes of lentil (*Lens culinaris* Medik) for improving productivity and resilence	Dr. D. P. Patel	Dr. Jitendra Kumar	2017-2020
11	CRSCIIPRSIL 201701100150	**Harnessing symbiotic efficiency of germplasm of major pulses for improving biological nitrogen fixation Coordinator: Dr. M. Senthilkumar**				2017-2020
			SP 1: Harnessing symbiotic efficiency of germplasm of major pulses for improving biological nitrogen fixation	Dr. M. Senthilkumar	Dr. Krishnashis Das	
	CRSCIIPRSIL 201402300117		**SP 2**: Interactive effect of lentil genotypes - *Rhizobia* on biological nitrogen fixation	Dr. Krishnashis Das	Dr. M. Senthilkumar	2014-2018
12.	CRSCIIPRSIL 201701200151	**Nutritional enhancement of pulse grains with special emphasis on increasing bioavailability of micronutrients Coordinator: Ms. Kalpana Tiwari**				2017-2020
			SP 1: Nutritional and phytochemical profile of cowpea (*Vigna unguiculata*) and fieldpea (*Pisam sativum*) with emphesis on their bioavailability and health promoting properties	Ms. Kalpana Tiwari		
13.	CRSCIIPRSIL 201701300152	**Development of nano-polymer based micro-encapsulated formulation of imazethapyr for weed control in pulses and minimizing residue dynamics to the environment. Coordinator: Dr. Lalit Kumar**				2017-2020
			SP 1: Development of nano-material based micro-encapsulated formulation of imazethapyr for weed control in pulse crop and minimizing residue dynamics to the environment	Dr. Lalit Kumar	Dr. C. P. Nath, Dr. Sobha Sondia, (Scientist from CIRCOT Mumbai)	
14	CRSCIIPRSIL 201701400153	**Development of extension methodologies to disseminate the pulse production technologies for raising socio-economic condition of the pulse farmers. Coordinator- Dr. Rajesh Kumar**				2017-20
	CRSCIIPRSIL 201301600095		**SP 1:** Enhancing pulses production for food, nutritional security and livelihoods of tribal farming community through demonstration and training.	Dr. Rajesh Kumar	Dr. Purshottam	July 2013 to Mar 2020
	CRSCIIPRSIL 201500500121		**SP 2:** Development of pulse based model village for sustainable rural livelihood in Central Zone of U.P.	Dr. Purshottam	Dr. Rajesh Kumar	June 2015 to May 2018
	CRSCIIPRSIL 201601200136		**SP 3:** Study on farmers adoption behaviour towards sustainable pulse production practices in Bundelkhand region of Uttar Pradesh	Mr. K Ravi Kumar	Dr. Rajesh Kumar	Nov. 2016 to June 2019

S No.	IIPR Code	Project name	Sub-project	PI	Co-PI	Period
15	**CRSCIIPRSIL 201701500154**	**Development of data management platform for pulse crops Coordinator: Dr. Devraj**				**2017-20**
	CRSCIIPRSIL 201500300119		**SP 4:** Development of web-based commodity profile for chickpea and pigeonpea	Dr. Devraj	Dr. Uma Sah	June 2015 to May 2018
	CRSCIIPRSIL 201601100135		**SP 5:** Assessing suitability of chickpea genotypes in multi-environment testing	Dr. Hemant Kumar	Dr. G. P. Dixit, Dr. A. K. Srivastava	July 2016 to June 2019
			SP 6: Development and Validation of Digital Platforms for Dissemination of Information on Pulse Production Technologies"	**Dr. Uma Sah**	Dr. Rajesh Kumar Dr. Purushottam Collaborators: PC (Chickpea) PC (Pigeonpea) PC (MULLaRP)	2017-20
16	**CRSCIIPRSIL 201701600155**	**Assessment of consumer preference, marketability, cost-effective pulse cultivation and policy support for stabilizing pulse production Coordinator: Dr. Shripad Bhat**				2017-20
	CRSCIIPRSIL 201601300137		**SP 7**: Farm-retail price behaviour and transmission in Indian pulses market	Dr Shripad Bhatt	Dr. Hemant Kumar	Nov. 2016 to June 2019

1. Management of plant genetic resources and genetic enhancement for grain yield and resistance to multiple diseases in cowpea and horse gram

(PI: Revanappa)

2. Enhancing productivity in diverse pulses based cropping systems through improved nutrient management in Peninsular India

(PI: Dr. M.S.Venkatesh.)

3. Plant Genetic Resources Management and its utilization through pre-breeding:

(Co-PI: Dr. Revanappa)

4. Genetic enhancement of Pulse Crops for yield, stability and quality:

(Co-PI: Revanappa)

5. Seed Production and Quality enhancement.

(Coordinator: Dr. P.K. Katiyar. Co-PI: Revanappa)

6. Characterization of pest and pathogens and host plant resistance in pulses

(CO PI: Dr.PR Saabale)

7. Bio-intensive management of major pest and pathogens of pulse crops

(Co-PI Dr. PR Saabale and Dr.Kodandaram MH)

Externally Funded Projects

Crop Improvement Division (18)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
1.	Development of lentil cultivar with high concentration of iron and zinc.	ICARDA	Dr. N.P. Singh	Dr. Jitendra Kumar	Jan.2013 to Dec, 2018	US$ 10,000
2.	Generation advancement and development of new genotypes through pre-breeding in lentil and *Kabuli* chickpea. Through DAC-ICARDA-ICAR collaborations	DAC-ICARDA-ICAR	Coordinator : Dr. N.P. Singh PI (Lentil) : Dr. Jitendra Kumar		Sept 2013 to July 2017 **(Closed on 31.07.17)**	152.448 Lentil :
			PI (*Kabuli* Chickpea), Dr. B. Mondal, Dr. S. K. Chaturvedi	Mr. Udai Chand Jha		Chickpea: 26.14
3.	Developing chickpea cultivars suited to mechanical harvesting and tolerant to herbicides	NFSM	Dr. S.K. Chaturvedi	Dr. Ummed Singh	Sept.2013 to July 2017	97.31
4.	Seed production in agricultural crops	DAC	Dr. P.K. Katiyar	Amrit Lamichaney	2005-06 to March 2018	
5.	ICAR (NSP) crops	DAC	Dr. P.K. Katiyar	Amrit Lamichaney	April 2007 to March 2018	
6.	Development of thermo insensitive and high yielding cultivars in green gram [*Vigna radiate* (L.) Wilczek] through AB-QTL approach	UPCAR	Dr. Aditya Pratap	--	Sept. 2014 to Sept. 2017	21.597
7.	CRP on molecular breeding for improvement of tolerance to biotic and abiotic stresses, yield and quality traits in crops-chickpea.	ICAR	Dr. Aditya Pratap	Dr. S.K. Chaturvedi Dr. K. R. Soren Dr. P S Basu	2015-17	28.80
8.	Introgression of photo-thermo insensitivity in mungbean (*Vigna rediata* L.) and its rapid fixation through doubled haploidy Breeding	Lal Bahadur Shastri Outstanding Young Scientist Award 2014	Dr. Aditya Pratap		April 2016 to March 2019	30.55
9.	Genomics data analysis for identification of economically important markers and viral diagnostics in pulses	Centre for Agril. Bioinformatics (IASRI)	Dr. Abhishek Bohra	Dr. K. R. Soren Dr. M. Akram	Dec. 2014 to March 2018	164.34
10.	Harnessing favourable QTL of wild and exotic germplasm for yield contributing traits in lentil using advanced backcross QTL analysis	DBT (DST)	Dr Jitendra Kumar	Dr. Aditya Pratap	Feb. 2015 to Jan. 2018	22.352
11.	CRP on hybrid technology in pigeonpea	ICAR	Dr. Abhishak Bohra		2015-16 to 2017-18	88.00
12.	Establishing the International Mungbean Improvement Network	AVRDC	Coordinator : Dr. N.P. Singh PI: Dr. Aditya Pratap		2017-2019	150.10

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
13.	Improving livelihood for small holder farmers: Enhanced grain legumes productivity and production in sub Saharan Africa and South-Asia **(TL III)**	Bill and *Melinda* Gates Foundation (ICRISAT Collaborative)	**Project Coordinator :** Dr. N.P. Singh PI: Uma Sah	Dr. Rajesh Kumar, Dr. P.K. Katiyar, Dr. Uma Sah, Dr. Archana Singh	2016 to 2019	US$ 57,050
14.	Characterization, mapping and transcryptome analysis of seed protein, β carotene and mineral contents in chickpea (*Cicer arietinun* L.)	NASF	**CC-PI :** Dr. Biswajit Mondal	CC-CoPI: Dr. Jagdish Singh, Dr. Meenal Rathore	Jan. 2017 to Dec. 2019	19.21
15.	CRP on Agro-biodiversity 1. Pigeonpea	ICAR	Dr. Dibendu Datta	Dr. Archana Singh Dr. D. N. Gawande	2014 to 2017	47.35
	2: Chickpea: **Sub-project 1** (Characterization, regeneration, distribution and documentation) **Sub-project II** (Detailed evaluation)		Dr. Archana Singh	Dr. G. K. Sujayanand		21.95 & 40.90
16.	Widening of genetic base in pigeonpea (*Cajanus cajan* L. Mill. Sp.) through pre-breeding efforts for developing next generation wilt resistant and photo-insensitive early pigeonpea	ICAR (Extramural Research Projrct)	1. ICAR-IIPR, Kanpur 2. PJTSU-RARS, Warangal 3. SDAU, S K Nagar 4. VNMKV-ARS, Badnapur **5.** NAU, Navsari	Dr. Farindra Fingh (Centre PI)	2015-16 2016-17	15.00 30.00
17.	Delivering more produce and income to farmers through enhancing genetic gains for chickpea and pigeonpea	NFSM	**Chickpea:** Dr. S. K. Chaturvedi **Pigeonpea:** Dr. K. R. Soren		2017-18 to 2019-20	104.61
18.	Genetic enhancements in pigeonpea (*C. cajan* L Millisp.) through pre-breeding efforts for developing phytophthora stem blight resistant/tolerant and photo-thermal insensitive early pigeonpea	SERB (DST)	Dr. Satheesh Naik SJ		2018-2021	36.68

Bio-Technology Unit (6)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
19.	Transgenic in chickpea and pigeonpea for pod borer resistance	NPTC-TG (ICAR)	Dr. Alok Das	Dr. Sujayanand G.K.	Sep.2005 to March 2020	X Plan : 93.11 XI Plan : 90.78 XII Plan : 30.29
20.	Identification and characterization of gram pod borer resistance Transgenic chickpea and pigeonpea for conducting confined trials	NASF (ICAR)	Dr. Alok Das	Dr. Meenal Rathore, Dr. Neetu Singh Kushwah, Dr. Sujayanand, G. K., Dr. Abhishak Bohra, Dr. Biswajit Mandal, Dr. K.R. Soren	Feb. 2018 to Jan. 2019	50.60

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
21.	Functional genomics in chickpea	NPTC-FG (ICAR)	Dr. K.R. Soren	Dr. S.K. Chaturvedi	Sep.2005 to March 2021	X Plan : 93.11 XI Plan : 96.40 12-13 : 17.54 13-14 : 10.91 14-15 : 5.99 15-16 : 6.25
22.	Utilizing chickpea genome sequence for crop improvement	DAC (NFSM)	**Co-Project Coordinator:** Dr. N.P. Singh **PI:** Dr. K.R. Soren	Dr. S.K. Chaturvedi, Dr. D.N. Gawande, Dr. P.R. Saable	19.06.2015 to 18.06.2017	78.84
23.	Incentivizing research in agriculture : molecular genetic analysis of resistance/tolerance to different stresses in chickpea	ICAR-CRRI	Dr. K. R. Soren	Dr. B. Mandal Dr. S.K. Chaturvedi Dr. S. K. Meena	2015 to 2018	15-16 : 26.35
24.	Functional genomics in pigeonpea (Genetic mapping of *Fusarium* wilt and SMD in pigeonpea)	NPTC-G (ICAR)	Sh. Shanmugavadivel, P. S.	Dr. Abhisekh Bohra, Dr. P.R. Saable	2015-18	7.00

Crop Protection Division (8)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
25.	Crop pest surveillance and advisory project (CROPSAP)	RKVY, Maharashtra	Dr. Bandi Sanjay Maruti	---	Oct. 2013 to March 2017	3.74
26.	Studies on climate volatility and its impact on pests of pulses at micro level in varied agro-ecosystem of Uttar Pradesh	UPCAR	Dr. S.K. Singh	Dr. Hemant Kumar	Sept. 2014 to Sept. 2017	24.1788
27.	Characterization and development of bio-pesticide from native microbes for the managements of Bihar hairy caterpillar in pulse crops	UPCAR	Dr. Sujayanand, G. K.		Sept. 2014 to Sept. 2017	24.955
28.	Development of microbial based formulations and their consortia for management of pigeonpea wilt diseases	CST, UP	Dr. R.K. Mishra	Dr. Naimuddin, Dr. P. R. Saabale	2016-19	11.94
29.	Transcriptome dynamics in host viruses interaction to identify multi virus resistant genotypes in mungbean	SERB (DST)	Dr. M. Akram	Dr. Naimuddin	April 2017 to March 2020	72.41
30.	Identification of potential Plant Growth Promoting Rhizobacteria's (PGPRs) against *Fusarium* wilt and dry root rot for enhancing chickpea productivity.	SERB (DST)	Dr. Krishna Kumar	Dr. Manjunatha L.	2017-2020	30.49

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
31.	Nematophagous bacteria: Identification and profiling of host specificity of *Pasteuria penetrans* infecting *Meloidogyne* spp. in pulses.	SERB (DST)	Dr. R. Jagadeeswaran		2017-2020	37.48
32.	Virulence profiling of *Ascochyta rabiei* and deciphering molecular interactions with chickpea	SERB (DST)	Dr. Manjunatha L.	K. Arvind Kumar	2017-2020	35.56

Basic Science Division (1)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
33	Rhizosphere micribiome for improving symbiotic nitrogen fixation and yield in lentil in North Eastern States of India	Biotech Consortium India Limited	Centre PI: Dr. M. Santhilkumar		2016-2019	24.76

Social Science (4)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
34.	Harnessing modern communication technologies for sharing of available knowledge resources with pulse growing farmers in Uttar Pradesh	UPCAR	Dr. Uma Sah	Dr. Devraj, Dr. S. K. Dubey	Sept. 2014 to Sept. 2017	23.9104
35.	Socio-economic and technological empowerment of pulse growers of Jalaun and Kanpur Dehat districts of Uttar Pradesh	DBT	Dr. Uma Sah	Dr. Narendra Kumar, Dr. P.R. Saabale	2015 to 2018	50.38
36.	Development of pulses based bio-village sustainable models through action research for livelihood security under different agro-ecosystems in Uttar Pradesh	DBT	Dr. Purshottam	Dr. Lal Bahadur (KVK, Shahjahanpur), Dr. Vijay Kr. Gautam Dr. Narendra Singh (KVK, Chitrakoot), Dr. Rajesh Kumar (IIPR, Kanpur)	2016-2019	25.56
37.	Integrated approaches for food, nutrition and livelihood security for rural household in Fatehpur district of Uttar Pradesh (**Farmers First**).	ICAR	Dr. Rajesh Kumar	Dr. Purshottam, Dr. Ummed Singh, Mr. Shripad Bhat, Dr. Subhash Chandra (CSAUAT), Dr. M. P. S. Yadav (CSAUAT)	2016-18	46.00

Institute Mega- Project (6)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
38.	National Initiative on climate Resilient Agriculture (NICRA)	ICAR	**Institute Coordinator :** Dr. N.P. Singh **PI:** Dr. Sanjeev Gupta	Dr. P.S. Basu, Dr. Aditya Pratap, Dr. Dibendu Datta, Dr. G.P. Dixit	**I** - 2011-2016 **II** - 2017-2020	567.00
39.	Implementation of PVP legislation, DUS test (Chickpea)	PPV & FRA	Dr. G.P. Dixit	Dr. A.K. Srivastava	2007 till date	PPV & FRA Budgets
40.	Implementation of PVP legislation, DUS test (Pigeonpea)	PPV & FRA	Dr. I.P. Singh	Dr. Farindra Singh	2007 till date	PPV & FRA Budgets
41.	Implementation of PVP legislation, DUS test (MULLaRP)	PPV & FRA	Dr. Sanjeev Gupta	Dr. A.K. Parihar	2007 till date	PPV & FRA Budgets
42.	Creation of seed hubs for increasing indigenous production of pulses in India	ICAR & DAC (NFSM)	**Institute Coordinator :** Dr. N.P. Singh	Dr. P. K. Katiyar (wef March 2017), Dr. S. K. Chaturvedi (till Feb.. 2017)	2016-2021	
43.	Enhancing breeder seed production for increasing indigenous production of pulses in India	ICAR & DAC (NFSM)	**Institute Coordinator :** Dr. N.P. Singh	Dr. P.K. Katiyar	2016-2021	

Young Scientist Project (3)

S No	Name of the project	Funding Agency	Principal Investigator	Associate	Period	Budget (₹ in lakh)
44.	Implémenting genomics approaches for breeding high yielding genotypes with enhanced resistsnce to yellow mosaic in mungbean (*Vigna rediata* (L.) Wilzek)	SERB	Dr. Chandra Mohan Singh	Mentor : Dr Aditya Pratap	07/07/2016 to 06/07/2019	32.50
45.	Développent of *Bemisia tabaci* and *Spodoptera litura* resistant marker free transgenic black gram (*Vigna mugo*) expressing Tma 12 and Cry IEC insecticidal proteins	SERB	Dr. Paras Pandey	Mentor : Dr Meenal Rathore	2017 - 2020	9.00 + Fellowship
46.	Agrobacterium tumefaciens-mediated dene editing in chickpea (*Cicer arietinum*) using CRISPR-Cas9 system	DST (INSPIRE)	Dr. Shallu Thakur		2017-2022	80,000/= per month (with 3.3% increment + 35 Lakh Res grant.

Institute Management Committee

As on 31.3.2018

Dr. N.P. Singh Director ICAR-Indian Institute of Pulses Research, Kanpur	Chairman
Asstt. Director General (O&P) ICAR Krishi Bhawan, New Delhi	Member
Mr. T.C. Sharma Finance and Accounts Officer ICAR-PDFSR, Modipuram, Meerut	Member
Dr. Ram Awatar Sharma Principal Scientist ICAR-CAZRI, Jodhpur (Raj.)	Member
Dr. C. Bhardwaj Principal Scientist ICAR-IARI, New Delhi	Member
Dr. S. Natarajan Principal Scientist ICAR-IARI-RBGRC, Aduthurai (TN)	Member
Dr. Rama Shankar Katiyar Billhor, Kanpur Dehat (U.P.)	Member
Mr. Shiv Poojan Chandel Mirzapur (U.P.)	Member
Dr. A.N. Sharma Principal Scientist ICAR-Directorate of Soybean Research, Indore	Member
Additional Director (Agril.) Govt. of U.P., Krishi Bhawan, Lucknow	Member
Joint Director (Agril.) Pant Krishinagar Bhawan, Jaipur	Member
Director Research JNKVV, Jabalpur	Member
Mr. Kumar Vivek Senior Administrative Officer ICAR-IIPR, Kanpur	Member Secretary

Research Advisory Committee

As on 31.3.2018

Dr. S.K. Sharma Ex. Vice-Chancellor CSK Himachal Pradesh Krishi Vishwavidylaya, Palampur, H.P.	Chairman
Dr. S.K. Rao Director Research Services Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	Member
Dr. P.K. Singh Sr. Scientist, Plant Biology & Genetic Engineering CSIR-NBRI, Lucknow	Member
Dr. V.G. Malathi Emeritus Scientist TNAU, Coimbatore	Member
Dr. Subhash Chander Professor, Division of Entomology ICAR-IARI, New Delhi	Member
Dr. Jayent Deka Principal Scientist DWSRC, Assam Agricultural University, Jorhat, Assam	Member
Dr. Baldev Singh Ex-Head, Division of Extension ICAR-IARI, New Delhi	Member
Assistant Director General (O&P), ICAR Krishi Bhawan, New Delhi	Member
Dr. N.P. Singh Director ICAR-Indian Institute of Pulses Research, Kanpur	Member
Dr. Rama Shankar Katiyar Vill. & PO-Billhor, Kanpur Dehat (U.P.)	Member
Mr. Shiv Poojan Chandel Vill- Mohlar (Barkar Chakki) PO- Buwar, Mirzapur (U.P.)	Member
Dr. Mohd. Akram Principal Scientist, Division of Crop Protection ICAR-Indian Institute of Pulses Research, Kanpur	Member Secretary

Institute Research Council

As on 31.3.2018

Dr. N.P. Singh Director ICAR-Indian Institute of Pulses Research, Kanpur	Chairman
Assistant Director General (O&P), ICAR Krishi Bhawan, New Delhi	Member
All Scientists of the Institute	Member
Dr. Aditya Pratap Principal Scientist, Division of Crop Improvement ICAR-IIPR, Kanpur	Member Secretary

Important Committees of the Institute

As on 31.03.2018

1.	Monthly Review Committee **(MRC)**	**Chairman**	: Director
		Members	: All Project Coordinators, All Heads of Divisions, All Scientists, Sr. AO., F&AO, AAOs, Chairmen's of various committees, Secretary- IJSC, Architect and I/c of various activities
		Member Secretary	: Dr. Naimuddin, Principal Scientist
2.	Farm Advisory Committee (FAC)	**Chairman**	: Dr. C.S. Prahraj
		Members	: All HoDs, I/c Farms, I/c Security & Dr. P.K. Katiyar, Nodal Officer (Seed)
		Member Secretary	: Dr. Narendra Kumar, Sr. Scientist
3.	Estate Management Committee	**Chairman**	: Er. Prasoon Verma
		Members	: Dr. Ummed Singh, Dr. R.K. Mishra, Er. Manmohan Deo, Dr. Omkar Nath, Sr. Administrative Officer, F. & A.O. , Mr. S.K. Garg, Mr. R.M. Pal
		Member Secretary	: Sh. D.N. Awasthi, CTO (Architect)
4.	Publication Committee	**Chairman**	: Director
		Members	: Dr. Krishna Kumar, Dr. P.S. Basu, Dr. (Mrs.) Meenal Rathore, Dr. Mohd. Akram and Dr. Aditya Pratap
		Member Secretary	: Dr. Rajesh Kumar Srivastava
5.	Purchase Advisory Committee (PC)	**Chairman**	: Dr. Naimuddin
		Members	: Dr. Krishna Kumar, Dr. Shiv Sewak, Er. Prasoon Verma, Dr. Narendra Kumar, Dr. P.K. Katiyar, Dr. Senthil Kumar, Dr. K.R. Soren, Sr. AO. and F&AO
		Member Secretary	: AAO (S)
6.	Results Framework Document Committee	**Chairman**	: Director
		Members	: Dr. Shiv Sewak, Dr. C.S. Prahraj, Dr. Jagdish Singh, Dr. Krishna Kumar, Dr, Rajesh Kumar, AO and F&AO
		Nodal Officer	: Dr. Mohd. Akram
		Co-Nodal Officer	: Dr. Senthil Kumar

7.	Institute Technology Management Committee (ITMC)	**Chairman**	: Director
		Members	: Dr. Shiv Sewak, Dr. Jagdish Singh, Dr. C.S. Prahraj, Dr. Krishna Kumar, Dr. Rajesh Kumar, Dr. Aditya Pratap, Dr. Devraj, Mr. Udai Chandra Jha
		Ex-Officio	: Dr. Sanjeev Gupta, Dr. I.P. Singh &
		Member	: Dr. G.P. Dixit
		Member Secretary	: Dr. Aditya Pratap
8.	Resource Generation and Farm Produce Price Fixation Committee	**Chairman**	: Dr. Krishna Kumar
		Members	: Dr. Devraj, Sr. Administrative Officer, Finance & Accounts Officer and Dr. (Mrs.) Uma Sah, I/c Library
		Member Secretary	: Dr. Ummed Singh
9.	Prioritization Monitoring and Evaluation Cell (PME Cell)	**Chairman**	: Director
		Members	: Dr. R.K. Mishra, Dr. Senthil Kumar, Dr. (Mrs.) Meenal Rathore, Dr. Uma Sah, Dr. (Mrs.) Archana Singh RS, Bhopal, Dr. M.S.Venkatesh, RS, Dharwad, Dr. Sripad Bhatt, Dr. Abhisek Bora
		Member Secretary	: Dr. C.S. Prahraj
10.	Library Committee	**Chairman**	: Director
		Members	: All HoDs, Sr. AO and F&AO
		Member Secretary	: Dr. (Mrs.) Uma Sah
11.	Institute Bio-safety Committee	**Chairman**	: Director
		Members	: Dr. Mohd. Akram, Dr. (Mrs.) Meenal Rathore, Dr. Senthil Kumar, Dr. Sujanand G.K., Dr. Jonaki Sen, IIT, Kanpur, Dr. Amaresh Chandra, IISR, Lucknow, Dr. P.K. Singh (GSVM Medical College, Kanpur)
		Member Secretary	: Dr. Alok Das, Scientist
12.	Germplasm & Genotype Identification Committee	**Chairman**	: Director
		Members	: Dr. Shiv Sewak, Dr. Sujayanand G.K. Dr. Aditya Pratap, Dr. Mohd. Akram, Dr. Jitendra Kumar
		Member Secretary	: Dr. Aditya Pratap
13.	Academic and HRD Committee	**Chairperson**	: Dr. (Mrs.) Minal Rathore
		Members	: Dr. Ummed Singh, Dr. R.K. Mishra, Dr. Senthil Kumar, Dr. Abhisek Bohra, Dr. Sripad Bhatt, Dr. Debjyoti Sen Gupta
		Member Secretary	: Dr. Alok Das, Scientist

14.	Grievance Cell	**Chairman**	: Dr. Rajesh Kumar
		Members	: Dr. Jitendra Kumar, Dr. (Mrs.)Archana Singh (RS,Bhopal), Dr. Revanappa (Dharwad) and Dr. Omkar Nath
		Member Secretary	: Sr. Administrative Officer
15.	Computer/ ARIS Cell & Instrumentation Committee	**Chairman**	: Dr. P.S. Basu
		Members	: Dr. Senthil Kumar, Dr. Hemant Kumar, Dr. Prakash G. Patil, Dr. Abhisekh Bora and Dr. Manmohan Deo
		Member Secretary	: Dr. Devraj
16.	Consultancy Processing Cell	**Chairman**	: Dr. Bansa Singh, Pr. Scientist
		Members	: Dr. Rajesh Kumar, Dr. Farindra Singh, Dr. Ummed Singh, Dr. A.K. Parihar, Dr. K.R. Soren and Dr. A. K. Srivastava
		Member Secretary	: Dr. R.K. Mishra
17.	Guest House Management Committee	**Chairman**	: Dr. Shiv Sewak
		Members	: Dr. Rajesh Kumar, Dr. Farindra Singh, Dr. Lalit Kumar and Dr. Ummed Singh
		Member Secretary	: Sr. Administrative Officer
18.	Vehicle Maintenance Committee	**Chairman**	: Dr. Lalit Kumar
		Members	: Dr. Naimuddin, Dr. Ummed Singh, Dr. Revanappa, (RS, Dharwad), Dr. (Mrs.) Archana Singh (RS, Bhopal) Sr. A.O., F&AO and AAO(S)
		Member Secretary	: Sh. Sukdeo Mahto
19.	Sports Committee	**Chairman**	: Dr. Bansa Singh
		Members	: Dr. (Mrs.) Vijay Laxmi, Dr. K.R. Soren, Dr. Jagdeeswaran, Dr. M.P. Singh and Mr. Yashwant Singh, Secretary IJSC
		Member Secretary	: Dr. Ummed Singh
20.	*Rajbhasha* Implementation Committee	**Chairman**	: Director
		Members	: All HoDs, Dr. (Mrs.) Uma Sah, Dr. R.K. Mishra, Dr. Purushottam and Mr. A.P. Singh
		Member Secretary	: Dr. Rajesh Kumar Srivastava
21.	Technical Advisory & Proprietary Committee	**Chairman**	: Dr. P.S. Basu
		Members	: Dr. Mohd. Akaram, Dr. Lalit Kumar Dr. Senthil Kumar
		Member Secretary	: Dr. (Mrs.) Meenal Rathore

22.	Local Purchase Committee	**Chairman**	:	Dr. Lalit Kumar
		Members	:	Dr. Rajesh Kumar, Dr. Farindra Singh, Dr. R.K. Mishra, Dr. K.R. Soren, Dr. Omkar Nath and F & AO
		Member Secretary	:	AAO (S)
23.	Co-ordination Committee	**Chairman**	:	Dr. Aditya Pratap
		Members	:	Dr. Omkar Nath and Mr. Rajendra Kumar Nigam
24	Women Grievance Cell	**Chairperson**	:	Dr. (Mrs.) Uma Sah
		Member	:	Dr. (Mrs) Meenal Rathore, Dr. (Mrs.) Archana Singh, RS (Bhopal) and Mrs. Kirti Singh
		Member Secretary	:	Sh. Rajeev Nigam
25.	**In-charges**	Mr. Kumar Vivek, Sr. A.O. - Head of Office		
		Dr. Jagdish Singh, Principal Scientist & Head-Member Secretary QRT and EFC		
		Dr. Aditya Pratap, PS – Member Secretary, IRC		
		Dr. Mohd. Akram, PS - Member Secretary, RAC		
		Dr. P.K. Katiyar, PS- I/c Seed, Farms and NRC		
		Dr. Rajesh Kumar, PS (Extn.)- I/c Photgraphy		
		Mr. Kumar Vivek, Sr. A.O.- I/c Guest House		
		Dr. Devraj, PS - I/c Computer		
		Dr. Ummed Singh, Sr. Scientist- I/c Farm (Main)		
		Dr. Narendra Kumar, PS - I/c New Research Campus (NRC)		
		Dr. Jitendra Kumar, PS - I/c Cold Module		
		Dr. (Mrs.) Uma Sah, PS - I/c Library & Convener Seminars		
		Mr. D.N. Awasthi, CTO - I/c Estate Management		
		Mr. S.K. Garg, ACTO I/c Farm Machinery & Seed Processing Machines		
		Mr. S.K. Garg, ACTO- I/c Maintenance of Power Supply & other electrical works related to NRC under the supervision of I/c NRC, Incharge EPABX		
		Dr. Omkar Nath, ACTO-I/c Sequrity		
		Mr. R.K. Singh, STO-Farm Manager (Main Farm)		
		Mr. S.P.S. Chauhan, ACTO-Farm Manager, NRC		
		Mr. Sukadeo Mahto, AAO-I/c Vehicles		
		Mr. R.M. Pal-I/c Electricity		
		Mr. H.N. Maurya-I/c Horticulture under Supervision of Dr. Shiv Sewak		
		Mr. Shiv Saran Singh, I/c Sanitation under supervision of Sr. A.O.		

IIPR Regional Research Centre, Dharwad

1.	Farm Produce Auction & Purchase*	**Chairman**	: Dr. M.S. Venkatesh, PS (RRC-Dharwad)
		Members	: Dr. B.S. Patil, Dr. Jayanth Bhat (IARI, RRS) : Dr. (Mrs.) Ganajakshi Math (MULLaRP Scheme, UASD) : Dr. Vinod Kumar (IGFRI-Dharwad)
		Member Secretary	: Dr. Ravanappa
2	Seed, Security & Farm Development Committee*	**Chairman**	: Dr. M.S. Venkatesh, PS (RRC-Dharwad)
		Members	: Dr. Shiv Kumar, BG Head (IGFRI-SRRS) : Dr. Suma Mogali (MULLaRP Scheme, USA, Dharwad) : Sh. Jayanth Bhat (IARI, RRS)
		Member Secretary	: Dr. Ravanappa

* Above committee(s) will work under overall supervision of Dr. M.S. Venkatesh, Principal Scientist & I/c Regional Station

IIPR Regional Research Station, Phanda, Bhopal

Nodal Officer : Dr. P.K. Patiyar, Principal Scientist & I/C Seed & Farm

1.	Purchase Committee	**Chairperson**	: Dr. (Mrs.) Archana Singh, Pr. Scientist
		Members	: Dr. R.P. Singh, PS, AICRP-MULLaRP, College of Agriculture, Sehore : Dr. Ram Lal Jat, Scientist
		Member Secretary	: Mr. Mayank Mishra
2.	Seed/Grain Auction Committee	**Chairman**	: Dr. P.K. Katiyar, Principal Scientist & Nodal Officer
		Members	: Dr. S.C. Gupta, PS, College of Agriculture, Sehore : Dr. (Mrs.) Archana Singh, Principal Scientist
		Member Secretary	: Dr. Ram Lal Jat

- **Above committee (s) will work under overall supervision of Nodal Officer**

In-Charges at IIPR, Regional Research Station, Phanda, Bhopal

I/c Sanitation and Landscaping	:	Dr. (Mrs.) Archana Singh, Principal Scientist
I/c Farm	:	Dr. Ram Lal Jat, Scientist
I/c Vehicles & I/c Security	:	Dr. (Mrs.) Archana Singh, Pr. Scientist
Farm Manager	:	Sh. Anand Kumar Yadav, Tech. Asstt.

Panorama

Hon. State Agriculture Minister visited IIPR, Scientist – Farmer Meet organized

On 17th March 2018, a grand Scientist – Farmer Meet was organized at IIPR, Kanpur. The programme was inaugurated by Hon. State Agriculture Minister, Shri Ranvendra Pratap Singh, the Chief Guest and Hon. MLA, Kalyanpur, Kanpur, Smt. Neelima Katiyar was the Guest of Honour in the presence of Dr N.P. Singh, Director IIPR, Kanpur. Around 1,000 participants including eminent scientists, educationists, students, industrialists and farmers from different parts of the country participated in this important Meet. During this mega event, scientists discussed the research activities and advancements in achieving self sufficiency and nutritional security in pulses in the country. On the occasion, two important bulletins were also released.

Speaking on the occasion, Chief Guest congratulated pulse scientists for achieving an all time high of 22.95 million tonnes of production of pulses. He said as pulses are grown largely in rainfed areas, they suffer a lot due to both high and low rainfall. He urged the scientists to work for the all round benefit of farmers. On this occasion, admiring the research works of the IIPR scientists, the Guest of Honour, Smt. Neelima Katiyar also expressed her views on the research advancements in achieving the self sufficiency and nutritional security in pulses in the country.

Dr N.P. Singh, Director IIPR briefed about the activities going on in the Institute. He informed that the various projects under National programmes have been successful. In the 'International Year of Pulses', research and development activities of the Institute were further strengthened towards increasing productivity which resulted in all time high production of pulses to the tune of 22.95 million tonnes. Dr Rajesh Kumar, Head of the Deptt. offered vote of thanks to all the esteemed guests and participants.

IIPR Celebrated Foundation Day

ICAR-Indian Institute of Pulses Research (IIPR) celebrated its 25th Foundation Day and Golden Jubilee Year of Pulses Research on September 5, 2017. *Padma Bhushan* Prof. R.B. Singh, Chancellor, Central Agriculture University, Imphal was Chief Guest of the occasion and Dr. Sushil Solomon, Vice-Chancellor, C.S. Azad University of Agriculture and Technology, Kanpur was the Guest of Honour.

Speaking on the occasion, Prof. R.B. Singh congratulated the pulse scientists for achieving an all time high 22.95 million tonnes production of pulses. Prof. Singh said that as pulses are grown largely in rainfed areas, they suffer a lot due to both high and low rainfall.

Dr. Solomon urged the scientists to work in the direction for the benefit of farmers. He said that if farmers ought to be partner in various research based programmes and this research if aplied in their fields, will surely give better results.

Dr. U.S. Gautam, Director, ICAR-ATARI, Kanpur expressed concern over changing climate scenario and the ill effects of rising pollution levels over aqcuasllened fields. He emphasized that availability of improved seed quality and production techniques

to the farmers will certainly increase production of pulse crop by 30%.

Dr. N.P. Singh, Director, ICAR-IIPR briefed about the activities going on in the Institute. He informed that the various projects under National programmes have been successful. In the 'International Year of Pulses', research and development activities of the Institute were further strengthened towards increasing productivity which resulted in all time high production of pulses to the tune of 22.95 million tonnes. During the year, high yielding varieties of pulses including IPL 220 (High Fe and Zn fortified variety) in lentil, IPH 09-5 (Early duration hybrid) in pigeonpea, IPM 205-7 (Virat-a super early variety) in mungbean and IPFD 10-12 (Green seeded variety) in fieldpea were identified for different zones. Besides, 15 promising genotypes of pulse crops were performing well in different parts of the country. Dr. Singh informed that scientists of the Institute have identified heat tolerant varieties of chickpea and lentil, and large seeded lentil that will be shortly available for cultivation. He also said that research on development of pod borer resistant transgenic chickpea and pigeonpea is moving in the right direction and is showing promise. On this occasion, two new publications *viz.,* Agro-technologies for Enhancing Pulses Production in Rice Fallows and *Varshik Prativedan 2017* were released.

During the function, Dr. C.S. Praharaj was awarded with the Best Scientist Award 2017 (Senior Catagory) and Dr. Abhishek Bohra was awarded Young Scientist Award 2017. Mr. R.K. Singh was awarded as the Best Worker in Technical Officer Category and Mr. Hasmat Ali in the Technical Assistant Category. Mr. R.K.P. Sinha was awarded as the Best Worker in Administrative Category and Mr. Rajendra Kumar in Finance and Accounts Category. Mr. Ram Sajeevan was awarded as the Best Worker in Skilled Supporting Staff Category.

Vote of thanks was proposed by Dr. I.P. Singh, Project Coordinator (Pigeonpea). The programme was convened by Dr. (Mrs.) Uma Sah and Dr. (Mrs.) Meenal Rathore.

National Symposium on "Pulses for Nutritional Security and Agricultural Sustainability" held at IIPR

Indian Society of Pulses Research and Development in collaboration with ICAR-Indian Institute of Pulses Research, Kanpur organized a National Symposium on **"Pulses for nutritional security and agricultural sustainability"** to commemorate the Golden Jubilee Year of Pulses Research in India at IIPR, Kanpur during December 2-4, 2017. The Symposium was inaugurated by Padma Bhushan Prof. R.B. Singh, the Chief Guest, while Dr. M.C. Saxena, Ex. ADG, ICARDA and Dr. S. Solomon, VC, CSAUA&T, Kanpur were the guests of honour. Dr. N.P. Singh, President, ISPRD was present on the occasion.

Speaking on this occasion, Prof. R.B. Singh congratulated pulse scientists for all time high 22.95 million tonnes of pulses. He expressed concern over the fluctuating production of pulses in the country and exhorted to address the reasons for this. He urged the scientists to work for the benefit of farmers. He emphasized that farmers ought to be partner in various research based programmes and these research activities, if applied on their fields, will surely deliver yield better results. Dr. S. Solomon, Vice-Chancellor, CSAUA&T, Kanpur and Dr. M.C. Saxena, Ex. ADG, ICARDA also expressed their views on research advancements in achieving self sufficiency and nutritional security in pulses in the nation.

Dr. N.P. Singh, Director, IIPR briefed about the

distinctive activities going-on in the Institute. He informed that the various projects under national programmes have been widely successful. In the 'International Year of Pulses', research and development activities of the Institute were further strengthened towards increasing productivity which resulted in an all time high production of pulses *viz* 22.95 million tonnes.

Around three hundred delegates (including foreign delegates, scientists, educationists, students, industrialists and farmers from different parts of the country) participated in the Symposium and discussed the research advancements in pulses in the country. On the second day, Dr. H.D. Updhyaya from ICRISAT and Dr. P.K. Chakrabarty, ADG, ICAR, New Delhi presided over the scientific sessions during which important strategies were prepared. To save pulse crops from different diseases/insects, permission to use suitable insecticides is awaited from the Central Insecticide Board. Moreover, topics like value addition in pulses, doubling farmers' income, various usage of mini *Daal Mill*, role of private sector in enhancing pulse production of the country were the centre of scientific interactions.

Closing ceremony of the Symposium was presided over by Dr. G.B. Singh, former VC & Director General, UPCAR during which Dr. H.C. Sharma, Vice-Chancellor was given Excellence Award and eighteen scientists/researchers were offered ISPRD Fellowship. Dr P.K. Katiyar, Secretary, ISPRD offered vote of thanks to all the guests and participants.

IMC Meeting held at the Institute

The 39th Institute Management Committee meeting was held on 29th December, 2017 under the chairmanship of Dr. N.P. Singh, Director. The meeting was attended by Dr. Ram Awatar Sharma, Pr. Scientist, ICAR-CAZRI, Jodhpur; Dr. C. Bhardwaj, Pr. Scientist, ICAR-IARI, New Delhi; Dr. S. Natarajan, Pr. Scientist, IARI-RBGRC (TN); Dr. A.N. Sharma, Pr. Scientist, ICAR-DSR, Indore; Dr. Ram Sharan Katiyar and Sh. Shiv Poojan Singh Chandel, farmer representations along with all Heads of Divisions and Project Coordinators. Besides deliberations on various agenda items, the members appreciated the progress made by the Institute.

Chairman and Member Secretary of IMC

Celebration of World Soil Day

To commemorate the importance of soil as a critical component of the natural system and nurture of human well being, World Soil Day was organized at the Institute on December 5, 2017. On this occasion, Dr. I.P. Singh, Officiating Director was the Chief Guest while Dr. C.S. Praharaj, Head (Acting), Division of Crop Production was the Chairman. Dr. Ummed Singh, Senior Scientist coordinated the programme.

While welcoming the participants, Dr. I.P. Singh stressed upon the importance of soil health, natural resources and soil *rhizosphere* which are the pillars of soil sustainability. He emphalized the importance of pulse-soil symbiosis as a building block for sustaining both crop and human/animal life on a long-term basis and also emphasized the need to protect our soil.

AICRP Group Meet held at Gwalior

The Annual Group Meet of AICRP on MULLaRP was held at Gwalior on November 10-11, 2017. About 80 delegates from SAU's and cooperating centres participated in the Group Meet. Dr. S.K. Rao, Vice-Chancellor, RVSKVV, Gwalior, in his chairman remarks, expressed happiness over the research and development efforts for promotion of pulses in new niches specially in spring, summer and rice-fallow conditions and specifically mentioned the success of short duration varieties of mungbean occupying large niches in the country and in many states, urdbean is becoming alternatives to soybean in *Kharif* season. Dr. A.K. Singh, Chief Guest applauded the role of pulses in food security, sustainability and nutritional security.

Dr. Sanjeev Gupta, Project Coordinator, MULLaRP crops expressed that there is tremendous scope of horizontal and vertical increase in production of mungbean and urdbean and specifically discussed on the grey areas in increasing production and productivity of rice fallow pulses. Dr. Shiv Sewak, Nodal Officer, Network Research Project on Arid Legumes, presented the summary of progress in arid legumes during the last spring/summer seasons. Dr. N.P. Singh, Director, IIPR desired that early duration varieties are the need of the hour and the special trials

should be conducted for conducting extra early trials across a large number of locations. One variety of cowpea, TC 901 was identified for release in the northern parts of the country for summer cultivation.

Vigna Day organized

A *Vigna* field day was organized at ICAR-IIPR, Kanpur on 4th October in which about 50 scientists working on mungbean, urdbean and other *Vigna* crops participated from across the country. Dr. Kuldeep Singh, Director, ICAR-NBPGR, New Delhi was the chief guest on the occasion while Dr. N.P. Singh, Director, ICAR-IIPR chaired the meet. The field day was organized with an objective to acquaint the participants with *Vigna* improvement programme at IIPR and showcase the segregating materials, advanced breeding lines, germplasm lines, wild accessions, etc. of mungbean and urdbean. Besides, it also aimed at helping them in making selections of the desired material which would be shared. The participants first visited the New Research Campus of the Institute where they saw the mungbean and urdbean seed production programme

followed by a visit to the main campus farm where a wide range of materials were grown including the wild accessions. This was followed by an interactive session where a presentation on recent strides in mungbean improvement at IIPR was made by Dr. Aditya Pratap, Organizing Secretary. Dr. Kuldeep Singh emphasized upon planned utilization of *Vigna* genetic resources besides harnessing their potential through introgression breeding. Dr. N.P. Singh exhorted the scientists to focus on trait-specific improvement, incorporation of multiple disease resistance and breeding for climate resilience and nutritional traits. The participants showed a keen interest in wild garden and molecular breeding programme of the Institute.

Group Meet on Pigeonpea held

The 22nd Annual Group Meet of AICRP on Pigeonpea was held on May 19-21, 2017 at Dr. Rajendra Prasad Central Agriculture University Pusa, Samastipur (Bihar). About 120 delegates from cooperating centres of SAU's and ICAR Institutes attended this group meet. Dr. R.C. Srivastava, Vice-Chanceller, DRCAU, Pusa, Bihar chaired the Inaugural Session and Dr. S.K. Varshney, Dean, Agriculture, Dr. R.P. Roy Sharma, Ex-VC, BAU, Ranchi, Dr. N.P. Singh, Director, IIPR (Kanpur), Dr.I.P.Singh, Project

Coordinator (Pigeonpea) and other dignitaries were present. Dr. Varshney while welcoming the dignitaries and delegates, highlighted the achievements made by the University and stressed upon development of early and mid-early varieties of pigeonpea especially for Bihar.

Dr. R.C. Srivastava, Vice-Chanceller, in his remarks, appreciated the constant research efforts of pulses research community that reflected in the form of record pulses production. He stressed upon the need for appropriate storage facility for pulses and suggested that the value addition at village level would greatly strengthen the livelihood of marginal farmers. Dr. R.P. Roysharma emphasized upon the necessity to examine the phenological alterations in pigeonpea during different temperature regimes. Similarly, problems in pigeonpea like high flower drop and effective number of seeds per pod should be addressed and this demands for a multidisciplinary approach.

Dr. N.P. Singh presented the scenario of pulses in the country and appreciated the sincere efforts of scientific community, in addition to favourable weather conditions and government policies in place, which collectively resulted in record production of pulses this year. He also underlined the challenge of sustaining the enhanced pulses production. He highlighted the development of seed hubs that cover 150 districts across the country. Dr. Singh also briefed about the important government schemes including development of biofertilizers and bio-control units. He stressed on pre-breeding programme to broaden the genetic base of pigeonpea. He informed that regulatory approval was obtained for conducting confirmed field trials on transgenic chickpea and pigeonpea. He said that the current scenario demands for photo-thermo insensitive pulse crops, and genotypes that are amenable to mechanical harvesting.

Dr. I.P. Singh, Project Coordinator (Pigeonpea) presented annual progress of the project. He informed that various entries found promising were promoted to next level of evaluation. Later in the technical session, programmes of various disciplines were discussed and finalized.

Group Meet on MULLaRP and Arid Legume Crops organised

Group meet on mungbean and urdbean under AICRP on MULLaRP and Network Programme on Arid Legumes was held at G.B.Pant University of Agriculture & Technology, Pantnagar on May 6-8, 2017. Prof. J.Kumar, Vice-Chancellor of the University inaugurated the meet. Dr. J.P. Singh, Director Research, GBPUA&T welcomed the dignitaries on the dias. Prof. J. Kumar, Vice-chancellor enlightened the house about the enormous existing possibilities for increasing pulses production in the country.

Dr. Sanjeev Gupta, Project Coordinator, MULLaRP while presenting report of the project, apprised about major achievements and constraints in mungbean and urdbean crops including problem of MYMV and some other emerging diseases like groundnut bud necrosis virus. He emphasized that plant types need to be changed inducing photo-thermo insensitivity and developing cold tolerance for rice fallow cultivation. He elaborated upon the efforts going on pre breeding, productive cropping systems with mungbean and urdbean, development of IPM modules and microbial consortium.

Dr. Shiv Sewak, Nodal Officer, AINP on Arid Legumes presented the report of the project. He informed the house that one cowpea variety KBC 9 was identified for cultivation in the South Zone.

Dr. N.P. Singh, Director, ICAR-IIPR elaborated the ongoing R&D activities in pulses in India. He highlighted the significance of coordinated pulses and arid legume research. He congratulated the entire NARS partners associated with pulses research for the current year's record production. Dr. Singh also stressed upon the need for transgenic development and updated the house regarding progress made in chickpea and pigeonpea.

In his special remarks, Dr. S.K.Chaturvedi, Acting ADG (O&P), ICAR briefly highlighted the research needs in these priority crops and ICAR's efforts to increase the pulses production in the country. The research aim should be to enhance the factor productivity and therefore, a holistic approach is required.

In the group meet, a session on inter-project linkages was also held in which Dr. Ram Krishnan Nair elaborated the activities of International Mungbean Network supporting NARS activities in India. Results of *Kharif* 2016 were discussed thoroughly and technical programme for *Kharif* 2017 was finalized.

NICRA Technical Programme Workshop held at IIPR

The technical programme finalization workshop of NICRA for the period 2017-20 for NICRA Partner Institutes was held on May 11, 2017 at IIPR, Kanpur. The meeting was chaired by Dr. N.P. Singh, Director, IIPR, Kanpur and co-chaired by Dr. K. Sammi Reddy, Acting Director, CRIDA, Hyderabad. Dr. Singh while welcoming the delegates emphasized the need to have coordination while working on the same crop by different Institutes. Dr. Sammi Reddy highlighted outcome from the past five years of NICRA and felt the need to take some of these technologies for on-farm testing and wide scale adoption. Presentations from PIs of 13 partner Institutes were made highlighting major achievement, focussed areas of research for next phase of NICRA and proposed technical programme for 2017-20. It was suggested that material generated in the NICRA project should be shared between the Institutes working on same crop *viz.*, wheat (IARI, IIWBR and NBPGR), rice (NRRI, IIRR, IARI and ICAR-NEH,) maize (IIMR, ICAR-NEH and CRIDA) and there is a need for convergence of activities across the institutions to avoid duplication of works. Results of NICRA project should be presented in the respective crop workshops for scientific inputs, fine-tuning of the activities and avoid duplication of works. Priority should be given for up keeping and maintenance of infrastructure facilities established under NICRA at different partner Institutes. This facilities should be made available to other research institutes, may be on charging basis to cover part of maintenance cost. After thorough discussion, the technical programme for each Institute was formulated. Dr. Sanjeev Gupta, PI of NICRA programme IIPR, Kanpur extended vote of thanks.

IIPR organized Summer School

An ICAR sponsored Summer School entitled "**Scaling Water Productivity and Resource Conservation in Upland Field Crops ensuring More Crop Per Drop**" was organized during Sept. 6-26, 2017 at ICAR-IIPR, Kanpur. Twenty five participants belonging to ICAR Institutes/Universities of nine States participated in this training programme.

In his Inaugural address, Dr. S.S. Singh, Director, ICAR-ATARI Zone V, Kolkata emphasized on the role of water in food production besides the role of water management, market and input management for crop production. Dr. Masood Ali, former Director, IIPR revealed that freshwater availability is only 2.8% of which 30% is available to human use only.

Dr. N.P. Singh, Director, IIPR expressed his satisfaction and happiness with the positive feedback from the participants for the organization of the Summer School. He emphasized that **More Crop Per Drop** is the need of the hour to deal with challenges like climate change. Prosperity and happiness can be positively correlated with availability of water as existence of our very civilization started on the bank of rivers. Dr. S.K. Singh, Chief Guest of the function emphasised that there is no other short-cut way but to save water as it cannot be produced in the labs.

Short Course on Next Generation Fertilizers

An ICAR sponsored short course on **'Enhancing Nutrient Use Efficiency through Next Generation Fertilizers in Field Crops'** was organised at IIPR, Kanpur during November 21-30, 2017. The objectives of the short course was to sensitize the participants about the present status and future perspectives of next generation fertilizers and to enable them to acquire the knowledge on the latest techniques/strategies for enriching nutrient use efficiency in field crops through efficient fertilizer use. The Chief Guest, Prof. Narendra Mohan stressed that working on nutrient symbiotic relationship between sugarcane and pulses intercropping needs to be explored extensively.

Dr. N.P. Singh, Director, ICAR-IIPR, Kanpur

expressed his satisfaction over the fact that the country has achieved self-sufficiency in food crops and highlighted the contribution of ICAR-IIPR towards increasing pulses production in the country. Dr. Singh reiterated on the role of developing nutrient use efficient genotypes of filed crops. Dr. C.S. Praharaj highlighted the futuristic scope of speciality fertilizers. Twenty three participants belonging to ICAR Institutes/SAUs located in more than seven states attended the short course at ICAR-IIPR, Kanpur.

Participation in ICAR Sports Meet-2017

A contingent of 47 staff members of ICAR-Indian Institute of Pulses Research participated in the ICAR Zonal Sports (North Zone) Tournament-2017 held at ICAR-Indian Institute of Sugarcane Research, Lucknow from 30th October to 2nd November, 2017. The team participated in various events *viz.,* Table Tennis, Badminton, field and track events, football, volleyball (shooting and smashing), basketball and *kabaddi*. The contingent was accompanied by Dr. Bansa Singh as Chief-de-Mission and Dr. Ummed Singh as Team Manager. IIPR volleyball (smashing) team played very well under the captaincy of Dr. A.K. Parihar and won the championship continuously second year by defeating CPRI, Shimla. IIPR football team also played well very under the captaincy of Dr. K.R. Soren and was runner up in the tournament. In field and track events, Dr. Amrit Lamichaney won the gold medal in long jump silver medal in 100 meter race.

After winning the championship in volleyball (smashing), gold medal in long jump and silver medal in 100 m race in ICAR-Zonal (North Zone) tournament at IISR, Lucknow, IIPR Volleyball (smashing) team and winner of field and track events participated in the ICAR Inter-Zonal Sport Meet-2017 held at ICAR-NAARM, Hyderabad from February 21-25, 2018. Dr. Bansa Singh accompanied the team as Chief-de-Mission. The team played four matches. Our team won two matches against CSWRI, Avikanagar and CMFRI, Kochi and lost two matches against IARI, New Delhi and CRIJAF, Barrackpore. Over all IIPR volleyball team was at 3rd position. In field and track events, Dr. Amrit got the silver medal in long jump.

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अन्तर्राष्ट्रीय योग दिवस 21 जून, 2017 को भारतीय दलहन अनुसंधान संस्थान के प्रांगण में बड़े उत्साह के साथ मनाया गया। प्रातः 6:00 बजे आयोजित इस योग कार्यक्रम में संस्थान के वैज्ञानिकों, तकनीकी व प्रशासनिक वर्ग के कर्मचारियों ने भाग लिया। इस अवसर पर विभिन्न योग क्रियाओं के अतिरिक्त योग पर व्याख्यान का आयोजन भी किया गया। इस अवसर पर संस्थान के निदेशक, डॉ. नरेन्द्र प्रताप सिंह ने जीवन में योग के महत्व पर प्रकाश डाला। उन्होंने कहा कि आज के इस प्रदूषित वातावरण में योग को जीवन में अपनाकर ही स्वस्थ रहा जा सकता है और तनाव मुक्त जीवन जीया जा सकता है। योग क्रियाएं आयुष मंत्रालय के प्रोटोकाल के अनुरूप संस्थान के प्रधान वैज्ञानिक, डॉ बन्सा सिंह ने पूर्ण करवाई। पतंजलि योग समिति, कानपुर

पश्चिम के अध्यक्ष, योगाचार्य श्री राम सिजोर ने अपने व्याख्यान में योगासनों पर विस्तार से चर्चा की। उन्होंने यह भी बताया

कि कौन से आसनों का नियमित अभ्यास करके कौन से रोगों से मुक्ति पाई जा सकती है। इस अवसर पर संस्थान के वरिष्ठ पदाधिकारी परियोजना समन्वयक डॉ. आई.पी. सिंह एवं डॉ. संजीव गुप्ता, विभागाध्यक्ष डॉ. कृष्ण कुमार, डॉ. शिव सेवक, डॉ. जगदीश सिंह, डॉ. राजेश कुमार, डॉ. सी.एस. प्रहराज, वरिष्ठ प्रशासनिक अधिकारी श्री कुमार विवेक एवं वित एवं लेखाधिकारी श्री डी.के. अग्निहोत्री भी मौजूद थे।

fgUnh fnol dk vk;ktu

भारतीय दलहन अनुसंधान संस्थान में दिनांक 26 सितम्बर, 2017 को हिन्दी दिवस समारोहपूर्वक मनाया गया। डॉ. कमल मुसद्दी कवि, साहित्यकार एवं प्रवक्ता, आयुध निर्माणी कालेज, अर्मापुर, कानपुर इस समारोह के मुख्य अतिथि थीं। समारोह की अध्यक्षता संस्थान के निदेशक डॉ. नरेन्द्र प्रताप सिंह ने की। स्वागत भाषण डॉ. जी.पी. दीक्षित, परियोजना समन्वयक (चना) ने प्रस्तुत किया। संस्थान में राजभाषा की प्रगति आख्या श्री दिवाकर उपाध्याय, मुख्य संपादक ने प्रस्तुत किया। समारोह में संस्थान के सभी वैज्ञानिक, तकनीकी, प्रशासनिक एवं सहायक वर्ग के कर्मचारियों ने भाग लिया। अपने उद्‌बोधन में श्रीमती मुसद्दी ने कहा कि हिन्दी अपनी सरलता और सहज बोधगम्यता के कारण पूरे देश में समझी और बोली जाती है और राष्ट्रीय सम्पर्क सूत्र की महती भूमिका निभा रही है। हमारे बहुभाषी देश में, सम्पर्क भाषा के रूप में हिन्दी का महत्वपूर्ण योगदान रहा है। हिन्दी एक समृद्ध भाषा है। सभी क्षेत्रों में हिन्दी की सफलता का परचम लहरा रहा है। प्रतिभाओं के मुखर होने में भाषा का प्रबल योगदान होता है।

अध्यक्षीय उद्‌बोधन में संस्थान के निदेशक, डॉ. एन.पी. सिंह ने कहा कि हमारे बहुभाषी देश में, सम्पर्क भाषा के रूप में हिन्दी का महत्वपूर्ण योगदान रहा है। आज विकास की गति में हमारी राजभाषा हिन्दी एक मजबूत सूत्रधार का कार्य कर रही है। हम अपनी भाषा में अधिक स्पष्ट एवं प्रभावी ढंग से अपने विचार एवं विषय को प्रकट कर सकते हैं। यही हमारी उन्नति का संवाहक होता है। अतः हमें अपनी राजभाषा हिन्दी का अधिक से अधिक प्रयोग करना होगा निजी कार्यों में और सरकारी कामकाज में भी। उन्होंने कहा कि हिन्दी जीवन के हर क्षेत्र में व्यापक स्तर पर उपयोग की जा रही है। सरकारी कामकाज में भी हिन्दी का प्रयोग निरंतर बढ़ रहा है। उन्होंने वैज्ञानिकों का आहवान किया कि नई तकनीकी जानकारी किसानों तक उन्हीं की भाषा में पहुँचाने के लिए सतत प्रयास करें और हिन्दी के नये प्रकाशनों पर बल दिया। यदि हमें भारत को उन्नत राष्ट्रों की श्रेणी में लाना है तो इसकी एक राष्ट्र व्यापी भाषा का होना उतना ही आवश्यक है जितना की नवीन प्रौद्योगिकियों का। इस अवसर पर मुख्य अतिथि ने संस्थान की राजभाषा पत्रिका 'दलहन आलोक 2017' का विमोचन भी किया।

हिन्दी पखवाड़े में आयोजित विभिन्न प्रतियोगिताओं के विजयी प्रतिभागियों, डॉ. आदित्य प्रताप, श्रीमती कीर्ति त्रिपाठी, डॉ. गोविन्द कान्त श्रीवास्तव, सर्वश्री, आलोक कुमार सक्सेना, राजेन्द्र कुमार, श्रीमती मीनाक्षी वार्ष्णेय, श्री अखिल कुमार गंगल, श्री देवी प्रसाद तथा कार्यालयीन कामकाज में हिन्दी का उत्कृष्ट प्रयोग करने के लिए सर्व श्री आलोक कुमार सक्सेना, श्रीमती कीर्ति त्रिपाठी, श्रीमती श्रुति श्रीवास्तव, श्रीमती रीता मिश्रा, श्रीमती मीनाक्षी वार्ष्णेय, सर्व श्री शिव शरण, राजेन्द्र कुमार, प्रोमित डायस एवं मो. शब्बीर को मुख्य अतिथि ने पुरस्कार और प्रमाण पत्र प्रदान किए। कार्यक्रम के अन्त में डॉ. आई.पी. सिंह, परियोजना समन्वयक (अरहर) ने धन्यवाद ज्ञापित किया। कार्यक्रम का संचालन, डॉ. राजेश कुमार श्रीवास्तव, वरिष्ठ तकनीकी अधिकारी ने किया।

Personnel

As on 31.3.2018

A. Research Management

1. Dr. N.P. Singh	Director

B. AICRP on Pigeonpea

2. Dr. I.P. Singh	Project Coordinator

C. AICRP on Chickpea

3. Dr. G.P. Dixit	Project Coordinator

D. AICRP on MULLaRP

4. Dr. Sanjeev Gupta	Project Coordinator (In-charge)

E. AINP-Arid Legumes

5. Dr. Shiv Sewak	Nodal Officer, AINPAL

F. P.C. (Linseed)

6. Dr. P.K. Singh	Project Coordinator

G. Scientific

Crop Improvement

7.	Dr. Shiv Sewak	Plant Breeding	Principal Scientist & Head (In-charge)
8.	Dr. S.K. Chaturvedi	Plant Breeding	Principal Scientist
9.	Dr. Sanjev Gupta	Plant Breeding	Principal Scientist
10.	Dr. Farindra Singh	Plant Breeding	Principal Scientist
11.	Dr. P.K. Katiyar	Plant Breeding	Principal Scientist
12.	Dr. Jitendra Kumar	Plant Breeding	Principal Scientist
13.	Dr. Aditya Pratap	Plant Breeding	Principal Scientist
14.	Dr. Dibendu Datta	Plant Breeding	Principal Scientist
15.	Dr. Awnindra Kumar Singh	Plant Breeding	Principal Scientist
16.	Dr. Yogesh Kumar	Plant Breeding	Senior Scientist
17.	Dr. A.K. Srivastav	Plant Breeding	Scientist (Senior Scale)
18.	Mr. Udai Chand Jha	Plant Breeding	Scientist
19.	Mr. Debjyoti Sen Gupta	Plant Breeding	Scientist
20.	Mr. Abhishek Bohra	Plant Breeding	Scientist
21.	Dr. Ashok Kumar Parihar	Plant Breeding	Scientist
22.	Mr. Biswajit Mondal	Plant Breeding	Scientist

23.	Mr. Amrit Lamichaney	Seed Science & Technology	Scientist
24.	Dr. Satish Niak S.J.	Genetics & Plant Breeding	Scientist
25.	Dr. Basavaraja T.	Genetics & Plant Breeding	Scientist
26.	Mr. Manu B.	Genetics & Plant Breeding	Scientist
	Plant Biotechnology		
27.	Dr. (Mrs.) Meenal Rathore	Biotechnology	Senior Scientist & Head (In-charge)
28.	Mr. Prakash G. Patil	Biotechnology	Scientist
29.	Dr. Khela Ram Soren	Biotechnology	Scientist (Senior Scale)
30.	Dr. Alok Das	Biotechnology	Scientist (Senior Scale)
31.	Ms. K.N. Purnima	Biotechnology	Scientist
32.	Mr. P.S. Shanmugavadivel	Biotechnology	Scientist
33.	Mr. Arvind Kumar Konda	Biotechnology	Scientist
34.	Dr. Neetu Singh Kushwah	Biotechnology	Scientist
35.	Mr. Sudhir Kumar	Biotechnology	Scientist
	Crop Production		
36.	Dr. C.S. Praharaj	Agronomy	Principal Scientist & Head (In-charge)
37.	Dr. Narendra Kumar	Agronomy	Principal Scientist
38.	Dr. Ummed Singh	Agronomy	Senior Scientist
39.	Mr. Prasoon Verma	ASPE	Scientist (SG)
40.	Mr. Kali Krishna Hajara	Agronomy	Scientist
41.	Mr. Chaitanya Prasad Nath	Agronomy	Scientist
42.	Mr. Man Mohan Deo	FMP	Scientist
	Crop Protection		
43.	Dr. Krishna Kumar	Plant Pathology	Head of the Division
44.	Dr. Bansa Singh	Nematology	Principal Scientist
45.	Dr. Mohd. Akram	Plant Pathology	Principal Scientist
46.	Dr. Naimuddin	Plant Pathology	Senior Scientist
47.	Dr. R.K. Mishra	Plant Pathology	Senior Scientist
48.	Dr. R. Jagdeeswaran	Nematology	Scientist
49.	Dr. G.K. Sujayanand	Entomology	Scientist
50.	Mr. Bandi Sanjay Maruti	Entomology	Scientist
51.	Mr. Devindrappa	Nematology	Scientist
52.	Dr. Manjunatha L.	Plant Pathology	Scientist
53.	Mr. Kiran Gandhi Bapatla	Entomology	Scientist
54.	Mr. Ravanasidda	Entomology	Scientist

	Basic Science		
55.	Dr. P.S. Basu	Plant Physiology	Principal Scientist & Head (In-charge)
56.	Dr. Lalit Kumar	Agril. Chemicals	Principal Scientist
57.	Dr. D.P. Patel	Plant Physiology	Principal Scientist
58.	Dr. T.N. Tiwari	Plant Physiology	Principal Scientist
59.	Dr. (Mrs.) Vijay Laxmi	Plant Physiology	Senior Scientist
60.	Dr. M. Senthilkumar	Microbiology	Senior Scientist
61.	Mr. S. Gurumurthi	Plant Physiology	Scientist
62.	Mr. Surendra Kumar Meena	Plant Physiology	Scientist
63.	Mr. Dhyaneshwar Namdeo Borase	Microbiology	Scientist
64.	Ms. Kalpana Tiwari	Biochemistry	Scientist
65.	Mr. Vaibhav Kumar	Biochemistry	Scientist
66.	Mr. Krishnashis Das	Microbiology	Scientist
	Social Science		
67.	Dr. Rajesh Kumar	Agril. Extension	Principal Scientist & Head (In-charge)
68.	Dr. (Mrs.) Uma Sah	Agril. Extension	Principal Scientist
69.	Dr. Devraj	Computer Application	Principal Scientist
70.	Dr. Purushottam	Agril. Extension	Senior Scientist
71.	Mr. Hemant Kumar	Agril. Statistics	Scientist (Sr. Scale)
72.	Mr. Shripad Bhat	Agril. Economics	Scientist
73.	Mr. K. Ravi Kumar	Agril. Extension	Scientist
H.	**Regional Centre-cum Off-Season Nursery, Dharwad (Karnataka)**		
74.	Dr. M.S. Venkatesh	Soil Science	Principal Scientist & Station In-charge
75.	Dr. M.H. Kondaram	Entomology	Principal Scientist
76.	Mr. P.R. Saabale	Plant Pathology	Scientist
77.	Dr. Revanappa	Plant Breeding	Scientist
I.	**Regional Station, Bhopal (Madhya Pradesh)**		
78.	Dr. (Mrs.) Archana Singh	EB & Plant Genetic Resourses	Pr. Scientist & Station In-charge
79.	Dr. Ram Lal Jat	Agronomy	Scientist
80.	Mr. Alok Kumar	Seed Science & Technology	Scientist
J.	**Technical**		
81.	Mr. D.N. Awasthi	Chief Architect (T-9)	
82.	Mr. Desh Raj	Chief Technical Officer (T-9)	
83.	Dr. M.P. Singh	Chief Technical Officer (T-9)	
84.	Mr. S.P.S. Chauhan	Chief Technical Officer (T-9)	
85.	Dr. G.K. Srivastava	Chief Technical Officer (T-9)	

86.	Mr. R.S. Mathur	Assistant Chief Technical Officer (T-7/8)
87.	Dr. Omkar Nath	Assistant Chief Technical Officer (T-7/8)
88.	Mr. Radha Krishan	Assistant Chief Technical Officer (T-7/8)
89.	Dr. Aditya Prakash	Assistant Chief Technical Officer (T-7/8)
90.	Mr. S.K. Garg	Assistant Chief Technical Officer (T-7/8)
91.	Mr. Ramesh Chandra	Assistant Chief Technical Officer (T-7/8)
92.	Mr. A.P. Singh	Senior Technical Officer (T-6)
93.	Mrs. Rashmi Yadav	Senior Technical Officer (T-6)
94.	Mr. Rajendra Prasad	Senior Technical Officer (T-6)
95.	Dr. Rajesh Kumar Srivastava	Senior Technical Officer (T-6)
96.	Mr. Krishna Autar	Senior Technical Officer (T-6)
97.	Mr. R.K.S. Yadav	Technical Officer (T-5)
98.	Mr. Kailash Chandra	Technical Officer (T-5)
99.	Mr. Lakhan	Technical Officer (T-5)
100.	Mr. R.K. Singh	Technical Officer (T-5)
101.	Mr. Rakesh	Technical Officer (T-5)
102.	Mr. Malkhan Singh	Technical Officer (T-5)
103.	Mr. Ashraf Khan	Technical Officer (T-5)
104.	Mr. Arvind Singh Yadav	Technical Officer (T-5)
105.	Mr. R.M. Pal	Technical Officer (T-5)
106.	Mr. H.N. Maurya	Technical Officer (T-5)
107.	Mr. K.S. Meena	Technical Officer (Driver)
108.	Mr. S.N. Hatiya	Technical Officer (Driver)
109.	Mr. Satish Kumar Singh	Technical Officer (Driver)

K. Administrative

110.	Mr. Kumar Vivek	Senior Administrative Officer
111.	Mr. D.K. Agnihotri	Finance & Accounts Officer
112.	Mr. Shukdeo Mehto	Assistant Administrative Officer
113.	Mr. Rajeev Nigam	Assistant Administrative Officer
114.	Mr. B.K.Verma	P.S. to Director

Appointments, Promotions, Transfers *etc.*

Appointments

Sl.	Name	Post	Discipline/Division	Date of joining
1.	Smt. Shruti Srivastava	Assistant	Administration	28/08/2017
2.	Sh. Sudhir Kumar	Scientist	Plant Biotechnology	16/10/2017 (F.N.)
3.	Sh. Revanasidda	Scientist	Entomology	116/10/2017 (F.N.)
4.	Sh. Manu B.	Scientist	Genetics & Plant Breeding	116/10/2017 (F.N.)

Promotions

Sl.	Name	Promoted to	w.e.f.
1.	Sh. A.B. Singh, Ex-ACTO	CTO (T-9)	03/02/2016
2.	Sh. R.S. Mathur, ACTO	CTO (T-9)	01/07/2016
3.	Dr. G.K. Srivastava, ACTO	CTO (T-9)	01/07/2016
4.	Sh. A.P. Singh, STO	ACTO (T-7/8)	02/09/2016
5.	Dr. Awnindra Kumar Singh, Sr. Scientist	Pr. Scientist	14/02/2017
6.	Dr. Uday Chand Jha, Scientist	Scientist 7000 (RGP)	15/12/2014
7.	Dr. Abhishek Bohra, Scientist	Scientist 7000 (RGP)	27/04/2015
8.	Dr. Debjyoti Sen Gupta, Scientist	Scientist 7000 (RGP)	03/05/2015
9.	Dr. P.G. Patil, Scientist	Scientist 7000 (RGP)	07/01/2013
10.	Dr. M. Senthil Kumar, Sr. Scientist	Pr. Scientist 10000 (RGP)	03/01/2017
11.	Sh. R.K.P. Sinha, UDC	Assistant Level-6	08/12/2017
12.	Sh. K.A. Chaturvedi, LDC	UDC- Level-5	08/12/2017

Transfers

Sl.	Name	Designation	From	To	Date
1.	Dr. D. P. Patel	Pr. Scientist	National Institute of Abiotic Stress Management, Pune	IIPR, Kanpur	27/06/2017
2.	Dr. T.N. Tiwari	Pr. Scientist	IISF, Mau	IIPR, Kanpur	12/07/2017
3.	Sh. Kumar Vivek	Sr. AO	CIAE, Bhopal	IIPR, Kanpur	03/04/2017
4.	Sh. D.K. Agnihottri	F&AO	IIVR, Varanasi	IIPR, Kanpur	15/04/2017
5.	Dr. P.G. Patil	Scientist	IIPR, Kanpur	NRC-POM, Solapur	29/06/2017
6.	Dr. Yogesh Kumar	Sr. Scientist	NRRI, Cuttack	IIPR, Kanpur	01/07/2017
7.	Dr. M.H. Kodandaram	Pr. Scientist	IIVR, Varanasi	IIPR, Kanpur	10/07/2017
8.	Dr. Awnindra Kumar Singh	Sr. Scientist	CIARI, Port Blair	IIPR, Kanpur	28/09/2017
9.	Smt. Kirti Singh	Assistant	IIPR, Kanpur	IISR, Lucknow	09/01/2018

Retirements

Sl.	Name	Post held	Date of retirement
1.	Sh. Ram Kishan	SSS	30/06/2017
2.	Sh. Krishna Pal	Tech. Assistant (T-3)	31/07/2017
3.	Sh. Diwakar Upadhyay	CTO	30/11/2017
4.	Sh. Kailash Chandra Saxena	UDC	31/12/2017
5.	Sh. Maiku Lal	SSS	31/12/2017
6.	Sh. J.B. Thapa	T-5 (Driver)	28/02/2018

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