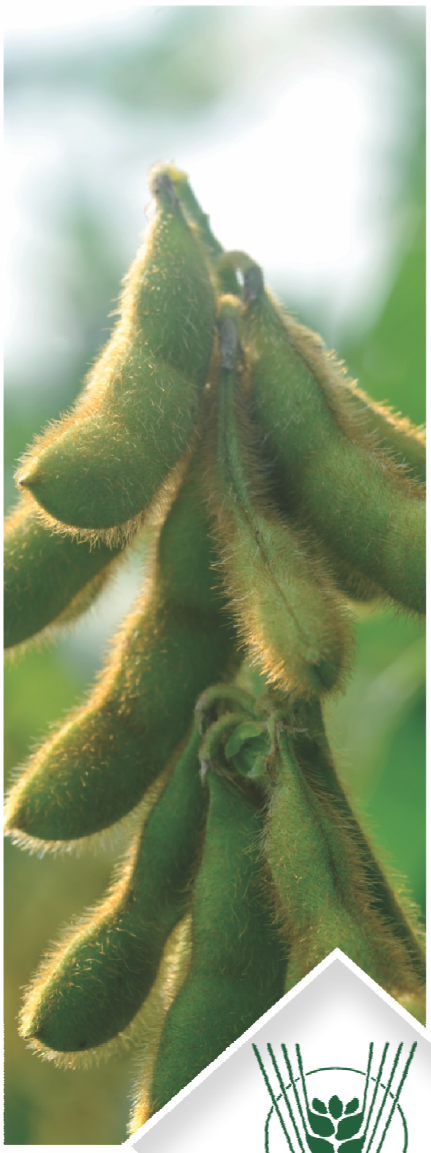
वार्षिक प्रतिवेदन
Annual Report
2014-15






भाकृअनुप
ICAR

भा.कृ.अ.प.-सोयाबीन अनुसंधान निदेशालय

ICAR - Directorate of Soybean Research

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Khandwa Road, INDORE - 452 001 (M.P.)

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P R E F A C E

India has the fifth largest vegetable oil economy in the world. After cereals, oilseeds the second largest agricultural commodity, accounting for the 14% of the gross cropped area in the country. However, the country is meeting its edible oil demand by importing almost 50% of its requirement. The per capita consumption of the vegetable oil is increasing very rapidly due to increase in population and improved economic status of the population. In this scenario, soybean has played and will continue to play pivotal role in meeting the edible oil requirement of the country. Currently, soybean contributes to 47% of the total oilseeds and about 26% of the total edible oil produced in the country. Soybean seed contains 40% protein and 20% oil and it is the cheapest source of good quality protein. It also contains many minerals and useful nutraceuticals like isoflavones which have immense health benefits. Therefore, the crop has a potential to provide nutritional security and eradicate protein malnutrition rampant in India masses.

Despite extraordinary growth in area and production of soybean during the past 40 years, the current productivity levels are much below the world average and the climatic potential of the crop. The bigger challenge for soybean scientists is to meet the manifold increase in demand of soybean for edible oil, animal feed and direct consumption as a food in the face of changing climatic scenario. The impact of climatic variability leading to considerable reduction in soybean productivity was evident during the last two years. In 2013 there was early onset of monsoon, planting of soybean was normal, but the excessive moisture and heavy rains at the time of maturity resulted in heavy loss of soybean crop. In 2014, monsoon arrived very late and planting of soybean could be done only after July 10th. Then there was intermittent and late season drought in many areas which affected the soybean productivity. Scientists at DSR are making all out efforts to overcome these problems and continue to strive for increasing productivity in the face of considerable climatic variability. The efforts are also on to enhance input use efficiency, minimize risks and improve the quality of end use commodity through conventional techniques as well as new science and tools. These researchable issues are being taken up on priority at DSR and have been included as the priority areas of XII plan.

I am glad to present the Annual Report of ICAR-Directorate of Soybean Research, Indore for the year 2014-15. A glance at this report will give the panoramic scenario of research and development activities undertaken during the period under report.

I take this opportunity to state my deep sense of gratitude and gratefulness to Dr. S. Ayyappan, Secretary, DARE, Govt. of India and Director General, ICAR for guidance, and consistent support to soybean research and development. I gratefully acknowledge the help and valuable guidance provided by Dr. J.S. Sandhu, Deputy Director General (Crop Science) for the progress of the Directorate. I sincerely thank Dr. B. B. Singh, Assistant Director General, (O&P) for his support and guidance for the growth and development of the Directorate.

All the scientific, technical, administrative, account and service staff of DSR who have contributed in bringing out this report are worthy of appreciations. I extend my hearty thanks and congratulations to each of them.

V.S. Bhatia

(V.S. Bhatia)
Director

CONTENTS

Executive summary

- Soybean accessions received from NBPGR (900) were evaluated and characterized for various quantitative traits under Agro biodiversity project

- Multilocation evaluation of 95 germplasm accessions was conducted at Indore, Pantnagar, Jabalpur and Parbhani. Principal component analysis was done to assess the germplasm diversity, genetic variation and promising genotypes to be used in breeding were identified.

- Genotyping for early maturity alleles *(e1 as)* was carried out for identified early maturing genetic sources (IC15089 and JS 95-60).

- *Glycine soja* (wild soybean) was crossed with three popular soybean varieties namely, JS 95-60, NRC 86 and NRC 37 to strengthen pre-breeding activities

- Developed promising genotypes NRC 99, which has -performed well in IVT in Central Zone and showed 17% increase in yield over best check. Another genotypes NRC 93- showed wider adaptability in AVT-II in North Eastern Zone (NEZ) and Southern Zone (SZ) Promising YMV resistant line NRC 94 is in AVT-2 and secured 3rd position among the entries

- Genotyping revealed that except EC 333897, all six lines identified as photoperiod insensitive possessed recessive allele at E3 locus. In all photoperiod insensitive genotypes dominant allele was found at E4 locus. However, genotypes EC 325097 and EC 325118 had the recessive alleles *e4 kes* and *e4 kam*, respectively.

- Breeding lines with low canopy air temperature differential and high relative water content were identified for developing drought tolerant/ resistant varieties

- Recombinant inbred lines (RILs) derived from cross (JS 97-52 x NRC 37) and parents were evaluated for drought tolerance by spraying 0.4% chemical desiccant potassium iodide (KI).

- Genotypes (JS 97-52 and JS 20-38) having tolerance to water-logging were identified. These genotypes developed adventitious roots characterized with conspicuous aerenchyma upon inundation.

- Positive correlation was observed between high grain yield and ability of genotypes to translocate nitrogen from roots to shoots efficiently.

- Multiparent Advanced Generation Intercross (MAGIC) population in soybean was further advanced to generate 4 way intercross hybrids

- Seed quality parameters such as seed germination, seedling vigour, storability of seeds were severely affected due to field weathering.

- Sequence characterization of *Rpp4* genes (conferring resistance to soybean rust) from the contrasting genotypes (JS335, EC241780, and JS93-05) and their phylogeny reconstruction revealed inherent genetic differences between the genotypes.

- Genetic fingerprinting of *Phakopsora pachyrhizi* isolates causing Asian soybean Rust (ASR) was completed.

- To validate yield QTLs, phenotyping of advanced backcross population BC2F2 developed from wild species Glycine soja and JS335 (as recurrent parent) was carried out.

- Small non-coding RNAs (sncRNAs) based binary plasmid (ihp-rep-pFGC5941) to silence the expression of yellow mosaic virus rep gene developed.

- Introgression of null allele of Kunitz trypsin inhibitor in JS97-52 using gene specific and linked marker Satt228 was accomplished

- Two genotypes namely, EC 538828 and NRC 7 were identified as relatively tolerant to high temperature conditions.

- Reproductive organs such as pollen size and pollen germination were found to be highly sensitive to high temperature conditions.

- Soybean-wheat cropping system was found to be the most productive, remunerative and energy efficient than soybean-mustard and soybean- chickpea cropping system.

- Among the tillage practices, application of single cultivator every year was found to be at par with conventional tillage after every two years or after every four years.

- On-line data management systems for AICRPS Agronomy trial and AICRPS Plant Breeding trial were developed. These data management systems provide user friendly interface for multi-location data entry, analysis and summary table report generation.

- Co-inoculation of *B. aryabhattai* (MDSR14) and AM fungi significantly increased dry matter accumulation (root and shoot) in intercrop soybean andmaize.

- Mass multiplication of AM fungi in pot cultures using soybean processing mill wastes as substrates was optimized. Higher mycorrhizal spore density was obtained in the pots containing soybean wastes (hulls, DOC burnt ash) amended with two parts of soil-sand mix.

- Preliminary design, for tractor operated disc harrow and Rotary weeder for soybean based cropping system was developed.

- The yield index (yield of 1970-71=100) for soybean has increased to 318 during the span of 43 years of its commercial cultivation, whereas the total oilseed yield index (1950-51=100) has barely crossed 240. Varieties have played very important role in enhancing this yield index.

- Habitat diversification studies identified *Anethum graveolens* as a preferred host for *Chrysodeixis acuta*, and *Sesbania* for *O.brevis*. Grain yield was found highest in soybean + A. graveolens (2476 Kg ha-1) compared to soybean + *Sesbania* (1650 Kg ha-1) system.

- Treatments of native strains of *Beauveria bassiana* (DSRBB1 and DSRBB3) against major lepidopteron defoliators decreased semilooper population.

- Cultural and molecular characteristics of eleven *Colletotrichum* isolates were documented. Six germplasm lines were identified to be resistant against *C. truncatum*.

- Distribution of plant parasitic nematodes in the soils of soybean growing regions was studied. *Heterodera cajani,* which is a major parasitic nematode of pigeon pea, was found to be predominant.

- All common insecticides, except Indoxacarb, are compatible with entomopathogenic nematode (EPN), *Steinernema glaseri* (Nematoda: *Rhabditida*) hence could be tank mixed as spray mixtures.

- Genotypes were screened for resistance to defoliators, stem fly and girdle beetle. One tolerant line (Cat No: 147), was identified which yielded highest under both unprotected (2123 kg/ha) and protected (2612 kg/ha) conditions.

- Ten Front line demonstrations (FLDs) were conducted for transfer of improved production technology.

- ICAR-DSR had actively participated in two major agricultural exhibitions during the year.

- Non exclusive licenses were issued and MoUs were signed for the commercialization of high oleic acid (IC210) and null Kunitz trypsin inhibitor (KTI) (NRC 102) soybean genotypes with ITC limited, India, and KTI free genotype (NRC 101) with Ruchi Hi-Rich seeds Private Limited.
- Non exclusive licenses were issued and MoUs were signed for the commercialization for nine agricultural implements (BBF machine, FIRBS planter/drill, Sweep seed drill, Sub-soiler, BBF planter, Soybean seed planter, Soybean seed drill cum planter, Single ridge seed planter, Ridge Fertilizer cum Seed Planter).

1. INTRODUCTION

The ICAR- Directorate of Soybean Research (DSR) was established by Indian Council of Agricultural Research in the year 1987 at Indore in the State of Madhya Pradesh to take up the centralized research to support soybean production systems with basic information and breeding material. Coordinating unit of All India Coordinated Research Project on Soybean (AICRPS), Soybean Breeder Seed Production (BSPS) and National Active Germplasm Site (NAGS) for soybean germplasm are also situated at DSR.

1.1. Physiography

DSR campus is situated in the village Piplyarao of district Indore, which lies in Vidhyanchal range of Malwa Plateau at 22° 4'37"N latitude and 75° 52'7"E longitude. It is positioned at an altitude of 550 meter above the mean sea level. The Directorate with an area of 56.7 hectare is situated at a distance of 4 km from the heart of Indore city and 6 km from Railway station.

1.2. Soil

The soil of DSR research farm is deep black cotton soil with pH 7.6 to 8.1 (basic / alkaline), low to medium in organic carbon and available phosphorus and high in potassium. Taxonomically it is classified as fine, montomorillonitic, hyperthermic family of Typic Chromusterts and fine clay loam, montmorillonitic family of Lithic Vertic Ustochrepts.

1.3. Climate

The climate of the Malwa Plateau of Madhya Pradesh is semi arid with a growing period of 150 180 days. As such, the climate of this region is characterized by 3 distinct agricultural seasons. These are: (a) rainy season, also known as Monsoon or *kharif,* usually begins from mid June and extends up to early October. Generally duration of monsoon is approximately 98 days with about 800 mm mean annual rainfall. Usually pre-monsoon showers are experienced in last week of May or early June. Soybean is generally grown during this season as rainfed crop, (b) post-rainy season which runs from mid October to March, also known as *rabi,* is dry and cool and (c) Warm and dry season, which begins in February and lasts until April May/June is called *zaid* or summer/spring. Any crop grown during this season requires irrigation.

1.4. Past Achievements

Directorate of Soybean Research has emerged as a catalyzing force to facilitate rapid increase in acreage and production of soybean from last 25 years. It has also been instrumental in providing sustainability to soybean cultivation in different regions of the country. Introduction of soybean in its present command area has resulted in filling up of fallow land (monsoon fallows), crop diversification and increased cropping intensity. The transfer of research emanated improved production technology has led to increase in national productivity from 700 to 1300 kg/ha during past 25 years. Total area under the crop is 12.03 m ha accounting for 11.95 m t of soybean grain production in the country for year 2013-14 & 2014-15. The annual soy meal exports from the country in the financial year 2013-14 were 2.60 m t. In an endeavour to further increase the productivity and production of soybean, the Directorate has been actively engaged in procurement and evaluation of genetic material to identify desirable traits, development of advance breeding material and its distribution to different cooperating centres. Through the AICRP system, the Directorate has developed and released more than 104 varieties. The Centre has been instrumental in developing integrated insect pest, disease, weed and nutrient management practices and low input technologies for improved soybean production system. Improved soybean production technology has been disseminated through frontline demonstrations since 1989; as a result yield gap II could be narrowed down from 1050 kg/ha to 412 kg/ha during 2011-12.

1.5. Mandate

Following are the mandate to support production systems research along with basic information and breeding material:

- To serve as National Repository of soybean germplasm and its utilization in basic, strategic and applied research.
- To conduct basic, strategic and applied research on environmentally eco-friendly technologies and value addition.
- To coordinate multilocation interdisciplinary soybean research through AICRP for soybean.
- To facilitate transfer of research emanated technologies and to conduct impact analysis through socio-economic research.
- To produce breeder seed of improved varieties of soybean.

1.6. Organizational Set-up

For efficient functioning of the Centre and to achieve the mandate and objectives, the organizational pattern of the Directorate has been evolved and depicted in Fig.1.

1.7. Library

The Directorate has developed a reasonably good library equipped with relevant books, journals, etc. to provide the research needed support to the scientists. At present the library is equipped with 2925 books and subscribing 05 international and 39 national journals. DSR library is also a beneficiary of CERA for accessing more than 2000 scientific journals on-line.

1.8. Staff and Budget

The total sanctioned staff position of DSR as on 31 March 2015 is 93 comprising 35 scientific, 29 technical, 13 administrative and 16 supporting positions. Out of which a total of 70 persons were in position as on 31 March 2015 (Details given in Chapter 14).

The budget allocation and expenditure of the DSR for 2014-15 is shown below (Table 1).

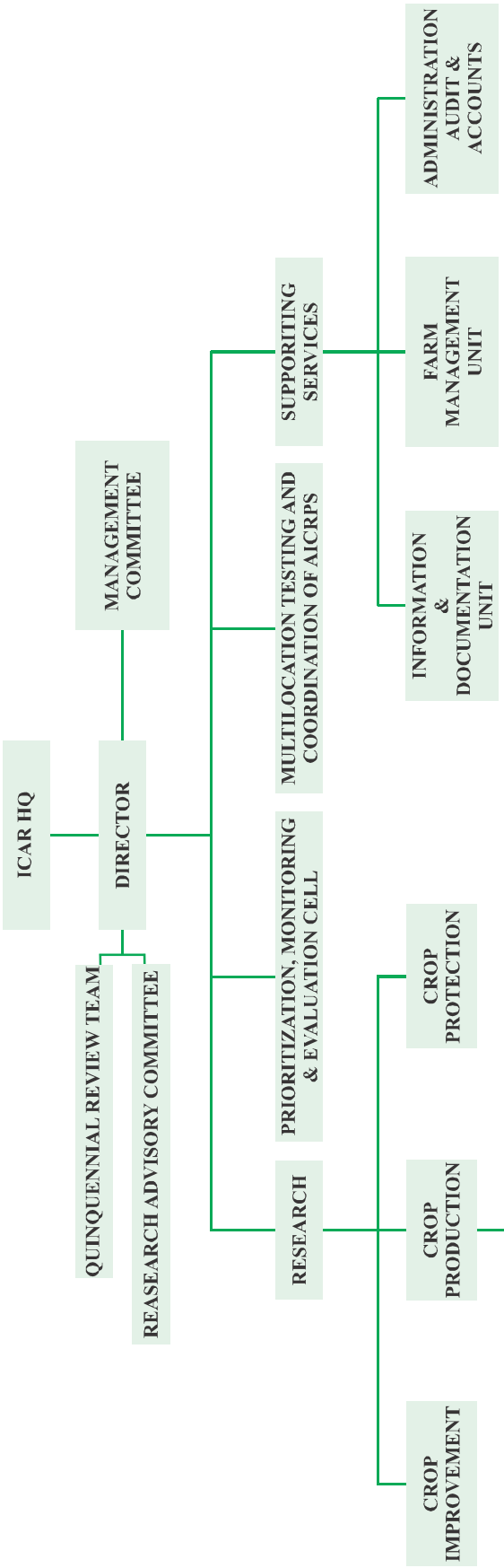


Fig. 1. Organogram of DSR

Table 1. Budget and expenditure of DSR for the year 2014-15

(Rs. in lakhs)

Head	Plan		Non Plan	
	R. E.	Actual Exp.	R. E.	Actual Exp.
Pay & Allowances	-	-	638.20	638.17
Wages	-	-	18.15	18.12
T.A.	8.00	7.94	6.00	5.98
O.T.A.	-	-	0.10	0.10
Other Charges Recurring	108.95	108.85	86.80	86.09
(a) Information Technology	15.78	15.78	-	-
(b) Equipments	66.59	66.46	3.00	2.53
(c) Works	-	-	14.00	14.00
(d) Library	12.62	12.62	-	-
(e) HRD	1.06	1.06	-	-
(f) TSP	7.00	6.87	-	-
(g) Furniture & Fixtures	-	-	2.00	1.96
(h) Livestock	-	-	-	-
(i) Other Items	-	-	-	-
Total	**220.00**	**219.58**	**768.25**	**766.95**

2. RESEARCH ACHIEVEMENTS

2.1 CROP IMPROVEMENT

2.1.1. Augmentation, Management and Documentation of Soybean Genetic Resources

2.1.1.1. Evaluation and Characterization of genetic resources:

Under Agro-biodiversity Project 900 accessions received from NBPGR were evaluated and characterized for eleven quantitative *viz.* days to 50% flowering, days to pod initiation, days to maturity, plant height, primary branches, secondary branches, No. of pods/ plant, No. of seeds/ pod, No. of nodes/ plant, 100 seed weight, seed yield/ plant; and twenty one qualitative traits *viz.* hypocotyle colour, early plant vigour, flower colour, leaf shape, leaflet color, No. of leaflet, pub scence, pubescence colour, pubescence density, pubescence type, stem determinate, plant type, pod colour, shattering score, lodging score, seed coat colour, cotyledon colour, hillum colour, seed coat pattern, strophiale at the hillum, seed coat surface lusture. In addition 526 accessions, comprising 95 MLT accessions, 112 advance breeding lines, 191 accessions for multiplication, 66 new accessions and 66 trait-specific accessions, were also grown for rejuvenation and multiplication. Genetic variability in these 1426 accessions was found to be well distributed over fifteen qualitative traits (Table 2).

Table 2. Frequencies of accessions in phenotypic classes of qualitative traits

S. No.	Qualitative Traits	Phenotypic Classes				
1	Hypocotyle Color	Green (27.1%)	Purple (72.9%)			
2	Early Plant Vigor	Poor (23.6%)	Good (20.4%)	Very Good (56.0%)		
3	Flower Color	White (28.4%)	Light Purple (6.0%)	Purple (60.6%)	Dark Purple (4.7%)	Other (0.2%)
4	Leaf Shape	Round Ovate (38.2%)	Pointed Ovate (57.9%)	Lanceolate (3.9%)		
5	Leaf Color	White (0.0%)	Light Green (8.8%)	Green (83.3%)	Dark Green (7.9%)	
6	No. of Leaflet	3 (100.0%)	(4 - 6) (0.0%)	7 (0.0%)		
7	Pubescence	Absent (3.7%)	Present (96.3%)			
8	Pubescence Color	Gray (20.2%)	Light tawny (3.8%)	Tawny (75.8%)	Other (0.2%)	
9	Pubescence Density	Glaborous (1.4%)	Sparse (0.1%)	Semi-sparse (65.7%)	Normal (2.5%)	Dense (30.3%)

10	Pubescence type	Erect (73.8%)	Semi-apprised (26.2%)			
11	Stem determinate	Determinate (63.0%)	Semi-determinate (37.0%)	Indeterminate (0.0%)		
12	Plant type	Erect (72.2%)	Semi-erect (27.8%)			
13	Pod Colour	Light Brown (17.6%)	Brown (53.5%)	Dark Brown (26.8%)	Black (2.1%)	
14	Shattering Score	No (41.5%)	Slight (10.9%)	Medium (6.7%)	Shattering (3.3%)	High (37.6%)
15	Lodging Score	None (13.0%)	Slight (61.3%)	Moderate (14.9%)	Sever (7.7%)	V. Sever (3.1%)

High coefficient of variation in quantitative traits were noted for No. of pods /plant (62%) followed by seed yield /plant (60%), No. of primary branches/ plant (40.4%), plant height (38%), 100-seed weight (30.7%), no. of nodes/ plant (24%), days to 50% flowering (21.1%) and days to pod initiation (20.3%), with the least value (10.1%) for days to maturity. Frequencies of accessions were grouped in phenotypic classes of quantitative traits (Table 3).

Table 3. Frequencies (%) of accessions in phenotypic classes of qualitative traits

S. No.	Quantitative Traits		Phenotypic Classes	
1	Date of Maturity	Early (< 95 days) (20.8%)	Medium (96-105 days) (35.6%)	Late (> 105 days) (43.6%)
2	Plant Height	Short (<40 cm) (34.5%)	Medium (41-60 cm) (35.0%)	Tall (> 60 cm) (30.5%)
3	No. of Pods/ Plant	<65 pods/ plant (88.6%)	>65 pods/ plant (11.4%)	
4	100 Seed Weight	Small (<10.0 g) (47.4%)	Medium (10.1-13.0 g) (34.4%)	Large (>13.0 g) (18.2%)
5	Seed Yield/ Plant	<14gm/ plant (96.6%)	>14gm/ plant (3.4%)	

2.1.1.2. Multilocation Evaluation of Soybean Germplasm

Multi-location trial was conducted for 95 accessions at four locations *viz*. Indore, Pantnagar, Jabalpur and Parbhani. Variability, in terms of coefficient of variation, and its phenotypic and genotypic counterparts, was high in all the traits except days to maturity. Whereas, phenotypic and genotypic variances were high for days to maturity, days to 50% flowering, plant height, and No. of pods/ plant. Heritability, genetic advance and percentage genetic advance of mean were high for days to 50% flowering, days to maturity, plant height, and 100 seed weight (Table 4).

Table 4. Genetic variability parameters for major quantitative traits

	DF	DM	PH	Pods/pl	Primary branches	100 Seed wt (g)	Yield/ plant(g)
Genotypic variance	16.16	13.95	85.44	22.83	0.22	1.93	1.44
Phenotypic variance	23.29	27.82	250.80	289.92	2.77	3.87	8.75
Geno.Coeff.vari.(%)	9.03	3.78	13.97	8.94	10.60	16.19	14.66
Pheno.Coeff.vari (%)	10.84	5.34	23.94	31.87	37.92	22.91	36.17
Heritability (%)	69.39	50.16	34.06	7.87	7.82	49.96	16.42
Genetic Advance	689.93	545.00	1111.00	276.16	26.80	202.45	100.02
GA % of mean	1550.10	551.43	1679.00	516.97	610.66	2357.88	1223.15
General Mean	44.51	98.84	66.15	53.42	4.39	8.59	8.18
CV (%)	6.00	3.77	19.44	30.59	36.41	16.21	33.07
CD(P=05)	4.27	3.04	20.58	26.15	2.56	2.23	4.33

Cluster analysis: Agglomerative cluster analysis grouped 95 accessions into three clusters (Table 5).

Table 5. Agglomerative cluster analysis of soybean accessions

Cluster No.	No. of Genotypes	Genotypes
Cluster 1	46	AGS 25, C-1263, C-1487, C-1582, C-1734, C-1788, C-2007A, C-2511, C-2562, C-2698, C-2705, C-2857A, C-2931, C-2950, C-2952, C-302, C-3041, C-315, C-3218, C-3219, C-3299, C-3412, C-503, C-537, C-683, C-772, C-868, C-945, DS 91-3, DT 21, EC 15966, EC 172576, EC 329156, EC 39536, G 3, GP 116, GP 465, GP 499, JS 20-50, JS 79-302, JS 288, PK 747, RKS 54, SL 29-51, SL 599, VGM 70
Cluster 2	17	AMS 115, C-1892, C-195, C-7048, C-2430, C-305, C-3129, C-3150, C C-3174, C-3230, C-675, C-778, C-844, EC 457198, EC 65772, G5P22 (IR), JS 20-72
Cluster3	32	C-147, C-1502, C-165, C-2502, C-2503, C-2722, C-2746, C-2755, C-2758, C-2809, C-2928, C-3166, C-322, C-3229, C-3243,C-3327, C-3391, C-3406, C-357, C-44, C-592, C-710, C-716, C-79, C-799, C-87A, C-905, G 141, JS 20-48, JSM 284, PP6 (PI), Sizta 194

2.1.1.3. Principal component variance

Principal component analysis was used to assess the diversity of genetic variations present in the soybean germplasm used for multilocation trails (Table 6) and depicted in screen plot diagram (Fig. 2). The PCA reveals two principal components with more than one eigenvalue which together contribute 67.152 per cent of total variations.

Table 6. Principal component diagram of soybean germplasm

	F1	F2
Eigenvalue	2.765	1.936
Variability (%)	39.498	27.654
Cumulative %	39.498	67.152

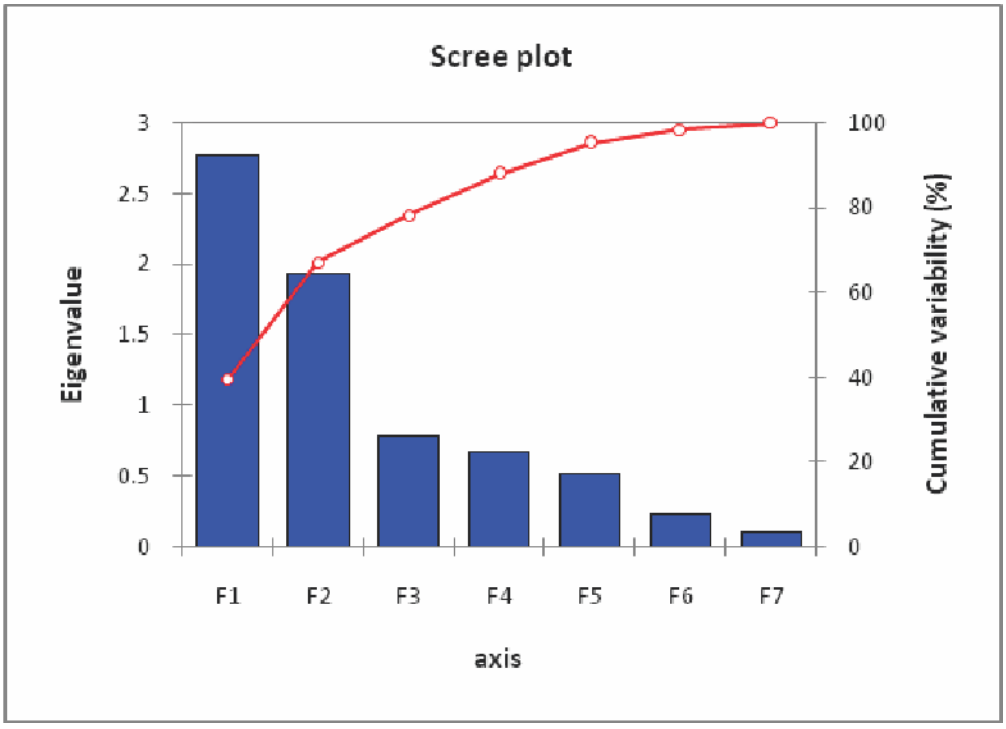


Fig. 2: Diversity of soybean germplasm (Cumulative variability) depicted in Scree plot

2.1.1.4. Relative contribution of genotypes and identification diverse germplasm

Principal component score value was used to estimate the relative contribution of each genotype. Based on relative contribution 21 accessions were identified as the diverse genotypes (Table 7). (Fig 3 & 4)

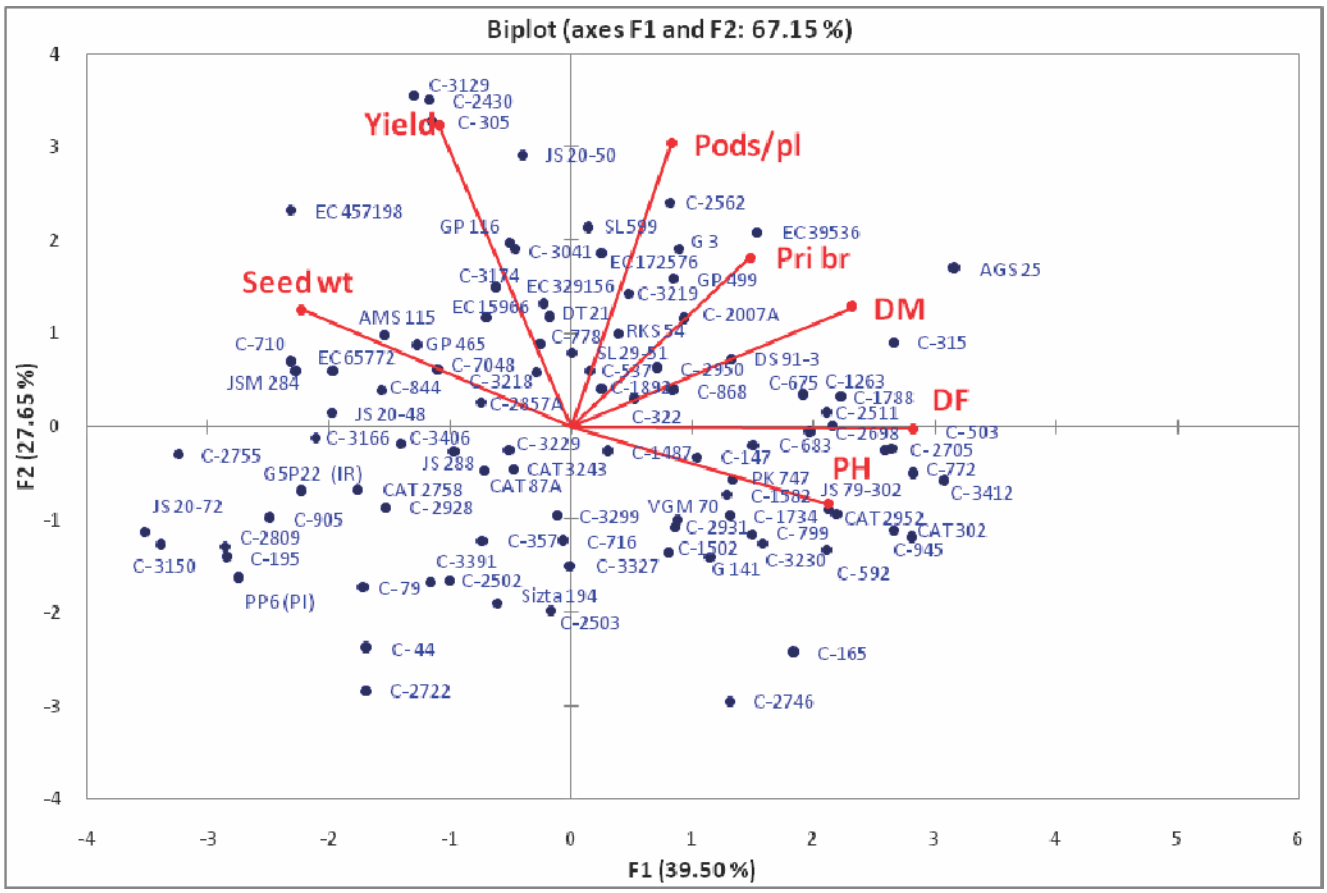


Fig.3: Distribution of both genotypes and characters are simultaneously shown in biplot diagram.

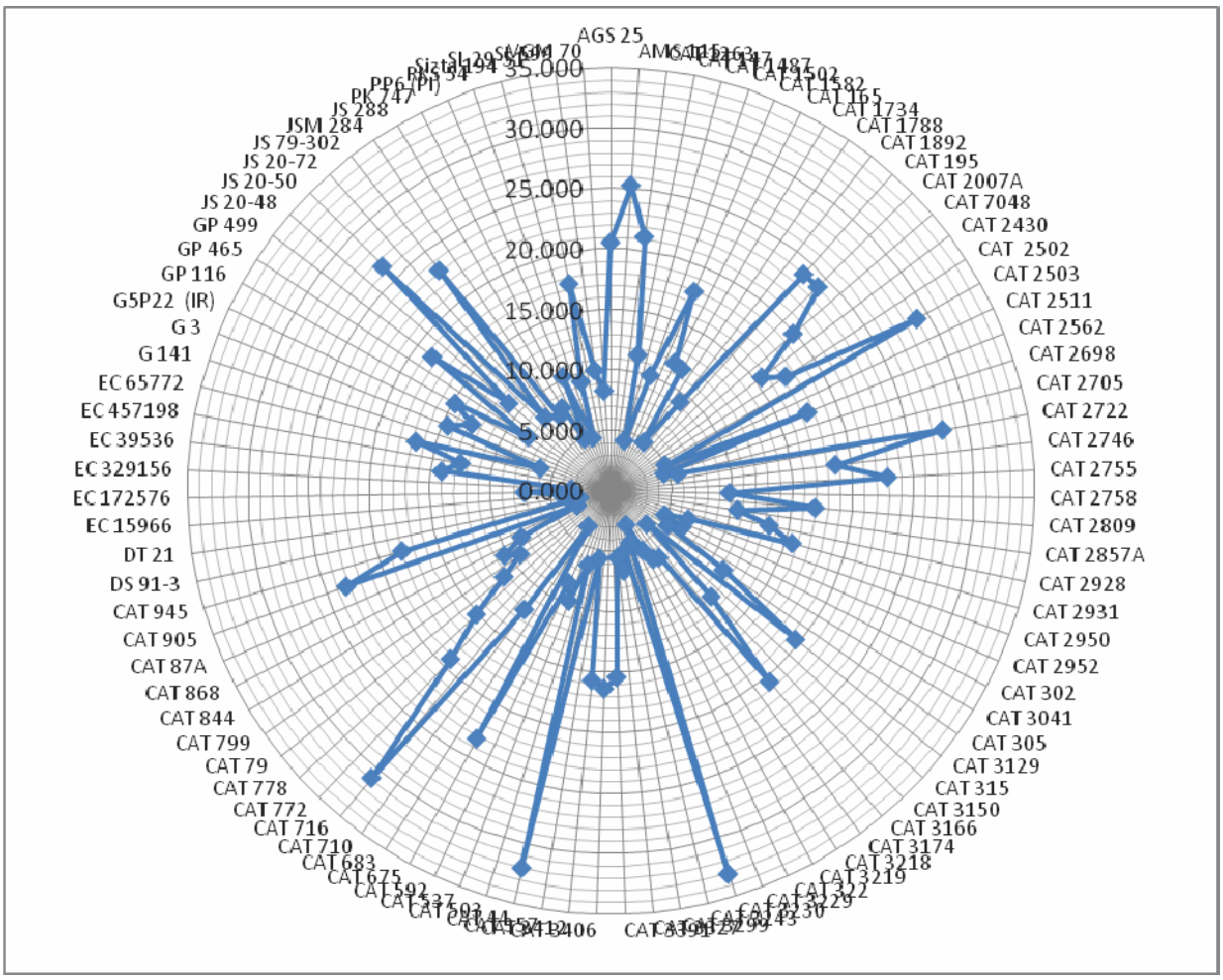


Fig.4: The diagram depicts the relative contribution of soybean germplasm to total uncorrelated phenotypic variance.

Table 7. Diverse genotypes identified based on principal component analysis

S No.	Accessions	Identification No.	S No.	Accessions	Identification No.
1	C-3129	EC 572115	12	PP6 (PI)	- -
2	C-2430	EC 457326	13	C-44	AGS 150
3	C-305	EC113773	14	C-195	BR4
4	C-2722	EC 481571	15	C-2755	EC 547464
5	JS 20-72	- -	16	C-2809	EC 528623
6	C-2746	EC 490302	17	C-3412	EC 638228
7	AGS 25	- -	18	C-945	EPS 472
8	C-3150	EC 572136	19	C-2562	EC 468600
9	EC 457198	- -	20	C-302	EC 113744
10	JS 20-50	- -	21	EC 39536	- -
11	C-165	B401			

Promising genotypes were identified for major traits *viz*. EC 572115, EC 113773, JS 20-50 for yield, CM 60, EC 547464, EC 30967, EC 572136, KT Rameshwar, EC 457198, GP 116, EC 615192 for 100-seed weight and EC 468600, EC 572115, EC113773 for pods per plant. (Table 8/Table 9)

Table 8. Promising genotypes identified on the basis of mean performance across locations

Genotypes	Identification No. & Trait	Seed yield /Plant
JS 20-50	- -	13.64*
C-305	EC113773	13.37*
C-3129	EC 572115	12.72*
	100 seed weight	
C-3406	CM 60	12.07*
C-2755	EC 547464	11.86*
C-710	EC 30967	11.57*
C-3150	EC 572136	11.49*
C-2758	KT Rameshwar	11.11*
EC 457198	- -	10.99*
GP 116	- -	10.96*
C-3391	EC 615192	10.85*
	No. of Pods /plant	
C-2562	EC 468600	77.53
C-3129	EC 572115	76.40
C-305	EC113773	73.60

*Significant at $p<0.05$

Table 9. Mean performance of soybean germplasm in multilocation trial

Genotypes	Identification	DF	DM	PH	PB	Pods/pl	Seed	Yield
AGS 25		54.33	102.00	75.07	6.73	68.93	6.84	8.92
AMS 115		39.00	104.00	45.53	4.60	47.00	10.39	9.46
C-1263	MACS 54	51.67	103.33	80.27	6.00	46.27	8.29	8.69
C-147	Alankar	49.67	101.33	64.93	4.00	50.07	7.34	8.29
C-1487	Ricum	44.33	100.33	70.40	3.60	56.93	8.03	7.75
C-1502	SC15B	44.00	100.67	62.37	5.07	44.40	7.03	5.04
C-1582	TGX 1086-2E	49.67	102.33	87.33	2.80	53.13	8.74	7.89
C-165	B401	49.00	100.67	74.93	3.93	38.80	5.62	5.09
C-1734	TGX 802-	46.33	100.33	63.40	4.00	57.73	5.55	5.92
C-1788	TGX 816-	49.67	104.00	67.47	5.07	58.87	6.88	6.90
C-1892	TGX 85B-48-	45.33	101.33	53.67	5.53	52.07	8.82	7.35
C-195	BR4	39.00	97.33	35.32	3.53	32.20	10.63	6.37
C-2007A	- -	41.67	102.00	76.53	5.07	70.93	8.06	8.11
C-7048	- -	39.33	102.33	43.73	4.33	54.60	8.61	8.34
C-2430	EC 457326	39.33	103.00	45.64	5.93	69.47	10.39	12.19
C-2502	EC	39.00	90.67	68.27	3.73	52.33	6.79	6.31
C-2503	EC	40.00	91.67	76.27	4.07	47.80	5.64	6.43
C-2511	EC 467295	50.33	103.67	74.67	5.20	55.73	7.83	6.79
C-2562	EC 468600	44.67	100.00	67.93	5.93	77.53	8.66	9.69
C-2698	EC 481500	49.00	101.00	72.47	5.47	57.87	6.96	6.71
C-2705	EC 481510	49.33	103.33	81.73	5.80	53.27	7.13	6.46

C-2722	EC 481571	39.33	87.33	58.93	3.60	37.00	6.14	5.92
C-2746	EC 490302	48.67	94.67	67.60	4.67	36.60	5.25	3.98
C-2755	EC 547464	39.00	88.00	59.80	4.00	46.40	11.86	9.00
C-2758	KT	42.33	97.33	65.73	3.00	41.53	11.11	8.69
C-2809	EC 528623	35.00	94.33	63.73	2.53	44.87	10.49	7.44
C-2857A	EC 528674	42.00	98.67	75.60	3.47	53.73	9.67	9.86
C-2928	EC 542431	42.67	92.33	62.60	4.80	39.67	10.28	7.61
C-2931	EC 542434	47.00	99.00	74.47	2.60	60.13	6.77	6.77
C-2950	EC 550830	44.67	100.67	68.20	4.87	63.60	8.24	7.76
C-2952	EC 537947	49.33	104.33	78.03	4.73	46.87	7.38	6.28
C-302	EC 113744	49.67	103.33	85.40	4.73	49.40	6.31	6.14
C-3041	EC 572027	44.33	98.67	67.07	4.47	65.53	9.65	11.55
C-305	EC113773	42.33	99.67	52.33	4.67	73.60	9.71	13.37
C-3129	EC 572115	41.67	100.67	36.27	5.07	76.40	9.09	12.72
C-315	EC 1 24357A	51.33	106.00	73.67	5.47	61.80	7.32	8.05
C-3150	EC 572136	37.33	92.00	49.87	3.40	37.40	11.49	7.17
C-3166	EC 572152	44.67	92.67	60.95	2.87	49.13	10.81	10.05
C-3174	EC 572160	44.67	99.00	50.43	5.07	58.53	9.15	10.25
C-3218	EC 581520	45.00	100.33	60.00	3.47	61.03	8.77	9.05
C-3219	EC 581521	44.67	100.00	61.67	5.80	64.07	8.56	8.90
C-322	EC 14458	46.33	99.67	65.20	5.13	51.97	8.25	8.51
C-3229	EC 590224	44.67	99.33	63.12	3.22	52.43	8.91	8.49
C-3230	EC 592184	51.00	104.00	58.27	2.60	55.70	5.95	5.82
C-3243	EC 592195	45.00	99.33	60.87	3.40	50.87	9.07	7.75
C-3299	EC 589398	43.00	98.00	70.53	3.27	54.53	7.97	6.84
C-3327	EC 615128	44.33	100.33	68.07	4.07	38.20	8.94	6.15
C-3391	EC 615192	43.00	94.67	76.53	3.60	38.13	10.85	6.60
C-3406	CM 60	43.33	98.33	65.60	4.40	39.13	12.07	8.51
C-3412	EC 638228	50.00	106.33	89.25	4.73	51.60	6.36	6.99
C-357	EC 232019	43.00	98.67	64.67	2.87	45.93	8.65	7.25
C-44	AGS 150	40.00	86.67	59.93	3.07	44.73	5.81	6.89
C-503	- -	49.33	101.67	78.07	5.20	61.80	5.59	6.56
C-537	EC 251403	44.67	100.67	69.13	4.20	61.90	9.46	8.18
C-592	EC 251842	50.33	104.00	73.73	4.73	41.33	7.07	5.90
C-675	EC 308314	46.00	103.00	55.33	6.27	61.40	5.69	5.97
C-683	EC 309505	48.67	100.00	69.00	5.20	54.73	7.10	7.10
C-710	EC 30967	40.33	93.33	55.80	4.93	49.73	11.57	9.51
C-716	EC 313969	44.67	99.00	58.13	6.40	28.93	9.71	5.51
C-772	EC 333868	51.33	105.67	85.93	6.07	45.53	8.82	5.66
C-778	EC 333874	41.33	99.00	54.67	6.47	53.40	8.78	8.10
C-79	AGS 230	39.00	96.00	70.40	3.00	40.00	10.21	6.53
C-799	EC 333895	50.67	103.00	71.27	3.93	43.40	7.79	6.65
C-844	EC 333940	43.00	95.33	48.72	3.80	53.20	8.77	9.90
C-868	EC36816	49.33	101.33	69.20	3.93	58.93	8.76	8.53
C-87A	ACS 38A	44.33	98.00	64.73	3.73	47.67	9.74	7.97
C-905	EC 39751	34.33	90.00	65.93	3.60	53.47	9.13	7.21

C-945	EPS 472	48.67	104.67	91.47	5.67	42.60	7.41	5.53
DS 91-3		47.33	100.67	77.73	5.00	61.73	8.07	8.78
DT 21		43.00	100.67	65.40	4.27	64.00	9.06	9.53
EC 15966		41.00	100.33	61.40	4.73	58.87	9.54	9.58
EC		43.00	101.33	67.20	5.47	63.87	8.78	10.53
EC		44.00	99.33	65.33	4.13	65.00	8.79	10.33
EC 39536		47.67	101.00	81.37	6.27	68.87	9.31	9.92
EC		41.00	98.00	37.73	4.93	58.67	10.99	11.74
EC 65772		41.33	92.33	44.53	4.80	56.93	9.39	8.84
G 141		48.00	99.00	76.80	4.80	40.73	7.79	6.40
G 3		47.67	98.00	80.67	4.73	73.27	8.61	11.10
G5P22		39.67	96.33	39.20	3.93	41.07	9.18	7.63
GP 116		40.67	101.33	69.00	5.87	58.67	10.96	10.37
GP 465		42.00	94.33	63.53	4.33	57.20	9.15	10.72
GP 499		47.00	95.67	80.20	5.53	68.67	8.33	10.56
JS 20-48		41.67	94.67	65.07	2.80	51.93	10.08	10.62
JS 20-50		44.33	102.33	63.30	4.85	63.97	9.87	13.64
JS 20-72		34.67	91.67	49.27	3.40	38.93	10.28	8.00
JS 79-302		53.33	101.00	72.73	3.40	59.73	6.37	6.18
JSM 284		41.67	95.00	56.20	3.53	50.53	10.79	10.72
JS 288		41.00	94.67	65.60	3.40	60.27	8.14	8.17
PK 747		47.67	99.67	77.53	4.13	57.90	7.42	6.80
PP6 (PI)		36.33	91.33	67.40	3.13	38.60	10.25	7.61
RKS 54		45.67	98.67	67.87	4.27	67.20	7.99	9.44
Sizta 194		43.67	92.67	75.20	3.80	39.27	8.27	6.99
SL 29-51		43.67	102.33	80.40	3.73	55.73	9.93	10.32
SL 599		43.67	101.33	71.60	4.53	68.60	8.96	11.64
VGM 70		47.67	101.33	79.00	3.33	50.13	8.68	6.83

2.1.1.5. Genetic diversity analysis of advanced breeding lines in soybean

One hundred and twelve (112) advanced breeding lines collected from eight centres were studied for genetic diversity through Mahalanobis D^2 analysis (Table 10).

Table 10. Details of breeding lines used for genetic diversity analysis

S No.	Institute	No. of advanced breeding lines	Advanced breeding lines
1	IARI, New Delhi	20	V-1, V-2, V-3, V-4, V-5, V-6, V-7, V-8, V-9, V-10, V-11, V-12, V- 13, V-14, V-15, V-16, V-17, V-18, V-19, V-20
2	JNKVV, Jabalpur	10+2checks	JS 20-102, JS 20-103, JS 20-107, JS 20-109, JS 20-112, JS 20-115, JS 20-117, JS 20-119, JS 20-121, JS 20-123, JS 95-60 (C), JS 9752(C)
3	UAS, Dharwad	10	DSB 21, DSB 23-2, LINE NO.23 A, DSB 30-2, DSB 22, DSB 21, DSB 12, DSB 24,

4	MPKV, ARS, Kasbe Digraj	10	LINE NO. 8, DSB 19 KDS 726, KDS 730, KDS 754, KDS 786, KDS 797, KDS 798, KDS 8 04, KDS 8 37, KDS 889, KDS 970
5	PAU, Ludhiana	10	SL 688, SL 958, SL 983, SL 982, SL 1031, SL 744, SL 980, SL 525, SL 955, SL 979
6	GBPAUT, Pantanagar	20	PS 1571, PS 1572, PS 1569, PS 1570, PS 1577, PS 1578, PS 1579, PS 1580, PS 1573, PS 1574, PS 1575, PS 1576, PS 1565, PS 1566, PS 1567, PS 1568, PS 1581, PS 1582, PS 1583, PS 1584
7	DSR, Indore	22	Indore 1, Indore 2, Indore 3, Indore 4, Indore 5, Indore 6, Indore 7, Indore 8, Indore 9, Indore 10, Indore 11, Indore 12, Indore 13, Indore 14, Indore 15, Indore 16, Indore 17, Indore 18, Indore 19, Indore 20, Indore 21, Indore 22
8	RVSKVV, Sehore	10	Sehore 1, Sehore 2, Sehore 3, Sehore 4, Sehore 5, Seho re 6, Sehore 7, Sehore 8, Sehore 9, Sehore 10

The D^2 values for all comparisons between pairs of genotypes were calculated. On the basis of divergence, 112 genotypes and two checks were grouped into 11 clusters. Cluster 2 had maximum lines i.e. twenty five, while cluster 4 and 7 had one genotype each *viz.* Line No. 8 and PS 1566 (Table 11).

Table 11. List of clusters and genotypes

Cluster	Within SS	No. of genotypes	Cluster
1	3.8556	13	V-1, Indore 3, Indore 6, Indore 8, Indore 9, Indore 11, Indore 13, Indor e 19, In dore 20, Sehore 3, Sehore 4, Sehore 6, Sehore 9
2	3.8556	25	V-2, V-3, V-4, V-5, V-6, V-7, V-8, V-9, V-10, V-11, V-12, V-13, V-14, V-16, V-17, V-18,V-19,V-20, SL 1031, SL 98 0, SL 525, SL 979, PS 1572, Indore 10, Indore 21
3	1.8039	12	JS 20-102, JS 20-107, JS 20-109, JS 20-117, JS 20-121, DSB 12, KDS 730, KDS 786, Indore 1, Indore 15, Sehore 7, Sehore 10
4	0	1	LINE NO. 8
5	1.4942	11	JS 20-103, JS 20-119, DSB 22, DSB 24, KDS 726, KDS 754, KDS 837, KDS 889, KDS 970, Indor e 16, Sehore 5
6	1.7335	11	DSB 21, DSB 19, SL 958, SL 955, PS 1571, PS 1573, PS 1574, PS 1575, PS 1576, PS 1567, Indore 17
7	0	1	PS 1566
8	3.5942	19	V-15, DSB 25, DSB 23-2, SL 688, SL 983, SL 982, SL 744, PS 1569, PS 1570, PS 1577, PS 1578, PS 1579, PS 1580, PS 1565, PS 1568, PS 1581, PS 1582,

			PS 1583, PS 1584
9	1.7147	8	JS 20-112, JS 20-115, Indore 2, Indore 4 , Indore 5, Indore 7, Indore 12, Sehore 8
10	1.8786	9	JS 20-1 23, LINE NO.23 A, DDSB 30-2, KDS 797, KDS 798, KDS 804, Indore 14, JS 9752(C), Sehore1
11	1.1043	4	JS 95-60, Indore 18, Indore 22, Sehore 2

Distance between all pairs of genotypes was calculated using squared Euclidean distance method and the genotypes were clustered based on Tocher's method (Fig. 5).

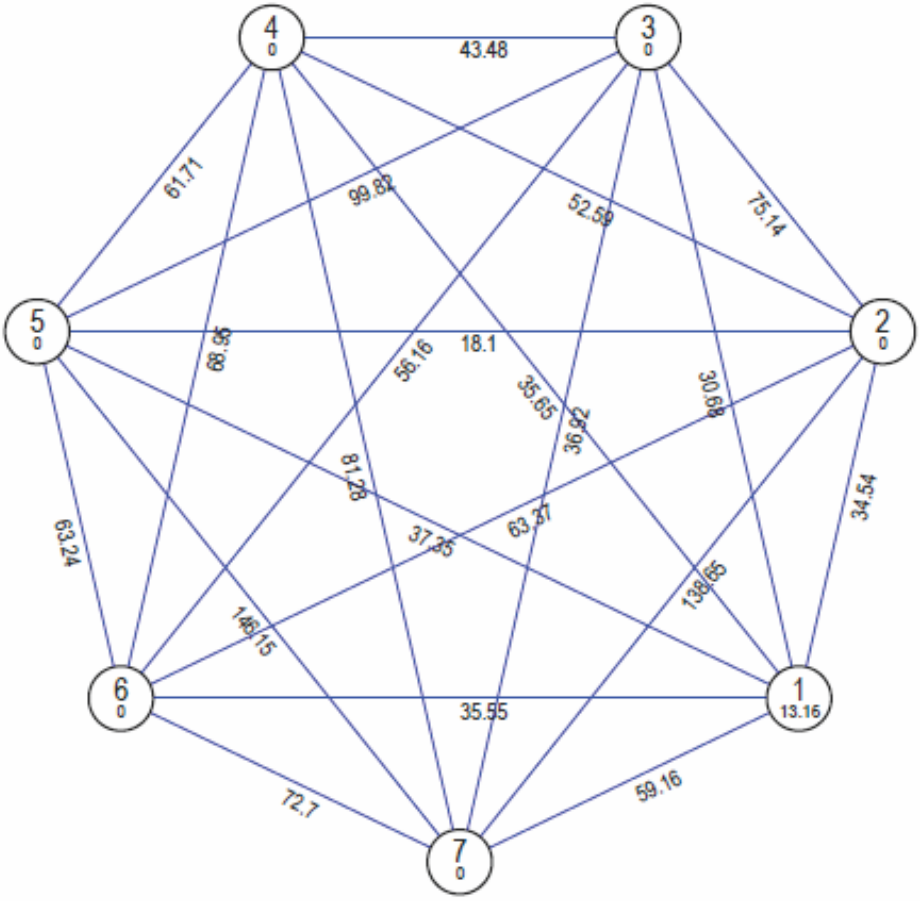


Fig.5: Clustering by Tocher method resulted in seven clusters. If inter cluster distance is maximum, genotypes are more diverse.

The mean value of each cluster for various characters was compared (Table 12). The lowest days to 50 per cent flowering (33.50 days) was found in Cluster 11, followed by Cluster 1 (38.46 days). Days to maturity was the lowest in Cluster 4 (84.50 days) followed by cluster 11 (96.88 days). Cluster 11 showed the lowest plant height of 27.68cm followed by cluster 9 with 43.77cm. The lowest number of primary branches was in cluster 4 (3.70) followed by cluster 2 (4.21). Cluster 2 showed the lowest numbers of pods per plant (25.86) followed by cluster 11 (27.18). Hundred seed weight was minimum in cluster 7 (9.65g) followed by cluster 2 (10.15) and maximum in cluster 11(13.09) followed by cluster 9 (12.94). Maximum seed yield per plant was found in cluster 9 (10.64) followed by cluster 3 (9.44). (Fig.6)

Table 12. Cluster mean, standard deviation and CV of clusters

Cluster	DF	DM	PH	Pri br	pods/pl	seeds/pod	nodes/pl	seed	yield
Cluster 1	38.46	104.04	44.64	5.13	37.23	2.51	11.41	12.31	7.82
Cluster 2	38.90	108.66	45.87	4.21	25.86	2.46	10.92	10.15	4.22
Cluster 3	41.21	99.04	56.13	4.97	36.15	2.68	12.33	11.98	9.44
Cluster 4	43.00	84.50	68.80	3.70	28.90	3.00	12.80	11.60	8.05
Cluster 5	42.86	102.45	58.38	5.26	38.98	2.61	12.10	11.27	7.25
Cluster 6	42.18	108.18	54.78	5.19	35.14	2.40	12.55	10.75	6.07
Cluster 7	55.00	110.00	70.43	4.88	57.80	2.30	15.93	9.65	4.88
Cluster 8	42.79	109.66	54.07	5.30	30.11	2.35	11.07	12.08	4.26
Cluster 9	38.63	99.44	43.77	4.85	40.44	2.66	11.58	12.94	10.64
Cluster	44.11	102.17	67.11	4.34	41.20	2.62	14.22	10.98	8.16
Cluster	33.50	96.88	27.68	4.90	27.18	2.45	8.58	13.09	5.01
SD	5.31	7.46	12.79	0.504	8.93	0.19	1.8	1.09	2.16
CV	12.68	7.29	23.78	10.51	24.62	7.69	15.53	9.48	31.40

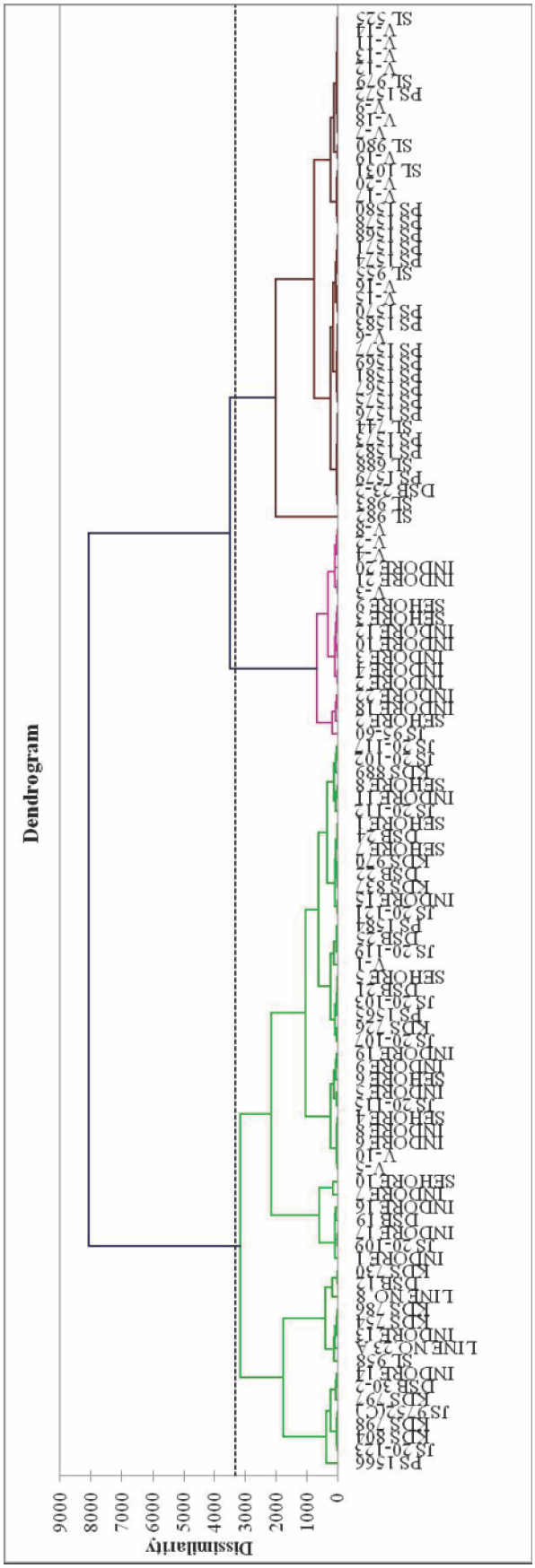


Fig.6: A dendrogram of advanced breeding lines of soybean

2.1.1.6. Identification of genotypes for early maturity allele *e1-as* :

A total of 46 indigenous germplasm accessions were used for identification of recessive allele of E1 loci (***e1-as***) which confers early maturity. A derived CAPS marker (dCAPS) was used for characterization of recessive allele *e1-as*. One genotype IC15089 was identified to be carrying recessive allele *e1-as*. This genotype may used as a source for transferring early maturity allele *e1-as* in medium and late maturing cultivars.

2.1.1.7. Pre breeding programme:

As part of pre breeding programme *Glycine soja* wild soybean was crossed with three popular soybean varieties namely, JS 95-60, NRC 86 and NRC 37. The F_1 plants from each cross was confirmed and advanced to F_2 generation.

2.1.1.8. Development of nested association mapping population (NAM):

Variety JS 335, as common parent, was crossed with 20 promising genotypes. The F_1 seeds from respective cross combinations were harvested.

2.1.2. Genetic improvement for yields and associated characters in soybean

2.1.2.1 Promising entries in AICRPS breeding trials

NRC 99 a progeny of cross EC 546882 x PS 1044 performed well in IVT in Central Zone showing 17% increase in yield over best check. It is a medium duration line maturing in 96 days. NRC 93 developed from cross RKS 15 x EC38109, showed wide adaptability in AVT-II in NEZ and SZ. It out yielded best check by 9% in NEZ and 13.6% in SZ. NRC 93 matures in 102 days and 94 days in NEZ and SZ respectively (Table 13).

Table 13. Performance of NRC 93

Zone	Trial	Yield (Kg/ha)	Per cent increase over best check	Maturity days
North Eastern Zone	AVT II	1966	9.5	102
Southern Zone	AVT II	2407	5.7	94

2.1.2.2 Evaluation of advanced breeding lines

Thirty six advanced progenies of different crosses were evaluated in three separate trials along with checks. Many lines recorded yields up to 3.1 t/ha. The highest yielding four lines namely NRC117, 118 119 and 120 have been selected for testing AICRPS initial varietal trials (Table 14).

Table 14. Promising lines selected for initial varietal trial (IVT)

Number	Name of the entry	Yield kg/ha	Maturity days	% Yield increase best check (NRC 37)	Per day productivity (kg/ha/day)
NRC117	NRC 2013-C-1-2-1	3128	97	32.20	32.24
NRC 118	NRC 2013-E-1-6-3	3174	99	34.15	32.06
NRC 119	NRC2013-G-3-16-1-3	2950	97	24.68	30.41
NRC 120	NRC2013-D-3-2-1-2	2823	101	19.31	27.95
Check	NRC 37	2366	97	-	24.39

In addition to these four lines, several breeding lines showed superior performance compared to check. NRC2013C 1-8-1(2970), NRC2012B-1-8-1(2614) and NRC2013-B1-8-1-4(2826kg/ha) showed highest yield increases over best check NRC37. The maturity duration of these lines ranged from 95-107 days (Table 15)

Table 15. Performance of selected advanced breeding lines

S.No.	Name of the entry	Yield kg/ha	Maturity days	% Yield increase best check (NRC 37)	Per day produetinty kg/ha
1	NRC 2013-C-1-8-1	2970	101	25.52	29.40
2	NRC 20012- B-1-8-1	2614	101	10.48	25.88
3	NRC 2013-B-1-8-1-4-1-2-2	2826	99	19.44	28.54
4	NRC 2013-K-3-9-1-1	2604	99	10.05	26.30
5	NRC 2013-F--1-1-1	2960	101	25.10	29.30
6	NRC 20013-C-2-10-2	2913	94	23.12	30.99
7	NRC 2013-C-1-1-1	2794	101	18.09	27.66
8	NRC 2013-E-1-3--2	3053	99	29.04	30.84
9	NRC 2012-G-3-16-2	2670	94	12.85	28.40
10	NRC 2013-C-2-10-1	2670	99	12.85	26.99
11	NRC 2013-G-3-17-1-1	2749	94	16.19	29.24
12	NRC 2013-E-1-10-3	2608	97	10.23	26.88
13	NRC 2013-D-3-2-1-1	2710	99	14.54	27.37
Check	NRC 37	2366	97	-	24.39

2.1.2.3. Evaluation of mid-generation breeding stocks

In an augmented trial 95 progenies in F4/F5 generation of different crosses were planted with five checks. Data on yield and associated characters was recorded. Lines from crosses PBM1 x JS93-05, Doko x JS 95-60, JS93-05 x EC538805, NRC7xEC538828 out performed checks by huge margins. The highest yielding line PBM1xJS93-05 yielded 3754 kg/ha and matured in 95 days. The yields of selected progenies ranged from2621 to 3754 kg/ha. The maturity duration ranged from 94 days (JS93-05xNRC37) to 101 days (JS97-52/PBM1) (Table 16).

Table 16. Performance of selected mid-generation progenies

S.NO	ENTRIES	Yield Kg/ha	Maturity days	100 seed wt (g)
1	NRC 7XEC538828-5-4	2657	95	12.18
2	DOKO XJS 95-60-1-16-1-1	3527	96	13.20
3	NRC 37 XPBM-1 -1-2-1-2	2621	97	11.14
4	PBM 1 XJS 93-05-1-10-1-1	3754	97	13.34
5	EC546882 XPS 1044-1-22-1-1-16	2718	97	13.10
6	NRC 37 XPBM-1 -1-2-3-2-3	2764	95	11.38
7	EC546882 XPS 1044-1-25-2-1-1	2831	97	12.89
8	PBM 1 XJS 93-05-2-5-1-1	2800	100	12.18
9	JS 97-52 X PBM 1-1-6-1-3	2859	97	10.71
10	NRC 7XEC538828-5-3	2641	97	11.65
11	JS 97-52 X PBM 1-1-9-2-8	2957	101	11.50

12	PBM 1 XJS 93-05-1-10-1-2	3144	101	12.27
13	EC546882 XPS 1044-1-22-2-1-4	2625	101	12.50
14	JS 93-05 X NRC 37-1-1-3-3-1	2610	94	13.85
15	JS 97-52 X PBM 1-2-1-13-1	2653	101	12.13
16	PBM 1 XJS 93-05-1-16-2-1	2909	100	12.13
17	EC546882 XPS 1044-1-22-2-1-2	2845	101	13.20
18	MAUS61-2 XNRC 7-1-8-1-2-2-3-1	2736	101	18.21
19	MAUS61-2 XNRC 7-1-8-1-2-2-2-6-1	3431	104	17.81
20	EC546882 XPS 1044-1-24-2-2-3	2924	95	13.57
21	EC546882 XPS 1044-1-24-2-2-1	3090	99	12.20
22	JS 97-52 X PBM 1-1-2-3-3	2613	99	11.03
23	JS 93-05 X EC 538805-1-1-1-2	3298	99	12.24
24	EC546882 XPS 1044-1-24-2-3-1	3207	95	13.66
	NRC 37 (C)	1837	97	10.01
	JS 93-05 (C)	1421	97	11.80
	JS 335 (C)	1021	101	10.19
	NRC 7 (C)	944	96	13.40
	JS 95-60 (C)	1569	93	15.46

2.1.2.4 Hybridization and generation advancement

Twenty seven new crosses were made in *Kharif* 2014. To broaden the genetic base and increase diversity for better adaptation, new germplasm lines/ high yielding breeding lines and varieties were selected as parents for these crosses. The targeted traits were high yield, early/medium maturity, resistance to biotic stress, early vigor and sturdy plant type etc.

Under generation advancement, confirmed F_1 plants were advanced to F_2. Also, F_2 population of four crosses was advanced to F_3. Six hundred plants belonging to 16 crosses were selected in $F_3/F_4/F_5$ generations (Table 17)

Table 17. Yield of selected plants in F3-F6 generation

S no.	Crosses	Single plant yield (gm)	100-seed wt.(gm)
1.	NRC 37 X EC 602272-2-1-6-1	51.80	11.80
2.	NRC 37 X EC 602272-2-3-2-1	42.33	12.80
3.	NRC 37 X EC 602272-2-3-4-1	45.24	10.18
4.	NRC 37 X EC 602272-2-3-4-2	44.73	11.40
5.	NRC 37 X EC 602272-2-4-1-1	45.40	11.60
6.	NRC 37 X EC 602272-2-6-1-1	47.90	11.28
7.	NRC 37 X EC 602272-2-6-1-2	42.74	13.02
8.	NRC 37 X EC 602272-2-6-6-1	44.52	15.40
9.	NRC 37 X EC 602272-2-10-2-1	44.80	11.30
10.	NRC 37 X JS 93-05-1-13-1	32.92	10.40
11.	NRC 37 X JS 93-05-1-13-2	37.70	10.44
12.	JS 97-52 XJSM 276-1-1	47.84	15.82
13.	JS 97-52 XJSM 276-1-2	53.90	15.80
14.	JS 97-52 XJSM 276-1-3	64.77	13.04
15.	JS 97-52 XJSM 276-1-4	50.94	15.00

16.	JS 97-52 XJSM 276-1-5	49.56	17.14
17.	JS 97-52 XEC 602288-1-1	58.34	13.32
18.	JS 97-52 X EC 602288-1-5	49.48	11.50
19.	JS 97-52 X EC 602288-1-6	66.73	12.80
20.	NRC 7 XEC 538828-2-3-1-1	49.92	14.54
21.	NRC 7 XEC 538828-1-12-2-1	47.46	9.46
22.	NRC 7 XEC 538828-5-9-3-1	40.00	11.68
23.	NRC 7 XEC 538828-5-14-3-1	43.10	12.10
24.	EC 546882 X EC 538823-1-2-1-1	37.05	10.11
25.	EC 546882 X EC 538823-1-12-4-1	35.02	12.14
26.	EC 546882 X EC 538823-1-12-4-2	51.64	12.10

2.1.2.5 Selection among uniform progeny rows bulk

Seventy four row bulk from 13 crosses with high yield and other desirable traits were selected after evaluation in 2m rows. The yields of these progeny rows ranged from 1666 kg/ha to 4244 kg/ha (Table 18).

S. No	Crosses	Yield kg/ha	100-Seed wt. (g)
1	NRC 7 X EC 538828-5-9-1	4255	10.91
2	NRC 7 X EC 538828-2-1-3	4066	10.67
3	NRC 7 X EC 538828-5-2-1	3611	12.34
4	NRC 7 X EC 538828-5-7-1	3644	11.91
5	NRC 7 X EC 538828-5-13-1	3522	12.58
6	JS 97-52XPBM 1-1-9-1-5-2	3155	10.53
7	JS 97-52XPBM 1-1-2-3-1-3	3522	9.80
8	JS 97-52XPBM 1-1-2-3-1-4	3299	9.19
9	JS 97-52XPBM 1-2-4-4-2-2	3322	10.15
10	NRC 37 X PBM 1-1-2-3-5-1	3011	10.43
11	NRC 37 X PBM 1-1-2-3-2-1	3233	11.05
12	NRC 37 X EC 602272-2-3-4	4088	11.07
13	NRC 37 X EC 602272-2-6-5	5788	12.94
14	NRC 37 X EC 602272-2-3-5	3288	12.09
15	NRC 37 X EC 602272-2-11-3	3333	9.64
16	JS 93-05 X NRC 37-1-5-2-2-2-2	2799	9.14
17	PBM 1X JS 93-05-1-12-1-2-1	2888	11.38
18	PBM 1X JS 93-05-2-5-2-3-1	3088	11.85
19	EC 546882 EC 538823-1-14-1	2988	8.32
20	EC 546882 X EC 538823-1-13-3	2966	7.92
21	EC 546882 X EC 538823-1-12-1	4366	9.04

2.1.2.6. Supply of breeding materials to different co-operating centers

Advanced breeding lines and donor parents (15) were supplied to co-operating centres by Directorate of Soybean Research, Indore. Details of these lines are mentioned below:

Early maturing and high yielding - 2
Extra early with bold seeds - 2
High yield, profuse branching - 3
High yield medium duration with good seed longevity - 4

Tall medium duration large number of pods per plant - 3
Insect tolerant - 1

These lines were distributed to 10 co-operating centres including Bengaluru, Adilabad, Imphal, Ranchi, Raipur, Parbhani, B. Chariali, Sehore, Kota and Amravati

2.1.2. Breeding for Food Grade Characters and High Oil Content

2.1.3.1. Pyramiding null alleles of lipoxygenase, kunitz trypsin inhibitor and to develop high oil genotypes:

Crosses were attempted to incorporate null alleles of lipoxygenases, kunitz trypsin inhibitor into high yielding background and vegetable type soybean, to pyramid null alleles of both the character in same genetic background and to develop high oil genotypes. NRC105 X NRC101(recently developed KTi free soybean line);NRC86 X NRC101; SL525 x (SL525 X NRC101); Dadachamame X NRC101(recently developed KTi free soybean line); (NRC7 X NRC101) x NRC109(recently developed Lox2 free soybean line);(JS97-52 X PI542044 null KTi line) X (JS97-52 X PI596540,source of null allele of lipoxygenase2); MAUS71 X (JS97-52 X PI542044 null Kti line);NRC108,recently developed high oil line X AGS191,high oil germplasm line;HO20 (high oil line derived from Hardee x NRC7) X HO6 (high oil line derived from Hardee x NRC7) for recurrent selection.

HO8 (high oil line derived from Hardee x NRC7) X HO2 (high oil line derived from Hardee x NRC7) for recurrent selection;HO2 (high oil line derived from Hardee x NRC7) X HO21 (high oil line derived from Hardee x NRC7) for recurrent selection;BO3(high oil line derived from JS93-05x G760) X HO8(high oil line derived from Hardee x NRC7);HO16 (high oil line derived from NRC7 x AGS191) X HO14 (high oil line derived from NRC7 x G76) ;HO14 (high oil line derived from NRC7 x G76) X HO1 (high oil line derived from Hardee x NRC7).

HO16 (high oil line derived from NRC7 x AGS191) X HO18 (high oil line derived from Hardee x NRC7); HO11 (high oil line derived from NRC7 x G76) X HO20 (high oil line derived from Hardee x NRC7).

F_1 of the above crosses have been raised in the glasshouse and tested for their trueness to hybridity using flower color, pubescence and molecular markers (gene specific and polymorphic SSR primers).

F_3 populations of NRC105 x NRC101, Dadachamame x NRC101 &Dadacha2000 x NRC101 and F_2 population of SL525 x NRC101 were genotyped using gene specific primers for null Kti allele and linked marker Satt228.

Segregating populations were tested for presence/absence of lipoxygenase activity using PCR amplification of gene specific primers and rapid bleaching test. Four LOX3 free soybean lines were developed from a cross between JS 335 and PI205085, donor of null Lx3 allele. (Fig.7 and Fig.8)

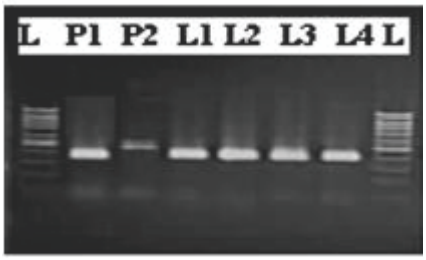


Fig.7. PCR amplicons resolved on 1% agarose gel using Lox3-3' (STS) primer. P1 and P2 depict the amplified products from PI205085 (lx3lx3) and JS335 (Lx3Lx3), respectively. Lanes L1, L2, L3, L4 depict Lx3 free advanced lines Jlx3-1, Jlx3-2, Jlx3-3 and Jlx3-4, respectively, derived from JS335 × PI205085 and L denotes the 100 bp DNA ladder.

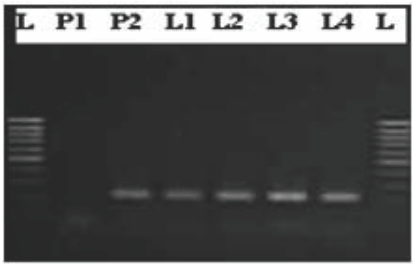


Fig.8. PCR amplicons resolved on 1% agarose gel using LOX-3-PM1 (SNP) primer. P1 and P2 depict the amplified products from JS335 *(Lx3Lx3)* and PI205085 *(lx3lx3)*, respectively. Lanes L1, L2, L3, L4 depict the advanced lines Jlx3-1, Jlx3-2, Jlx3-3 and Jlx3-4, respectively, derived from JS335 X PI205085 and L denotes the 50 bp DNA ladder.

2.1.3.2. Introgression of null lipoxygenase-2 in JS97-52:

Five plants which exhibited 98 % retrieval of recurrent parent genome were selfed. BC_3F_2 generation obtained from 5 plants exhibiting 98% retrieval of recurrent parent genome was raised and subjected to foreground selection first using null allele specific marker. The plants identified to harbour null allele of *Lox2* (*Lox2lox2*/*lox2lox2*) were surveyed using tightly linked marker Satt656 (Fig. 9). This resulted in the identification of 260 homozygous recessive plants (*lox2lox2*), all of which were surveyed using 6 SSR markers, heterozygous in the previous background selection (BC_3F_1). This showed a recovery of 96.33-98.66 % of recurrent parent genome. Twelve lines ($BC_3F_{2:3}$) introgression lines exhibited recurrent parent genome recovery of 97.66-98.66% recover of one line is shown in Fig.10. Qualitative data of parents and ILs corresponded well with the results of quantitative assay, which confirmed the absence of lipoxygenase-2 in ILs.

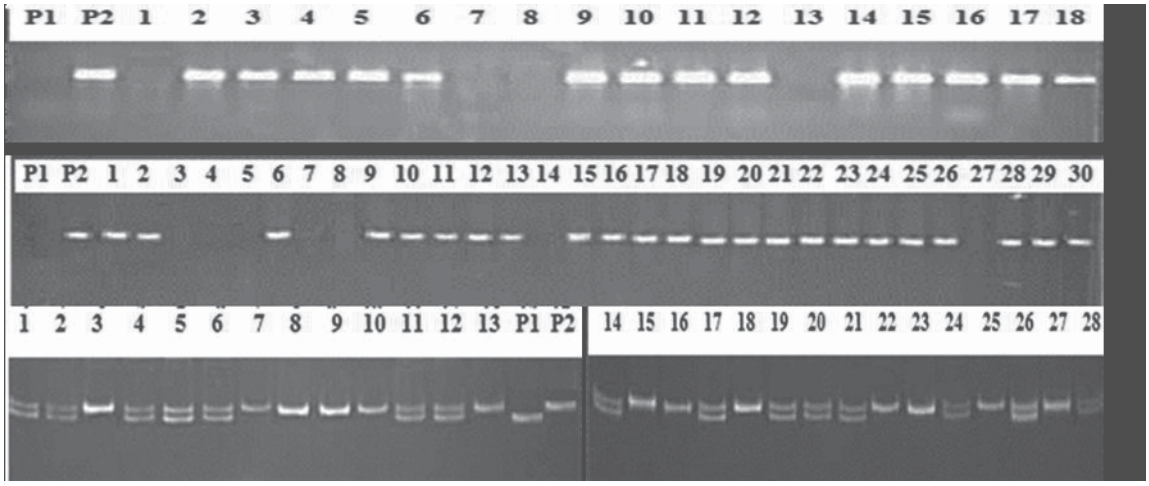


Fig.9. Foreground selection in BC1F1 (A) and BC3F2 (B) generations using null allele specific marker on 1 % agarose gel and in BC3F2 (C) generation using linked marker Satt656 on 8% polyacrylamide gel

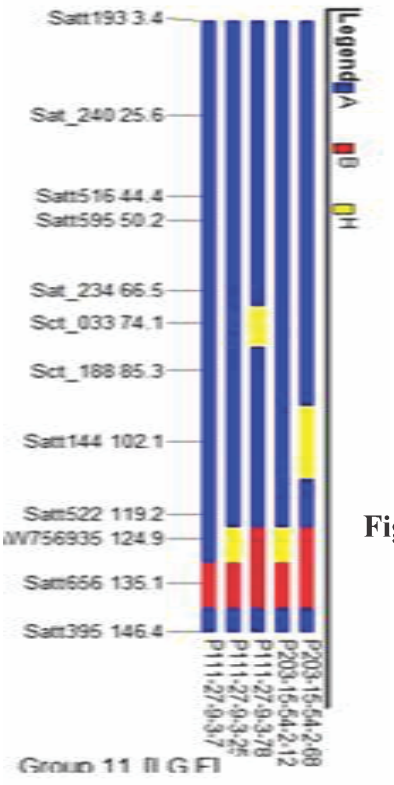


Fig.10. Graphical genotyping of selected plants in BC1F1 (A), BC2F1 (B), BC2F2 (C), BC3F1 (D) and BC3F2 (E) generation on carrier chromosome (LG 'F') through GGT 2.0

2.1.3.3. Breeding for higher oil content: One hundred and twenty advanced lines were tested for oil content. Following lines showed >23% oil content (Table 19.)

Table 19. Advanced lines that showed higher oil content (>23%)

S No.	Cross	Plant No.	Oil content %
1	NRC7XG76	NGO9	24.04
2	NRC7XG76	NRC7XG76	23.78
3	NRC7XG76	NGO8	24.14
4	NRC7XG76	NGO14	25.03
5	HardeeXG76	HGO36	23.38
6	NRC7XAGS191	NAHO16	24.82
7	HardeeXNRC7	HNHO8	24.66
8	HardeeXNRC7	HNHO19	23.88
9	HardeeXNRC7	HNBO15	24.82
10	JS93-05XG76	JGO105	25.02
11	JS93-05XG76	JGO104	25.13

2.1.4. Breeding for Resistance to Rust and Yellow Mosaic Virus Diseases in Soybean

Crosses were affected between SL295 x EC 241780 and B23J x EC 241780 so as to generate segregating material and to select desired plant material. Promising YMV resistant line 'NRC-94' is under AVT-2 and secured 3rd position among the entries during *Kharif* 2014 of AICRP on Soybean. In Marker assisted breeding for YMV resistant soybean varieties, BC_1F_2 population obtained from the cross JS 335 x SL525 was raised. YMV resistant BC_2F_1 plants were crossed with JS335 and F_2 of JS95-60X SL525 was also raised.

2.1.5. Molecular Mapping and Genomics Assisted Breeding for Rust Resistance in Soybean

2.1.5.1. Developing mapping population

New crosses were initiated between the susceptible parent (JS-335) and resistant parent (EC241780) for the development of recombinant inbred lines (RILs). F1 seeds were obtained and will be advanced to next generation during June-September 2015.

2.1.5.2. Polymorphism studies between parents:

DNA was extracted from the resistance/susceptible parents and from 15 F1 individuals. SSR markers were used to identify the polymorphic markers between JS-335 and resistant parent EC241780. Low level of polymorphism was observed. Additional screening is being done to identify the polymorphic markers.

2.1.5.3. PCR Amplification and sequencing of Rpp4 genes:

PCR primers were designed from the conserved region of Rpp4 gene. These primers were used to amplify Rpp4 genes from soybean cultivars and other accessions. PCR amplifications indicated that Rpp4 gene sequences are present in all the 20 cultivars (Fig. 11). Rpp4 gene from three selected lines was sequenced and comparative analysis was done. Phylogenetic tree indicated differences in the Rpp4 gene from JS335, EC241780, and JS93-05.

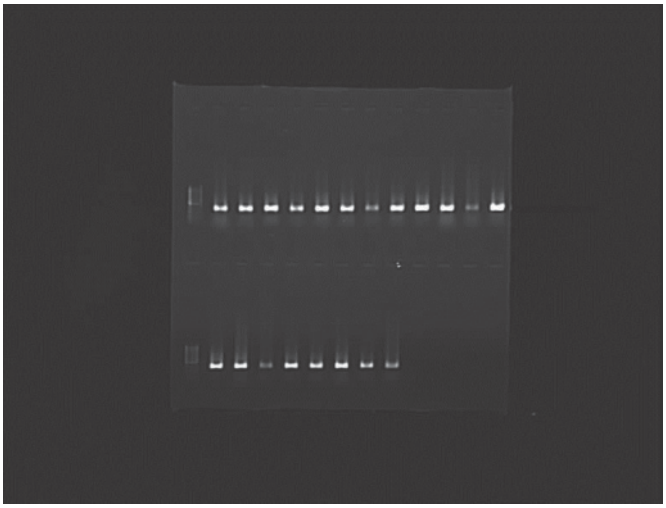


Fig 11: PCR amplifications of Rpp4 gene from soybean cultivars. All the cultivars showed amplification of 500 bp region of Rpp4 gene. Sequencing was done for Rpp4 gene from cultivars JS335, JS93-05 and EC241780.

2.1.5.4.PCR amplifications of NBS-LRR genes:

PCR primers were designed to amplify the NBS-LRR genes from 15 soybean cultivars. Amplified genes from four cultivars were sequenced and used for comparative studies. Results indicate differences in conserved NBS region. Phylogenetic and comparative studies of NBS-LRR genes are in progress.

2.1.5.5. Genetic fingerprinting of *Phakopsora pachyrhizi*:

Isolates of *Phakopsora pachyrhizi* were collected from different states such as Maharashtra, Karnataka and North East States. DNA was extracted from the isolates and is being used for PCR amplification of ITS region (Fig. 12).

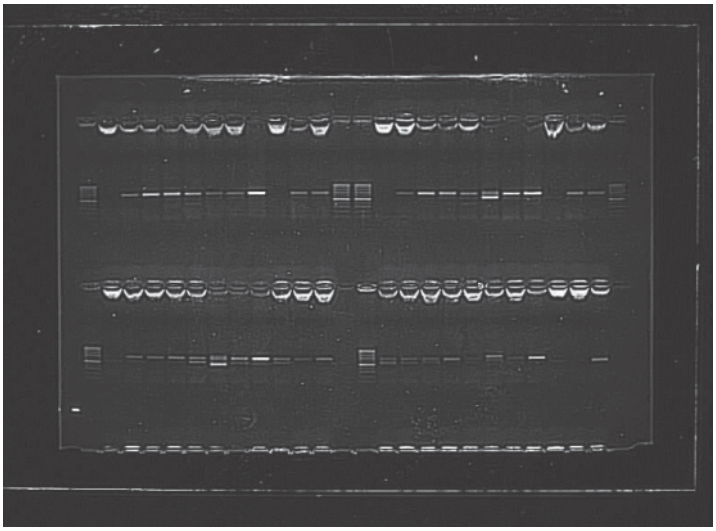


Fig. 12: PCR amplifications of ITS region from Phakopsora pachyrhizi isolates collected from Maharashtra, Karnataka and North East region. Sequencing of ITS region is in progress.

2.1.6. Mapping QTLs for oleic acid and development of high oleic acid soybean

Fatty acid composition of 108 recombinant inbred lines RILs (derived from LSb1×NRC7) was determined through Gas Chromatography. Nine 9 recombinant inbred lines (RILs) exhibited oleic acid content > 50% and α-linolenic acid < 4.2 %.

Crosses were effected between high oleic acid RILs (P4-19 ×P1-39, P1-39 ×P4-4,P3-35 ×P4-4, P3-35 ×P6-13, P1-33 ×P6-13), between RIL and other high oleic sources (P6-13×IC210, IC210 ×P6-13,P3-35×IC210,IC210 ×P3-35, IC210 xP4-4, IC210 ×P4-19) and between other diverse high oleic sources (NRC106×IC210, IC210×NRC105, NRC106×NRC105.

9 $BC_3F_{2:3}$ soybean lines introgressed with null allele of kunitz trypsin inhibitor in 'JS97-52' using gene specific and linked marker Satt228 exhibited 97.64-99.05 % recurrent parent genome content (RPGC).

Fig 13 exhibits the recovery of some plants on carrier chromosome A2

These introgression lines were confirmed to be free from kunitz trypsin inhibitor using Native PAGE. Trypsin inhibitor content in these KTI free lines declined to range of 68.7-83.5%.

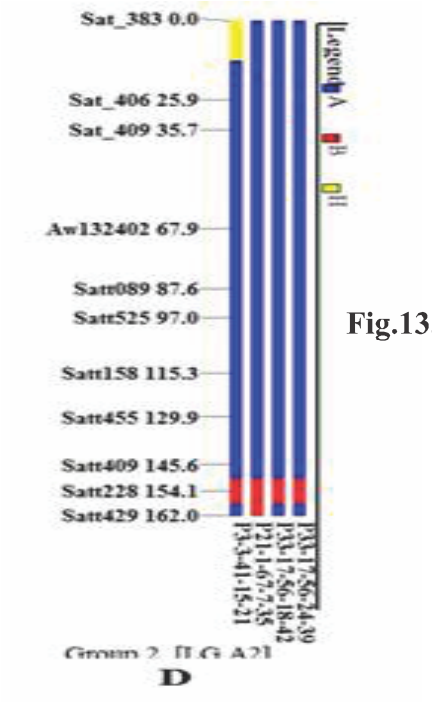


Fig.13. Graphical representation of recovery on carrier chromosome (LG A2) in BC_3F_2 (D) plants using GGT 2.0. Chromosomal regions shown in blue and red corresponded to homozygosity for recurrent parent ('JS97-52') and null allele donor genotype (PI542044), respectively. Loci shown in yellow colour exhibited heterozygosity

2.1.7. Breeding Soybean for Wider Adaptability Using Photoperiod Response and Growth Habit

2.1.7.1. Marker assisted backcross selection for photo insensitivity

Forty eight BC_2 plants from JS 97-52 (photosensitive) x [JS 97-52 x EC 390977 (photo insensitive)] were screened through validated molecular markers for E3 and E4 genes and true backcross plants with donor alleles (e3, e4, e3e4) were identified. Thirteen plants for E4 locus, six plants for E3 locus and four plants for both E3 and E4 loci carried recessive donor allele e3, e4, e3e4, respectively. These plants have been used for generating BC_3 generation for transfer of photo insensitive alleles e3 and e4 to JS 97-52.

2.1.7.2. Sequencing of E1 gene

Fourteen varieties / genotypes were sequenced for the coding region of E1 gene. All of the varieties and genotypes had E1 allele except for JS 95-60 which had recessive leaky mutant allele e1-as. These sequences have been submitted to NCBI where they have been assigned accession numbers KM386858 to KM386871.

2.1.7.3. Genotyping at Dt1 locus

Ninety six varieties / genotypes were genotyped for this locus using three SCAR markers Dt1-tb, Dt1-ab and Dt1-bb. Thirty six varieties / genotypes exhibited the presence of recessive allele through one or more of the markers and rest of the all exhibited dominant genotype.

2.1.7.4. Genotyping at photoperiodic loci

Ninety six soybean varieties and genotypes were genotyped at photoperiodic E3 and E4 loci. E3 locus was genotyped using FLP marker for e3-tr, E3 Harasoy (E3-H) and E3 Misuzudaizu (E3-M), CAPS marker for e3-fs and dCAPS markers for e3-ns alleles. Twenty two genotypes had the recessive allele at this locus. All of the six photo insensitive genotypes except EC 333897 had the recessive e3-tr allele for one or more of these markers at this locus. E4 locus was genotyped using CAPS markers e4-oto, e4-kam and e4-kes and dCAPS marker for e4-tsu alleles. All photo insensitive genotypes had the dominant allele for this locus except for genotypes EC 325097 and EC 325118 which had the recessive alleles e4 kes and e4 kam, respectively.

2.1.7.5. Hybridizations

Growth habit of *G. soja* is known to be indeerminate with genotype Dt1Dt1dt2dt2. Growth habit of ADT1 & Lee has been worked out as indeterminate and that of Pusa 24 as determinate through field screening. Genotype for ADT1 and Lee is probably Dt1Dt1 and that of Pusa 24 is dt1dt1 but their genotype at Dt2 locus is not known. To confirm the genotype and inheritance at Dt1 and Dt2 loci and to validate molecular markers for growth habit following hybridizations were conducted. ADT 1 x *G. soja*; JS 335 x ADT 1; PK 416 x Pusa 24; JS 97-52 x Pusa 24; JS 97-52 x Lee; ADT 1 x EC 390977; Pusa 24 x ADT 1.

For photo insensitivity and long juvenility following hybridizations were conducted: MACS 330 x AGS 25; JS 335 x EC 325097; JS 97-52 x EC 390977; JS 97-52 x JS 95-60; JS 97-52 x EC 333897.

2.1.8. Breeding for Drought Tolerant / Resistant Varieties in Soybean

2.1.8.1. Hybridization, selections and generation advancement:

Crosses were initiated between drought tolerant and drought susceptible parents viz. EC 602288 x NRC 2, Hardee x JS90-41, PK472 x AGS27 along with backcrosses viz. JS 335 x F_1 (PI416937 x JS335), JS 97-52 x F_1 (PI416937 x JS97-52) and crosses for the enhancement of RILs *viz.*, Young x Kaeri 651-6, Young x JS 95-60, NRC 7 x Jackson, Doko RC x JS 335. Drought responsive cultivars regularly used as parents, among them thirteen exotic and twelve indigenous, were maintained in *Kharif* 2014. F_1 generation of crosses *viz.* PI 416937xJS 97-52, PI 416937xJS 335, PI 416937xJS 95-60, and JS 71-05xJS 97-52, having PI 416937 as one of the parents for slow wilting trait were advanced. Selected 728 single plant progenies from 21, 5, 13 and 9 crosses in different generations *i.e.* F_3 - F_6, respectively, were advanced in *Kharif*- 2014.

2.1.8.2. Off-season screening of breeding populations for drought tolerance:

Thirty seven populations in F_3, eight in F_4, and nine in F_5 generation were grown in off-season 2014. Irrigation was withheld at pod fill stage (R5) to induce terminal drought condition. Populations with good pod bearing plants under terminal water stress condition were selected. In this way, thirty populations in F_3 generation, eight in F_4, and seven in F_5 generation were selected.

In a separate experiment, thirty-seven F_5 generation populations were evaluated along with thirteen drought responsive varieties for low canopy air temperature differential ($\delta T\ ^0C$) and high relative water content (RWC %) under water-stressed and irrigated conditions. A negative correlation ($r=-0.429$; $p < 0.05$) was noted between δT (^0C) under water stress and RWC (%) under irrigated condition. Five populations *viz.* 59 (-7.2^0C, 77.2%), 107 (-5.6^0C, 76.2%), 91 (-5.4^0C, 76.7%), 60 (-5.2^0C, 74.3%), 110 (-4.9^0C, 79%) showed significantly low δT under water stress and high RWC under irrigated condition, whereas one population 104 (JS 90-41xJS 97-52) had significantly low δT and high RWC both under irrigated conditions, when compared with drought tolerant variety Hardee (Table 20). The populations 104 and 107 were identified for these traits, in a similar trial conducted in off-season 2013. Selections in such populations will be effective.

Table 20. Promising breeding populations with low canopy air temperature differential and high relative water content in off-season trial 2014

S. No.	Population	Cross	δT(0C)-WS	δT(0C)-I	RWC(%)-WS	RWC(%)-I
1.	59	JS 335 x C-2797	-7.2*	-9.9	75.1	77.2
2.	107	JS 97-52 x NRC 37	-5.6*	-14.3*	75.3	76.2
3.	91	Valder x Jackson	-5.4*	-9.3	72.3	76.7
4.	60	JS 335 x C-2797	-5.2*	-9.7	69.0	74.3

5.	110	EC 546882xJS 335	-4.9*	-10.3	73.5	79.0
6.	108	NRC 37 x JS 97-52	-4.4	-11.1	64.7	78.5
7.	104	JS 90-41xJS 97-52	-3.1	-13.0*	70.0	70.6
8.		EC 602288	-5.5	-15.8	65.7	69.4
9.		Bragg	-4.3	-11.6	74.6	65.8
10.		JS 97-52	-4.2	-15.1	71.0	70.0
11.		PK 472	-3.0	-11.1	79.0	73.4
12.		Hardee	-3.0	-10.7	74.6	59.3
13.		NRC 37 (S)	-2.7	-9.7	58.4	37.2
	CD5%		1.62	2.11	-	-
	CV(%)		4.94	3.76	-	-
	Hbs(%)		77.33	69.21	-	-
	EGA(%)		83.50	28.51	-	-

2.1.8.3. Evaluation of advance breeding lines showing drought tolerance:

323 single plants with large number of pods /plant selected in *kharif* 2013 were evaluated under water stress condition in off season trial 2014 as progenies in F_5 generation for low δT^0C and high pod bearing trait. A total of 153 progenies comprised of 35 in cross 107(JS 97-52 x NRC 37), 7 in 108(NRC 37 x JS 97-52), 42 in 105(JS 93-05 x JS 97-52), 68 in 104(JS 90-41 x JS 97-52) and 1 in cross 70(JS 71-05 x C-2797) were selected.

Evaluation of F_6 generation 148 progenies derived from off season 2014 was carried out for yield and ancillary traits in augmented design, with 9 checks in 6 replications, in kharif 2014. High broad sense heritability and high expected genetic advance for important yield contributing traits *viz.* number of pods/ plant (78.08%, 76.13%) and plant height (92.11%, 65.47%), respectively, were estimated. A selection criterion with critical differences above mean values of checks lead to the identification of advance breeding lines with No. of pods/ plant more than 90.1, plant height taller than 61.1cm and summer canopy air temperature differential (δT^0C) less than -7.3^0C noted for drought tolerant cultivar JS 71-05. A medium 100-seed weight (9.8-12.9 gm) will strike a balance between high no. of nodes/ plant (>14.6) and high seed yield (>15gm/ plant) under water stress condition (Table 21).

Table 21. Correlation coefficient among canopy air temperature differential, seed yield and ancillary attributes.

Traits	Correlation coefficient (r); p<0.05, 0.01
Off season δT (ºC), Plant height	-0.16
Plant height, no. of nodes/ plant	0.58
No. of pods/ plant, no. of nodes/ plant	0.50
No. of pods/ plant, seed yield/ plant	0.50
No. of nodes/ plant, seed yield/ plant	0.30
100 seed weight, seed yield/ plant	0.29
No. of nodes, 100 seed weight	-0.19
No. of pods/ plant, no. of seeds/ pod	-0.16
No. of nodes, off season δT (ºC)	-0.16
Off season δT (ºC), kharif δT (ºC)	Nil

Fourteen advance breeding lines possessing terminal drought tolerance and high yielding traits were identified from crosses 104 (JS 90 41 x JS 97-52), 107 (JS 97-52 x NRC 37), and 70 (JS 71 05 x C-2797) (Table 22).

Table22. Identified advance breeding lines for drought tolerance and high yield.

Lines	Plant Height (cm)	No. of nodes/ plant	Off. S. W.S. δT(0C)	Kh. δT (0C)	Seed Yield/ Plant (gm)	No. of pods/ plant	100 Seed Weight (gm)	No. of seeds/ pod
104 (JS 90-41 x JS 97-52)								
104-41	113.4	21.0	-7.6	-6.7	15.60	108.0	9.8	2.0
104-33	118.0	19.2	-9.3	-9.1	23.14	88.0	11.1	2.0
104-31	120.3	18.6	-9.8	-8.9	15.86	49.0	12.1	3.0
104-44	75.2	26.0	-8.9	-8.4	26.70	302.0	7.2	2.0
104-51	117.3	22.6	-8.5	-7.5	27.06	116.8	9.3	3.0
104-28	105.6	18.6	-8.9	-8.1	14.96	112.4	8.2	2.0
104-1	81.0	17.4	-9.7	-10.1	16.76	67.8	8.8	2.0
104-25	103.3	17.0	-10.1	-7.1	14.50	82.6	8.4	3.0
104-57	328.3	16.7	-7.3	-8.1	16.50	88.3	8.6	3.0
104-3	83.0	15.8	-12.1	-9.5	18.88	109.2	8.7	2.0
104-36	70.4	15.2	-9.1	-8.0	16.50	47.4	9.2	2.2
107 (JS 97-52 x NRC 37)								
107-83	72.9	15.8	-7.9	-8.5	15.38	67.0	8.9	2.0
107-70	81.0	14.6	-8.1	-6.9	17.00	82.8	8.6	2.0
70 (JS 71-05 x C-2797)								
70-4	49.4	14.6	-8.3	-6.6	17.1	77.2	13.1	2.0
Bragg	64.7	14.7	-6.9	-7.5	16.0	90.0	8.4	2.1
Hardee	75.9	15.4	-6.2	-7.5	19.3	71.3	12.3	2.1
C-2797	69.1	16.4		-7.3	10.5	73.8	11.3	2.0
JS 97-52	65.6	14.4	-10.6	-8.6	14.3	92.3	7.9	2.0
EC 602288	70.5	14.1	-11.3	-7.9	16.2	84.7	8.4	2.1
JS 93-05	46.2	12.4		-8.3	13.2	41.1	12.9	3.0
JS 71-05	45.2	12.2	-5.4	-8.1	13.4	50.0	12.2	3.0
JS 335	31.2	12.0	-4.8	-4.5	17.0	121.6	15.6	3.0
JS 95-60	25.7	9.4	-7.8	-7.6	4.5	19.8	13.2	2.9
Mean of checks	**61.1**	**14.6**			**15.0**	**90.1**		
CD5%	6.19	1.21	-	1.89	4.47	18.47	1.53	0.13
CV (%)	7.18	2.84	-	3.07	10.33	18.76	3.91	0.74

2.1.8.4. Cut-cylinder method root phenotyping in advance breeding lines:

Fourteen genotypes comprising of ten exotic and four indigenous collections, were grown in cut-cylinder pipes under water stressed and irrigated conditions in *kharif* as well as off-seasons for assessing the feasibility of phenotyping root traits with canopy air temperature differential (δT °C) in advance breeding lines.

Cool canopy is a desirable trait which determines plant water status in a genotype under water stress condition. Root dry weight under water stress condition in off-season had significant positive correlation (r=0.62; $p<0.05$) with this trait under normal condition in *kharif* (Table 23). Root surface area under water stress condition in off-season was found positively correlated (r=0.46; $p<0.1$) with this trait under normal condition in *kharif*. Thus, phenotyping of advance breeding lines for root traits in cut cylinder PVC pipes under water stress condition can be performed both in *kharif* and off-season using δT (^{0}C), root dry weight and root surface area.

Table 23. Correlation of root traits under terminal water stress and irrigated conditions in *Kharif* and in off season under cut-cylinder pipes method.

	Kh Root Dry Wt.	Off WS Root Surface Area	Kh Root Surface area
Off WS Root dry weight	0.62*	0.87**	0.40
Kh Root Dry Wt.		0.63*	0.88**
Off WS Root Surface Area			0.46 a

a, *, ** Significant at p< 0.1, 0.05, 0.01; d.f. (n-2) = 12

2.1.8.5. Useful variability of KI-induced terminal drought tolerance in F_4 generation RILs 107(JS 97-52 x NRC 37):

Evaluation of 122 recombinant inbred lines of a F_4 generation cross 107(JS 97-52 x NRC 37) along with drought tolerant variety JS 97-52 and susceptible variety NRC 37 as parents under chemical desiccant treatment Potassium iodide (KI) 4.0 percent spray and untreated control was carried out in *kharif*-2014. KI simulates tolerance response of a plant under water-stress condition in *Kharif* season by disrupting the photosynthetic assembly of plant and remobilizing stem carbohydrate during the formation of seeds. The response of chemical treatment was recorded on 100-seed weight (Table 24). Drought tolerance of JS 97-52 was expressed in terms of less (27.7%) decrease in 100-seed weight under treatment over control, as compared to NRC 37 (28.9%).Coefficient of variation (CV) for this trait under KI treatment was high (24.3%) as compared to control (20.9%). The mean decrease in 100 seed weight in treated population was 35.3 percent over control and reflected in high range (3.1 – 70.6) and high CV (41.8%) for further exploitation.

Table 24. Variability for 100 seed weight in treated and untreated RILs (JS 97-52 x NRC 37)

107(JS 97-52 x NRC 37)	100 seed wt. KI -	100 seed wt. KI +	Decrease (%)
Mean+SE	9.0 + 0.2	5.7 + 0.1	35.3 + 1.3
Range	5.3 - 13.9	3.2 - 11.4	3.1 - 70.6
CV (%)	20.9	24.3	41.8
JS 97-52 (gm)	9.4	6.8	27.7
NRDC 37 (gm)	9.7	6.9	28.9

These two traits had high significant positive correlation (r = 0.440; $p < 0.01$ and a regression line for these traits reflects a gradient of predictable 0.325gm increase in 100 seed weight under treatment KI (+) over 1gm increase under control KI (-) (Fig. 14). The intercept value is outside the range of the data.

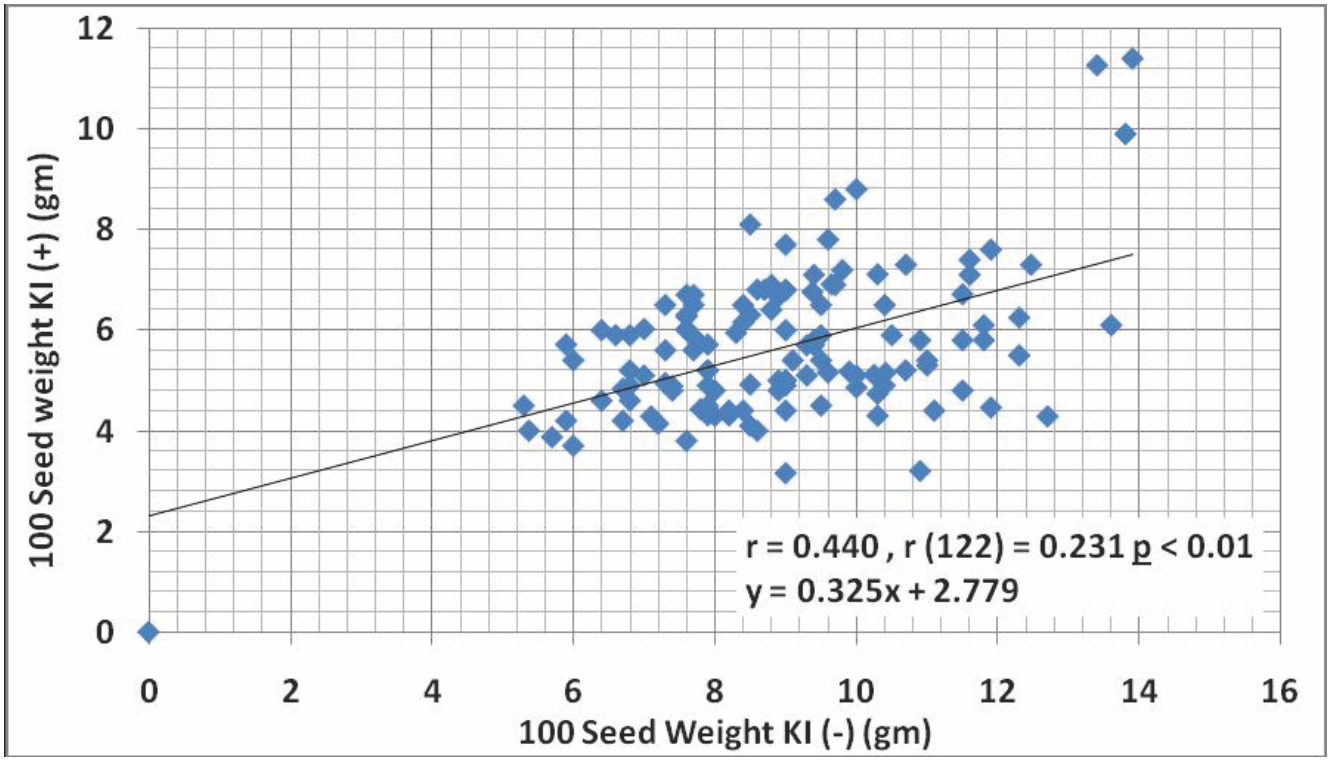


Fig.14: The scatter plot with regression line for 100 seed weight of treated population (KI +) over control (KI-).

2.1.8.6. Development of RILs in F4 and F5 generation

The lines were grown to advance the generations of four crosses in F_4 and three in F_5. Germination of some lines in different crosses was affected in *kharif* 2014 due to late arrival of monsoon and consequent late sowing (Table 25).

Table 25. RILs development in F4 and F5 generations

Generation		Code	Cross	Lines
F4	1.	107	JS 97 52 x NRC 37	200
	2.	58/60	JS 335 x C-2797	109
	3.	70	JS 71 05 x C-2797	62
	4.	110	EC546882 x JS 335	54
F5	1.	63/66	JS 335 x Young	66
	2.	68	NRC 7 x Jackson	24 (under enhancement)
	3.	46/76	JS 95 60 x Young	28 (under enhancement)

2.1.9. Breeding for water logging tolerance in soybean

2.1.9.1. Hybridization program:

Based on previous year's performances, seven genotypes *viz.,* JS 20-38, JS 97-52, JS 335, JS 90-41, JS 95-60 and Cat 3299 were used as parents to make crosses in all possible combinations with following successful crosses: JS 335 X JS 97-52; JS 335 X JS 20-38; JS 20-38 X JS 90-41; JS 20-38 X JS 95-60; JS 20-38 X Cat 3299. Hybridity was checked for last year's crosses as given in Table 26.

Table 26: Hybridity confirmation for different cross combinations

S.No.	Cross combinations	No of plants germinated	No of hybrid plants
1.	JS 88-66 X JS 335	6	6
2.	JS 97-52 X JS 88-66	6	4
3.	JS 90-41 X JS 95-60	2	2
4.	JS 88-66 X JS 95-60	4	4
5.	JS 335 X JS 97-52	6	6
6.	JS 88-66 X JS 97-52	1	1
7.	JS 97-52 X JS 95-60	7	7
8.	JS 97-52 X JS 335	14	14
9.	PK 472 X JS 335	2	2
10.	PK 472 X JS 97-52	3	3
11.	PK 472 X JS 90-41	1	1
12.	PK 472 X JS 95-60	2	2
13.	PK 472 X JS 88-66	4	4
14.	JS 335 X PK 472	1	1

2.1.9.2. Screening:

The genotypes showing distinctness were evaluated for their root characters during off season. Out of those evaluated under field conditions, ten genotypes *viz.,* NRC 7, JS 95-60, JS 97-52, JS 20-38, JS 335, JS 90-41, NRC 37, PK 472, JS 88-66 and JS 93-05 were sown in pots water logging treatment was given at germination (for 24 hrs), V1 and V2 stage (upto survival). Observations on root characters were recorded including time taken for specialized roots formation, anatomical study of specialized roots and normal roots and root porosity measurement for survived genotypes as given by Raskin (1983) and modified by Visser and Bogemann (2003).

There was impact of water logging stress on germination as very sensitive genotypes *viz.,* NRC 7 and JS 95-60 failed to germinate. The survival ability of genotypes could be correlated directly to their ability to produce adventitious roots and it was found that more early they were able to produce adventitious roots, more was their survival probability. As shown it Table 27, first rank was given to JS 97-52 and JS 20-38 as they were able to produce adventitious roots within one day of water logging.

Table 27: Adventitious root emergence and survival

S.No.	Genotype	Adventitious root emergence	Survival	Rank
1.	NRC 7	Nil (died in 3 days)	NIL	
2.	JS 95-60	4 days	1/3	
3.	JS 97-52	1 day	All 3	I
4.	JS 90-41	3 days	All 3	III
5.	PK 472	2 days	All 3	II
6.	NRC 37	3 days	2/3	III
7.	JS 335	3 days	All 3	III
8.	JS 20-38	1 day	All 3	I
9.	JS 88-66	4 days	NIL	
10.	JS 93-05	4 days	1/3	

Root porosity is the amount of air spaces formed in roots in response to water logging conditions. It is percentage of porous tissue out of total root biomass. Out of the survived genotypes JS 20-38 ranked first with a root porosity of 44% followed by JS 97-52 (40%) and PK 472 (33%) (Table 28).

Table 28: Root porosity of the survived genotypes (%)

Genotype	Control	Treatment	Rank
JS 95-60	7	19	
JS 97-52	16	40	II
PK 472	10	33	III
NRC 37	8	31	
JS 335	7	28	
JS 20-38	3	44	I
JS 93-05	9	18	

In this study, it was also confirmed that the adventitious roots formed were aerenchymatous in nature (Fig 15). The intensity of aerenchyma corresponded with the tolerance of the genotype towards water logging. Based on anatomical studies, JS 20-38 was again found to have conspicuous and severe aerenchyma with 100% survival rate followed by JS 97-52 (100%), PK 472 (100%) and JS 335 (100%).

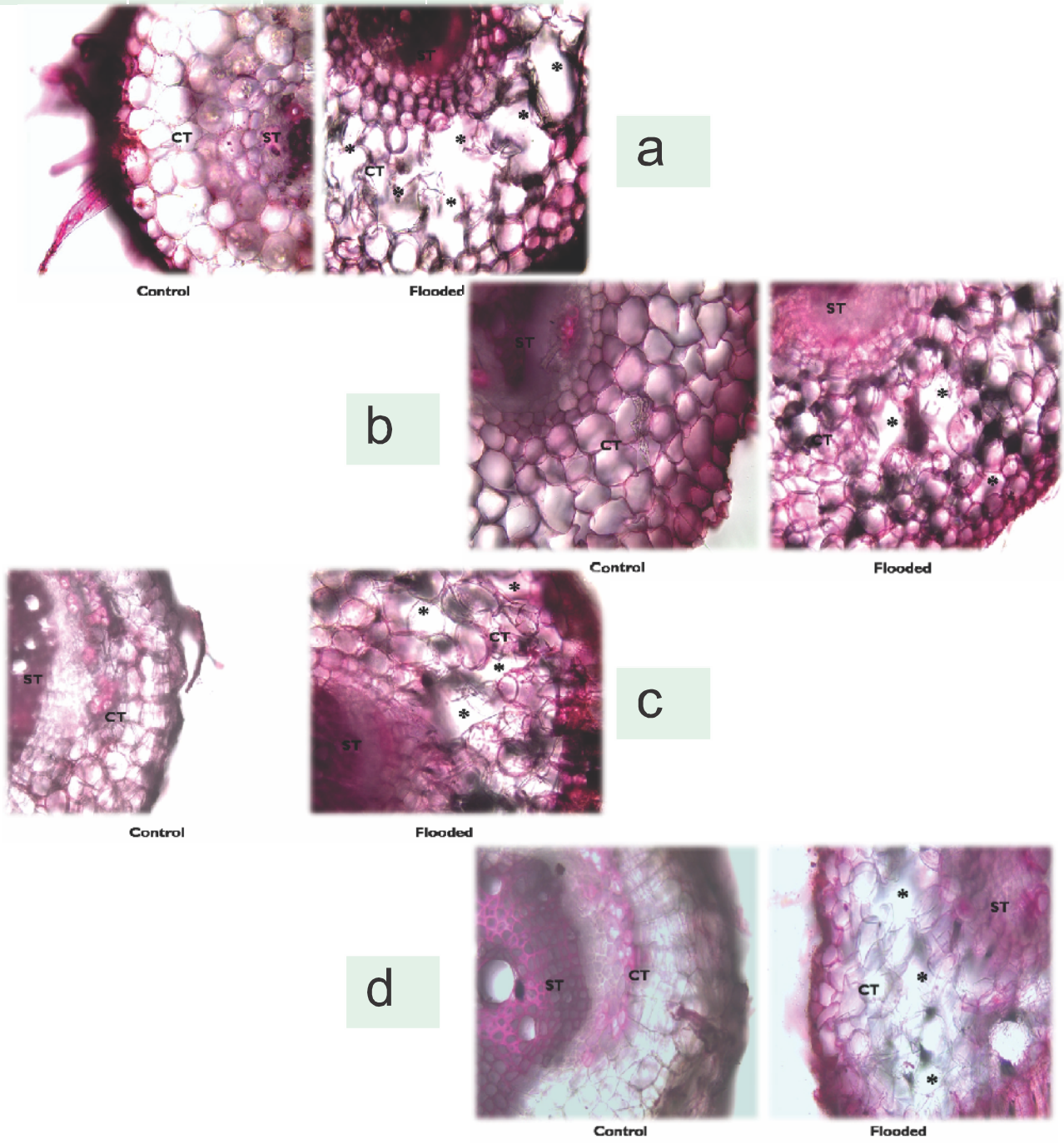


Fig 15. Root TS showing difference between normal and aerenchymatous roots: (a) JS 20-38, (b) JS 97-52, (c) PK 472, (d) JS 335 (ST, stele; CT, cortex; asterisks, aerenchyma)

Field screening of twenty more genotypes was done in *Kharif* 2014 under control and treatment plots with two replications each. JS 97-52 was used as check. Data on plant height, dry weight, number of pods, grain yield and 100-seed weight has shown that JS 20-38, JS 335, Hardee, PK 472 and Kalitur have performed well in field conditions as well. Whereas JS 95-60 and JS 20-29 were found to be most sensitive to water logged conditions (Fig 16).

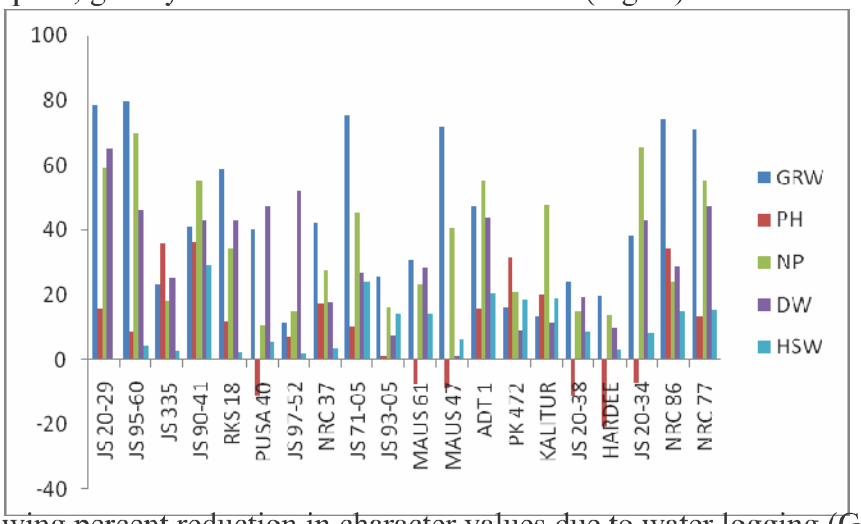


Fig.16: Graph showing percent reduction in character values due to water logging (GRW-grain weight, PH-plant height, NP- no. of pods, DW-dry weight, HSW- hundred seed weight)

2.1.10. Evaluation of soybean genotypes for increased nitrogen fixation efficiency and development of mapping population

2.1.10.1. Screening for high nodulation and yield:

Forty popular varieties of soybean were screened for their nodulation and yield characters along with root and shoot nitrogen content (Table 29). There was a positive correlation of nodule dry weight with number of nodules, grain yield and total shoot and root nitrogen content. On the basis of yield, the varieties were differentiated into high yielding, intermediate and low yielding and their correlation with shoot and root nitrogen content was carried out separately (Table 30). The results reveal that for high yielding and intermediate genotypes, the correlation of grain yield with shoot nitrogen was positive and with root nitrogen content was negative whereas for low yielding the correlation of grain yield was positive with root nitrogen but negative with shoot nitrogen content. This directs that genotypes with high grain yield had high efficiency of nitrogen translocation from root to seeds, whereas low yielding genotypes were failed to translocate the root nitrogen efficiently to shoot and seed respectively.

Table 29: List of varieties evaluated for their nodulation and yield characters along with root and shoot nitrogen content

S.No.	Variety	S.No.	Variety	S.No.	Variety	S.No.	Variety
1.	ADT 1	2.	JS 335	3.	JS 2	4.	Punjab 1
5.	NRC 37	6.	MAUS 47	7.	Birsa Soy 1	8.	Shilajit
9.	MACS 58	10.	MAUS 158	11.	Co soy 3	12.	VLS 21
13.	NRC 86	14.	Palam Soya	15.	Hara Soya	16.	JS 75-46
17.	NRC 77	18.	PS 1225	19.	PS 1029	20.	JS 79-81
21.	JS 93-05	22.	RKS 18	23.	Gaurav	24.	JS 80-21
25.	JS 97-52	26.	VLS 65	27.	Guj Soy 1	28.	JS 76-205
29.	JS 95-60	30.	RVS 2001-4	31.	JS 71-05	32.	TAMS 38
33.	JS 20-29	34.	Hardee	35.	MACS 13	36.	Monetta
37.	JS 20-34	38.	Co-1	39.	MACS 57	40.	MACS 124

Table 30: Classification of genotypes based on their yield performances

Class	Genotypes
High Yielding	NRC 77, NRC 86, Hardee, JS 97-52, Guj-Soy-1, ADT 1, NRC 37, MACS 124, TAMS 38, JS 79-81, JS 20-29, JS 20-34, Shilajit, JS 335, JS 95-60
Intermediate	JS 71-05, MACS 58, MACS 57, RVS 2001-4, Monetta, RKS 18, PS 1225, Hara Soya, MACS 13, Punjab 1
Low Yielding	PS 1029, Co Soy 3, Co-1, JS 93-05, JS 80-21, JS 75-46, VLS 65, JS 76-205, JS 2, VLS 21, Palam Soya, Gaurav, MAUS 158, Birsa Soy 1, MAUS 47

2.1.11. Development of Multiparent Advanced Generation Intercross (MAGIC) Population in Soybean

The 2 way intercross hybrid seeds from crosses EC572109 x JS9560, EC572136 x JS335, EC546882 x NRC37 and EC333901 x NRC86 were confirmed for their hybridity through morphological markers. The hybridity test identified only 2-3 % of the plants found selfed which indicated high success rate of non emasculated method of hybridization (>60%). The confirmed hybrid plants were further used in hybridization program to generate 4 way intercross hybrids. The developed 4 way intercrossed hybrids namely, [EC546882 x NRC37] X [EC572136 x JS335], [EC546882 x NRC37] X [EC333901 x NRC86], [EC546882 x NRC37] X [EC572109 x JS9560], [EC333901 x NRC86] X [EC572136 x JS335], [EC572109 x JS9560] X [EC572136 x JS335] and [EC572109 x JS9560] X [EC333901 x NRC86] will be used in generating 15 combinations of 8 way intercross hybrids. To develop BC_1F_1 backcross population three inter-specific hybrids were used to backcross with their respective three recurrent parents (JS9560, NRC86 and NRC37). The harvested BC_1F_1 seeds will be further used in backcrossing to recover the genomes of the recurrent parents. The details of the hybridization programme carried out during *Kharif* 2014 are presented in the Table 31. Further, the harvested F_2 seeds from single crosses namely, EC546882 x NRC37, EC572136 x JS335, EC333901 x NRC86 and EC572109 x JS9560 will be advanced in the subsequent generation and harvested F_2 seeds from three inter-specific crosses namely, JS9560 x G. *soja,* NRC86 x G. *soja* and NRC37 x G. *soja* will be used in further genetic analysis.

Table 31. Summary of hybridization success in the development of 4 way intercross F_1 hybrids and inter-specific backcross populations

S.No.	4 way intercross F1 hybrid combinations /Inter-specific backcrosses#	No. of pollinations	No. of pods	No. of seeds	Success Ratio (%)
1	[EC546882 x NRC37] X [EC572136 x JS335]	71	39	58	54.93
2	[EC546882x NRC37] X [EC333901 x NRC86]	105	64	105	60.95
3	[EC546882x NRC37] X [EC572109 x JS9560]	84	49	76	58.33
4	[EC333901x NRC86] X [EC572136 x JS335]	138	75	135	54.34
5	[EC572109 x JS9560] X [EC572136 x JS335]	48	31	52	64.58
6	[EC572109x JS9560] X [EC333901 x NRC86]	263	145	211	55.13
7	JS9560 X [JS9560 x *G. soja*]#	155	106	223	68.38
8	NRC86 X [NRC86 x *G. soja*]#	88	45	81	51.13
9	NRC37 X [NRC37 x *G. soja*]#	40	16	20	40.00
	Total	992	570	961	57.46

2.1.12. Genome diversity of soybean-infecting *Begomoviruses* in the major soybean cultivating areas in India and RNAi mediated viral gene silencing of Yellow mosaic virus (YMV)

Small non coding RNAs (ncRNAs) are gaining importance in the context of RNA mediated gene regulation in plants and animals. Genome sequence of *Mungbean yellow mosaic India virus* infecting soybean (KC852204 and KP828155) in the central Indian region were employed for predicting potent siRNA generating capability. Complete nucleotide sequences of MYMIV DNA A and DNA B genomic components were subjected to *in silico* analysis using the tools like CLUSTAL W, Vienna packages and web based algorithms for prediction/obtaining potent target region in the viral genome. Multiple sequence alignment studies on rep gene and AC2 ORF identified a stretch of conserved nucleotide sequences present in both the species MYMIV and MYMV of genus *Begomovirus*. Potent siRNA generating capability of the conserved rep gene sequence was identified using web based algorithms like siRNA at whitehead, Jack Lin's siRNA Sequence Finder and the DEQOR etc. The potent target viral region were identified and selected for the generation of an appropriate small ncRNAs (siRNAs) targeting the transcript of rep gene based on their silencing potential and RNA duplex free energy values.

A target region of 187 bp neg gene with appropriate restriction enzyme sites in the primers (forward primer with sites *Nco* I and *Xba* I and Reverse primers with sites *Bam* HI and *Asc* I) was amplified. The amplicon was cloned in pGEM-T easy vector and confirmed via sequenced. The cloned fragment was restricted with *Nco* I and *Asc* I to obtain the sense portion of the construct similarly to generate antisense orientation of the construct restriction by *Bam* H I and *Xba* I was performed. Both the restriction fragments were cloned in a generic RNAi vector pFGC5941 sequentially to develop RNAi inducing inverted repeats gene constructs. Finally *Agro bacterium tumefaciens* strain LBA 4404 was transformed with the intron spliced hairpin RNA (ihpRNA) binary vector. Thus sncRNA generating plasmid system targeting the gene expression of Yellow mosaic virus infection in soybean was developed. The vector system is a binary plasmid hence suitable for plant transformation (Fig.17.)

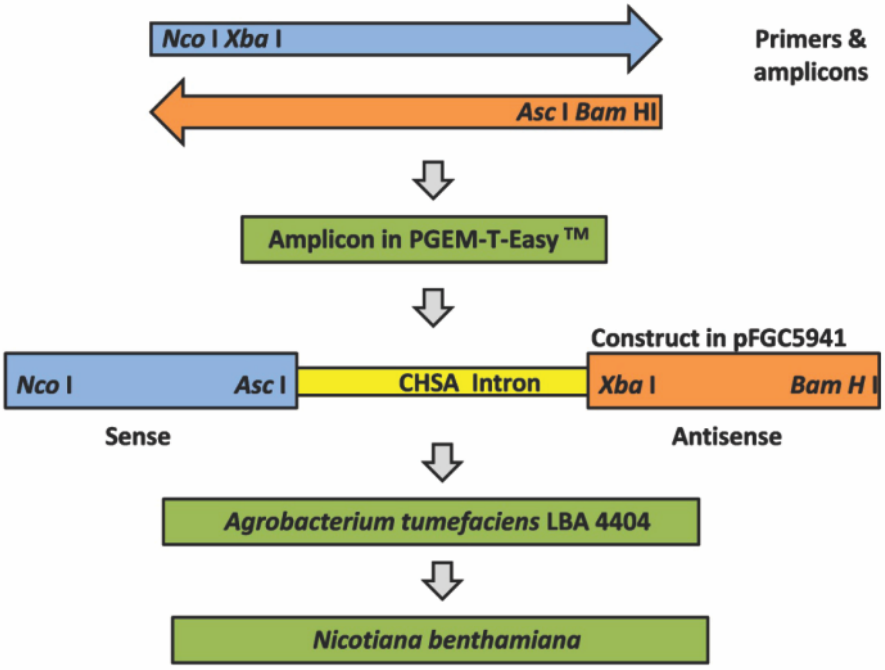


Fig.17: Scheme depicting engineering hairpin (hpRNA) mediated antiviral resistance in soybean targeting replication initiator protein gene of Mungbean yellow mosaic India virus-sb (MYMIV-sb)

2.1.13. Validation of yield QTLs for marker assisted breeding:

2.1.13.1. Phenotyping of advanced backcross population BC_2F_2

An advanced backcross population BC_2F_2 developed from wild species *Glycine soja* and JS335 (as recurrent parent) was shown in augmented design. Phenotyping data for number of pods and seed yield/plant were recorded. The number of pods in BC_2F_2 families ranged from 31 to 113 whereas the seed yield/plant ranged from 2.7 to 17.8 gm indicating wide genetic variability among families (Fig. 18 and table 32). The population has been shown in summer 2015 for further advancement to BC_2F_4 and genotyping with SSR markers is under progress.

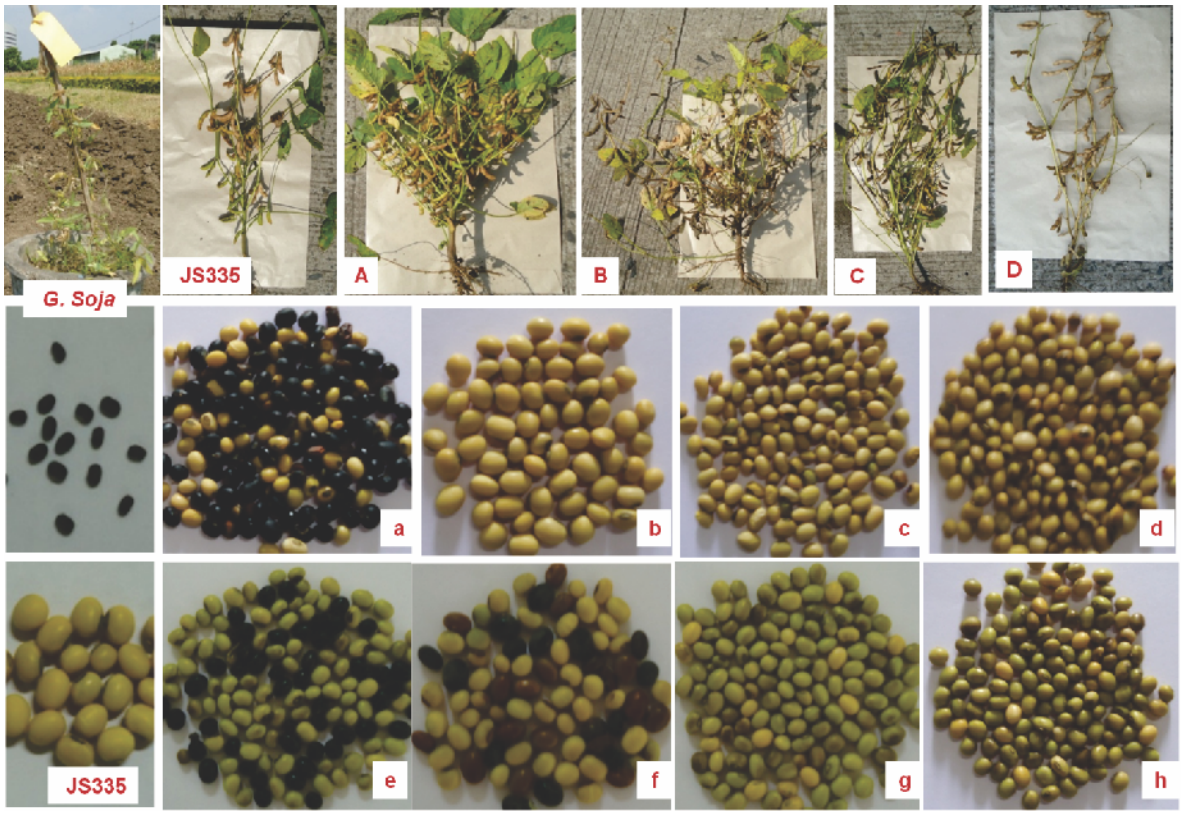


Fig.18: Phenotypic comparisons between the donor parent, recurrent parent and BC_2F_2 Families

Table 32: Phenotypic performance of BC_2F_2 families

	Number of pods/plant	Seed yield /plant (gm)
1. JS335	62.0	15.0
2. BC2F2		
Maximum	113.3	17.8
Minimum	31.7	2.7
Mean	59.26	9.67
Std. Deviation	14.88	3.45

2.1.14. Studies on impact of field weathering on soybean seed quality and its management.

Three varieties namely JS9560, NRC 7 and JS9305 were grown to study the field weathering and its impact on seed quality. Four different time points were taken *viz*., physiological maturity, harvest maturity, 10 days from harvest maturity and 15 days from harvest maturity. Response to field weathering varied widely with

the soybean variety.

Differential seed germination response was also observed. Germination percentage of seed at physiological maturity was 78% for JS 93-05, 70% for JS 95-60 and 57% for NRC 7. 3-5% loss in germination was recorded between seeds harvested at physiological maturity and at harvest maturity. 7 to 30% loss in germination occurred when seeds were harvested at 10 days delay from harvest maturity and for 15 days delay the loss of germination 10-42%. Highest loss in germination percentage was observed with cultivar NRC 7 followed by JS 95-60 and JS 93-05. Therefore, it was evident that varietal difference was there for sensitivity to field weathering.

2.1.14. 1. Storability of field weathered seeds:

Storage potential of seeds were highly influenced by delay in harvesting i.e. field weathering. 24-54% germination loss was observed for physiologically matured seeds after 6 months of storage as compared to 13-33% for harvest matured seeds, 14-59% for 10 days delayed harvested seeds and 20-100% for 15 days delayed harvested seeds during *Kharif* 2013-14.

Seedling vigour was evaluated for all different harvest date of seed samples. Physiologically matured seed had highest seedling vigour among all the harvesting dates and the range was (1352-2250) maximum vigour was with variety JS9305 and minimum with NRC7. There was slight reduction in seedling vigour was observed from physiological maturity to harvest maturity. Significantly lowest seedling vigour (210-1700) was found with the sample of 15 days delay harvest from harvest maturity.

Table. 33. Electrical conductivity of seed leachate of different harvest dates of soybean seeds during storage

Variety	Electrical Conductivity (µsiemen/cm/g/seed)							
	Physio. Maturity		Harvest Maturity		10 days delay in HM		15 days delay in HM	
	Initial	Six month	Initial	Six month	Initial	Six month	Initial	Six month
JS 9305	0.375	0.938	0.404	0.817	0.463	1.578	0.462	1.784
JS 9560	0.474	1.278	0.527	0.904	0.602	1.675	0.735	1.997
NRC 7	1.233	2.015	0.930	1.989	1.095	2.421	0.988	2.981

Initial electrical conductivity of variety varied from 3.75to 1.233 µSiemens/cm/g seed. Lower electrical conductivity signifies the higher value of seed. After six month of storage the electrical conductivity was increased from 0.938 to2.015µSiemens/cm/g seed of physiological matured seeds. In harvest matured seeds after six month of storage the electrical conductivity increased from initial but it was lower than the physiological matured stored seed. This result may be due to high moisture in physiological matured seed which reduced moisture suddenly after harvest. Field weather seed showed highest deterioration in terms of membrane degradation as indicated in the table 33 with higher electrical conductivity value.

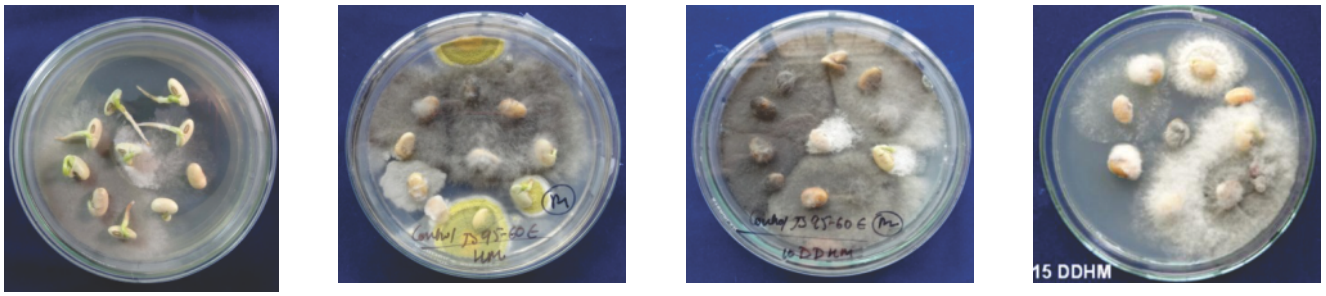
Table 34. Lipid peroxidation of the seeds of different harvest dates during storage

Variety	MDA Content (nM/g seed)							
	Physio. Maturity		Harvest Maturity		10delay HM		15days delay HM	
	Initial	Six month	Initial	Six month	Initial	Six month	Initial	Six month
JS 9305	46.549	99.55	49.698	90.08	59.40	115.44	72.25	178.21
JS 9560	83.861	187.94	80.65	167.64	113.31	229.59	105.88	199.14
NRC 7	94.48	196.74	90.45	172.12	115.52	178.81	120.15	248.48

The extent of seed deterioration is regulated by the accumulation of oxyradical along with the degree of field weathering. Field weathering inexorably weakens the antioxidant defense mechanism of seeds and leads to rapid deterioration. Malondialdehyde (MDA), product of lipid peroxidation is the indicator of biochemical degradation of phospholipids of cell membrane and unit membrane of cell macromolecules. Higher the MDA content higher is the degree of seed deterioration. Irrespective of vatieties it was found that after storage of six month the field weathered seed produced maximum Malondialdehye content ranged from (178.21to 248.48 nM/g seed) which indicates the extent of seed deterioration (Table 34).

Initial seed germination test after harvest reveals high number of dead seed in the field weathered seed and the variety which got rain at harvest maturity time. Seed health test report found that the seed which get rains during its maturity and the sample which was subjected for field weathering for 10-15 days were highly infected with mycofloral fungi especially *Fusarium sp.* and *Macrophomina sp*. and *Cerospora kikuchi* in all the sample studied. was found that the seed which was harvested at physiological maturity had lowest intensity (8-10%) of pathogen infection. Variety JS 9560 seeds were highly infected with (65-70%) on harvests mature seed as well as delayed maturity (Fig 19 a). Highly infected seeds were mostly the dead seed JS 9305 variety was less infected as compared to JS 9560 irrespective of pathogens and its intensity In variety JS 9305 and NRC7 in harvest matured seed lot infection of *Fusarium* was increased upto 35-40 % of seeds. But JS9560 seeds were maximum upto 70 % seeds were infected with fungal pathogens (Fig. 19.b and c)

Fig.19a. Infestation of mycoflora on seeds of variety JS 95-60 on harvest and delayed maturity



JS 9560 PM **JS9560 HM** **JS9560 10 DD HM** **15 DDHM**

Fig. 19b. Infestation of mycoflora on seeds of variety NRC 7 from due to delayed harvesting

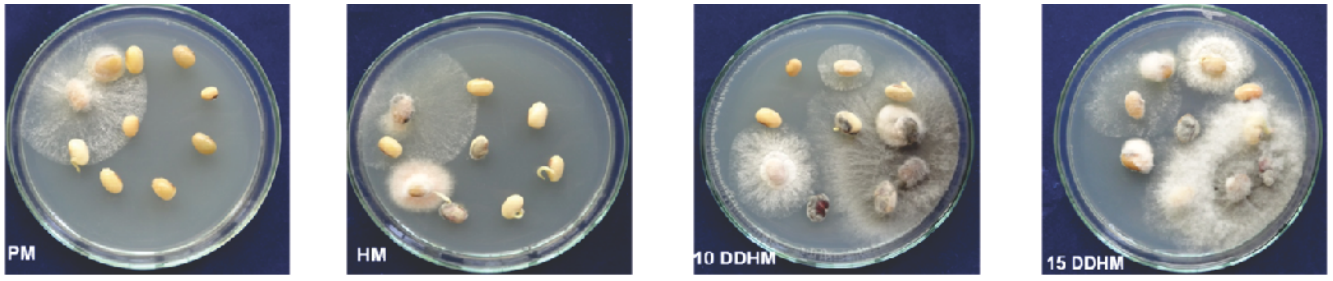
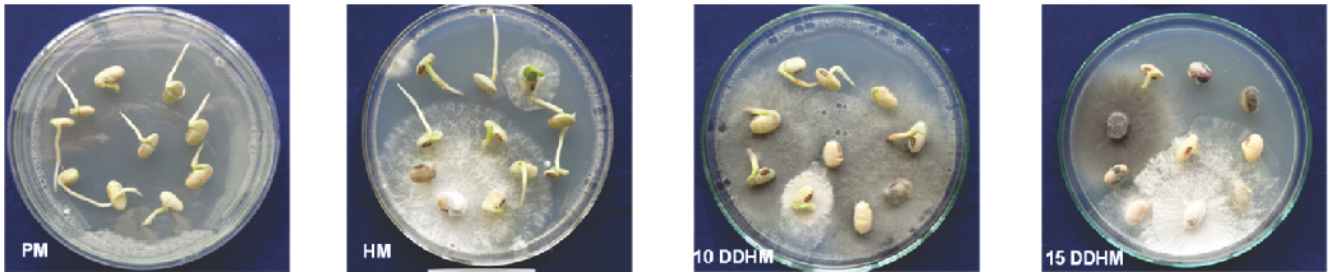
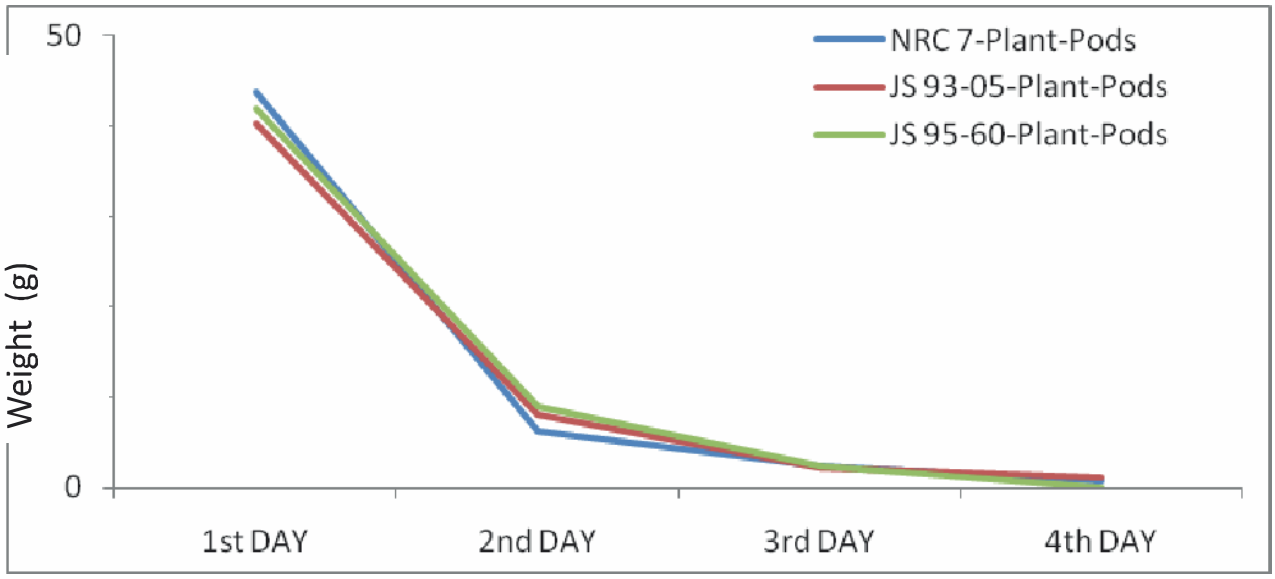


Fig. 19 c. Infestation of mycoflora on seeds of variety JS 93-05 due to delayed harvesting



PM: Physiological Maturity, HM: Harvest maturity, DDHM: Days delay from harvest maturity

Fig.20. Kinetics of artificial drying of pods attached in mother plant (pods+plant)



The practical limitation of harvesting physiologically matured seeds is high seed moisture. Drying of physiologically matured pods in hot air oven at 32-35^{0}C was done to find out rate and time of drying. The initial rate of drying was average 33% on first day, 14% on 2nd day and 3% on 3rd day. Average 4 days were required to dry seeds to safer moisture at 32-35^{0}C (Fig. 20)

2.1.14. 2.Screening of soybean varieties for sensitivity to field weathering:

Seed health test was carried out to find out the reason for number of dead seeds found in highly deteriorated seed lot due to field weathering. In most of soybean varieties, seed quality was affected resulting in less than 70% germination just after harvest of the crop. The germination pattern of soybean varieties as influenced by natural harvest rain was studied and it was found that out of 106 varieties germination of 31% varieties was above **70%**, 39% varieties between 50-**70**% and 27% varieties between 20-**50**%. Among the late and medium maturity group JS 97-52, ADT-1, CO 1, CO 3, Hara Soya, Durga, VLS 47, Punjab 1 were less affected due to harvest rain than early varieties and had more than 80% germination. The variety which got rain (JS 9560, PRS1, LSB1) during maturity deteriorated significantly high with maximum number of dead seeds due to field weathering.

2.1.15. Central Sector Scheme for Plant Variety and Farmers' Right Authority (DUS Testing)

All the released and notified soybean varieties (102 varieties) and 71 collections from farmers' field of Madhya Pradesh were maintained and characterised under this project as per Guidelines of "Distinctiveness, Uniformity and Stability Testing in Soybean" during *Kharif* 2014-15. DUS Testing was conducted for one "New Variety" for first (1st) year and one farmer's variety at DSR, Indore and UAS, Dharwad during Kharif 2014-15. Monitoring of DUS testing of the candidate variety was done on 25.08.2014 at DSR, Indore.

Certificate of Registration under PPV&FR Act-2001 has been awarded to seven soybean varieties namely Pant Soya-1092 (Registration No.359/2014), Pant Soybean-1225 (Registration No.360/2014), Pant Soybean-1347 (Registration No.361/2014), MAUS-158 (Registration No. 9/2015), MAUS-61 (Registration No. 10/2015), MAUS-81 (Registration No. 15/2015) and Pusa 97-12 (Registration No. 12/2015). Seed samples of different varieties were also sent to different AICRPS Centres and other research institutes as requested for research purposes under Material Transfer Agreement.

2.2. CROP PRODUCTION

2.2.1. Evaluation of Soybean Genotypes for Tolerance to High Temperature Conditions

2.2.1.1. Physiological responses of soybean genotypes for tolerance to high temperature

High temperature conditions are known to have an adverse effect on soybean productivity. The occurrence of high temperatures, particularly during reproductive phase is now common phenomenon in major soybean growing regions of the country. Further rise in temperature under future climate is projected which could further aggravate the conditions. Therefore, experiments were conducted with an objective to evaluate soybean genotypes for their performance under elevated temperatures. Twelve soybean genotypes were planted in four green houses. These green houses were maintained at day/night temperatures of 30/22, 34/24, 38/26 and 42/28° C with an average temperature of 26, 29, 32, and 35 °C, respectively. One set was also grown under ambient conditions. Beside physiological parameters, data on yield and its attributes was recorded at harvest. The maximum average seed yield of soybean genotypes (13.2 g/pl) was observed in plants grown under ambient temperature conditions and increase in temperature up to 30/22 (12.2 g/pl) and 34/24 °C (11.4 g/pl) did not affect the yield significantly. However, further increase in temperature had a significant negative influence on seed yield of soybean (Table 35). The seed yield declined by 51 and 65 % in plants grown at 38/26 and 42/28 °C as compared to the plants grown under ambient conditions. Among the genotypes, the average yield was significantly high in JS 97-52 (12.7 g/pl), EC 602288 (11.9 g/pl), NRC 7 (11.6 g/pl), EC 538828 (11.5 g/pl) and EC 456548 (11.4 g/pl) as compared to genotypes such as Punjab-1(6.2 g/pl) and JS 95-60 (6.3 g/pl) which gave lowest seed yield. The interaction of temperature with genotypes was significant which indicated that in response to temperature, the reduction in seed yield among genotypes varied significantly. Based on percent reduction in seed yield at different temperatures compared to ambient condition, EC 538828 and NRC 7 were found to be less sensitive to change in temperature as compared to rest of the genotypes (Fig 21). Beside reduction in other yield attributing characters, a severe reduction in number of pods was observed as the temperatures increase. However, large genotypic variation was observed in yield attributes particularly number of pods/plant.

2.2.1.2. Effect of temperature on reproductive biology

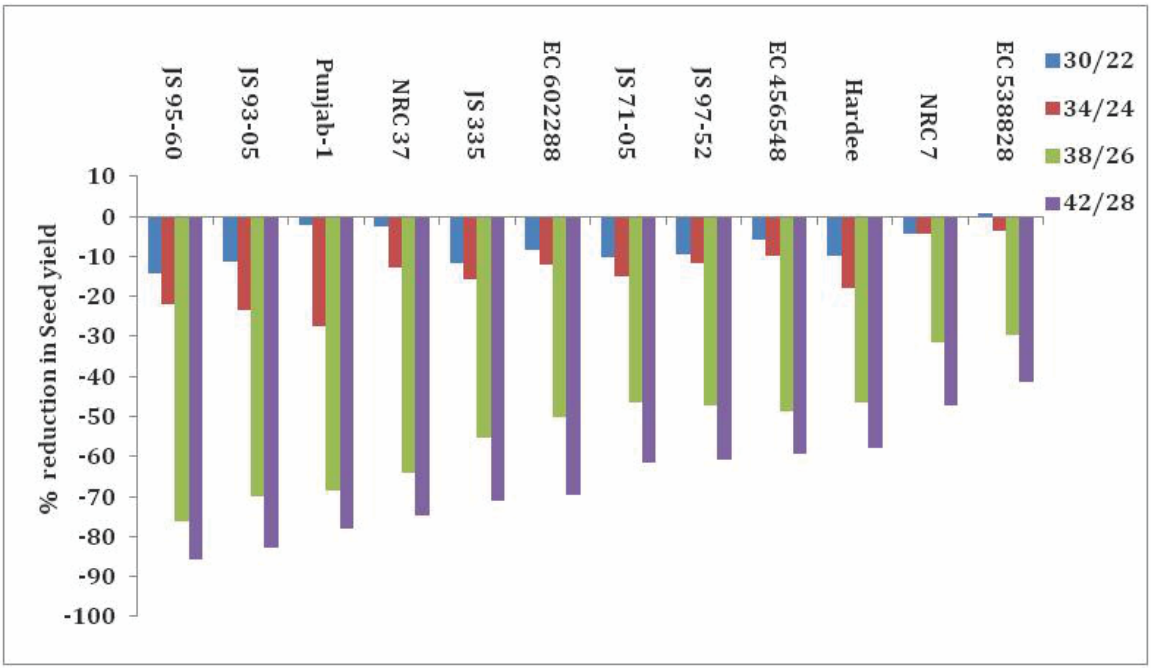
In order to understand the severe reduction in pod numbers due to high temperature condition, attempts were made to understand the impact of high temperature on reproductive biology in terms of total duration of flowering, total number of flowers and pods formed, pollen size, pollen germination, pollen tube length and reproductive efficiency (Table 35). Average duration of flowering of soybean genotypes under ambient conditions was 24 days, which was increased to 25, 28, 33, and 34 days in the plants grown at 30/22, 34/24, 38/26, and 42/28°C, respectively. The average numbers of flowers/pl was maximum (179) in plants grown at ambient temperature and was marginally reduced to 176 and 167 in plants grown at 30/22 and 34/24°C, respectively. However, reduction was more drastic in plants grown at 38/26 and 42/28 °C, with average flower numbers/pl 151 and 140, respectively. The average number of pods/pl in plants grown under ambient condition was 64 which significantly reduced to 59, 53, 40 and 33 pods/pl in plants grown at 30/22, 34/24, 38/26, and 42/28 °C, respectively. The maximum reproductive efficiency (percent of pods formed from total number of flowers) of 42% was observed in plants grown under ambient conditions. It reduced to 40% in plants grown at 30/22 °C further increase in temperature to 34/24, 38/26 and 42/28 °C resulted in significant reduction in RE to 37, 32 and 28%, respectively. Average pollen size was maximum (876.5 μm^2) at ambient

temperature and was reduced by 3, 6, 11 and 15% in the plants grown at 30/22, 34/24, 38/26, and 42/28°C, respectively. Among the temperatures, the average pollen germination was maximum (87.3%) in plants grown at ambient temperature and was significantly but marginally reduced to 82.1 and 72.2%, in the plants grown at 30/22 and 34/24 °C. However, further increase in growing temperature to 38/26, and 42/28 °C resulted in severe reduction in pollen germination with an average value of 58.7, and 48.1%, respectively. The average pollen tube length was maximum (516.8µm) at ambient temperature, which was reduced by 4, 22, 45, and 61% in the plants grown at 30/22, 34/24, 38/26, and 42/28°C, respectively. This clearly indicated that severe reduction in reproductive efficiency due mainly to reduced pollen germination, pollen size and pollen tube length at high temperature could be the main factors associated with reduced number of pods and hence, seed yield in soybean genotypes (Table 35). Large genotypic variation was observed in these characters and thus evaluation of large number of genotypes is needed which may help in identifying sources which are less sensitive to temperature for these traits. The difference observed in pollen tube size and pollen tube length in most sensitive genotype JS 95-60 grown at ambient and 42/28˚C day/night temperature are presented in Fig 22 and 23, respectively,

Table 35. Effect of temperature on average seed yield and reproductive biology of 12 soybean genotypes

Traits	Ambient	30/22˚C	34/24˚C	38/26˚C	42/28˚C
Sed yield (g/pl)	13.2	12.2	11.4	6.4	4.7
Flowering duration	24	25	28	33	34
Flowers/pl	179	176	167	151	140
Pod/pl	64	59	53	40	33
Rep efficiency	42	40	37	32	28
Pollen size	876.5	853.4	820.0	779.7	746.9
Pollen germination (%)	87.3	82.1	72.2	58.7	48.1
Pollen tube length	516.8	498.1	401.7	281.7	203.2

Fig. 21. Reduction in seed yield (%) in different soybean genotypes grown at day/night 30/22, 34/24, 38/26 and 42/28 ˚C temperatures as compared to ambient temperature conditions



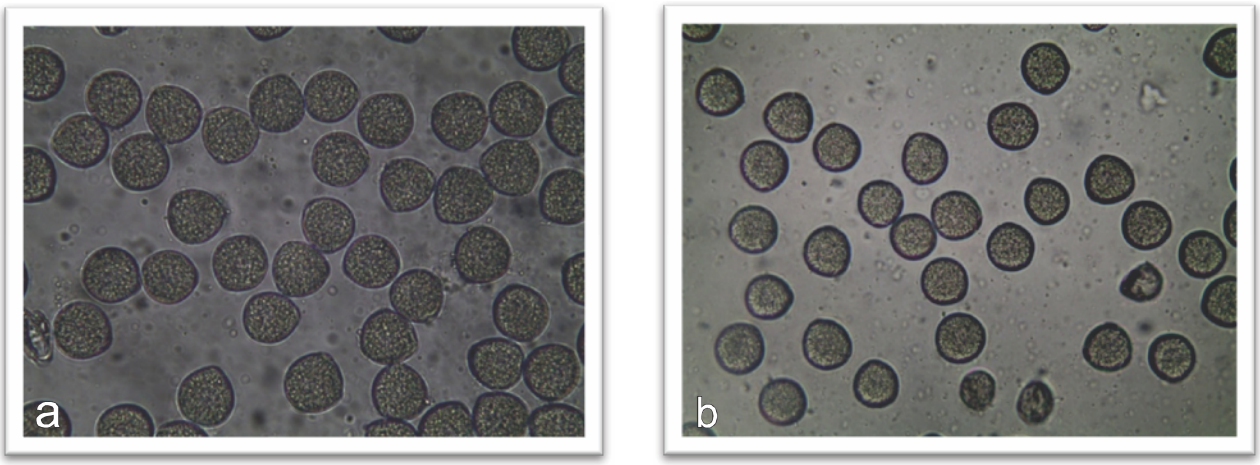


Fig.22: Difference in pollen size observed in genotype JS 95-60 grown at a) ambient temperature and b) at 42/28˚C day/night temperature

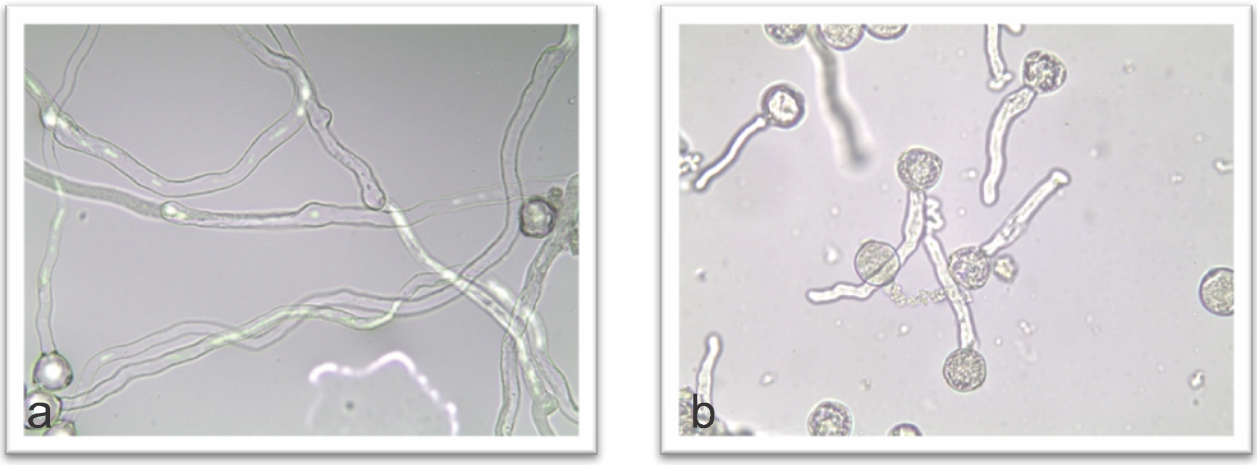


Fig.23: Difference in pollen tube length observed in genotype JS 95-60 grown at a) ambient temperature and b) at 42/28˚C day/night temperature

2.2.2. System Efficiency Enhancement through Conservation Technologies

A long term field trial (initiated during 2009) was conducted during 2014-15 involving 7 rotational tillage systems i.e. Conventional-Reduced (CR-CR-CR-CR),CR-RR-CR-RR, CR-RR-RR-CR, CR-RR-RR-RR, RR-RR-RR-RR, SRR(single reduced tillage) and sub soiling and 3 soybean based cropping systems [Soybean-wheat (S-W) , Soybean-chickpea (S-C) and Soybean - mustard (S-M). The project was initiated during k*harif* 2009 and the tillage treatments have to stabilize in due course of time for actual assessment of tillage impact on system productivity. The sixth year results revealed that the highest soybean yield was recorded under single cultivator every year and remained at par with conventional tillage every after two year or every after four year and sub soiling. Conventional tillage carried out every year and alternate year behaved identically. A similar trend was also noted in soybean equivalent yield, net returns, B:C ratio and energy parameters. This year chickpea crop was failed due to abnormal weather conditions. Soybean yield remained unaffected due to cropping system, however, marginally higher yield was recorded when chickpea was grown in *rabi* season. The highest productivity was associated with wheat and followed by mustard. Soybean –wheat cropping system was found to be the most productive, remunerative and energy efficient than soybean-mustard and soybean- chickpea cropping system.

2.2.3. Online Data Management System for AICRPS Agronomy Trial Data

An on-line data management system for AICRPS Agronomy trial has been developed. It provides user-friendly interface for multi-location data entry, analysis and summary table report generation. It facilitates statistical analysis for calculation of SeM and CD for main factors and their interactions. The system supports four types of plot designs-RBD, Split plot, Strip Plot and factorial design. It has separate modules for management of users having different authorizations-administrator and data entry operator. It also provides on-line registration form for new-users.

A web-based Data Management System for AICRPS Plant Breeding trial is also developed. It provides user-friendly interface for on-line data entry, statistical analysis, multiyear pooled analysis and summary table report generation. The authorized users use this system from different locations across India. An on-line Pedigree Data Management system for Soybean varietal crossing data is also developed. It facilitates an efficient system for easy maintenance and rapid retrieval of varietal crossing data of different breeding research programme.

2.2.4. Growth, Rhizosphere Properties, P Acquisition and Mobilization of Intercropped Soybean and Maize in Soil Amended With Phosphate

2.2.4.1. Co-inoculation of *B. aryabhattai* (MDSR14) and AM fungi on P mobilization

Co-inoculation of *B. aryabhattai* (MDSR14) and AM fungi significantly increased dry matter accumulation (root and shoot) in intercrop soybean and maize. Nodule number and dry weight was also increased in intercrop soybean as a result of co-inoculation. Co-inoculation of *B. aryabhattai* (MDSR14) and AM fungi also improved rhizosphere properties pertaining to phosphorus availability such as acid and alkaline phosphatase and microbial biomass P and decreased rhizosphere pH in intercrop soybean and maize as compared to sole cropping (Table 36-37).

Highest soybean and maize yield and phosphorus uptake was also registered with Co-inoculation of *B. aryabhattai* (MDSR14) and AM fungi. Co-inoculation of B. aryabhattai (MDSR14) (Table 38). Co-inoculation of *B. aryabhattai* MDSR14 (JF792521) and AM fungi significantly increased dry matter accumulation, seed yield and Phosphorus use efficiencies in intercrop soybean and maize. Co-inoculation of B. aryabhattai and AM fungi also improved rhizosphere properties in intercrop soybean and maize as compared to sole cropping.

There was concomitant depletion in native organic P ($NaHCO_3$-Po and NaOH-Po) and acid extractable–P (HCl-P) and increase in inorganic P ($NaHCO_3$-Pi and NaOH-Pi) in rhizosphere soil with co-inoculation of *B. aryabhattai* (MDSR14) and AM fungi indicating their role in mobilization of native unavailable organic P and inorganic insoluble-P pool of soil to available P.

Table 36. Co-inoculation of *Bacillus aryabhattai* and AM fungi on changes in rhizosphere pH and microbial biomass-phosphorus under soybean/maize cropping system

Treatments	Sole soybean	Intercrop soybean	Sole maize	Intercrop maize
Rhizosphere pH				
100%P	7.82	7.80	7.84	7.79
75% P	7.88	7.85	7.84	7.82
75% P + Bacillus aryabhattai	7.72	7.65	7.72	7.65
75% P +AM fungi	7.80	7.75	7.75	7.70
75% P+ Bacillus aryabhattai+ AM	7.66	7.65	7.61	7.60

LSD(P=0.05)	Treatments:0.06,Cropping system(CS):0.04, PXCS:0.11		Treatments:0.06,Cropping system(CS):0.05, PXCS:0.11	
Microbial biomass-Phosphorus (mg P kg-1)				
100%P	22.5	23.9	30.6	31.2
75% P	18.9	19.5	28.5	30.1
75% P + Bacillus aryabhattai	24.5	26.8	33.8	35.6
75% P +AM fungi	20.7	24.2	31.2	33.8
75% P+ Bacillus aryabhattai+ AM	27.2	29.5	35.9	39.2
LSD(P=0.05	Treatments:3.2,Cropping system(CS):1.9, TXCS:5.1		Treatments:3.5,Cropping system(CS):2.2, TXCS:5.8	

Table 37. Co-inoculation of *Bacillus aryabhattai* and AM fungi on changes in acid and alkaline phosphatase activity (µg p-nitrophenol g^{-1} soil h^{-1}) under soybean/maize cropping system

Treatments	Sole soybean	Intercrop soybean	Sole maize	Intercrop maize
Acid phosphatase				
100%P	222	230	231	242
75% P	228	244	244	249
75% P + Bacillus aryabhattai	249	266	255	260
75% P +AM fungi	235	257	245	251
75% P+ Bacillus aryabhattai+ AM	256	274	260	267
LSD(P=0.05)	Treatments:10,Cropping system(CS):9, TXCS:20		Treatments:14,Cropping system(CS):10, TXCS:22	
Alkaline phosphatase				
100%P	492	512	510	527
75% P	525	545	528	542
75% P + Bacillus aryabhattai	575	595	583	605
75% P +AM fungi	538	566	555	578
75% P+ Bacillus aryabhattai+ AM	592	605	599	620
LSD(P=0.05	Treatments:22,Cropping system(CS):11, TXCS:29		Treatments:22,Cropping system(CS):12, TXCS:32	

Table 38. Co-inoculation of *Bacillus aryabhattai* and AM fungi on changes in seed yield and phosphorus uptake under soybean/maize cropping system

Treatments	Sole soybean	Intercrop soybean	Sole maize	Intercrop maize
Seed yield (kg/ha)				
100%P	2674	2780	9320	9560

75% P	2540	2668	9150	9395
75% P + Bacillus aryabhattai	2711	2859	9600	9950
75% P +AM fungi	2582	2694	9410	9760
75% P+ Bacillus aryabhattai+ AM	2772	2862	9956	10540
LSD(P=0.05)	Treatments:152,Cropping system(CS):126, TXCS:270		Treatments:274,Cropping system(CS):230, TXCS:485	
Phosphorus uptake (kg/ha)				
100%P	21.45	23.65	32.69	34.56
75% P	19.56	21.45	29.85	31.69
75% P + Bacillus aryabhattai	24.26	25.96	35.69	39.12
75% P +AM fungi	20.31	22.69	32.12	33.40
75% P+ Bacillus aryabhattai+ AM	26.95	27.54	39.85	44.21
LSD(P=0.05	Treatments:2.2,Cropping system(CS):2.1, TXCS:4.2		Treatments:3.2,Cropping system(CS):2.1, TXCS:5.2	

2.2.5. Soil Microorganisms for Higher Productivity of Soybean

2.2.5.1. Soil Microorganisms for mitigating carbon and enhancing productivity of soybean

At DSR, research on plant growth promoting microbes where mass multiplication of predominant niche AM fungi are being carried out through pot cultures utilizing soybean processing mill wastes, developing root organ culture (*in vitro* method) eventually utilizing for enhancing carbon sequestration in soil, drought tolerance and improving the productivity of soybeans. The interaction and compatibility studies on AM fungi with other PGPR strains for soybean growth promotion and mineral nutrition is also being studied.

2.2.5.2. Optimization of substrates for mass production of AM fungi

Irrespective of soil management practice, *Rhizopgagus irregularis* was found to be the most predominant AM species harbouring in soybean-wheat; soybean-chickpea system. Organic soybean-wheat or soybean-chickpea plots harbouring higher AMF biomass and hence selected as substrate for mass multiplication in different soybean processing mill substrates using Sorghum and Amaranthus as hosts. Out of eight different soybean processing mill wastes tested based on having higher organic carbon (25-27%), total nitrogen (1.5 to 4.9%) and having low phosphorus (2 to 7 g/kg), only three wastes i.e., burnt DOC ash, hulls and kani (broken pieces husk) was selected for further use in AMF mass production studies. Out of three wastes selected for making amendment of potting mix with soil collected from long-term field trial soil, only two wastes viz., soybean hulls and burnt DOC ash did well in terms of providing higher shoot and root growth. However, kani waste did not support the growth of both the plants (Sorghum and *Amaranthus*) and was found to be toxic in all the mixes made with soil and sand. AMF spore count indicated that in the pots containing soybean wastes (hulls, DOC burnt ash) amended with two parts of soil-sand mix produced higher mycorrhizal spore density when compared to unamended mix with wastes (Fig. 24.)

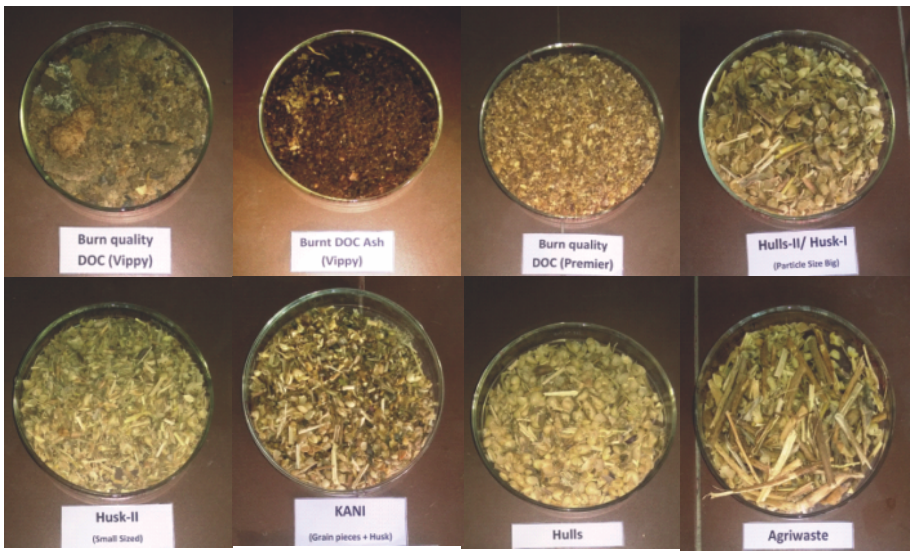


Fig.24. Soybean processing mill wastes

2.2.5.3. Carbon sequestration through AM fungi

Under DST funded programme field trials have been established consisting soybean-based cropping system in organic and inorganic soil management practices to determine the impact of AM fungi inoculation on C-sequestration through glomalin production. This AM fungus (mainly Glomalean type) produces a glycoprotein called glomalin which aids in soil carbon sequestration and improves soil quality.

2.2.5.4. Optimization of protocol for extraction and quantification of glomalin soil

Glomalin extraction was optimized by the protocol of Wright and Upadhyay (1996). Glomalin which is more appropriately known as Glomalin Related Soil Protein exists in two fractions viz., easily extractable glomalin (EEG) and total Glomalin (TG). These two fractions were extracted by adding to the soil, sodium citrate (tri sodium citrate dihydrate) of two molarities i.e., 20mM for EEG and 50mM for TG followed by autoclaving and centrifugation. For extracting easily extractable glomalin 8 ml of sodium citrate (20mM) is added to 1 g of soil followed by autoclaving of 30-60 minutes and centrifugation of 15 minutes at 10,000 rpm. For extracting total glomalin 8 ml of sodium citrate (50mM) was added to 1 g of soil followed by autoclaving of 60-90 minutes and centrifugation of 15 minutes at 10,000 rpm. In both the extractions mentioned above the cycles of autoclaving and centrifugations were repeated (nine times) till no brown color appears in the solution (Fig. 25). The supernatant of all EEG extractions are pooled and concentrated by heating on water bath. Same was done with TG extracts. These supernatants were used for analysis. The concentrated extracts were precipitated with Trichloroacetic acid and pellet was solubilized in sodium hydroxide. The quantification was done by Bradford Protein Assay and absorbance was measured at 595nm using micro-plate reader. Protein concentration was expressed in mg/g soil using Bovine Serum Albumin (BSA) as standard.

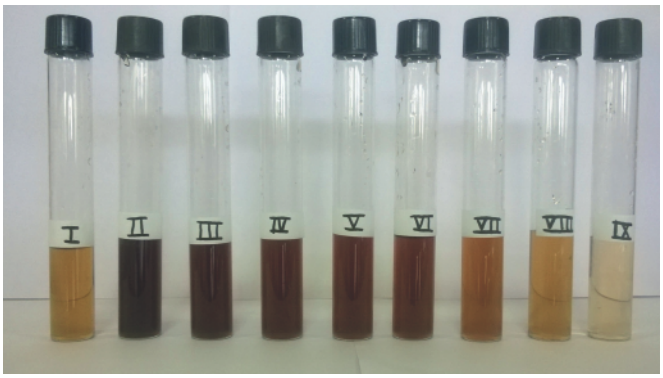


Fig. 25. Extracts obtained after repeated extracti on of glomalin in soil

2.2.5.5. Assessment of C-sequestration in AM-mediated soil and crop management practices

During last year soil carbon sequestration in terms of glomalin production and c-stocks was studied in the field growing soybean and maize individually or in intercropping system under organic and inorganic farming practices with AMF inoculation. It has been observed that AMF inoculation in the soybean-maize intercropping system under organic farming system enhanced C-stocks (12.91 Mg C $Ha^{-1}Yr^{-1}$), glomalin production (Soybean: 784.16 g/g soil and Maize: 791.59 g/g soil), organic carbon content (0.66 mg/kg) and microbial biomass carbon (341.45 mg C kg^{-1}). Glomalin was found to be positively correlated with AMF biomass. Glomalin (total) contributes to substantial amount of stable carbon (about 15% to SOC) in the soil which was determined after the extraction of glomalin in the soil (Fig. 26). This suggests that glomalin production via AMF forms stable soil aggregates which store carbon inside thus may help in prevention of re-emission of CO_2 into the atmosphere without compromising the productivity of system.

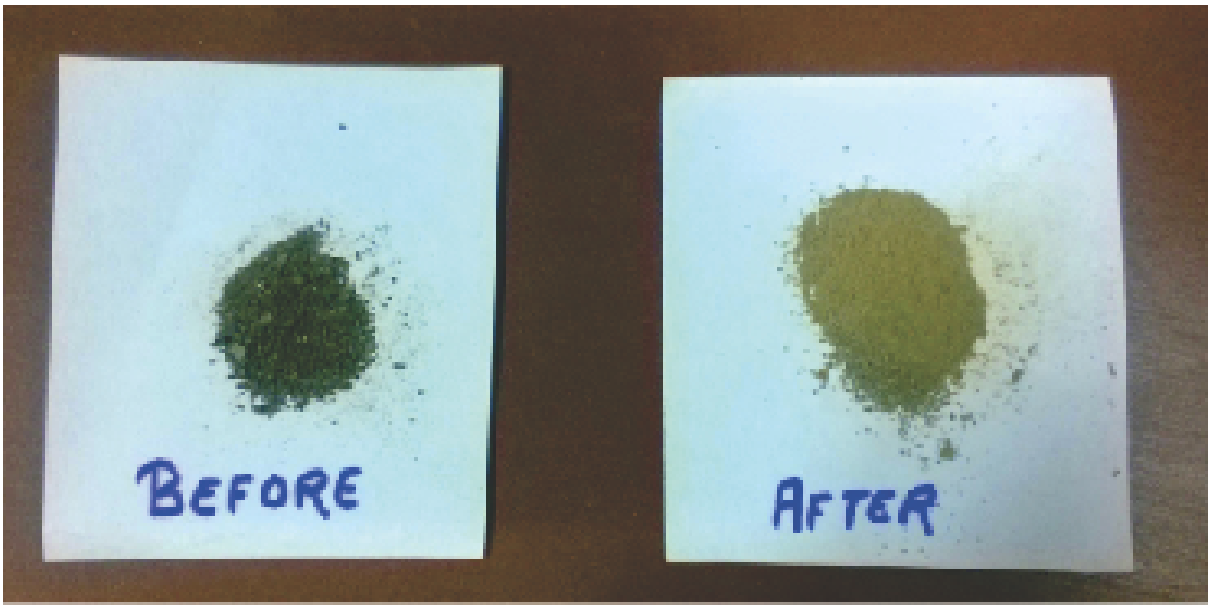


Fig. 26. Colour of soil before and after extraction of glomalin

2.2.6. Soybean yield improvement and its impact in India

The varietal developmental programme of soybean had resulted in releasing 98 varieties, of which many varieties were released in the last decade and twelve more varieties have recently been identified for release. The varietal development programme led to maximum yield potential of released varieties was 25 qt/ha achieved during 1970s to 35 qt/ha in 1990s and 40 qt/ha in 2000s. In FLDs also the maximum yield achieved was 46.66 qt/ha at Indore during 2001-02 and 45 qt/ha at Pantnagar in the year 2002-03 with full package of practices.

2.2.6.1. Impact: yield

The yield index (yield of 1970-71=100) for soybean has increased to 318 during the span of 43 years of its commercial cultivation, whereas the total oilseed yield index (1950-51=100) has barely crossed 240 recently (Fig. 27). The movement of yield index indicates total oilseeds yield index has increased mainly due to higher soybean yield index, particularly after mid-1980s. Thus, yield improvement in soybean has helped in improving productivity levels of total oilseeds.

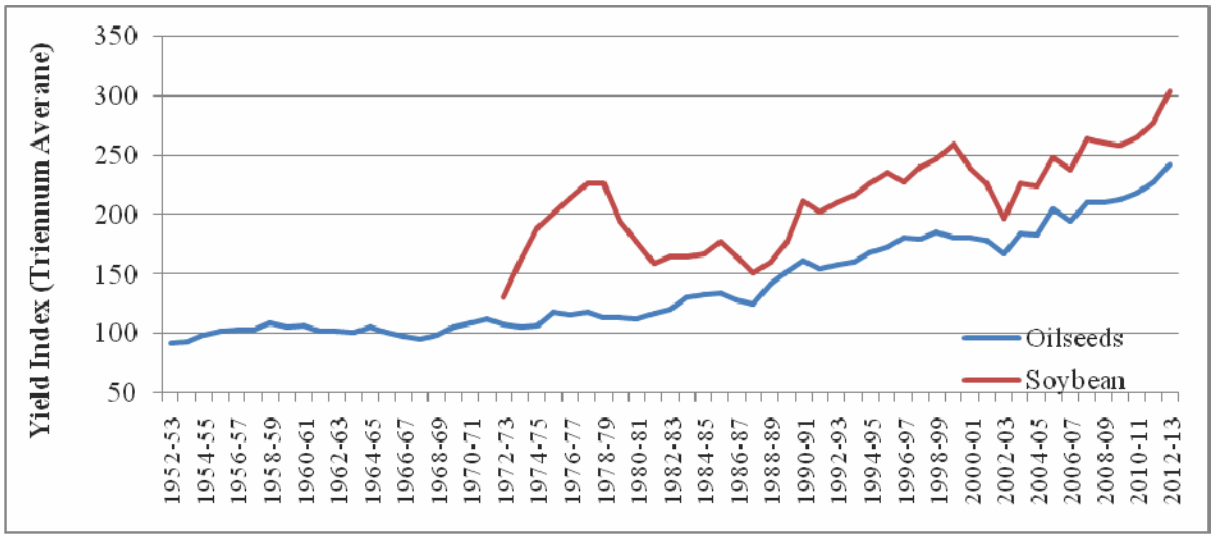


Fig.27. Yield index of soybean and total oilseeds of India

2.2.6.2. Impact: Value of output and Technology Achievement index

Value of soybean output estimated at constant (1999-00) prices was below Rs. 5000/ha during the year 1986-87 and 1987-88, and had increased to Rs. 11150/ha for the year 2010-11. Given that the value of output per hectare is in constant prices, an increase in per hectare value implies an increase in productivity per hectare over time. Since early 1980s, the yield level of soybean had nearly doubled from around 701 kg/ha during TE 1982-83 to 1300 kg/ha during TE 2012-13 (Fig. 28). However, the real concern here is high year-to-year variation in value of output per hectare particularly in the past decade.

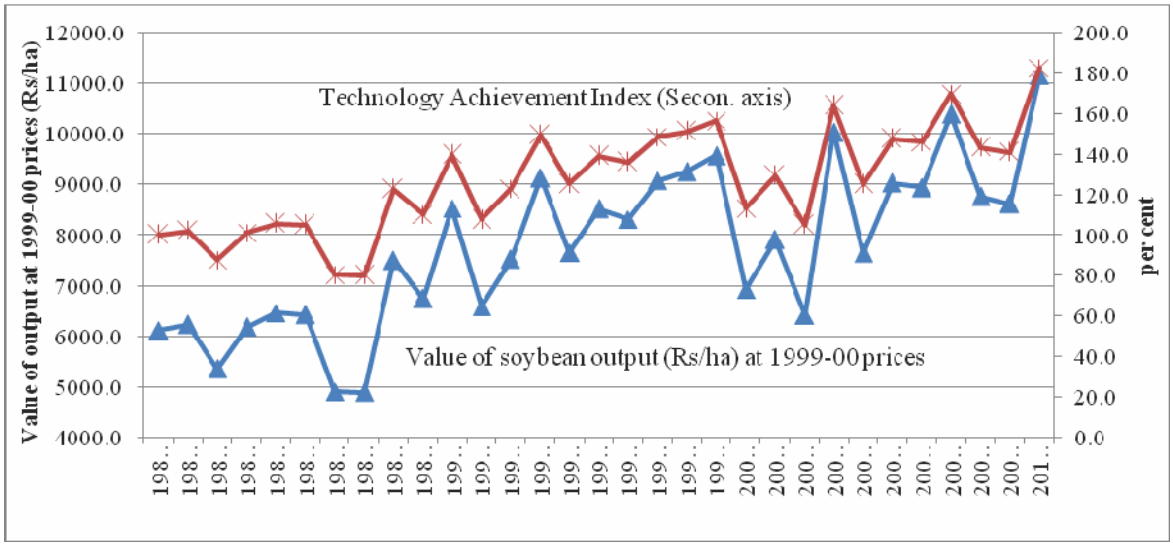


Fig.28. Value of output and technology achievement index of soybean in India

The technological interventions in soybean especially the varietal improvement programme resulted in changes in yield, production, edible oil production, export earnings from soy products, and value of output. The value of output per hectare is taken as an indicator of technology achievement and an index was derived by using the time series of value of output per hectare of soybean at constant prices (base 1980-81=100). The value of technology achievement index had increased from 100 in 1980-81 to 156.3 in 1999-2000 and 182 in 2010-11(Fig. 24).

2.2.7. Geoinformatic Analysis of Expansion in Area under Soybean Cultivation in India since its Commercial Introduction

The decadal three year average of Crops, Fertilizers/Nutrients consumption and Rainfall pattern of different districts of major soybean growing states are demonstrated through thematic maps. These decadal thematic maps also demonstrate crops which soybean has replaced. The area of soybean is mainly concentrated in western Madhya Pradesh (MP) and adjoining districts of Rajasthan (RJ) and was about 0.73 mHa in 1982-84. But in 2008-10 it spread to about 9.44 mHa, which about 13 times the area of first decade. The soybean is spread to Maharashtra (MH) covered almost whole MH and some parts of Andhra Pradesh (AP), Karnataka (KR), Chhattisgarh (CG), and RJ. The 95% of soybean production of the country are MP, MH, RJ, AP, KR, and CG. The soybean production, increases from 0.53 mTon (1982-84) to 10.35 mTon (2008-10). The soybean yield increased from 7.25 Quintals/Ha (1982-84) to about 10.96 Quintals/Ha (2008-10). The area of Cotton, Jowar, Bajra, Arhar, Groundnut and Sesame decreased but production has been increased and this is clearly seen on the spatial map.

Country-wide scenario shows that soybean area increases very rapidly, Arhar shows slightly increase from 1971-2010, Maize area starts increasing after 1996-97 and Cotton area begins increasing after 2004-05 whereas Jowar area decreased rapidly and Bajra area decreases slowly and slightly, Groundnut area begin decreasing 2000-01.

2.2.8. Design, development and validation of Tractor operated Disc harrow and rotary weeder for soybean

2.2.8.1. Design, development and validation of Tractor operated disc harrow for tillage in Soybean in vertisols

Initial study of Tractor operated disc harrow for tillage in soybean in vertisols showed great promise. The discs of 8 mm specification and total weight of the machine approximately 550 Kg (10 discs) along with relevant gang angle which have been found to be incorporated in the Prototype of the machine to be manufactured. Front discs need to be notched/cutaway for better elimination of weeds. It is a circular concave disc which cuts and inverts the soil. Disc needed is of heat-treated hardened steel. Tractor drawn disc harrows have concave discs of size varying from 70 cm diameter. Concavity of the disc affects penetration and pulverization of soil. Two types of disc are needed in disc harrows, plain disc and cut away disc. Plain discs have plain edges and they are used for all normal works. Most of the harrows are fitted with plain discs only. Cut away discs (notched) have serrated edges (without serrations) and they cut root stalks, grass and other vegetation in the soybean fields.

2.2.8.2. Design, development and validation of Tractor operated rotary weeder for Soybean.

Initial study of Tractor operated rotary weeder for Soybeans have indicated that horizontal blades or vertical blades can be considered for the prototype of the machine to be manufactured. Stability of the machine will be ensured with the tine between (ahead) of the rotary blades.

2.2.8.3. Machines developed and commercialized:

Soybean BBF Planter developed and approved for commercialization.

A **BBF Planter** has been developed for Vertisols (Fig 29). This machine facilitates plant to plant distance operation along with forming channels on either sides of the bed formed and sowing of soybean simultaneously. This machine has a facility of tilling the space between the rows of seed. This combination of operations helps to protect the crop from water stagnation during excessive rains. A prototype of soybean **BBF Planter** has been commercialized and is earning royalty for the Directorate.

Fig.29. Crop sown with BBF Planter

Tractor operated Ridge seed planter developed and commercialized:

A Ridge seed planter has been developed for soybean crop, which is capable of placing the soybean seeds at desired depth on the ridge formed (Fig 30.). Placement of seed on the formed ridge increases moisture use efficiency benefitting the crop. This machine is useful for moisture stress management in Vertisols due to variations in rainfall. Ridge seed planter machine has been commercialized. This land configuration technique helps to drain out excessive rainwater and can also facilitate irrigation with ease as and when needed.

Fig.30. Ridge seed planter

Ridge fertilizer drill cum seed planter developed and commercialized:

Under the unpredictable behavior of monsoon in Central India, quick seedbed preparation and timely sowing are critical factors to achieve higher soybean [*Glycine max* (L.) Merrill] yield. Therefore, a 'tractor drawn ridge fertilizer cum seed planter' hitched to link of three-point linkage system on tractor was conceived, manufactured and farm validated for facilitating development of ridge of soil along with placement of fertilizer under the ridge and sowing of seeds operations upon it (Fig 31) Planting of soybean using ridge fertilizer drill cum seed planter resulted in 17.22% increased plant population and consequently seed yield by 31.16 %. The fertilizer drill cum seed planter made by the machine is capable of placing the fertilizer deep as desired below the seed and mitigating the effect of dry spells as well as water logging conditions. The ridge fertilizer drill cum seed planter system of sowing helps to save 44% starter basal fertilizer for the soybean crop below the seed of the plant unlike other methods of starter doze fertilizer application such as common practice of broadcasting starter basal doze fertilizer followed by use of tine tiller to mix the fertilizer. Besides saving fertilizer, there was considerable reduction in weed growth in the field of soybean crop (Fig 32 and 33).

Fig. 31 Ridge fertilizer drill cum seed planter

Fig.32. Soybean crop sowing operation with Ridge fertilizer drill cum seed planter

Different steps of operations of the ridge fertilizer drill cum planter

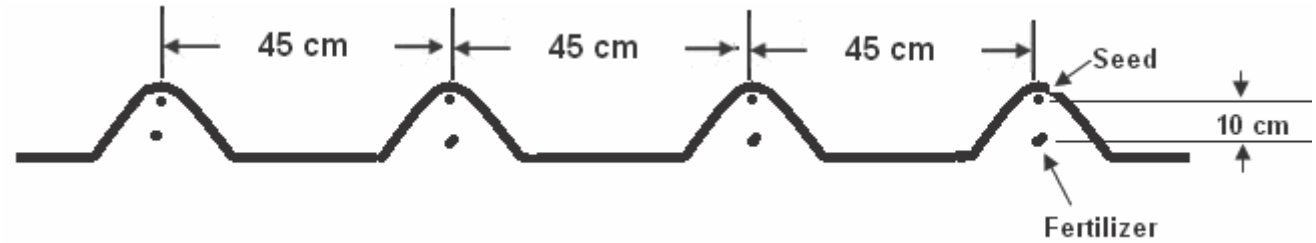


Fig.33. Specification of machine for seed & fertilizer on ridges formed by Ridge fertilizer seed planter

Design development and validation of Tractor operated FYM spreading trailer

Tractor PTO operated Farm yard manure spreading trailer: Tractor PTO operated Farm yard manure spreading trailer was developed which can successfully spread the pulverized farm yard manure on the surface of the soils (Fig 34). In this Tractor PTO operated Farm yard manure spreading trailer has provision for increasing and decreasing the forward speed of spreading. It is capable of spreading the 1.5 hectares of Farm yard manure in an hour. The trailer can hold 1.5 tonnes of FYM in its box for one pass in the field .The Power take off (PTO) of the tractor should be as per the category I or category II of OECD standards. It can be operated with 35 PTO HP tractors. High carbon steel is used for making different components of the machine. PTO clutch provided with the tractor helps to engage and disengage the PTO of the tractor with the trailer consequently the spreading or stopping of farm yard manure from the trailer box.

This machine can successfully overcome the problem of uniform and faster Farm yard manure spreading in vertisols and all other associated soils of India. It helps in adding farm yard manure to the soil in the fields which is a cumbersome process with conventional methods. This machine has the facility to break the clods of the farm yard manure and also pulverize it before spreading the Farm yard manure. This machine can also be used for Poultry manure application in the fields. This machine has provision to maintain different quantity of FYM as per the need of the crops. This machine shall provide a big boost to organic farming in the country at a reasonable cost for various crops. The machine has been commercialized.

Fig: 34. Tractor PTO operated Farm yard manure spreading trailer

2.3. CROP PROTECTION

2.3.1. Conservation and Enhancement of Natural Enemies of Soybean through Habitat Diversification

To study the influence of intercrops in soybean namely; *Sesbania* (daincha), *Tagetus sp.* (Marigold), *Vigna unguiculata* (cowpea), *Fagopyrum esculentum* (kutu, buckwheat), and *Anethum graveolens* (suwa) observations on the population of semiloopers, *Chrysodeixis acuta*; tobacco caterpillar, *Spodoptera litura*; stemfly, *Melanagromyza sojae*, girdle beetle, *Obereopsis brevis*, and yield were recorded in a field experiment. Observations on *C. acuata* and *S. litura* were recorded at 50 and 60 days after germination (DAG). At both the intervals *C. acuta* population was significantly higher in *A. graveolens* as compared to soybean alone or soybean in combination with intercrops (Table 39) suggesting *A. graveolens* as a choice host to *C. acuta*. With respect to *S. litura* and *M. sojae* the treatment effects were not significant. Sesbania was found to be a host plant for the problematic *O. brevis*. Per cent damage was significantly higher in sesbania as compared to soybean alone and rest of the comparisons were not significant (Table 40). Grain yield was highest in soybean+*A. graveolens* (2476 Kg ha^{-1}) which was significantly high as compared only to soybean+sesbania (1650 Kg ha^{-}).

Table 39. Influence of intercrops on the incidence of semiloopers, tobacco caterpillar and stemfly in soybean

S. No.	Treatment	Semiloopers (No. of larvae per meter crop row)		Tobacco caterpillar (No. of larvae per meter crop row)		Per cent stem tunnelling	Yield (Kg ha^{-1})
1	Soybean						
	+*Sesbania* sp.	3.6b (2.0)	13.0bc (3.7)	0.5a (0.3)	4.5 a (1.6)	10.2a (5.8)	1650b
2	Soybean						
	+*Tagetus* sp.	1.8 b (1.5)	18.4 b (4.3)	0.5a (0.3)	4.5a (1.5)	7.0 a (4.0)	2121ab
3	Soybean						
	+*Vigna unguiculata*	4.5 b (2.2)	13.4 bc (3.7)	0.0a (0.0)	2.8a (1.1)	7.0 a (4.0)	2319ab
4	Soybean						
	+*Fagopyrum esculentum*	3.1 b (1.9)	11.8 c (3.5)	0.3a (0.2)	1.8a (0.8)	6.3 a (3.6)	2124ab
5	Soybean						
	+*Anethum graveolens*	2.4 b (1.6)	16.8 bc (4.1)	0.8a (0.5)	5.8a (1.4)	11.8 a (6.8)	2476a
6	Control	3.8 b (2.1)	15.6 bc (4.0)	1.0a (0.6)	6.4a (1.9)	8.2 a (4.7)	2278ab
7	*Anethum graveolens* alone	37.6 a (6.1)	40.3 a (6.4)	0.4a (0.2)	0.8a (0.5)		
	F	64.92	23.82	1.26	1.48	1.13	1.13
	df	(6,17)	(6,17)	(6,17)	(6,17)	(5,15)	(5,15)
	P	<.0001	0.0001	0.3262	0.2429	0.3852	0.3852

Table 40. Influence of daincha on the per cent infestation and damage by girdle beetle in soybean

S. No.	Treatment infestation		Per cent damage	Per cent	
1	Sesbania sp.		5.3 (3.0)	1.9 (1.1)	
2	Soybean +Sesbania sp.		7.3(4.2)	1.2 (0.8)	
3	Soybean		6.0 (3.4)	0.9 (0.5)	
Per cent infestation					
		t-value	**df**	**P**	**SED**
1 and 2		1.5	6.0	0.195	0.78
1 and 3		0.557	6.0	0.597	0.71
2 and 3		1.110	6.0	0.308	0.69
Per cent damage					
1 and 2		0.777	6.0	0.467	0.37
1 and 3		2.424	6.0	0.052	0.26
2 and 3		1.008	6.0	0.352	0.32

2.3.2. Field Evaluation of Entomopathogenic Fungi against Soybean Defoliators

Efficacy of native strains of *Beauveria bassiana* against major soybean lepidopteron defoliators; *Chrysodeixis acuta* (Walker), *Diachrysia orichalcea* (Fabricius), *Gesonia gemma* Swinhoe, and *Spodoptera litura* (Fabricius) was evaluated in a field trial. There were four treatments consisting of three *B. bassiana* strains of DSR, Indore and an untreated control. One aqueous spray @ 10^8 spores/ml strength was applied at pod initiation stage. Observations were recorded ten days after spraying for number of larvae for meter crop row and yield at harvest. Treatment effects on number of larvae per meter crop row and yield were not significant (Table 41). However, in treatments DSRBB1 and DSRBB3 lower semiloopers population (7.7 and 10.0 respectively per mrl) was recorded as compared to the control (12.3 per mrl) which accounted for 38 and 19 per cent reduction over control respectively. In the treatment DSRBB2 a higher number of larvae were observed (13.0 per mrl) as compared to control. Grain yield in treated plots was higher as compared to control (1412 Kg ha^{-1}). Highest yield was recorded in the treatment DSRBB3 (1701 Kg ha^{-1}) followed by DSRBB1 (1693 Kg ha^{-1}) that is nearly 20 per cent increase over control.

Table 41. Efficacy of native *Beauveria bassiana* isolates against semiloopers in soybean in year 2014 at Indore

Treatment	No. of larvae per meter crop row*		Yield Kg-1	PCOC§ Incidence	PCOC Yield
	1DBT$	10DAT#			
DSRBB1	5.0a (2.34)	7.7a (2.81)	1693a	-38	+19.9
DSRBB2	5.3a (2.41)	13.0a (3.41)	1604a	+5	+13.6
DSRBB3	5.3a (2.40)	10.0a (3.17)	1701a	-19	+20.5
Control	4.0a (2.11)	12.3a (3.54)	1412a	0	0.0
F (3, 6)	1.65	0.47	0.29	-	-
P>F	0.27	0.72	0.83	-	-

Figures in the parentheses are square root transformed values. Means within a column followed by the same alphabet are significantly not different (Tukey's test, P>0.05). **Chrysodeixis acuta+Diachrysia orichalcea+Gesonia gemma* [$] DBT: days before treatment [#]DAT: days after treatment [$]PCOC: Per cent change over control

2.3.4. Biology, Epidemiology and Management of Stem Blight Disease of Soybean

2.3.4.1. Multiplication and maintenance of cultures:

Eleven isolates of *Colletotrichm sp.* prepared earlier from the stem /pod blight samples from different parts were purified as and when required and multiplied and maintained for further studies. Six isolates of *Trichoderma* sp. consists of *T. viride* and *T. harzianum* and two isolates of *S. rolfsii* were also purified and multiplied and maintained.

2.3.4.2. Cultural studies of *Colletotrichum* isolates:

All the isolates were grown on potato dextrose agar medium and incubated for 5-7 days for full growth. After full growth, the colony character, growth pattern, reverse pigmentation and per day growth were noted (Table 42).

Table 42: Cultural studies of *Colletotrichum* isolates

S. No.	Name of Isolate	Place	Isolation from	Colony characters	Reverse pigmentation	Growth/ day (mm)
1	Indore -coll	Indore	NRC 7, stem	Margin irregular, mycelail growth, out side dark black	Dark black	3.533
2.	Dhar Seed	Dhar	Infected Seed	Grayish black, irregularmargin, raised centre, mycelium whitish grey	Black	3.300
3.	Palampur	Palampur	NRC 92	Centre dark, surrounded by light grey mycelial growth	Grey	3.416
4.	Umiam	Umiam	DS 2708	Margin regular, off white mycelium, circular	Light pink	2.719
5.	Nagaland	Nagaland	JS 335	Centre dark, surrounded by light grey mycelial growth	Dark black	3.160
6.	Amravati-gl	Amravati	JS 335	Margin regular, off white mycelium, circular	Light/dark pink	3.833
7	Dharwad -gl	Dharwad	JS 335	Light pink white cottony mycelium surrounded by irregular pinkish hairy margin	Light pink	2.684

8	Anth-Indore	Indore	JS 335	Circle over circle, outer circle, irregular, margin irregular dark centre grayish mycelium	Dark black	3.210
9.	Jabalpur	Jabalpur	JS 335	Margin complete, serrated, centre grayish white, circular, smooth	Light grey	2.882
10	Raipur	Raipur	JS 335	Grayish black, irregular shiny margin, raised centre	black	2.543
11	Amravati-coll	Amravati	JS 335	Grayish black, irregular margin, raised centre	black	2.450

2.3.4.3. Dry Mycelium production:

Potato dextrose broth was prepared and 50 ml broth was poured in 150 ml conical flask and sterilized. Three flasks was inoculated with 5 mm 7-days old culture of each isolates maintained on PDA medium and incubated for 21 days at 26 ± 1 ^{0}C. After incubation the mycelium filtered through previously weighed Whatman filter paper no.1 and after it was dried in oven at 55 ^{0}C for constant weight. The filter paper along with mycelium was again weighed and the total dry mycelium was calculated by deducting the of filter paper weight. The Dhar seed isolate produced maximum dry weight (355 mg/50ml) and the minimum (105 mg/50ml) was in Raipur isolate (Table 43).

Table 43: Dry mycelium production studies of various *Colletotrichum* isolates

Isolate	Dry mycelium weight (mg/50ml) broth
Indore -coll	272
Dhar Seed	355
Palampur	302
Umiam	341
Nagaland	345
Amravati-gl	246
Dharwad -gl	315
Anth-Indore	335
Jabalpur	191
Raipur	105
Amravati-coll	295

2.3.4.4. Crude Toxin production and bioassay:

As a preliminary step to establish the biological role of the toxin produced by the Colletotrichum spp. All the 11 isolates were grown in 250 ml flask containing 100ml potato dextrose broth for 15 days at room temperature. The flasks were hand shaken twice every day. After incubation the culture filtrate was filtered through filter paper and again the filtrates were centrifuged for 5 min at 500rpm to remove the spores/ mycelium if any. The filtrates decanted off separately in a beaker and two sets were made for each isolate. Sterilized water served as control. 20 days old plants of soybean were dip in each beaker. Observations were recorded after 3, 6 and 12 hr and 24 hr. The symptoms of wilting started after 3 hr and plants died completely after 24 hr. In control the plants could not died after 5 days of incubation in sterile water (control) (Fig 35 & 36).

Fig.35 CONTROL

Fig. 36 TREATMENT

2.3.4.5. Effect of culture filtrate on seed germination:

Seed of JS 335 variety were soaked in culture filtrate for 1 hr and plated in sterile wet plate for germination. Simultaneously seeds soaked in sterile water served as control. In control the average germination percentage was 79.27%, whereas in treated the germination was 51.31%. The decrease in germination (79.27- 51.31= 27.96) percentage was because of the toxin produced by *C. truncatum*.

2.3.4.6. Effect of different seed dressers on germination and vigour:

Fungicide recommended for seed treatment for anthracnose/pod/stem blight was used in this experiment (Table 44). The plant height, nodule number, nodule dry weight and plant dry mass were recorded at R2 stage. The results presented in table 43 revealed that St with vitavax power produced highest vigour index followed by St with carbendazim, seed St with benlate and St with Tv and minimum in untreated control. The highest nodule number and nodule dry weight were also recorded with vitavax treatment.

Table 44. Effect of different seed dressers on nodule no nodule dry weight and vigour index

Treatments	Plant height (cm)	No. of nodule	Nodule dry weight (g)	Dry mass (g)	Vigour Index
Untreated control	19.1	33	0.142	3.54	662
St with benlate @2 g/kg seed	22.3	50	0.298	4.71	791
St with vitavax power @3 g/kg seed	22.50	66	0.212	4.73	1336
St with thiophanate methyl @2 g/kg seed	22.50	43	0.285	4.23	731
St with carbendazim @2 g/kg SEED	21.20	56	0.246	3.74	930
St with Tv @4 g/kg seed	21.20	57	0.197	3.61	758

2.3.4.7. Screening of germplasm against *C. truncatum*:

101 germplasm lines received from Sehore centres were artificially screened using detached leaf methods (Fig 37).

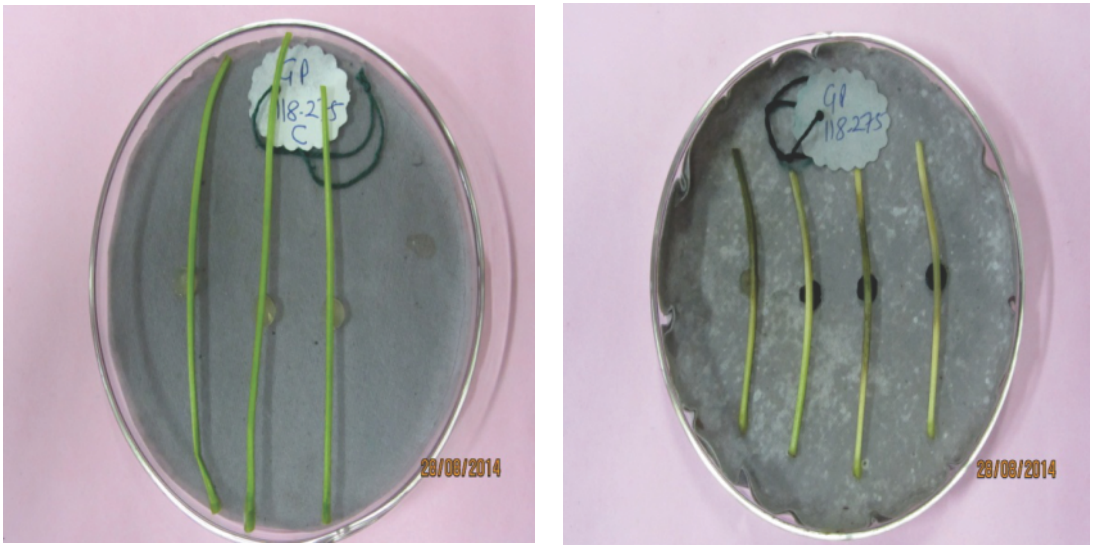


Fig.37 Detached leaf inoculation of *C. truncatum*

Out of 96 lines 6 showed resistance, 16 moderate resistance and remaining were susceptible to *C. truncatum* (Table 45).

Table 45: Screening of soybean germplasm for resistance against *C. truncatum*

Resistant	GP 399, Cat 2310, JS 20-53, , JS 20-49, GP 109, Cat 368
Moderate resistance	AMS 59, AMS 25-1, GP448, Cat 2755, AMS 50, CAT 96, BRAGG 13, JB MA –GP 465, AMS 243-73, GP 305, HIMSO 775, CAT 368, JS 20-53, GP 109, AMS 243, JS 20-75,
Susceptible	GP118-275, GP115, TGX709-7-E, JS 20-60, AGX-814-53-D, CAT 646, GP 133, PS 1225, TGX 814-33-F, GP 98, EC 389153, TGX348205, AMS108,PI 307-87, GP 32, CAT 2310, GS 91-68, GP 20-47, GP 14, CAT2758, EC 39322, GP 141, GP 40, CAT 76, KB 65, SEHORE 3, GP 383-101, GP 168, GP 146, JS 2051, GPP 12, GP 96, MALIS 43, CAT 27, SL688-1, JS 20-79, JS 20-31, AGS 10, MAUS 702, TGX 753416, GP 114, GP 928, JS 97-302, EC 34057, JS 20-50, CAT 2387-A, AMS 39-2-2, EC 333892, GP136, JS 82, DR 15-126-3, GP110, GP 93, AGS218, AJS 12, EC 14624, TGX 8114491, SEHORE 40, GP 448, JS 20-42, JS 20-84, TGX 253-416, GP 76, CAT 2660, GP 83, CAT 1113, CAT 2660, GP 448, GP 110, EC 14626, TGX 253416, TGX 814491, AGS 218, AMS-MB-5-18, DR15-126-3, GP 76, SEHORE 40, GP 83,

2.3.4.8. Management of Pod/stem blight:

A field experiments was conducted in randomized design with three replicates using soybean variety NRC 7 under natural field conditions. There were 9 different treatments, which includes seed treatment alone with fungicides and with spraying of fungicides at R2 stage and 21 days after first spray. Observations on germination, total number of plant and anthracnose / pod blight affected plants were recorded and percent infection and disease reduction over untreated control were calculated.

As compared to control all the treatments were effective, however seed treatment (St) alone was less effective than St + fungicide sprays. In field trial the minimum disease incidence was recorded in case of T3 (St with vitavax + spraying of kasugamycin @ 0.3% +COC @ 0.3 spray) (5.9%) and the maximum in untreated control (51.1%). St vv + spraying of kasugamycin @ 0.3%

+COC had less disease incidence (5.1%) than T9 i.e. St tv + kasugamycin @ 0.3% +COC (10.4%). Seed treatment had reduced the disease incidence and spraying further reduced the disease incidence and decreased the chaffy pods /plant, which contributed in yield (Table 46).

Table 46. Effect of fungicides on disease incidence and yield contributing characters

S. No.	Treatments	Plant Hight (cm)	No. of Branches / Plant	Pods/ Plant	Chaffy pods/ Plant	Seed yield/ Plant (g)	Seed Index	No. of diseased Plant	% disease reduction over control
1	Untreated Control	26.4	2.3	34.4	4.4	7.4	12.4	51.1	_
2.	ST with Benlat@0.2% + spray of Benlat@0.2%	31.2	4.5	55.1	2.1	13.2	14.2	10.2	80.0
3.	ST with Vitavax + kasuga@ 0.3% +COC @ 0.3 spray	32.5	3.7	55.4	1.1	13.4	14.3	5.9	88.5
4.	ST with Thiophanate methyl+ Spray Thio methyl @0.2	31.6	4.1	54.1	3.4	12.2	13.7	10.3	80.0
5.	ST with Vitavax + maize intecropping	31.5	3.1	41.5	3.9	7.9	12.3	8.7	83.0
6.	ST with TV @ 4g / kg seed +s praying of Tv @10 8CFU/ml	28.7	3.4	44.0	2.7	11.1	12.8	15.2	70.2
7.	ST with Tv @ 4g /kg seed + Thiophanate methyl @ 0.2 spray	28.4	3.5	47.8	1.7	12.3	13.7	9.7	81.0
8.	ST with Tv + maize intecroppin	22.4	3.7	41.6	1.9	11.4	12.4	10.6	79.2
9.	ST withTv + kasuga @ 0.3 + coc @0.3% spray	29.7	4.3	53.2	2.3	16.2	13.8	10.4	79.6
	CD at 5 %	3.87	1.64	17.52	3.50	4.94	0.58	2.86	--

2.3.4.9. Molecular characterization of *Colletotrichum* isolates

Seven isolates of *Colletotrichum truncatum* were collected from different regions of India. These isolates were named as: Jabalpur, Dhar, Palampur, Col A, Amravati, U 335 and C.Gl.A. Genomic DNA was isolated from all the samples and PCR amplifications were performed using ITS and EST (Expressed sequence Tag) specific primers (Fig 38, 39). ITS and EST region was sequenced and used for multiple sequence alignment and phylogenetic studies. DNA sequence variations were observed between various samples. ITS region was used for BLASTN analysis and related *Colletotrichum* sequences were obtained from NCBI. Phylogenetic tree was constructed based on the variable ITS region from Indian isolates and compared with the other *Colletotrichum species* (Fig 40).

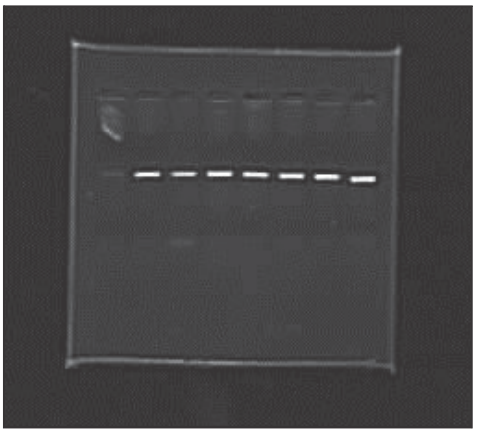


Fig. 38: PCR amplification of ITS region from seven *Colletotrichum truncatum* isolates.

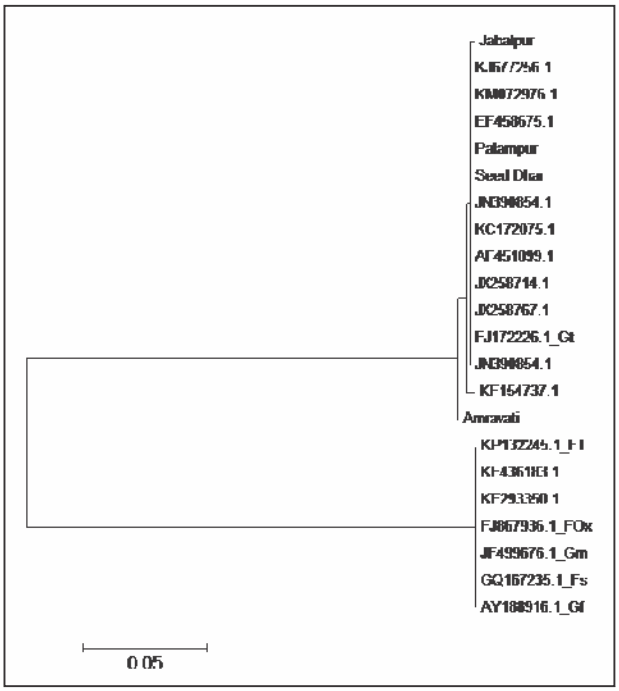


Fig. 39: Phylogenetic analysis of *Colletotrichum truncatum*. Results indicates genetic variability at DNA level among the *Colletotrichum truncatum* isolates.

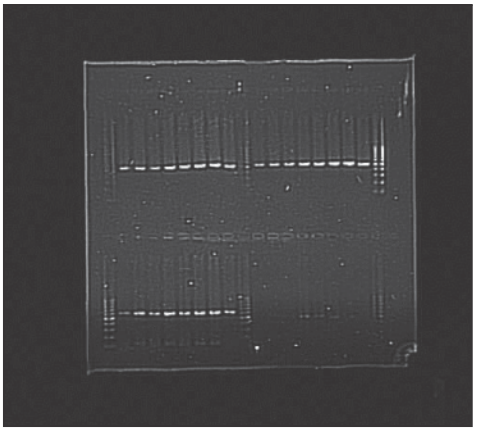


Fig. 40: PCR amplification of EST (Expressed Sequence Tag) from *Colletotrichum truncatum* isolates. Sequencing of EST from all the seven isolated confirmed that they belong to *Colletotrichum Species*. BlastN analysis of EST sequences matched with *Colletotrichum truncatum* and *Colletotrichum gloeosporioides*

2.3.5. Studies on the Distribution of Plant Parasitic and Entomopathogenic Nematodes associated with Soybean Cultivation and Utilization of EPN for the Management of Major Insect Pests of Soybean.

2.3.5.1. Studies on the Distribution of Plant Parasitic Nematodes associated with Soybean Cultivation:

DNA was extracted from nematode samples collected from different area in Malwa region. PCR conditions were standardized for amplification of ITS region from the nematodes. Sequencing of nematode ITS region was performed (*Heterodera cajani* internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence Sequence ID: gb|AF274389.1|AF274389) . Blast Results

showed homology to *Heterodera Cajan*. Thus results indicated that the nematode from Malwa region represent *Heterodera cajani.*

2.3.5.2. Effect of soil texture on population development of reniform nematode (*Rotylenchulus reniformis*) infesting soybean (*Glycine max*)

Being the most prevalent plant parasitic nematode in the soybean growing areas of India, the present study was initiated to ascertain the development of *Rotylenchulus reniformis* on soybean in different soil textures under microcosm conditions. Different levels of sand (0 %, 25 %, 50 % and 75 %) was added to the natural soil collected from Research farm, Directorate of soybean research, Indore, to obtain four different textural classes namely, clay, clay loam, sandy clay loam and sandy loam. The experiment was carried out in 4" plastic pots containing 500 cm^3 of respective pasteurized soils with one plant per pot. Each pot was inoculated with 750 infective stage nematodes after one week of sowing. Reproductive index (RI=final population/initial population) of different treatments were calculated after 70 days of inoculation. Maximum RI of 30.22 was observed in sandy clay loam followed by 25.27 in clay loam and 12.73 in sandy loam soils. However, the lowest RI of 5.19 was recorded in clay soil, which is the prevailing soil type of Malwa plateau. Our study revealed the possible threat of *R. reniformis* for soybean cultivation in sandy clay loam or clay loam soils as compared to clay or sandy loam soils.

2.3.5.3. Compatibility of Entomopathogenic Nematode, *Steinernema glaseri* (Nematoda: Rhabditida) with common insecticides used in soybean cultivation

Entomopathogenic nematodes are lethal insect pathogens with immense biocontrol potential for managing insect pests of agricultural imporatance. The compatibility of entomopathogenic nematode, *Steinernema glaseri* (Steiner) was tested with three different doses of 12 insecticide formulations recommended for insect pest management in soybean. Survival of the infective juveniles of *S. glaseri* without any mortality was recorded even after 7 days in all the tested doses of the insecticides namely emamectin benzoate, fipronil, lambdacyhalothrin, spinosad, chloranthraniliprole, thiamethoxam, thiacloprid and flubendiamide. Amongsts the remaining insecticides, chlorfenapyr, quinalphos and triazophos were observed to be safe only for short term exposures up to 48 hours. However, indoxacarb was found to be highly incompatible as it recorded 98 % nematode mortality in its recommended dose only after 24 hours of treatment exposure. Our study concluded that these formulations except Indoxacarb, in their recommended doses are compatible with *S. glaseri* and could be tank mixed in spray mixtures of respective pesticide formulations.

2.3.6. Breeding soybean varieties resistant to defoliators, stem fly and girdle beetle

Sixteen germplasm lines were screened for resistance against major insect pests, maturity and yield under natural field conditions and their performances were compared with standard checks of central zone. Genotype Cat. No. 139 was earliest flowering (22 days) and maturing (74 days) and was also resistant to girdle beetle, *Obereopsis brevis* (Table 47). Cat. No. 52 was also resistant to girdle beetle showing no damage symptoms. Genotypes Cat. Nos. 47 and 146 were found to resistant to defoliators viz. green semilooper (*Gessonia gemma*) and tobacco caterpillar (*Spodoptera litura*). All the above mentioned genotypes performed better than the standard check varieties of central zone.

On the basis of yield under unprotected and protected conditions, several test genotypes were found to be tolerant to insect-pest complex by Maximin-Minimax method (Table 48). Cat. No. 147, though susceptible against major insect pests, but yielded highest under both unprotected (2123 kg/ha) and protected (2612 kg/ha) conditions, thus showing tolerance to insect damage / incidence. The yield levels were better than those of standard checks. Although, Cat. No. 139 yielded relatively less, but the yield loss was only 9.29 %, next only to JS 335 (7.48 %).

Table 47: Evaluation of some promising soybean genotypes for insect resistance, maturity and yield (*Kharif*-2014)

S. No.	Genotype	Flowering Days	Maturity Days	Girdle beetle % infestation	Girdle beetle % damage	Stem fly (% stem tunnelling)	Green semilooper (larvae/m)	Tobacco caterpillar (larvae/m)
1.	EC333902	37	88	19.85 (26.27) LR	10.18 (18.40) LR	20.02 (26.93) LR	19.67 (4.37) LR	1.89 (1.37) LR
2.	VP1165	34	93	11.75 (19.56) LR	7.76 (15.80) LR	12.03 (20.00) MR	13.78 (3.66) MR	1.22 (1.10) MR
3.	TGX814-35E	35	93	11.35 (19.60) LR	7.46 (15.83) LR	13.28 (20.74) MR	19.11 (4.36) LR	3.33 (1.77) LR
4.	TGX854-42D-1	32	85	17.81 (24.74) LR	11.66 (19.76) LR	14.86 (21.89) MR	16.78 (4.05) LR	2.78 (1.65) LR
5.	SREC-56A	35	86	4.11 (11.62) MR	3.53 (10.80) MR	11.24 (18.58) MR	14.22 (3.76) MR	1.33 (0.93) MR
6.	Cat.No.47	25	76	6.73 (14.87) MR	4.27 (9.75) MR	18.37 (25.35) MR	**6.33 (2.47) HR**	**0.22 (0.27) HR**
7.	Cat.No.52	29	88	**2.42 (7.31) R**	**0.00 (0.00) HR**	20.60 (26.96) LR	14.89 (3.86) LR	5.22 (2.28) HS
8.	Cat.No.87	35	95	9.76 (18.20) LR	6.18 (14.34) LR	39.93 (38.93) S	19.78 (4.44) LR	3.55 (1.88) LR
9.	Cat.No.127-A	26	88	18.47 (24.30) LR	7.34 (15.50) LR	21.47 (27.34) LR	14.22 (3.76) MR	1.33 (1.12) MR
10.	Cat.No.139	**22**	**74**	**2.52 (8.97) R**	**1.56 (5.78) R**	12.79 (20.75) MR	9.89 (3.13) MR	**0.00 (0.00) HR**
11.	Cat.No.146	25	75	5.00 (10.36) MR	2.16 (6.81) MR	14.16 (22.01) MR	**4.34 (2.06) HR**	**0.33 (0.46) R**
12.	Cat.No.147	38	91	17.19 (24.27) LR	10.30 (18.35) LR	22.08 (27.98) LR	15.67 (3.93) LR	3.11 (1.76) LR
13.	Cat.No.612	35	90	15.07 (22.26) LR	11.96 (19.54) LR	12.76 (20.84) MR	15.00 (3.82) LR	2.67 (1.62) LR
14.	Cat.No.1616	37	91	17.14 (24.31) LR	12.72 (20.56) LR	16.45 (23.58) MR	19.00 (4.30) LR	2.11 (1.18) MR
15.	Cat.No.1818	35	89	13.99 (21.94) LR	10.42 (18.35) LR	21.82 (27.63) LR	17.33 (4.14) LR	1.89 (1.33) MR
16.	Cat.No.143	29	78	8.69 (16.27) MR	4.56 (11.83) MR	21.11 (27.30) LR	9.66 (3.10) MR	1.00 (0.99) MR
17.	JS93-05 (C)	31	87	6.50 (14.65) MR	4.89 (12.68) MR	14.30 (20.99) MR	21.22 (4.58) LR	5.33 (2.30) HS
18.	JS97-52 (C)	41	93	9.54 (17.81) MR	6.12 (14.29) LR	21.32 (26.59) LR	21.33 (4.62) LR	2.34 (1.52) LR
19.	JS335 (C)	36	92	8.33 (15.83) MR	4.52 (11.76) MR	14.94 (22.42) MR	16.67 (4.07) LR	3.44 (1.85) LR
20.	Bragg (C)	31	95	7.99 (16.04) MR	4.88 (12.50) MR	19.08 (25.01) MR	14.11 (3.73) MR	3.89 (1.96) LR
	SEm+	-	-	(3.04)	(2.47)	(3.88)	(0.31)	(0.24)
	CD at 5%	-	-	(8.68)	(7.06)	(11.08)	(0.89)	(0.68)
	CD at 1%	-	-	(11.61)	(9.45)	(14.83)	(1.19)	(0.91)

Table 48: Categorization of soybean genotypes into resistant categories by Maximin-Minimax method

S. No.	Genotype	Grain Yield (kg/ha)		% Yield loss	RP	RY	Category
		Unprotected	Protected				
1	EC333902	1740	2131	18.35	90.44	81.96	S-HY(T)
2	VP1165	1207	1355	10.92	53.82	56.85	S-LY
3	TGX814-35E	1604	1939	17.28	85.17	75.55	S-HY(T)
4	TGX854-42D-1	1430	1765	18.98	93.54	67.36	S-LY
5	SREC-56A	1661	2032	18.26	90.00	78.24	S-HY(T)
6	Cat.No.47	1018	1163	12.47	61.46	47.95	S-LY
7	Cat.No.52	1352	1509	10.40	51.26	63.68	S-LY
8	Cat.No.87	1469	1843	20.29 (SC)	100.00	69.19	S-LY
9	Cat.No.127-A	634	765	17.12	84.38	29.86	S-LY
10	Cat.No.139	1191	1313	9.29	45.79	56.10	S-LY
11	Cat.No.146	918	1135	19.12	94.23	43.24	S-LY
12	Cat.No.147	2123 (RC)	2612	18.72	92.26	100.00	S-HY(T)
13	Cat.No.612	1299	1572	17.37	85.61	61.19	S-LY
14	Cat.No.1616	1940	2164	10.35	51.01	91.38	S-HY(T)
15	Cat.No.1818	1536	1757	12.58	62.00	72.35	S-LY
16	Cat.No.143	1088	1312	17.07	84.13	51.25	S-LY
17	JS93-05 (C)	1889	2256	16.27	80.19	88.98	S-HY(T)
18	JS97-52 (C)	1868	2112	11.55	56.92	87.99	S-HY(T)
19	JS335 (C)	2116	2287	7.48	36.87	99.67	S-HY(T)
20	Bragg (C)	1375	1559	11.80	58.16	64.77	S-LY
	SEm+	115.67	109.21	-	-	-	-
	CD at 5%	330.60	312.13	-	-	-	-

3. TECHNOLOGY TRANSFER

3.1. Assessment of interactions of technological adoption with soybean yield

Farmers are found to have witnessed aberrant climatic variations during the period of last four decades which were studied based on the data collected from the farmers with the help of structured interview schedule. It was observed that farmers had to change their strategies to cope up with the yield reduction due to late arrival and uneven distribution of rainfall, long dry spells, early and late cessation of monsoon, prolonged cloudy weather, high atmospheric temperature, increased incidences of biotic problems like insect-pest and disease etc. Due to this, farmers have not been able to harvest satisfactory yield of soybean in sustainable way. The farmers have slowly learnt to prefer short duration varieties with high yielding attributes and resistant to biotic factors in order to maximize soybean yield.

3.2 Participation in Agricultural Exhibitions:

The DSR has actively participated in two major agricultural exhibitions during the year which included Haldhar Krishi Expo a mega event organized by Department of Agriculture, Madhya Pradesh at Bhopal during 26-28 September 2014 and also at National Agricultural Exhibition organized by IIOR, Hyderabad during 18-19 January 2015

3.2. Frontline demonstrations

Ten FLDs were conducted for transfer of improved production technology and its different components of soybean on the farmers' fields. The FLDs results indicated that the adoption of improved technology substantially enhanced the soybean productivity in the Sindoda village (Rau), Indore. The results of frontline demonstrations on full package (10 trials) revealed yield levels increased from of 2035 to 2320 kg/ha by adopting improved production technology (IT) as compared to farmers practice (FP). On an average basis the yield increase by IT was 285 kg/ha. The average additional cost of cultivation of Rs. 1989/- could result in a yield increase of 14.00 % fetching additional net returns of Rs. 6565/ha.

3.3. Soybean yield improvement and its impact in India

The varietal developmental programme of soybean had resulted in releasing 98 varieties, of which many varieties were released in the last decade and twelve more varieties have recently been identified for release. The varietal development programme led to maximum yield potential of released varieties was 25 qt/ha achieved during 1970s to 35 qt/ha in 1990s and 40 qt/ha in 2000s. In FLDs also the maximum yield achieved was 46.66 qt/ha at Indore during 2001-02 and 45 qt/ha at Pantnagar in the year 2002-03 with full package of practices.

3.3.1 Impact: yield

The yield index (yield of 1970-71=100) for soybean has increased to 318 during the span of 43 years of its commercial cultivation, whereas the total oilseed yield index (1950-51=100) has barely crossed 240 recently. The movement of yield index indicates total oilseeds yield index has increased mainly due to higher soybean yield index, particularly after mid-1980s. Thus, yield improvement in soybean has helped in improving productivity levels of total oilseeds. (Fig. 41)

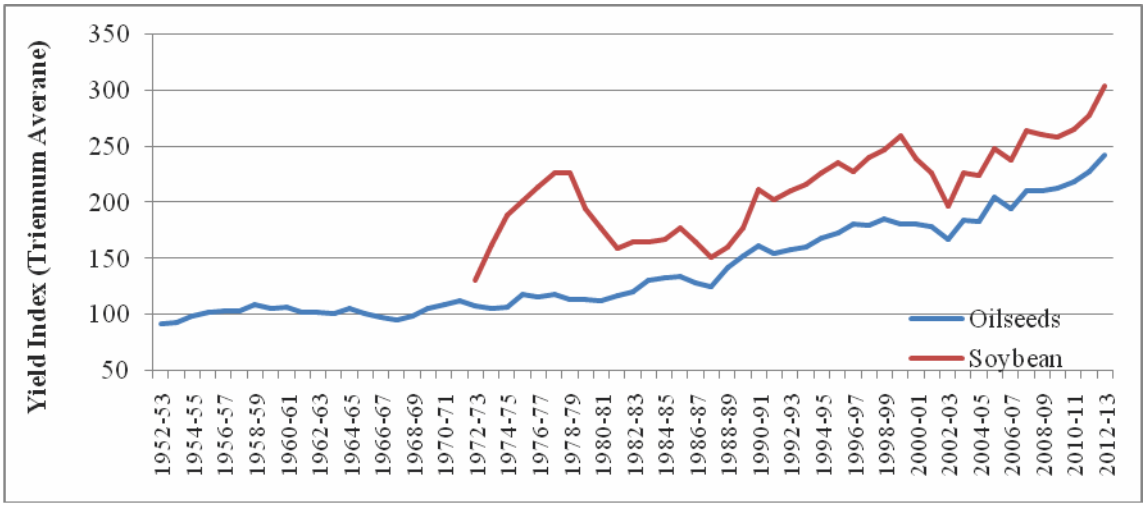


Fig. 41. Yield index of soybean and total oilseeds of India

3.3.2 Impact: Value of output and Technology Achievement index

Value of soybean output estimated at constant (1999-00) prices was below Rs. 5000/ha during the year 1986-87 and 1987-88, and had increased to Rs. 11150/ha for the year 2010-11. Given that the value of output per hectare is in constant prices, an increase in per hectare value implies an increase in productivity per hectare over time. Since early 1980s, the yield level of soybean had nearly doubled from around 701 kg/ha during TE 1982-83 to 1300 kg/ha during TE 2012-13. However, the real concern here is high year-to-year variation in value of output per hectare particularly in the past decade. (Fig. 42)

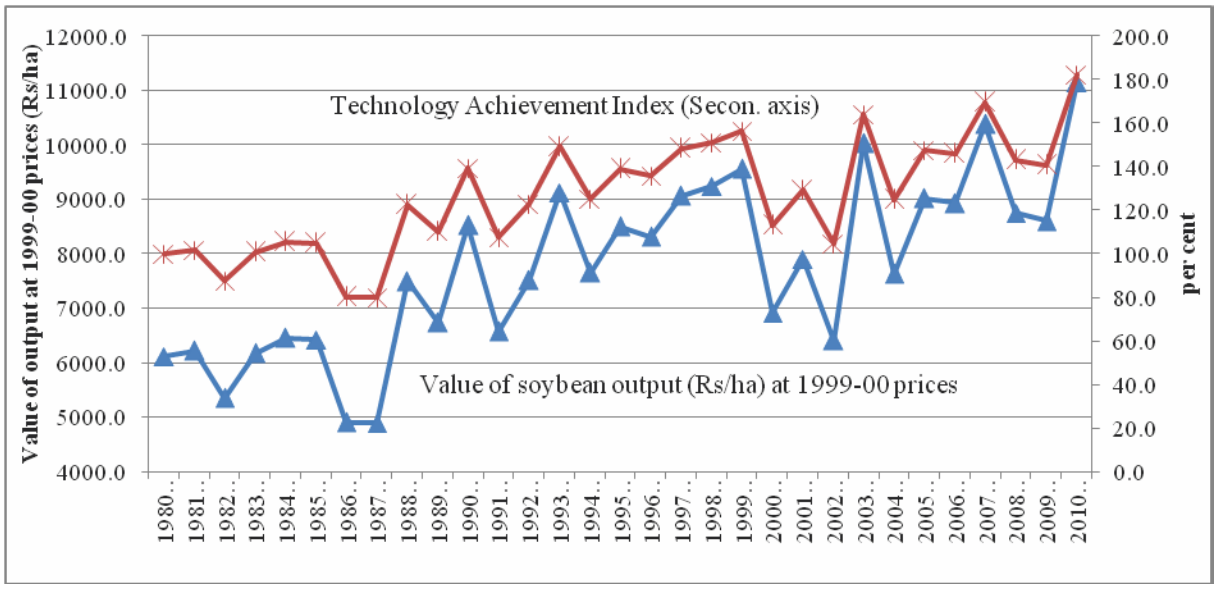


Fig. 42 Value of output and technology achievement index of soybean in India

The technological interventions in soybean especially the varietal improvement programme resulted in changes in yield, production, edible oil production, export earnings from soy products, and value of output. The value of output per hectare is taken as an indicator of technology achievement and an index was derived by using the time series of value of output per hectare of soybean at constant prices (base 1980-81=100). The value of technology achievement index had increased from 100 in 1980-81 to 156.3 in 1999-2000 and 182 in 2010-11.

4. TRAININGS AND CAPACITY BUILDING

4.1 Trainers' Training Programmes:

DSR has successfully conducted a Training Programme Course on Improved Soybean Production Technology' for the participants of Harit Ruchi Soya during May 2014. A total of 10 field officers from this company involved in production of vegetable type soybean variety developed at DSR were trained on various aspect its production technology.

4.2. Workshops:

A two day Review workshop was organized at the Directorate for the scientists belonging to Madhya Pradesh, Chhatisgarh & Orissa in association with Zonal Project Directorate, Zone VII, Jabalpur during 1-3 March 2014. In this workshop, review was undertaken about different OFTs and VTs on soybean conducted during the year and necessary modifications were suggested for formulation of annual plan for the coming season.

4.3. Farmers' Training Programmes

4.3.1. One day Farmers' Training Programmes on Improved Soybean Production Technology:

During this year, 100 Farmers' Training Programmes of day long duration were organized with the cumulative participation of 3176 farmers belonging to the states of Madhya Pradesh, Rajasthan, and Maharashtra. All the recommended package of practices including agronomic, moisture conservation techniques during the stress period, integrated approach of managing weeds, insect pests and diseases etc as well as processing aspects of value added soy products were covered in these training programmes which were facilitated in participatory mode.

4.3.2. One day Women's Training Programme on Processing and Utilization of Soybean:

Sixteen training programmes on "Processing and Utilization of Soybean for Food Uses at household level" were organized with the participation of 527 women belonging Madhya Pradesh and Rajasthan respectively.

4.3.3. Farmers/Farm Women Training Programme under Tribal Sub-Plan (TSP):

A total of 100 frontline demonstrations were conducted in Dhar and Jhabua districts of Madhya Pradesh in association with KVK Dhar and Jhabua falling under the jurisdiction of RVSKVV, Gwalior. Further, a farmers training programme on Improved Soybean Production technology and Processing of Soybean for Nutritional Security was organized on 27th March 2015, at Khalwa District-Khandwa with the participation of 329 tribal famers/farm women.

Organized a 3 Days Arc-GIS 10.2 software training program for all the scientists and technical in the Institute.

5.AWARDS AND RECOGNITIONS

5. 1. Awards to Institution

Nil

5. 2. Award to Individuals

Shri S.K. Verma, Technical Officer and Dr. B. U. Dupare, Senior Scientist (Agricultural Extension) received First Prize for Best Hindi Article which was conferred upon by the Honorable His Excellency Shri Pranab Mukherjee, the President of India at Rashtrapati Bhawan on the occasion of Hindi Diwas celebration on 14th September 2015.

- **Sharma, M.P.,** Deputation abroad: AwardedDBT-CREST Award to work abroad on cutting edge research technologies for scientific advancement by Department of Biotechnology, Govt. of India and worked on signature fatty acid biomarkers at USDA-ARS, Beltsville, MD, USA from October 19 2013 to April 21st, 2014.
- **Ramesh S.V.,** Deputation abroad: Awarded DBT-CREST Award to work abroad on cutting edge research technologies for scientific advancement by Department of Biotechnology, Govt. of India and worked on "Small non-coding RNAs mediated strategies to engineer antiviral resistance in crops" at Washington State University, Pullman, WA, USA from October 14th 2013 to October, 13th 2014.
- **Sharma M.P.** Nominated as expert member of project approval committee for 3 years by Department of Science and Technology, Govt of MP, Bhopal to review the project and other research activities of MP Biotechnology Council, Bhopal
- **Ramesh S.V.,** Inducted as Member, International Working group on Legume and Vegetable Viruses (IWGLVV)
- **Best paper award:** First prize for best poster award for the contribution "Agnihotri R, Pandey A, Ramesh A, Patra A.K, Hajela K & Sharma M.P. Soil carbon sequestration through glomalin production by Arbuscular Mycorrhizal Fungi in soybean-maize intercropping system under organic and inorganic farming practices" presented during National Workshop on Carbon Sequestration in Forest and Non Forest Ecosystems (February 16-17, 2015) at JNKVV, Jabalpur.

5.3. Other Achievements:

5.3.1. Commercialization of research emanated products:

i) Kunitz trypsin inhibitor free soybean NRC101 and NRC102 commercialized. License for NRC101 and NRC102 for 5 years transferred to M/S Ruchi Hi-Rich Seeds Pvt Limited and M/S ITC Limited, respectively.

ii) High oleic acid soybean IC210 commercialized. License for 5 years transferred to M/S ITC Limited

5.3.2. Copyrights obtained

i) Expert System of Soybean Diseases (sw-7929/2014 dt. 28.05.2014)

ii) Knowledge Acquisition System of Soybean Disease (sw-7928/2014 dt. 28.05.2014)

iii) Intelligent Soybean Disease Tutor System (sw-7930/2014 dt. 28.05.2014)

iv) Knowledgebase of Soybean Diseases (sw-7931/2014 dt. 28.05.2014)
Screens of Soybean Disease Expert System (sw-7932/2014 dt. 28.05.2014)

6. LINKAGES AND COLLABORATION

Effective linkages and collaborations were made with the following International, National and Regional institutions/organizations for soybean research and development and extension activities.

International

1.	Asian Vegetable Research and Development Centre, Taiwan
2.	International Institute of Tropical Agriculture, Ibadan, Nigeria
3.	Brazilian Agricultural Research Enterprise, National Soybean Research Center, EMBRAPA.
4.	University of Illinois, Urbana, Illinois, 61821, USA.
5.	University of Arkansas, USA
6.	Soybean Production Research, USDA, ARS, Stoneville, Mississippi 38776, USA.
7.	IOWA State University, USA.
8.	International Potash Institute, Switzerland.
9.	International Plant Genetic Resources Institute, Rome, Italy

National

1.	SAUs in the States of Madhya Pradesh, Chhatisgarh, Maharashtra, Himachal Pradesh, Uttar Pradesh, Uttarakhand, Rajasthan, Punjab, Haryana, Jharkhand, Tamil Nadu, Karnataka, Andhra Pradesh, West Bengal, North-Eastern States.
2.	National Bureau of Plant Genetic Resources, New Delhi
3.	Directorate of Oilseeds Research, Hyderabad
4.	Central Research Institute for Dryland Agriculture, Hyderabad
5.	Indian Institute of Pulse Research, Kanpur
6.	Central Institute of Agricultural Engineering, Bhopal
7.	National Research Centre for Plant Biotechnology, New Delhi
8.	National Research Centre for DNA Finger Printing, New Delhi
9.	Directorate of Oilseed Research & Development, Hyderabad
10.	Indina Agricultural Research Institute, New Delhi
11.	National Academy of Agricultural Research Management, Hyderabad
12.	National Bank for Agriculture and Rural Development
13.	National Fertilizer Limited
14.	Agharkar Research Institute, Pune

Regional

1.	Department of Agriculture of Madhya Pradesh, Chhatisgarh, Maharashtra, Himachal Pradesh, Uttar Pradesh, Uttarakhand, Rajasthan, Punjab, Haryana, Jharkhand, Tamil Nadu, Karnataka, Andhra Pradesh, West Bengal, North-Eastern States
2.	NGOs like SOPA, OILFED
3.	State Cooperative Development Banks of respective States.
4.	State Seed Corporation
5.	Deptt. of Seed Certification

7. INTELLECTUAL PROPERTY MANANAGEMENT AND TECHNOLOGY TRANSFER/COMMERCIALIZATION

1. Issued non exclusive license and MoU signed for the commercialisation of high oleic acid (IC 210) and KTI free (NRC 102) soybean genotypes with ITC Limited, India on 09/06/2014 and for KTI free soybean genotype NRC 101 with Ruchi Hi-Rich Seeds Private Limited, Mumbai.
2. Registration of eleven extant soybean varieties viz. Pratikar (MAUS-61), MAUS-81, MAUS 158, Pusa 9712 (DS 9712), JS 20-29, JS 20-34, MACS 1188, MAUS-162, RAUS-5 (Pratap Soya-1), Pratap Soya 45 (RKS 45) and Pratap Soya-2 (RKS-18) have been submitted to PPV&FR Authority through NBPGR, New Delhi.
3. Issued a non-exclusive license and singed MOA for nine agriculture implements viz. BBF machine, Furrow irrigated raised bed system planter / drill, Sweep seed drill machine, Subsoiler machine, BBF planter, Soybean seed planter, Ridge fertilizer drill cum seed planter, Soybean seed drill cum planter (DSR two in one) and Single ridge seed planter with M/s Rohit Steel Works, Pune, M/s Mahashakti Agro Energy& Innovation private Ltd Wardha (M.S) and M/s S.R. Engineering & Services,Wardha (M.S).
4. Renewal of MOA was done for commercialization of four agricultural implements with M/s New Patidar Iron Work, Rau, Indore (M.P) on 28/02/2015.
5. MOA has been signed with M/s New Patidar Iron Work, Rau, Indore (M.P) for commercialization of five agriculture implements on 01/10/2014
6. One more agricultural implement Viz. Farm yard manure spreading trailer have been approved by ITMC/ITMU for commercialization.
7. Copyright has been obtained for following Softwares
   I. Expert System of Soybean Diseases
   II. Knowledge Acquisition System of Soybean Diseases
   III. Intelligent Soybean Disease Tutor System
   IV. Knowledgebase of Soybean Diseases
   V. Screens of Soybean Disease Expert System

Composition of Institute Technology Management Committee, (ITMC)

- Dr. V.S. Bhatia, Director (Chairman)
- Dr. M.M. Ansari, Principal Scientist (Member)
- Dr. P.C. Bargale, Principal Scientist & Head-ICAR-CIAE, Bhopal (External Member)
- Dr. S.D. Billore, Principal Scientist (Member)
- Dr. M.P. Sharma, Principal Scientist (Member Secretary)

Institute Technology Management Unit, (ITMU)

- Dr. M. P. Sharma, Principal Scientist- Nodal Officer
- Dr S.M. Husain, Principal Scientist- Member
- Dr. A.N. Sharma, Principal Scientist- Member
- Dr. M.K. Kuchlan, Scientist- Member Secretary
- Finance & Accounts Officer-Member
  Administrative Officer-Member

8. ALL INDIA COORDINATED RESEARCH PROJECT ON SOYBEAN

Since 1987 All India Coordinated Research Project on Soybean (AICRP on Soybean) is an integral part of the directorate of Soybean though established in 1967 but subsequently it was reorganized in manpower, coordinating centers and budget in each five year plans. Presently, It is comprising of 22 regular centers (8 main center 14 sub-center) and 14 need based testing center, located in the states of Andhra Pradesh, Assam, Chhattisgarh, Bihar, Himachal Pradesh, Haryana, Jharkhand, Karnataka, MP Maharashtra, Meghalaya, Manipur, Nagaland, Orissa, Gujarat, Punjab, Rajasthan, Tamil Nadu, Uttarakhand and U.P. The Objective of AICRP on Soybean is to coordinate, monitor and guide the research activities on soybean at national level with the mandate of evaluation of soybean genetics resources, development of location specific high yielding varieties with other desirable traits and improved agronomical practices, maintenance of genetic purity and production of breeder seed, refinement and validation of integrated management of nutrients, insect pests, diseases, water and weeds, basic studies on physiological and molecular aspects and value addition in soybean and technology transfer through demonstration and trainings.

8.1. XLV Annual Group Meeting of AICRP on Soybean

45th AGM of AICRP on Soybean was organized by ICAR-Directorate of Soybean Research, Indore and Regional Research Centre, Amrawati (Dr. PD Krishi Vidyapeeth, Akola) from May 9-11, 2015, which was attended by 82 soybean scientists from various states of the country. The meet was inaugurated by Dr Ravi Prakash Dani, H'ble Vice Chancellor, PDKV, Akola with Dr. B.B. Singh, Asst. Director General (O&P), ICAR as the Chief Guest. Dr. Dani in his inaugural speech stressed upon addressing the emerging problems in soybean cultivation. He expressed great concern over vagaries of monsoon experienced during last two years which led to significantly low productivity, particularly in the state of Maharashtra. Dr. B.B. Singh in his speech assured that soybean scientists would take note of changing situations and orient their research activities to overcome them. Considering the global climatic changes, Dr. V.S. Bhatia, Director, ICAR-Directorate of Soybean Research, Indore stressed upon need to make soybean crop more climate resilient.

8.2. Breeder Seed Production

The indent of soybean breeder seed for 2015, to be produced in 2014, was 15210 quintal. The indent comprised of 29 varieties. The highest indent was for JS 95-60 (5443 q) comprising 35% of total indent. JS 335 (4412 q) and JS 93-05 (3266 q) were the second & third most popular varieties. These three varieties contributed 87% of the total indent. Against this indent, a target of 14918 quintal was set for AICRPS entries. Table 6 shows variety wise, centre wise production of breeder seed in *Kharif* 2014. The total production of 8960 quintal fell far short of indent. The major shortage was in JS 95-60 (70%) and JS 93-05 (55%). JNKVV, Jabalpur marked the large deficit in both varieties while UAS, Dharwad in JS 93-05.

8.3. Front Line Demonstrations

During the year, 23 centers have conducted a total of 714 FLDs on farmer's fields against the target of 700 FLDs in plot of 0.4 ha each. The physical and financial targets and achievements were presented in Table 1. The data from Dholi centre was not received .Of the 714 FLDs, 83.47 and 16.53% were represented by man and farm women. While the representation of categories wise beneficiaries were 11.06% by SC, 9.94% by ST, 44.96% by OBC and 34.03% by general.

Data accrued from 713 FLDs on full package (all the recommended inputs and cultural practices and improved soybean varieties) revealed that the adoption of research emanated improved soybean production technology led to an increase in yield and net returns to the tune of 30.83 and 48.55% over farmers practice which was achieved by the additional expenditure of only Rs. 5570/ha. The difference in gross returns due to improved technology and farmer's practice was 32.77%. Soybean yield as high as 2746 and 2338 kg/ha could be obtained in some of the farmer's field under the improved production technology and farmer's practice at Sangli. The lowest yield under improved technology and Farmer's practice was recorded at Amravati (793 and 743 kg/ha). The yield levels under farmer's practice were lower than 1 t/ha at Amravati, Raipur, Imphal and Palampur centres. The estimated yield gap II was 419 kg/ha.

In all 713 frontline demonstrations, a total of 23 improved varieties have been demonstrated in farmer's fields. The maximum demonstrations was conducted on variety JS 95 60 followed by JS 335. Among the varieties, soybean variety KDS 344 gave highest yield (2746 kg/ha) followed by MACS 1188 (2619 kg/ha), PS 1347 (2500 kg/ha) under improved soybean production practice. The lowest yield was recorded in MAUS 162 (892 kg/ha). Soybean varieties like KDS 344, MACS 1188 and PS 1347 produced more than 2.5 t/ha soybean yield while JS 97 52, DSb21, PS 1368, SL 958, MAUS 2 and SL 525 yielded between 2 to 2.5 t/ha. Varieties like JS 95 60, JS 93 05, RKS 18, NRC 37, MAUS 158, SL 744, PS 1225 and PS 1042 yielded between 1.5 to 2 t/ha. The levels between 1 to 1.5 t/ha were observed in JS 335, Hara soya, PS 1092, CO3 and Shialik varieties.

The details of cost of soybean cultivation have been worked out. The information have not been provided by the different centres like Pantnagar, ITC, NICT, SOPA, Srijan, Dholi, and Sehore. The details of cost of cultivation under improved technology and farmers practice (Table 5) indicated that the soybean cultivation cost under improved technology was higher to the tune of 18.66% as compared to farmers practice cultivation cost. Under the improved production technology, the trend of expenditure was in line- seed and sowing, followed by fertilizer, land preparation, harvesting, threshing, bird watching, interculture operations, herbicide, irrigation, insecticide, seed treatment and inoculation, and fungicide spray. However, in case of farmers practice the trend was seed and sowing, fertilizer, interculture operations, land preparation, harvesting, threshing, hand weeding, herbicide, bird watching, insecticide, irrigation, seed treatment and fungicide use.

8.4. Major Highlights

- Soybean variety MAUS 612 developed at Marathwada Agricultural University, Parbhani was identified for Southern Zone which includes Kolhapur, Sangli belt of

Maharashtra. The variety has and yield potential of 25 q/ha and matures early 91-95 days.

- Variety SL 979 developed at Punjab Agricultural University, Ludhiana was identified for cultivation in Northern Plain Zone.
- Keeping in view the shortage of quality seed target of 17000 quintal of breeder seed production has been earmarked which will ensure availability of seed of improved varieties to the farmers in coming years.
- As soybean rust is a recurring problem in Southern Maharashtra, efficient management strategy has been developed and recommended, which includes spray of Hexaconazole @ 0.1% along with Magnesium Sulphate and Potassium Nitrate both @ 0.1%.
- A package of integrated management of major insects and diseases in soybean has been developed and recommended for adoption by the farmers.
- For efficient and cost effective management of major insect-pests and weeds in soybean, suitable tank-mix combinations of insecticides and weedicides were identified and recommended for different situations of insect-pests and weeds infestation.
- To mitigate inconsistent rainfall and prolonged dry spells during the season application of straw mulch 5 t/ha with anti-transparent KNO_3 @ 1% or $MgCO_3$ @ 5% or Glycerol @ 5% 15 days after flowering are recommended in all the zones for water stress tolerance in soybean.
- Planting of soybean on Ridge and Furrow under Rice-fallow system in North Eastern and Southern zones has been recommended.
- A new pre-emergence herbicide, Sulfentrazone 48 SC @ 360 g a.i./ha has been found effective against major weeds. However, formal recommendations will be made only after it has obtained label for use in soybean crop by CIB-RC.
- Zone wise production technologies have been recommended for harnessing good yields of soybean.

9. PUBLICATIONS

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- वर्मा श्याम किशोर – औद्योगिक विकास और भारतीय कृषि का पर्यावरण पर प्रभाव – सूचना और समाज अंक फरवरी 2015, पेज न. 115-124
- वर्मा श्याम किशोर – राष्ट्र निर्माण एवं भारतीय कृषि में महिलाओं का योगदान – सूचना और समाज अंक फरवरी 2015, पेज न. 125-130
- वर्मा श्याम किशोर – भारत में प्रौद्योगिकी विकास के लिए जैव प्रौद्योगिकी के बढ़ते कदम – सूचना और समाज अंक फरवरी 2015, पेज न. 138 -150
- वर्मा श्याम किशोर, दुपारे बी.यू., जगदीशन ए.के. – खाद्य एवं पोषण – सुरक्षा में सोयाबीन की भूमिका – सूचना और समाज, पेज न. 172 -181.
- वर्मा श्याम किशोर – भारतीय कृषि में सतरंगी क्रांति के नए आयाम – – सूचना और समाज अंक फरवरी 2015, पेज न. 267 - 276
- वर्मा श्याम किशोर – भारतीय कृषि की समृद्धि में जनोपयोगी प्राचीन कृषि विशेषज्ञों का योगदान – 4वीं भारतीय विज्ञान सम्मेलन पणजी गोवा – 5-8 फरवरी 2015
- वर्मा श्याम किशोर – हेल्दी लिविंग के लिए जैविक खेती – कृषक सुरक्षा – पेज सं. 21 – 22, अंक मार्च 2015
- पोस्टर – स्वास्थवर्धक जैविक प्रोटीन का पॉवर हाऊस एवं रावी का फंशनल फुड – सोयाबीन, वर्मा श्याम किशोर – भारतीय विज्ञान सम्मेलन पणजी गोवा – 5-8 फरवरी 2015
- पोस्टर – वर्मा श्याम किशोर – भारतीय कृषि में सूचना प्रौद्योगिक के नए आयाम – अतीत और वर्तमान परिदृश्य – भारतीय विज्ञान सम्मेलन पणजी गोवा – 5-8 फरवरी 2015
- पोस्टर – वर्मा श्याम किशोर – पोषण प्रबंधन के लिए सोया आटा आधारित बेकरी उद्योग खाद्य प्रसंस्करण उद्यम हेतु एक महत्वपूर्ण आयाम – द्विभाषी अंतर्राष्ट्रीय सम्मेलन – डी.आर.डी.ओ., दिल्ली, – 19-21 फरवरी 2015
- वर्मा श्याम किशोर – मौसम आधारित देशज ज्ञान और भारतीय कृषि – 4वीं भारतीय विज्ञान सम्मेलन – 5-8 फरवरी 2015, पणजी गोवा.
- वर्मा श्याम किशोर – ग्रामीण भारत और शिक्षा के निजीकरण के प्रभावी कदम – द्विभाषी अंतर्राष्ट्रीय सम्मेलन रक्षा अनुसंधान तथा विकास संगठन, नई दिल्ली – 19-21 फरवरी 2015.

9.6. Invited lectures in workshops, summer schools, government programmes, meetings, etc.

- Billore SD (2014) 44 rd Annual Group meet of "All India Coordinated Research Project on Soybean" on 25-27 May 2014 at BAU, Ranchi (Jharkhand).
- Kolhe S (2014) Web-based Soybean Disease Expert System. Model Training course on Use of ICTs for increasing production and productivity of Oilseeds. 7-14 Oct, 2014. Directorate of

- Satpute GK. delivered lecture on सोयाबीन की उन्नत किस्में in One day exposure visit of farmers facilitated by M/s NABARD, Dewas at ICAR- DSR, Indore, 16th Dec. 2014.
- Satpute GK delivered lecture on सोयाबीन की बीज उत्पादन तकनीक in One day training programme for Field staff of M/s Ruchi Hirich Seeds Ltd., ICAR- DSR, Indore, 19th Sep. 2014
- Satpute GK. delivered lecture on सोयाबीन के गुणवत्तापूर्ण बीज उत्पादन की उन्नत तकनीक in Haldhar Agri-Expo 2014: A State level Krishi Mela, organized by ICAR-CIAE Bhopal and Farmers' Welfare & Agricultural Development Department, Govt. of M.P. at Lal Parade Ground, Bhopal 26-28 Sep. 2014.
- Satpute GK delivered lecture on सोयाबीन के सफल उत्पादन में बीज का महत्त्व in Krishi Vigyan Mela (Krishi Mahotsav) organized by Farmers' Welfare & Agricultural Development Department, Govt. of M.P., as an expert for Krishak Sangosthi at Distt. Khargaon on 13th Oct. 2014.
- Sharma MP (2014) Prospects of Sebacinales: A novel cultivable mycorrhizal fungal endophytes in Agriculture. Presentation made during Endophyte Expert Consultation Meeting held on 23rd Dec 2014 at ICAR-NBAIM, Mau (UP) India.
- Sharma P. 2014. Invited as guest speaker to deliver on 'Guar Seed to Gum Supply Chain: Issues and Options' in Brainstorming Workshop on 29th May, 2014, at Jodhpur on 'Boosting of Guar Gum Exports: Technical Needs and Requirements and the Way Forward' organised by TIFAC, New Delhi.
- Sharma P. 2014. Invited to deliver lecture on "Producer Organisations: Bridging Farmer-Market Linkages" in a training programme organized by MANAGE, Hyderabad on 01.08.2014 at Bhopal.
- Sharma P. 2014. Invited to deliver special session on 'Integrated Supply Chain Management in Guar: Issues and Challenges' in Guar International Conference 2014 organised by NCDEX from 10th to 11th Oct., 2014 at Jaipur.

10. ON-GOING PROJECTS

Project No.	Project Title	Name of P.I.	Duration
	CROP IMPROVEMENT		
Mega Project 1	**Soybean genetic resource management- Acquisition, conservation, characterization, documentation and utilization**		
NRCS 1.1/87	Augmentation, management and documentation of soybean germplasm	Dr. C. Gireesh	1987-LT
Mega Project 2	Genetic amelioration of soybean for yield, wide adaptability. nutrient use efficiency, resistance to biotic and abiotic stresses and improvement in quality of soybean seed		
NRCS 1.6/92	Genetic improvement for yields and associated characters in soybean	Dr. S. M. Husain	1992-LT
DSR1.18/10	Breeding soybean for wider adaptability using photoperiod response and growth habits	Dr. Sanjay Gupta	2010-17
DSR1.19/10	Breeding soybean for improved phosphorus uptake efficiency	Dr. Sanjay Gupta	2010-15
DSR 5.6b/09	Breeding for drought resistance / tolerance varieties in soybean	Dr. Gyanesh K. Satpute	2008-19
DSR 5.6c/11	Breeding for waterlogging tolerance in soybean	Dr. Mamta Arya	2011-21
NRCS 1.9/99	Evaluation of germplasm and breeding for resistance to rust and YMV and Rhizoctonia root rot	Dr. R. Ramteke	1999-LT
DSR 1.25/13	Development of multiparent intercross population for quantitative traits improvement in soybean	Dr. M. Shivakumar	2013-20
DSR 1.26/13	Studies on impact of field weathering on soybean seed quality and its management	Dr. P. Kuchlan	2013-17
DSR 1.27/14	Application of nano particlesto soybean seed to improve germination	Dr. M.K.Kuchlan	2014-17
DSR 1.29/14	Breeding for increased nitrogen fixation efficiency in soybean	Dr. Mamta Arya	2014-19
Mega Project 3	Molecular breeding and transgenic approaches for soybean improvement		
DSR 1.22/11	Validation of yield QTLs for marker assisted breeding in soybean	Dr. G. Kumawat	2011-14

DSR 1.23/12	Molecular mapping and genomics-assisted breeding for rust resistance in soybean	Dr. Milind B. Ratnaparkhe	2012-17
DSR 1.24/12	Genome diversity of soybean-infecting Begomoviruses in the major soybean cultivating areas in India and RNAi mediated viral gene silencing of Yellow mosaic virus (YMV)	Dr. S. V. Ramesh	2012-16
Mega Project 4	Development of specialty soybean varieties for secondary agriculture and industrial uses		
NRCS 1.12/02	Breeding for food grade characters and high oil content	Dr. Anita Rani	2005-LT
DSR 1.28/14	Mapping and pyramiding QTLS for high oleic acid soybean	Dr. Vineet Kumar	2014-21
	CROP PRODUCTION		
Mega Project 5	Managing the impact of current and future climate variability in soybean		
DSR 5.6/09	Genetic and physiological enhancement for abiotic stresses	Dr. V. S. Bhatia	2008
DSR 5.6a/09	Physiological basis of tolerance/ resistance to abiotic stresses in soybean	Dr. V. S. Bhatia	2009-17
Mega Project 6	Development of technologies for soybean based cropping system efficiency enhancement through resource conservation technologies, nutrient management, plant growth promoting microbes and farm machineries		
DSR 4.10/09	System efficiency enhancement trough resource conservation technologies rotation in soybean based cropping system	Dr. S. D. Billore	2009-20
DSR 4.12/11	Identification of sustainable/resilient soybean production system for changing climate	Dr. S. D. Billore	2011-13
DSR 4.11/10	Growth, rhizosphere properties P acquisition and mobilization of intercropped soybean and maize in soil amended with phosphate	Dr. A. Ramesh	2013,
DSR 6.8/13	Inoculum development of niche AM fungi for application in soybean-based cropping system	Dr. M. P. Sharma	2013-18
DSR 9.8/13	Design, development and validation of tractor operated disc harrow and rotary weeder for soybean	Dr. D. V. Singh	2013-16

	CROP PROTECTION		
Mega Project 7	Surveillance, forecasting and control strategies for insect pest complex in soybean		
DSR 2.8/10	Isolation evaluation and characterization of entomo- pathogenic fungi for insect pest management in soybean	Dr. Y.Sridhar	2013-15
DSR 2.10/13	Conservation and enhancement of natural enemies of insect pests of soybean	Dr. Y. Sridhar	2013-16
Mega Project 8	Developing plant protection modules for mitigating adverse effect of plant diseases in soybean		
DSR 3.9/10	Interactive effect of native isolates of Trichoderma spp., Pseudomonas fluorescence and Sclerotium rolfsii on health and growth of soybean	Dr. G. K. Gupta	2010-15
DSR 3.10/12	Biology Epidemiology and Management of Anthraconose disease in soybean	Dr. M. M. Ansari	2012-17
DSR 3.11/12	Studies on distribution of plant parasitic and entomopathogenic nematodes (EPN)	Dr. K. M. Anes	2012-15
	associated with soybean cultivation and utilization of EPN for the management of major insect pests of soybean		
Activity	Effect of elevated temperature on feeding behavior of S. litura	Dr. A.N.Sharma	
	EXTENSION and ALLIED SCIENCES		
Mega Project 9	Information digitization, technology dissemination, impact analysis and socio-economic research for soybean		
DSR 8.10/11	An impact analysis of awareness and utilization of soybean for food preparation in Madhya Pradesh	Dr. B.U. Dupare	2011-13
DSR 8.9/11	Assessment of interaction of technological adoption and climatic variation with soybean yield	Dr. B.U. Dupare	2011-15
DSR 7.4/11 DSR 7.4/12	Geo-informatic analysis system of soybean On-line data entry system for AICRPS agronomy trials data	Dr. R. M. Patel Dr. Savita Kolhe	2011-14

DSR 8.12/13	Socio-Economic Analysis of Growth in Soybean Crop Productivity and Impact in Madhya Pradesh	Dr. P. Sharma	2013-15

EXTERNALLY FUNDED PROJECTS

S. No.	Sponsoring Agency	Project Title	P.I.	Duration
1.	DAC	DUST Project	Dr. M. Kuchlan	Since 2002
2.	ICAR	Development of transgenic soybean for resistance against YMV.	Dr. Anita Rani	2006-15
3.	DBT	Marker assisted selection for development of Kunitz Trypsin inhibitor free soybean varieties	Dr. Vineet Kumar	2009-15
4.	DST	Soil Carbon Sequestration through Agricultural Practices and Mycorrhizal Fungi in Soybean-Based Cropping system	Dr. M.P.Sharma	2013-15.
5.	ICAR-AMAAS	Identification of high-trehalose producing soybean rhizobia and their integration with AM for enhanced drought tolerance in Soybean	Dr. M.P.Sharma	2014-16

11. IMPORTANT COMMITTEES

There are number of committees which support the R&D programme as well as management and administrative work of the Directorate.

11.1 Research Advisory Committee (w. e. f. 18.9.2013 to 17.9.2016)

Chairman	Dr. V. S. Tomar, Vice Chancellor, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Nagar, Adhartal Jabalpur -482 004 (M.P.)
Member	Dr. V. D. Patil, Ex. Assistant Director General (O&P), ICAR Plot No. 5&6, Sanjeevani Hospital, Mahalaxmi Housing Society Near Kachore Lawn, Manish Nagar, Nagpur- 440015 (Maharashtra)
Member	Dr. M. A. Shankar, Director of Research, University of Agricultural Science, GKVK Campus, Bangalore-560065 (Karnataka)
Member	Dr. O. P. Singh, Ex. Professor (Entomology), JNKVV, Sehore, President (R&D), M/s. Dhanuka Agritek Ltd. Dhanuka House 861-862. Joshi Road, Karol Bag New Delhi-110005
Member	Dr. Shatrughan Pandey, Principal Scientist (Retd.), D-13A/6, Ist Floor, Platinum Green, Ardee City Colony, Sector -52, Gurgaon- 122002 (Haryana)
Member	Director, ICAR- Directorate of Soybean Research, Khandwa Road Indore 452001 (M.P.)
Member	Dr. B. B. Singh, ADG (Oil Seeds & Pulses), ICAR, Krishi Bhawan, New Delhi
Member	Shri G. P. Saxena, Secretary, Society for Horti- Agro Environment Development & Research Programming, 1068, Scheme No. 114, Phase-I, Vijay Nagar, Indore (M.P.)
Member	Shri J. S. Pangaria, Business Advisor & Facilitator 335, Saket Nagar, Indore- 452018 (M.P.)
Member Secretary	Dr. G. K. Gupta, Principal Scientist (Plant Pathology), Directorate of Soybean Research, Khandwa Road, Indore-452001(M.P.) (up to 31 December, 2014) Dr. S.M. Husain, Principal Scientist (Plant Breeding), Directorate of Soybean Research, Khandwa Road, Indore-452001(M.P.) (w.e.f. 1 January, 2015)

11.2 Institute Management Committee (2014-15)

Chairman	Dr. S. K. Srivastava, Director, Directorate of Soybean Research, Khandwa Road, Indore-452 001 (M.P.) - (Up to 30 Nov. 2014)
Chairman	Dr. G.K.Gupta, Acting Director, Directorate of Soybean Research, Khandwa Road, Indore-452 001 (M.P.) - (Up to 31 December 2014)

Chairman	Dr. V.S.Bhatia, Director, Directorate of Soybean Research, Khandwa Road, Indore-452 001 (M.P.) - (w.e.f. 01 January 2015)
Member	Joint Director (Agriculture), Government of Madhya Pradesh, Indore
Member	Director, Soil Conservation & Water Management, Department of Agriculture, Government of Rajasthan, Jaipur
Member	Director of Research, JNKVV, Jabalpur
Member	Dr. S. D. Kulkarni, Project Director, APPD, Central Institute of Agricultural Engineering (CIAE), Nabi Bagh, Bersia Road, Bhopal
Member	Dr. N. P. Singh, Project Coordinator, AICRP on Chickpea, Indian Institute of Pulses Research, Kanpur
Member	Dr. M. Maheshwari, Principal Scientist & Head, Division of Crop Sciences, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad
Member	Shri G. P. Saxena, Secretary, Society for Hort-Agro, Environment Development & Research Programme,1068, Scheme No. 114, Phase-I, Vijay Nagar, Indore
Member	Shri J.S.Pangaria, Business Advisor & Facilitator, 335, Saket Nagar, Indore-452018 (M.P.)
Member	Dr. A. N. Sharma, Principal Scientist, Directorate of Soybean Research Khandwa Road, Indore-452 001 (M.P.)
Member Member Secretary	Finance and Account Officer, Indian Institute of Soil Science (IISS), Bhopal Administrative Officer, Directorate of Soybean Research, Khandwa Road, Indore-452 001 (M.P.)

11.3 Institute Joint Staff Council

Chairman	Dr. S. K. Srivastava, Director (Up to 30 Nov. 2014) Dr. G.K.Gupta Acting Director (Up to 31 December, 2014) Dr. V.S. Bhatia, Director (w.e.f. 01 January 2015)
	OFFICIAL SIDE
Member	Dr. A. N. Sharma, Principal Scientist
Member	Dr. M. P. Sharma, Principal Scientist
Member	Dr. S. D. Billore, Principal Scientist
Member	Dr. Savita Kolhe, Senior Scientist
Member	Finance & Accounts Officer
Member Secretary	Administrative Officer
	STAFF SIDE
Secretary	Shri S. K. Verma, Technical Officer (T-5)
Member	Shri O. P. Vishkarma, Tractor Driver (L/V) (T-5)
Member	Shri R. N. Kadam, Junior Clerk

11.4. Other Committees of the Centre (2014-15)

Official Language Implementation Committee Committee	**Institute Technical Management Unit (ITMU)**
Director, DSR (Chairman)	Director, DSR (Chairman)
Dr. A. N. Sharma,	Dr. G. K. Gupta
Smt. Savita Kolhe	Dr. S.M.Hussain
Shri S. S. Vasuniaya	Dr. V. S. Bhatia
Shri S. K. Pandey	Dr. A. N. Sharma
Shri S. K. Verma	Dr. M.P.Sharma
Administrative Officer	Dr. Vineet Kumar
Finance & Accounts Officer	Finance & Accounts Officer
	Administrative Officer
Priority Setting, Monitoring & Evaluation Cell	**Purchase Advisory Committee**
Dr. V. S. Bhatia (In charge)	Dr. A.N.Sharm (Chairman)
Dr. B. U. Dupare	Dr. S. D. Billore
Dr. S. V. Ramesh	Dr. S.D.Billore
	Dr. Ramesh , S.V.
	Indenter
	Finance & Accounts Officer
	Administrative Officer
Human Resource Development Committee	**Consultancy Processing Cell (CPC)**
Dr. S.D.Billore, (Chairman)	Dr. A. N. Sharma (Chairman)
Dr. B. U. Dupare	Dr. S. D. Billore
Dr. Milind B. Ratnaparkhe	Dr. Vineet Kumar
Dr. S.V.Ramesh	Dr. Gyanesh Satpute
Administrative Officer	Finance & Accounts Officer
	Administrative Officer
Foreign Deputation and Higher Study Committee	**Printing and Publication Committee**
	Dr. G. K. Gupta (Chairman)
Dr. S.M.Hussain (Chairman)	Dr. V. S. Bhatia
Dr. M.P.Sharma	Dr. B.U. Dupare
Dr. Milind Ratnaparkhe	Dr. Y.Sridhar
Dr. S.V.Ramesh	Dr. Greesh C.

Administrative Officer	Dr. Ramesh S.V.
	Dr. Surendra Kumar
Editing (Hindi Publication)	**Editing (English Publication)**
Dr. A. N. Sharma	Dr. D. V. Singh
Dr. B. U. Dupare	Dr. Vineet Kumar
Dr. Rajkumar Ramteke	Dr. Y. Sridhar
	Dr. S. V. Ramesh
Library Advisory Committee	**Hindi Cell**
Dr. M. M. Ansari (Chairman)	Dr. A. N. Sharma (In charge)
Dr. D.V.Singh	Shri S. K. Verma
Dr. R. Ramteke	Shri Avinash Kalenke
Dr. Poonam Kuchlan	
Dr. Gireesh C.	
Finance & Accounts Officer	
Administrative Officer	
Dr. Surendra Kumar	
Works Committee	**Estate Committee**
Dr. M. P. Sharma (Chairman)	Dr. M. P. Sharma (Chairman)
Dr. Vineet Kumar	Dr. Vineet Kumar
Dr. A.Ramesh	Shri R. N. Srivastava
Dr. B.U.Dupare	Shri R. C. Shakya
Estate Officer	Shri S. N. Verma
Administrative Officer	Administrative officer
Public Information Officer	**Public Relation Officer**
Dr. G. K. Gupta	Administrative Officer
Dr. A. N. Sharma	Assistant Administrative Officer
Administrative Officer	
ARIS Committee	**House Allotment Committee**
Dr. A. N. Sharma (Chairman)	Dr. S.M.Hussain (Chairman)
Dr. Savita Kolhe	Dr. M.P. Sharma
Shri Ram Manohar Patel	Dr. Purshottam Sharma
	Secretary, IJSC
	Administrative Officer

Centralized Public Grievance Cell and Monitoring Systems (CPGCMS)	**Women Harassment Complaint Committee**
Dr. S. M. Hussain	Dr. Savita Kolhe (Chairperson)
	Dr. Poonam Kuchlan
	Dr. Gireesh C.
	Ku. Priyanka Sawant
	Third party representative
	(As when Required)
	Administrative Officer
Nodal Scientist Agro biodiversity	**Nodal Officer, RFD Unit**
Consortium Project	Dr. Anita Rani (w.e.f. 31.01.2014)
Dr. S. M. Hussain	
Nodal Scientist IASRI-NAIP	**Library In Charge**
Statistics Project	Dr. M. M. Ansari (up to 28.12.2014)
Shri Ram Manohar Patel	Dr. Surendra Kumar (w.e.f. 29.12.2014)
Guest House /Management Committee	**Publicity Committee**
Dr. V. P. Singh Bundela	Dr. Purshottam Sharma (Chairman)
Shri Om Prakash Vishvakarma	Dr. Savita Kolhe
Shri R. C. Shakya	Dr. Gyanesh Satpute
Shri S. N. Verma	Shri S. K. Verma
Administrative officer	Shri D. N. Baraskar
Technical Specification Committee	**Price Fixation Committee**
Dr. Sanjay Gupta (Chairman)	Dr. S. D. Billore (Chairman)
Dr. M.P.Sharma	Dr. M.K.Kuchlan
Dr. Millind Ratnaparkhe	Store officer
Dr. Giriraj Kumawat	Farm Manager
Indenter	Estate officer
	Finance & Account Officer
	Administrative Officer
Farm Produce Disposal and Price Fixation Committee	**Condemnation and Auction Committee**
Dr. S. D. Billore (Chairman)	Dr. Anita Rani (Chairperson)
Shri Charan Singh	Dr. B.U.Dupare

Dr. V. P. S. Bundela	Dr. Giriraj Kumawat
Finance & Accounts Officer	Store officer
Administrative Officer	Estate Officer
	Shri Ram Manohar Patel
	Finance & Accounts Officer
	Administrative Officer
Laboratory In Charges	**Security Cell**
Dr. M. M. Ansari - Pathology	Dr. V. P. S. Bundela
Dr. V. S. Bhatia - Physiology	Dr. Giriraj Kumawat
Dr. S. M. Husain - Plant Breeding,	Shri O. P. Vishwakarma
Seed Technology, DUS Testing, Germplasm	
Dr. Milind B. Ratnaparkhe- Biotechnology	**Physical Verification Committee**
Dr. A. N. Sharma - Entomology	Dr. Vineet Kumar (Chairman)
Dr. Anita Rani - Transgenics	Dr. Y. Sridhar
Dr. M. P. Sharma - Microbiology	Dr. P. Sharma
Dr. Vineet Kumar – Biochemistry	Shri Charan Singh
Dr. S. D. Billore - Agronomy	
Dr. Savita Kolhe - Computer	**Estate Officer**
Dr. B. U. Dupare - Extension	Shri R. N. Shrivastava
Student Affairs Committee	**Record Officer**
Dr. Vineet Kumar (Chairman)	Assistant Administrative Officer
Dr. A. Ramesh	Vehicle In charge
Dr. Millind B. Ratnaparkhe	Dr. Nikhlesh Pandya
Dr. Gyanesh Satpute	
	Store In charge
	Shri Charan Singh
	Tofu Plant In charge
	Dr. V. P. Singh Bundela

12. PARTICIPATION IN SEMINAR, SYMPOSIUM, CONFERENCE, WORKSHOPS, ETC

Participant	Event	Venue and date
Dr. Ramesh S.V.	Legume (Medicago) Bioinformatics workshop. NSF- funded Bioinformatics Workshop organized by J. Craig Venter Institute (JCVI).	J. Craig Venter Institute (JCVI). Rockville, Maryland, USA. 16th -20th June 2014
Dr. Ramesh S.V.	Brief Introduction to Statistics in R. Department of Food Science and Human Nutrition, Washington State University, Pullman USA	Department of Food Science and Human Nutrition, Washington State University, Pullman USA. 15th Jul -05th Aug. 2014
Dr. Ramesh S.V.	American Phytopathological Society-Canadian Phytopathological Society (APS-CPS) Joint Meeting 2014.	Minneapolis, Minnesota, USA, 9th to 13th Aug. 2014
Dr. G. Kumawat	National Symposium on crop Improvement for inclusive sustainable development	Panjab Agricultural University, Ludhiana 7th -9th Nov. 2014
Dr. Shivakumar, M.	National Symposium on Crop Improvement for Inclusive Sustainable Development, Punjab Agricultural University, Ludhiana,	PAU, Ludhiana, Nov 7th -9th , 2014
Dr. G.K. Satpute	State-level Sustainable Agriculture Mission Committee Meeting on Rainfed Area Development. Department of Farmers' Welfare & Agricultural Development, Govt. of M.P.	Vallabh Bhavan, Bhopal on 15th Dec. 2014
Dr. G.K. Satpute	Workshop on "Redefining the Priorities in the National Action Plan for Genetic Resources Management in India". ICAR-NBPGR, New Delhi and NAAS, New Delhi	NASC Complex, New Delhi on 23rd -24th Dec. 2014
Dr. G.K. Satpute	Annual Breeder Seed Review Meeting 2015. ICAR-DSR, Maunath Bhanjan & Department of Agriculture & Cooperation	ICAR Research Complex for NEH Region, Umiam, Meghalaya on 7th – 8th Jan. 2015
Dr. Ratnaparkhe, M.K.	5th International Conference on Next Generation Genomics and Integrated Breeding for Crop Improvement	ICRISAT, Hyderabad, during 18th -20th Feb. 2015.

13. DISTINGUISHED VISITORS

The following are the eminent persons visited this Directorate during the year 2014-15

S. No.	Name and Affiliation	Date of Visit
1.	Shri Mamika Dabathe, State Ministry Agriculture and Rural Development	25.07.2014
2.	Shri Premier E. S. Magashle, Free- State Proving, Republic of South Africa	25.07.2014
3.	Prof. Anwar Alam, Ex.VC, SKVAST –K and IGKV, Raipur and Ex. DDG (Eng.). s-319 Vivekanand MA, PLA-2, Sector-5, New Delhi	14.08.2014
4.	Shri Raghav Chandra, IAS, Additional Secretary, Financial Advisor, Ministry of Agricultural & Cooperative, Government of India, Krishi Bhawan, New Delhi	29.08.2014
5.	Dr. S.Rajendra Prasad. Project Director, Director of Seed Research, Mau (U.P.)	24.09.2014

14. PERSONNEL

(As on 31 March 2015)

A.	**Research Management**		
1.	Dr. S. K. Shrivastava	Director (Upto 30 November 2014)	
2.	Dr. G.K.Gupta	Acting Director (Up to 31 December 2014)	
3.	Dr. V.S.Bhatia	Director (w.e.f. 01 January 2015)	
B.	**Scientific**		
4.	Dr. G. K. Gupta	Principal Scientist (upto 30.11.2014)	Plant Pathology
5.	Dr. S. M. Husain	Principal Scientist	Plant Breeding
6.	Dr. V. S. Bhatia	Principal Scientist (upto 31.12.2014)	Plant Physiology
7.	Dr. M. M. Ansari	Principal Scientist	Plant Pathology
8.	Dr. A. N. Sharma	Principal Scientist	Entomology
9.	Dr. Sanjay Gupta	Principal Scientist	Plant Breeding
10.	Dr. Anita Rani	Principal Scientist	Plant Breeding
11.	Dr. S. D. Billore	Principal Scientist	Agronomy
12.	Dr. Mahaveer P. Sharma	Principal Scientist	Microbiology
13.	Dr. Vineet Kumar	Principal Scientist	Biochemistry
14.	Dr. B. U. Dupare	Principal Scientist	Agricultural Extension
15.	Er. (Dr.) D. V. Singh	Senior Scientist	Farm Machinery and Power
16.	Dr. A. Ramesh	Senior Scientist	Soil Science
17.	Dr. Savita Kohle	Senior Scientist	Computer Application
18.	Dr. Y. Sridhar	Senior Scientist	Entomology
19.	Dr. Milind B. Ratnaparkhe	Senior Scientist	Biotechnology
20.	Dr. Gyanesh Satpute	Senior Scientist	Genetics
21.	Dr. Purushottam Sharma	Senior Scientist	Agricultural Economics
22.	Dr. Raj kumar Ramtake	Scientist (Senior Scale)	Genetics
23.	Dr. Poonam Kuchlan	Scientist (Senior Scale)	Seed Technology
24.	Dr. S. V. Ramesh	Scientist	Biotechnology
25.	Dr. C. Gireesh	Scientist	Plant Breeding (Upto 22 Nov. 2014)
26.	Dr. M. K. Kuchlan	Scientist	Seed Technology
27.	Shri Ram Manohar Patel	Scientist	Agril. Statistics
28.	Dr. K. M. Anes	Scientist	Nematology

29. Dr. Giriraj Kumawat	Scientist	Biotechnology
30. Dr. Mamta Arya	Scientist	Genetics
31. Dr. M. Shivakumar	Scientist	Genetics and Plant Breeding
32. Dr. Neha Pandey	Scientist	Food Technology
C. Technical		
33. Dr. Surendra Kumar	Chief Documentation Officer	Library & Documentation
34. Shri R. N. Singh	Chief Technical Officer	Field & Farm
35. Dr. Nikhlesh Pandya	Chief Technical Officer	Field & Farm
36. Shri S. K. Pandey	Assitt. Chief Technical Officer	Field & Farm
37. Shri Charan Singh	Assitt. Chief Technical Officer	Field & Farm
38. Dr. V. P. S. Bundela	Assitt. Chief Technical Officer (Farm Manager)	Field & Farm
39. Dr. Yogendra Mohan	Assitt. Chief Technical Officer	Field & Farm
40. Dr. Sushil Kumar Sharma	Assitt. Chief Technical Officer	Field & Farm
41. Shri S. S. Vasunia	Assitt. Chief Technical Officer	Field & Farm
42. Shri R. N. Srivastava	Assitt. Chief Technical Officer	Field & Farm
43. Shri D. N. Baraskar	Senior Technical Officer	Artist & Photograpy
44. Shri S. K. Verma	Technical Officer	Field & Farm
45. Shri O. P. Vishwakarma	Technical Officer (L/V)	Tractor Driver
46. Shri Mahaveer Singh	Senior Technical Assistant	Field & Farm
47. Shri I. R. Khan	Senior Technical Assistant	Field & Farm
48. Shri Devendra Singh Yadav	Technical Assistant	Field & Farm
49. Shri Gorelal Chouhan	Technical Assistant	Field & Farm
50. Shri Francis Yunis	Technical Assistant (L/V)	Staff Car Driver
51. Shri R. C. Shakya	Assitt. Technical Assistant	Field & Farm
52. Shri Bilbar Singh	Senior Technician (L/V)	Staff Car Driver
53. Shri Shambhu Nath Verma	Senior Technician	Field & Farm
D. Administration and Accounts		
54. Shri A. K. Maheshwari	Finance and Account Officer	
55. Shri S.P.Singh	Asstt. Administrative Officer	Up to 27th Nov. 2014
56. Shri S.P.Singh	PA to Director	w.e.f. 28th Nov. 2014
57. Shri Lokendra Soni	PA to Director.	
58. Shri Ajay Kumar	Assistant	
59. Ku. Priyanka Sawan	Assistant	
60. Shri. Ravishankar Kumar	Assistant	

61. Shri Avinash Kalanke	Senior Clerk
62. Shri Anil Kumar Carrasco	Senior Clerk
63. Shri R. N. Kadam	Junior Clerk
64. Shri Sanjeev Kumar	Duplicating Operator
E. Skilled Supporting Staff	
65. Shri Gulab Singh	
66. Shri Dhan Singh	
67. Shri Roop Singh	
68. Shri Nirbhay Singh	
69. Shri Bhav Singh	
70. Shri Janglia	
71. Shri Surla	
72. Shri Sur Singh	
73. Smt. Prakaswati Sura	
74. Shri Balveer Singh	
75. Shri Prahlad Singh	

15. APPOINTMENTS, PROMOTIONS, TRANSFER, ETC.

15.1. Appointments

S. No.	Name	Post	Date of joining
1.	Dr. Neha Pandey	Scientist (Food Technology)	8th April 2014
2.	Shri Vikas Kumar Keshari	Technical Assitt. (Hindi Translator)	26th March 2015

15.2. Promotions

S. No.	Name	Promoted to the Post of	w.e.f.
1.	Dr. B.U.Dupare	Principal Scientist	15.02.2014
2.	Shri R.N.Singh	Chief Technical Officer	20.04.2014
3.	Dr. Nikhlesh Pandya	Chief Technical Officer	09.12.2013
4.	Dr. Sushil Kumar Sharma	Assitt. Chief Technical Officer	17.11.2012
5.	Shri R.N.Shrivastava	Assitt. Chief Technical Officer	16.10.2013
6.	Shri S.S.Vasuniya	Assitt. Chief Technical Officer	27.03.2013
7.	Shri Mahaveer Singh	Senior Technical Assistant	18.08.2012
8.	Shri I.R.Khan	Senior Technical Assistant	31.10.2013

15.3. Deputations/Selection

S.No.	Name	As	Period
1.	Dr. M.P.Sharma	As Visiting Scientist to USDA-ARS, Beltsville, MD, USA under DBT- Cutting Edge Research Enhancement and Scientific Training Award (DBT-CREST Award) by Department of Biotechnology, Govt. of India	October 19th 2013 to April 21st, 2014
2.	Dr. S.V.Ramesh	As Visiting Scientist to Washington State University, Pullman, WA, USA under DBT- Cutting Edge Research Enhancement and Scientific Training Award (DBT-CREST Award) by Department of Biotechnology, Govt. of India	October 14th 2013 to October 13th 2014

15.4. Transfers

Name	From	To	w. e. f.	
1.	Dr. Gireesh C.	DSR, Indore	DRR, Hyderabad	12.11.2014
2.	Shri Lokendra Soni	DSR, Indore	CIAE, Bhopal	31.03.2015

15.5. Retirement:

Dr. G.K. Gupta, Principal Scientist and Acting Director, W.E.F.31st December 2014

15.6. Higher education

Nil

15.7. Obituary

Nil

16. INFRASTRUCTURAL DEVELOPMENT (2014-15)

16.1. Works

16.2 Equipments

The following major equipment costing above Rs. 50, 000 were purchased:-

1.	Vis-Vis Spectrometer-2
2.	Root Scanner with software miw rhizotrom
3.	Ultra water purification system
4.	Dual cool gel electrophorus
5.	Gas liquid chromatography
6.	Densitometer
7.	Fluorescent Microscope

17- राजभाषा कार्यान्वयन

संवैधानिक प्रावधानों के अनुसार राजभाषा कार्यान्वयन हेतु सरकारी एवं सरकार के अधीनस्थ या संबद्ध कार्यालयों, सार्वजनिक उपक्रमों एवं प्रतिष्ठानों में कार्यरत प्रत्येक कर्मचारी प्रतिबद्ध है । उसी संकल्प को व्यवहारिक रूप प्रदान करने हेतु भा.कृ.अनु.परि. सोयाबीन अनुसंधान निदेशालय, इंदौर में भी विगत वर्षों से इस दिशा में अनेकानेक कदम उठाए । जिनके फलस्वरूप सोयाबीन अनुसंधान निदेशालय में राजभाषा कार्यान्वयन के क्षेत्र में उत्तरोत्तर प्रगति के साथ अनेक आधारभूत कार्य हुए हैं, जो राजभाषा के प्रगामी प्रयोग में अत्यंत सार्थक सिद्ध हो रहे हैं। राजभाषा कार्यान्वयन के क्षेत्र में भा.कृ.अनु.परि.-सोयाबीन अनुसंधान निदेशालय की प्रगति आख्या का एक स्वर्णिम झलक आपके समक्ष प्रस्तुत है । उपरोक्त गतिविधियों पर यदि दृष्टिपात करें तो ज्ञात होता है कि निदेशालय में राजभाषा कार्यान्वयन की दिशा में एक सकारात्मक एवं सार्थक कार्य हो रहा है, जो निदेशालय में हिन्दी के सुनहरे भविष्य का आभास कराती है।

क. प्रोत्साहन योजनाएं : निदेशालय में सर्वप्रथम राजभाषा संबंधित गतिविधियों के प्रसार-प्रचार हेतु प्रोत्साहन योजनाओ पर ध्यानाकर्षित किया गया । चूँकि यह "क" स्थित क्षेत्र है फिर भी कर्मचारियों, अधिकारियों एवं वैज्ञानिको में हिन्दी सम्बंधित जागरूकताओं की वृद्धि करने हेतु समयानुसार प्रोत्साहन योजनाओं का आयोजन किया जाता है, ताकि सभी संवर्गो को हिन्दी में कार्य हेतु प्रेरणा मिलता रहे । अतैव प्रोत्साहन योजना के माध्यम से इस कार्य में अत्याधिक सार्थकता प्रदान करने की कोशिश की जा रही है ।

ख. हिन्दी कार्यशालाएं : इसी दिशा में निदेशालय में हिन्दीमय वातावरण विनिर्मित करने हेतु प्रत्येक तिमाही में कम से कम एक हिन्दी कार्यशाला का आयोजन किया जा रहा है । जिसमें इकाई के सभी सवंर्गों को आमंत्रित किया जाता है तथा संबंधित विषयानुसार कार्यशालाएं सम्पन्न की जाती है । वर्ष 2014-15 में 04 कार्यशालाओं का आयोजन किया गया, जिसकी सूचि निम्नवत है :

क्र.	दिनांक	विषय	अतिथि वक्ता
1	18 जून 2014	विज्ञान तकनीकी प्रद्योगिकी में हिन्दी भाषा और सम्प्रेषण	डॉ शोभा चतुर्वेदी अध्यापक हिन्दी विभाग, शासकीय नवीन विज्ञान महाविद्यालय, इंदौर ।
2	4 सितम्बर 2014	भाषा की अभिव्यक्ति और शब्द शक्ति प्रभाव तथा भाषा में वर्तनी का तात्पर्य	डॉ. मिनाक्षी जोशी, अध्यक्ष भाषा अध्ययनशाला, महरानी लक्ष्मीबाई शासकीय कन्या स्नातकोत्तर, इंदौर ।
3	24 नवम्बर 2014	संस्कृत भाषा और हिन्दी का प्रतिनिधित्व	डॉ. विनायक पाण्डे, प्राचार्य संस्कृत महाविद्यालय, इंदौर
4	27 मार्च 2015	भाषा का विकास और प्रसार कैसे हुआ	डॉ. योगेंद्र नाथ शुक्ल, विभागाध्यक्ष हिंदी अनुभाग, शासकीय श्री निर्भय सिंह पटेल विज्ञान, इंदौर ।

ग. प्रशिक्षण : निदेशालय में राजभाषा के प्रचार-प्रसार हेतु कृषको एवं प्रशिक्षणार्थियों को प्रशिक्षण संबंधित सारी सामग्रियाँ हिन्दी में भी प्रदान की जा रही है । इस दृष्टिकोण से सम्पूर्ण वर्ष में 9000 प्रतियाँ प्रसार फोल्डर एवं 10000 प्रतियाँ प्रसार बुलेटिन वितरित की गई ।

घ. राजभाषा नीति पर जागरूकता कार्यक्रम : उक्त प्रशिक्षणों के अतिरिक्त निदेशालय में कर्मचारियों, अधिकारियों एवं वैज्ञानिको हेतु राजभाषा नीति के संवैधानिक प्रावधानों से अवगत कराने तथा इसके प्रति जागरूक करने हेतु समय-समय पर राजभाषा नीति विषय पर विचारों का आदान-प्रदान किया जा रहा है ।

ङ. अनुवाद द्विभाषी प्रपत्र : निदेशालय में कार्यालयीन कार्य में प्रयुक्त होने वाले विभिन्न पत्रों, प्रपत्रों आदि का अनुवाद कार्य भी प्रगति पर है, जिससे दैनिंदिन के साथ ही प्राय: प्रयुक्त होने वाले सभी पत्रों, प्रपत्रों के द्विभाषी मुद्रित रूप को प्रभावी किया जा सके । यह कार्य राजभाषा क्रियान्वयन की दिशा में स्थाई एवं आधारभूत उपलब्धि है ।

च. मौलिक लेखन कार्य का प्रादुर्भाव : निदेशालय में राजभाषा संबंधी विभिन्न क्रियाकलापों के साथ मौलिक लेखन कार्य को द्रुतगामी आयाम प्रदान करने में श्री श्याम किशोर वर्मा, तकनीकी अधिकारी लेखक एवं डॉ. बी.यू दुपारे, प्रधान वैज्ञानिक सह लेखक को उत्कृष्ट लेखन हेतु राजभाषा विभाग, गृह मंत्रालय का प्रथम राजभाषा पुरस्कार महामहीम राष्ट्रपति श्री प्रणव मुखर्जी के कर-कमलों से दिनांक 14 सितम्बर 2014 को राष्ट्रपति भवन में प्रदान किया गया। श्री श्याम किशोर वर्मा को रक्षा अनुसंधान एवं विकास संगठन रक्षा मंत्रालय, दिल्ली द्वारा आयोजित वैज्ञानिक तकनीकी अंतर्राष्ट्रीय राजभाषा सम्मेलन में भाग लेकर शोध-पत्र एवं पोस्टर प्रस्तुतीकरण किए तथा उनके द्वारा लिखित आलेख छः पुस्तकों में बुक चेप्टर के रूप में प्रकाशित किये गए, जो राजभाषा कार्यान्वयन के क्षेत्र में एक दस्तावेजी कार्य है।

छ. हिन्दी में कार्य हेतु साफ्टवेयर एवं अन्य सुविधाएं: राजभाषा हिन्दी के अधिकाधिक प्रयोग के साथ इसमें कर्मचारियों, अधिकारियों एवं वैज्ञानिकों की सहभागिता में लगातार वृद्धि हेतु समस्त कम्प्यूटरों पर हिन्दी संबंधित साफ्टवेयर "नवीन अक्षर" को भी उपलब्ध कराया गया है, जिसके माध्यम से कर्मचारियों, अधिकारियों एवं वैज्ञानिकों अति सरलता से अपने दैनिंदिन के कार्यों में हिन्दी का प्रयोग कर सकते हैं।

ज. हिन्दी में कार्य हेतु यूनीकोड सुविधा : यद्यपि निदेशालय के सभी कम्प्यूटर्स पर हिन्दी फॉन्ट की सुविधा उपलब्ध है, इसके अतरिक्त संपूर्ण भारत में प्रचलित यूनिकोड फॉन्ट की भी सुविधा समस्त कम्प्यूटर्स पर उपलबध की गई है। इसी श्रृंखला में प्रतिदिन एक शब्द हिन्दी एवं अंग्रेजी को द्विभाषी रूप में "आज का शब्द" के रूप में प्रदर्शित किया जा रहा है, ताकि कर्मचारियों, अधिकारियों एवं वैज्ञानिकों के हिन्दी शब्द ज्ञान में वृद्धि करने के साथ ही साथ हिन्दी के कार्यालयीन उपयोग में भी सहायता प्रदान कर सके।

झ. राजभाषा कार्यान्वयन समिति की तिमाही बैठक

- प्रथम बैठक : दिनांक 21 जून 2014
- द्वितीय बैठक : दिनांक 11 अगस्त 2014
- तृतीय बैठक : दिनांक 19 नवम्बर 2014
- चतुर्थ बैठक : दिनांक 24 फरवरी 2015