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Molecular Characterization of Replication Initiator Protein Gene (rep) Encoded by Mungbean Yellow Mosaic India Virus (Genus: *Begomovirus*; Family: *Geminiviridae*) Infecting Soybean in Central India

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ABSTRACT

Begomoviruses infecting legumes (family *Geminiviridae*) pose a serious threat to the productivity of grain legumes in general and soybean in particular. In this study, replication initiator protein gene (rep) of begomovirus causing yellow mosaic disease on soybean in Central Indian region is characterized. A total of 85 complete rep gene sequences of legume begomoviruses including sequence reported in this study were employed to delineate genetic diversity, population selection and evolutionary lineage. Nucleotide diversity analysis revealed that the major legume yellow mosaic viruses (LYMVs) viz., MYMV and MYMIV are less diverse than legume begomovirus population as a whole. Test of neutral evolution also reiterates the operation of purifying selection and population expansion of major legume begomoviruses. However interestingly, LYMVs as a whole, show decrease in population size and act of balancing or neutral selection. Recombinants have also been detected only among the isolates of MYMIV suggesting frequent genetic exchanges.

Key words: *Begomovirus*, evolutionary genomics, genetic diversity, population genetics, soybean

Begomoviruses infecting legumes belong to family *Geminiviridae* - a larger family of plant infecting viruses (Brown *et al.*, 2015). Legume Begomoviruses are transmitted by whiteflies and cause Yellow Mosaic Disease (YMD) which is a major constraint that limits productivity of the legumes in general and soybean in particular (Varma and Malathi, 2003). The YMD of legumes in SE Asia was attributed to four species of *Begomoviruses* such as, Mungbean yellow mosaic virus (MYMV), Mungbean yellow mosaic India virus (MYMIV), Dolichos yellow mosaic virus (DoYMV) and Horsegram yellow mosaic virus (HgYMV) and are

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collectively called as legume yellow mosaic viruses (LYMVs) (Fauquet and Stanley, 2003; Qazi *et al.*, 2007). In India the first report of disease was in year 1960 (Nariani, 1960), later Suteri (1974) reported the disease damage in soybean. Among the LYMVs, *Mungbean Yellow Mosaic Virus* (MYMV) and *Mungbean Yellow Mosaic India Virus* (MYMIV) are the major YMVVs that were reported to cause disease epidemics in mungbean, cowpea (Nariani, 1960), horsegram (Muniyappa *et al.*, 1975), lablab bean (Capoor and Varma, 1948) and French bean (Singh, 1979) in India. Further, economic loss caused by the infection of yellow mosaic virus accounts for 300 million US \$ in all the legume crops including soybean (Varma and Malathi, 2003).

Genomes of yellow mosaic viruses are characterized with two ssDNA genomic components *i. e.* DNA-A and DNA-B, each approximately of 2800nts in length hence the genome is bipartite. Genome encodes for proteins in both sense and complementary strands [Qazi *et al.*, 2007]. DNA-A encodes coat protein (AV1) and pre-coat proteins (AV2) in viral sense and three functional ORFs (AC1, AC2 and AC3) in its complementary sense strand. Among these, ORF AC1 encodes for replication initiator protein and AC3 encodes for replication enhancer protein. Thus, genomic component DNA-A encodes for proteins involved in encapsidation and replication. Component DNA-B encodes for the proteins involved in movement functions as ORF BC1 encoded nuclear shuttle protein is involved in

intracellular transport of viral ssDNA, whereas ORF BV1 encoded movement protein (MP) is implicated in cell to cell movement of the virus particle (Bridson *et al.*, 2010). Among the viral derived proteins, ORF AC1 encoded replication initiator protein is essential for the virus to establish infection as it is involved in the initiation of rolling circle amplification of *Begomovirus* genome.

Cultivation of soybean -a major oil seed crop- is gaining momentum with increasing acreage and export potential of de-oiled cake (DOC) obtained from the crop (Anonymous, 2014-15). At this moment the damage inflicted upon soybean by yellow mosaic virus is a hindrance to meet the demand for the soy crop and its products. Studies have also reported that *mungbean yellow mosaic India virus* causes the disease in Northern and Central Indian region (Usharani *et al.*, 2004; Girish and Usha, 2005; Ramesh *et al.*, 2013). The present research aims to perform sequence characterization of replication initiator protein gene of *Begomovirus* causing YMD in soybean in Central India, a focal point for soybean cultivation and processing. Notwithstanding, significant yield losses due to LYMVs in the cultivation of grain legumes, studies on genetic diversity, population selection and evolutionary lineage analysis of YMVVs are uncommon. In order to fill this knowledge gap, global analysis of replication initiator protein gene was conducted to decode the genetic diversity, and population structure and evolutionary lineage analysis of legume infecting *Begomoviruses*.

MATERIAL AND METHODS

Sample collection and DNA Extraction

Symptomatic soybean leaves from central Indian state of Madhya Pradesh were surveyed and collected. Occurrence of apparent mosaic symptoms on leaves and association of whiteflies with the plants formed the basis for leaf sample collection. Total DNA from infected soybean leaves expressing viral symptoms and healthy leaf samples (control), were isolated as described previously (Doyle and Doyle, 1987).

PCR Amplification, cloning and sequencing

The DNA extracted was used as template for PCR amplification of replication initiator protein gene (*rep*) using the primers R13: 5' ATGGATCCATGCCAAGGGAAGGTCT 3' and R14: 5' TGAAAGCTTTCAATTCGAGATCGTCTG A 3'. The reaction volume (20 µl) comprised 1µl of diluted DNA (50 ng/µl) as template, 1 µl each of forward and reverse primers (100 ng/µl), other components of PCR like 1µl of dNTPS (10 mM), 1µl of MgCl₂, 1 U of *Taq* polymerase (MBI-Fermentas). The temperature profile for PCR amplification comprise 1 cycle of DNA denaturation at 94°C for 5 min followed by 30 cycles each having a denaturation at 94°C for 30 sec. annealing at 55°C for 40 sec. and a primer extension at 72°C for 30 sec. followed by final extension of 72°C for 5 min. Amplified *rep* gene was cloned in pGEM-T easy vector (Promega, Madison, USA) and sequenced at Merck Biosciences (Bengaluru, India). Nucleotide sequence

was deposited in GenBank, NCBI, USA under accession numbers (KC836518).

Phylogeny reconstruction

Replication initiator protein gene (*rep*) sequences of other legume infecting *Begomoviruses* were obtained from GenBank database. A total of 85 complete *rep* gene sequences derived from MYMIV, MYMV, DoYMV, and HgYMV were obtained from GenBank database including the sequence reported in this study. Sequence alignment and phylogenetic trees were generated in MEGA 6 using ClustalW algorithm (Tamura *et al.*, 2013). The phylogenetic tree was constructed using the maximum likelihood method. In order to measure the reliability of nodes in the phylogenetic tree, bootstrap re-sampling analysis was carried out with 1000 replicates.

Molecular Diversity and Neutrality tests

To study *rep* gene nucleotide diversity and DNA polymorphism, DnaSP (Librado and Rozas, 2009) was used. The analysis included quantifying the levels of DNA polymorphism such as the number of haplotypes and haplotype diversity in order to analyze the distribution pattern of DNA variation, or to compare alternative evolutionary scenarios. To test the theory of neutral evolution of *rep* gene test statistics like Tajimas's D (Tajima, 1989); Fu and Li's D and Fu and Li's F (Fu Y, 1997; Fu and Li, 1993) were determined employing DnaSP software [Librado and Rozas 2009].

Recombination detection

Recombination among the

replication initiator protein gene sequences derived from all known legume *Begomoviruses* were detected using Recombination Detection Program-4 (RDP 4 Beta 4.16) (Martin *et al.*, 2010). Multiple sequence alignment of rep gene sequences created in MEGA 6 was used as a query in the recombination detection program. The analysis was run with default settings except that highest acceptable p-value was set at 0.05 for all nine recombination detection methodologies (RDP, BootScan, GENECONV, MAXCHI, CHIMAERA, SISCAN, LARD, PhylPro and 3SEQ) available in RDP4. In addition, to avoid false positives, recombination events detected by 3 and more of these methods alone were considered for analysis.

RESULTS

Characterization of Replication initiator protein gene (*rep*)

Rep gene isolated from YMV infected soybean leaf samples was found to be 1089bp in length (KC836518) [<http://www.ncbi.nlm.nih.gov/nuccore/KC836518>]. The accession (KC836518) displayed highest nucleotide sequence identity of 98 per cent with soybean isolate of MYMIV (AJ416349) and 96 per cent nucleotide identity with various other MYMIV isolates (FM208843; AY271895; AM950268; FM208842). The replication initiator protein sequence reported in this study is accessioned in the GenBank as locus (AGR83968.1) [<http://www.ncbi.nlm.nih.gov/protein/523510116>]. Amino acid sequence identity analysis revealed that the protein ID AGR83968.1 displayed 99 per cent

sequence identity with accessions ACD40298.1 and ABD60109.1 which are replication initiator proteins encoded by MYMIV infecting soybean and cowpea isolates respectively.

Rep gene diversity, polymorphism and molecular phylogeny

In order to study the nucleotide sequence diversity and to perform haplotype analysis all known complete *rep* gene sequences encoded by LYMV were obtained from GenBank database and along with the sequences from this report were employed as query in DnaSP software (Librado and Rozas, 2009). Nucleotide diversity (π) analysis of Rep gene encoded by all MYMIV ($\pi=0.03034$) and MYMV ($\pi=0.03273$) revealed that the diversity between these two major species of LYMV is almost negligible (Table 1). However nucleotide diversity of LYMV as a whole revealed relatively high values ($\pi = 0.13915$). This could be due to relatively low nucleotide diversity of HgYMV (0.01900). On absolute terms MYMIV ($S = 201$) showed more number of polymorphic sites than MYMV ($S = 155$). However, taking into consideration the number of isolates under analysis, MYMV ($S = 155$ for a sample size of $N = 22$) displayed more number of segregating sites than expected as against relatively low polymorphic sites ($S = 201$ for $N=48$) of MYMIV (Table 1). Thus, LYMV population as whole was found to have highest number of segregating sites ($S = 532$) corroborated with highest nucleotide diversity ($\pi = 0.13915$). Further number of segregating sites in the population of DoYMV ($S = 97$) is also found to be relatively high considering

the number of isolates studied (Fu and Li, 1993). Haplotype analysis was performed to identity single nucleotide polymorphism variants within species, genotypes and in whole population. The uniqueness of haplotypes present in the virus population was inferred from the parameter haplotype diversity (Hd). It

thus revealed high level of haplotype diversity overall in the population and among the respective genotypes (Table 1). Thus, *Begomovirus* infecting legumes are characterized with relatively low nucleotide diversity and high level of haplotype diversity overall and among the virus species (Table 1).

Table 1. Genetic diversity of replication initiator protein gene (*rep*) of legume infecting *Begomoviruses*

Genotype	Isolates (No)	Polymorphic (segregating) sites (No)	Nucleotide diversity (π)	Haplotype diversity (Hd)
<i>Mungbean yellow mosaic India virus</i> (MYMIV)	48	201	0.03034	0.996
<i>Mungbean yellow mosaic virus</i> (MYMV)	22	155	0.03273	0.987
<i>Dolichos yellow mosaic virus</i> (DoYMV)	8	97	0.03776	0.929
<i>Horsegram yellow mosaic virus</i> (HgYMV)	7	56	0.01900	0.952
LTMV (All four)	85	532	0.13915	0.997

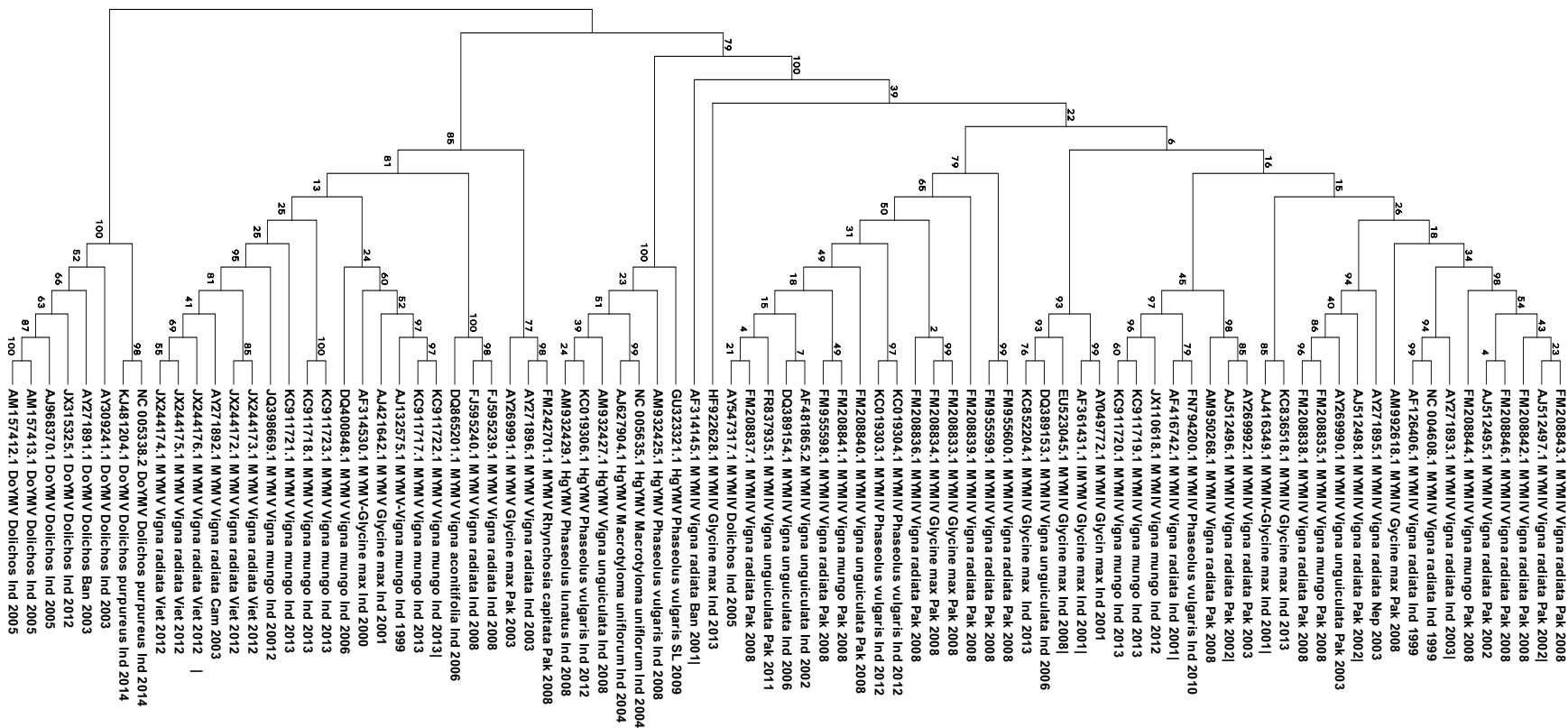
Molecular phylogeny of replication initiator protein gene sequences revealed that all LTMVs formed two major clusters (Fig. 1). The larger branch, cluster-I comprises major LTMVs (MYMIV, MYMV) and HgYMV as distinct sub-clades. Rep gene accession reported in this study also formed a part of MYMIV sub-clade. Within the cluster-I, the major LTMV (MYMIV), and HgYMV are represented as sub-clades arising from one large branch. However another major LTMV, MYMV forms a separate clade basal to this major clade. Regardless of the host plants, the virus accessions have clustered together. Interestingly, the missing LTMV from the

cluster-I, DoYMV also formed completely a distinct cluster basal to the Cluster I (Fig. 1).

Test of neutral evolution

Test of neutral evolution, from population statistic parameters, revealed that all groups of LTMVs except DoYMV, displayed negative Tajima’s D indicating the operation of purifying selection and population expansion (Table 2) which is in accordance with the codon substitution studies (Data not shown). Among all the genotypes studied, MYMIV displayed greater negative Tajima’s D (-1.45412), hence more purifying selection than in MYMV (-0.96406) and in HgYMV

Evolutionary analyses were conducted in MEGA6



(-0.74801). However, both the major selection than all LYMVs (-0.17174) LYMVs (MYMIV and MYMV) and (Table 2). HgYMV reveal greater purifying Similarly with other population

Table. 2. Neutrality tests in *Begomoviruses* infecting legumes (N-refers to number of isolates, Tajimas’s D, Fu and Li’s D, and Fu and Li’s F refer to the test statistic parameters to evaluate the theory of neutral evolution

Genotypes	Isolates (No)	Tajimas’s D	Fu and Li’s D	Fu and Li’s F
<i>Mungbean yellow mosaic India virus</i> (MYMIV)	48	-1.45412	-2.85070	-2.78225
<i>Mungbean yellow mosaic virus</i> (MYMV)	22	-0.96406	-0.35607	-0.63855
<i>Dolichos yellow mosaic virus</i> (DoYMV)	8	0.02601	0.14717	0.13264
<i>Horsegram yellow mosaic virus</i> (HgYMV)	7	-0.74801	-0.63165	-0.72833
LYMV (All four)	85	-0.17174	0.53880	0.28115

statistic parameters like Fu &Li’s D and Fu &Li’s F, the major LYMV, (MYMIV, MYMV), and HgYMV revealed negative values reiterating the operation of purifying selection and population expansion that could have played a role in the observed diversity. Nevertheless, DoYMV genotype showed positive values for Tajima’s D, Fu and Li’s D and Fu and Li’s F indicating the operation of neutral selection in the population. Interestingly, LYMV population as whole show positive Fu and Li’s D and Fu and Li’s F values (0.53880 and 0.28115). The combination of low negative Tajima’s D and positive Fu and Li’s D and Fu and Li’s F values, indicate that with LYMV the population size is decreasing and act of balancing or neutral selection is under process (Table 2).

Evidence for Recombination

Recombination detection programme detected altogether 19 unique recombinants (detected at least by 3 algorithms in-built in RDP) among the accessions studied and the details of the recombination are presented in (Table 3). Most of the recombination events identified belong to Event no 3 (15 out of 19 recombinants). Soybean isolate of MYMIV described in this study (KC836518) appears to be a putative recombinant arising from a MYMIV isolate infecting *Glycine max* as major parent (AJ416349) and another MYMIV isolate infecting *Glycine max* (KC852204.1) as a minor parent. This event (Event no: 1) was detected by Max-Chi, SiScan and 3 Seq methodologies. This isolate also appears to be contributing as a minor parent for emergence of 17 other *Begomovirus* isolates (Table 3). Moreover, among the 19 recombinant isolates

Table 3. Recombination detection analysis with replication initiator protein genes encoded by all legume infecting *Begomoviruses* as query employing RDP 4 Beta 4.27

Event	Recombinant	Major parent	Minor parent	Start point	End point	P-Value
3	FM208841.1_MYMIV_ <i>Vigna_mungo</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vi</i> <i>gna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>G</i> <i>lycine_max</i> _Ind_2013	41	912	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM208836.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vigna_radiat</i> _Pak_2008	KC836518.1_MYMIV_ <i>G</i> <i>lycine_max</i> _Ind_2013	44	580	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM208837.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vi</i> <i>gna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>G</i> <i>lycine_max</i> _Ind_2013	41	912	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM208840.1_MYMIV_ <i>Vigna_unguiculata</i> _Pak _2008	FM208842.1_MYMIV_ <i>Vi</i> <i>gna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>G</i> <i>lycine_max</i> _Ind_2013	44	584	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM955600.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vi</i> <i>gna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>G</i> <i>lycine_max</i> _Ind_2013	44	568	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM955599.1_MYMIV_ <i>Vig</i> <i>na_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Gl</i> <i>ycine_max</i> _Ind_2013	FM208842.1_MYMIV_ <i>V</i> <i>igna_radiata</i> _Pak_2008	41	590	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM955598.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>G</i> <i>lycine_max</i> _Ind_2013	41	886	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	AF481865.1_MYMIV_ <i>Vig</i> <i>na_unguiculata</i> _Ind_2002	FM208842.1_MYMIV_ <i>Vigna_adiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	41	590	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	AY547317.1_MYMIV_ <i>Dolichos</i> _Ind_2005	FM208842.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	41	886	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)

3	DQ389154.1_MYMIV_ <i>Vigna_unguiculata</i> _Ind_ 2006	FM208842.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	44	580	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
1	DQ389153.1_MYMIV_ <i>Vigna_unguiculata</i> _Ind_ 2006	AJ416349_MYMIV_ <i>Glycine_max</i> _Ind_2001	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	200	865	MaxChi (4.969E-3), SiScan (4.481E-3), 3 Seq (3.268E-3)
3	KC019304.1_MYMIV_ <i>Phaseolus_vulgaris</i> _Ind_20 12	FM208842.1_MYMIV_ <i>Vigna_adiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycin_max</i> _Ind_2013	44	581	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	KC019303.1_MYMIV_ <i>Phaseolus_vulgaris</i> _Ind_ 2012	FM208842.1_MYMIV_ <i>Vigna_adiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	44	581	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FR837935.1_MYMIV_ <i>Vigna_unguiculata</i> _Pak_ 2011	FM208842.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	46	580	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM208833.1_MYMIV_ <i>Glycine_max</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	41	886	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
3	FM208834.1_MYMIV_ <i>Glycine_max</i> _Pak_2008	FM208842.1_MYMIV_ <i>Vigna_adiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	41	886	MaxChi (1.160 E-3), Chimaera (2.283 E-3), 3 Seq (7.290E-3)
4	HF922628.1MYMIV_ <i>Glycine_max</i> _Ind_2013	FM208842.1_MYMIV_ <i>Vigna_radiata</i> _Pak_2008	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	44	881	MaxChi (8.655 E-3), SiScan (2.099E-5), 3 Seq (5.160E-3)
1	KC836518.1_MYMIV_Ind _2013	AJ416349_MYMIV_ <i>Glycine_max</i> _Ind_2001	KC852204.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	129	865	MaxChi (4.969E-3), SiScan (4.481E-3), 3 Seq (3.268E-3)
1	EU423045_MYMIV_ <i>Glycine_max</i> _Ind_2008	AJ416349_MYMIV_ <i>Glycine_max</i> _Ind_2001	KC836518.1_MYMIV_ <i>Glycine_max</i> _Ind_2013	200	865	MaxChi (4.969E-3), SiScan (4.481E-3), 3 Seq (3.268E-3)

identified in this study 5 isolates of the legume infecting *Begomoviruses* were found to be infecting *Glycine max*, so with virus isolates infecting *Vigna unguiculata* and *Vigna radiata*. Interestingly RDP 4 analysis revealed all the recombinants and contributing parents were belonging to MYMIV isolates infecting legume crops.

DISCUSSION

Global genomic analysis of legume infecting *Begomovirus* is essential to delineate the dynamics of viral evolution, factors driving the observed genome diversity and to categorize the population structure. Availability of around 85 rep gene nucleotide sequences in GenBank and the menace of Legumoviruses in tropical conditions warrant a global analysis to delineate the evolutionary and population dynamics.

Among the LYMV, major YMV like MYMIV, MYMV and DoYMV showed relatively high nucleotide diversity compared to other LYMV HgYMV even though nucleotide diversity of MYMV is little higher than MYMIV. Molecular phylogeny, however, revealed distinct lineage of DoYMV as it formed a basal cluster to the main cluster formed by all other LYMV (Fig. 1). It implies that both YMV (MYMIV and MYMV) infecting legumes are genetically isolated group when compared to other legume infecting *Begomoviruses*. Previous studies on phylogeny of mungbean infecting YMV in Pakistan revealed that MYMIV and MYMV are the major infectious agents and represent distinct old world *Begomovirus* lineage (Hameed

and Robinson, 2004). A recent work on coat protein gene based diversity in LYMV in Southern India revealed MYMV and Horse gram yellow mosaic virus (HgYMV) are the two different species of *Begomoviruses* causing disease (Maheshwari *et al.*, 2014).

Furthermore the distinctness of YMV infecting legumes (MYMIV and MYMV) from other legume infecting *Begomoviruses* is proven from test of neutral evolution studies. Test of neutral evolution revealed that population is under purifying selection hence population expansion is observed with both the viruses. However, LYMV population as a whole showed decrease in size owing to operation of balancing or neutral selection this could be due to the effect of DoYMV population which is under balancing selection. Similarly, results of rep codon substitution analysis reveal that both the viruses (MYMV and MYMIV) are under purifying selection meaning deleterious non-synonymous substitutions are being eliminated from the population (Data not presented).

Contrary to the established belief that legume yellow mosaic viruses (LYMV) are genetically isolated (Qazi *et al.*, 2007; Surendranath *et al.*, 2005) ie) genetic recombination or genomic components exchange are rare- putative recombinants have been detected. Statistically significant recombination events have been identified among various MYMIV isolates infecting legume crops giving rise to other MYMIV isolates. The reason for genetic isolation is attributed to its limited host range. However, results herein indicated

that legume infecting *Begomoviruses* are source of genetic variation and hence might lead to the development of novel genotypes. Similarly, genetic recombination among MYMIV isolates (Girish and Usha, 2005) and among replication initiator proteins of *Geminivirus* isolates have been demonstrated (Vadivukarasi *et al.*, 2007). This genetic variation and genetic recombination based on DNA-A derived rep gene emphasizes the role of

Begomoviral DNA A in generating variability which is in contrary to the greater genetic diversity observed with DNA B component of the *Begomoviruses* (Briddon *et al.*, 2010). Thus the information generated from molecular evolutionary genomics, identifying factors driving the process of natural selection in LYMV population and their genetic variability is pertinent to devise suitable disease control management strategies.

Competing interests: The authors declare that they have no competing interests

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REFERENCES

- Anonymous. 2014-15. ICAR-DSR Annual Report 2014-15
- Briddon R W, Patil B L, Bagewadi B, Nawaz-ul-Rehman M S, Fauquet C M. 2010. Distinct evolutionary histories of the DNA-A and DNA-B components of bipartite *begomoviruses*. *BMC Evolutionary Biology* **10**: 97.
- Brown J K, Zerbini F M, Navas-Castillo J, Moriones E, Ramos-Sobrinho R, Silva Jose C F, Fiallo-Olive E, Briddon R W, Hernandez-Zepeda C, Idris A, Malathi V G, Martin Darren P, Rivera-Bustamante R, Ueda S and Varsani A. 2015. Revision of *Begomovirus* taxonomy based on pairwise sequence comparisons. *Archives of Virology* **160**: 1593-619.
- Capoor S P and Varma P M. 1948. A new virus disease of *Dolichos lablab*. *Current Science India* **19**: 248-9.
- Doyle J J and Doyle J L. 1987. A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochemical Bulletin* **19**: 11-5.
- Fauquet C M and Stanley J. 2003. Geminivirus classification and nomenclature; Progress and problems. *Annals of Applied Biology* **142**: 165-89.
- Fu Y. 1997. Statistical tests of neutrality of mutations against population growth, hitchhiking and background selection. *Genetics* **147**: 915-25.
- Fu Y and Li W H. 1993. Statistical tests of neutrality of mutations. *Genetics* **133**: 693-709.
- Girish K R and Usha R. 2005. Molecular characterization of two soybean-infecting *Begomoviruses* from India and evidence for recombination among legume-infecting *Begomoviruses* from South-East Asia. *Virus Research* **108**: 167-76.

- Girish K R and Usha R. 2005. Molecular characterization of two soybean-infecting *Begomoviruses* from India and evidence for recombination among legume-infecting *Begomoviruses* from South-East Asia. *Virus Research* **108**: 167-76.
- Hameed S and Robinson D J. 2004. Begomoviruses from mungbeans in Pakistan: epitope profiles, DNA A sequences and phylogenetic relationships. *Archives of Virology* **149**: 809-19.
- Librado P and Rozas J. 2009. DnaSP v5: A software for comprehensive analysis of DNA polymorphism data. *Bioinformatics* **25**: 1451-2.
- Maheshwari R, Panigrahi G and Angappan K. 2014. Molecular characterization of distinct YMV (Yellow mosaic virus) isolates affecting pulses in India with the aid of coat protein gene as a marker for identification. *Molecular Biology Reports* **41**: 2635-44
- Martin D P, Lemey P, Lott M, Moulton V, Posada D and Lefeuve P. 2010. RDP3: a flexible and fast computer program for analyzing recombination. *Bioinformatics* **26**: 2462-3.
- Muniyappa V, Reddy H R and Shivshankar C. 1975. Yellow mosaic disease of *Dolichos biflorus* Linn. *Current Research* **4**: 176.
- Nariani T K. 1960. Yellow mosaic of mung (*Phaseolus aureus* L.). *Indian Phytopathology* **13**: 24-9.
- Qazi J, Ilyas M, Mansoor S and Briddon R W. 2007. Legume yellow mosaic viruses: genetically isolated *begomoviruses*. *Molecular Plant Pathology* **8**: 343-8.
- Ramesh S V, Bhaskale R, Admane N, Gupta, G K and Husain S M. 2013. Multiply Primed Rolling Circle Amplification (MPRCA) of Yellow mosaic virus genome from infected soybean in central Indian region divulges it as *Mungbean yellow mosaic Indian virus*-[sb] and its implications for RNAi mediated virus resistance. *World Soybean Research Conference-IX (WSRC-IX)*, Durban South Africa.
- Singh R N. 1979. Natural infection of bean (*Phaseolus vulgaris*) by *Mungbean yellow mosaic virus*. *Indian Journal of Mycology and Plant Pathology* **9**: 124-6.
- Surendranath B, Usharani K S, Nagma A, Victoria A K and Malathi V G. 2005. Absence of interaction of genomic components and complementation between Mungbean yellow mosaic India virus isolates in cowpea. *Archives of Virology* **150**: 1833-44.
- Suteri B D. 1974. Occurrence of soybean yellow mosaic virus in Uttar Pradesh. *Current Science India* **43**: 689-90.
- Tajima F. 1989. Statistical method for testing the neutral mutation hypothesis by DNA polymorphism. *Genetics* **123**: 585-95.
- Tamura K, Stecher G, Peterson D, Filipowski A and Kumar S. 2013. MEGA6: Molecular Evolutionary Genetics Analysis Version 6.0. *Molecular Biology and Evolution* **30**: 2725-9.
- Usharani K S, Surendranath B, Haq Q M R and Malathi V G. 2004. Yellow mosaic virus infecting soybean in northern India is distinct from the species infecting soybean in southern and western India. *Current Science* **86**: 845-50.
- Vadivukarasi T, Girish K R and Usha R. 2007. Sequence and recombination analyses of the geminivirus replication initiator protein. *Journal of Biosciences* **32**: 17-29.
- Varma A and Malathi V G. 2003. Emerging *Geminivirus* problems- A serious threat to crop production. *Annals of Applied Biology* **142**: 145-64.

Phenotypic Stability Analysis for Major Yield Traits in Newly Developed Soybean Genotypes

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ABSTRACT

*Twenty five newly developed strains of soybean were grown in three conditions (control, excess moisture and high plant population). Genetic parameters, inter-relationships and stability parameters for various yield and contributing traits were recorded. High heritability estimates coupled with high genetic advance was recorded for days to 50 per cent flowering, days to maturity and pods per plant under all three environments. Correlation studies showed that seed yield is positively related with harvest index (0.697**) followed by biological yield (0.586**). RVS 2007-1, RVS 2007-2, RVS 2007-4, JS20-53, JS 20-73 and JS 20-79 were identified as stable genotypes.*

Key words: Heritability, genetic advance, correlation coefficient, stability

Soybean [*Glycine max* (L.) Merrill], a golden nugget of the orient, is recognized worldwide as a miracle crop. The whole bean contains about 40 per cent protein, 20 per cent carbohydrate and 20 per cent oil. India ranks fifth in the world with an area of 12.20 million hectares and production of 11.00 million tonnes after USA, Brazil, Argentina and China (USDA, 2013-14). Selection for various traits requires the presence of genetic variability, high heritability and genetic advance. Since most of the economical traits are quantitative, they are affected by environment and hence

their selection based on their correlation with another trait proves more useful. For wider adaptability, developed strains should be able to perform well in different type of environments. Considering these points, we evaluated 25 newly developed strains for ten characters in three environments and measured the amount of variability through genotypic and phenotypic coefficients, broad sense heritability and genetic advance. For identifying the strains with wider adaptability we used the model of Eberhart and Russell, (1966) and identified the stable strains as ones

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which are capable of utilizing the resources available in high yielding environment and have a mean performance that is above average in all environments.

MATERIAL AND METHODS

Twenty five newly developed strains were evaluated under randomized block design with three replications at RAK College of Agriculture, Sehore during *kharif* 2013. Each genotype was sown in four rows plot of 2 meter length with 45 cm row to row and 3-4 cm plant to plant distance. Healthy crop was raised using recommended package of practices. The observations on various physiomorphic and yield traits were recorded on five competitive plants. The root nodules were counted by deep uprooting and washing of the root system with water at 40 days after sowing. The branches per plant were counted and recorded at the time of maturity. The data were finally

analysed for analysis of variance as per the standard procedure (Panse and Sukhatme, 1967). Genetic parameters, correlation coefficients were computed as per method suggested by Singh and Chaudhary (1977). The analysis of variance was computed as per method given by stability analysis was carried out as per procedure outlined by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Heritability and genetic advance

High heritability estimates coupled with high genetic advance were recorded for days to 50 per cent flowering, days to maturity and pods per plant under all of the three environments. Number of branches per plant, harvest index, 100 seed weight, biological yield per plant and seed yield recorded lower value for heritability and genetic advance under all of the three environments (Table 1).

Table 1. Estimates of heritability (%) in broad sense and genetic advance

Characters	Heritability			Genetic advance		
	Environment			Environment		
	E-1	E-2	E-3	E-1	E-2	E-3
Days to 50 % flowering	95.6	97.2	96.2	7.89	8.41	8.25
Days to maturity	99.5	98.6	99.2	18.64	17.43	17.48
Primary branches (No/plant)	12.8	17.6	24.2	0.99	0.86	1.09
Plant height (cm)	46.1	24.3	25.7	5.52	5.10	3.37
Nodules (No/plant)	58.9	21.1	58.2	14.25	2.58	11.75
Pods (No/plant)	42.1	71.6	63.8	8.05	11.65	12.95
100 seed weight (g)	27.2	58.2	46.8	1.02	2.06	1.41
Biological yield per plant (g)	37.2	16.6	48.8	2.90	1.20	3.80
Harvest index (%)	10.9	11.9	11.7	0.32	1.82	2.13
Seed yield per plant (g)	59.5	20.1	21.2	2.60	0.64	4.15

Correlation coefficient

Seed yield per plant exhibited highly significant and positive association with harvest index (0.697**) followed by biological yield per plant (0.586**).

Days to 50 per cent flowering had highly significant relationship with biological yield per plant (0.759**) followed by number of pods per plant (0.725**), days to maturity (0.545**), branches per plant (0.542**). Days to maturity was found to be highly and positively associated with number of nodules per plant (0.981**) followed by plant height (0.835**), primary branches per plant (0.731**), number pods per plant (0.558**), biological yield per plant (0.499**). Plant height was found to be highly and positively associated with number of nodules per plant (0.839**) followed by harvest index (0.558**), biological yield per plant (0.439). Primary branches per plant were found to be highly and positively associated with biological yield per (0.824**), number of nodules per plant (0.734**) and 100 seed weight (-0.448). Number of pods per plant exhibited significantly positive association with biological yield per plant (0.953**) followed by seed yield per plant (0.301), harvest index (0.154) and significantly negative correlation with 100 seed weight (-0.897).

Number of nodules per plant was found to be highly and positively associated with harvest index (0.346). Biological yield per plant had high and positive significant association with seed yield per plant (0.586) followed by harvest index (0.104). Harvest index exhibited high positive significant association with seed yield per plant (0.697**) (Table-2).

Stability Analysis

The pooled analysis of variance of yield and yield contributing traits (Table 3) indicated that the genotypes differed significantly for all the characters except biological yield per plant in E-3 (high plant population). The interaction of genotype x environment means sum of square were also found non-significant for all the characters. The response of genotype to changing environment was measured by the environmental linear effect, which was statistically significant for all the characters.

The stability parameters namely, mean regression coefficient (b) and deviation from regression S^2_d were computed for all the characters (Table 4). The substantial magnitude of deviation from linearity was observed for all the characters suggesting large fluctuation in the expression of all characters over environments. Stability parameters worked out for all the 25 genotypes for yield and its component traits showed that the genotypes namely RVS 2007-2, RVS 2007-1, JS 95-60, JS 20-87 and NRC 37 were stable for 10 characters studied. Genotypes RVS 2007-4, RVS 2007-6, JS 93-05, JS 20-53, JS 20-59 and JS 20-79 exhibited stable performance for nine characters including seed yield per plant. Genotypes RVS 2007-3, RVS 2007-5 and RVS 2001-4 exhibited stability for eight characters including seed yield per plant. JS 20-73 was found to be least stable showing stability only for five characters including seed yield per plant. For the development of improved varieties, genotype x environment interaction had been of great importance to the plant

Table 2. Genotypic correlation coefficients among different characters of the genotypes of soybean

Character	Days to maturity	Primary branches (No/plant)	Plant height (cm)	Nodules (No/plant)	Pods (No/plant)	100 seed weight (g)	Biological yield (g/plant)	Harvest index (%)	Seed yield (g/plant)
Days to 50% flowering	0.545*	0.542*	-0.632	-0.195	0.725**	-0.873	0.759**	-0.195	0.150
Days to maturity		0.731**	0.835**	0.981**	0.558*	-0.653	0.499*	-0.357	-0.174
Primary (No/plant)			0.268	0.734**	-0.274	-0.448	0.824**	-0.190	-0.057
Plant height (cm)				0.839**	0.083	-0.259	0.439*	0.558*	-0.572
Nodules (No/plant)					-0.541	-0.116	-0.079	0.346*	-0.700
Pods (No/plant)						-0.897	0.953**	0.154	0.301
100 seed weight (g)							-0.977	-0.089	-0.409
Biological yield (g/plant)								0.104	0.586**
Harvest index (%)									0.697**

**Significant at 5% level of significance; **significant at 1% level of significance*

Table 3. Analysis of variance for stability with regards to yield and its components in soybean (Mean sum of squares)

Source of variation	Degree of freedom	Days to 50% flowering	Days to maturity	Branches (No/plant)	Plant height (cm)	Nodules (No/plant)	Pods (No /plant)
Genotype	24	48.421**	22.71024**	3.28984 **	11.51016**	734.0847**	106.8657**
Environment	2	73.558**	12.57690**	2.74672**	233.9574**	159.8592**	299.0002**
Geno.× Environ.	48	0.29327	0.50660	3.21846**	2.146122*	6.27684**	3.518825**
Pooled error	144	0.76390	0.67108	0.11545	2.69808	4.5118	3.432240
Environ.+ Geno.× Environ.	50	3.1097	9.89414	0.31995	29.9610	12.4201	4.574073
Environment (linear)	1	14.6490**	25.4252**	54.9487**	467.9094**	319.721**	598.0086**
Geno.× Environ. (linear)	24	3.66832**	0.54689	0.25770**	1.61127*	38.3289**	3.305037**
Pooled deviation	25	0.21118**	0.43679**	0.37053	2.57374	8.37183	3.583275**
Pooled error MSS for testing pooled deviation MSS		0.25463	0.22369	0.38485	0.89935	1.50395	1.144080
Source of variation	Degree of freedom	100 seed weight (g)	Biological yield (g/plant)	Harvest index (%)	Seed yield (g/plant)		
Genotype	24	4.36692**	18.74678**	25.96724**	5.60291**		
Environment	2	9.6689**	21.66644**	504.2880**	19.9998**		
Geno.× Environ.	48	0.41572	2.213626*	11.58013**	11.3566**		
Pooled error	144	0.15859	8.800732	19.81533	6.17452		
Environ.+Geno.× Environ.	50	0.43777	2.99173	31.28844	1.89025		
Environment (linear)	1	1.19355**	43.3267**	100.8571**	40.0000**		
Geno.× Environ. (linear)	24	0.36625	2.58598*	12.59493	0.11851		
Pooled deviation	25	0.44653**	1.76786	10.1430**	0.10427		
Pooled error MSS for testing pooled deviation MSS		0.52864	2.93357	6.60511	0.20581		

* Significant at 5% level of significance; **significant at 1% level of significance

Table 4. Grouping of soybean genotypes based on of regression coefficient and deviation from regression showing suitability for different environmental conditions

Characters	Genotypes stable over Environment High mean (\bar{X})	Genotypes stable for poor Environment regression coefficient ($b = 1$)	Genotypes stable for favourable Environment least deviation (\bar{S}_d^2)
Days to 50 % flowering	JS 95- 60, RVS 2007-7, JS 93-05, JS 20-79	RVS 2007-3, JS 20-71, RVS 2007-1, RVS 2007-4	NRC 7, JS 20-59, JS 20-73
Days to maturity	RVS 2007-4, JS 95-60, JS 93-05, RVS 2001-4	RVS 2007-6, RVS 2007-5, JS 20-50	RVS 2007-3, JS 20-53, JS 20-69
Primary branches (No/plant)	RVS 2007-5, RVS 2007-6, RVS 2007-4	RVS 2001-4, NRC 37, JS 335, RVS 2007-7, JS 20-80	JS 20-71, JS 20-86, JS 20-69
Plant height (cm)	JS 20-87, JS 20-86, JS 20-71	JS 20-71, JS 97-52, JS 20-69, RVS 2007-5	RVS 2007-6, JS 20-59, RVS 2007-7
Nodules (No/plant)	JS 95-60, JS 20-59	RVS 2007-1, RVS 2007-3, JS 20-87, JS 20-80	RVS 2007-2, RVS 2007-5, NRC 7, JS 20-71, JS 20-73
Pods (No/plant)	RVS 2001-4, JS 20-59, RVS 2007-2, RVS 2007-3	JS 20-69, JS 20-87, JS 20-50	Bragg, NRC 7, JS 20-71
Seeds (No/plant)	JS 20-53, JS 20-50	RVS 2007-3, RVS 2007-5, JS 20-86	RVS 2007-6, RVS 2007-7, JS 20-69, JS 20-71
Biological yield (g/plant)	JS 20-79, JS 97-52, RVS 2007-7	RVS 2007-2, JS 20-50, JS 20-69, JS 20-73	RVS 2007-1, RVS 2007-7, NRC 7, JS 20-80
100 seed weight (g)	RVS 2007-2, JS 20-79, RVS 2007-1	RVS 2007-6, JS 20-73, JS 20-86	RVS 2007-5, RVS 2001-4, JS 20-71
Harvest index (%)	RVS 2007-2, NRC 37, RVS 2007-1	RVS 2007-7, JS 20-80, JS 20-87	RVS 2007-3, JS 20-73, JS 20-69
Seed yield (g/plant)	RVS 2007-2, RVS 2001-4, JS 20-71	JS 20-80, JS 20-79, RVS 2007-6	RVS 2007-5, RVS 2007-7, NRC7

breeder. When genotypes are compared over a series of environments relative ranking usually differ which causes difficulty in demonstrating the significant superiority of one genotype over the other. For reducing the impact of genotype x environment interaction breeder select stable genotypes, which will interact less with the environment in which they are likely to be grown.

Under present investigation adaptive potential and relative stability of 25 strains of soybean for yield and its contributing traits have been determined. The pooled analysis of variance carried out to know the response of different characters to various environmental factors, revealed that genotype x environment interactions were non-significant for all the characters

which indicated that these traits were well adapted and showed least effect to the changes in the environmental conditions. However Rawat *et al.* (2001), Joshi *et al.* (2005), Pan *et al.* (2007) and Rajkumar and Husain (2008) reported significant genotype \times environment interaction for most of the yield and yield attributing characters.

Variances due to genotype \times environment (linear) was significantly different for days to 50 per cent flowering, plant height, number of nodules per plant, number of primary branches per plant, number of pods per plant and biological yield per plant. It indicated the differential response of genotypes to varying environment conditions. Similar result also reported by Ramana (2006).

According to Eberhart and Russell (1966) an ideal genotype is one having high mean (\bar{X}), unit regression coefficient ($b = 1$) and least deviation (\bar{S}_d^2) around the regression slope, *i.e.* mean deviation square from regression not significantly different from zero. Therefore, it implies that while selecting varieties, predicting rate of seed yield in a given environment, mean values, regression slope of the genotypes and deviation from regression should be considered. Overall stable genotypes identified were overall conclusion from the present investigation that stable genotypes were identified namely RVS 2001-4, RVS 2007-1, RVS 2007-2, RVS 2007-4, JS 20-79, JS 95-60 and JS 20-53 which are suitable for growing over of wide range of environments of Madhya Pradesh.

REFERENCES

- Dewey D R and Lu K H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* **51**: 515-8.
- Eberhart S A and Russell W A. 1966. Stability parameters for comparing varieties. *Crop Science* **6**: 36-40.
- Joshi H J, J J Vaghani, B V Radadia and Mehta D R. 2005. Genotype \times environment interaction and stability analysis in soybean. *Advances in Plant Science* **18**(2): 515-8.
- Pan R S, Singh A K, Kumar S and Rai Mathura. 2007. Stability of yield and its components in vegetable soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **77**(1): 28-31.
- Panase V G and Sukhatme P V. 1967. *Statistical Methods for Agricultural Workers*, 2nd Ed., Indian Council of Agricultural Research, New Delhi.
- Rajkumar Ramteke and Husain S M. 2008. Evaluation of soybean (*Glycine max*) varieties for stability of yield and its components. *Indian Journal of Agricultural Sciences* **78**(7): 625-8.
- Ramana M and Satyanarayana A. 2006. Stability analysis quality character in soybean (*Glycine max* (L.) Merrill). *Legume Research* **29**(4): 274-7.

- Rawat G S, Nandan Mehta, Y Mishra and Shukla R S. 2001. Phenotypic stability for seed quality characters in soybean. *JNKVV Research Journal* **34**(1/2): 65-6.
- Singh B and Chaudhary D N. 1977. Correlation and path coefficient analysis of yield components of soybean. *Indian Journal of Agricultural Sciences* **44**: 487-489
- USDA 2013-14. - www.nass.usda.gov.
- Valencia-Ramirez R A and Ligarreto-M Abady, S. Merkeb, F. and Dilnesaw, Z. year Heritability and path-coefficient analysis in soybean (*Glycine Max* L. Merrill) genotypes at Pawe, North Western Ethiopia *Journal of Environment Science and Water Resources* **2**(8): 270-6.

Effect of Integrated Nutrient Management on Productivity, Profitability, Nutrient Uptake and Soil Fertility in Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Field experiments were conducted at Agricultural Research Station, Kota, (Rajasthan) in two consecutive rainy (kharif) seasons (2010 and 2011) to evaluate the effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in soybean (*Glycine max* (L.) Merrill). Application of 100 per cent recommended dose of fertilizers (RDF) (N₂₀ P₆₀ K₄₀) + FYM @ 5 tons per ha produced significantly higher dry matter at 60 DAS (18.54 g/plant), mean CGR 30-45 DAS (7.43 g/m²/day), mean CGR 45-60 DAS (26.12 g/m²/day), mean RGR 45-60 DAS (0.0324 g/g/day), pods per plant (55.87), seed yield (1,793 kg/ha), straw yield (2,559 kg/ha), net returns (Rs 20,090/ha) and B: C ratio (2.21), oil content (18.39 %), oil yield (330 kg/ha), protein content (36.09 %), N (162.17 kg/ha), P (15.84 kg/ha) and K uptake (108.10 kg/ha) as compared to control. The next best treatment was 125 per cent RDF (N₂₅ P₆₅ K₅₀) + FYM @ 5 tons per ha. Soybean var. JS 97-52 gave higher values in terms of yield, yield attributes, net returns and oil yield followed by JS 95-60. A significant built up of available N (326.5 kg/ha), P₂O₅ (27.5 kg/ha) and K₂O (287.8 kg/ha) and maximum net balance of N (6.95 kg/ha), P (3.8 kg/ha) and K (9.0 kg/ha) was registered with 125 per cent RDF + FYM @ 5 tons per ha.

Key words: *Bradyrhizobium japonicum*, FYM, integrated nutrient management, N-balance, nutrient uptake, soybean

Soybean [*Glycine max* (L.) Merrill] is predominantly cultivated under rainfed condition during *kharif* season at Hadoti region of Rajasthan. Soybean is one of the major *kharif* oilseed crops in India, mainly in semi-arid tropics of central India comprising the states of Madhya Pradesh, Maharashtra and Rajasthan. The total cultivable area under soybean in Rajasthan is about 1.06 m ha area with a contribution to production to about 1.01 m t with an average

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productivity of 956 kg per ha. This is well below the national productivity of 1,035 kg per ha from an area of 12.03 m ha (Anonymous, 2014). This stems from the fact that though the soils under soybean are productive, inappropriate soil moisture and nutrient management strategies adopted by the farmers resulted in skewed crop productivity. Under rainfed production system, low productivity of crops was linked to the soil moisture stress, non-availability and use of organic manures which are rich sources of plant nutrients, poor recycling of crop residues, and imbalanced inorganic fertilization leading to continuously negative balances nutrients (Rego *et al.*, 2003; Sahrawat *et al.*, 2007).

Therefore, application of required amount of nutrients through organic manures and inorganic fertilizers to improve soil fertility on a sustained manner and increased utilization of applied nutrients can improve crop productivity in general, and soybean in particular. (Sarkar *et al.*, 2000). Manures contain high amount of organic matter and that increases the moisture retention of the soil and improves nutrient cycling. Farm yard manure although not useful as a sole source of nutrients is, however, a good complementary and supplementary source of mineral fertilizers (Chaudhary *et al.*, 2004). To improve soybean productivity in rainfed areas by efficient utilization of nutrients and natural resources through agronomical manipulation through integrated plant-nutrient supply system is necessary. Keeping these points in view, a study was conducted for two consecutive

seasons to evolve a viable nutrient management option for higher productivity and profitability of rainfed soybean.

MATERIAL AND METHODS

A field experiment was conducted at Agricultural Research Station, Kota (Rajasthan) for two consecutive *kharif* seasons (2010 and 2011) on a fixed site. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.58), medium in organic C (0.58 %), available N (319.5 kg N/ha), available phosphorus (23.1 kg P₂O₅/ha) and available potassium (278 kg K₂O/ha). The experiment was carried out in a factorial randomized block design with three replications. The treatments comprised of eight fertility levels (75, 100 and 125 per cent recommended dose of fertilizers (RDF) with farmyard manure (FYM) @ 5 tons per ha, 75, 100 and 125 per cent RDF, FYM @ 10 t per ha and an absolute control) and involving two promising and prevalent varieties (JS 95-60 and JS 97-52). The soybean crop was sown at 45 cm on 12th July, 2010 and 4th July, 2011, respectively. Total rainfall received during the crop growth period was 555.2 mm and 871.5 mm in 2010 and 2011, respectively. Minimum temperature ranged from 23.14 to 28.20 °C and 21.74 to 25.74 °C and maximum temperature from 31.73 to 37.17 °C and 29.94 to 35.44 °C during growing seasons of 2010 and 2011, respectively.

The FYM was incorporated in earmarked plots as per treatments in both the years. On oven dry basis, the FYM

contained 0.55, 0.24 and 0.56 per cent of N, P_2O_5 and K_2O , respectively. The RDF for rainfed soybean in south eastern parts of Rajasthan is 20 kg N, 60 kg P_2O_5 and 40 kg K_2O per ha. The nutrients in the treatments were applied as basal using urea, di-ammonium phosphate and muriate of potash, respectively. The crop was harvested on 7th October, 2010 (JS 95-60) and 19th October, 2010 (JS 97-52) and 29th September, 2011 (JS 95-60) and 20th October, 2011 (JS 97-52), respectively. The dry matter production were recorded at 30, 45, and at 60 DAS from randomly selected five plant. The CGR and RGR were calculated on the basis of dry matter at different crop stages by adopting standard procedures. While observations on grain yield and yield attributing parameters, such as numbers of branches per plant, pods per plant, seeds per pod and seed index were recorded at harvest. Oil content was determined by Soxhlet ether extraction method (AOAC, 1965) and protein content in seed was calculated by multiplying per cent nitrogen in the seed by the factor 5.8 (Simon *et al.*, 1965). Oil and protein yields were worked out by multiplying the seed yield with oil and protein content for corresponding treatment. N, P and K were analysed using Nessler's reagent colorimetric method (Linder, 1944), ammonium vanadomolybdate yellow color method (Richards, 1968) and Flame photometric method (Richards, 1968), respectively. To find out the most profitable treatment, economics of various treatments was worked out in terms of net returns and benefit: cost ratio.

RESULTS AND DISCUSSION

Growth and yield parameters

Nutrient management treatments recorded significantly higher pods per plant (Table 1) and dry matter production at different crop stages that is 30, 45 and 60 DAS (Table 2) of soybean as compared to control. Application of 100 per cent RDF + FYM 5 tons per ha produced significantly higher pods per plant, which did not differ with 125 per cent RDF + FYM and 125 per cent RDF per ha, whereas at different crop stages (30, 45 and at 60 DAS), maximum dry matter production was recorded with application of 100 per cent RDF + FYM 5 tons per ha and was significantly the same with 125 per cent RDF + FYM 5 tons and 125 per cent RDF per ha. The per cent increase registered was 19.21, 29.37 and 32.23 over control, respectively. Similar trend was recorded for CGR during crop growth period 30-45 and 45-60 DAS. The increased doses of RDF led to higher number of pods per plant and dry matter in soybean, which might be due to increased availability of nutrients. Further, addition of FYM acted as a buffer in the soil leading to decrease in soil pH, improved physio-chemical condition of the soil favourably influencing nutrient uptake thereby increasing yield components as against without FYM addition. Combined use of FYM along with inorganic fertilizers had better effect on increasing yield of soybean over FYM alone. This might be due to adequate supply of nutrients through inorganic and organic sources which increased the protoplasmic

Table 1. Effect of integrated nutrient management practices on yield attributes, quality and economics of soybean (pooled data of 2 year)

Treatment	Pods (No/ plant)	Seed index (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net returns (Rs/ha)	B:C ratio	Oil content (%)	Oil yield (kg/ha)	Protein content (%)
<i>A. Nutritional schedule</i>										
75 % RDF	42.64	10.66	1442	2088	40.83	15255	2.07	17.31	250	34.97
75 % RDF+FYM*	46.30	10.75	1548	2222	41.03	15426	1.95	17.58	272	35.65
100 %RDF	51.13	10.81	1670	2386	41.14	19573	2.34	18.34	306	35.89
100 % RDF+ FYM*	55.87	10.91	1793	2559	41.17	20090	2.21	18.39	330	36.09
125 % RDF	52.67	10.84	1688	2412	41.14	19574	2.31	18.36	310	35.93
125% RDF+FYM*	54.63	10.89	1715	2454	41.11	18133	2.07	18.38	315	36.00
FYM**	50.83	10.85	1635	2342	41.09	16266	1.94	18.33	299	35.85
Absolute control	33.54	10.57	1070	1555	40.75	8686	1.66	17.17	184	34.80
SEm (+)	1.30	0.40	42.59	58.26	0.32	873.60	0.06	0.11	8.35	0.21
CD (P=0.05)	3.78	NS	123.52	168.95	NS	2498.5	0.17	0.33	24.21	0.62
<i>B. Varieties</i>										
JS 95-60	44.86	12.54	1502.88	2162	40.98	15253	1.98	18.23	275	36.00
JS 97-52	52.05	9.04	1636.69	2342	41.08	17997	2.16	17.74	292	35.29
SEm (+)	0.61	0.17	21.97	30.26	0.15	622.14	0.04	0.06	5.93	0.11
CD (P=0.05)	1.71	0.50	61.52	84.74	NS	1742	0.12	0.165	16.60	0.31

*5 tons/ha; **10 tons/ha

Table 2. Effect of integrated nutrient management practices on dry matter production of soybean (pooled data of 2 years)

Treatment	Dry matter (g/plant)			Mean CGR (g/m ² /day)		Mean RGR (g/g/day)	
	30 DAS	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS
A. Nutritional schedule							
75 % RDF	2.20	5.03	15.97	6.29	22.07	0.0244	0.0314
75 % RDF+FYM*	2.24	5.13	16.26	6.44	22.47	0.0245	0.0318
100 % RDF	2.40	5.63	17.92	7.17	25.08	0.0250	0.0321
100 % RDF+FYM*	2.42	5.77	18.54	7.43	26.12	0.0254	0.0324
125 % RDF	2.40	5.65	17.99	7.21	25.18	0.0250	0.0321
125% RDF+FYM*	2.42	5.70	18.19	7.30	25.51	0.0251	0.0322
FYM**	2.36	5.47	17.43	6.90	24.35	0.0246	0.0321
Absolute control	2.03	4.46	14.02	5.38	19.02	0.0233	0.0316
SEm (+)	0.03	0.08	0.24	0.15	0.29	0.0024	0.0026
CD (P=0.05)	0.10	0.24	0.68	0.44	0.87	NS	NS
B. Varieties							
JS 95-60	2.29	5.27	16.78	6.62	23.33	0.0245	0.0320
JS 97-52	2.33	5.44	17.30	6.91	24.12	0.0249	0.0320
SEm (+)	0.02	0.04	0.10	0.09	0.12	0.0012	0.0013
CD (P=0.05)	NS	0.12	0.31	0.26	0.40	NS	NS

*5 tons/ha; **10 tons/ha

constituents and accelerated the process of cell division, cell elongation and extensive root development enhanced more absorption of nutrients and ultimately increased plant height and dry matter production of the maize Totawat *et al.* (2001). Application of FYM@ 5 tons per ha along with 75 per cent RDF gave significantly higher number of pods per plant, dry matter production; per cent increase was registered by 38.04 and 15.76 over control, but did not differ with 75 per cent RDF without FYM and 100 per cent RDF without FYM. The values for seed index did not differ between treatments.

The results clearly indicated that there is a need to add organic manures to the soil in conjunction with inorganic fertilizers, which increases the availability of nutrients considerably resulting in positive effect on growth parameters. These results are in agreement with the findings of Babalad (1999) in soybean, who have opined that there is a need of organics application along with inorganic fertilizers.

Yield

The seed and straw yields were found to increase with application of nutrients through organic or inorganic sources or their combinations over absolute control (Table 1). Application of 100 per cent RDF + FYM @ 5 t per ha produced the maximum and significantly higher seed and straw yields by 67.57 and 64.56 per cent over control and did not significantly differ with 125 per cent RDF, 125 per cent RDF + FYM @ 5 tons per ha and 100 per cent RDF. The treatment FYM @ 10 tons per ha also recorded

significantly higher seed and straw yields over 75 per cent RDF and absolute control. The increase in seed and straw yields might be due to increased growth and yield parameters. Higher yields might be due to better growth and metabolism of carbohydrates, which might have got readily translocated to the reproductive parts under FYM application. Similar, results were obtained in soybean by Maheshbabu *et al.* (2008) who have recorded higher seed yield, with combined application of FYM and RDF.

Economic evaluation

Application of 100 per cent RDF + FYM @ 5 tons per ha resulted in significantly higher net returns (Rs 20,090/ha) and benefit: cost ratio (2.21) over control (Table 1). The additional net returns was of Rs 11,404 per ha due to application of 100 per cent RDF + FYM @ 5 tons per ha over control, but did not significantly vary with 125 per cent RDF with FYM @ 5 tons per ha, 125 per cent RDF, and 100 per cent RDF. Maximum B:C ratio 2.34 was recorded with RDF followed by 125 per cent RDF and 100 per cent RDF + FYM @ 5 tons per ha. This might be due to achieved higher productivity as well as lower cost of cultivation owing to increased economic returns in soybean under rainfed situations of Rajasthan. These results are in close conformity with the findings of Chandrasekhar *et al.* (2000).

Quality parameters

Application of 100 per cent RDF + FYM @ 5 tons per ha produced the maximum and significantly higher oil

Table 3. Effect of integrated nutrient management practices on nutrient uptake by soybean and soil fertility (pooled data of 2 year)

Treatment	Total nutrient uptake (kg/ha)			Available nutrient status in soil (kg/ha) at harvest		
	N	P	K	Available N	Available P	Available K
<i>A. Nutritional schedule</i>						
75 % RDF	124.50	12.42	87.04	309.62	19.60	270.53
75 % RDF+FYM*	136.48	13.42	93.46	321.15	24.58	276.00
100%RDF	148.87	14.68	100.74	313.98	22.27	273.33
100 % RDF+FYM*	162.17	15.84	108.10	325.20	25.47	282.83
125 % RDF	152.83	14.98	102.28	316.85	23.33	279.42
125% RDF+FYM*	157.86	15.30	104.22	326.47	27.48	287.83
FYM**	141.16	14.10	98.14	310.80	21.32	270.33
Absolute control	88.86	9.12	64.42	287.45	16.40	256.17
SEm (+)	4.32	0.40	2.80	-	-	-
CD (P=0.05)	12.52	1.13	7.96	-	-	-
<i>B. Varieties</i>						
JS 95-60	130.55	13.11	90.86	313.02	22.55	274.46
JS 97-52	147.65	14.36	98.74	315.02	22.57	274.65
SEm (+)	2.24	0.36	1.45	-	-	-
CD (P=0.05)	6.26	1.0	3.98	-	-	-

*5 ton/ha; **10 ton/ha; Initial available nutrients in kharif 2010 (N: 318, P: 22.5 and K: 277 kg/ha) in kharif 2011 (N: 321, P: 23.7 and K: 279 kg/ha)

Table 4. Nitrogen balance sheet as influenced by integrated nutrient management in soybean (pooled data of 2 year)

Treatment	Nitrogen (kg/ha)						
	Initial soil N status (kg/ha) (a)	N added (b)	N Uptake by crop (c)	Expected nutrient balance (d=(a+b)-c)	Actual nutrient balance (kg/ha) (e)	Apparent gain/loss f=e-d	Actual difference of initial and final (g=e-a)
<i>A. Nutritional schedule</i>							
75 % RDF-FYM*	319.5	15	124.50	200.45	309.60	99.61	-9.9
75 % RDF+FYM*	319.5	40	136.48	223.00	321.20	98.16	1.65
100%RDF-FYM*	319.5	20	148.87	190.65	314.00	123.34	-5.55
100 % RDF+FYM*	319.5	45	162.17	202.35	325.20	122.86	5.70
125 % RDF-FYM*	319.5	25	152.83	191.65	316.85	125.19	-2.65
125% RDF+FYM*	319.5	50	157.86	211.60	326.45	114.80	6.95
FYM**	319.5	25	141.16	203.35	310.80	107.45	-8.7
Absolute control	319.5	0	88.86	230.60	287.50	143.19	-232.05
Mean	319.5	27.5	139.09	208.15	288.95	81.05	-30.55
<i>B. Varieties</i>							
JS 95-60	319.5	27.5	130.55	209.05	312.14	79.95	-30.50
JS 97-52	319.5	27.5	147.65	207.25	310.20	81.60	-30.60
Mean	319.5	27.5	139.09	208.15	311.17	81.05	-30.55

*5 ton/ha; **10 ton/ha

Table 4. Phosphorus balance sheet as influenced by integrated nutrient management in soybean (pooled data of 2 year)

Treatment	Phosphorus (kg/ha)						
	Initial soil P status (a)	P added (b)	P Uptake by crop (c)	Expected nutrient balance (d=(a+b)-c)	Actual nutrient balance (e)	Apparent gain/loss (f=e-d)	Actual difference of initial and final (g=e-a)
A. Nutritional schedule							
75 % RDF-FYM*	23.1	45.0	12.41	55.64	17.80	-36.54	-3.95
75 % RDF+FYM*	23.1	55.0	13.41	64.70	23.90	-40.80	0.80
100%RDF-FYM*	23.1	60.0	14.70	68.41	22.10	-46.36	-1.00
100 % RDF+FYM*	23.1	70.0	15.82	77.23	25.10	-52.18	2.00
125 % RDF-FYM*	23.1	75.0	15.01	83.15	22.80	-60.30	-0.30
125% RDF+FYM*	23.1	90.0	15.29	97.81	26.90	-70.91	3.80
FYM**	23.1	50.0	14.11	58.99	20.95	1.96	-2.10
Absolute control	23.1	0.0	9.12	13.96	16.10	2.14	-7.00
Mean	23.1	50.6	13.25	60.04	22.15	-37.89	-0.96
B. Varieties							
JS 95-60	23.1	50.6	12.60	60.16	22.15	-38.54	-0.96
JS 97-52	23.1	50.6	13.90	59.85	22.15	-37.24	-0.96
Mean	23.1	50.6	13.25	60.04	22.15	-37.89	-0.96

*5 ton/ha; **10 ton/ha

Table 4. Potassium balance sheet as influenced by integrated nutrient management in soybean (pooled data of 2 year)

Treatment	Potassium (kg/ha)						
	Initial soil K status (a)	K added (b)	K Uptake by crop (c)	Expected nutrient balance (d=(a+b)-c)	Actual nutrient balance (e)	Apparent gain/loss (f=e-d)	Actual difference of initial and final (g=e-a)
<i>A. Nutritional schedule</i>							
75 % RDF-FYM*	278.0	30.0	87.00	220.95	270.15	49.19	-7.85
75 % RDF+FYM*	278.0	55.0	93.46	239.55	275.75	36.20	-2.25
100%RDF-FYM*	278.0	40.0	100.76	217.25	273.45	56.19	-4.55
100 % RDF+FYM*	278.0	65.0	108.10	234.90	282.05	47.15	4.10
125 % RDF-FYM	278.0	50.0	102.10	225.70	279.50	53.79	1.50
125% RDF+FYM*	278.0	75.0	104.00	248.80	287.00	38.22	9.00
FYM**	278.0	25.0	98.10	204.90	270.50	65.72	-7.40
Absolute control	278.0	0.0	64.50	213.60	256.50	42.88	-21.5
Mean	278.0	42.5	94.83	225.85	274.50	48.73	-3.60
<i>B. Varieties</i>							
JS 95-60	278.0	42.5	90.85	226.45	274.40	47.90	-3.61
JS 97-52	278.0	42.5	98.75	225.20	274.50	49.25	-3.59
Mean	278.0	42.5	94.83	225.85	274.50	48.73	-3.60

*5 ton/ha; **10 ton/ha

content, oil yield and protein content over control but did not vary with 125 per cent RDF + FYM @ 5 tons per ha, 125 per cent RDF, 100 per cent RDF and FYM @ 10 tons per ha. The per cent increase was 7.11, 79.35 and 3.73 over control, respectively. The variety of JS 95-60 produced the maximum and significantly higher oil (18.23 %) and protein (38.80 %) contents as compared to variety of JS 97-52. The per cent increase registered was 2.76 and 2.02, respectively. The variety of JS 97-52 produced the maximum and significantly higher oil yield (292 kg/ha) as compared to JS 95-60 (275 kg/ha) (Table 1).

Nutrient uptake and balance

Significantly higher uptake of N, P and K by soybean crop was recorded with application of 100 per cent RDF + FYM @ 5 tons per ha over other treatments tried, with the exception of 125 per cent RDF and 125 per cent RDF + FYM @ 5 tons per ha. The per cent increase in N, P and K uptake under 100 per cent RDF + FYM @ 5 ton per ha recorded were 82.50, 73.68 and 10.15, respectively over absolute control. However, application of 125 per cent RDF + FYM 5 tons per ha also recorded significantly higher uptake of N, P and K to the magnitude of 69.0, 6.18 and 39.8 kg per ha, respectively as compared to absolute control (Table 3). This increase was mainly due to increased soybean seed and straw yield and higher concentration of respective applied nutrients. Similar results were

also reported by Singh *et al.* (2010) in baby corn and Paliwal *et al.* (2011) in soybean. The variety of JS 97-52 recorded significantly higher amount of N, P and K uptake as compared to JS 95-60.

Maximum positive balance of N (6.95 kg/ha) was observed under application of 125 per cent RDF+ FYM @ 5 tons per ha, followed by 100 per cent RDF+ FYM @ 5 t per ha and 78 per cent RDF + FYM @ 5 tons per ha. A negative P balance was computed under most of the treatments except in treatments where FYM was applied (Table 4).

Application of 100 per cent RDF + FYM @ 5 tons per ha increased available N, P and K and the increase was 1.78, 8.65 and 1.73 per cent, respectively over initial nutrient status of the soil (Tables 4, 5, 6). The improvement in the available N, P and K in soil over absolute control and increased by 272, 55.30 and 10.40 per cent, respectively. It might be due to direct addition of partial N, P and K through FYM and greater multiplication of soil microbes, which convert organically bound nutrients to inorganic forms as well as its capacity to form a cover on sesquioxide which reduces the phosphate fixation. Secondly, the availability of nitrogen, phosphorus, potassium of the soil improved with the integration of FYM + RDF which enhanced the use of organic and inorganic nutrient sources for higher production and stable soil health. These results corroborate the findings of Ranjit Singh and Rai (2004) and Panwar (2008).

Thus, from the present investigation it may be concluded that integrated use of farmyard manure and

chemical fertilizers helps in achieving higher productivity of soybean and economic returns.

REFERENCES

- Anonymous. 2013-14. *Annual Report, All India Coordinated Research Project on Soybean, Director's Report and Summary Tables of Experiments 2013-2014*, pp. ii.
- A O A C. 1965. *Official Methods of Analysis*, (10th ed.) Association of official Agricultural Chemists, Washington.
- Babalad H B. 1999. Integrated nutrient management for sustainable production in soybean based cropping system. *Ph.D. Thesis*, University of Agricultural Sciences, Dharwad (India).
- Chandrasekhar G K, Harlapur S I, Muralikrishna S and Girish G. 2000. Response of maize (*Zea mays* L.) to organic manures and with inorganic fertilizers. *Karnataka Journal of Agricultural Science* **13**: 144-6.
- Chaudhary D R, Bhandari S C and Shukla L M. 2004. Role of vermicompost in sustainable agriculture: A review. *Agricultural Review* **25** (1): 29-39.
- Lindner R C. 1944. Rapid analytical methods for some of the more common substances of plant and soil. *Plant Physiology* **19**: 76-84.
- Maheshbabu H M, Hunje Ravi, Biradar Patil N K and Babalad H B. 2008. Effect of organic manures on plant growth, seed yield and quality of soybean. *Karnataka Journal of Agricultural Sciences* **21**(2): 219-21.
- Panwar A S. 2008. Effect of integrated nutrient management in maize (*Zea mays* L.)-mustard (*Brassica campestris* var *toria*) cropping system in mid hills altitude. *Indian Journal of Agricultural Sciences* **78**(1): 27-31.
- Paliwal D K, Kushwah H S, Thakur H S, Tailor R S and Deshwal A K. 2011. Effect of vermicompost in combination with fertilizers on nodulation, growth and yield of soybean (*Glycine max*) in soybean-wheat cropping system. *Soybean Research* **9**: 95-102.
- Ranjit Singh and Rai R K. 2004. Yield attributes, yield and quality of soybean (*Glycine max*) as influenced by integrated nutrient management. *Indian Journal of Agronomy* **49**: 271-4.
- Rego T J, Rao N V, Seeling B, Pardhasaradhi G and Rao K J V D K. 2003. Nutrient balances-a guide to improving sorghum and groundnut-based dry land cropping system in semi-arid tropical India. *Field Crop Research* **81**: 53-68.
- Richards L A. 1968. Diagnosis and improvement of saline and alkaline soils. *USDA Handbook No. 60*.
- Sahrawat K L, Wani S P, Rego T J, Pardhasaradhi G and Murthy K V S. 2007. Widespread deficiency of sulphur, boron and zinc in dry land soils of the Indian semi-arid tropics. *Current Science* **93**: 1428-32.
- Sarkar A K, Singh K P, Singh B P and Singh R P. 2000. Long-term effects of fertilizers, manures and amendments on crop production and soil fertility. *Technical Bulletin of Soil Science and Agricultural Chemistry (BAU)* No. 2/2000, pp. 31-45.
- Simson T E, Adair C R, Kohler G P, Dabald H A, Kestar F B and Hlick J T. 1965. Quality evaluation studies of foreign and domestic rices. *Technical Bulletin* No. 1331, USDA. PP. 1-16.

- Singh M K, Singh R N, Singh S P, Yadav M K and Singh V K. 2010. Integrated nutrient management for higher yield, quality and profitability of baby corn (*Zea mays*). *Indian Journal of Agronomy* **55** (2): 100-4.
- Totawat K L, Somani L L, Singh R and Singh G. 2001. Integrated nutrient management in maize-wheat cropping sequence on typic Haplustalfs of western India. *Annals of Arid Zone* **40**: 439-44.

Assessment of Economic Optimum Level and Sulphur Use Efficiencies in Soybean Varieties

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ABSTRACT

Field experiments were conducted during 20011 and 2012 to study the effect of sulphur levels on productivity, sulphur uptake and sulphur use efficiency by promising soybean (*Glycine max* L. Merrill) genotypes under Malwa plateau conditions of Central India. Soybean variety 'NRC 37' gave higher yield (4.36 %), sulphur uptake (10.94 %), sulphur use efficiencies, net returns and IBCR over JS 95-60. The magnitude of yield response to sulphur was to the tune of 15.06, 34.73 and 37.06 per cent due to 20, 40 and 60 kg S per ha over control, respectively. Potassium uptake increased concomitantly with the levels of sulphur. Physical maximum and economical optimum sulphur level for soybean worked out were 45.17 and 45.10 kg S per ha, respectively. The partial factor productivity and apparent recovery efficiency linearly decreased as the levels of sulphur increased; highest was being with 20 kg S per ha. The agronomical and physiological efficiencies increased only up to 40 kg S per ha and thereafter these declined.

Key words: Economic optimum level, *Glycine max*, productivity, soybean, sulphur level, sulphur use efficiency

The crop productivity improvement through the adoption of high-yielding varieties and multiple cropping systems, fertilizer use has become more and more important to increase crop yields and their quality. Sulphur is an essential plant nutrient for crop production. For oil crop producers, S fertilization is especially important because oil crops require more S than cereal crops. For example, the amount of S required to produce one ton of seed is

about 3-4 kg S for cereals (range 1-6); 8 kg S for legumes (range 5-13); and 12 kg S for oil crops (range 5-20) (Jamal *et al.*, 2010). In general, oil crops require about the same amount of S as, or more than, phosphorus for high yield and product quality. The role of sulphur in soybean production has been reported by Shrivastava *et al.* (2000). The yield response with optimum S application differed among the plant species and it has been suggested that legumes differ

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in their S demand (Scherer and Lange, 1996). Application of sulphur improved nitrogenase activity, nitrogen fixation, plant dry matter and quality of soybean grain in sulphur deficient soil (Kandpal and Chandel, 1993). Sulphur application @ 20 to 40 kg per ha in soybean produced maximum yield in various soils (Billore and Vyas, 2012).

Soybean [*Glycine max* (L.) Merrill], being an oil yielding leguminous crop, richest source of high quality protein, oil, calcium, iron and in amino acid like glycine, has established its potential as an industrially and economically viable oilseed crop in the world by virtue of its high nutritional value and myriad uses. In India, soybean has emerged as an important oilseed crop. One of the major constraints for low soybean productivity is provision of imbalanced nutrition (Joshi and Bhatia, 2003). Unless soybean is provided with required nutrient input to produce sufficient biomass, it may not yield high (Singh *et al.*, 2003). The present investigation was undertaken to study the effect of sulphur levels on productivity of soybean varieties.

METHODS AND MATERIALS

A field study was carried out during 2011 and 2012 at research farm, Directorate of Soybean Research, Indore on a typic Haplustert. The pre-experimental soil of the site analyzed: pH, 7.86; EC, 0.14 dS per m; organic carbon, 0.45 per cent; available N, P and K of 205 N, 10.20 P₂O₅ and 460 K₂O kg per ha, respectively. In all eight treatments (two soybean varieties, namely JS 95-60 and NRC 37 and 4 levels

of sulphur, *viz.* 0, 20, 40 and 60 kg S/ha) were laid out in randomized block design in factorial arrangement with three replications. The uniform recommended levels of nitrogen (20 kg N/ha), phosphorus (26.2 kg P/ha) and potassium (16.2 kg K/ha) were applied as basal to all the treatments. Planting of soybean was carried out in the month of June and harvested in the first week of October. All the recommended practices were adopted for raising a healthy crop. The yield data were fitted to a quadratic function for determining the physical maximum and economical optimum level of sulphur for each genotype (Gomez and Gomez, 1984). The input data were transformed for ease of calculation, *viz.* 10 kg S = 1 and based on that data have been interpreted. The economic optimum level was also determined for different prices of input and output. Sulphur uptake of seed and straw of soybean (kg/ha) was calculated by multiplying grain /straw yield (kg/ha) with nutrient concentration for the particular treatment / 10⁻³, while, total S uptake (kg/ha) by the crop was calculated by sum of nutrient uptake in grain and straw. Sulphur use efficiencies were calculated by adopting standard procedures.

RESULTS AND DISCUSSION

Varietal performance

Soybean varieties differed significantly in almost all the parameters studied (Table 1). Significantly highest values all the characters except harvest index were associated variety NRC 37 as compared to JS 95-60. Variety NRC 37 produced higher seed and straw yield to

the tune of 4.36 and 21.51 per cent over JS 95-60. The higher yielding ability of NRC 37 may be due to higher number of yield attributes, taller plants and longer maturity duration.

The relationship between yield and sulphur levels for both the varieties was found to be curvilinear (JS 95 60- $\hat{Y} = 442.01 + 1104.71 x - 122.51 x^2$ and NRC 37- $\hat{Y} = 250.68 + 1154.99 x - 127.55 x^2$). The physical maximum and economical optimum level for variety JS 95-60 and NRC 37 were 45.09 and 44.97; and 45.28 and 45.17 kg S per ha, respectively and corresponding yield for JS 95- 60 and NRC 37 were 2,932.38 and 2,932.37; and 2865.34 and 2865.33 kg per ha, respectively.

Soybean variety NRC 37 showed superiority over JS 95-60 with reference to S uptake, partial factor productivity, agronomic and physiological efficiency, while JS 95-60 possessed higher apparent recovery efficiency (Table 2). These differences might be due to the differences in genetic makeup of the varieties. The genotypic variation for nutrient uptake and utilization efficiency was also observed by Shafii *et al.* (2011).

Effect of sulphur levels

Soybean plant height and branches per plant remained unaffected due to various levels of sulphur applied. However, the application of graded levels of sulphur brought out substantial improvement in yield and yield attributes of soybean (Table 1). Pods per plant linearly increased up to 40 kg S per ha and thereafter it declined marginally. A similar trend was also observed in seed yield. The application of sulphur @ 40

and 60 kg S per ha, also increased the yield by 17.09 and 19.12 per cent, respectively. However, the magnitude of increase was only 1.73 per cent due to 60 kg S per ha as compared to 40 kg S per ha. The increase in grain yield owing to S addition could be attributed to the increased yield attributes. Sulphur fertilization also resulted in an increased uptake of nutrients *viz.*, N, P, K and S, thus resulting in higher yield. The higher magnitude of grain yield response indicated greater contribution of sulphur in grain production. These results are in agreement with the findings of Vyas *et al.* (2006), Sharma (2011), Najar *et al.* (2011) and Devi *et al.* (2012), while Shinde *et al.* (2007) noted yield improvement up to 60 kg S per ha.

The relationship between yield and sulphur levels was found to be curvilinear ($\hat{Y} = 445.84 + 1130.11 x - 125.09 x^2$). The physical maximum and economical optimum level of sulphur were worked out to be 45.17 and 45.10 kg S per ha, which resulted in corresponding yield levels of 2998.30 and 2998.28 kg per ha, respectively. The physical and economical optimum levels of sulphur for Central zone (four centres) worked out by Billore and Vyas (2012) varied from 17.89 to 45.77 and 18.51 to 47.46 kg S per ha. The sulphur uptake significantly improved with the applied sulphur levels and maximum being with 60 kg S per ha. Due to the acidifying effect of S oxidation, the availability of other nutrients like nitrogen and phosphorus and sulphur was also influenced (Togay *et al.*, 2008). The partial factor productivity and apparent recovery

Table 1. Effect of sulphur levels on yield and yield attributes, sulphur uptake and their use efficiencies and economics of soybean varieties

Treatment	Plant height (cm)	Bran-ches (No/plant)	Pods (No/plant)	Seed yield (kg/ha)	Straw yield (kg/ha)	HI (%)	Total S uptake (kg/ha)	Partia l factor produ-ctivity (kg/kg)	Agro-nomic effici-ency (kg/kg)	Physiol-ogical effici-ency (kg/kg)	Recov-ery effici-ency	Net returns (Rs/ha)	IBCR
<i>Variety</i>													
JS 95 60	43.37	2.54	19.94	2041	2492	45.05	11.62	63.73	12.03	108.58	0.11	65461	22.97
NRC 37	73.50	3.34	49.93	2130	3028	41.54	12.88	66.52	13.53	130.48	0.10	68810	23.97
SEm (±)	1.04	0.09	0.75	17.36	30.35	0.15	0.72	7.86	0.61	7.43	0.004	1421	2.83
CD	3.01	0.26	2.17	50.33	88.56	0.43	2.08	22.72	1.77	21.51	0.010	4110	8.19
(P=0.05)													
<i>S level (kg/ha)</i>													
0	58.59	2.94	31.91	1713	2405	42.13	9.18	-	-	-	-	-	-
20	57.09	3.07	36.93	1971	2665	42.82	11.66	98.55	12.90	104.03	0.12	61296	35.51
40	59.04	2.82	36.70	2308	2991	43.91	13.38	57.70	14.88	141.66	0.105	70304	20.79
60	59.73	2.97	34.20	2348	2979	44.31	15.32	39.13	10.58	103.42	0.102	69808	14.10
SEm (±)	1.55	0.12	1.11	40.92	27.99	0.59	1.02	11.12	0.86	10.51	0.005	1421	4.00
CD	NS	NS	3.21	118.63	81.15	1.71	2.95	32.14	2.50	30.41	0.014	5813	11.58
(P=0.05)													

Table 2. Effect of sulphur levels on productivity of soybean genotypes

S level (kg/ha)	2011			2012			Pooled		
	JS	NRC	Mean	JS	NRC	Mean	JS	NRC	Mean
	95- 60	37		95- 60	37		95- 60	37	
0	1470	1740	1605	1914	1728	1821	1692	1734	1713
20	1780	2002	1891	2104	1998	2051	1942	2000	1971
40	2201	2520	2361	2271	2237	2254	2236	2379	2308
60	2158	2434	2296	2425	2375	2400	2292	2405	2348
Mean	1902	2174	2718	2179	2085	2132	2041	2130	
SEm (\pm)	208.09					138.82			163.27
CD	629.70					420.09			472.03
(P=0.05)									

efficiency linearly decreased as the levels of sulphur increased and highest being with 20 kg S per ha. The agronomical and physiological efficiency increased only up to 40 kg S per ha and thereafter it declined. On the contrary, Billore and Vyas (2012) reported that the

agronomical efficiency decreased with the increasing levels of sulphur.

On the basis of two year results it could be concluded that for profitable soybean production 45 kg S per ha should be recommended in *Malwa* Plateau of Madhya Pradesh.

REFERENCES

- Billore S D and Vyas A K. 2012. Optimization of sulphur levels for soybean production under different agro-ecological regions of India. *Soybean Research* **10**: 67-74.
- Devi Konthoujam Nandini, Singh Laikangbam Nongdren Khomba, Singh Maibam Sumarjit, Singh Soibam Basanta, Singh Keisham Khamba. 2012. Influence of sulphur and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. *Journal of Agricultural Sciences* **4**(4): 1-10.
- Gomez Kwanchai A and Gomez Arturo A. 1984. *Statistical Procedures for Agricultural Research*, Ed.2, Published by Johan Wiley & Sons, New York.
- Jamal Arshad, Moon Yong-Sun and Abdin Malik Zainul. 2010. Sulphur- a general overview and interaction with nitrogen. *Australian Journal of Crop Science* **4**(7): 523-9.
- Joshi O P and Bhatia V S. 2003. Stress management in soybean. In: National Seminar on "Stress Management in Oilseeds for Attaining Self-reliance in Vegetable Oils" held during January 28-30, 2003 at Directorate of Oilseeds Research, Andhra Pradesh: Pp. 13-25.
- Kandpal B M and Chandel A S. 1993. Effect of gypsum and pyrites as sources of sulphur on nitrogen fixation, dry matter yield and quality of soybean (*Glycine max*). *Indian Journal of Agronomy* **38**: 137-9.

- Najar G R, Singh S R, Akhtar F and Hakeem S A. 2011. Influence of sulphur level on yield, uptake and quality of soybean (*Glycine max*) under temperate conditions of Kashmir valley. *The Indian Journal of Agricultural Sciences* **81**(4): 340-3.
- Scherer H W and Lange A. 1996. N₂ fixation and growth of legumes as affected by sulphur fertilization. *Biology and Fertility of Soils* **23**: 449-53.
- Sharma Arun 2011. Economic viability of soybean production with Sulphur and phosphorus nutrients on yield and yield attributes of soybean, *Journal of Progressive Agriculture* **2**(2): 13-5.
- Shafii Farzaneh, Ebadi Ali, Kamel Sajed golloje and Amir Eshghi-Gharib. 2011. Soybean response to nitrogen fertilizer under water deficit conditions. *African Journal of Biotechnology* **10**(16): 3112-20.
- Shinde H P, Hiwarale J S and Mahulikar D N. 2007. Yield and quality of soybean (*Glycine max* L. Merrill) as influenced by sulphur and phosphorus application. *Journal of Soils and Crops* **17**(2): 350-3.
- Singh M V, Patel K P and Ramani V P. 2003. Crop responses to secondary and micronutrients in swell-shrink soils. *Fertilizer News* **48**(4): 63-6.
- Srivastava U K, Rajput R L and Devedi M L. 2000. Response of soybean-mustard cropping system to sulphur and biofertilizers on farmer's field. *Legume Research* **23**: 277-8.
- Togay Y, Togay N, Cig N, Erman M and Celen A E. 2008. The effect of sulphur applications on nutrient composition, yield and some yield components of barley (*Hordeum vulgare* L.). *African Journal of Biotechnology* **7**: 3255-60.
- Vyas A K, Billore S D, Joshi O P and Pachlania N. 2006. Productivity of soybean (*Glycine max*) genotypes as influenced by nitrogen and sulphur nutrition, *Indian Journal of Agricultural Sciences* **76**(4): 272-3.

Effect of Organic and Inorganic Farming Conditions on Biological Properties of Vertisols under Soybean - Wheat Cropping System

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ABSTRACT

Organic farming can be a useful farming system in improving crop productivity and soil biological properties. Soil biological properties of Vertisols were studied under organic and inorganic farming conditions during 2008-09 and 2009-10 at farmers' fields of Indore district. Experiment was carried out in randomized block design with four treatments and five replications. Treatments comprised of organic farming ≥ 3 years, organic farming (< 3 years), recommended dose of fertilizers (RDF) and farmers' practice of nutrient application. Each farmer was taken as a replicate. Significantly higher organic carbon content, bacterial, fungal and actinomycetes populations in soil were recorded with organic farming conditions irrespective of the years of organic farming practiced. Similarly, organic farming recorded highest soil microbial biomass carbon (Cmic) and microbial biomass nitrogen (Nmic). Organic farming treatment ≥ 3 years recorded significantly higher soil biological properties followed by treatments involving organic farming (< 3 years), recommended dose of fertilizer (RDF) and farmers' practice of nutrient application. Soybean productivity was higher in organic farming conditions by 3.68 % over RDF, while, wheat productivity was higher in RDF by 1.09 % as compared to organic farming.

Key words: Organic and inorganic farming conditions, soil biological properties, Vertisol

Soil micro-organisms play a very important role in soil fertility not only because of their ability to carry out biochemical transformation, but also due to their importance as a source and sink for mineral nutrients (Jenkinson and Ladd, 1981). Several groups of microorganisms have the potential to enhance growth,

crop productivity and quality of crops. Microbial biomass is the total sum of all micro- organisms present in soil. The number and activity of these microbes (Tilak *et al.*, 1995) exhibit variable responses to different agricultural management practices.

'Green Revolution' had shown a

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path to the country for getting self-sufficiency in food grain production, but the indigenous knowledge and local wisdom was ignored in adopting scientific approach, particularly in applying fertilizers. Most of the agro-ecological regions are presently showing reduction in organic carbon content as a consequence to the adoption of intensive cropping and improper crop management practices (Srinivasarao *et al.*, 2006). As a result, soils are encountering diversity of constraints broadly on account of physical, chemical and biological health and ultimately leading to poor soil quality. This shows signs of reversing trend in production at several places, in spite of increased inputs (Srinivasarao, 2011).

Several researchers and activists believe that agriculture in general and organic farming in particular is more specific with respect to local than global level due to wide variations in soil, climate and captive water resources. Since it is site specific farmer's knowledge and identification of local practices are important to create new approaches to achieve sustainability (Shroff, 1994 and Deshpande, 2009). To evaluate the influence of organic and inorganic management, the present study was planned with soybean [*Glycine max* (L.) Merrill] - wheat (*Triticum aestivum* L.) cropping system on Vertisols of Central India.

MATERIAL AND METHODS

The experiment was conducted at the farmers' field located at different sites

of Indore district (Madhya Pradesh) using randomized block design with four treatments, namely organic farming (≥ 3 years), organic farming (< 3 years), inorganic farming with recommended dose of fertilizers and farmer's practice of nutrient application, replicated 5 times (each farmer was assumed as one replication). The study was carried out during *rabi* and *kharif* seasons of 2008-09 and 2009-10 in five villages like Semliyachau, Asrawad Khurd, Badiya Khema, Ralamandel and Morod Haat of Indore district. These villages are located at $76^{\circ} 54'$ to $24^{\circ} 57' 30''$ N latitude and $80^{\circ} 43' 30''$ to $80^{\circ} 54' 15''$ E longitude. These bio-villages were adopted by the Department of Farmer's Welfare and Agriculture Development (Government of Madhya Pradesh), where in farmers have been practicing organic farming for the past 2-7 years.

The two organic farming treatments received NADEP compost @ 7.5 t per ha, vermicompost @ 2.5 t per ha, bio-gas slurry @ 2.0 t per ha and biofertilizers *Rhizobium japonicum* + PSB (for soybean) and azotobacter + PSB (for wheat) as seed inoculants @ 10 g per kg seed each and soil application @ 2 kg per ha. Inorganic farming treatment involved application of recommended levels of $\text{NP}_2\text{O}_5\text{K}_2\text{O}$ (120:60:30 kg/ ha) to wheat and $\text{N:P}_2\text{O}_5\text{K}_2\text{O}$ (20:60:20 kg/ha) to soybean through chemical fertilizers. The above three treatments were evaluated over farmer's practice of application of $\text{N:P}_2\text{O}_5\text{K}_2\text{O}$ (150:50:0 kg/ ha) to wheat and $\text{N:P}_2\text{O}_5\text{K}_2\text{O}$ (40:40:0 kg/ha) to soybean through chemical fertilizers. The popular variety Lok 1 for wheat and

JS 335 for soybean were raised as per standard package and practices. The data on various parameter recorded in both the years were pooled, statistically analysed and presented in table 1.

The soils of the study area was medium black (Sarol series), belonging to fine, Montmorillonitic, hyperthermic family of Vertic Haplusterts. The organic carbon (%) content of the soil samples was estimated by adopting Walkley and Black's rapid titration method as described by Chopra and Kanwar (1980). The rhizosphere soil samples collected at the time of harvest, were analysed for population of soil fungi, bacteria and actinomycetes by the standard serial dilution plate count method using nutrient agar for bacteria (Thornton, 1922) Martin's Rose Bengal agar for fungi (Martin, 1950), Kenknight and Munair medium for actinomycetes (Wollum, 1982). Microbial biomass carbon (Cmic) was determined by the fumigation-extraction method with 0.5 M K₂SO₄ (Vance *et al.*, 1987). Microbial biomass Nitrogen (Nmic) was estimated by chloroform fumigation-extraction (FE) (Anderson and Ingram, 1993).

RESULTS AND DISCUSSION

Effect of different farming conditions on organic carbon content of soil

Significant higher organic carbon content was noted in the organic farming conditions (5.58 to 6.32 g/kg soil) as compared to inorganic (4.86 g/kg soil) and farmer's practice of nutrient application (4.31 g/kg soil). This appeared feasible due to the direct and continuous addition of organic matter

through organic sources. Bhandari *et al.* (1992) and Hapse (1993) reported similar increase in organic carbon content of soil due to continuous addition of organic manures.

During the course of study, significant improvement in the population of soil micro-organisms such as bacteria, fungi and actinomycetes were noticed under organic farming conditions. The highest total microbial count (bacteria, fungi and actinomycetes all three together) was found with the treatment of organic farming (≥ 3 years) followed by organic farming (< 3 years), inorganic farming with RDF and minimum under farmer's practice of nutrient application. This might be due to cumulative effect of both organic manures in increasing organic carbon content of soil which acted as carbon and energy source for microbes and biofertilizers in quick build up of microflora and fauna (Yadav and Mowade, 2004). Whereas, inorganic farming conditions showed significantly lower soil microbial population as carbon substrate availability is limited and might be due to deleterious effect of inorganic fertilizers as they contain hazardous metals also which might put adverse effect on growth and reproduction of soil microbes (Katyal, 1989). Increase in soil microbial population due to addition of organics manures were also reported earlier by Patil and Varde (1998), Penfold (2000), and Kannan *et al.* (2005) in paddy.

The soil microbial biomass carbon (Cmic) is an important component of soil organic matter and comprises 1-3 per

Table 1. Soil biological properties and crop productivities as influenced by organic and inorganic farming conditions

Treatment	Organic carbon (g/kg soil)	Bacterial population × 10 ⁶ CFU/g soil	Fungal population × 10 ⁴ CFU/g soil	Actino-mycetes population × 10 ⁵ CFU/g soil	Microbial biomass - carbon (mg C/kg soil)	Microbial biomass - nitrogen (mg N/kg soil)	Seed yield (kg/ha)	
							Soybean	Wheat
Organic farming (≥ 3 years)	6.32	28.0	31.8	17.0	246.76	20.70	2165	3698
Organic farming (<3years)	5.58	23.4	28.9	13.6	223.05	17.80	1849	3376
Inorganic farming with RDF	4.86	19.0	24.5	11.9	186.64	15.70	2088	3995
Farmer's practice of nutrient application	4.31	15.4	15.7	8.8	164.64	11.70	1576	3417
SEm (±)	0.17	0.79	0.65	0.72	2.71	0.73	0.16	0.29
CD at 5%	0.52	2.43	2.01	2.22	8.34	2.25	49	89

cent of total organic carbon in soil (Jenkinson and Ladd, 1981). During the course of present investigation, Cmic and microbial biomass nitrogen (Nmic) was found to be significantly higher under organic farming conditions. Organic farming (≥ 3 years) recorded the highest Cmic (246.76 mg kg⁻¹) and Nmic (20.70 mg kg⁻¹) in soil. This was followed by organic farming (<3 years) and inorganic farming with RDF. Farmer's practice recorded the lowest Cmic and Nmic in soil. In general, increase in microbial biomass carbon in soil under organic farming was due to increased availability of substrate-C that stimulates microbial growth, but a direct effect from microorganisms added through the compost is also possible (Powlson *et al.*, 1987). A large number of research findings have been well documented which also supports the findings of this study. Ramesh *et al.* (2004) noticed a wide variation in 27 soils with contrasting management histories under soybean based cropping systems in soils of Madhya Pradesh. Palojarvi *et al.* (2002) reported that Nmic, basal respiration and Cmic were found significantly higher under organic farming system in Finland.

Crop productivity

The grain yield is a complex polygenic character and the manifestation of various growth and yield attributing characters. In case of soybean, the higher productivity was obtained under organic farming (≥ 3 years) treatment, followed by inorganic farming with RDF. On the contrary, in case of wheat, being cereal, the inorganic

farming with RDF gave highest productivity as compared to rest of the treatments. Higher soybean productivity under organic conditions as compared to farmer's practice of nutrient application might be due to regulated availability of nutrients, throughout the crop growth as soybean gets majority of its nitrogen requirement through symbiotic N-fixation. Further, the addition of manure and biofertilizers causes increased activity of beneficial microorganisms which mediated biological process like N-fixation and P-solubilization (Shwetha, 2007). Lower productivity of wheat under organic farming conditions may be argued on the basis of lower availability of N at various growth stages of wheat, which should be more for cereals. Besides, it might be due to slow mineralization of organic manure and non-availability of required nutrients, which resulted in slow crop growth at early stage of wheat and thus affected the crop yield (Prasad, 1994). The lower wheat productivity under organic farming conditions due to inadequate supply of nutrients during entire crop growth period through lower readily available nutrients has earlier been reported (Halberg and Kristensen, 1997).

The present study clearly indicated that continuous practising organic farming for extended favourable soil environment for the growing crops by improving soil organic carbon and soil biological properties leading to better seed yield of soybean than inorganic farming conditions with RDF. However, the later one recorded better wheat yield than the former one, *i.e.* organic farming

> 3 years. The farmer's practices of nutrient application do not compete over other conditions.

REFERENCES

- Anderson J M and Ingram J S I. 1993. *Tropical Soil Biology and Fertility - A Handbook of Methods*, 2nd edn., CAB International, Wallingford, UK.
- Bhandari A L, Sood Anil, Sharma K N and Rana D S. 1992. Integrated nutrient management in a rice-wheat system. *Journal of Indian Society of Soil Science* **40**: 742-7.
- Chopra S L and Kanwar J S. 1980. *Analytical Agricultural Chemistry*, Kalyani Publishers, Ludhiana.
- Deshpande W R. 2009. *Basics of Organic Farming*, All India Biodynamic and Organic Farming Association, Indore, pp 81-3.
- Halberg N and Kristensen I S. 1997. Expected crop yield loss when converting to organic dairy farming in Denmark. *Biological Agriculture and Horticulture* **14**: 25-41.
- Hapse D G. 1993. Organic farming in the light of reduction in use of chemical fertilizers. *Proceedings of 43rd Annual Deccan Sugar Technology Association*, Pune, Part-I, pp. SA37-SA51.
- Jenkinson D S and Ladd J N. 1981. Microbial biomass in soil: Measurement and turnover. *Soil Biochemistry* (E.A. Paul and J. N. Ladd, Eds.), pp. 415-471, Dekker, New York.
- Kannan P, Saravanan A, Krishnakumar S and Natarajan S K. 2005. Biological properties of soil as influenced by different organic manures. *Research Journal of Agriculture and Biological Sciences* **1**(2): 181-3.
- Katyaj J C. 1989. *Fertilizer use and Impact on Environment*, FAI Seminar on Fertilizer, Agriculture and National Economy, The Fertilizer Association of India, New Delhi, Dec 4-6.
- Martin J P. 1950. Use of acid rose-bengal and streptomycin in plate method for estimating soil fungi. *Soil Science* **69**: 215-32.
- Palojarvi A, Alakkuku L, Martikainen E, Marina N, Vanhala P, Jorgensen K, Esala M. 2002. Effects of organic and conventional farming on soil. *17th WCSS*, 14-21 August, 2002. Thailand.
- Patil Rita B and Varde P A. 1998. Microbial population in rhizosphere as influenced by high input rates of fertilizer application to sorghum on a Vertisol. *Journal Indian Society Soil Science* **46**(2): 223-7.
- Penfold, C M. 2004. *The Relative Sustainability of Organic, Biodynamic, Integrated and Conventional Broadacre Farming Systems in Southern Australia*, Unpublished Masters Thesis, University of Adelaide, Adelaide.
- Powlson D S, Brookes P C and Christensen B T. 1987. Measurement of soil microbial biomass provides an early indication of changes in total soil organic matter due to straw incorporation. *Soil Biology and Biochemistry* **19**: 159-64.
- Prasad B. 1994. Integrated nutrient management for sustainable agriculture. *Fertilizer News* **39**(9): 19-25.

Domestic Utilization of Soybean Based Food Preparations in Rural Area: An Action Research

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ABSTRACT

The present study was aimed at assessing the impact of efforts made by ICAR- IISR for popularization of processing techniques of various soybean based food preparations to the doorstep of rural housewives of Madhya Pradesh. By studying their daily food intake pattern, it was explored whether the rural people are making use of any of the soybean based food preparations in their daily use. A well designed questionnaire consisting of semi-structured questions on various aspects of knowledge gained/spread and its retention among the trained housewives was formulated and pre-tested before the data collection. A sample for this study consisted of 200 respondents belonging to villages where training-cum-demonstration programmes were conducted during past 10 years. It was observed that majority of the respondent families had awareness on the presence of quality protein, essential vitamins and minerals in soybean food and beneficial to human health. Further, majority of them were found to use soy nuggets (soy bari) as the most preferred soy products which they are using on regular basis in the rural areas. Interestingly, out of different soy products, nearly 22 per cent of the respondent families were found to have liking for soy pakora which is their most preferred soy product because of its crispy nature. However, the respondents from semi-urban area (adjacent to Indore city) are found to utilize tofu (soy paneer) which they are consuming on regular basis. Only 12 per cent of the respondent families are utilizing soybean for fortification with wheat flour but without following proper processing techniques. A small proportion of respondent families (7.5 %) are found making use of fried soy nuts (snack) regularly as well as during festive seasons.

Key words: Food preparations, rural area, soybean

Soybean, which is commercially an export oriented commodity. After cultivated by the farmers of India since extraction of oil, about 58 per cent of last four and half decades, is still largely resultant soy meal is being exported

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and remaining 42 per cent of it is utilized for poultry and fish meal domestically (Sharma *et al.*, 2014). In spite of capabilities to mitigate energy-protein malnutrition and health benefits, its domestic utilization as processed food in any form was found to be negligible (Agarwal *et al.*, 2013). However, the supplementation of edible oil by nearly 25 per cent (Sharma and Bhatia, 2015) by the crop has helped the country to reduce its import and thereby drain of valuable foreign exchange.

There is large vegetarian population in the country which mainly depends on pulses for protein source (TAAS, 2014). Since, the demand of pulses in the country is supplemented through imports; soybean is a better and less expensive alternative for fulfilling the protein requirement of large masses. Although, the use of soybean in daily diet in India is limited, efforts are being made to make aware households on benefits of its food uses. Several ethnic communities of Northeast India have invented the traditional technology of converting protein rich soybeans into flavoured fermented food with easy digestibility and bio-nutrients (Tamang *et al.*, 2009). Soybean is considered to be a functional food as it contains significant levels of biologically active compounds that impart health benefits besides basic nutrition (TAAS, 2014).

With the major objective of promoting the food uses of soybean coupled with creation of awareness on its capability of mitigating energy-protein malnutrition and other health benefits,

Indore based ICAR-Indian Institute of Soybean Research (Formerly NRCS or DSR) in addition to its major mandated R & D activities of production technologies, is also actively engaged in conducting activities specially targeting the rural womenfolk to utilized soybean at domestic level in the form of various soybean based preparations. The institution has so far educated more than 2,000 housewives and other clientele groups in the past 10 years through number of off-campus training programmes. The study was, therefore, conducted to know primarily, the nutritional intake profile of rural people, the associated impact of efforts of ICAR-IISR in translating the actual use by the rural housewives of Madhya Pradesh. The study also included perception of common people and their awareness about the health benefits and utility of soybean for food preparation, domestic utilization pattern of soybean, and bottlenecks in this food chain as felt by the trained housewives.

MATERIAL AND METHODS

An interview schedule was designed encompassing relevant questions about different issues like food habits of the respondents, consumption of different protein sources, use of soybean for food uses, their knowledge about health benefits and nutraceutical aspects of soybean and constraints (if any) faced by them during utilization of soybean for food uses and their suggestions in this regard. The interview

schedule also contained information on awareness of rural people about the benefits and nutraceutical properties of soybean which was aimed at studying the knowledge gain, and its retention/utilization in routine life particularly in their food intake behaviour. Accordingly, the data were collected from 200 respondents using pre-tested interview schedule which were analyzed after its scoring, compilation and coding of qualitative data applying quantification measures. The results of the study are presented in following sections.

RESULTS AND DISCUSSION

A. Daily food consumption pattern of rural households in the study area

It was observed that the trained women participants not only shared the knowledge received through training to their neighbors but also to their relatives located in other villages. The information generated related to daily food intake of the rural family clearly provided an interesting picture which is entirely different from the urban households. Rural People were found to take only morning tea (7 AM) in their breakfast and directly go for their lunch (10 AM), while the dinner time for rural household is 8.00 PM. In their daily food consumption pattern, *Dal*, *Roti* and *Sabji* are major ingredient in their diet prevalent in this part of the state. Very few households are found to cook rice at home on regular basis. *Dal Bati* is a very popular food item

for majority of respondents on every Sunday. Few people take this food twice a week.

As far as background information of respondents' families are concerned, majority were found to have nuclear type of family and sometime on special occasions like religious festivals they go on fast as a devotion to god/goddesses. It was also found from the survey results that majority of the respondents were vegetarian (97 %) and fulfils their protein requirement using pulses. The intake of soybean products in their daily diet serves an important purpose not only for the health of their family members, but also for other neighboring families through demonstration effect. Since, prices of pulses is skyrocketing recently, soybean can serve as an economical alternative source of protein for the vegetarian population in rural areas.

B. Awareness of respondent families about the nutraceutical aspects of soybean

ICAR-IISR activities carried out for popularization of different soybean based food preparations after following proper processing techniques are enlisted (Table 1) along-with the survey response. The results indicated that, most of the respondents (89.5 %) were found to have awareness about the utility of soybean as richest and cheapest source of good quality protein which is useful for maintaining health and increasing the work efficiency of the people. Similarly, majority of them were found to

be aware about the availability of different vitamins essential for human body. About two third majorities (77-78 %) of the respondents were found to have knowledge about the availability of minerals like calcium and iron, which helps to maintain bone and blood content. Similar results have earlier been reported by Dupare and Vinayagam (2006) in their previous studies.

However, with regard to medicinal and nutraceutical properties of soybean, only 35 per cent of the respondents had knowledge about usefulness of soymilk for lactose intolerant kids. Further, only 44 per cent of the respondents were found to have awareness about medicinal

properties of soybean which helps the women to avoid specific ailments like menopause and breast cancer, *etc.* Out of 200 respondents, it was found that nearly 39 per cent had knowledge regarding medicinal properties of soybean for prevention of cancer, diabetic and cardiac diseases. The role of daily intake of soybean in food on nutrition and health benefits is well documented (Grewal, 2000; Gandhi, 2006; Gandhi 2009; Nahashon and Kilonzo-Nthenge, 2011). Sandhya (2012) in a study reported that the knowledge of soybean processing technology through trainings to farm women will help to utilize soybean in their daily diet.

Table 1. Awareness about nutritional and nutraceutical aspects of soybean (N=200)

Attribute	Aware	Not Aware
<i>Nutritional properties</i>		
Cheapest Protein Source	179 (89.5%)	19(9.5%)
Availability of Vitamins	162 (81%)	36(18%)
Availability of Calcium (Osteoporosis)	156 (78)	42(21%)
Availability of Iron (Anaemia)	154 (77)	44(22%)
<i>Medicinal properties</i>		
Lactose intolerance (For Kids)	70 (35)	128(64%)
Especially useful for Women	89 (44.5)	109(54.5%)
Prevention of cancer	79 (39.5)	119(59.5%)
Cardiac diseases	78 (39)	120(60%)
Diabetic/Sugar/cholesterol	78 (39)	120(60%)

C. Domestic utilization pattern of soybean in rural household

The utilization of soybean in the daily diet of respondents was analyzed (Table 2). Results indicated that, nearly one third of the respondents were found to use soybean in their daily diet in the

form of fortified soy flour mixed with wheat, soy nuts and soy pakora. Preparation and consumption of soy nuggets (*soy bari*) was said to be the most preferred soy products (60.5 %), which they are using on regular basis in the rural areas. As it is easily available in the

market outlets even in rural areas, they available soy product as protein substitute. Interestingly, out of different soy products, nearly 22 per cent of the respondent families had liking for *soy pakora*, which is their most preferred soy product because of its crispy nature. However, the respondents from semi-urban area (adjacent to Indore city) are found to utilize tofu (*soy paneer*), which they are found to consume on regular

found it most economical and easily basis. Only 12 per cent of the respondent families are utilizing soybean for fortification with wheat flour without following proper processing techniques (Table 2). However, a small proportion of respondent families (7.5 %) are found making use of fried soy nuts (snack) regularly as well as during festive seasons.

Table 2. Utilization of soy products

Soy Preparation	Utilization by the respondents (N=200, multiple response)
Soy Flour (Fortified with wheat flour)	24 (12%)
Soy Nuts	15 (7.5%)
Soy <i>Pakora</i>	44 (22%)
Soy milk	5 (2.5%)
Tofu	39 (19.5%)
Preferred Soy Product (Soy Bari)	121 (60.5%)

Soybean based food preparations are slowly making inroads into rural households as they becoming aware of its nutraceutical and medicinal properties. The commercially available products such as soy nuggets and soy granules are by now very popular among the predominant vegetarian type of rural households. Further, their awareness and inclination about the processing

techniques for making of various soybean based food preparations can change the health and nutritional status of common people of rural background. More and more systematic and concerted efforts are needed to make these people aware about the domestic utilization of soybean commodity which they are growing in their farm for more than four decades.

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REFERENCES

- Agarwal D K, Billore S D, Sharma A N, Dupare B U and Srivastava S K. 2013. Soybean: Introduction, improvement and utilization in India-Problems and prospects. *Agricultural Research* (December 2013) **2**(4): 293-400
- Dupare B U and Vinayagam, S S. 2006. Impact of training intervention on knowledge and domestic utilization of soy-based food preparations for health benefits and nutritional security. *Soybean Research* **4**: 63-68
- Gandhi A P. 2006. *Soybean - the greater bean*, *World Grain* (USA), February issue, pp 59-62.
- Gandhi A P. 2009. Quality of soybean and its food products, *International Food Research Journal* **16**: 11-9.
- Grewal R B. 2000. Utilization and processing of soybean to prepare traditional foods of India. *The Third International Soyabean Processing and Utilization Conference (ISPUC-III): 2000 of the Innovative Era for Soyabeans*, October 15-20, 2000, Tsukuba, Ibarak, Japan, pp 325-6.
- Nahashon S N and Kilonzo-Nthenge A K. 2011. *Advances in Soybean and Soybean By-Products in Monogastric Nutrition and Health, Soybean and Nutrition*, El-Shemy H. (Ed.), ISBN: 978-953-307- 536-5, InTech, Available from: <http://www.intechopen.com/books/soybean-and-nutrition/advances-in-soybean-and-soybean-by-products-in-monogastric-nutrition-and-health>.
- Sandhya K. 2012. Strategic transfer of soy processing technology among rural women for enhancing the health status and for enhancing the home economy of rural area, *International Research Journal of Social Sciences* **1**(1): 6-14.
- Sharma P and Bhatia V S. 2015. Oilseed and Edible Oil Economy in India: Enhancing Supplies through Augmenting Productivity. In: *Souvenir 53rd All India Convention on Oilseeds, Oils Trade and Industry*, organized by COOIT on 24th - 25th October, 2015 at Nagpur.
- Sharma P, Patel R M and Srivastava S K. 2014. Comparative advantage of Indian soymeal *vis-à-vis* major exporters, *Soybean Research* **12** (spl. 1); 129-43.
- TAAS 2014. Proceedings and Recommendations of Brainstorming workshop on "Soybean for Household Food and Nutrition Security" organised on 21-22 March, 2014 by Trust for Advancement of Agricultural Sciences, Indian Council of Agricultural Research and National Academy of Agricultural Sciences, New Delhi.
- Tamang J P, Chettri R and Sharma R M. 2009. Indigenous knowledge of Northeast women on production of ethnic fermented soybean foods, *Indian Journal of Traditional Knowledge* **8**(1): 122-6.

Enhancement of Soybean Production through Varietal Replacement- A Case Study

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ABSTRACT

Soybean [Glycine max (L.) Merrill] is an important leguminous oilseed crop, which is the economical source of good quality protein and edible oil. The crop has a distinct attribute of improving soil fertility in a cropping system. The KVK Panna has made consistent efforts to popularize the improved variety JS 97-52 along with recommended production technology since kharif 2009 in Gram Panchayat, Richhora for enhancing yield and income of farmers. The present case study deals with enhancement of soybean productivity through varietal replacement in the Richhora village of district Panna under Kymore Plateau and Satpura Hills Agro-climatic Zone of Madhya Pradesh during 2009 to 2014, which showed that by the end of 2014, 77.7 per cent area has been occupied with improved soybean variety 'JS 97-52' in the said village with an increase in yield by 690 kg per ha and net returns by 85.3 per cent over locally cultivated varieties. Maximum yield (2,630 kg/ha) was obtained during 2012-13 when annual rainfall in Gunour block recorded was 1,112.3 mm. During 2013-14 as well, with higher rainfall (1,821.2 mm) in the area the improved variety of soybean (JS 97-52) produced 2,070 kg per ha. This shows that this variety is suitable under higher rainfall regime also. The returns per rupee investment varied between 1: 2.5 and 1: 4.2 in case of improved variety (JS 97-52) and appropriate production technology as compared to 1: 2.1 to 1.3.0 in locally cultivated varieties with traditional farmers practice during 2009 to 2014.

Key words: Economic impact, improved varieties, soybean, spread of technology

The Panna district is situated between 23°, 45' N and 25°, 10' N latitudes and 75°, 45' E and 80°, 40' E longitudes in Kymore Plateau and Satpura Hills Agro-climatic zone of Madhya Pradesh. The Panna district had an area of 26, 000 ha under soybean cultivation during kharif 2014, which was only 12,500 ha in 2009. Current average productivity of the crop in the district is 885 kg per ha as against the state and national productivity of 1,086 and 959 kg

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per ha, respectively (SOPA, 2014). However, the productivity of soybean is quite low as compared to yield potential in the experimental station (Kumar, 1997). Though there are several factors for low production and productivity of soybean crop in the district, however, lower seed replacement with improved varieties is a crucial one. The lower seed replacement rate with improved varieties is due to their inadequate availability in spite of development of numerous location specific varieties with 20-25 per cent yield superiority over the local cultivars with additional trait of better resistance against insect-pests and diseases (Mukherjee, 2003). Moreover, the farmers did not follow the recommended production technology. In view of these, KVK Panna introduced the improved variety JS 97-52 during *kharif* 2009 along with improved production technology to progressive farmer Sri Basant Lal Patel, village-Richhora, block- Gunour, district-Panna and continued till 2014. The results of this demonstration module and the spread effect have been discussed in the present investigation.

MATERIALS AND METHODS

The modules was demonstrated (0.4 ha) at farmer's field during *kharif* 2009 included use of improved variety JS 97-52, balanced dose of fertilizers (20:60:20 $\text{NP}_2\text{O}_5\text{K}_2\text{O}$ kg/ha) based on soil test values and seed treatment with fungicide (Carbendazim + Thiram @ 1+2 g/kg seed) followed by seed inoculation with *Bradyrhizobium japonicum* and phosphorus solubilizing bacteria (PSB) @ 5 g per kg seeds each and one spray of

imazethapyer @ 1 litre per ha at 15 days after sowing for weed management. The performance of the crop was compared with the farmer's practice on the same location, which included use of only 50 kg DAP per ha, higher seed rate (125 kg/ha) and sowing of seeds without seed treatment with fungicides and biofertilizers. Most of the farmers were using soybean variety JS 335. The soil of demonstrations site belonged to Vertisols. The Soybean crop was sown between second fortnights of June and harvested during last week of September to first week of October. The seed rate of improved variety of soybean (JS 97-52) was used @ 70 kg per ha. Soil test based tailored NPK fertilization was applied as basal form. The crop was protected from insect-pests and diseases as per recommendation. The yield data from demonstration field and farmer's crop was collected after harvesting the crop during 2009. In subsequent years (2010-2014), the horizontal spread of the improved variety (JS 97-52) in the said village was made through frequent farmers contact, interface with farmers, training to farmers and Rural Agricultural Extension Officer (RAEO), *Krishak Sangoshthi* and field days about good attributes of the variety. In addition, the progressive farmer Sri Basant Lal Patel also disseminated the information about improved variety among the farming community through personal contact in subsequent years of study. For economic evaluation in term of gross and net return and cost benefit ratio, the prevailing rates for input, labour and produce was utilized. Rainfall data

recorded during the study period to analyse the performance of the variety (JS 97-52) in high rainfall condition. For getting feedback about the introduced variety from soybean grower a comprehensive questionnaire was developed. The information was mainly collected with due cooperation of RAO through comprehensive questionnaire, which was administered among the farmers of the village. The personal interviews with the farmers were also

conducted for getting the feedback in the study area.

RESULTS AND DISCUSSION

Yield performance

Adoption of improved soybean variety 'JS 97-52' increased the seed yield by 43.9 per cent over existing varieties ('JS-335') a span of six years of study (Table 1). Irrespective of seasonal variations, the average yield achieved

Table 1. Horizontal Spread of Improved Variety of Soybean (JS 97-52) in Richhora village

Year	Horizontal Spread (ha)		Horizontal Spread (%)		Average yield (kg/ha)	
	JS 97-52	Locally cultivated varieties	JS 97-52	Locally cultivated varieties	JS 97-52	Locally cultivated varieties
2009-10	0.4	359.6	0.11	99.88	2000	1500
2010-11	4.8	355.2	1.33	98.66	2300	1640
2011-12	55.2	304.8	15.33	84.67	2550	1680
2012-13	100	240.0	27.77	66.66	2630	1760
2013-14	200	160.0	55.50	44.4	2070	1440
2014-15	280	80.0	77.70	22.2	2000	1400
Mean	-	-	-	-	2260	1570

Table 2. Effect of Rainfall on the production of Soybean in Richhora village

Year	Rainfall (mm)		Average yield (kg/ha)	
	Gunour Block	Panna District	JS 97-52	Locally cultivated varieties
2009-10	808.8	873.4	2000	1500
2010-11	1141.0	954.4	2300	1640
2011-12	1290.0	1186.9	2550	1680
2012-13	1112.3	1139.0	2630	1760
2013-14	1821.2	1642.0	2070	1440
2014-15	678.3	865.9	2000	1400

from improved variety was 2,260 kg per ha as compared to that of 1,570 kg per ha under farmer's practice during entire study period. It is evident from the results that the improved variety of soybean (JS 97-52) performed better under high rainfall situation (Table 2). Maximum yield (2,630 kg/ha) was obtained during 2012-13 when annual rainfall in Gunour block was recorded as 1112.3 mm. During 2013-14, with higher rainfall (1821.2 mm) in Gunour block, the improved variety of soybean (JS 97-52) produced respectable yield (2,070 kg/ha), which showed that this variety can perform better under higher rainfall regime also. The yield increase with the improved variety under the farming situation of demonstration area is likely to be effective in area with similar microclimate. The year-to-year fluctuations in yield can be explained on the basis of variations in microclimatic condition of that particular village. Mukherjee (2003) has also opined that depending on identification and use of farming situation, specific interventions may have greater implications in enhancing systems productivity. Yield enhancement in different crops in front line demonstration has amply been documented (Tiwari *et al.*, 2003; Tomer *et al.*, 2003; Singh *et al.*, 2013).

Horizontal spread of the variety

Improved soybean variety 'JS 97-52' was sown only in 0.4 ha area during *kharif* 2009-10 in village Richhora. And in the second year this variety occupied 4.8 ha area in same farmer's fields. During 2014, the horizontal spread of the variety

'JS 97-52' increased by 77.7 per cent. Out of 360 ha area under soybean crop in the village, this variety occupied around 280 ha (Table 1). Before adoption of this variety the farmer used to harvest an average production of soybean of 1,250-1,500 kg per ha, and now the same farmer is producing 2,000-2,500 kg per ha of soybean. The better performance of soybean variety over others grown at the location appears on account of its trait of doing well under higher rainfall conditions, better germinability, inbuilt resistance to YMV and collar rot diseases, moderately resistance to *Rhizoctonia* aerial blight disease and tolerance to insect-pests. This makes it possible to optimize productivity of soybean by adoption of variety 'JS 97-52' in light and heavy black soils of high rainfall regions.

Economic evaluation

The cost of cultivation in improved cultivar was comparatively higher (Rs. 15,500 - 20,000) as compared to farmer's practice (Rs. 14,000 -19,000) on account of additional input provided in the demonstration. Higher gross returns (Rs. 40,000 - 78,900) and net returns (Rs 24,500 - 60,300) were obtained from improved variety (JS 97-52) as compared to local cultivar (Rs. 30,000 - 52800) and (Rs 16,000 - 35,300) respectively. The average net returns obtained from improved variety were 85.3 per cent higher over locally cultivated varieties (Table 3). The returns per rupee investment were accordingly reflected in improved variety (1:2.5 to 1:4.2) as compared to locally cultivated varieties (1:2.1 to 1:3.0). The variation in cost of

cultivation during study period is attributed to variation in cost of inputs and that of produce. The result suggests economic viability and agronomic feasibility of adopted module in soybean

cultivation. The results are in conformity of findings reported by Siddique *et al.* (2004), Deshmukh *et al.* (2005), Jain and Trivedi (2006) and Singh *et al.* (2013).

Table 3. Economic Evaluation of Horizontal Spread of Improved Variety of Soybean (JS 97-52) in Richhora village

Year	Average cost of cultivation (Rs./ha)		Gross returns (Rs./ha)		Net returns (Rs./ha)		Returns/Rupee investment	
	JS 97-52	Locally cultivated varieties	JS 97-52	Locally cultivated varieties	JS 97-52	Locally cultivated varieties	JS 97-52	Locally cultivated varieties
2009-10	15500	14000	40000	30000	24500	1600	1:2.5	1:2.1
2010-11	16800	15000	52900	37720	36100	22720	1:3.1	1:2.5
2011-12	17300	16500	63750	42000	46450	25500	1:3.6	1:2.5
2012-13	18600	17500	78900	52800	60300	35300	1:4.2	1:3.0
2013-14	19900	18600	68310	47520	48410	28920	1:3.4	1:2.6
2014-15	20000	19000	66000	46200	46000	27200	1:3.3	1:2.4
Mean	18016.6	16766.6	61643.3	42706.6	43626	23540	1:3.3	1:2.5

Impact of technology

The achievements and outcome of improved variety (JS 97-52) are outstanding. Soybean has registered significant increase in productivity and returns per rupee investment. The average yield of improved variety (JS 97-52) of soybean has exhibited 43.9 per cent increase in yield against to farmers locally cultivated varieties. This is primarily due to introduction of high yielding and disease resistant variety along with improved technology against farmer practices as cited by Singh *et al.* (2013). Nearly 190.4 tonnes additional yield was obtained from adoption of improved variety (JS 97-52) in 280 hectare area in the village. It could be possible mainly due to effective dissemination of improved variety (JS 97-52) of soybean

crop by bringing awareness among farmers and farm women along with RAO of the village through various field oriented activities, training programme and availability of literature related to package and practices of soybean crop.

Feed back of soybean growers

Adoption of a given variety (JS 97-52) is usually a process, which passes through awareness about the variety, assessment of the expected returns from the variety, the farmer may then decide to grow. Good performance of the variety was observed during evaluation with the farmers. For getting feedback about the variety, approximately 35 farmers were interviewed through comprehensive questionnaire in the study area. Since this variety has tolerance to excessive soil

moisture, resistant to YMV and collar rot diseases and tolerant to insect-pests therefore, it was found suitable in terms of increased profitability and reduced risk. The farmers decided to switch off the other varieties and were inclined for adoption of this improved variety. Scientists should get insights about the level of adoption and the underlying factors that constraint or facilitate the adoption process, it is useful to examine the factors that determine technology uptake. This information is important to both researchers and policy makers. The researcher would gain useful feedback on the level of uptake of the variety/technology by the soybean growers and the attributes of the technology that conditioned the level of adoption. This can be useful in making decision to develop well-suited variety that meets the needs of the target of

increasing population in future. Policy makers can use such information to reform the policies that slower down the technology uptake or formulate and implement new instruments that hasten and support the adoption process.

The farmers of Richhora village have been sowing the improved variety (JS 97-52) of soybean crop consistently since last six years which brought out significant increase in yield of soybean crop that leads positive socio-economic changes in their life. The study also suggests that similar kind of approach can effectively convince the other farmers in other villages to adopt improved variety (JS 97-52) with recommended package of production to optimize their productivity which may effectively contribute to increase the national production of soybean.

REFERENCES

- Deshmukh K K, Khatik S K and Dubey D P. 2005. Effect of integrated use of inorganic, organic and bio-fertilizer on production, nutrient availability and economic feasibility of soybean grown on soil of Kaymore Plateau and Satpura hills. *Journal of Soils and Crops* **15** (1): 21-5.
- Jain P C and Trivedi S K 2006. Response of soybean (*Glycine max* (L) Merrill) to phosphorus and biofertilizers. *Legume Research* **28**(1): 30-3.
- Kumar J. 1997. Missed opportunities. In: *The Hindu Survey of Indian Agriculture*, pp. 49-53.
- Mukherjee N. 2003. *Participatory Learning and Action*. Concept Publishing Company, New Delhi, India, pp 63-5.
- Siddique M H, Lakho A A and Oad F C. 2004. Economics of inoculated and uninoculated soybean under different nitrogen level. *Assian Journal of Plant Science* **3**: 254-5.
- Singh R K, Singh S R K, Singh T K, Gautam U S and Dixit A K. 2013. Yield performance of soybean in Vindhyan plateau of Madhya Pradesh. *Soybean Research* **11**(1): 66-73.
- SOPA. 2014. *Estimates of Area, Production and Productivity of Soybean Crop during Kharif (Monsoon 2014)*, based on crop survey conducted by SOPA) Ref.: SOPA/2.11/DJ/2014/18 dated 3 November 2014
- Tiwari R B, Singh Vinay and Parihar Pushpa. 2003. Role of front line demonstration in transfer of gram production technology. *Maharashtra Journal of Extension Education* **22**(1): 19-20.
- Tomer L S, Sharma P B and Joshi K. 2003. Study on yield gap and adaptation level of potato production technology in gird region. *Maharashtra Journal of Extension Education* **22** (1): 15-18.

Technology to Mitigate Climate Change Adversities in Soybean

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ABSTRACT

Under the collaborative project of Solidaridad, South and South East Asia and Hindustan Unilever Foundation (HUF), a total of 65 demonstration involving interventions namely, broad bed furrow planting of soybean (40 Nos) and incorporation of vermicompost (25 Nos) to evaluate their impact on performance were organised in farmers' fields in kharif 2014. The region received deficit monsoon during the year. Planting soybean on broad bed and furrow system in districts of Madhya Pradesh and Maharashtra revealed seed yield increase by 12 per cent fetching Rs 4,555 per ha additionally over flat planting by the farmers. In case of incorporation of vermicompost, the seed yield increment was 8 per cent and additional income was Rs 2,652 per ha over farmers practice. The vermicompost was prepared by the farmers on their own farms using their resources.

Key words: Climate change, BBF Planting, Vermicompost

Soybean crop in India is severely affected in past few years owing to climate change, particularly erratic monsoon quantum and distribution. The climate prevailed during 2013-2015 has been detrimental for the performance of the crop. The triennium average for area production and productivity use to be 10.18 mha, 13.21 m t and 1,296 kg per ha during 2010-2012 is reported to be 11.38 m ha, 9.93 mt and 869 kg per ha (Table 1). There has been decline in productivity by 49 percent in the triennium average for 2013-2015, which is a matter of concern threatening the sustainability of soybean.

Soil water stress (deficit as well as excess) either on account of delayed monsoon, longer dry spells or early withdrawal of monsoon has been identified as one of the major factors for poor performance of the soybean crop (Joshi and Bhatia, 2003; Joshi *et al.*, 2006; Tiwari, 2014). The interventions like planting on changed land configuration (broad bed furrow and ridges and furrow) and incorporation of crop residues/organic sources and combination thereof have been found effective in mitigating the adverse effect of water stress and improvement in

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Table 1. Area, production and productivity of soybean in India during past 6 years

Year	Area (mha)	Production (mt)	Productivity (kg/ha)	Monsoon rains (mm) in Central India	Remarks
2010*	9.60	12.74	1327	1028*	Years of better quantum and distribution of rainfall
2011*	10.11	12.21	1208	1074*	
2012*	10.84	14.67	1353	935*	
Mean	10.18	13.21	1296	1012	
2013*	12.20	11.99	983	1195*	Years of deficit/excess rainfall with long dry spells at varying crop growth stages
2014**	10.88	10.44	959	879*	
2015**	11.06	7.38	667	816*	
Mean	11.38	9.93	869	963	

* <http://agricoop.nic.in/agristatisticsnew.html>; ** sopa.org

soil physical and biological environment (Anonymous. 2007-08 and 2008-09). Although, these technologies for management the ill effect of moisture stress have been research evaluated and proved effective, there is lack of data on their efficacy under real farm conditions (at farmers fields). In view of above, Solidaridad, South and South East Asia in collaboration with Hindustan Unilever Foundation (HUF) has initiated a joint project to evaluate the impact of broad bed furrow planting and incorporation of vermicompost through demonstrations independently at farmers fields since 2013.

MATERIAL AND METHODS

To evaluate the performance of broad bed furrow planting and incorporation of vermicompost, field demonstrations (0.4 ha each) on these two interventions were organised in real farm conditions (at farmer's fields) by the stakeholders under collaborative project initiated by Solidaridad, South and South East Asia and Hindustan Liver

Foundation in the year 2014. On broad bed and furrow method of sowing, a total of 40 demonstrations in districts of Madhya Pradesh (Agar - 8 Nos; Jhabua - 5 Nos; Sehore -8 Nos; Dewas - 11 Nos) and Maharashtra (Akola - 8 Nos) (Table 1) were laid out. On incorporation of vermicompost, a total of 25 demonstrations were organised in Madhya Pradesh (Hoshangabad - 8 Nos; Dhar - 17 Nos). All these trials were conducted on Vertisols and associated soils in the fields of small farmers. All the recommended cultivation practices in case of demonstrations and control plots were same except these two interventions. The farmers were trained by the stakeholders for the preparation of vermicompost, which was incorporated in soil at the rate of 10 t per ha at the time of final preparation of seed bed. The general composition of vermicompost was: nitrogen 2.1-2.6 per cent, phosphorus was 1.5-1.7 per cent and potassium 1.4-1.6 per cent (<http://hillagric.ac.in/edu/coa/agronomy/lect/agron-3610/Lecture-10-BINM->

Vermicompost.pdf). In majority of cases the soybean variety was same in demonstration and control plots.

Since the performance of the soybean crop was affected on account of rainfall quantum as well as distribution, cropping season of *kharif* 2014 was unusual and unfavourable for soybean. Most of the districts where the demonstrations were organised experienced deficit rainfall. The rainfall data in the cropping season (up to 30.09.2014) (www.sopa.org/RF_01102014.xls) for district Agar (taken data for Ujjain district in vicinity was deficient by 31%), Jhabua (- 3 %), Sehore (- 23 %), Dewas (- 38 %), Hoshangabad (- 22 %), Dhar (- 16 %) in Madhya Pradesh and Akola (- 3 %). The total rainfall in the Central India was also deficient by 10 per cent (<http://agricoop.nic.in/agristatisticsnew.html>)

The seed yield in demonstrations and control plot were recorded and expressed in terms of kg per ha. The mean for each location was worked out for demonstration plot and farmers plot to evaluate the impact of the two interventions. For evaluation of the monetary gain, the average price of soybean for the year 2014-15 has been utilized.

RESULTS AND DISCUSSION

Impact of broad bed and furrow planting

In spite of unfavourable rainfall (quantum and distribution) during the year, the planting of soybean led to average increase (12 %) in seed yield in district of Madhya Pradesh. The seed

yield increment in Agar, Jhabua, Sehore and Dewas was 9, 10, 15 and 16 per cent, respectively over flat planting in farmers field with concomitant average gain in income of Rs 4,118, Rs 3,526, Rs 4,586 and Rs 6,022 per ha. The overall average monetary gain in the state of Madhya Pradesh was Rs 4,555 per ha. The demonstrations organised in Akola district of Maharashtra also followed the suit. The increase in seed yield of soybean was 17 per cent with addition monetary gain of Rs 2,808 per ha. Although, the deficit of rainfall in Akola was only 3 percent, the rainfall distribution must have influenced causing the yield levels to below. Since the demonstrations were conducted at varied location and farmers' practice was different at different locations, the other factors like variation nutrient and pest management are responsible for varying seed yield levels between locations.

Broad bed furrow planting was suggested by ICRISAT (Joshi *et al.*, 2002) in view to improve *in situ* moisture conservation and drainage in Vertisols and associated soils to facilitate effective management of rainwater. Subsequently, this technology was found to be effective by researchers in *in situ* conservation of rainwater and with other advantages like soybean growth and yield increase (Reddy, 2009; Hariram *et al.*, 2011; Paliwal *et al.*, 2011; Lakhpale and Tripathi, 2012), soil physical and biological environment improvement, improved soil moisture content and better utilisation of native and applied nutrient resources (Anonymous, 2007-08 and 2008-09). The increased productivity

Table 1. Performance of soybean under broad bed furrow planting and incorporation of vermicompost under real farm conditions (2014)

Intervention, location and name of farmer	Variety		Yield (kg/ha)				Additional income to farmer (Rs/ha)*	Stakeholder responsible for demonstration
	Demons- tration	Farmers' field	Demons- tration	Farmers' field	Increase over Farmer's field (%)	Absolute increase (kg/ha)		
A. Broad bed furrow sowing								
Shri Pavan, Village Ahirbardiya, Agar, M P	JS 95-60	JS 95-60	1713	1575	9	138	4306	Centre for Advanced Research and Development (CARD) Bhopal, MP
Shri Man Singh, Village Pancharundi, Agar, M P	JS 95-60	JS 95-60	1530	1418	8	112	3494	
Shri Lal Singh, Village Pancharundi, Agar, M P	JS 95-60	JS 95-60	1528	1418	8	110	3432	
Shri Badrilal, Village Kundlakheda, Agar, M P	JS 335	JS 95-60	1578	1434	10	144	4493	
Shri Babulal, Village Payli, Agar, M P	JS 95-60	JS 95-60	1760	1578	12	182	5678	
Shri Narayan, Village Kundlakheda, Agar, M P	JS 95-60	JS 335	1587	1434	11	153	4774	
Shri Ramkaran, Village Payli, Agar, M P	JS 95-60	JS 95-60	1532	1421	8	111	3463	
Shri Harinarayan, Village Sarpoi, Agar, M P	JS 95-60	JS 95-60	1543	1432	8	111	3463	
Mean			1596	1464	9	132	4118	
Shri Bharatlal, Village Bawadi, Jhabua, M P	JS 95-60	JS 335	1085	986	10	99	3089	
Shri Narayan, Village Bawadi, Jhabua, M P	JS 95-60	JS 335	1248	1132	10	116	3619	
Shri Ganpat, Village Jamli,	JS 335	JS 335	1288	1189	8	99	3089	

Jhabua, M P								
Shri Ramesh, Village Jamli, Jhabua, M P	JS 95-60	JS 335	1267	1132	12	135	4212	
Shri Shankarlal, Village Jamli, Jhabua, M P	JS 95-60	JS 95-60	1283	1167	10	116	3619	
Mean			1234	1121	10	113	3526	
Shri Vijay Singh, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	944	812	16	132	4118	Vrutti-Livelihood Resource Centre, Bhopal MP
Shri Mohan Singh, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	847	734	15	113	3526	
Shri Bharat Lal, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	1140	988	15	152	4742	
Shri SatishSahu, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	1400	1230	14	170	5304	
Shri Ram Bharosh, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	1270	1135	12	135	4212	
Shri GoluUike, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	744	623	19	121	3775	
Shri Udham Singh, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	1067	921	16	146	4555	
Shri RajendraYaduwanshi, Village Borgahti, Sehore, M P	JS 95-60	JS 9560	1600	1396	15	204	6365	
Mean			1127	980	15	147	4586	
Shri RatanLal Singh , Village Bangar, Dewas, M P	JS 95-60	JS 9560	1470	1231	19	239	7457	Indian Grameen Services (IGS), Bhopal, MP
Shri Kailash , Village Bangar, Dewas, M P	JS 95-60	JS 9560	1550	1310	18	240	7488	
Shri Meharban Singh , Village Amlavti, Dewas, M P	JS 95-60	JS 9560	1360	1167	17	193	6022	
Shri Gopidash , Village Amlavti, Dewas, M P	JS 95-60	JS 9560	1280	1103	16	177	5522	
Shri Shankar ,Village Mudka, Dewas, M P	JS 95-60	JS 9560	1410	1187	19	223	6958	

Shri Prahlad , Village Mudka, Dewas, M P	JS 95-60	JS 9560	1460	1243	17	217	6770	
Shri Devi Singh , Village Nagukhedi , Dewas, M P	JS 95-60	JS 9560	1270	1165	9	105	3276	
Shri Vikash Singh, Village Nagukhedi, Dewas, M P	JS 95-60	JS 9560	1380	1168	18	212	6614	
Shri Motilal , Village AwliaPiplia, Dewas, M P	JS 95-60	JS 9560	1387	1230	13	157	4898	
Shri Phateh Singh, Village Jaleria, Dewas, M P	JS 95-60	JS 9560	1450	1260	15	190	5928	
Shri Harikaran ,Village Manasa, Dewas, M P	JS 95-60	JS 9560	1360	1188	14	172	5366	
Mean			1398	1205	16	193	6022	
Grand Mean			1339	1193	12	146	4555	
Shri Sanjy R.Rondle, Village Pohi, Akola, Maharashtra	JS 335	JS-335	600	534	12	66	2059	Indian Grameen Services (IGS), Maharashtra
Shri Vitthal Yshvant Dhere, Village, Akola, Maharashtra	JS 335	JS-335	750	643	17	107	3338	
Shri Praful Bapurao More, Village Lonsana, Akola, Maharashtra	JS 335	JS-335	563	456	23	107	3338	
Shri Mnohar Manikrao Dhere, Village Matoda, Akola, Maharashtra	JS 335	JS-335	875	750	17	125	3900	
Shri Bapurav Sudamsa Pranjale, Village Nimba, Akola, Maharashtra	JS 335	JS-335	700	590	19	110	3432	
Shri Devchand Hrichand Casture, Village Jamthi , Akola, Maharashtra	JS 335	JS-335	550	489	12	61	1903	
Shri Yogesh Bhaskar Bhalerao, Village Bramhi , Akola, Maharashtra	JS 335	JS-335	475	410	16	65	2028	

Shri Pramod Rameshwar Khedkar, Village Jitapur , Akola, Maharashtra	JS 335	JS-335	525	445	18	80	2496	
Mean			630	540	17	90	2808	
B. Vermicompost incorporation								
Shri Tulsiram, Village Padrai Thakur, Hoshangabad, M P	JS 95-60	JS 95-60	1027	693	48	334	10421	Vrutti-Livelihood Resource Centre, Bhopal, MP
Shri Bablu, Village Kamdan, Hoshangabad, M P	JS 95-60	JS 95-60	1440	803	79	637	19874	
Shri Suresh Kumar, Village Kapoori, Hoshangabad, M P	JS 93-05	JS 335	943	728	30	215	6708	
Shri Keshavsingh, Village Isarpur, Hoshangabad, M P	JS 95-60	JS 95-60	901	867	4	34	1061	
Shri Jaswantsingh, Village Rahatwada, Hoshangabad, M P	JS 95-60	JS 95-60	967	856	13	111	3463	
Shri Persotam, Village Jasarwani, Hoshangabad, M P	JS 335	JS 93-05	1100	875	26	225	7020	
Shri Sunil Kumar Sahu, Village Nayagoaw, Hoshangabad, M P	JS 95-60	JS 95-60	765	693	10	72	2246	
Shri Damoder Prasad Vishwakarma, Village Kharchli, Hoshangabad, M P	JS 95-60	JS 95-60	955	832	15	123	3838	
Mean			1012	793	28	219	6833	
Shri Ansing Dagdiya, Village Bhilberkheda, Dhar, M P	JS 95-60	JS 95-60	1209	1123	8	86	2683	Centre for Advanced Research & Development (CARD), Bhopal, MP
Shri Jhamiya Sitaram, Village Bhilberkheda, Dhar, M P	JS 95-60	JS 95-60	1155	1043	11	112	3494	
Shri Kishan Hemla, Village Bhilberkheda, Dhar, M P	JS 95-60	JS 95-60	1102	1021	8	81	2527	
Shri Ambaram Chhitar, Village Bhilberkheda, Dhar, M P	JS 95-60	JS 95-60	1137	1046	9	91	2839	
Shri Bhavsing Chhitar, Village	JS 95-60	JS 95-60	1120	1068	5	52	1622	

Bhilberkheda, Dhar, M P									
Shri Nanudibai Rajaram, Village	JS 95-60	JS 95-60	1198	1077	11	121	3775		
Bhilberkheda, Dhar, M P									
Shri Amichand Nathiya, Village	JS 335	JS 95-60	1138	1054	8	84	2621		
Mausapur, Dhar, M P									
Shri Ramsing Nathiya, Village	JS 335	JS 95-60	1103	1039	6	64	1997		
Musapur, Dhar, M P									
Shri Jagdish Nannu, Village	JS 95-60	JS 95-60	1201	1087	10	114	3557		
Kothisodpur, Dhar, M P									
Shri Chensing Amarsing,	JS 95-60	JS 95-60	1156	1096	5	60	1872		
Village Kothisodpur, Dhar,									
M P									
Shri Karan Chhagan, Village	JS 95-60	JS 95-60	1123	1066	5	57	156		Centre for Advanced Research & Development (CARD) Bhopal MP
Kothisodpur, Dhar, M P									
Shri Vijay lalsing, Village	JS 95-60	JS 95-60	1156	1038	11	118	3682		
Kothisodpur, Dhar, M P									
Shri Kalu Punja, Village	JS 95-60	JS 95-60	1145	1069	7	76	2371		
Kothisodpur, Dhar, M P									
Shri Fatehsing Hukumsing,	JS 95-60	JS 95-60	1136	1082	5	54	1685		
Village Mohanpur, Dhar, M P									
Shri Motia Narottam, Village	JS 95-60	JS 95-60	1187	1075	10	112	3494		
Mohanpur, Dhar, M P									
Shri Vikram Ratan, Village	JS 95-60	JS 95-60	1155	1085	6	70	2184		
Mohanpur, Dhar, M P									
Shri Sukhlal Madia, Village	JS 95-60	JS 95-60	1173	1074	9	99	3089		
Mohanpur, Dhar, M P									
Mean			1153	1067	8	85	2652		
Grand Mean			1083	930	18	152	4743		

*31.20/kg (2014-15)

of sole crops and crops in cropping systems involving soybean by planting on broad bed and furrow system in Vertisols of Central India was also reported earlier (Mandal *et al.*, 2013). The yield increase in the present demonstrations affirms the impact of this technology under real farm conditions.

Impact of incorporation of Vermicompost

Two districts namely Hoshangabad and Dhar were covered for this intervention showed 28 and 8 per cent increase in yield in demonstrations as compared to farmer's field. The corresponding monetary gain was Rs 6,833 and Rs 2,652 per ha. The incorporation of crop residues and manures has been age old practice in India for better crop performance. Nayak *et al.* (2005) have reported yield increments of several pulses and oilseeds inclusive of soybean by incorporation of

organic sources including vermicompost. Addition of vermicompost to soybean-wheat system was found to increase the yield of crops in the sequence (Paliwal *et al.*, 2011). Most of above workers have reported improvement in growth parameters of soybean by incorporation of vermicompost and the reported improvement in physical, chemical and biological properties (Kannan *et al.*, 2005; Romina Romaniuk, 2011)) must have been the cause of seed yield increase in soybean by incorporation of vermicompost.

These trials clearly indicated that the research emanated technology of *in situ* water conservation (planting on broad bed furrow and incorporation of vermicompost) is replicable under farmers' field to encounter the experienced aberrant monsoon due to climate change for resource poor farmers.

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REFERENCES

- Anonymous. 2007-08 and 2008-09. Annual Reports, Directorate of Soybean Research, Indore
- Hari Ram, Singh Guriqbal, Aggarwal Navneet and Kaur Jagmeet. 2011. Soybean (*Glycine max*) growth, productivity and water use under different sowing methods and seeding rates in Punjab. *Indian Journal of Agronomy* **56** (4): 377 -80.
- <http://agricoop.nic.in/agristatisticsnew.html>
- <http://hillagric.ac.in/edu/coa/agronomy/lecture/agron-3610/Lecture-10-BINM-Vermicompost.pdf> (Rana S S, Biological Intensive Nutrient Management: Vermicompost)
- Joshi O P, Billore S D, Ramesh A and Vyas A K. 2006. Analysis of the factors responsible for low yield of soybean in

- India. *SOPA Digest*, **November 2006**: 28-37.
- Joshi O P and Bhatia VS. 2003. Stress management in soybean. In: National Seminar on "Stress Management in Oilseeds for Attaining Self-reliance in Vegetable Oils" held during January 28-30, 2003 at Directorate of Oilseeds Research, Andhra Pradesh: Pp. 13-25.
- Joshi P K, R L Shiyani, M C S Bantilan, P Pathak and G D Nageswara Rao. 2002. *Impact of Vertisol Technology in India*, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, Pp 33
- Kannan P, Saravanan A, Krishnakumar S and Natarajan S K. 2005. Biological properties of soil as influenced by different organic manures. *Research Journal of Agriculture and Biological Sciences* **1**(2): 181-3.
- Lakpale Rajendra and Tripathi Vivek Kumar. 2012. Broad- bed Furrow and Ridge and Furrow Method of Sowing under Different Seed Rates of Soybean (*Glycine Max L.*) for High Rainfall Areas of Chhattisgarh Plains. *Soybean Research* **10**: 52- 9.
- Mandala K G, Hatib K M, Misrab A K, Bandyopadhyay K K and Tripathi A K. 2013. Land surface modification and crop diversification for enhancing productivity of a Vertisol. *International Journal of Plant Production* **7**(3): 455-4
- Nayak G V, Meli S S and Shivprasad M. 2005. Comparative performance of pulses and oilseeds under residual fertility of organic and bio-fertiliser treatments in paddy fallows of low rainfall hill zone of Karnataka. *Karnataka Journal of Agricultural Sciences* **18**(1): 8-12.
- Paliwal DK, Kushwaha HS and Thakur HS. 2011. Performance of soybean (*Glycine max*) - wheat (*Triticum aestivum*) cropping system under land configuration, mulching and nutrient management. *Indian Journal of Agronomy* **56** (4): 334 -9.
- Reddy K S. 2009. *Two Decades of Soil Research*, Indian Institute of Soil Science, Rao A S (Eds); Biswas A K; Hati K M; Rao A S (Eds), Bhopal, Pp 132
- Romina Romaniuk, Lidia Giuffr , Rosario Romero. 2011. A soil quality index to evaluate the vermicompost amendments effects on soil properties. *Journal of Environmental Protection* **2**: 502-10
- Tiwari S P. 2014. Raising the yield ceiling in Soybean- An Indian Overview. *Soybean Research* **12**(2): 1-43.
- www.sopa.org. 2015. Estimates of area, production and yield for soybean crop in kharif 2015.
- www.sopa.org/RFO1102014.xls

Technical Efficiency of Soybean Production in Madhya Pradesh: A Stochastic Frontier Approach

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ABSTRACT

Technical efficiency of soybean production and its determining factors has been worked out by collecting primary data from randomly selected farmers from selected three villages of Sehore and Ujjain districts. Results of analysis indicated that the mean technical efficiency of soybean farmers was 72 per cent (ranging from 22 to 95 %), implying that the soybean output of the 'average farmer' could be increased by 28 per cent by adopting the technology followed by the 'best practice' farmers. The positive and significant coefficients of human labour and machine labour implied that these variables were underutilized. The analysis of determinants of technical inefficiency indicated that coefficient for extension contact was positively significant and for age was negatively significant suggesting that contact of farmers with extension agencies reduces the inefficiency in soybean production. The older people do not have good contact with extension agencies and are less inclined to take risk leading to lower efficiency. For raising the technical efficiency of the soybean farmers, policy attention is needed to improve the extension services.

Key words: Determinants, stochastic production frontier, soybean, technical efficiency

Soybean plays an important role in oilseed economy of India. The crop is the largest oilseed crop accounting for about 56 per cent of area under *kharif* oilseeds and 38 per cent of total oilseeds area in the country during Triennium average Ending (TE) 2012-13. It accounted for 62 per cent of the *kharif* oilseeds production and 42 per cent of total oilseeds production in the country,

contributing to about 28 per cent of the total vegetable oils and two-thirds of the oil meals supplies during the corresponding period. The cultivation of soybean in India is mainly concentrated in Madhya Pradesh and adjoining areas of Maharashtra and Rajasthan states, three states together contributes to more than 95 per cent of total soybean production in the country. Soybean is the

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main *kharif* crop of Madhya Pradesh, and the state contributes largest share (nearly 56 %) of soybean production in India (GoI, 2015).

There has been phenomenal increase in area, production and yield of soybean in the country during the last four and half decades of its start of commercial cultivation in India (ICAR-DSR, 2015). The government policies and research support from national agricultural research system paved the way for almost trebling the average productivity of soybean in the country. However, there exists large yield gap in terms of yield realised with adoption of improved production technology under demonstrations and the average yield of the state (s) (Mruthyunjaya and Kiresur, 2000; Bhatnagar and Joshi, 2004; Billore *et al.*, 2004), which arise mainly due to sub-optimal and inefficient use of resources. The inefficiencies in oilseeds production have also categorically been stated (World Bank, 1997). Increasing efficiency and productivity of soybean production in India is of paramount importance to fulfil the fast increasing domestic demand for edible oils and for protein meals in the country. Growing population as well as income leading to enhanced demand for agricultural produce and there is increasing trend of diversion of cultivable land for non agricultural purposes (Deshpande and Bhende, 2003). Therefore, increase in agricultural production can only be achieved through adoption of improved production technology and efficient use of available resources. As majority of the soybean farmers are smallholders

(Mruthyunjaya *et al.*, 2005), achieving higher efficiency and productivity is no longer debatable to enhance their profitability and income. Against this backdrop, the present study was taken up to understand resource use efficiency across farm sizes for soybean production in Madhya Pradesh.

Technical efficiency is one of the measures of overall resource use efficiency, which is the ratio of actual and potential output of farm units and the variations in efficiency levels is determined by production environment in which a farm operates (Kalirajan and Shand, 1994). In this study an attempt is made to estimate the farm specific technical efficiency of soybean production in Madhya Pradesh. Further, attempt was also to identify the factors determining the technical efficiency of farmers in producing soybean. Enhancing the technical efficiency is important to reap the potential benefits of existing technology, rather than searching for new technology (Kalirajan *et al.*, 1996). There is dearth of studies on technical efficiency of soybean production in India.

DATA AND METHODOLOGY

Technical efficiency is measured as ratio of farm's actual output to its own maximum possible frontier output for given level of inputs and the chosen technology (Kalirajan and Shand, 1994). The concept of technical efficiency was introduced by Farrell (1957) and extended by Farrell and Fieldhouse (1962), Aigner and Chu (1968) and Seitz (1970) estimated a deterministic parametric frontier by specifying

a homogenous Cobb-Douglas production function. This approach ignores the fact that firms performance is affected by exogenous factors like weather, which is not in the control of the firm. Aigner *et al.* (1977), Meeusen and van den Broeck (1977), Battese and Coelli (1988), and Battese and Coelli (1995), Coelli *et al.* (2005) proposed stochastic frontier model taking into consideration the influence of uncontrollable exogenous shocks in the estimation process.

The farm level technical efficiency can be estimated through stochastic frontier production function model of the form:

$$Y_i = f(x_i; \beta) + \varepsilon_i \quad i = 1, 2, n \quad (1)$$

$$\varepsilon = v_i - u_i \quad (2)$$

Where Y_i represents the output level of the i^{th} soybean grower; $f(x_i; \beta)$ is a function such as Cobb-Douglas or translog production function of vector, x_i denoting the actual inputs used by i^{th} soybean grower, and a vector β of unknown parameters. The ε is the error term that is composed of two elements; v_i is the symmetric disturbances assumed to be identically, independently and normally distributed as $N(0, \sigma_v^2)$ which is associated with random factors such as measurement error in production and uncontrollable climatic factors, u_i is denotes a non-negative random variable associated with farm specific factors, which hinders the i^{th} farm from attaining maximum efficiency; u_i is associated with technical inefficiency of the farm and ranges between 0 and 1. N represents the

number of farms included in the cross sectional survey.

The variance of ε is given by $\sigma^2 = \sigma_u^2 + \sigma_v^2$, where, the term σ^2 is the variance parameter that denotes the total deviation from the frontier, σ_u^2 is the deviation from the frontier due to inefficiency, and σ_v^2 is the deviation from the frontier due to stochastic noise. $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$, Where, γ is an indicator of relative variability of u_i and v_i that differentiates the actual yield from the frontier. When σ_v^2 tends to zero, it implies that u_i is the predominant error, then $\gamma=1$. This means yield difference is mainly due to non-adoption of best practice or technique. When σ_u^2 tends to zero, it implies that the symmetric error-term, v_i is the predominant error and γ will be tending to zero. This means that yield differences from the frontier yield is mainly due to either statistical error or external factors that are not included in the model.

DATA AND MODEL

The study is based on the primary data collected from farmers' selected using pre-tested questionnaire prepared specifically for the purpose. Multi-stage sampling was used for sample selection. At the first stage, Ujjain and Sehore districts of Madhya Pradesh, representing different yield levels (high and medium) based on mean (+/-) standard deviation of yield in all districts for TE 2012-13 were selected for the study. At the second stage, one *tehsil* was selected, from each chosen district, based on the highest area under the crop. A cluster of villages (one key village and

two nearby villages) were selected randomly for the study from the list of soybean growing villages. At the last stage, a list of soybean growing farmers was prepared and sample of 100 farmers from each district were selected randomly from the list. Thus, two hundred farmers were selected and interviewed for the study.

The stochastic frontier production function of the Cobb-Douglas form used in the study is given by Equation (3):

$$\ln Y_i = \alpha + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \beta_3 \ln x_3 + \beta_4 \ln x_4 + \beta_5 \ln x_5 + v_i - u_i \quad \dots(3)$$

Where, Y_i = soybean production of i^{th} farm in quintal per ha,

α = constant term

x_1 = human labour input used in man-hours per ha,

x_2 = seed used in quintal per hectare,

x_3 = chemical fertiliser (NPK) quantity used in kilograms per hectare,

x_4 = Machine hours/ha

x_5 = Plant protection chemicals per ha,

β_i = unknown parameters to be estimated,

v_i = symmetric component of the error term and

u_i = non-negative random variable which is under the control of the farm.

' u_i ' takes the value of zero when the farmer is efficient and assumes the value greater than zero when the farmer is inefficient. Negative value of u varies depending on the level of inefficiency. The Maximum Likelihood Estimation (MLE) method enables us to obtain the maximum possible output function. The computer programme FRONTIER

version 4.1c was used for this study (Coelli, 1996).

The model for assessing technical inefficiency is given by Eq. (4):

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 \quad \dots(4)$$

Where, u_i is the technical inefficiency in the i^{th} farm, Z_1 is the age of head of household (in years), Z_2 is the education of a farmer (in years), Z_3 is the farm size (in ha), Z_4 is the extension contact (dummy binary variable, 0 if farmer doesn't have extension contact and 1 if farmer has extension contact), Z_5 is loan (dummy binary variable, 0 if farmer not availed crop loan and 1 if farmer availed crop loan) and $\delta_1, \delta_2, \delta_3, \delta_4$ and δ_5 are the inefficiency parameters.

The technical efficiency of individual farm was worked out using formula (5):

$$TE = Y_i / Y_i^* \quad \dots(5)$$

Where, Y_i^* is the frontier yield and Y_i is the actual yield.

RESULTS AND DISCUSSION

The ordinary least square (OLS) as well as maximum likelihood estimates (MLE) of the estimated stochastic frontier production function (Cobb-Douglas model) are presented (Table 1). The coefficient of multiple determination (R^2) indicates that 33 per cent of the variation in yield could be explained by the variables included in the model for the soybean crop. All the variables considered in the model had positive coefficient except for capital (other

Table 1. OLS and maximum likelihood estimates of parameters of the stochastic frontier production function (Cobb-Douglas Model) of soybean farmers in M P

Variables	OLS		MLE	
	Coefficient	Pr > t	Coefficient	Pr > t
General model				
Constant	0.498	0.3693	1.1141**	0.0188
Human Labour	0.191*	<.0001	0.1676*	<.0001
Seed	0.102	0.3611	0.1108	0.2435
Fertilizer nutrients	0.011	0.7683	0.0009	0.9767
Machine labour	0.191*	0.0004	0.1162*	0.0045
PP Chemicals	0.094	0.1117	0.0627	0.2034
Capital	-0.006	0.8655	-0.0043	0.8905
F Stat	15.52*			
R ²	0.33			
Variance parameters				
σ_v			0.1431	<.0001
σ_u			0.4523	<.0001
Lambda			3.161	
Sigma-Squared (σ^2)			0.225*	
Gamma (γ)			0.909*	
Log Likelihood			-39.067	
LR Test			19.246	
Mean TE			0.725	
Min TE			0.22	
Max TE			0.95	

Note= *, ** denotes significance at 1 and 5 per cent, respectively

expenses). The labour variables, viz. human labour (0.191) and machine labour (0.191) turned out to be positively significant indicating their importance in soybean production in Madhya Pradesh. This indicates that these inputs were productive and underutilised by the farmers.

The OLS estimates could narrate the response of the average farms while the frontier production function reflects the response of the best and efficiently managed farms. The estimate of gamma (γ), which measures the effect of technical inefficiency on the variation of observed

output. The estimated value of γ is 0.91 (Table 1), which indicates that the vast majority of error variation is due to the inefficiency error u_i (and not due to the random error v_i). This indicates that the component of the inefficiency effects does make a significant contribution (91 %) in variation of soybean production which is under the farmers' control. The one sided LR test of $\lambda=0$ provides a statistic of 19.25 which exceeds the chi-square five per cent critical value. Hence, the stochastic frontier model does appear to be a significant improvement over an average (OLS) production function. The Lambda

denotes the ratio of the variance of farm-specific production behaviour (σ_u) to the variance of the statistical noise (σ_v) and its value (3.161) indicates that the one-sided error component dominated more than the symmetric error component.

The value of constant term was observed higher in the stochastic frontier production function than the OLS method, which signifies that the stochastic production function could shift vertically as compared to the OLS method. The estimates of the stochastic frontier production reflect the efficient use of available technology and coefficients denotes production elasticities, and sum of coefficients is returns to scale. The positive and significant coefficients of human labour (0.167) and machine labour (0.116) implied that these variables were underutilized. The soybean output increases by about 0.17 per cent and 0.12 per cent for each extra percentage utilisation of human labour and machine labour, respectively. The under utilisation

of human and machine labour may be due to the fact that the survey year was the excess rainfall year and farmers could not find time for different farm operations timely. The average yield was also lower than the previous year as reported by the farmers.

Technical efficiency of soybean farmers

Technical efficiency is defined as the farmer’s ability to produce maximum potential output (Y_{max}) given the technology and level of input use. Thus, the farm specific technical efficiency is the ratio of the actual output obtained by the farmer (Y_t) to the maximum potential output (Y_{max}). The results of frequency distribution of technical efficiency of soybean farmers (Table 2) revealed that about 21.5 per cent farmers were in the minimum efficiency level of below 60 per cent, 16 per cent in the level of 60-70, 21.5 per cent in 70-80 per cent level, 32 per cent in 80-90 per cent level and only 9 per cent soybean farmers were in the

Table 2. Distribution of soybean growers under different levels of technical efficiency

Efficiency level (%)	Number of farms	Percentage to total farms	Technical Efficiency (%)
< 60	43	21.5	0.49
60-70	32	16.0	0.66
70-80	43	21.5	0.75
80-90	64	32.0	0.85
>90	18	9.0	0.92
Total	200	100	0.72

efficiency level of more than 90 per cent. Results further revealed that the mean technical efficiency of soybean farmers

ranging from 22 per cent to 95 per cent, with an average of 72 per cent (Table 1). This implied that the soybean output

of the 'average farmer' could be increased by 28 per cent by adopting the technology followed by the 'best practice' farmers. Mruthyunjaya *et al.* (2005) revealed that technical efficiency of soybean farmers was 59 per cent in Madhya Pradesh (ranging from 25 - 95 per cent) and 73 per cent in Maharashtra (ranging from 33 to 73 per cent).

Technical efficiency and input Use

The details of input use across different levels of technical efficiency (Table 3) indicates that technically most efficient producers (more than 90 % efficiency level) used 123 hours per ha human labour, 1.36 hours per ha machine and bullock labour, about 92 kg seed per ha, 88.6 kg per ha fertilizer nutrients (N, P, K and S) and 1.7 Lt per ha plant protection chemicals including herbicides. However, efficient among the selected soybean growers, they still use lower fertilizer nutrients than the recommended (20:60:40:20, N:P:K:S).

Almost all the farmers use higher seed rate (above 90 kg/ha) than recommended (75-80 kg/ha) leading to high plant population and lower yield of crop.

The higher use of seed rate by farmers was mainly due to factoring in of lower seed germination without proper germination test by the farmers, although the recommended seed rate is based on the germination rate of most common varieties. The farmers with least efficiency level used lower human labour, machine labour and plant nutrients leading to higher inefficiency in soybean production and limiting the yield achieved. The lower use of human labour by the least efficient farmers may be due to the fact that use of labour by them was higher for wage and non-agricultural uses. Mruthyunjaya *et al.* (2005) reported that inputs such as seed, human labour and irrigation was underutilised by the soybean growers in Madhya Pradesh and Maharashtra.

Table 3. Input use of soybean growers under different levels of technical efficiency

TE level (%)	Human labour (hrs/ha)	Machine labour (hrs/ha)	Seed (kg/ha)	Fertilizer nutrients (kg/ha)	Plant Protection chemicals (kg/ha)
< 60	117.38	1.43	90.25	73.26	1.59
60-70	161.38	2.10	94.82	94.98	1.77
70-80	135.39	2.07	98.74	99.93	1.83
80-90	110.55	1.95	96.02	77.91	1.95
>90	122.67	1.36	91.77	88.59	1.70
Overall	125.68	1.80	94.55	84.89	1.79

The potential yield for each farmer was calculated and the average potential yield as per different technical

efficiency levels has been worked out (Table 4). Since, the efficiency is the ratio of actual yield achieved to the maximum

potential yield, potential yield is calculated by dividing actual yield with the efficiency of the farmer. Overall, the potential yield of soybean was estimated at 1,368 kg per ha based on the efficiency level of the farmers. Thus, with the efficient allocation of resources, the average yield would have been increased by about 35 per cent. This could go up to

1,555 kg per ha among the most efficient farmers having the efficiency level of more than 90 per cent. Among the least efficient farmers, the average yield level of 635 kg per ha could be almost doubled with the potential of 1,231 kg per ha, if the resources were efficiently allocated by the farmers.

Table 4. Estimated potential yield under different levels of technical efficiency

TE level (%)	Average Technical Efficiency (%)	Average yield (kg/ha)	Potential yield (kg/ha)
< 60	0.49	635	1231
60-70	0.66	919	1389
70-80	0.75	1021	1369
80-90	0.85	1187	1393
>90	0.92	1429	1555
Overall	0.72	1013	1368

Determinants of technical efficiency

Since the performance of crops could be improved considerably with improved technical efficiency in resource-use through optimal input selection and use, analysis of determinants of technical efficiency is crucial. The results of technical inefficiency effects model (Table 5) showed that technical inefficiency could be due to a number of personal, household and farm-specific variables. The results of technical extension contact had significant impact on the efficiency of soybean production. The inefficiency effects indicated that variables such as age of the head of household and negative and significant coefficient of extension contact suggests that contact of farmers with extension agencies reduces the inefficiency in soybean production or

in other words, improves technical efficiency. The variable age was positive and significant, indicating that as the age of head of household increases, the efficiency of soybean production decreases. This may be due to the fact the older people does not have good contact with extension agencies and are less inclined to take risk leading to lower efficiency. For raising the technical efficiency of the soybean farmers, policy attention is needed to improve the extension services. Mruthyunjaya *et al.* (2005) reported that age and education of the head of household, seed quality and soil quality seemed to be important variables affecting efficiency of soybean production in Madhya Pradesh and Maharashtra, needs appropriate policy attention for raising technical efficiency.

Table 5. Estimates of technical inefficiency effects model for soybean in MP

Variables	Coefficient	Pr > t
Constant	0.0822	0.1087
Age (years)	0.0057*	<.0001
Education (no. of years of schooling)	-0.0006	0.8046
Farm Size (hectares)	-0.0025	0.2706
Extension Contact (1= farmer has extension contact & 0= no extension contact)	-0.0790*	<.0001
Loan (1= crop loan availed & 0= not availed)	0.0111	0.5599
R ²	0.2880	
F value	15.69*	

Note= * denotes significance at 1 per cent

Conclusions and policy implications

The technical inefficiencies in soybean production in selected districts of Madhya Pradesh have been found to be one-fourth to two-third and even more at the farm level. If prevented/minimised, the soybean and oil production in the country could significantly be enhanced. Under utilization of resources reflects a poor resource base of the farmers having implications for optimal utilisation of inputs and optimum production of

output to reduce inefficiencies. Timely and cost effective supply of quality inputs is the key to enhance the productivity of crops. Extension contact of farmers in one of the factors determining the level of technical efficiency in soybean production, hence, needs strengthened. Government may use the extension machinery to create awareness about adoption of improved crop production technology and seed replacement with high yielding varieties.

REFERENCES

- Aigner D J and Chu S F. 1968. On estimating the industry production function. *American Economic Review* **58**: 826-39.
- Aigner D J, Lovell C A K and Schmidt P. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* **6**: 21-37.
- Battese G E and Coelli T J. 1995. A model for technical efficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* **20**: 325-32.
- Battese G E and Coelli T. 1988. Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of Economics* **28**(4): 387-99.
- Bhatnagar P S, Joshi O P, 2004. Current status of soybean production and utilization in India. In: *Proceedings of VII World Soybean Research Conference, IV International Soybean Processing and Utilization Conference, III Congresso Mundial de Soja (Brazilian Soybean*

- Congress), Embrapa Soybean, Londina, Brazil, pp. 26-37.
- Billore S D, Joshi O P and Dupare B U. 2004. Impact of frontline demonstrations on augmenting the soybean, *Glycine max* L. productivity. *Journal of Oilseeds Research* **21**: 352-3.
- Coelli T J, Rao D S, O'Donnell C J and Battese G E. 2005. *An Introduction to Efficiency and Productivity Analysis*. New York, NY: Springer Incorporation.
- Coelli, T. 1996. 'A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation', CEPA Working Paper 96/08, University of New England.
- Deshpande, R S and Bhende, M J. 2003. *Land Resources and Policy in Karnataka*, Working Paper 132, Institute for Social and Economic Change, Nagarbhavi, Bangalore.
- Farrell M J and Fieldhouse M. 1962. Estimating efficient production function under increasing returns to scale. *Journal of Royal Statistical Society Series, General* **120**, Part 3: 252-67.
- Farrell M J. 1957. The measurement of productive efficiency. *Journal of Royal Statistical Society* **120**: 253-81.
- GoI. 2015. *Agricultural Statistics at a Glance 2014*. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, GoI.
- ICAR-DSR. 2015. *Vision 2050*, ICAR-Directorate of Soybean Research, Indore.
- Kalirajan K P and Shand R T. 1994. *Economics in Disequilibrium: An Approach from the Frontier*. Macmillan India Ltd., Delhi.
- Kalirajan K P, Obwona M M and Zhao S. 1996. A decomposition of total factor productivity growth: The case of Chinese agricultural growth before and after reforms. *American Journal of Agricultural Economics* **78**: 331-8.
- Meeusen W and van den Broeck J. 1997. Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review* **18**: 435-44.
- Mruthyunjaya and Kiresur V R. 2000. Oilseed Research and Development- Socio-economic Settings, In: Mangala Rai, Harvir Singh and D M Hegde (Eds.) *Oilseeds and Oils: Research and Development Needs*, Indian Society of Oilseeds Research, Hyderabad.
- Mruthyunjaya, Kumar S, Rajashekharappa M T, Pandey L M, Ramanrao S V and Prem Narayan 2005. Efficiency in Indian edible oilseed sector: Analysis and Implications. *Agricultural Economics Research Review* **18**(2), 153-66.
- Seitz W D. 1970. The measurement of efficiency relative to a frontier production function. *American Journal of Agricultural Economics*, **52**: 505-11.
- World Bank. 1997. *The Indian Oilseed Complex: Capturing Market Opportunities*. The World Bank, Washington DC.

Response of Soybean Varieties to Date of Sowing, Plant Population and Fertilizer Dose

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In India, area under soybean crop is increasing steadily. At present, it has 10.88 million hectare area producing 10.43 million tons with 0.95 ton per ha productivity (SOPA, 2014). Soybean is nutritionally important grain legume crop due to better quality edible oil (20 %) and proteins (40 %). It contributes 40 per cent of oilseed area and 25 per cent of edible oil production; besides 8 million ton of soy-meal production in the country. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh are the leading soybean producing states in India. To harvest a good yield of soybean, it is necessary to sow the crop at proper time, to maintain optimum plant density and to provide adequate nutrition. In combination with these important parameters, selection of suitable genotype plays a vital role in crop production. The choice of right genotypes of soybean helps to augment crop productivity by 20-25 per cent (Singh *et al.*, 2013. Increase in the seed

rate ultimately results into increased density of plants per hectare. Either higher or lower density of plants than the optimum leads to the reduction in yield. Highly dense crop suffers from low space for growth; compete for soil moisture, sun light and nutrition. On the other hand, crop with low plant population per hectare is unable to produce yield to its potential, resulting in low yield. Supply of insufficient quantities of nutrients also leads to reduced crop yields. Hence, the present investigation was carried out to evaluate response of elite soybean varieties to date of sowing, plant population and fertilizer dose.

The study was conducted during the *kharif* season of 2014 on the experimental farm of Agharkar Research Institute, Pune to evaluate the response of new cultivars of soybean to sowing date, planting density and fertilizer dose. The experimental site is situated at 18°14' N latitude, 75°21' E longitude and an altitude of 548.6 m from mean sea level.

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Total rainfall received during the *kharif* season, from June to November (crop growth period), was 480.9 mm. Soil of the experimental plot belongs to the order Vertisols with slight alkaline pH 7.5 and low in organic carbon (0.44 %). The available N (294 kg/ha) and available P₂O₅ (17.67 kg/ha) were medium and the available K₂O (339 kg/ha) was high. Three experiments were separately laid out each in split plot design and replicated thrice. Main plots were assigned to sowing dates (20th June, 5th July and 20th July), plant populations (0.30, 0.45 and 0.60 million/ha) and fertilizer doses (75, 100 and 125 % RDF). Sub-plots were assigned to six varieties (MACS 1407, MACS 1416, MACS 1340, RKS 18, JS 335 and Bragg). Recommended dose of fertilizer (20:80:20 N:P₂O₅:K₂O kg/ha) was applied to sowing date and plant population experiments. In fertilizer experiment, fertilizers were applied as per treatments as basal dose. All recommended package of practices were followed. Observations on yield contributing characters were recorded on randomly selected ten plants and averaged out. Oil content was estimated on Oxford-4000 NMR. Seed yield was recorded on net plot basis and expressed as kilogram per hectare. Data were analyzed using standard variance techniques given by Gomez and Gomez (1984).

Effect of date of sowing

Seed yield of crop sown on 20th June (3,143 kg/ha) and 5th July (2,936 kg/ha) was significantly higher than that sown on 20th July (2,452 kg/ha) (Table 1). Percent increase in yield over 20th July

sowing was 28.18 per cent and 19.74 per cent, respectively for 20th June and 5th July sowing, respectively. Billore *et al.* (2000) reported that planting of soybean beyond 25th June reduces productivity linearly by 188.77 kg per ha for every 5 days delay in sowing. Bhatia *et al.* (1999) reported a sharp decline in seed yield of soybean sown after 10th July. Plant height, branches per plant, pods per plant, seed index, harvest index and oil content, although numerically higher in 20th June sowing, were not significantly affected due to sowing dates. 'MACS 1407' (3,279 kg/ha) recorded maximum seed yield and was at par with 'MACS 1416' (3,234 kg/ha) and 'MACS 1340' (2,968 kg/ha). Variation in yield among varieties might be due to their genetic variability. Interaction of sowing dates and varieties was non-significant.

Effect of plant population

Data on response of varieties to three plant populations (Table 2) indicated significant differences among varieties and plant populations for seed yield, branches per plant, pods per plant and seed index. However, interaction was non-significant for all the characters except pods per plant. Maximum seed yield (2,472 kg/ha), branches per plant (3.11), pods per plant (40.00), seed index (12.16 g) and harvest index (51.99 %) were recorded in 0.45 million per ha plant population. Significant increase in yield may be due to increase in yield contributing characters resulted due to optimum plant stand. The optimum plant population is the function of appropriate seeding rate which resulted in optimum plant canopy and increased light

Table 1. Effect of date of sowing on growth, yield and yield attributes of soybean

Treatments	Plant height (cm)	Branches (No/plant)	Pods (No/ plant)	Seed index (g)	Harvest index (%)	Oil content (%)	Seed yield (kg/ha)
<i>A. Main plot: Date of sowing</i>							
20 th June	59.68	2.88	42.64	13.56	50.52	18.04	3143
05 th July	55.37	3.12	39.97	12.91	52.03	18.14	2936
20 th July	56.70	2.70	39.64	13.02	44.06	18.04	2452
SEm (\pm)	1.53	0.16	0.93	0.48	3.55	0.25	126
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	495
<i>B. Sub plot: Varieties</i>							
MACS 1407	58.74	3.18	43.41	13.04	53.04	18.05	3279
MACS 1416	55.78	2.87	42.57	13.34	52.89	18.04	3234
MACS 1340	62.69	2.80	41.58	15.00	49.70	17.58	2968
RKS 18	62.07	2.92	41.24	11.36	45.86	18.32	2593
JS 335	59.00	2.29	40.40	10.17	42.96	17.03	2488
Bragg	45.22	3.33	35.31	16.05	48.76	19.41	2480
S Em (\pm)	1.53	0.22	1.41	0.24	2.21	0.09	116
CD (P = 0.05)	4.52	NS	4.17	0.70	6.53	NS	343
S Em (\pm)	2.66	0.37	2.45	0.41	3.84	0.16	201
Int. CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of plant population on growth, yield and yield attributes of soybean

Treatments	Plant height (cm)	Branches (No/plant)	Pods (No/plant)	Seed index (g)	Harvest index (%)	Oil content (%)	Seed yield (kg/ha)
<i>A. Main plot: Plant population</i>							
0.30 million/ha	49.69	2.00	30.11	12.03	51.63	18.45	2116
0.45 million/ha	48.31	3.11	40.00	12.16	51.99	18.24	2472
0.60 million/ha	54.08	2.28	35.49	11.58	46.48	17.91	2378
S Em (+)	2.46	0.18	1.25	0.09	1.50	0.14	47.89
CD (P = 0.05)	NS	0.72	4.91	0.38	NS	NS	187.9
<i>B. Sub plot: Varieties</i>							
MACS 1407	50.27	2.78	46.73	11.11	55.60	17.88	2688
MACS 1416	48.81	2.56	46.14	10.80	51.86	17.59	2562
MACS 1340	53.76	2.56	37.56	12.90	87.89	17.83	2468
RKS 18	52.47	2.33	28.49	10.97	53.48	17.95	2199
JS 335	54.67	2.44	28.87	11.51	48.05	18.32	2158
Bragg	44.18	2.11	23.43	14.25	43.32	19.63	1857
S Em (+)	2.42	0.19	1.36	0.65	2.57	0.31	57.36
CD (P = 0.05)	7.13	NS	4.02	1.91	7.59	0.91	169.19
S Em (+)	4.19	0.33	2.36	1.13	4.46	0.54	99.34
CD (P = 0.05)	NS	NS	6.96	NS	NS	NS	NS

Table 3. Effect of fertilizer dose on growth, yield and yield attributes of soybean

Treatments	Plant height (cm)	Branches (No/ plant)	Pods (No/plant)	Seed index (g)	Harvest index (%)	Oil content (%)	Seed yield (kg/ha)
A. Main plot: Fertilizer dose							
75% RDF	50.30	2.54	33.17	11.33	47.87	18.60	2372
100% RDF	54.22	3.12	41.45	11.71	45.97	18.57	2513
125% RDF	49.62	2.35	36.79	11.91	47.51	18.58	2381
S Em (+)	1.64	0.15	1.49	0.11	0.93	0.09	29.18
CD (P = 0.05)	NS	0.58	5.85	0.43	NS	NS	114
B. Sub plot: Varieties							
MACS 1407	47.29	3.27	46.76	11.16	51.61	18.59	2678
MACS 1416	50.29	3.11	42.12	10.40	52.69	18.03	2622
MACS 1340	58.20	2.47	38.28	13.45	44.65	18.54	2503
RKS 18	56.09	2.60	34.69	10.37	44.20	18.01	2290
JS 335	54.60	2.33	34.84	10.07	44.84	18.11	2242
Bragg	41.82	2.26	26.14	14.47	44.71	20.22	2198
S Em (+)	2.18	0.16	1.74	0.22	1.63	0.12	43.90
CD (P = 0.05)	6.44	0.49	5.13	0.66	4.82	NS	229
S Em (+)	3.78	0.29	3.02	0.39	2.82	0.22	76.03
CD (P = 0.05)	NS	NS	8.89	1.17	NS	NS	224

intensity and leads to higher dry matter accumulation and finally yield (Billore and Srivastava, 2014). Among the varieties 'MACS 1407' (2,688 kg/ha) recorded significantly higher seed yield and was at par with 'MACS 1416' (2,562 kg/ha) and 'MACS 1340' (2,468 kg/ha). Higher yield in these genotypes is mainly attributed to significantly higher pods per plant.

Effect of fertilizer dose

A significant increase in soybean yield was observed with the application of 100 per cent RDF (2,513 kg/ha) over 75 per cent RDF (2,371 kg/ha) and 125 per cent RDF (2,381 kg/ha), which was 5.99 per cent and 5.54 per cent higher than respective doses (Table 3). It revealed that supply of insufficient or excess quantity of nutrients to crop directly or indirectly affects on the yield. Number of branches, pods per plant and seed index was also significantly higher in 100 per cent RDF which might be mainly due to optimum supply of N, P and K. Increase in yield with application of 100 per cent

RDF was earlier reported by Sawarkar *et al.* (2010). Variety 'MACS 1407' (2,678 kg/ha) recorded significantly higher soybean yield than RKS 18, JS 335 and Bragg while, it was at par with 'MACS 1416' (2,622 kg/ha) and 'MACS 1340' (2,503 kg/ha). Significantly higher yield in variety 'MACS 1407' attributed mainly to significant increase in branches per plant, pods per plant, harvest index. The differential behavior in soybean varieties for growth and development may be attributed to their genetic makeup (Singh *et al.*, 2013). Interaction of fertilizer dose and varieties was significant for seed yield (Table 4). Variety 'MACS 1407' with 100 per cent RDF recorded significantly highest yield (2,858 kg/ha) and was at par with 'MACS 1416' (2,727 kg/ha) and 'MACS 1340' (2,717 kg/ha). In this study soybean variety 'MACS 1407' with recommended dose of fertilizer was found significantly superior in yield followed by 'MACS 1416' and 'MACS 1340' with recommended dose of fertilizer.

Table 4. Interaction effect of fertilizer dose and soybean varieties on yield (kg/ha)

Varieties	Fertilizer Dose		
	75% RDF	100% RDF	125% RDF
MACS 1407	2641	2856	2537
MACS 1416	2480	2727	2658
MACS 1340	2354	2717	2438
RKS 18	2352	2275	2242
JS 335	2372	2210	2144
Bragg	2036	2294	2265
S Em (+)	76.03		
CD (P = 0.05)	224		

Thus, the present study on sowing date, plant density and fertilizer dose for soybean varieties revealed that sowing on the 20th June (3,143 kg/ha), 0.45 million per ha plant population (2,472 kg/ha) and 100 per cent RDF (2,513 kg/ha) recorded maximum seed yield of soybean in respective trials. Sowing

should not be delayed beyond the 20th June. In the present studies, three varieties viz., MACS 1407, MACS 1416 and MACS 1340 showed better yield performance and response to above three parameters than remaining three varieties.

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REFERENCES

- Billore S D and Srivastava S K. 2014. Effect of seed rate and row spacing on productivity of soybean varieties under different agro-climatic zones of India. *Soybean Research* **12**(2): 83-9.
- Billore S D, Joshi O P and Ramesh A. 2000. Performance of soybean (*Glycine max*) genotypes on different sowing dates and row spacing in Vertisols. *Indian Journal of Agricultural Sciences* **70**(9): 577-80.
- Bhatia V S, Tiwari S P and Joshi O P. 1999. Yield and its attributes as affected by planting dates in soybean (*Glycine max*) varieties. *Indian Journal of Agricultural Sciences* **69**(10): 696-709.
- Gomez K A and Gomez A A. 1984. *Statistical Procedure for Agricultural Research*, John Willey and Sons, New York.
- Sawarkar S D, Thakur R and Khamparia R S. 2010. Impact of long-term continuous use of inorganic and organic nutrients on micronutrients uptake by soybean in Vertisol. *Journal of Soils and Crops* **20**(2): 207-10.
- Singh Rakesh, Sharma H B, Parveen Kumar, Dinesh Kumar Paliwal and Pradeep Kumar. 2013. Effect of integrated nutrient management on growth, yield and nutrient uptake by soybean (*Glycine max*) cultivars. *Indian Journal of Agronomy* **58**(3): 379-83.
- SOPA. 2014. Estimates of area, productivity and production of soybean in India during *khari* 2014 (www.sopa.org).

Effectiveness of Pesticides against Green Semilooper, *Thysanoplusia orichalcea* (Fab.) in Soybean Crop and its Natural Enemy

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The luxuriant crop growth, soft and succulent foliage of soybean attracts many insects-pests and provides unlimited source of food, space and shelter. About 380 species of insects have been reported on soybean crop from many parts of the world. About 65 insect species have been reported to attack soybean from cotyledon stage to harvesting stage from Karnataka (Rai *et al.*, 1973; Adimani, 1976; Thippaiah, 1997).

Soybean semilooper, *Thysanoplusia orichalcea* (Fab.) is a major defoliator causing significant yield loss (Singh and Singh, 1990) which damages the crop from August to September during *kharif*. The infestation can result into 30 per cent underdeveloped pods and about 50 per cent yield loss. In case of heavy attack, the caterpillars are also found to feed on flowers and pods (Anonymous, 2007).

Indiscriminate use of chemical insecticides disturbs the natural balance of pest, leading to resurgence, outbreak

of secondary pests, and pollution in crop ecosystem. From this angle, botanicals have become more attractive and are considered to provide an eco-friendly alternative (Dodia 2008). Bio-pesticides and botanicals play an important role in insect-pest management as they are best alternative to chemical insecticides against major defoliators on soybean. They are locally available, relatively cheap, biodegradable and easy to handle which enable to minimize input cost of management for major defoliators of soybean and keep balance of ecosystem.

A field study was conducted during *kharif* 2014 to determine the efficacy of different insecticides against semilooper *Thysanoplusia orichalcea* (Fab.) in soybean ecosystem in the insectory premises of Agricultural Entomology Section, College of Agriculture Nagpur. Soybean variety JS 335 grown at a spacing of 30 cm x 5 cm with following treatments: neem seed extract (NSE) 5 per cent, neem oil 2 per cent, *Beauveria bassiana* 1×10^8 CFU @ 4 g per l, Spinosad

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45 SC @ 0.25 ml per l, Indoxacarb 15.8 EC @ 0.60 ml per l, Emamectin Benzoate 5 SG @ 0.3 g per l and Fenvalerate 20 EC @ 0.50 ml per l. Insect population of semilooper was maintained in the insectory. If the natural infestation does not occur, we can release the population in the field. So the experiment was carried out in the insectory premises.

The spraying of treatments was done with the help of knapsack sprayer and obtained uniform coverage of insecticide in each plot. First spray was given at 30 days after emergence (DAE), second spray at 45 DAE and third spray at 60 DAE. All the recommended practices were adopted for raising the crop. The observation on number larvae per meter row length was taken at five randomly selected spots in plot at seven days after germination till the harvest of the crop. The average population of major pests on soybean was observed at 7 and 14 days after each spray application. The pre-counting of larvae per one meter row length (mrl) was taken one day before spraying of chemicals on infestation of both larvae of semilooper.

The field data collected during the course of experimentation was subjected to statistical analysis (Gomez and Gomez, 1984) after appropriate transformation for interpretation of results.

Observations on 7 DAT of first spray (30 DAS)

Fenvalerate 20 EC @ 0.50 ml per l (0.11/mrl) was found very effective than other treatments. This was followed by Indoxacarb 15.8 EC @ 0.60 ml per l (0.19/mrl), Spinosad 45 SC @ 0.25 ml per l (0.20/mrl) and Emamectin Benzoate 5

SG @ 0.3 g per l (0.20/mrl), which were on par with Fenvalerate in reducing the number of larvae. Whereas, NSE @ 5 per cent (0.53/mrl), neem oil @ 2 per cent (0.47/mrl) and *Beauveria bassiana* 1×10⁸ CFU @ 4 g per l (0.60/mrl) were least effective in reducing the number of larvae. The more average number of larvae was recorded in control (water spray; 0.83/ mrl) (Table. 1). The comparative results have earlier been reported by Mascarenhas and Boethel (2000), who found the diagnostic concentration (concentration that kill 90-95 % of susceptible individuals) of Emamectin Benzoate was 5 ppm and Spinosad was 60 ppm against soybean looper, *P. includes*.

Observations on 14 DAT of first spray (30DAS)

Fenvalerate 20 EC @ 0.50 ml per l (0.09/mrl) was found more effective treatment in reducing the number of larvae. The next effective treatments namely, Emamectin Benzoate 5 SG @ 0.3 g per l (0.13/mrl), Indoxacarb 15.8 EC @ 0.60 ml per l (0.15/mrl), Spinosad 45 SC @ 0.25 ml per l (0.16/mrl) were found on par with the Fenvalerate treatment in reducing the number of larvae. Whereas, neem seed extract @ 5 per cent (0.67/mrl), neem oil @ 2 per cent (0.60/mrl) and *B. bassiana* 1×10⁸ CFU@ 4 g per l (0.73/mrl) were least effective in reducing the number of larvae. The more average number of larvae recorded in control (water spray; 0.93/ mrl) (Table 1).

The above results are in conformity with studies conducted by Sullivan *et al.* (1999), who found that new insecticides namely, Pirate R (Pyrolle),

Tracer R (Spinosyn), Proclaim R (Avermectin) and Steward R (Oxadiazine) provided adequate control of beet army worm *S. exigua*, fall army worm *Spodoptera furgiperda* (Smith) and soybean looper *Pseudoplusia includens* (walker) in cotton. Similarly, Jagadish *et al.* (2006) found that the IPM module

(seed treatment with Imidacloprid @ 5g/kg + two sprays of NSKE 5 % + two sprays of *HaNPV* 250LE/ha) gave a significant decrease in population of all sucking pests and defoliators, besides higher incidence of predators and lower incidence of *H. armigera*.

Table 1. Efficacy of different treatments on semilooper in soybean ecosystem and yield

Treatments	30 DAS		45 DAS		60 DAS		Seed yield (kg/ha)
	7 DAT	14 DAT	7 DAT	14 DAT	7 DAT	14 DAT	
Neem seed extract @ 5%	0.53b (1.01)*	0.67b (1.08)	0.80b (1.14)	1.00b (1.22)	1.02b (1.23)	1.17b (1.29)	1228
Neem oil @ 2%	0.47b (0.98)	0.60b (1.05)	0.73b (1.11)	0.83b (1.20)	0.77b (1.13)	0.92b (1.15)	1452
Spinosad 45 SC @ 0.25 ml/l	0.20c (0.84)	0.16c (0.81)	0.06c (0.75)	0.04c (0.73)	0.03c (0.75)	0.00c (0.71)	1902
<i>Beauveria bassiana</i> 1x10 ⁸ CFU @ 4 g/l	0.60b (0.98)	0.73b (1.08)	0.83b (1.15)	0.93b (1.20)	1.17b (1.29)	1.32b (1.35)	1303
Indoxacarb 15.8 EC @ 0.60 ml/l	0.19cd (0.83)	0.15c (0.81)	0.09c (0.75)	0.08c (0.76)	0.07c (0.75)	0.00c (0.71)	2010
Emamectin benzoate 5 SG @ 0.3 g/l	0.20c (0.84)	0.13c (0.79)	0.08c (0.76)	0.06c (0.75)	0.05c (0.76)	0.00c (0.71)	1830
Fenvalerate 20 EC @ 0.50 ml/l	0.11d (0.78)	0.09c (0.77)	0.07c (0.75)	0.05c (0.74)	0.04c (0.73)	0.01c (0.71)	2105
Control (water spray)	0.83a (1.15)	0.93a (1.20)	1.33a (1.35)	1.53a (1.42)	1.74a (1.50)	1.99a (1.58)	1036
SEm(±)	0.07	0.07	0.07	0.07	0.05	0.06	2.71
CD @ 5%	0.20	0.22	0.21	0.22	0.15	0.19	8.22
CV	12.94	14.06	13.14	13.45	9.31	11.44	11.48

*Figures in parenthesis indicates square root transformation

Observations on 7 DAT of second spray (45DAS)

Spinosad 45 SC @ 0.25 ml per l (0.06/mrl) was found superior over other treatments. The next effective treatments namely, Fenvalerate 20 EC @ 0.50 ml per l

(0.07/mrl), Emamectin Benzoate 5 SG @ 0.3 g per l (0.08/mrl) and Indoxacarb15.8 EC @ 0.60 ml per l (0.09/mrl) were found on par with Spinosad in reducing the number of larvae. Whereas, neem seed extract @ 5 per cent (0.80/mrl), neem oil

@ 2 per cent (0.73/mrl) and *B. bassiana* 1×10^8 CFU @ 4 g per l (0.83/mrl) were least effective in reducing the number of larvae. The maximum average number of larvae was recorded in control (water spray; 1.33/mrl) (Table 1). Above results are in line with those obtained by Knight *et al.* (2000), who reported Indoxacarb, Methoxyfenozide and Spinosad as potential insecticides against soybean looper. Jagadish *et al.* (2010) also recorded that the neem seed kernel extract (5 %) and Prosopan (10 ml/lit) were significantly superior to the other treatments for the suppression of *H. armigera*. Significant differences were observed among the treatments with respect to the volume weight of seeds (g/100 ml).

Agnihotri *et al.* (1987) reported that Cypermethrin at 60 g a.i. per ha, Permethrin at 90 g a.i. per ha and Fenvalerate at 120 g a.i. per ha as more effective insecticides in controlling American bollworm than the traditional insecticides, Carbaryl, Acephate and Quinalphos applied at 300 g a.i. per ha.

Observations on 14 DAT of first spray (45DAS)

The least number of larvae was found in Spinosad 45 SC @ 0.25 ml per l (0.04). The next effective treatments were Fenvalerate 20 EC @ 0.50 ml per l (0.05/mrl), Emamectin Benzoate 5 SG @ 0.3 g per l (0.06/mrl) and Indoxacarb 15.8 EC @ 0.60 ml per l (0.08/mrl) were found on par with Spinosad 45 SC @ 0.25 ml per l. However, neem seed extract @ 5 per cent (1.00/mrl), neem oil @ 2 per cent (0.83/mrl) and *B. bassiana* 1×10^8 CFU @ 4 g per l (0.93/mrl) were least effective in

reducing the number of larvae. The maximum average number of larvae recorded in control (water spray; 1.53/mrl) (Table 1).

Observations on 7 DAT of third spray (60DAS)

Spinosad 45 SC @ 0.25 ml per l (0.75/mrl) was found superior than other treatments. The next effective treatments namely, Fenvalerate 20 EC @ 0.50 ml per l (0.73/mrl), Emamectin Benzoate 5 SG @ 0.3 g per l (0.76/mrl) and Indoxacarb 15.8 EC @ 0.60 ml per l (0.75/mrl) were found on par with the treatment of Spinosad in reducing the number of larvae. Whereas, neem seed extract @ 5 per cent (1.02/mrl), neem oil @ 2 per cent (0.77/mrl) and *B. bassiana* 1×10^8 CFU @ 4 g per l (1.17/mrl) were least effective in reducing the number of larvae. The more average number of larvae was recorded in control (water spray; 1.74/mrl) (Table 1). The present investigation is in accordance with Shankarganesh *et al.* (2007), who reported similar conclusions about the susceptibility of *S. litura* to Indoxacarb and Profenophos with leaf dip bioassay technique. Ahmed *et al.* (2004) studied the comparative efficacy of three insecticides, namely, Indoxacarb 15.8 EC, Methomyl 40 SP and Chlorpyrifos 20 EC @ 100, 400 and 500 ml per 100 lit of water against *H. armigera* and *S. litura* in tobacco.

Observations on 14 DAT of third spray (60DAS)

Indoxacarb 15.8 EC @ 0.60 ml per l (0.00/mrl), Spinosad 45 SC @ 0.25 ml per l

(0.00/ml) and Emamectin Benzoate 5 SG superior over other treatments. The next effective treatment Fenvalerate 20 EC @ 0.50 ml per l (0.01/ml) was found on par with above treatments. Whereas, neem seed extract @ 5 per cent (1.17/ml), neem oil @ 2 per cent (0.92/ml) and *B. bassiana* 1×10⁸ CFU @ 4 g per l (1.32/ml) were least effective in reducing the number of larvae. The more average number of larvae recorded in control (water spray; 1.99/ml) (Table 1). Badge *et al.* (1999) reported that-NSE @ 7 per cent resulted in cent per cent mortality of *S. litura* and prolonged the pupal period.

Natural enemy (*Chrysoperla cornea*)

Minimum average number of grubs (0.33 *Chrysopa*/5 plants) recorded in treatment of Fenvalerate 20 EC @ 0.50 ml found to be superior as compared to other treatments at 30 DAE, while no population was recorded at 60 DAE. The next effective treatments were Emamectin Benzoate 5 S G @ 0.3 g per l, Spinosad 45 SC @ 0.25 ml per l, Indoxacarb 15.8 EC @ 0.60 ml per l, which were on par with T6 and T3. Whereas, *Beauveria bassiana* 1×10⁸ CFU @ 4 g per l and neem seed extract (NSE) @ 5 per cent were recorded more *Chrysopa* population and were found to be on par with untreated control.

Soybean seed yield

All the insecticidal treatments led to significant increase (192 to 1069 kg/ha) in seed yield over control. Maximum seed yield was recorded in case of Fenvalerate 20 EC @ 0.50 ml per l (2,105 kg/ha) with an increase of 1,069 kg per ha over control (1,036 kg/ha). The other two

@0.3 g per l (0.00/ml) were found treatments which were on par were Indoxacarb 15.8 EC @ 0.60 ml per l (increase of 974 kg/ha over control) and Spinosad (increase of 866 kg/ha over control). The lowest yield among insecticidal treatments was recorded was 1,228 kg per ha in case of NSE. Similar yield increase in pigeon pea was recorded by application of different insecticides, among which Indoxacarb 0.0075 per cent followed by Spinosad 0.009 per cent (Giraddi *et al.*, 2002) were found superior. Murugaraj *et al.* (2006), who reported that Emamectin Benzoate 5 SG @ 11 g a.i. per ha as well was highly effective in reducing the larval population and fruit damage and in increasing the yield of tomato. Prasad and Devappa (2006a, b) also noted that Emamectin Benzoate 5 SG @ 200 g per ha as effective in reducing dead hearts, fruit damage, and increasing the total yield of brinjal; and Emamectin Benzoate 5 SG @ 150 and 200 g per ha to be effective in suppressing the larval population of the pest, increase in yield of cabbage per hectare compared to other insecticides. In Pakistan, Wakil *et al.* (2009) while studying the management of the pod borer, *Helicoverpa armigera* showed the integration of weeding, hand picking of larvae and Indoxacarb sprays as the most effective in reducing the larval population, pod infestation and maximum grain yield in chickpea crop.

Considering the efficacy against semilooper and the yield obtained, Spinosad could be a good and effective alternative to chemical insecticides like Fenvelarate and Indoxacarb.

REFERENCES

- Adimani B D. 1976, Studies on the insect pests of soybean [*Glycine max.* (L) Merrill.] with special reference to the bionomics and control of the pod borer, *Cydia ptychora* Myr (Lepidoptera: Tortricidae). M. Sc. Thesis, University of Agricultural Sciences, Bangalore (India).
- Agnihotri, A.P., K.P. Srivastava, V.T. Gaibhiye and N.K. JA. 1987. Relative efficacy of some synthetic pyrethroids and other commonly used insecticides against bollworm and their residues in cotton. *Review on Applied Entomology Series A* **75**(1): 35.
- Ahmed S, Rasool M, Ulah Irfan and Rauf Imran. 2004. Studies on comparative efficacy of some insecticides against *Helicoverpa armigera* Hub. and *Spodoptera* Spp. on tobacco. *International Journal of Agriculture and Biology* **6**(1): 18-21
- Anonymous. 2007. Soybean, *www.ikisan.com*, pp. 1-7.
- Badge M A, Sarnaik D N and Satpute S K. 1999. Influence of Neem seed extract in combination with some fertilizers on *Spodoptera litura* (Fabricius). *Pestology* **23**(9): 57-9.
- Dodia S B and Patel I S. 2008. Botanical Pesticides for Pests Management, pp. 1-5 (www.cabdirect.org/abstracts/20093033837.html).
- Giraddi R S, Dasareddy S V and Lingappa S L. 2002. Bioefficacy of new molecules of insecticides against gram pod-borer (*Helicoverpa armigera*) in pigeonpea (*Cajanus cajan*). *Indian Journal of Agricultural Sciences* **72**(5): 311-2.
- Gomez, K.A. and A.A. Gomez. 1984). *Statistical Procedures for Agricultural Research* (2nd Edn), Book of an International Rice Research Institute, Philippines Awiley - Interscience publication John Wiley and Sons, New York, Chichester, Brisbane, Toronto, Singapore, PP. 680.
- Jagadish K S, Shadakshari Y G, Puttarangaswamy K T, Nagaraju and Jagannath D P. 2006. Evaluation of integrated pest management module against insect pests of sunflower. *Journal of Oilseeds Research* **23**(2): 178-81.
- Jagadish K S, Shadakshari Y G, Puttarangaswamy K T, Karuna K, Geetha K N and Nagarathna T K. 2010. Efficacy of some biopesticides against defoliators and capitulum borer, *Helicoverpa armigera* (Hubner) in sunflower, *Helianthus annuus* (L.). *Journal of Biopesticide* **3**(1 Special Issue): 379-81.
- Knight K, Brier H and Desborough P. 2000. The efficacy of new insecticides and dipel for soybean looper control in soybean and effects on beneficial insects and arthropods. In: *Proceedings of 11th Australian Soybean Conference*, Ballina Australia, pp 62-71.
- Mascarenhas R N and Boethel D J. 2000. Development of diagnostic concentrations for insecticide resistance monitoring in soybean looper (Lepidoptera: Noctuidae) larvae using an artificial diet overlay bioassay. *Journal of Economic Entomology* **93**(3): 897-904.
- Murugaraj P, Nachiappan R M and Selvanarayanan V. 2006. Efficacy of Emamectin benzoate (Proclaim 05 SG) against tomato fruit borer, *Helicoverpa armiger* (Hubner). *Pestology* **30**(1): 11-6.
- Prasad Kumar and Devappa V. 2006a. Bioefficacy of emamectin benzoate 5 % udar. SG (Proclaim) against brinjal shoot and fruit borer. *Pestology* **30**(3): 17-9.

- Prasad Kumar and Devappa V. 2006b. Bioefficacy of emamectin benzoate 5% SG (Proclaim) against diamond back moth in cabbage. *Pestology* **30**(2): 23-5.
- Rai P S, Seshu Reddy K V and Govindan R. 1973. A list of insect-pests of soybean in Karnataka state. *Current Research* **2**: 97-8.
- Shankarganesh K, Dhingra S and Rao G R. 2007. Relative toxicity of some synthetic insecticides against different populations of *Spodoptera litura* (Fabricius). *Pesticide Research Journal* **19**(2): 172-5.
- Singh, O. P. and Singh, K. J. 1990. Insect pests of soybean and their management. *Indian Farming*, **39**(10): 9-14.
- Sullivan M J, Turnipseed S G, Robinson D, Dugger P and Richter D. 1999. Insecticidal efficacy against a complex of fall and beet army worms and soybean looper in South California. In: *Proceedings of Beltwide Cotton Conferences*, Orlando, Florida, USA 2: 1034-6.
- Thippaiah M. 1997. Bioecology of semilooper, *Thysanoplusia orichalcea* (Fabricius) (Noctuidae: Lepidoptera) with observation on other pest complex of soybean and their management. *M Sc (Agri) Thesis*, University of Agricultural Sciences, Bangalore (India).
- Wakil W, Ashfaq M and Ghazanfar M U. 2009. Integrated management of chickpea in rainfed areas of Punjab, Pakistan. *Phytoparasitica* **37**: 415-20.

Development of Management Tactics against the Major Insect-Pests of Soybean

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Soybean [*Glycine max* (L.) Merrill] is a unique crop with high nutritional value. It is playing an important role in augmenting both the production of edible oil and protein simultaneously under the circumstances in which the shortage of these commodities are being experienced by people. Cultivation of soybean in Bangladesh covered about 55,000 hectares of land and produced about 90,000 metric tons of seeds during the period 2009-2010 (Anonymous, 2011). Leaf roller (*Lamprosema dicata* Fab.), hairy caterpillar (*Spilarctia obliqua* Walk.) and common cutworm (*Spodoptera litura*) are the major and serious pests of soybean and acting as limiting factors for successful cultivation of this crop in recent years (Biswas *et al.*, 2001). The green larvae of leaf roller fold and roll the leaves from tip downwards then feed inside. The pest infests about 70-90 per cent soybean plants, which resulted in about 10 per cent loss of yield (Singh, 1990). The hairy caterpillar and common cut worm are defoliated the leaves and

feed viciously and cause a great economic losses. Natural enemies play an important role in biological control of the insect-pests. *Trichogramma* are minute wasp parasitic on eggs of lepidopteran insect-pests. Parasitoidation by *Sturmia* spp. (19.6 %) and larval mortality by entomopathogenic fungi in lepidopteran insects (58.9 %) have also been documented by Sharma and Ansari (2007). *Trichogramma* lays, its eggs in the host insect eggs, multiply therein, thus preventing hatching of the host insect larvae. *Braconhebetor* is an aggressive – parasitic wasp. Female wasp at first injects venom and thus paralyzes insect larvae. It lays its eggs on the host larvae: multiply therein and thus destroying the pests. Use of sex pheromone is a new dimension of a specific pest management. Sex pheromone of *Spodoptera* attracts the adult male of this insect. But suitable eco-friendly management technique against these pests is scanty. Therefore, the study was undertaken to develop a most effective management option for

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managing these pests.

The experiment was conducted in the field Oilseed Research Centre (ORC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during 2012-13. Seeds of the variety BARI soybean-5 were sown on 2nd January, 2013 in 3 m x 4 m plots following RCB design with 3 replications. Fertilizers and other intercultural operations were done uniformly as per recommendation of ORC. The four treatments used in this experiment included IPM package-1 (hand picking of infested leaf with larvae + use of sex pheromone of *S. litura* + release of *Braconhebetor* @ 1 bunker (1000-1200 adults)/ha/week + *Trichogramma chilonis* @ 1 g parasitized egg/ha/week); IPM package-2 (hand picking of infested leaf with larvae + use of sex pheromone of *S. litura* + Bt - *Bacillus thuringiensis*); farmers practice (use of Chlorpyrifos @ 2ml/l); and a untreated control. One litre of Chlorpyrifos @ 2ml per litre was machine sprayed only once using machine spray volume of 10 litre per 200 m². *Spodoptera* adults were collected from the pheromone trap in every 7 days intervals from February 24 to March 24, 2013. The bio-control agent were collected from IPM laboratory, Entomology Division of BARI and sex pheromone (Spodolure) from Ispahani Agro - Bio Tech Ltd. Gazipur, Bangladesh. Larvae of the insects were counted from the different treatments at 15 days intervals during crop growing season in 3 frequencies. The crop was harvested on last week of April, 2013. Yield data and benefit cost ratio (BCR) of the treatments were calculated by

dividing net income with management cost. Data were analyzed statistically.

For working out the economics of treatments, the considerations were: cost of sex pheromone trap - TK. 60.00 per trap; cost of *Bracon* and *Trichogramma* - 100 TK per container; cost of Chlorpyrifos 20 EC - 800 TK per litre; cost of labor = 200 TK per head per day; price of soybean seed - 25 Tk per kg. Three labours and 1 litre Chlorpyrifos 20 EC @ 2 ml per litre being required for 1 ha of crop field sprayed in one time. One machine spray volume - 10 litre required 200 sqm field spraying in one time. Other variable costs were same in all the treatments; $BCR = \text{Net income} / \text{management cost}$

Leaf roller infestation was observed in the soybean crop on the 2nd week of February, 2013 at the vegetative stage of the crop. Common cut worm and hairy caterpillar infestation were observed during 2nd week of March, 2013 at the flowering stage. The highest number (72/trap) of *Spodoptera* adult captured in the sex pheromone trap during 3rd week of March, 2013 at the pod formation stage and then declined gradually (Fig. 1). A total of 372 *Spodoptera* adults were captured in the 2 sex pheromone traps. Result revealed that the lowest number of *Spodoptera* larva was found in the IMP Package-1 (3.53/5 plants/m²) followed by IPM Package-2 (4.50 larvae/ 5 plants/m²) due to the use of sex pheromone traps (Table 1). The lowest number of leaf roller larvae was also observed in the IPM Package -1 applied plots followed by IPM Package-2 applied plots (Table 1). The minimum

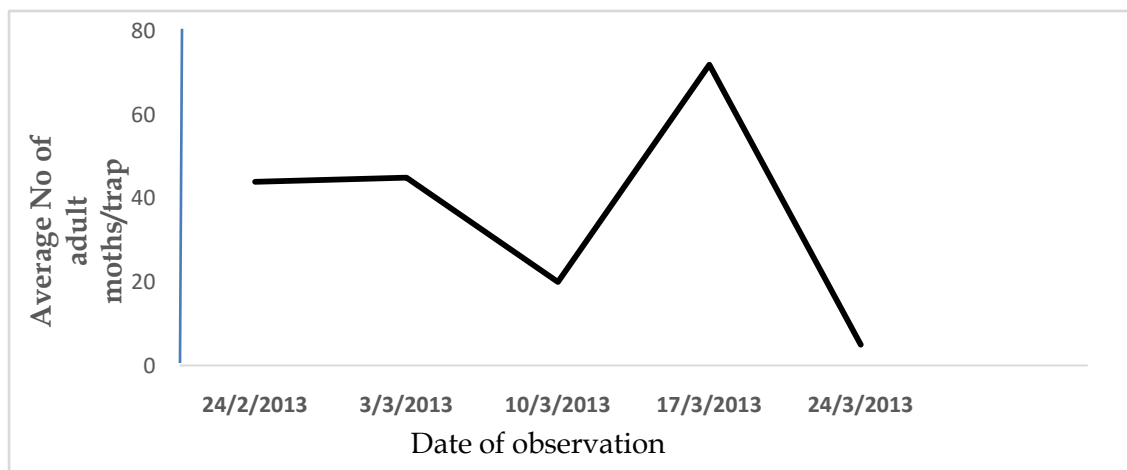


Fig 1. Average no. of adult *Spodoptera litura* captured in sex pheromone trap in during 2012-13

Table 1. Efficacy of different management package for managing the major insect-pests in soybean crop during 2012-13 at BARI, Gazipur

Management package	No of larvae/5 plants/m ²			Percent infestation reduction over untreated		
	Common cutworm	Leaf roller	Hairy Caterpillar	Common cutworm	Leaf roller	Hairy Caterpillar
IPM Package-1(Package 1 - Hand picking + Pheromone trap + <i>Bracon</i> + <i>Trichogramma</i>)	3.53 d	1.60 d	6.81b	55.87	68	56.68
IPM Package-2 (hand Picking + Pheromon trap + Bt)	4.50 c	2.75 c	4.89 c	43.75	45	46.38
Farmer's practice(<i>Chlorpyrifos</i> @ 2ml/l))	5.83 b	2.78 b	3.95 d	27.12	44.4	25.32
Untreated control	8 a	5.00 a	9.12 a	-	-	-
CV	8.59	16.13	10.78	-	-	-

Means followed by the same letters in a column do not differ significantly at 5% level by DMRT;; Data were recorded on average of 5 plants/plot/ m²

number of hairy caterpillar (3.95/ 5 plants/ m²) was observed from the farmer's practices (spray of Chlorpyrifos). Significantly highest number of larvae of these pests was recorded from untreated plots. The highest infestation reduction of common cutworm, leaf roller and hairy

caterpillar was 55.87, 43.75 and 27.12 per cent, respectively recorded from IPM Package-1. The highest seed yield (1.5 t/ha) was obtained from IPM Package-1 with highest BCR (2.21) followed by Package-2 and farmers practices (Table 2).

Table 2. Economics of different treatments spraying against major pests of soybean during Rabi, 2012-13 at Gazipur

Treatments	Yield (t/ha)	Increased yield over control (t/ha)	Cost of insecticide and spray (Tk/ha)	Additional Income (Tk/ha)	Net income (TK/ha)	MBCR
IPM Package-1(hand picking + Pheromon trap + <i>Bracon</i> + <i>Trichogramma</i>)	1.50	0.50	4000	12500	6250	2.21
IPM Package-2(hand Picking + Pheromone trap + <i>Bt</i>)	1.39	0.39	3500	9750	4500	1.78
Farmer's practice(<i>Chlorpyrifos</i> @ 2ml/l)	1.24	0.24	2500	6000	3500	1.4
Untreated control	1.0	-	-	-	-	-

Means followed by the same letters in a column do not differ significantly at 5% level by DMRT

IPM package - 1 (hand picking+ Pheromone trap+ *Trichogramma*) was found to be effective (about 56 -68%

infestation reduction) for managing common cutworm, leaf roller and hairy caterpillar in soybean crop.

REFERENCES

- Anonymous. 2011. *Krishi Diary-2011*, Agricultural Information Service, Khamarbari, Farm Gate, Dhaka-1215, pp 573.
- Biswas G C. 2001. Screening of some soybean entries for resistance to stem flies (*Ophiomyia phaseoli* Tryon and *Melanagromyza ozae* Zehntner) and their incidence. *Journal of the Asiatic Society of Bangladesh, Science* 27(1): 93-100.
- Sharma A N and Ansari M M. 2007. Potential and naturally occurring bio-control agents of lepidopterous defoliators infesting soybean. *Soybean Research* 5: 84-6.
- Singh S R. 1990. *Insect Pest of Tropical Food Legumes*, John Willy and Sons. Inc., New York, USA, pp 451.

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SOYBEAN RESEARCH

GUIDE LINES FOR SUBMISSION OF MANUSCRIPT

Where to submit?

The Society of Soybean Research and Development publishes full paper, short communications, and review articles related to soybean research and development in its official journal "SOYBEAN RESEARCH". The journal is published twice in a calendar year at present. All submissions should be addressed to: The Editor-in-Chief, Society of Soybean Research and Development (SSRD), ICAR-Indian Institute of Soybean Research, Khandwa Road, Indore 452 001, India (Email: ssrdindia03@rediffmail.com). The submissions of the manuscripts may preferably be done online on Society's web-site (www.ssr.co.in or www.soybeanresearch.in)

Editorial Policy

- All authors in a manuscript (MS) for publication in Soybean Research should be member of the society.

(a)	Annual member	Subscription
	Indian	₹. 500.00
	Foreign	US \$ 125.00
(b)	Student member	
	Indian	₹. 250.00
	Foreign	US \$ 100.00
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	Indian	₹. 2, 000.00
	Foreign	US \$ 150.00
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	Indian	₹. 3, 000.00
	Foreign	(1 or in 3 equal instalments. in a year) US \$ 1000.00
(e)	Corporate member	
	Indian	₹. 20, 000.00
	Foreign	US \$ 2,000.00

- An admission fee of **₹.50/-** for Indian citizen and US \$ 5.00 for Foreign National shall be paid at the time of enrolment.

- MS must be original and contribute substantially to the advancement of knowledge in soybean research and development.
- MS should have unpublished data and not submitted elsewhere (wholly or in part) for publication.
- MSs are subjected to 'peer review' by two experts in the relevant field and by the members of Editorial Board. The decision of Editor-in Chief in accepting the MS with major/minor revision or rejecting the paper would be final. MSs sent for revision to authors, should be returned within four weeks.
- All submission must accompany a self-addressed appropriately stamped envelope for sending the MS for revision/change if any or the proof for corrections.

Manuscript Format

Manuscript should be initially submitted on line on E-mail address (ssrdindia03@rediffmail.com) or web-sites (www.ssrd.co.in or www.soybeanresearch.in) of the Society/journal. The manuscript should also carry the E-mail address of the corresponding author in addition to the postal address. MS should be formatted in double space on A-4 size paper in Times New Roman with font size 12 with a 4 cm margin at top bottom and left. All pages including text, references, tables and legends to figures should be numbered. MS should be concise and devoid of repetition between Materials and Methods and Results or Results and Discussion. Revised and corrected MS should be also be submitted on line.

Full Paper

- A full paper should not exceed 4000 words (up to 15 typed pages, including references, tables etc.) Its contents should be organized as: Title, Author(s), Address, Abstract, Key words, Introduction, Material and Methods, Results and Discussion, Acknowledgements and References.

Title: It should be short, concise and informative, typed in first letter capital, Latin name italicized.

Authors: Name of the authors may be typed in all capitals.

Abstract: This should not exceed 150 words and should indicate main findings of the paper, without presenting experimental details.

Key words: There should be 4-5 key words indicating the contents of the MS and should follow the abstract. Invariably the name of host and pest should be included in key words.

Results and Discussion: Data should be presented in text, tables or figures. Repetition of data in two or three forms should be avoided. All quantitative data should be in standard/metric units. Each table, figure or illustration must have a self-contained legend. Use prefixes to avoid citing units as decimals or as large numbers, thus, 14 mg, not 0.014 g or 14000 µg. The following abbreviations should be used: yr, wk, h, min, sec., RH, g, ml, g/l, temp., kg/ha, a.i., 2:1(v/v), 1:2 (w/w), 0:20: 10 (N:P:K), mm, cm, nm, cv. (cvs., for plural), % etc.

References: References should be cited by authors and year: Ansari (2000) or Ansari and Sharma (2000) in the text. References should be arranged in alphabetical order and listed at the end of the paper as follows:

Ansari M M and Sharma A N. 2000. Compatibility of *Bacillus thuringiensis* with chemical insecticides used for insect control in soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **70**: 48-9. (**Journal**)

Joshi O P, Billore S D, Ramesh A and Bhardwaj Ch . 2002. Soybean-A remunerative crop for rainfed farming. *In: Agro technology for dry land farming*, pp 543-68. Dhopte AM (Eds.). Scientific Publishers (India), Jodhpur. (**Book chapter**)

Ansari M M and Gupta G K. 1999. Epidemiological studies of foliar diseases of soybean in Malwa plateau of India. *Proceedings, World Soybean Research Conference VI*, Aug 4-7, 1999, Chicago, Illinois, USA, 611p. (**Symposium/Conf./Workshop**)

Pansae V G and Sukhatme P V. 1978. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi. pp.186. (**Book**)

Table: Each table should be typed on separate page and numbered sequentially. Tables should have descriptive heading. Authors are advised to avoid large table with complex columns. Data are restricted to only one or two decimal figures only. Transformed values should be included if these are discussed in the text.

Illustrations: Number all illustrations consecutively in the text. Line drawing should be made in undiluted black ink on smooth white card or tracing paper. Original and two Photostat copies should be drawn approximately twice the size of reproduction. Original should not be labeled and should also not be numbered. Line diagrams of plants, fungi etc. should indicate the scale.

Photographs: Photographs should be on glossy paper and have good contrast. Trim unnecessary areas. Three copies of the photographs should be provided. On the back of the photographs write names of authors, figures numbers and indicate top of the photographs with an arrow using a soft pencil. Show magnification with a bar scale. **Coloured photographs can be printed on payment of full printing cost by the authors.** Legends for figures should be typed separately and numbered consequently.

Short research notes

They should not exceed more than 1300 words (total 5 typed pages, which deal with (i) research results that are complete but do not warrant comprehensive treatment, (ii) description of new material or improved techniques or equipment, with supporting data and (iii) a part of thesis or study. Such notes require no heading of sections. It should include key words. Figures and tables should be kept to a minimum.

Review articles

Authors with in-depth knowledge of the subject are welcome to submit review articles. It is expected that such articles should consist of a critical synthesis of work done in a field of research both in India and/or abroad, and should not merely be a compilation.

Proofs

Authors should correct the proof very critically by ink in the margin. All queries marked in the article should be answered. Proofs are supplied for a check-up of the correctness of the type settings and facts. Excessive alterations will be charged from the author, Proof must be returned immediately to shorten the reproduction time.

Application for Membership
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(Website: www.ssrd.co.in)

The General Secretary
Society for Soybean Research & Development
ICAR-Indian Institute of Soybean Research
Khandwa Road, Indore -452 001

Dear Sir,

I wish to enrol myself as a Life Member/ Annual Member of the **Society for Soybean Research & Development.**

I remit Rupees (in words)-----
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-----of -----bank in favour of the Society for Soybean
Research & Development, Indore as membership and admission fee for the year-----
-----I agree to abide by the Rules and Regulations of the Society.

Yours faithfully,

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Designation	-----
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	E-mail :-----
Proposed by:	Signature & Name-----
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SOCIETY FOR SOYABEAN RESEARCH AND DEVELOPMENT
KHANDWA ROAD, INDORE

BALANCE SHEET AS AT 31ST MARCH 2015

LIABILITIES	AMOUNT	ASSETS	AMOUNT
Capital Fund		Fixed Assets	
Opening Balance	3,724,725	Computer & Printer	1,782
ADD : Life Membership	9,500	Less :- Depreciation	1,069
Add : Surplus of the year	285,873		713
	4,020,098	Furniture & Fixture (Purchase during the year)	18,475
		Less :- Depreciation	1,848
			16,627
		Investments	
		Fixed Deposit (in Canara Bank)	3,800,000
		Current Assets	
		Advance for Expenses	23,368
		Bank Balance - Canara Bank	179,390
TOTAL	₹ 4,020,098	TOTAL	₹ 4,020,098

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED ON 31.03.2015

EXPENDITURE	AMOUNT	INCOME	AMOUNT
Printing of Soybean Research	78,619	Grant (ICAR, Delhi) for Conference (SOYCON-2014)	250,000
Web Designing Expenses	19,500	Misc. Income	86,961
Postage & Stationery	8,157	Membership Fees	19,600
Legal & Professional Fees	7,303	Sale of Publications	750
Interest	13,700	Interest Received	
Depreciation	2,917	- On Fixed Deposit	17,293
Misc. Expenses	680	- On Saving Account	42,145
Excess of Income over Expenditure	285,873		
TOTAL	₹ 416,749	TOTAL	₹ 416,749

For SOCIETY FOR SOYABEAN RESEARCH
AND DEVELOPMENT

G.K. Gupta
President

Ansari
Treasurer

PLACE : Indore
DATE : 21/08/2015

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OBITUARY



Dr M V Rao, one of the crusaders of “Green Revolution” passed away

Dr. Mangina Venkateswara Rao (1928-2016), noted agriculture scientist and one of the key persons in India's 'Green Revolution', M V Rao, passed away on 8th March in Hyderabad. He was 88 and is survived by his wife, a son and two daughters.

In the company of Nobel laureate Norman Borlaug, M S Swaminathan, C Subramanian and many others who ushered in the Green Revolution during the early 1960s, Dr Rao was involved in testing and identifying the best varieties of wheat from Mexico that were then grown in the country and changed the agriculture scenario forever.

Ironically for MV Rao, the golden jubilee celebrations of the Green Revolution held in New Delhi in November 2015, turned out to be his last big engagement. He was felicitated by Agriculture Minister, Radha Mohan Singh, and his 30-minute address to the galaxy of scientists drew wide applause. However, on his return to Hyderabad, his health suffered a setback. He had to be admitted in a corporate hospital. Being a man of discipline and healthy lifestyle, Rao put up a valiant fight. However, the former Special Director General of ICAR and Special Secretary of the Department of Agriculture, Research and Extension breathed his last on Tuesday night.

Born on June 21, 1928, at Perupalem in West Godavari district of Andhra Pradesh, Rao joined the Indian Agriculture Research Institute (IARI) in 1956 as an assistant wheat breeder, after completing his master's degree from Purdue University. He became the coordinator of the All-India Wheat Improvement Project in 1971.

During a long career, Rao rose to the highest posts in agriculture. He was asked by Prime Minister Rajiv Gandhi to head the Technology Mission on Oilseeds (one of the four tech missions) in 1986. Post-retirement he became an Agriculture Expert with the World Bank in 1990. The Andhra Pradesh Chief Minister at that time, N Janardhana Reddy, invited him to take over as the Vice-Chancellor of the Acharya NG Ranga Agriculture University (1991-97).

A former Vice-President of the National Academy of Agricultural Sciences (2000-2003), Rao played an important role on several committees, especially chairing the Committee on the New National Seed Policy. He has served as a member of the board of directors of the International Rice Research Institute (IRRI) and as member of the Wheat Advisory Committee of the Food and Agricultural Organisation (FAO). He served as a member of the Legislative Council of AP during 2008-14.

A recipient of the Norman Borlaug Award and the Linker's Award, Rao was honoured with the Padma Shri.

The members of Society for Soybean Research and Development and scientists from Indian Institute of Soybean Research express their gratitude for his serves rendered for Indian Agriculture and express their condolences on the sad demise of Dr M V Rao and pray that his soul may rest in peace.