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Validation of molecular markers for pod shattering tolerance in soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Tagging of pod shattering/dehiscence tolerance trait in soybean (*qPDH* loci) with molecular markers was undertaken in a segregating population of cross cultivar Kalitur (shattering of 12.02% at field level; 77.71% on oven drying) x DS-9712 (shattering of 1.63% at field level; 10.94% on oven drying) by bulked segregant analysis (BSA). Pod shattering was partially dominant over the tolerance in the cross. Inhibitory epistasis of two major genes was evidenced from F_2 ratio (13:3) (3.0-16.0% shattering field level and 5-85% on oven drying), with chi-square test indicating goodness of fit which was confirmed by test cross. Only two of the five shortlisted microsatellite markers from previous study *viz.,* Satt674 and SRM1generated polymorphism between shattering tolerant and susceptible parents and their corresponding F_2 bulks. Satt674 marker alleles were closely placed (223 bp vrs. 228 bp) hampering clear resolution and hence this primer was not used for further validation. SRM1 primer yielded distinct polymorphic markers (237bp vrs. 225 bp) between shattering-tolerant and susceptible parents and bulks. SRM1 marker was validated in 60 individual F_2 plants which were contrasting for pod dehiscence trait. Forty-seven susceptible plants yielded either only 237 bp bands or were heterozygous (having both 237 bp and 225 bp bands), while 13 shattering tolerant F_2 plants amplified only 225 bp marker. Hence, in future this SRM1-225bp marker linked to a major pod shattering tolerance loci *qPDH1*, could be utilized for screening the parental lines, segregating generations, breeding lines and varieties of soybean.

Keywords: Bulk segregant analysis, Pod shattering, Soybean, SSR markers

Fully matured pods of soybean (*Glycine max* L. Merrill) are extremely sensitive to opening, resulting in seed dehiscence. Pod shattering involves opening of pods along both the dorso-ventral sutures. Though this trait is important for the adaptation of the wild species to natural habitat as a mechanism for seed dispersal, it leads to a significant yield loss in soybean production, if found in cultivated forms. Pod shattering trait in soybean can be controlled by several strategies. In Japan, timely planting is done so that, seeds are generally harvested in cool and humid seasons, which mask the problem of pod dehiscence (Funatsuki *et al.,* 2008). Genetic improvement, by introducing tolerance genes is usually more effective, less costly, not subject to environmental conditions and easier for growers to implement. However, this is both time consuming and laborious. The hybridization strategy also has to cope with transferring two or more genes, which are recessive in action, into each of the breeding lines. Indeed, different genetic backgrounds have revealed different number of genes to be important in shattering tolerance/tolerance in soybean (Caviness, 1963).

Funatsuki *et al.* (2006) reported one major QTL for pod shattering in soybean between SSR markers Sat_093 and Sat_366 on linkage group J. Suzuki *et al.* (2009) examined near isogenic lines for this major QTL and designated it as *qPDH1*. Yamada *et al.* (2009) reported that shattering-tolerant cultivars harbor recessive shattering-tolerance allele at *qPDH1* regardless of their origin and that molecular markers near *qPDH1* could be used for marker-assisted selection for shattering tolerance in soybean. Kang *et al.* (2009) reported four minor QTLs for pod dehiscence in addition to a *qPDH1* which explained 46% of phenotypic variation. Suzuki *et al.* (2010) carried out high-resolution mapping of *qPDH1* to a 134-kb region on chromosome 16 (formerly linkage group J) to develop useful selection markers.

Selection for a specific genotype among segregating populations is the main bottleneck in conventional breeding. Identification of the molecular markers closely linked with soybean shattering tolerance genes is necessary in order to advance the generations for early selection for marker assisted selection (MAS). The efficacy of molecular markers relies on finding tight linkages between markers and genes of interest which permits indirect selection for the presence of a desirable gene and thus shorten the breeding procedure (Tanksley *et al.,* 1989). Tightly linked DNA markers to the important genes may be used as molecular tools for MAS in plant breeding, which helps in more efficient, reliable, and commercial phenotype selection compared to the classical plant breeding methods (Collard *et al.,* 2005). MAS has advantages like selection for recessive genes, selection for two or more independent genes that give a similar phenotype, and selection for quantitative traits. Selection of two or more independent genes is difficult to attain using a direct selection process since the phenotype is the same whether one, two, or more tolerance genes are present. Once the

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markers linked to genes or QTLs of interest are identified, prior to field evaluation of a large number of plants and at the early stages of growth, breeders may use specific DNA marker alleles as a diagnostic tool to identify plants carrying the genes or QTLs (Collard *et al.,* 2005).

Bulked segregant analysis (Michelmore *et al.,* 1991) was followed initially for molecular tagging as a rapid, technically simple alternative for identifying markers linked to specific traits. The only prerequisite is a segregating population for the trait of interest. The present study was undertaken for tagging of markers for pod shattering tolerance/tolerance using Bulked segregant analysis, followed by verification of tagged marker in individual segregating plants.

MATERIALS AND METHODS

During the present study the field work was conducted at PGI, Research Farm, Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, India while the laboratory work was conducted at State Level Biotechnology Centre, MPKV, Rahuri. The F_2 population of Kalitur x DS-9712 was derived from one of the four crosses developed (Thakare, 2016). The F_1s of this cross were used for raising around 300 F_2s, sixty of which were randomly selected for the present study. Pod shattering screening was carried out as per oven dry method reported by Tiwari and Bhatnagar (1997). Twenty matured pods harvested from each of P_1, P_2, and F_2, generation were kept in brown paper bags at room temperature for 15 days to equalize the moisture content of all pods. Then the bags were kept in hot air oven at 60°C for 6 hrs in a day and at ambient temperature at night for 7 days. Percentage of shattering was recorded when more than 70% pods of susceptible parents had shattered and number of shattered pods were counted and expressed in percentage as,

$$\text{Pod shattering percentage (\%)} = \frac{\text{Number of pods shattered}}{\text{Total number of pods}} \times 100$$

Percentage of pod shattering induced was recorded and determined according to 1-5 scale (Anonymous, 1979). This scoring was done as per AVRDC (Asian Vegetable Research Development Centre) 1 to 5 scale *viz.,* 1=0%, 2=1-10%, 3=11-25%, 4=26-50% and 5=>50% that were termed very resistant, resistant, moderately resistant/tolerant, moderately susceptible and very susceptible, respectively. To study the mode of inheritance of pod shattering, plants in segregating population were classified into tolerant (R) (scale 1-2), intermediate (I) (scale 3-4) and susceptible (S) (scale5) to pod shattering on the basis of shattering scores. Observations were recorded on 10 plants for parents and 60 out of 300 plants were randomly selected for further study from F_2 generations. The segregation of pod shattering trait in the F_2 population was studied by Chi-square test (χ^2) to know its goodness of fit with the expected segregation ratio.

Soybean SSR markers reportedly linked to pod shattering loci were selected based on the SOYBASE website (http://www.soybase.org) (Grant *et al.,* 2010) (Table 1). Five SSR primers, known to amplify markers linked topod shattering tolerance, and polymorphic between parents (Kaliturand DS-9712) used for developing the population, were used for BSA analysis and individual F_2 plant validation.

Table 1 The details of Five SSR markers used in the present study

QTL/Gene	Primer	Sequence	Annealing temp. (°C)	Product size bp	LG/ Chr. No.
qPDH1-7	Sat_350	F-CGTAAGAGCATCTCCAAACCATCAAACTCA R-CGATTTATTACATTTAACAATTGTTATTA	56	280 vrs 230	J/16
qPDH1-3	Satt185	F -GCGCATATGAATAGGTAAGTTGCACTAA R -GCGTTTTCCTACAATAATATTTCAT	56	232 vrs 264	E/15
qPDH3-5	Satt166	F -TTGCACAGTTGATTTTTGTTT R -GCATCGAATTTCTGGATTTAC	46	200 vrs 237	L /19
qPDH1	SRM1	F-AGAGCAAGAAATCACGTTGCA R-CACCTCACCCCTTTTTCTCA	46	234 vrs 226	J/16
qPDH1-5	Satt674	F -GCGAATCCTCTAGCTTACCAAAGAA R-GCGATTAGCCATCAAAACCTAT	53	200 vrs 189	J/16

Where, bp-Base pair, LG-Linkage group and Chr. No.- Chromosome number

DNA isolation and SSR marker analysis: Genomic DNA was extracted by CTAB method (Keim *et al.,* 1988) from young leaves (15-20 DAS) from 60 F_2 plants, and the quality was checked by using 0.8% (w/v) agarose gel electrophoresis. The polymerase chain reaction (PCR) mixture (20µl) contained template DNA (30 ng), 2.0 µl Taq buffer B (10X), 1.7 µl$MgCl_2$ (), 2.0 µl dNTP (2 mM) and 1.0 µl of forward and reverse primer (30 picomoles each), and 0.33µl*Taq* DNA polymerase (1unit). Amplification was performed in 0.2 ml (each tube) thin walled PCR tubes in Corbett Palm cycler. PCR programme comprised of initial incubation at 94.0°C for 5 min and then subjected to 40 cycles: 94.0°C for 30 sec, 46-56°C for 30 sec and 72.0°C for 30 sec, and final extension was carried out at 72.0°C for 5 min. The amplified SSR products were analyzed using 2% metaphor agarose gel.

Bulk segregant analysis (BSA): Two contrasting bulk DNA samples i.e. Pod shattering tolerant (of scale1-2) and susceptible bulks (of scale 5) were generated from the F_2 segregating population. Within each pool, or bulk, the individuals were identical for the trait of interest (pod dehiscence) but differed randomly for other traits. Separate tolerant and susceptible bulks were made by mixing equal amounts (ng) of DNA from ten highly tolerant and susceptible individual plants, respectively from F_2 segregating population of cross Kalitur × DS-9712. Further individual plant validation was carried out in sixty F_2 plants.

RESULTS AND DISCUSSION

Pod shattering at field level and under oven drying conditions: At field level, the F_2 generation recorded a mean of 10.98% (ranging from 3.0 to 16.0%) pod shattering as compared to susceptible parent, Kalitur (exhibited 12.02%) and tolerant parent, DS-9712 (1.63%). On oven drying at 60°C the F_2 generation recorded an average of 62.49% pod shattering (ranging from 5.0 to 85%), as against susceptible parent Kalitur (77.71%) and tolerant parent DS-9712 (10.94%).

Inheritance of pod shattering in soybean: Sixty F_2 segregantsof the cross (Kalitur × DS-9712) were studied for inheritance of pod shattering trait. These plants were grouped into five different classes as per the scale recommended by AVRDC (Table 2). For chi-square analysis, plants that showed disease scale of 1-3 were grouped into resistant type and the plants with scale of 4 and 5 were grouped into susceptible type (Table 3). According to the chi-square test these F_2 plants fitted into two phenotypic classes with the intermediates also behaving as susceptible phenotypes. This data showed chi-square values that were below the table value for the expected ratio of 13 susceptible: 3 tolerant. The ratio observed 47 (Susceptible +Intermediate): 13 (Resistant) number of plants in F_2, as against the expected number of plants 48.75 S: 11.25 R. This indicated presence of two major genes along with inhibitory epistasis for the inheritance of pod shattering in soybean. (Table 3). These results are in agreement with Tukamuhabwa *et al.* (2002); Bhor *et al.* (2014) and Thakare *et al.* (2016), who had reported that pod shattering in soybean was controlled by two major genes with inhibitory type of epistasis.

Table 2 Frequency distribution of 60 F_2 plants for pod shattering trait under laboratory condition (oven dry method) as per AVRDC scales

Classes	Scale	Frequency	Classification for chi-square analysis
1	0%	0	
2	1-10%	3	Resistant
3	11-25%	10	
4	26-50%	5	Susceptible
5	>50%	42	
Total : 60			

Polymorphism of SSR markers: In the past two decades, QTL mapping in soybean has revealed a series of pod shattering loci scattered among several linkage groups (Cregan *et al.,* 1999; Bailey *et al.,* 1997; Kang *et al.,* 2009; Suzuki *et al.,* 2009; Suzuki *et al.,* 2010). Thakare *et al.* (2017) studied markers linked to different *qPDH* loci and shortlisted five of them showing polymorphism between parents studied. In parental PCR studies, these five primers linked with different QTLs for pod dehiscence loci would discriminate between susceptible parent 'Kalitur' and the tolerant parent DS-9712 and only two of them (Satt674 and SRM1) showed polymorphism corresponding with contrasting pod shattering trait i.e. same sized bands were shared by both pod shattering tolerant parents, while another band was shared by both pod shattering susceptible parents.

Identification of SSR markers linked to shattering tolerance through BSA: Out of the five SSR primers which were polymorphic between the parents,two primers associated with qPDHloci *viz.,* Satt674 (qPDH1-5) and SRM1 (qPDHl loci) were informative in bulk segregant analysis (Table 4).

Combined marker regression analysis: Based on shattering scoring for pod shattering in soybean, 60 F_2 individual plants with extreme scores were selected from plant progeny for studying the association of molecular marker to the respective phenotype. The markers were subjected to combined regression analysis by using the data of amplification profile of two molecular markers and their respective shattering score.

Table 3 Phenotypic evaluation of F_2 plants of cross (Kalitur × DS-9712) for pod shattering on oven drying at 60°C

Class of segregation	Observed ratio (No. observed plants)	Expected ratio	χ^2 value	χ^2 table	Probability
Susceptible	48.75 (47)	13	0.225	3.842	0.8732
Tolerant	11.25 (13)	3			
Total	60	16			

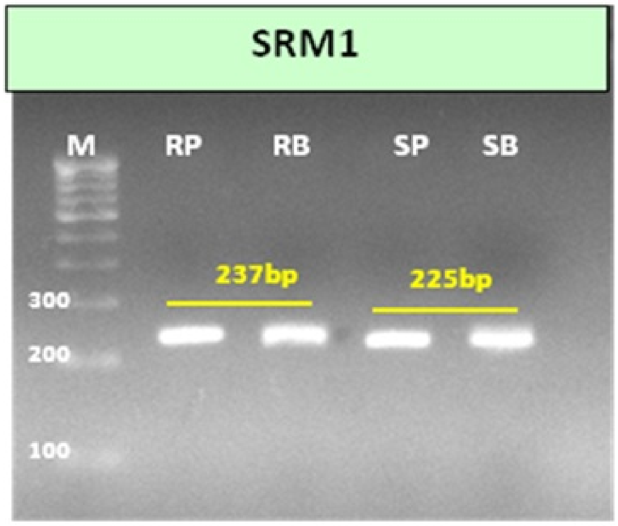
Table 4 SSR markers which showed polymorphism in BSA

Name of primer	Size (bp)	Location (Linkage group/Chromosome No.)	Gene
Satt674	223bp (RP-RB) vs. 228bp (SP-SB)	J/16	*qPDH1-5*
SRM1	237bp (RP-RB) vs. 225bp (SP-SB)	J/16	*qPDH-1*

Validation of markers for pod shattering tolerance: The validated primers on various segregating plant populations are much more useful in marker assisted breeding. The markers Satt674 (*qPDH*1-5 like loci) and SRM1 (*qPDH*1 loci) were validated for their association with tolerance to pod shattering over an extremely tolerant and susceptible individual sixty plants. Segregation ratios of SRM1 marker in F_2 plants of cross Kalitur x DS-9712 is presented in Table 5. To obtain the segregation of marker alleles in F_2 plants, heterozygotes were merged with the dominant homozygous typs and then subjected to chi-square analysis (Table 5).

Two SSR markers Satt674 (223-228 bp) locus on J/16 and SRM1 (237-225bp) locus on chromosome 16, showed (Table 5) polymorphic bands between tolerant parent DS-9712 and tolerant bulk and susceptible parent Kalitur and susceptible bulk (Fig. 1). SSR primers Satt 674 amplified 223 (R) vs. 228 (S) bp while, SRM1 237 (R) vs. 225 (S) bp in bulked segregant analysis and these were chosen as candidate markers for analysis of individuals in segregating F_2 population. The association of markers with the soybean pod shattering tolerance trait was analyzed in F_2 population (Fig. 2).

Satt674 marker alleles were closely placed (223 bp vs. 228 bp) hampering their clear resolution and hence this primer was not used for subsequent validation in60 individual F_2 plants populations. SRM1 marker was used for screening of 60 individual F_2 plants which were highly contrasting for pod dehiscence trait. Thirteen plants yielded only 237 bp bands and 34 plants were heterozygous having both the 237 bp and 225 bp bands, since pod shattering susceptibility is dominant over pod shattering tolerance, heterozygous plants behaved like susceptible. Twelve F_2 plants had 225 bp bands, with no amplification being observed in a single sample. The SRM1 marker is known to be linked to major loci qPDH1 present on chromosome 16 (Funatsuki *et al.,* 2006; Funatsuki *et al.,* 2008; Suzuki *et al*., 2009; Suzuki *et al*., 2010). Dong *et al*. (2014) identified that the key feature of the shattering-resistant trait lies in the excessively lignified fibre cap cells (FCC) in the pod ventral suture. They further indicated for it is likely to encode NAC (NAM, ATAF1/2 and CUC2) gene that activates secondary wall biosynthesis as molecular markers for soybean pod shattering tolerance genes qPDH1-5 and qPDH1.



RP- Tolerant parent (MACS-450), RB- Tolerantbulked sample; SP-Susceptible parent (Monetta) and SB - Susceptible bulked sample

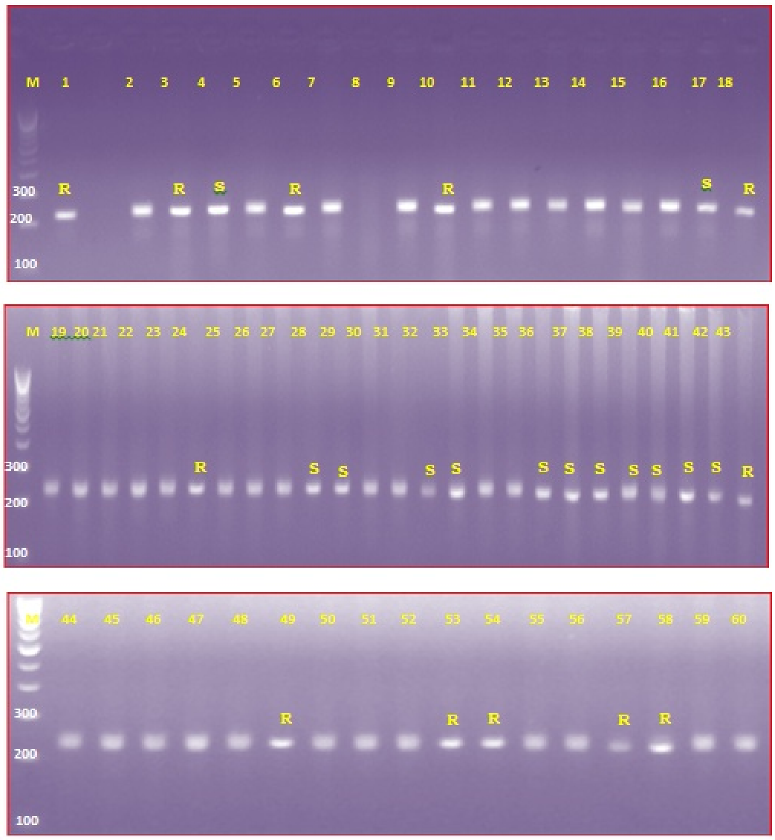
Fig. 1. Bulked segregant analysis for the pod shattering tolerance for cross 'Kalitur x DS-9712' using SSR markers

On Chi-square analysis, as expected for SRM1 linked with major dominant QTL qPDH1 segregated in 1:2;1 ratio and when the two classes were combined and analysed it fitted into a 3:1 ration with a value of 0.0386 (P=0.844) for F_2 of cross-between Kalitur×DS-9712, indicating that soybean shattering tolerance in the parent DS-9712 was governed by two genes. Suzuki *et al.* (2010) narrowed down the candidate region of qPDH1to 134 kbp region, which was used to develop three DNA markers *viz.,* SRM0, SRM1 and SRM2 for qPDH1. The stable effect of qPDH1 has encouraged breeders to use this QTL for breeding SR soybean lines. Yamada *et al.* (2010) used backcrossing to introduce qPDH1 from donor SJ2 to 11 major Japanese soybean cultivars to develop shattering tolerant lines.

The present investigation indicated that in the F_2 (Kalitur × DS-9712) population pod shattering susceptibility was dominant over shattering tolerance. The SSR marker SRM1 linked to pod shattering trait major locus *qPDH1* perhaps interacted with other minor QTLs thereby influencing pod shattering trait. This marker might help in more efficient, reliable and commercial selection of the phenotype compared to the classical plant breeding methods. In prospect, markers specific to chromosome/linkage group 16/J can be used for screening the parental lines. These results suggest that pod shattering tolerant cultivar DS-9712 harbour recessive pod shattering tolerance alleles at QTL regardless of their origin and the molecular markers identified could be used for marker assisted selection for pod shattering tolerance in soybean. Pod shattering tolerant soybean thus developed may assist in mechanical harvesting of soybean.

Table 5 Molecular evaluation of F_2 plants of cross (Kalitur × DS-9712) for SSR markers SRM1 (*qPDH1*)

Marker	Class of segregation	Observed ratio	Expected ratio	Calculated χ^2 value	Table χ^2 value	Probability
SRM1	237 bp + heterozygous (both 237+ 225bp)	47 (44.25)	3			
	225 bp Tolerant	13 (14.75)	1	0.0386	3.842	0.844
	Total	60				



M: 100 bp ladder, RP: MACS-450; RB: Tolerant Bulked sample; SP: Monetta; SB: Susceptible Bulked sample; No. 1 to 60 indicates individual F2 progenies

Fig. 2. Validation of SSR marker SRM1 (*qPDH1*) in individual F_2 progenies

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GDM-5: Region specific high yielding and high oil content variety of Indian mustard (*Brassica juncea* L. Czern & Coss.) suitable for rainfed ecosystem

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ABSTRACT

Indian mustard (*Brassica juncea* L. Czern & Coss.) variety GDM-5 (Gujarat Dantiwada Mustard 5) was developed by pedigree method of breeding from a cross between BIO 129-97 and NDR 9503 at Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar, Gujarat. GDM-5 was evaluated in IVT and AVT Trials (rainfed) along with national check Kranti and zonal checks *viz*., Geeta, RB-50 and RGN-48 at five different locations during *rabi* 2011-12 to 2013-14. The genotype GDM-5 exhibited wider adaptability and consistent superiority for seed and oil yield in rainfed condition of Zone II as compared to the check varieties during the three year of testing. On the basis of weighted mean performance, GDM-5 gave 2213 kg/ha yield, which was higher than national check Kranti (1758 kg/ha) and zonal checks *viz*., Geeta (1238 kg/ha), RB-50 (1808 kg/ha) and RGN-48 (2013 kg/ha). GDM-5 with 40.50 per cent oil in its seed, gave on an average 897 kg/ha oil yield, which was higher than Kranti (by 24.6 %), Geeta (by 81.2 %), RB-50 (by 23.7 %) and RGN-48 (by 6.8 %). The genotype GDM-5 with medium tall growth habit has an inbuilt capacity for tolerance to lodging and shattering. It was found tolerant to biotic stresses like mustard aphid (under natural conditions), Sclerotinia stem rot, white rust and alternaria blight. On the basis of consistent superior performance, GDM-5 has been released in 2015 for general cultivation in rainfed area of Zone II including Punjab, Haryana, Delhi, Northern Rajasthan and Jammu states.

Keywords: GDM-5, High oil content, High yield, Hybrid, Indian mustard, Rainfed ecosystem

India is one of the largest rapeseed-mustard growing countries in the world occupying the third position in area and production after Canada and China. Indian mustard belongs to the family *Brassicaceae* and genus *Brassica.* Indian mustard is naturally amphidiploids (2n = 36) of *Brassica rapa* (2n = 20) and *Brassica nigra* (2n = 16). It is self-compatible and largely self pollinated crop (85-90%). However, owing to insects, especially honeybees, the extent of cross-pollination varies from 4 to 16.6 % (Rambhajan *et al.,* 1991). It is a plant of Asiatic origin with its major center of diversity in China (Vaughan, 1977).

Indian mustard is one of the most important oilseed crops in India grown next to groundnut. There has been remarkable increase in the production and productivity of rapeseed mustard during the last 25 years. In India, it is cultivated in an area of 6.23 million hectares with an annual production of 7.98 million tonnes and productivity of 1281 kg/ha (Anonymous, 2016a). It is cultivated mainly in Rajasthan, Uttar Pradesh, Punjab, Haryana, Gujarat, Madhya Pradesh and Assam. Mustard thrives well in sub tropical as well as temperate zone. The growth, development and yield of Brassicas depend upon the optimum conditions of different weather parameters such as rainfall (conserved soil moisture for rainfed condition), temperature, humidity and duration of sun light hours. Out of them, soil moisture is most important factor for mustard cultivation in rainfed area and it depends upon the number of rainy days as well as quantity of total rainfall precipitated during the monsoon.

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In India, there are several areas with sufficient amount of rainfall in monsoon and suitable for mustard cultivation under rainfed conditions using conserved soil moisture. However, limited efforts have been made for research on development of mustard variety suitable for rainfed conditions in India. Considering this research need of rainfed areas, continuous breeding efforts were made at Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar to develop Indian mustard variety suitable for rainfed conditions. As a result of these efforts, GDM-5 has been developed with high seed and oil yield potential, suitable for rainfed ecosystem.

MATERIALS AND METHODS

In order to develop high yielding, high oil content and stress tolerant variety for rainfed areas, hybridization programme was initiated in 1999-2000 at Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar, Gujarat. A promising genotype GDM-5 was derived from the cross between BIO 129-97 and NDR 9503. Elite plants with desirable yield component characters contributing to seed yield and oil content were selected from F2 generation onwards. Segregating material was handled through pedigree method of plant breeding. The genotype GDM-5 was first evaluated in Preliminary Yield Trial (PYT) at station level and later evaluated in a randomized block design in different categories of state trials *viz.,* Small Scale Varietal Trial (SSVT) and Large Scale Varietal Trial (LSVT) in Gujarat. Further, this genotype was nominated for inclusion in AICRP on Rapeseed Mustard Trials and evaluated in Initial Varietal Trial (IVT), Advanced Varietal Trial I (AVT I) and Advanced Varietal Trial II (AVT II) during *rabi* 2011-12 to 2013-14. Field screening was also carried out for its reaction to major pests and diseases. The analysis was performed following standard procedures as per Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The results on seed yield and oil yield of GDM-5 (Gujarat Dantiwada Mustard 5) along with national check Kranti and zonal checks *viz.,* Geeta, RB-50 and RGN-48 are presented in Table 1 and 2. Entry GDM-5 recorded a (weighted) mean seed yield of 2213 kg/ha, which was 9-79% higher than the check varieties, *viz.,* Kranti (1758 kg/ha), Geeta (1238 kg/ha), RB 50 (1808 kg/ha) and RGN 48 (2013 kg/ha). Variety GDM-5 was significantly superior to national check Kranti with a higher frequency of first rank of fifteen trials. It has recorded 40.50% oil content and 897 kg/ha oil yield which was 6.8% to 81.2% higher than the check varieties (Table 2).

Ancillary observation of days to maturity of GDM-5 along with the checks is presented in Table 3. The perusal of data showed that GDM-5 matured in 144 days which was at par with national check Kranti and zonal checks i.e., Geeta, RB 50 and RGN 48. The performance of GDM-5 was also tested in agronomical trial under different fertility levels at four different locations *viz.,* Bawal, Navgaon, New Delhi and Hisar. The results of these trials revealed that GDM-5 responded positively to higher fertilizer dose (125% RDF) over the recommended doses of fertilizers at all locations except Bawal (Table 4).

The genotype GDM-5 was screened for resistance to insect pests and diseases during 2012-13 and 2013-14 and data are presented in Table 5 and 6. The genotype GDM-5 was found at par for the reaction to Alternaria leaf/pod blight, white rust and downy mildew with the check variety Rohini and qualifying variety Albeli 1. However, the genotype GDM-5 showed significantly lower incidence of Sclerotinia rot and stage head formation than qualifying variety Albeli 1 (Table 5). The testing genotype also exhibited lower incidence of mustard aphid as compared to check varieties under natural conditions (Table 6). Previously, varieties GM-3 (Gujarat Mustard 3) with early maturity, higher seed yield and bold seed (Thakkar *et al.,* 2010) and GDM 4 (Gujarat Dantiwada Mustard 4) with higher seed yield and oil content (Prajapati *et al.,* 2017) have been released.

By virtue of its special features and superior performance, GDM-5 was identified for commercial cultivation in mustard growing areas in Zone II (Punjab, Haryana, Delhi, North Rajasthan and Jammu) under rainfed conditions by the Varietal Identification Committee in 22nd Annual Group Meeting of AICRP on Rapeseed-Mustard held at State Institute of Agriculture Management (SIAM), Durgapura, Jaipur, (Rajasthan) during August 3-5, 2015 (Anonymous 2016b). The variety GDM-5 has been registered (IC 618418) and conserved under long term storage at NBPGR, New Delhi and notified for release under cultivation in Zone II with notification no. S.O. 3540 (E), on 22nd November, 2016 (Anonymous, 2016c).

Table 1 Performance of GDM-5 in Coordinated Varietal Trials of Zone II under rainfed conditions during 2011-14

Parameter	Year of testing	No. of trials	GDM-5	Check variety				
				Kranti (NC)	Geeta (ZC)	RB 50 (ZC)	RGN 48 (ZC)	Qualifying variety Albeli-1
Mean seed yield (kg/ha)	2011-12 IVT	5	2081	1632	1238			2260
	2012-13 AVT I	5	2198	1967		1808		2158
	2013-14 AVT II	5	2360	1676			2013	1880
	Weighted Mean	15	2213	1758	1238	1808	2013	2099
Per cent increase (+) or decrease (-) over checks	2011-12 IVT			(+) 27.51	(+) 68.09			(-) 07.92
	2012-13 AVT I			(+) 11.74		(+) 21.57		(+) 01.85
	2013-14 AVT II			(+) 40.81			(+) 17.24	(+) 25.53
	Mean			(+) 25.88	(+) 78.76	(+) 22.40	(+) 09.94	(+) 05.43
Frequency in the top five group	2011-12 IVT		5/5	1/5	0/5	-	-	2/5
	2012-13 AVT I		5/5	2/5	-	0/5	-	2/5
	2013-14 AVT II		5/5	3/5	-	-	3/5	3/5
Pooled Mean			15/15	6/15	0/5	0/5	3/5	7/15

Zone II: Bhatinda, Hisar, Navgaon, Sriganganagar and Bawal (5); NC- National check, ZC-Zonal check

Table 2 Summary of oil yield (kg/ha) data of GDM-5 in Coordinated Varietal Trials of Zone II under rainfed conditions during 2011-14

Parameter	Year of testing	No. of trials	GDM-5	Checks			
				Kranti (NC)	Geeta (ZC)	RB 50 (ZC)	RGN 48 (ZC)
Oil yield kg/ha	2011-12 IVT	5	837	662	495	-	-
	2012-13 AVT I	5	881	806	-	725	-
	2013-14 AVT II	5	973	693	-	-	840
	Mean		897	720	495	725	840
	% increase over checks			24.6%	81.2%	23.7%	6.8%

*Zone II: Bhatinda, Hisar, Navgaon, Sriganganagar and Bawal (5)

Table 3 Summary of days to maturity data of GDM-5 in Coordinated Varietal Trials of Zone II under rainfed conditions during 2011-14

Parameter	Year of testing	No. of trials	GDM-5	Checks				Qualifying variety Albeli 1
				Kranti (NC)	Geeta (ZC)	RB 50 (ZC)	RGN 48 (ZC)	
Days to maturity	2011-12 IVT	5	145	144	145	-	-	145
	2012-13 AVT I	5	142	143	-	145	-	143
	2013-14 AVT II	5	145	144	-	-	147	144
	Mean		144	144	145	145	147	144

*Zone II: Bhatinda, Hisar, Navgaon, Sriganganagar and Bawal (5)

Table 4 Yield performance of GDM-5 as influenced by different fertility levels at four locations (Zone II) during 2014-15

Entries/Varieties	Fertility levels									
	75% of RDF		100% of RDF		125% of RDF		150% of RDF		Mean	
Bawal										
GDM-5	2056		2225		2267		-		2183	
RH 0406	1902		2078		2117		-		2032	
RGN 48	1716		1897		1942		-		1852	
Mean	1891		2067		2108		-			
CD (p = 0.05)	E =	136	F =	153	ExF =	NS				
DOS: Oct 17; Recommended fertility level: 100 kg N, 30 kg P_2O_5/ha										
Hisar										
GDM-5	1733	(38.3)	1987	(38.0)	2064	(37.9)	2112	(36.7)	1974	(37.7)
RH 0406	1994	(37.3)	2368	(37.3)	2489	(37.4)	2542	(36.6)	2348	(37.2)
RGN 48	1773	(37.7)	2149	(37.2)	2228	(37.3)	2275	(37.1)	2106	(37.3)
Mean	1833	(37.8)	2168	(37.8)	2260	(37.5)	2310	(36.8)	-	
CD (p = 0.05)	E = 95	(0.4)	F = 115	(0.4)	ExF = NS	(NS)				
Recommended fertility level: 40 kg N, 20 kg P_2O_5/ha										
IARI, New Delhi										
GDM-5	1941		2296		2459		-		2232	
RH 0406	1852		2222		2296		-		2123	
RGN 48	1815		2148		2237		-		2067	
Mean	1869		2222		2331		-			
CD (p = 0.05)	E=	92	F=	70	ExF=	NS	-			
DOS: Oct 30; Recommended fertility level: 40 kg N, 20 kg P_2O_5, 20 kg K_2O/ha, 15 kg S/ha										
Navgaon										
GDM-5	2128		2433		2681		2547		2447	
RH 0406	2160		2318		2715		2574		2442	
RGN 48	2081		2220		2573		2491		2341	
Mean	2123		2324		2656		2538			
CD (p = 0.05)	E = NS		F= 230		ExF= NS					

*Oil content (%) in parenthesis

Table 5 Reaction of GDM-5 against major diseases of Indian mustard in Zone II (BHT, HSR, NAV, SGN and BAW) during 2012-14

Parameter	Year of testing	No. of trials	GDM-5	Check variety Rohini (SC)	Qualifying variety Albeli 1	CD (p = 0.05)	C.V. (%)
Alternaria leaf blight under natural condition (%) at 100 DAS	2012-13	8	48.8	49.0	52.7	8.3	7.0
	2013-14	8	32.3	29.0	27.6	6.9	12.8
	Mean	16	40.6	39.0	40.2	7.6	9.9
Alternaria pod blight under natural condition (%)	2012-13	10	22.2	26.9	28.0	7.0	12.1
	2013-14	7	26.0	24.5	25.0	5.9	11.8
	Mean	17	24.1	25.7	26.5	6.5	12.0
Sclerotinia rot under natural condition (%)	2012-13	5	38.0	48.3	58.0	8.2	5.2
	2013-14	6	37.4	29.0	40.7	9.8	17.0
	Mean	11	37.7	38.5	49.4	9.0	11.1
White rust severity (%) at 100 DAS	2012-13	4	35.0	36.3	30.7	8.1	8.2
	2013-14	5	21.8	17.8	18.8	2.7	11.3
	Mean	9	28.4	27.05	24.8	5.4	9.8
Downey mildew severity (%)	2012-13	3	44.3	47.5	44.0	4.7	8.4
	2013-14	-	-	-	-	-	-
	Mean	3	44.3	47.5	44.0	4.7	8.4
Staged head (%)	2012-13	4	16.5	8.0	34.9	2.3	-
	2013-14	4	13.9	21.9	22.4	2.9	11.8
	Mean	8	15.2	15.0	28.7	2.6	11.8
Alternaria blight severity on pod (15 days before harvesting) (%)	2012-13	-	-	-	-	-	-
	2013-14	5	26.8	25.6	29.7	4.8	11.9
	Mean	5	26.8	25.6	29.7	4.8	11.9

(BHT = Bhatinda; HSR = Hisar; NAV = Navgaon; SGN = Sriganganagar and BAW = Bawal)

Table 6 Average aphid infestation index of GDM-5 against mustard aphids in different locations of Zone II during 2012-14

Year	Locations	GDM-5	Checks						Qualifying variety Albeli 1
			Rohini (SC)	JMT 05-03 (R/TC)	PT (R/TC)	Bhawani (SC)	JMM 927 R/TC)	Varuna (SC)	
2012-13	NAV	1.3	1.2	1.2	2.2	20	1.3	2.2	0.4
	BPR	1.5	2.0	1.0	1.3	1.7	1.5	1.6	1.3
	BER	1.4	1.4	2.5	2.7	1.5	1.5	1.5	1.3
	HSR	0.6	1.4	1.0	1.2	1.2	1.2	1.0	1.2
	KAN	3.4	2.1	2.9	4.4	2.7	2.5	2.6	2.0
	SKN	3.0	2.0	2.5	3.0	1.5	3.0	2.5	3.0
	PTN	0.2	0.1	0.1	0.0	0.0	0.2	0.3	0.1
	LDH	1.0	1.6	05	0.7	1.0	1.1	0.9	0.9
	Mean	1.5	1.4	1.4	1.9	1.4	1.5	1.5	1.2
		GDM-5	Rohini (SC)	JMT 04-03 (R/TC)	PT (R/TC)	Bhawani (SC)	JMM 927 (R/TC)	Varuna (SC)	Albeli 1
2013-14	NAV	1.0	1.5	1.3	0.9	1.0	1.2	1.2	1.3
	BPR	1.8	2.0	1.8	2.1	2.1	2.0	2.1	2.0
	BER	1.4	1.7	1.6	1.5	1.6	1.6	1.7	1.7
	HSR	1.4	1.0	1.4	1.6	2.0	2.2	1.4	2.0
	KAN	0.4	0.1	0.1	0.1	0.1	0.1	0.4	0.3
	SKN	1.2	0.7	0.8	1.0	1.0	0.7	0.5	0.8
	PTN	0.3	0.1	0.7	0.8	0.4	0.1	0.4	0.1
	NDH	3.1	3.1	3.1	3.5	3.2	3.2	2.5	2.6
	LDH	0.6	0.4	0.8	1.8	1.3	0.5	0.5	0.5
	Mean	1.2	1.2	1.3	1.5	1.4	1.3	1.2	1.3

(NAV = Navgaon; BPR = Bharatpur; BER = Berhampore; HSR = Hisar; KAN = Kanpur; SKN = Sardarkrushinagar; PTN = Pantnagar; NDH = New Delhi and LDH = Ludhiana)

Fig. 1. Plant, siliquae and seeds of Indian mustard variety GDM-5

Table 7 Morphological features of Indian mustard variety GDM-5

Character		Particular	
Growth habit	:	Medium Tall	
Leaf Character	:		
Simple/Compound	:	Simple	
Colour	:	Medium Green	
Pubescent/Glabrous	:	Pubescent	
Stem colour	:	Green	
Flower colour	:	Light Yellow	
Siliqua	:	Medium (4.4 cm with 13-15 seeds)	
Seed	:	Blackish brown in colour	
Agronomic Traits			
Days to flowering	:	Mean : 46 days, Range: 42-52 days	
Days to maturity	:	Mean: 144 days, Range : 134-155 days	
Plant height	:	Mean: 187 cm, Range: 181-195 cm	
No. of primary branches	:	Mean: 5.1, Range: 4.0-7.0	
No. of siliquae per plant	:	Mean: 255, Rang: 210-280	
No. of seeds per siliqua	:	Mean: 14 seeds, Range: 13-15 seeds	
1000 seed weight	:	Mean: 4.9 g, Range: 3.7-6.0 g	
Disease reaction	:	Low incidences of Sclerotinia stem rot, white rust and Alternaria blight.	
Pest reaction	:	Low incidence of mustard aphid	
Qualitative characters	:	Oil content : 40.5%, Range: 38.0-41.4%	
Special characters	:	Erect plant type Tolerant to lodging and shattering Suitable for timely sown rainfed condition (Zone II) Non shattering habit High oil yielding strain	Late maturity group suitable for Zone II Low water requirement Wide adaptability

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Agro-morphological characterization of soybean germplasm

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ABSTRACT

Two hundred seventy three germplasm lines of soybean including three checks (JS-97-52, Bragg and JS-335) were evaluated for agro-morphological characters in an augmented block design at Raipur, Chhattisgarh. These traits belonged to two categories *viz*., qualitative-measured through visual observation like anthocyanin pigmentation (present and absent), flower colour, pod colour, leaf colour, etc and quantitative- measurable traits like plant height, size of seed (100-seeds weight g), etc. The entire (273 genotypes) soybean under study showed wide range of genetic variation in respect to these traits. The frequency distributions of 20 agro-morphological characters showed variable range of characters. Most of the genotypes were distinguishable on the basis of characters published in the DUS guidelines.

Keywords: Agro-morphological characterization, Germplasm, Soybean, Traits

Soybean (*Glycine max* L. Merrill) is one of the oldest cultivated crops which is native of 'North-eastern China and belongs to the family fabaceae. It is a versatile crop with innumerable possibilities of not only improving agriculture but also supporting industries. A number of cultivars have been released in India from different soybean breeding centres for cultivation under different agro climatic conditions by introduction, selection, mutation and hybridization of elite cultivars and germplasm through systematic breeding and evaluation programmes. The plant is classified as an oil seed rather than a pulse crop by the UN Food & Agricultural organization (FAO). It is an important oil seed crop in India. Soybean is ranked number one in international market among world's major oilseed crops (Chung and Singh, 2008).The protein and oil components of soybean seed are high in quantity and quality. Soy oils contain high proportion of unsaturated fatty acids; hence it is healthy oil. It contains about 37-42% of good quality protein, 6% ash, 29% carbohydrate and 17-24% oil comprising 85% polyunsaturated fatty acid with two essential fatty acids (linoleic and linolenic acid) which are not synthesized by the human body (Antalina, 2000; Balasubramaniyan and Palaniappan, 2003).

The characterization of a variety is essential for plant breeders, seed inspectors, researchers and other clientele to meet their specific needs. In the present context, identification of plant varieties of common knowledge is essential for the protection of new plant varieties under the Protection of Plant Varieties and Farmers Right Act (PPV&FRA), 2001. Article 15.3(b) of the PPV&FR Act states that the new variety must be clearly distinguishable by one or more essential characters from any variety whose existence is a matter of common knowledge at the time of seeking protection. The uniqueness of a variety is to be established by the test called DUS (Distinctiveness, Uniformity and Stability). Therefore, candidate variety is to be compared with all the varieties, whose existence is a matter of common knowledge, which is a huge task. This task can be minimized by comparing candidate variety with the most similar variety. Therefore, it is a prerequisite to study the essential characters of all the varieties of common knowledge because these characters are explicit and repeatable.

The presence and magnitude of genetic variability in a gene pool is the pre-requisite of a breeding programme. For the effective selection of superior genotype to use in hybridization programmes aimed at developing superior varieties, proper study of genetic variability due to genetic and non-genetic causes and other genetic parameters is necessary (Prasad *et al.*, 2012). It is desirable for plant breeder to know the extent of relationship between yield and its various components, which will facilitate selection of desirable characteristics (Jain *et al.*, 2015). Large variability in the initial breeding material ensures better chances of producing new desired forms of a crop (Raturi et al., 2014). A good knowledge of genetic resources might also help in identifying desirable genotypes for future hybridization program. The present investigation was undertaken to study the essential characters of soybean genotypes for grouping them and to study the distinctness among them.

MATERIALS AND METHODS

The experimental material of the present study comprised of 273 germplasm lines of soybean including three checks (JS-97-52, Bragg and JS-335) in augmented design divided into 6 blocks and every block had 47 entries and three checks. Out of these, 12 entries (obtained from AICRP on soybean, Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India) did not germinate. Each entry was raised in three rows, 2 m length spaced at 30 cm and 20 cm between plants, respectively. The recommended package of practices for

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soybean cultivation were followed for raising a healthy crop. The crop was sown in the field on 27th June 2015. The varieties were characterized for 20 characters as per DUS test guidelines (Anonymous, 2009). Randomly five plants were selected in each genotype. The method for seed coat peroxidase activity described by Buzzell and Buttery (1969) was used.

RESULTS AND DISCUSSION

Qualitative characters are considered as the diagnostic markers traits for identification and distinguishing soybean varieties or genotypes. These traits are less influenced by environment (Raut, 2003). Traits such as flower colour, presence or absence of hairs on pod, colours of hairs, seed colour, etc have been considered as stable traits across the agro-climatic zones (Satyavathi *et al.,* 2004; Gupta *et al.,* 2010). To establish distinctiveness among soybean varieties and genotypes of present study, 20 stable diagnostic traits were recorded as per the National test guidelines for the conduct of DUS test for Soybean (Anonymous, 2009). The characterization of all the varieties and germplasm accessions are presented on the basis of descriptors. These genotypes and varieties could be classified for their similarity or dissimilarity varieties on the basis of manifestation of the traits (Table 1). Nature, range and classes of agro-morphological descriptors recorded for the soybean germplasm under study is presented in Table 1.

Soybean genotypes were evaluated to assess the genetic variability on the basis of 20 important agro-morphological characters including both qualitative and quantitative. The frequency distribution of the characters showed variable range of characters (Table 1). The study revealed that the characters, hypocotyl anthocyanin pigmentation and flower colour were closely associated. Out of 273 genotypes, all genotypes having anthocyanin pigmentation on hypocotyl had purple flower colour, whereas the genotypes with non-pigmented hypocotyl had white flowers colour. These results are in conformity with the findings of previous workers (Gupta *et al.,* 2010; Ramteke and Murlidharan, 2012).

On the basis of flower colour, soybean varieties of India were grouped into two major categories. The flower colour is reported to be controlled by six genes (W1, W2, W3, W4, Wm and Wp) and pubescence colour by two genes (T and Td) (Palmer *et al.,* 2004; Takahashi *et al.,* 2008). Out of 273, 171 genotypes exhibited purple flowers, whereas 102 genotypes exhibited white flowers. Most of the genotypes were distinguishable on the basis of characters published in the DUS guidelines (Table 1). Out of 273 genotypes, 197 genotypes were semi determinate and 76 genotypes were determinate types. Five soybean genotypes namely JS-335, VLS 2, MAUS-145, VS-2004-18 and DS-98-14 were distinct from rest of the genotypes on the basis of rounded ovate leaf shape in which JS-335, VLS 2 and DS-98-14 had dark green leaf colour while both MAUS- 145 and VS-2004-18 had green leaf colour. Out of 273 genotypes, 230 genotypes had green leaf colour and rest 43 genotypes has dark green leaf colour. Two hundred seven genotypes were with erect growth habit and 66 genotypes were semi erect type in the growth habit. Out of 273 genotypes, pubescence were absent in 63 genotypes and in the remaining 210 genotypes pubescence was present on pods. Presence of pod pubescence was recorded in all the genotypes with either grey or tawny colour.

Twenty four genotypes namely JS-80-54,JS-95-60, JS-93-05, NRC-2007-1-3, NRC-2006-4-13, VS-2005-21, NRC-96-02-02, AMS-50-B, AMS-115, AMS-148, Cat-1113,Cat-2722, Cat-3299, EC-34078, EC-100027, EC-685243, EC-685255, JS-20-59, JS-20-78, JSM-224, JSM-258, Delhi-2, Delhi-5 and VS-495 exhibited black pod colour.

One hundred sixty genotypes were recorded as non-shattering and 113 genotypes were recorded as shattering type. Pod shattering behaviour of soybean variety is found to be associated with other agronomic characteristics and it has been linked to both genetic and environmental influences (Tiwari and Bhatnagar, 1991; Salih and Khidir, 1975).

When we compared the relation of flower colour in soybean with pod shattering trait, out of 273 accessions, 104 with purple flower colour and 42 genotypes with white flower colour had the shattering pod type. The present finding is not in confirmation with the findings of Ramteke and Murlidharan (2012) where they reported that all white flower varieties were resistant to pod shattering except LSb-1.One hundred seventy one genotypes were recorded as spherical seed shaped and 102 genotypes were elliptical seed shape. Himso15-63, NRC-2007-1-3, Delhi-16 and Delhi 18 genotypes which had green seed coat colour with yellow cotyledons except Himso 15-63 which had green cotyledons. Out of the total 273 genotypes, 4 genotypes namely Birsa soya 1, JS-80-54, SL-328 and Cat-1368had black seed coat colour, two genotypes, JS-79-263 and JS-92-14,had brown seed coat colour. Out of 273 genotypes, 184 genotypes recorded shiny lustre seed while 89 genotypes had dull lustre seed. Positive reaction of peroxidase activity was recorded in 165 genotypes whereas in 108 genotypes the reaction was negative.

In most of the accessions (105 genotypes) brown seed hilum colour was noticed and in 24 genotypes yellow seed hilum colour was recorded The colour of seed coats and hilum is controlled by five loci (Palmer and Kilen, 1987).

Studies on quantitative characters have earlier been made by Karnwal and Singh (2009) and Ramteke *et al.* (2010), Ramteke and Murlidhara (2012). Out of 273 genotypes, 48 genotypes were short, 103 genotypes were of medium height and 151 genotypes (55.31%) were tall.

Table 1 Morphological descriptors scales and their distribution in soybean germplasm

Descriptor	Scale of descriptor	Frequency distribution	Per cent distribution
Anthocyanin pigmentation on hypocotyl	1 = Absent	102	37.36%
	9 = Present	171	62.63%
Plant growth type	1= Determinate	76	27.83%
	2 = Semi determinate	197	72.16%
	3 = Indeterminate	0	0.00%
Days to 50% flowering	3 = Early flowering (≤ 35 days)	17	6.22%
	5 = Medium flowering (36 – 45 days)	173	63.36%
	7 = Late flowering (> 45 days)	83	30.40%
Leaf shape	1 = Lanceolate	44	16.11%
	2 = Pointed ovate	224	82.05%
	3 = Rounded ovate	5	1.83%
Leaf colour	1 = Green	230	84.24%
	2 = Dark green	43	15.75%
Plant growth habit	1 = Erect	207	75.82%
	2 = Semi erect	66	24.17%
Flower colour	1 = White	102	37.36%
	2 = Purple	171	62.63%
Plant height(cm)	3 = Short (≤ 40)	48	17.58%
	5 = Medium (41 – 60)	103	37.72%
	7 = Tall(> 60)	151	55.31%
Pod pubescence	1 = Absent	63	23.07%
	9 = Present	210	76.92%
Pod pubescence colour	1 = Grey	115	42.12%
	2 = Tawny	96	35.16%
Pod colour	1 = Yellow	109	39.92%
	2 = Brown	140	51.28%
	3 = Black	24	8.79 %
Shattering on pod	1= Shattering	113	41.39%
	9 = Non shattering	160	58.60%
Days to maturity	3 = Early maturity (≤ 95 days)	89	32.60%
	5 = Medium maturity (96 – 105 days)	170	62.27%
	7 = Late maturity (≥ 105 days)	15	5.50%
Size of seed(100 seeds weight g)	3 = Small(≤ 10.0 g)	86	31.50%
	5 = Medium (10.1 – 13.0 g)	176	64.46%
	7 = Large(≥ 13 g)	11	4.02%
Seed shape	1 = Spherical	171	62.63%
	2 = Elliptical	102	37.36%
Seed colour	1 = Yellow	204	74.73%
	2 = Yellow green	59	21.61%
	3 = Green	4	1.46%
	4 = Black	4	1.46 %
	5 = Brown	2	0.73%
Lustre on seed	1 = Shiny	184	67.39%
	9 = Dull	89	32.60 %
Colouration due to peroxidase activity in seed coat	1 = Absent	108	39.56 %
	9 = Present	165	60.43%
Seed hilum colour	1 = Yellow	25	9.16%
	2 = Grey	55	20.14%
	3 = Brown	105	38.46 %
	4 = Black	88	32.23%
	5 = Variegated	0	0.00%
Cotyledon colour	1 = Yellow	269	98.53%
	2 = Green	3	1.09%

Maximum plant height (104.17 cm) was observed in NRC-2014-P-8-2-3-1-1, while the minimum wascin in Delhi-24 (31.82 cm). 100-seeds weight among varieties varied from 5.81g (Himso-15-21) to 14.29g (RSC-10-15). Eleven genotypes namely JS-93-05, RSC-10-15, NRC-2012-A-3-2-1-1, NRC-2011-B-1-8-1-43, NRC-2011-E-4-11-1-1, VLS-2, VLS-47, NNR-95-08-01, AMS-50-B and Delhi-19 were bold seeded. The most delayed flowering (51days) was recorded in PK-515 while JS-20-35 genotype was the earliest to flower (31 days). Earliest maturity (81days) was recorded in genotype NRC-2007-A-3-1 whereas genotypes MACS 693, MACS-694 matured very late in 110 days. Fifteen genotypes namely, Indira soya-9, Birsa soya-1, JS-99-76, Himso-15-63, DS-228, MACS-693, MACS-694, JS (SH)-94-21, RAUS-5, JS-97-52, NRC-2006-A-7, NRC-2006-4-1-2, NRC-2006-I-1, NRC-2006-J-7 and Cat-1368 were grouped under late maturity category. In soybean eight loci with two alleles at each locus have been reported to control time to flowering and maturity through their response to photoperiod (Cober and Morrison, 2010).

Agromorphological characterization of soybean has been carried out by other workers also (Karnwal and Singh, 2009; Ramteke *et al.,* 2010). They have also reported the variability for quantitative traits such as plant height, maturity period, test weight, etc. It is suggested that while identifying the variety or germplasm accession as useful for crop improvement programme, all the traits should be taken in to consideration in toto. In the present study the lines which found to be with important characters such as early flowering and maturity, and pod shattering resistance characters are being used in crop improvement programmes.

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Evaluation of crop establishment methods and foliar nutrition for enhancing productivity of rice fallow/follow sesame (*Sesamum indicum* L.)

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ABSTRACT

Field experiment to evaluate crop establishment methods and foliar nutrition for rice fallow/follow sesame (*Sesamum indicum* L.) was conducted for two consecutive years during *rabi*/summer 2015-16 and 2016-17 at TNAU, Regional Research Station, Vridhachalam under All India Coordinated Research Project on Sesame. The experiment was laid out in split plot design replicated thrice, with three crop establishment techniques in main plots and four foliar nutrition techniques in sub plots. Among the different crop establishment methods, sowing of sesame after harvest of rice under till condition recorded higher final plant stand, maximum number of branches/plant (5.3), more number of capsules/plant (49) and maximum sesame seed yield (627 kg/ha). Similarly, sowing of sesame after harvest of rice under till condition recorded maximum gross return (₹51,828/ha), net return (₹ 29,653/ha) and B:C ratio (2.34). Poor crop stand and low yield was recorded under sowing 5 days before harvest of rice under moist condition. Among the foliar nutrition, combined foliar spray of 1% urea and 2% DAP at 35 DAS recorded more number of branches/plant (6.3) and capsules/plant (54) but it was on par with other foliar nutrition. The combined foliar spray of 1% urea and 2% DAP at 35 DAS showed its superiority by recording a maximum sesame seed yield (584 kg/ha), gross return (₹ 48,238/ha), net return (₹ 26,738/ha) and B:C ratio (2.24).

Keywords: Crop establishment, Foliar nutrition, No-till, Sesame, Rice fallow

Sesame (*Sesamum indicum* L.) is the earliest domesticated plants of India and an important edible oilseed crop cultivated throughout the world. India ranks second in sesame production and first in area by contributing 23.2 per cent and 13.1 per cent of the world production and area respectively (Lizabeni Kithan and Rajesh Singh, 2017). In India, sesame is cultivated in an area of 16.66 lakh hectares with production of 6.75 lakh tonnes and productivity of 405 kg/ha (Anonymous, 2015). India has achieved self sufficiency in food grains but yet to achieve the same in oilseeds. Area expansion under oilseed crops is utmost important but it is difficult in traditional oilseeds due to the pressure of other competitive crops. Rice fallow regions provide ample scope for area expansion of oilseeds. In India, rice is cultivated both under irrigated and rainfed conditions in various cropping systems across the length and width of the country occupying about 43 million hectares area (Anonymous, 2018). Rice-rice, rice-sugarcane, rice-groundnut, rice-vegetables, rice-pulses, rice-sunflower, rice-sesame and rice-fallows are the prevalent rice-based cropping systems in various parts of the country. Major area under rice production during *kharif* season in India remains fallow in the subsequent *rabi* due to various reasons, but lack of production technologies is considered as a major determinant. Being short duration in nature, sesame is an ideal crop for cultivation in rice fallows (Sreedhar Chauhan *et al.*, 2016). To cope up with the increasing demand of oilseeds in the country, sesame should be included as an integral part in rice fallow areas with a dual advantage of crop diversification for sustainable production and increasing the area under sesame. To utilize the rice fallow areas with sesame, location specific and economically viable technology for better performance of sesame are required to be evaluated through proper understanding of the system ecology and constraints for adoption. Conservation agriculture practices may also help to establish the sesame crop by utilizing the residual moisture of rice crop.

If the rice fallow area is brought under sesame cultivation with appropriate crop establishment and nutrient management techniques, it may usher another yellow revolution in India benefiting millions of farmers. Promotion of rice fallow sesame would also improve sustainability of the rice production system besides enhancing production and augmenting income. It should be considered appropriate to identify the constraints in *rabi* cropping that can be addressed through appropriate technological intervention. Considering the scope for area expansion in rice fallow areas, this study was conducted to identify suitable crop establishment method and develop foliar nutrition technique for rice fallow/follow sesame cropping system.

MATERIALS AND METHODS

Description of study area: The field experiment was conducted for two consecutive years during *rabi*/summer 2015-16 and 2016-17 at TNAU, Regional Research Station, Vridhachalam under All India Coordinated Research Project on Sesame (AICRP on Sesame). The soil of experimental field was sandy loam with a pH of 6.5 and organic carbon of 0.20 %.

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Experimental materials and lay out of experiment: The field experiment was laid out in a split plot design with three replications. The main plot consisted of three crop establishments *viz.,* M_1 - Sowing 5 days before harvest of rice under moist condition, M_2 - Sowing immediately after harvest of rice (No-till condition), M_3 - Sowing one day after harvest of rice (with till condition). The sub plot consisted of four nutrition techniques *viz.,* S_1 - Control, S_2 - 1% urea foliar spray at 30 and 45 DAS, S_3 - 2% DAP foliar spray at 30 and 45 DAS, S_4 - S_2 + S_3. Foliar spray of Urea and DAP was done early morning using a knapsack sprayer with a spray fluid of 500 litres per hectare. Rice variety ADT 50 of 150 days duration and sesame variety VRI 1 with a duration of 70-75 days was used for the study. During the crop season, light irrigation was given and inter-cultural operations *viz.,* thinning and weeding were done on 15 and 25 DAS irrespective of treatments.

Crop calendar: Rice was sown during 34th meteorological standard week (MSW) and transplanted during 37th MSW. The rice crop was harvested during 4th MSW followed by sesame sowing as per the treatment schedule.

Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
		Samba season				Summer	
		Rice				Sesame	

Fig.1. Crop calendar showing two crops in cropping pattern of study area

Data collection: The data on growth attributes *viz.,* plant height, number of branches/plant and LAI were also recorded. The plant height was measured (in cm) from tagged plants from the ground to the tip of the main stem. The crop was harvested at 75 DAS. The capsules present in the tagged plants were counted and average was calculated to obtain the number of capsules per plant. The number of seeds per capsule were counted and recorded. One thousand seeds from each plot were taken and their weight was estimated and expressed in gram. Cleaned and sun-dried grains of net plot area were weighed and sesame seed yield was computed and expressed in kg/ha.

Statistical analysis: Data were statistically analysed following the procedure given by Gomez and Gomez (2010). A two-way ANOVA was used to determine significant difference among establishment methods and foliar nutrition supply methods. Wherever the results were significant, critical differences were worked out at five per cent level and non-significant results were denoted as N.S.

RESULTS AND DISCUSSION

Growth parameters: Crop establishment and foliar nutrition significantly influenced growth and yield attributes of sesame under rice-sesame cropping system (Table 1). Sowing of sesame after harvest of rice under till condition (M_3) recorded higher final plant stand (1,00,000 plants/ha), higher plant height (117 cm) and maximum number of branches/plant (5.3). The crop stand (86,000 plants/ha), plant height (93 cm) and number of branches (4.0) were significantly lower when sown 5 days before harvest of rice under moist condition. Sowing of sesame after harvest of rice under till condition (M_3) had a positive impact on germination and crop growth rate in comparison to sowing under no-till condition. This is in conformity with the findings of Sangakkara (2007). Combined foliar spray of 1% urea and 2% DAP at 30 and 45 DAS recorded higher plant stand (97,000/ha), higher plant height (115 cm) and higher number of branches/plant (6.3).

Yield attributes and yield: The yield attributes *viz.,* number of capsules per plant and number of seeds per capsule are two important parameters for yield of sesame were found to be significantly influenced by crop establishment method and foliar nutrition (Table 1). Sowing after harvest of rice (with till condition) (M_3) registered higher number of capsules per plant (49/plant) which resulted in highest sesame seed yield (627 kg/ha). Whereas, sowing 5 days before harvest of rice under moist condition (M_1) and sowing immediately after harvest of rice under no-till condition (M_2) recorded less yield of 478 kg/ha and 511 kg/ha respectively. It is obvious that in sowing under zero tillage practice, the soil becomes hard, in contrast to sowing after harvest of rice under till condition where the soil remained loose and facilitated root growth, nutrient uptake etc., resulting in better plant growth and dry matter production at early stages resulting in higher yield (Behera *et al.,* 2014). In general, crop rotation with non-host crops, particularly rice, helps in reduction of pest and disease incidents which ultimately increase the yield of sesame (Kumaraswamy *et al.,* 2015). Among the foliar nutrition, combined foliar spray of 1% urea and 2% DAP at 30 and 45 DAS showed its superiority by recording higher number of capsules/plant (54) and maximum seed yield (584 kg/ha). Yield increase in sesame through foliar application of fertilizer has been reported earlier (Mishra, 2010; Mahajan *et al.,* 2016). Supply of a combination of 2% DAP and 1% urea facilitated enhancing the number of floral buds and reducing the flower drop resulting in higher number of capsules. The results are in conformity with the findings of Shirazy *et al.* (2015) and Roul *et al.* (2017) in sesame. The increase in the seed yield with combined nutrient spray over the control was 21.6 per cent. This can be ascribed to the superiority of growth and yield attributes due to easy availability and efficient utilization of nutrients by the plants. This is in confirmity with the results of Samadhiya (2017) in safflower. Martin Stanley and Basavarajappa (2014) also revealed that foliar spray of urea and 2% DAP twice at flower initiation and 10 days thereafter remarkably increased the seed yield of sesame.

Economics: Perusal of the data (Table 2) on economic analysis clearly revealed that sowing of sesame after harvest of rice under till condition recorded maximum gross return (₹51,828/ha), net return (₹29,653/ha) and B:C ratio (2.34). Among the foliar nutrition the cost of cultivation (₹21,375/ha) was maximum in combined foliar spray of 1% urea and 2% DAP 30 and 45 DAS, however the combined foliar spray showed its superiority by recording a maximum gross return (₹ 48,238/ha), net return (₹ 26,738/ha) and B:C ratio (2.24).

In conclusion, sowing of sesame after harvest of rice under till condition with combined nutrient spray of 1% urea and 2% DAP significantly increased the leaf area index, number of branches per plant, number of capsules per plant and number of seeds per capsule resulting in higher sesame seed yield.

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Table 1 Effect of crop establishment and foliar nutrition on growth and yield of sesame under rice-sesame cropping system (Pooled data of two years)

Crop establishment	Final plant stand ('000/ha)	Plant height (cm)	No. of branches/ plant	No. of capsules/ plant	Test weight (g)	Seed yield (kg/ha)
M_1	86	93	4.0	40	2.7	478
M_2	90	105	4.6	43	2.8	511
M_3	100	117	5.3	49	2.9	627
S.Ed	2.05	2.33	0.12	1.07	0.10	10.86
CD (0.05)	7.65	9.44	0.41	4.33	NS	43.92
CV (%)	11.15	10.50	10.35	12.20	10.40	11.45
Foliar Nutrition						
S_1	87	91	3.5	33	2.7	480
S_2	92	106	4.0	42	2.8	539
S_3	94	108	4.7	47	2.8	552
S_4	97	115	6.3	54	2.9	584
S.Ed	2.72	4.69	0.16	1.48	0.13	18.17
CD (0.05)	7.76	12.20	0.48	4.44	NS	54.44
CV (%)	13.10	13.05	13.70	13.35	10.85	12.90

Table 2 Effect of crop establishment and foliar nutrition on economics of sesame under rice-sesame cropping system (Pooled data of two years)

Crop Establishment	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	BCR
M_1	20300	39351	19051	1.94
M_2	20250	42184	21934	2.08
M_3	22175	51828	29653	2.34
Foliar Nutrition				
S_1	20275	39590	19090	1.93
S_2	21050	44459	23359	2.11
S_3	21100	45531	24431	2.16
S_4	21375	48238	26738	2.24

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Influence of intercropping systems and sulphur on yield and quality of castor (*Ricinus communis* L.) in eastern Uttar Pradesh

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ABSTRACT

A field experiment was conducted during *kharif* 2012 and 2013 at BHU, Varanasi, Uttar Pradesh to study the growth, yield and quality parameters influenced by different sulphur levels and intercropping systems. The soil of the experimental field was loamy sand having pH 7.35, organic carbon (0.37%), available nitrogen (205 kg N/ha), phosphorus (25 kg P_2O_5/ha) and potash (216 kg K_2O/ha). The treatments consisted of five intercropping systems [castor + mungbean (1:1), castor + mungbean (1:2), castor + mungbean (1:3), castor + mungbean (2:2 paired row) and castor + mungbean (2:3 paired row)] and four levels of sulphur (0, 20, 40 and 60 kg S/ha) were taken in strip plot design with three replications. Intercropping system (castor + mungbean, 1:1 ratio) resulted in taller plants which was at par with castor + mungbean (1:2) ratio. Application of sulphur @ 60 and 40 kg/ha produced statistically similar plant height, but significantly higher than application of sulphur @ 0 and 20 kg/ha. Dry weight of castor was higher in castor + mungbean (1:1 and 1:2 ratios) than castor + mungbean (2:2 and 2:3 ratios) of castor and mungbean crops. The highest dry matter accumulation was recorded with the application of 60 kg S/ha which was at par with 40 kg S/ha, while dry matter accumulation was lowest with no S application. During the year 2013, significantly higher seed yield (1428 kg/ha), stalk yield (2548 kg/ha) and biological yield (3977 kg/ha) of mungbean was recorded in castor + mungbean (1:1) intercropping and gradually reduced with increase in row proportion. Similar trend was followed in year 2012. The highest grain, stalk and biological yields of castor and mungbean were recorded with application of 60 kg S/ha (1045, 1740, 2786 and 1364, 2408, 3771 during 2012 and 2013 respectively) which was statistically similar with S40 during both years of study. Higher carbohydrate per cent, protein yield and protein per cent were recorded with castor + mungbean (1:1) which was statistically similar with castor + mungbean (1:2) during both the years of study.

Keywords: Castor, Growth, Intercropping, Quality, Mungbean, Yield

Castor (*Ricinus communis* L.) is an important non edible oilseed crop widely grown in arid and semi-arid regions and plays an important role in the agricultural economy of the country by increasing substantial foreign exchange due to export of the castor oil, apart from fulfilling the internal demand of various industries. Castor oil has a wide range of uses in industries as lubricants, medicines for human and animals, non drying oil and fuel for operating aero-engines. Castor oil is also used for producing sebacic acid for the synthesis of nylon and fibre to manufacture perfumed hair oil, cotton dye, printing ink and leather industries. Stem pulp of castor is used for manufacturing paper and its leaves are used for rearing silkworm. Castor cake is also used as manure.

Mungbean is primarily a rainy season crop but with the development of early maturing varieties, it has also proved to be an ideal crop for spring and summer season. Mungbean is an excellent source of protein (24.5%) with high quality of lysine (460 mg/g N) and tryptophan (60 mg/g N). It also has remarkable quantity of ascorbic acid when sprouted and also bear riboflavin (0.21 mg/100 g) and minerals 3.84 g/100 g (Gopalan *et al.*, 1995). Mungbean being a leguminous crop has the capacity to fix atmospheric nitrogen through symbiotic nitrogen fixation. Being a short duration crop it suits well in various multiple and intercropping systems. With the release of early maturing and diverse crop varieties, it is proved beyond doubt that such a system, when based on sound production principles, will provide greater stability, productivity and profitability. The system of intercropping not only improves the yield and net returns but also reduces the risk of complete crop failure as compared to the sole cropping system (Rao and Singh, 1990). The yield advantage obtained through intercropping is due to efficient utilization of available growth resources like water (Bandopadhyay and De, 1986), nutrients (Ofari and Stern, 1987) and sunlight. Intercropping, besides utilizing growth resources efficiently, suppressed weeds (Venkateswarlu and Ahlawat, 1986) and disease-pest incidences (Paoline *et al.*, 1988), resulting in an overall improvement in production over sole cropping with an efficient land use system.

Research work done in different parts of the country indicate that application of sulphur to all crops and oilseeds and pulses in particular is highly profitable and seems essential for boosting the crop production. Sulphur plays an inevitable and imperative role in formation of amino acids *viz*., methionine, cystine and cysteine. It is also associated with synthesis of vitamins (biotine, thiamine), metabolism of carbohydrates, proteins and fats. Sulphur deficiency results in poor flowering and fruiting, cupping of leaves, reddening

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of stems, petioles and stunted growth. Keeping this in view, the present field investigation was conducted.

MATERIALS AND METHODS

Field experiment was conducted at the Agriculture Research Farm of BHU, Varanasi during *kharif* 2012 and 2013. The experimental farm is located at 34.01°N latitude, 71.35° E longitude at an altitude of 350 m above sea level in India. Varanasi has continental type of climate. Soil texture is clay loam, low in organic matter (0.37%), low in available nitrogen (195 kg/ha), high in extractable phosphorus (27.0 kg/ha), medium in exchangeable potassium (219 kg/ha), and soil pH was 7.30. Soil physico-chemical properties such as soil organic matter (Walkely and Black method, 1934), available soil nitrogen (alkaline permanganate method, Subbiah and Asija, 1956), phosphorus (Olsen *et al.,* 1954), available potassium (Flame photometer method, Richards, 1954) were determined by following standard procedures. The field experimentation with 5 x 4 factors was conducted in a strip plot design with three replications. The treatments consisted of five intercropping system in main plots [castor + mungbean (1:1), castor + mungbean (1:2), castor + mungbean (1:3), castor + mungbean (2:2 paired row) and castor + mungbean (2:3 paired row)] and four levels of sulphur in sub plots (0, 20, 40 and 60 kg S/ha). Castor hybrid, GCH-4 and mungbean variety, HUM-2 were used in the experiment. The seeds of castor were sown in rows that were 90 cm apart and within the row a spacing of 30 cm was maintained for sole castor crop. In intercropping, one/two rows of mungbean were sown in interspaces of castor in 1:1 and 1:2 intercropping system respectively. Whereas, after pairing two rows of castor at 60 cm leaving the space of 120 cm in between pairs, two and three rows of mungbean were sown in 2:2 and 2:3 intercropping system, respectively. Net plot size of 4.5 m x 4.0 m was used. Sulphur was applied through elemental sulphur as per treatment and a recommended dose of 60 kg N/ha and 40 kg P_2O_5/ha was applied through DAP and urea. Full dose of phosphorus through DAP and half dose of nitrogen through urea after adjusting with DAP was applied as basal dose and remaining half dose of nitrogen was top dressed at 40 days after sowing (DAS) through urea. Data on plant height, taken from five randomly selected plants from each plot at harvest in both the crops was measured from plant base to tip of the main axis and average was worked out. The produce from net plot area after thoroughly sun drying was weighed for recording biological yield. After threshing and winnowing the weight of seed of main and intercrop from each net plot area was recorded as kg/plot and then converted into q/ha. Stalk/straw yield (q/ha) was obtained by subtracting the seed yield from biological yield. Protein and total carbohydrate in mungbean seed were determined by Modified Lowry's Method and Anthrone Method respectively. Oil per cent in the castor seed was determined by Soxhlet apparatus using petroleum ether (60-80ºC) as an extractant (A.O.A.C., 1960). Oil yield was calculated by using following formula:

$$\text{Oil yield (q/ha)} = \frac{\text{Per cent oil content in seed x Seed yield (q/ha)}}{100}$$

RESULTS AND DISCUSSION

Plant height of castor and mungbean: The plant height of castor and mungbean were significantly influenced due to different intercropping systems at harvest during both the year of study (Table 1). Plants were taller in 2013 than 2012 probably due to the differences in the amount and distribution of rainfall during the two years. Intercropping system (castor: mungbean, 1:1 ratio) produced taller castor plants which was at par with castor + mungbean 1:2 ratio intercropping systems. Its might be due to favourable environment available to plants as also evident from higher dry matter accumulation under this system. Whereas, significantly higher seed and straw yields were obtained in castor + mungbean (1:1) intercropping system, which might reflect the effect of higher plant population in the system. Sharma and Kulhari (2005) also reported similar result as our findings.

Pooled analysis of results showed that different levels of sulphur also significantly influenced plant height of castor and mungbean at harvest stage during both the years. Application of 40-60 kg/ha sulphur produced statistically similar plant height, but significantly higher than 20 kg/ha and no sulphur application. At higher levels of sulphur at initial stages resulted in better utilization of sulphur during vegetative period and resulted in taller plants compared to the latter. Similar results were also reported by Ikramullah *et al*. (1996).

Dry matter accumulation of castor and mungbean: The dry matter of castor and mungbean was significantly influenced due to different intercropping systems at harvest stage (Table 1).The higher dry weight was recorded in castor + mungbean (1:1 and 1:2 ratios) compared to castor + mungbean (1:3 and 2:3 ratios). This might be due to favorable environment available to plants for light, moisture.

The dry matter accumulation was significantly affected due to different levels of sulphur in castor and mungbean during both the years (Table 1). Dry matter accumulation improved with advancement of plant age towards maturity. The highest dry matter accumulation was recorded when castor and mungbean was applied with 60 kg S/ha which was at par with application of 40 kg S/ha, while lowest dry matter accumulation was observed with application of 0 kg S/ha. The increase in dry matter production with higher dose of sulphur was due to better crop growth, which resulted in more plant height, dry matter production and seed yield. These results are in line with previous studies conducted by Bina *et al.* (1989), where in maximum dry matter production was observed with application of 60 kg S/ha.

Yields of castor and mungbean: In the present study, different intercropping systems had significant effect on seed yield, stalk yield and biological yield of castor and mungbean during both the years of study on pooled basis (Table 2 and 3). During the year 2013, significantly higher seed yield (1428 kg/ha), stalk yield (2548 kg/ha) and biological yield (3977 kg/ha) of mungbean was recorded in castor + mungbean (1:1) intercropping and gradually reduced with increase in row proportion. Similar trend was followed in year 2012. Similar trends were observed when castor intercropped with groundnut (Ganvir *et al.,* 2004), and when castor intercropped with mungbean (Porwal *et al.,* 2006). During the year 2013, significantly higher seed yield (1782 ka/ha), stalk yield (3734 kg/ha) and biological yield (5515 kg/ha) of castor was recorded in castor + mungbean (1:1) intercropping. The higher seed yield of mungbean at lower plant population might be due to lower inter and intra plant competition leading to higher yield components and seed yield.

Table 1 Plant height (cm) and dry matter (g/plant) of castor and mungbean as influenced by different row ratio and sulphur levels

Treatments	Plant height (cm)						Dry matter					
	Castor			Mungbean			Castor			Mungbean		
	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Intercropping systems												
Castor + mungbean (1:1)	45.44	53.73	49.59	3.09	3.24	3.17	105.04	119.50	112.27	84.82	100.94	92.88
Castor + mungbean (1:2)	41.27	46.86	44.07	3.03	3.18	3.11	101.23	115.18	108.21	82.48	98.37	90.43
Castor + mungbean (1:3)	37.75	44.50	41.13	3.01	3.13	3.07	94.32	109.37	101.85	78.83	94.34	86.59
Castor + mungbean (2:2 PR)	30.31	40.55	35.43	2.83	3.03	2.93	82.95	100.10	91.53	73.12	87.93	80.53
Castor + mungbean (2:3 PR)	30.26	39.84	35.05	2.73	2.93	2.83	83.86	100.18	92.02	70.08	86.06	78.07
SEm(±)	1.99	2.34	2.17	0.16	0.16	0.16	2.09	2.71	2.40	1.71	1.76	1.74
CD (P =0.05)	6.50	7.64	7.07	0.53	0.53	0.53	6.81	8.83	7.82	5.58	5.73	5.66
Sulphur levels (kg/ha)												
S_0	32.59	40.64	36.62	2.89	2.97	2.93	79.51	94.07	86.79	69.98	84.78	77.38
S_{20}	35.64	43.63	39.64	2.91	3.01	2.96	90.30	105.61	97.96	77.53	93.23	85.38
S_{40}	37.96	46.15	42.06	2.82	3.10	2.96	99.44	115.67	107.56	80.48	97.00	88.74
S_{60}	41.83	47.56	44.70	3.13	3.33	3.23	104.66	120.13	112.40	83.48	99.10	91.29
SEm (±)	0.79	0.71	0.75	0.10	0.11	0.11	1.77	1.64	1.71	1.02	1.05	1.04
CD (P =0.05)	2.29	2.05	2.17	0.29	0.31	0.30	5.12	4.74	4.93	2.93	3.03	2.98

Table 2 Effect of planting pattern and sulphur on seed, straw and biological yield of mungbean

Treatments	Seed yield (kg/ha)			Stalk yield (kg/ha)			Biological yield (kg/ha)		
	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Intercropping systems									
Castor + mungbean (1:1)	1041	1428	1235	1917	2548	2233	2958	3977	3468
Castor + mungbean (1:2)	903	1343	1123	1683	2364	2024	2587	3706	3147
Castor + mungbean (1:3)	878	1278	1078	1533	2224	1879	2410	3502	2956
Castor + mungbean (2:2 PR)	746	1142	944	1226	1924	1575	1972	3065	2519
Castor + mungbean (2:3 PR)	804	1093	949	1144	1828	1486	1948	2922	2435
SEm(±)	39.67	38.49	39.08	84.72	82.75	83.74	123.73	121.24	122.49
CD (P =0.05)	129.36	125.51	127.44	276.30	269.86	273.08	403.49	395.37	399.43
Sulphur levels									
S_0	721	1122	922	1222	1887	1555	1943	3009	2476
S_{20}	814	1225	1020	1424	2110	1767	2238	3335	2787
S_{40}	918	1316	1117	1616	2306	1961	2533	3622	3078
S_{60}	1045	1364	1205	1740	2408	2074	2786	3771	3279
SEm (±)	17.12	18.25	17.69	45.15	39.24	42.20	61.27	57.49	59.38
CD (P =0.05)	49.46	52.71	51.09	130.41	113.33	121.87	176.95	166.05	171.50

Table 3 Effect of planting pattern and sulphur levels on seed, stalk and biological yield of castor

Treatments	Seed yield (kg/ha)			Stalk yield (kg/ha)			Biological yield (kg/ha)		
	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Intercropping systems									
Castor + mungbean (1:1)	1655	1782	1719	3625	3734	3680	5280	5515	5398
Castor + mungbean (1:2)	1474	1614	1544	3286	3430	3358	4760	5044	4902
Castor + mungbean (1:3)	1347	1466	1407	3109	3179	3144	4455	4645	4550
Castor + mungbean (2:2 PR)	1159	1284	1222	2848	2849	2849	4007	4133	4070
Castor + mungbean (2:3 PR)	1214	1272	1243	2759	2749	2754	3972	4021	3997
SEm (±)	48.26	55.22	51.74	97	95.00	96.00	139.17	145.10	142.14
CD (P =0.05)	157.37	180.07	168.72	317	309.82	313.41	453.86	473.20	463.53
Sulphur levels (kg/ha)									
S_0	1100	1226	1163	2758	2818	2788	3858	4043	3951
S_{20}	1274	1406	1340	2985	3091	3038	4259	4497	4378
S_{40}	1467	1599	1533	3292	3358	3325	4759	4957	4858
S_{60}	1638	1703	1671	3467	3486	3477	5105	5189	5147
SEm (±)	35.93	36.98	36.46	46	48.52	47.26	76.65	80.39	78.52
CD (P =0.05)	103.78	106.81	105.30	132	140.14	136.07	221.38	232.17	226.78

Table 4 Effect of planting pattern and sulphur levels on quality parameters of castor and mungbean

Treatments	Castor									Mungbean								
	Oil content (%)			Oil yield (kg/ha))			Crude protein (%)			Carbohydrate (%)			Protein (%)			Protein yield (kg/ha)		
	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Intercropping systems																		
Castor + mungbean (1:1)	45.93	48.28	47.11	764.62	865.12	814.87	18.12	19.25	18.69	52.42	60.32	56.37	21.20	22.99	22.10	210.47	333.70	272.09
Castor + mungbean (1:2)	43.52	45.79	44.66	646.98	743.86	695.42	17.20	18.33	17.77	49.92	57.24	53.58	18.23	21.15	19.69	170.08	287.14	228.61
Castor + mungbean (1:3)	42.16	44.58	43.37	574.01	659.49	616.75	16.20	17.33	16.77	46.12	54.49	50.31	17.73	19.29	18.51	158.70	249.58	204.14
Castor + mungbean (2:2 PR)	39.50	41.89	40.70	462.65	542.33	502.49	14.82	15.92	15.37	42.21	50.60	46.41	14.51	16.07	15.29	116.83	184.66	150.75
Castor + mungbean (2:3 PR)	39.32	41.70	40.51	486.22	536.37	511.30	14.27	15.33	14.80	41.09	49.25	45.17	13.59	15.16	14.38	107.85	167.31	137.58
SEm (±)	0.55	0.80	0.68	24.56	30.86	27.71	0.38	0.42	0.40	1.15	1.06	1.11	0.80	0.77	0.79	11.06	14.13	12.60
CD (P =0.05)	1.79	2.61	2.20	80.10	100.63	90.37	1.25	1.38	1.32	3.76	3.45	3.61	2.62	2.52	2.57	36.06	46.07	41.07
Sulphur levels (kg/ha)																		
S_0	37.57	40.04	38.81	419.62	496.63	458.13	17.20	15.96	16.58	42.01	50.12	46.07	12.46	14.71	13.59	92.31	166.91	129.61
S_{20}	40.93	43.37	42.15	527.20	616.27	571.74	18.12	16.63	17.38	45.48	53.38	49.43	15.61	17.76	16.69	130.54	219.94	175.24
S_{40}	44.03	46.55	45.29	649.69	747.68	698.69	16.20	17.91	17.06	48.21	56.21	52.21	19.38	20.94	20.16	180.49	280.52	230.51
S_{60}	45.81	47.84	46.83	751.07	817.15	784.11	14.82	18.43	16.63	49.71	57.81	53.76	20.75	22.31	21.53	207.80	310.54	259.17
SEm (±)	0.48	0.55	0.52	15.08	16.43	15.76	14.27	0.23	7.25	0.66	0.57	0.62	0.73	0.69	0.71	8.78	10.84	9.81
CD (P =0.05)	1.39	1.60	1.50	43.57	47.44	45.51	0.38	0.66	0.52	1.91	1.64	1.78	2.10	1.99	2.05	25.35	31.31	28.33

The highest grain, stalk and biological yields of castor and mungbean were recorded with application of 60 kg S/ha (1045, 1740, 2786 and 1364, 2408, 3771 during 2012 and 2013 respectively) which was statistically similar with S40 during both the years of study except on seed and biological yield of mungbean during 2012 (Table 2 and 3). A critical review of data showed that lower dose of sulphur application did not have positive effect probably due to lack of sufficient time for physiological, agronomic and sulphur uptake activities. The higher seed and stalk yields of castor with higher N and S concentration increased the total uptake in sole castor as uptake is the function of nutrient content and dry matter yields. Similar results were also reported with respect to nitrogen uptake by sole crop by Ikramullah *et al.* (1996).

Quality parameters of castor and mungbean: The quality parameters such as oil content, oil yield and crude protein content were significantly influenced due to different intercropping systems in castor and mungbean (Table 4 and 5). Maximum oil content, oil yield and crude protein content of castor and higher carbohydrate per cent, protein yield and protein per cent of mungbean were recorded with castor + mungbean (1:1) which was statistically similar with castor + mungbean (1:2) during both the years. Ganvir *et al.* (2004) also reported that quality parameters increased with castor + mungbean intercropping system in the ratio of 1:1.

Maximum values for each of the quality parameters in both the crops were observed when sulphur was applied @ 60 kg/ha followed by 40 kg S/ha and both these doses were significantly superior compared to application of 0 and 20 kg S/ha. Higher doses of sulphur might have resulted increase in cell division leading to improvement in quality parameters.

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Response of linseed (*Linum usitatissimum* L.) varieties to different plant spacing and fertilizer levels

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ABSTRACT

A field experiment was conducted during *rabi* 2016 in Vertisols at Oilseed Research Station, Latur to assess the response of linseed varieties to different plant spacing and fertilizer levels. Number of branches/plant, spread/plant, dry matter accumulation/plant, number of capsules/plant, weight of capsule/plant, number of seeds/capsule, seed yield/plant, test weight, seed yield (kg/ha), harvest index (%) and oil content (%) were significantly higher with linseed variety LSL-93 over variety NL-260. All individual plant characters were higher with plant spacing of 30 cm x 10 cm. The spacing of 30 cm × 5 cm gave significantly higher seed yield over the spacing of 45 cm × 5 cm and 30 cm × 10 cm. The significant response to applied fertilizer was up to 100% recommended dose of fertilizer and this level produced higher seed yield and gross returns.

Keywords: Fertilizer levels, Linseed, Spacing, Varieties

Linseed or flax is one of the important *rabi* oilseed crops. It contains 35 to 45 per cent oil. It is grown either for the oil from the seed or fibre from the stem. Edible linseed oil is used for human consumption and contains α-linolenic acid (ALA) a polyunsaturated fatty acid that has nutritional and health benefits. Apart from ALA, linseed is widely used as nutritional and functional food in the western world due to omega-3 fatty acid. The linseed oil is an important ingredient in the manufacture of paint varnish, printing ink and linoleum. Globally, linseed is cultivated in an area of 22.70 lakh ha with a production of 22.39 lakh tonnes and productivity of 986 kg/ha. In India, it occupies an area of 3.38 lakh ha with a production of 1.47 lakh tonnes and a productivity of 435 kg/ha. The area under linseed in Maharashtra is 39000 ha, with an annual production of 10000 tones and average productivity of 246 kg/ha (Anonymous, 2014).Yield variation in the crop is mostly brought by various agronomic practices. Among these, plant variety, spacing and fertilizer application are important factors contributing for higher production. Various varieties of linseed were released by State Agriculture Universities for getting higher productivity. Recently Oilseed Research Station, Latur has released new linseed variety LSL-93. At closer spacing, number of capsule/plant, number of seeds/capsule, weight of capsule and seed weight/plant decreased and at wider spacing all these traits increased. Therefore, it was felt that it is necessary to find out the optimum plant population for a variety to get higher yield.

Plant nutrition is a key input to increase the productivity. Nitrogen is a structural component of chlorophyll and protein and therefore, adequate supply of nitrogen is beneficial for both carbohydrates and protein metabolism as it promotes cell division and cell enlargement, resulting in more leaf area and thus ensuring better growth and development of plant producing higher seed and dry matter yield. Ahmed *et al.* (1997) reported that the application of phosphorus plays a vital role in the formation and translocation of carbohydrates, root development, crop maturation and resistance to disease pathogens. In view of above considerations, the present investigation was carried out to assess the response of linseed varieties to different plant spacing and fertilizer levels.

MATERIALS AND METHODS

A field experiment was conducted during 2016-17 in *rabi* season at Experimental Farm, Oilseeds Research Station, Latur, Maharashtra. Latur is situated between 180 05' to 180 75' latitude and between 76° 25' to 77° 25' longitude at 540 m above mean sea level. It has sub-tropical climate. The experimental soil was medium black, alkaline in nature (pH 8.0), containing low available nitrogen (189 kg/ha), low available phosphorus (14.8 kg/ha) and high available potassium (588 kg/ha). The experiment was laid out in factorial randomized block design (FRBD) with eighteen treatment combinations consisting of two varieties *viz.,* NL-260 and LSL-93; three plant spacing *viz.,* 30 cm x 5 cm, 45 cm x 5 cm, 30 cm x 10 cm; and three fertilizer levels *viz.,* 50% RDF, 100% RDF and 150% RDF with two replications. The recommended dose of fertilizer (RDF) was 60:30:0 N: P_2O_5: K_2O kg/ha. Half of nitrogen along with full dose of phosphorus was applied at the time of sowing and remaining half dose of nitrogen was applied at 30 days after sowing (DAS). The source of nitrogen and phosphorus was Diammonium Phosphate (DAP) and Urea. Recommended cultural practices were followed. The data recorded were statistically analyzed by using technique of analysis of variance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Growth attributing characters: Growth of linseed varied significantly due to varietal differences (Table 1). Linseed

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variety NL-260 recorded significantly higher plant height over LSL-93 whereas variety LSL-93 produced significantly higher number of branches/plant, mean spread/plant, total dry matter/plant over NL-260. The marked variation in growth could be ascribed to their genetic capabilities to exploit available resources for growth and development. Similar results were reported by Singh *et al.* (2013) and Gokhale *et al.* (2008). Among different plant spacing, the spacing of 30 cm ×10 cm produced significantly higher number of branches/plant and total dry matter than 45 cm × 5 cm and 30 cm × 5 cm plant spacing. It might be due to wider spacing which favored the plant to produce maximum branches, and resulted in more dry matter accumulation/ plant. Similar results were observed by Hassan and Arif (2012). The spacing of 30 cm × 10 cm recorded significantly higher spread and was on par with spacing of 45 cm × 5 cm. Linseed can compensate for low plant stands through extensive branching and increased spread when sown at wider spacing. Similar result was recorded by Gabiana *et al.* (2005). The plant height did not differ significantly due to different plant spacing (Malik *et al.,* 2008).

Perusal of data in Table 1 revealed that among different fertilizer levels application of 150% RDF recorded significantly higher plant height, plant spread and dry matter accumulation/plant over the application of 50% RDF and found at par with application of 100% RDF. Enhanced growth characters could be due to higher level of fertilizers applied and thereby ensuring availability of required nutrients to the growing plants. Similar results were also noticed by Kariuki *et al.* (2014) and Delesa *et al.* (2016). Application of 150% RDF recorded highest number of branches/plant which was significantly superior over application of 100% RDF and 50% RDF. It might be due to the enhanced the number of branches/plant that was seen with application of higher level of fertilizer. These results are in inconformity with the findings of Khajani *et al.* (2012).

Yield attributing character: Yield attributing characters *viz.,* number of capsule/plant, weight of capsule/plant, number of seeds/capsule, seed yield/plant and test weight (g) were also significantly higher with linseed variety LSL-93 over NL-260. Similar results of varietal differences have been reported by Rokade *et al.* (2015). Different plant spacing also influenced the yield attributing characters of linseed significantly due to. The plant spacing of 30 cm × 10 cm recorded significantly higher number of capsule/plant over 30 cm × 5 cm and found at par with spacing of 45 cm × 5 cm. The spacing of 30 cm × 10 cm recorded significantly higher values for weight of capsule/plant and seed yield/plant over rest of the spacing. Number of seeds/capsule and test weight were not influenced significantly by the plant spacing. Similar results have also been reported by Gokhale *et al.* (2008), Chaudhary (2009), Hassan and Arif (2012) and Ali *et al.* (2016).

The yield attributing characters presented in Table 1 revealed that application of 150% RDF produced significantly higher number of capsule/plant, weight of capsule/plant and seed yield/plant over application of 50% RDF and found at par with 100% RDF. The positive response of higher level of fertilizers on yield attributes could be ascribed to overall improvement in crop growth enabling the plant to absorb more nutrients and moisture and more quantities of photosynthates that could accumulate in sink. Similar results were also reported by Malik *et al.* (2008) and Khajani *et al.* (2012). Number of seeds/plant and test weight were not influenced significantly due to fertilizer level. Similar results were also recorded by Gabiana *et al.* (2005).

Seed yield: The data on seed yield (Table 1) revealed that the linseed variety LSL-93 recorded significantly higher seed yield (1036 kg/ha) over the variety NL-260. It might be due to higher yield attributes produced by LSL-93. Similar results were observed by Gokhale *et al.* (2008) and Rokade *et al.* (2015). Among different plant spacing, the spacing of 30 cm × 5 cm produced significantly higher seed yield (1021 kg/ha) over the spacing of 30 cm × 10 cm and 45 cm × 5 cm. This might be due to higher plant population per unit area in closer spacing. Similar result was reported by Ali *et al.* (2016).

Application of 150% RDF produced significantly higher seed yield over 50% RDF and found at par with application of 100% RDF. It might be due to favorable effect of increasing fertilizer levels on yield attributing characters which finally resulted in higher seed yield. Similar results have been reported by Tanwar *et al.* (2011) and Suryavanshi *et al.* (2012).

Harvest index and oil content (%): Harvest index (%) and oil content (%) of linseed were influenced significantly due to varieties (Table 1), the linseed variety LSL-93 recorded significantly higher harvest index (%) and oil content (%) over the variety NL-260. This might be due to better source sink relationship, which favored the maximum accumulation of photosynthates in the seeds of LSL-93. Similar genotypic differences for harvest index have been reported by Maurya *et al.* (2017). The harvest index (%) and oil content (%) of linseed were not influenced significantly by different plant spacing and fertilizer levels.

Gross returns: Linseed variety LSL-93 recorded higher gross returns of (₹ 51805/ha) over the variety NL-260. Among different plant spacing, the closer spacing of 30 cm × 5 cm recorded higher gross returns (₹ 50626/ha) over rest of plant spacing. Application of 150% RDF recorded higher gross returns (₹ 53172/ha) over the application of 50% RDF.

Interaction effects: Interaction effects among varieties, spacing and fertilizer levels for various growth and yield attributes and yield were found to be non-significant.

Table 1 Growth characters, yield and gross returns of linseed as influenced by different treatments

Treatment	Plant height (cm)	Number of branches/ plant	Spread/ plant (cm)	Dry matter (g/plant)	No. of capsules/ plant	Weight of capsule/ plant (g)	No. of seeds/ capsule	Seed yield/ plant (g)	Test weight (g)	Seed yield (kg/ha)	Harvest index (%)	Oil content (%)	Gross returns (₹/ha)
Varieties													
NL-260	55.2	5.1	12.0	11.4	45	3.5	7.6	2.2	6.9	875	34	37.5	43751
LSL-93	38.8	5.4	12.5	12.0	57	4.3	8.6	3.7	8.6	1036	46	39.4	51805
SEm (±)	0.7	0.1	0.2	0.2	1	0.1	0.2	0.1	0.2	17		0.1	
CD (P=0.05)	2.2	0.3	0.5	0.6	4	0.3	0.5	0.2	0.7	50		0.3	
Plant spacing (cm)													
30 x 5	45.8	4.5	11.6	10.9	44	3.4	7.9	2.6	7.5	1021	40	38.5	51026
45 x 5	47.3	5.3	12.4	11.6	53	3.8	8.3	3.0	8.0	901	39	38.5	45041
30 x 10	47.8	5.9	12.7	12.6	56	4.4	8.1	3.4	7.7	945	42	38.5	47267
SEm (±)	0.9	0.1	0.2	0.2	2	0.1	0.2	0.1	0.3	20		0.1	
CD (P=0.05)	NS	0.4	0.6	0.7	5	0.3	NS	0.2	NS	61		NS	
Fertilizer levels													
50% RDF	44.0	4.4	11.5	10.8	41	3.1	8.3	2.4	7.6	794	39	38.6	39710
100% RDF	47.8	5.4	12.3	12.0	55	4.1	7.9	3.2	7.6	1009	41	38.3	50453
150% RDF	49.3	5.9	12.8	12.4	57	4.4	8.1	3.3	8.0	1063	41	38.6	53172
SEm (±)	0.9	0.1	0.2	0.2	2	0.1	0.2	0.1	0.3	20		0.1	
CD (P=0.05)	2.7	0.4	0.6	0.7	5	0.3	NS	0.2	NS	61		NS	
Interactions	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	

From above study, it is concluded that the Linseed variety LSL-93 showed superiority in all growth and yield attributing characters, yield and gross returns. Though the spacing of 30 cm × 10 cm recorded higher growth and yield attributing characters of plant, 30 cm × 5 cm spacing recorded higher yield (kg/ha) and gross returns. The application of 150% RDF recorded higher growth and yield attributes, yield and gross returns, but the application of 100% RDF was found to be most remunerative for getting good returns.

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Impact of frontline demonstration on rapeseed productivity in South-western part of Punjab

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ABSTRACT

Farmers grow non-canola local varieties *viz.,* Reli and Rajasthani of rapeseed with lower seed rate, delayed sowing, low plant population, improper nutrient management and inadequate plant protection in Muktsar Sahib District, Punjab state. Also, the local varieties contain high erucic acid and high glucosinolates, considered to be undesirable to consumers from the health perspective. The Krishi Vigyan Kendra, Sri Muktsar Sahib, Punjab conducted frontline demonstrations (FLDs) during *rabi* 2015-16 to 2017-18 with improved technologies including better variety (GSC 7), optimum seed rate and spacing, line sowing, soil test based nutrient management and need based plant protection to show the productivity potential and profitability under farmers' situations. The mean seed yield improved by 11.7 per cent with higher gross monetary returns, net returns and BC ratio with improved technology compared to farmers' practice during the three year period. The technology gap decreased from 675 kg/ha to 145 kg/ha indicating the sustainability of the improved technology. The extension gap increased from 70 kg/ha to 330 kg/ha, due to higher yields with the improved technology. The technology index decreased from 30.3 to 6.5 per cent indicating the feasibility of the improved technology in farmers' fields. In order to improve the productivity of rapeseed-mustard in Muktsar Sahib district, concerted efforts have to be made involving all the stakeholders to popularize the improved technologies.

Keywords: B:C ratio, Canola, Frontline demonstrations, Oil seed crop, Technology index, Yield

Among conventional rapeseed varieties the presence of erucic acid and glucosinolates is considered undesirable. Erucic acid is feared to cause the human health problems and high glucosinolates in the oil cake are anti-nutritional for animal feed. Hence efforts to develop canola quality (with very low erucic acid and glucosinolates, or conventionally called double zero) varieties, acquire importance in the crop improvement programme of rapeseed-mustard in India. Canola oil contains a desirable profile of saturated fatty acids (7%) and high level of unsaturated fatty oleic acids (about 61%) and medium level of unsaturated fatty linoleic acids (21%) and linoleic acid (11%) (Molazem *et al*., 2013). 'Canola' which is a registered trade mark of Canadian Oil Association denotes the seeds having less than 2 per cent erucic acid in its oil and less than 30 micro moles of glucosinolate per gram of its deoiled meal (Elewa *et al*., 2014). Canola is only a quality standard and not a classification based on biological attributes. Canola cultivars of oilseed rape (*Brassica napus*) have been recently developed by the Punjab Agricultural University, Ludhiana, India. These cultivars have comparable yields with non-canola rapeseed-mustard and are resistant to white rust (Kaur *et al*., 2018). Nutritional and functional properties of oils are determined by their fatty acid composition and the distribution pattern of fatty acids (Crubbens and Denton, 2004; Pham and Pham, 2012). A good percentage of essential fatty acids (linoleic acid and linolenic acid) in rapeseed mustard oil makes it desirable from nutritional point of view, but high amount of erucic acid (40-57%) lowers its utility as edible oil (Ackman *et al*., 1977; Agnihotri *et al*., 2007; Singh *et al*., 2014; Wanasundara, 2011).

In Muktsar Sahib district, Punjab state, farmers grow non-canola local varieties *viz*., Reli and Rajasthani of rapeseed with lower seed rate, delayed sowing, maintain low plant population, improper nutrient management and inadequate plant protection. KVK, Sri Muktsar Sahibhas conducted FLDs to show the productivity potential and profitability of latest, improved technologies of gobhi sarson under irrigated situations *vis-à-vis* farmers' practices.

MATERIALS AND METHODS

The study was carried out in operational area of Krishi Vigyan Kendra, Sri Muktsar Sahib (lie between 30° 69' and 29° 87' latitude and 74° 21' and 74° 86' longitude) located in south-western part of Punjab. During *rabi* 2015-16 and 2016-17, forty FLDs each and during 2017-18 50 FLDs were conducted with improved technologies. Each demonstration plot was laid out in 0.40 ha for comparison with farmers practice plot. Soils from each demonstration were collected and analyzed for pH, EC, OC (%), available P and K. Among all demonstrations, the soil texture was loamy sand to loam. However, the soil was medium in OC and available P and high in available K in the entire demonstration site. The improved technology in the frontline demonstration included introduction of latest canola varieties, recommended package of practices including maintenance of optimum plant population and plant protection measures. During study

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years, sowing was done between middle of October to middle of November with 3.75 kg seed/ha and 45 cm row to row spacing. All N, P, and K were applied according to soil test results. Recommended weed control measure was taken up and irrigation was given according to the requirement of the crop. The crops were harvested at perfect maturity and yield data was collected. Gross returns were estimated based on the prevailing market prices and the yield obtained by the farmers during all the three years. For obtaining input cost, the sum of expenditure on land preparation, planting method, fertilizer, insecticide, fungicide, herbicide, irrigation, labour and harvesting cost, etc. were calculated from each plot. Further, return over variable cost and benefit : cost were calculated from these data. To estimate the technology gap, extension gap and technology index following formulae as used by Samui *et al.* (2000) were used: Technology gap = Potential yield - Demonstration yield, Extension gap = Demonstration Yield - Farmers yield, Technology index = (Technology gap/Potential yield) X 100.

RESULTS AND DISCUSSION

Seed yield: A comparison of yield performance between demonstrated practices and local checks is shown in Table1. It was observed that during 2015-16, improved technology gave higher seed yield (1550 kg/ha) as compared to farmers practice (FP) plot (1480 kg/ha). The increase in the yield over FP plot was 4.73 per cent. Similar results were obtained in 2016-17 and 2017-18 with improved technology. The FLD plot gave 11.45 and 18.86% higher seed yield, during 2016-17 and 2017-18, respectively as compared to FP plots. The FLD plots recorded higher mean seed yield (1849 kg/ha) as compared to FP plot (1650 kg/ha). The average increase in seed yield in IT was 11.68 per cent higher than FP for the three years. Similar yield enhancement in different crops in front line demonstration has been documented by Ajrawat *et al*. (2013).

Technology gap: The technology gap is the difference between the demonstrations yield and potential yield. The major technological gaps were observed regarding recommended varieties, seed rate, time of sowing, fertilizer dose, method of fertilizer application and plant protection measures. The technology gap was recorded 675 kg/ha, 308 kg/ha and 145 kg/ha during 2015-16, 2016-17 and 2017-18, respectively. Technology gap was lower in 2017-18 due to higher yield obtained with demonstration. The average technology gap of mustard was 376 kg/ha (Table 1) during all three years.

Table 1 Yield, technology gap, extension gap and technology Index of rapeseed in Sri Muktsar district

Year	Demonstration		Yield (kg/ha)			% Increase over check	Technology gap (kg/ha)	Extension gap (kg/ha)	Technology index (%)
	Variety	Number	Potential	Demonstration	Farmers' practice				
2015-16	GSC 7	40	2225	1550	1480	4.73	675	70	30.3
2016-17	GSC 7	40	2225	1917	1720	11.45	308	197	13.8
2017-18	GSC 7	50	2225	2080	1750	18.86	145	330	6.5
Total/Mean		130	2225	1849	1650	11.68	376	199	16.87

Extension gap: The extension gap is the difference or gap between the demonstration yield and farmers yield. The average extension gap of all years was found to be 199 kg/ha. During 2015-16 extension gap was 70 kg/ha, during 2016-17 it was 197 kg/ha and in 2017-18 it was 330 kg/ha (Table 1). There is a need to decrease this wider extension gap through implementation of latest techniques.

Technology index: The technology index shows the feasibility of new technology at the farmer's fields and the lower the value of technology index more is the feasibility of the technology. The average technology index was 16.87 per cent in Muktsar district during study period (Table 1). The study concludes that, there is lot of scope for improvement in production and productivity of oil seed crop in Sri Muktsar Sahib District.

Economic return: The economics of gobhi sarson production under frontline demonstration have been presented in Table 2. During the three year period higher average gross return was recorded with demonstration plots (₹ 72874/ha) as compared to FP plots (₹ 62530/ha). During 2015-16 improved technology produced higher gross return (₹ 62000/ha) compared to FP (₹ 59200/ha). Similar results were obtained during 2016-17 and 2017-18 where demonstration gave higher gross return in comparison to FP plot due to higher grain yield obtained. However, the average return over variable cost was also higher under demonstration plots (₹ 45065/ha) as compared to check plot (₹ 34830/ha). Higher net returns among demonstration was due to higher grain yield obtained and lower cost of cultivation as compared to FP plots. Ajrawat *et al*. (2013) and Sandhu and Dhaliwal, (2015) also reported similar results. The benefit: cost ratio during 2015-16 was 1.23:1 in IT plot as compared to FP plot (1.14:1). However, during 2016-17 and 2017-18 demonstration gave higher B:C ratio i.e. 1.67:1 and 1.99:1, respectively. Similarly, average across years indicated that the demonstration plot gave higher (1.63:1) B:C ratio from farmer practices (1.28:1).

Table 2 Return over variable costs and B:C ratio of rapeseed in Sri Muktsar district

Year	Gross Returns (₹)		Cost of cultivation (₹)		Net Returns (₹)		B:C ratio	
	Demonstration	Farmers' practice	Demonstration	Farmers' practice	Demonstration	Farmers' practice	Demonstration	Farmers' practice
2015-16	62000	59200	27800	27625	34200	31575	1.23	1.14
2016-17	73421	63640	27825	27850	45596	35790	1.67	1.37
2017-18	83200	64750	27800	27625	55400	37125	1.99	1.34
Mean	72874	62530	27808	27700	45065	34830	1.63	1.28

The findings of the study revealed that gap exists in yields of FLD plots and FP plots due to technology and extension gaps. The increase in yield of rapeseed to the extent of 11.68 % in FLDs over the farmers practice created greater awareness and motivated other farmers to adopt the improved package of practices of gobhi sarson. The recipient farmers of FLDs also play an important role as source of information and quality seeds for further dissemination of the improved varieties of oilseed crop. Improved technology performed better in terms of yield and economics as compared to farmers' practices. These technologies have to be up scaled by involving all the stakeholders in the district.

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Impact of improved production technology and mechanized decortication of groundnut (*Arachis hypogaea* L.) on productivity and income of farmers in Ramanagara district of Karnataka

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ABSTRACT

The major production constraints in groundnut cultivation in Ramanagara district, Karnataka are low seed replacement, growing old varieties with less productivity and high susceptibility to leaf spots and tikka diseases, lack of awareness on the use of micronutrients and manual decortication leading to drudgery of farm woman. Krishi Vignana Kendra, Ramanagara has conducted FLDs to show the productivity potential and profitability of improved technologies of groundnut and mechanical shelling in farmers' fields. The results revealed that the mean yield increased by 29.1 per cent over farmers' practice in FLD plots. Mechanized power operated shelling decorticator, shelled 62.5 kg/h, at an efficiency of 90.9 per cent. The efficiency was 50 per cent higher than manually peeling, which made the groundnut shelling faster and more thorough in manual operated shelling decorticator. Exclusive shelling performance of power and manual operated decorticator was evaluated. Power operated sheller was efficient than manual operated sheller recording higher shelling efficiency of 77 per cent and less mechanical damage 1.1 per cent over manual operated sheller which recorded 66 and 2.9 per cent, respectively.

Keywords: Extension gap, GKVK-5 variety, Groundnut decorticator, Manual peeling, Mechanization, Technology gap

In India, Gujarat is the leading producer of groundnut (*Arachis hypogaea* L.) contributing 34.83 per cent of total production followed by Rajasthan (15.52 %), Tamil Nadu (12.96%). Andhra Pradesh (11.78%) and Karnataka (7.12%). In Karnataka normal area under groundnut is 5.91 lakh ha, with a production of 4.85 lakh tonnes (NMOOP, 2017). About 70 per cent of the crop is grown in black soil and the remaining in red soils. Ramanagara in Karnataka is one of the major districts, where groundnut is being grown in kharif, rabi and summer seasons. The, normal area under groundnut in Ramanagara is 7373 ha with a production of 4604 tonnes and productivity of 624 kg/ha (https://ramanagara.nic.in/en/district-at-a-glance). The major production constraints in Ramanagara district are low seed replacement, growing old varieties with less productivity and high susceptibility to leaf spots and tikka diseases and lack of awareness on the use of micronutrients among farmers. Among the various micronutrients, sulphur, zinc and boron play a key role in promoting growth, seed yield, oil content and quality of groundnut crop. In order to achieve the required production level of groundnut through higher productivity, in depth analysis of groundnut production methods and adoption pattern of technology is necessary (Hruday Ranjan *et al.,* 2014). The present study was undertaken to assess the impact of improved production technologies of groundnut and mechanized shelling on farm productivity and income of farmers in Ramanagara district of Karnataka during 2016-17 and 2017-18.

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MATERIALS AND METHODS

Krishi Vigyan Kendra, Ramangara conducted frontline demonstrations (FLDs) to show the production potential and profitability of improved technologies of groundnut crop. The improved technologies included high yielding variety GKVK-5, seed treatment with chlorpyriphos @ 15 ml/kg seed followed by bio-fertilizers rhizobium and phosphorus solubilizing bacteria each @ 25gm/kg seed, recommended dose of fertilizers (25:50:25 kg NPK/ha), zinc (10 kg/ha), boron (4.5 kg/ha) and gypsum @ 500 kg/ha and mechanized harvesting. Fifteen FLDs were conducted during 2016-17 and 20 FLDs during 2017-18. Due to erratic rainfall, during 2017-18 10 FLDs were conducted in *kharif* and five each in *rabi* and summer, respectively. The frontline demonstrations were conducted in six adopted villages *viz.,* Basvenahalli, Sri Rampur, Bachenahatti, Gundamanapalya, Gejgarpalya and Motganalli of Magadi taluk, Ramangara district of Karnataka. During two years of study, 35 demonstrations covering an area of 14 hectares with plot sizes varying from 0.4 to 0.2 ha were conducted. Before conducting FLDs, a pre-season training was imparted to the selected farmers regarding different aspects of groundnut cultivation. The demonstrations were conducted in farmers' fields during both the years under irrigated and rainfed conditions. In rabi and summer, the demonstrations were conducted under protected irrigation. In the year 2016-17, the crop was grown under both protected irrigation and rainfed condition. The soils of demonstration plots ranged from medium to high nutrient status, while found deficit of zinc and boron micronutrients.

Farmers practice (FP) of cultivation of local variety samrat (3 seeded pods) was taken as control. Visit of farmers and the extension functionaries was organized at demonstration plots to disseminate the message on a large scale.

Farmers practice included local variety, farmer's method of sowing, weed management and nutrient management. The data were collected from both FLD plots and farmers' practice plots. The extension gap, technology gap, technology index and benefit cost ratio were worked out (Semim *et al.*, 2000). Extension gap is the difference between demonstrated plot yield and farmers practice plot yield. Technology gap is the difference between potential yield and demonstrated plot yield. The technology index shows the feasibility of evolved technology at the farmers' fields.

Technology gap = Potential yield - Demonstration Yield

Extension gap = Demonstration yield - Farmers practice Yield

$$\text{Technology Index} = \frac{\text{Potential Yield - Demonstration yield}}{\text{Pot ential yield}} \times 100$$

Evaluation of shelling performance of different methods of groundnut decortication: One of the major problems in groundnut production in Ramanagara district is the lack of groundnut shelling machines available to farmers increasing the time spent on shelling and drudgery of woman. Farmers in the district normally follow manual shelling of groundnut. Demonstration and evaluation of power operated groundnut decorticator was taken in comparison with manual operated and manual shelling of groundnut pods. The performance of the power operated machine was evaluated in terms of shelling efficiency, material efficiency and mechanical damage (Table 4). Test parameters, such as shelling efficiency (%), material efficiency (%) and mechanical damage (%), as used by Kutte (2001) and Maduako (2006) in evaluating a rice threshing machine, was applied in testing a power operated groundnut decorticator. The test parameters were estimated as follows:

$$\text{Throughput Capacity (kg/hr)} = \frac{Qs}{Tm}$$

$$\text{Shelling efficiency (\%)} = \frac{Qs}{Qt} \times 100$$

$$\text{Material efficiency (\%)} = \frac{Qud}{Qud + Qd} \times 100$$

$$\text{Mechanical damage (\%)} = \frac{Qd}{Qud + Qd} \times 100$$

Where: Qs- Quantity of shelled groundnut pods (kg)
Qt = total weight of shelled and unshelled groundnut pods (kg)
Qud= Quantity of undamaged groundnut seeds (kg)
Qd= Quantity of damaged groundnut seeds (kg)
Tm= Effective time of shelling Tm (min)

RESULTS AND DISCUSSION

The data of frontline demonstration, year-wise (Table 1) and pooled data Table 2 showed that improved technology gave pod yield of 2871.0 kg/ha as compared to farmers practice (2223.5 kg/ha). There percent mean increase in pod yield was 29.1 in demonstration plot (Table 2). According to the previous reports, Malewar *et al.* (1982), Helpyati (2001) and Sumangala (2003), increase in pod yield in groundnut could be achieved by use of micronutrients. The beneficial influence of micronutrients *viz.,* Zn and B could be through activation of various enzymes and basic metabolic rate in plants, facilitated synthesis of nucleic acids and hormones, which in turn enhanced the pod yield due to greater availability of nutrients and photosynthates. Application of zinc enhances the plant growth through increased auxins and better dry matter production. Zinc improved dry matter production though the nodulation and N fixation by enhanced root growth and by activation of several enzyme systems and auxins. Whereas, boron influenced the nitrogen and carbohydrate metabolism of plants which might have contributed for the better plant growth. Application of gypsum during second intercultivation (40 DAS) has helped in improving peg formation and peg penetration thereby increasing pod formation. Gypsum being source of sulphur is known to play an important role in increasing oil content in oil seed crops thus leveraging in increasing the pod weight. Our results clearly indicated that improved technologies did have a positive impact on the yield enhancement.

The extension gap observed during different years worked out to average of 648 kg/ha (Table 3). The highest extension gap 650 kg/ha was recorded in 2016-17. Higher extension gap emphasizes that there is a need to educate farmers for adoption of improved production technologies through various extension methods such as method demonstrations on seed treatment with chlorpyriphos for control of root grub, bio-fertilizers application through seed treatment to increase availability of nutrients to the plants, line sowing with proper seed rate to facilitate proper crop stand as well as intercultivation practices, application of fertilizers based on soil test results. Subsequently these technologies may replace the conventional practices, thus reversing the trend of wide extension gap. The observed average technology gap for two years where FLD was implemented was 129 kg/ha. Lower the value of the technology gap more is the feasibility of the technologies which could be easily adopted by the farmers as they are user friendly and more acceptable by the farming community. Similar results were reported by Sonwane *et al.* (2016).

Lower the value of technology index (2.7%) more is the practicability of the technology, where farmers could easily adopt at field level. The technology index varied from 2.7 to 5.6 per cent (Table 3). As such fluctuation in technology index (ranging from 2.7 to 5.6 %) during the study period in certain locations may be attributed to the dissimilarities in soil fertility status, weather conditions, improper intercultural operations, pest and diseases management practices etc. In the study area the technology gap was high 5.6 per cent during 2017-18 compared to 2.7 per cent in the year 2016-17, this is because during the 2017-18 year, as indicated earlier, there was erratic rainfall pattern and hence the demonstrations were taken in all the three seasons (*kharif, rabi* and summer).

The economics of groundnut crop under frontline demonstration have been presented in Table 2. The results of economic analysis application of zinc (10 kg/ha) and boron (4.5 kg/ha) along with the recommended dose of Fertilizer (25:50:25 kg NPK/ha) and Rhizobium 40 g/kg of seed as seed treatment in demo plot revealed that the average gross expenditure of ₹ 41763.00 per ha, was higher than the farmer's practices ₹ 39065.30 per ha, by about 6.90 per cent. The increase in gross expenditure in demo plot was due to the additional expenditure incurred on the inputs such as high yielding variety, seed treatment, application of gypsum and recommended dosage of fertilizers which are directly related to the farmer's income and sustainable groundnut productivity. These measures are necessary to enhance the productivity as well as income of the farmers and also supply of better groundnut for the benefit of consumers. Similar study was reported by Ashok Kumar *et al.* (2014). Thus, frontline demonstrations recorded higher average gross returns (₹ 1, 57,808/ha) and average net return (₹ 1,16,116/ha). Benefit cost ratio of demonstration plot (3.7) was also more than that of the farmer's practices (3.1).

Evaluation of shelling efficiency by different methods of decortication: To work out the decorticating capacity by manual method, the average out-turn of five farm woman was estimated. It was found that on an average one person can decorticate 2 to 4 kg of groundnut per hour. The percent damage of seeds in manual decorticating is 1.73 per cent. The results are in line with Darshan Gowda *et al.* (2018). The out-turn from this method was very less and could not satisfy the market demand as it was a time consuming process.

Manual or hand operated groundnut decorticator: The time taken to decorticate same quantity (2 to 4 kg) of groundnut by manual operated decorticator machine was 30 minutes. The percent damage of seeds was 3.55%, which was relatively higher than manual peeling (1.73 %). This clearly showed that it is more advantageous to peel groundnut seeds using manual operated decorticator than only with bare hand (Table 5).

Power operated groundnut decorticator: The results of the performance of power operated groundnut decorticator indicated that the shelling efficiency was 90.9 ± 2.5 per cent on the average. The material efficiency of the sheller was found to be 89.2 ± 2.1 on an average for two varieties of groundnut demonstrated in an average of 15 farmer's field. Judging by the fact that its material efficiencies of 89.2 ± 2.1, the shelling machine was consistent in the quality of shelled groundnut seeds,.The quality of its material handling and the final product (groundnut seeds) was consistent irrespective of groundnut variety.

Table 1 Performance on growth and yield of groundnut under improved cultivation practices under FLD programme in Ramanagara District of Karnataka

Parameters	Farmers' practice Samrat variety		Improved technology GKVK-5 variety	
	2016-17	2017-18	2016-17	2017-18
Plant height (cm)	36.7	35.9	30.7	30.8
Number of branches/plant	7	7	10	10
Number of pods/plant	68	68	84	84
Number of seeds/pod	3	3	2	2
Late leaf spot scoring (%)	0.8	0.8	0.2	0.2
Seed yield (kg/ha)	2260	2187	2910	2832
Increase over check (%)	-	-	28.8	29.4
Gross cost (₹/ha)	38977	39154	42087	41439
Gross return (₹/ha)	124300	120300	159866	155750
Net returns (₹/ha)	85322.8	81146	117792	114440
B:C ratio	3.2	3.08	3.8	3.77

Table 2 Mean performance on growth and yield of groundnut under improved cultivation practices

Parameters	Average of two years (2016-17 and 2017-18)	
	Farmers practice (Samrat)	Improved technology (GKVK-5)
Number of Demonstrations	15	20
Villages covered	6	6
Area covered (acres)	15	20
Plant height (cm)	36.7	30.7
Number of branches/plant	7	10
Number of pods/plant	68	84
Number of seeds/pod	3	2
Late leaf spot scoring (%)	0.8	0.2
Seed yield (kg/ha)	2223	2871
Mean Increase over check (%)	-	29.1
Gross cost (₹./ha)	39065	41763
Gross return (₹/ha)	122300	157808
Net returns (₹/ha)	83234.4	116116
B:C ratio	3.1	3.8

IT = Variety GKVK-5, RDF: 25:50:25 kg NPK/ha, Seed treatment: Chlorpyriphos 15 ml/kg seed followed by double the amount of biofertilizers Rhizobium (80g/kg of seed), Zinc - 10 kg/ha, Boron - 4.5 kg/ha, Gypsum - 500 kg/ha, mechanical decortication

Table 3 Technology gap, extension gap and technology index in groundnut cultivation

Year	Potential yield (kg/ha)	Average seed yield (kg/ha)		Increase in yield over farmers practice	Extension gap (kg/ha)	Technology gap (kg/ha)	Technology Index (%)
		Improved technology	Farmers practice				
2016-17	3000	2910	2260	28.7	650	90	2.79
2017-18	3000	2832	2187	29.4	645	168	5.6
Mean	3000	2871	2223	29.1	648	129	4.3

Table 4 Test parameters (averaged of five performances) of the power operated groundnut shelling machine

Parameters	Power operated Groundnut decorticator
Weight of total groundnut pods fed into the hopper - Qt (kg)	0.55
Weight of shelled groundnut seeds –Ws (kg)- Qs (kg)	0.37
Weight of groundnut husk removed Wh (kg)	0.13
Weight of unshelled groundnut pods, Wu (kg)	0.05
Weight of undamaged groundnut seeds, Qud- (Kg)	0.33
Weight of damaged groundnut seeds, Qd (kg)	0.04
Effective Time of shelling Tm (min.)	0.50
Throughput capacity (kg/hr)	60.0 kg/hr
Mechanical damage (%)	10.8 ± 2.0
Shelling efficiency (%)	90.9 ± 2.5
Material efficiency (%)	89.2 ± 2.1

Note =Ws +Wh; Qt =Ws + Wh + Wu; Ws= Qu + Qd; Qs- Quantity of shelled groundnut pods (kg)- (Ws +Wh); Qt = total weight of shelled and unshelled groundnut pods (kg)- (Ws + Wh + Wu,) ; Qud= Quantity of undamaged groundnut seeds (kg); Qd= Quantity of damaged groundnut seeds (kg).

Table 5 Evaluation of manual verses mechanized groundnut peeling

Particulars	Manual Peeling	Manual / hand operated decorticator	Power operated decorticator
Quantity of groundnut seeds	2 to 4 kg	2 to 4 kg	60 kg
Time taken to peel/shell	1h	30 minutes	1 h
Percent damage of seeds	1.73	3.55	10.8 + 2

Mechanical damage: On an average, the mechanical damage of the seeds was found to be 10.8 ± 2.0 (Table 4). Mechanized shelling at the rate of 60 kg/h obtainable with this machine and at an efficiency of 90.9 per cent will make the groundnut shelling operation faster and more thorough than manual shelling. Also, the material efficiency of 89.2 per cent with only a little damage of 10.8 per cent ensures a neat operation and high quality product. The sheller is operated with a 5.0 hp petrol engine, it can be used in rural areas where there is no electricity supply, but in urban areas, when there is electricity supply, the engine can be replaced with a 5.0 hp electric motor for the shelling operation. The efficiency of the machine is 40 % higher than manual peeling.

In conclusion. the demonstrations have clearly indicated the potential of the technology package as compared to farmers' practices. Farmers realized higher profits as compared to their existing practices. Hence, the technology has to be widely disseminated among larger groups by forging necessary partnerships with agricultural department and other stakeholders. Comparison of manual decortication with mechanical (manual operated and power operated) decortications of groundnut pods indicated less damage to groundnut kernels, higher efficiency of power operated machine followed by manual operated and manual decortication. Farmers were highly convinced with the technology package and the same has spread to the farmers of 20 villages in the neighboring taluks and districts over an area of 500 acres.

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Boosting sesame production through frontline demonstrations under rainfed conditions in Pali district of Rajasthan, India

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ABSTRACT

Sesame is an important *kharif* oilseed crop of India. It occupies about 3.6 per cent of area and 10.8 per cent of production of the total oilseeds production in India. Frontline demonstrations on sesame variety RT 351 were conducted at farmers' fields in district Pali, Rajasthan during *kharif* 2014-15 to 2018-19. The yield data indicated 36.7 per cent higher mean seed yield in demonstration plots as compared to farmers' traditional practices. The extension gap, technology gap and technology index were 200 kg/ha, 330 kg/ha and 31.4 per cent, respectively. Additional investments of ₹1320/ha coupled with scientific monitoring of demonstrations and non-monetary factors resulted in additional returns of ₹ 9459/ha. Fluctuating MSP sale price of sesame during different years influenced the economic returns per unit area. The mean benefit cost ratio over the five year period was 2.1 in demonstration plots and 1.4 in farmers' practice plots.

Keywords: Economics, Demonstration, Gap analysis, Seed yields, Sesame

Sesame (*Sesamum indicum* L.) is one of the earliest domesticated crops of India. It occupies about 3.6 per cent of area and 10.8 per cent of production of the total oilseeds production in India. Its area, production and productivity in the country is 13.9 lakh hectare, 41.8 lakh tonnes and 291 kg/ha, respectively (Anonymous, 2018). In Rajasthan state, the total area under sesame cultivation is 2.72 lakh hectares with an estimated production of 0.73 lakh tonnes and average productivity of 270 kg/ha (Anonymous, 2018).

The productivity of sesame is low in the country due to several biotic and abiotic stresses afflicting the crop, besides unavailability of quality seeds of improved varieties in time, poor crop management practices due to lack of awareness and non-adoption of recommended production and plant protection technologies. Therefore, it is very essential to demonstrate the productivity potential of high yielding varieties resistant to biotic and abiotic stresses and other production technologies. Further, wide gap exists in oilseeds *per se* and sesame in particular between the available technologies its actual application by the farmers in their fields. There is a tremendous opportunity for increasing the production and productivity of sesame crop by adopting the improved technologies. Many technologies have been generated by National Agricultural Research and Education System (NARES) but the transfer of these technologies to farmers is very low and hence low productivity of sesame.

In order to bridge the yield gaps and achieve additional production of oilseeds, sesame is one of the potential crop. Therefore, it is necessary to concentrate efforts on popularizing the scientific cultivation of sesame. In Pali district of Rajasthan, sesame is cultivated in an area of 0.62 lakh ha with a productivity of 307 kg/ha. Even though, the productivity of sesame in the district is above national average, tremendous scope exists to further increase the productivity. In order to demonstrate the productivity potential and profitability of improved technologies of sesame, frontline demonstrations were conducted by the KVK, Pali during *kharif* 2014-15 to 2018-19.

MATERIALS AND METHODS

The soils of the district is generally sandy loam in texture which is low in nitrogen, low to medium in phosphorus and medium to high in potash. Each demonstration was conducted over an area of an acre with recommended package of practices (improved variety: RT 346, recommended dose of fertilizers, use of bio fertilizers and need based plant protection) and the farmers' practice included local variety. A total of 180 demonstrations were conducted during the five year period. Sowing was done during first week of July to last week of July under rainfed conditions and harvested during first fortnight of October. The demonstrations on farmers' fields were regularly monitored by Scientists of Krishi Vigyan Kendra, CAZRI, Pali right from sowing to harvesting. The seed yield in demonstration plots and farmers practice plots were recorded and analyzed. Different parameters as suggested by Yadav *et al*. (2004) were used for calculating gap analysis, costs and returns as follows:

Extension gap (kg/ha) = Demonstration yield - Farmers practice yield

Effective gain (Rs/ha) = Additional return - Additional cost

Technology gap (kg/ha) = Potential yield - Demonstration yield

Additional return (Rs/ha) = IT Monetary returns - Farmers' practice monetary returns

B: C ratio = Gross monetary returns/Cost of cultivation

Technology index (%) = ((Potential yield - Demonstration yield) × 100)/Potential yield

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RESULTS AND DISCUSSION

Seed yield: The increase in seed yield under demonstration was 28.6 to 43.7 per cent as compared to farmers' local practices. On the basis of five years, 36.7 per cent yield advantage was recorded in demonstration plots with improved cultivation technology as compared to farmers' traditional way of sesame cultivation (Table 1).

Gap analysis: Extension gap between demonstration plot and farmer practice plot ranged from 160 to 220 kg/ha with a mean of 200 kg/ha over the five year period (Table 1). The extension gap was lowest (160 kg/ha) during 2014-15 and was highest (220 kg/ha) during 2017-18 and 2018-19. Such gap might be attributed to adoption of improved technology in demonstrations which resulted in higher seed yield than the farmers' traditional practices. Wide technology gaps were observed during different years and this was lowest (260 kg/ha) during 2018-19 and highest (360 kg/ha) during 2015-16 with mean technology gap of 330 kg/ha over a period of five years. The difference in technology gap during different years could be due to more feasibility of recommended technologies during different years. Similarly, the technology index for all the demonstrations during different years were in accordance with technology gap. Higher technology index reflected the inadequate proven technology for transferring to farmers and insufficient extension services for transfer of technology. The findings confirm with the findings of Dayanand *et al.* (2012), Naik *et al.* (2018), Singh *et al.* (2016) and Yadav *et al.* (2016).

Economic analysis: Various critical inputs such as quality seed, fertilizers, bio-fertilizers and pesticides were considered as cash inputs for the demonstrations as well as farmers practice and on an average an additional investment of ₹ 1320/ha was made under demonstrations. Economic returns as a function of seed yield and MSP sale price varied during different years. Maximum additional returns (₹ 13706/ha) during the year 2018-19 was obtained due to higher seed yield and higher MSP. The higher additional returns and effective gain obtained under demonstrations could be due to improved technology, non-monetary factors, timely operations of crop cultivation and scientific monitoring. The B:C ratio was high in IT plots as compared to FP plots in all the years indicating the profitability of the technology (Table 2). The B:C ratio varied over the years based on the seed yield and MSP of sesame. Overall, mean B:C ratio was 2.1 in IT plots as compared to 1.4 in FP plots. Highest BC ratio of 2.4 was recorded during 2018-19 in IT plot as compared to 1.9 in FP plot. The results confirm the findings by Yadav *et al.* (2004), Lathwal (2010), Meena *et al.* (2018), Singh *et al.* (2018), Meena and Dudi (2018), Singh and Meena (2017) and Singh *et al.* (2016) on oilseeds and pulses.

Table 1 Seed yield and gap analysis of frontline demonstrations on sesame at farmers' field

Years	No. of FLDs	Variety	Potential yield (kg/ha)	IT yield (kg/ha)	FP yield (kg/ha)	Increase over FP yield (%)	EG (kg/ha)	TG (kg/ha)	TI (%)
2014-15	30	RT 351	1050	650	490	32.7	160	400	38.1
2015-16	30	RT 351	1050	690	480	43.7	210	360	34.3
2016-17	40	RT 351	1050	700	500	28.6	200	350	33.3
2017-18	40	RT 351	1050	770	550	40.0	220	280	26.7
2018-19	40	RT 351	1050	790	570	38.6	220	260	24.8
Total/mean	180	-	1050	720	520	36.7	200	330	31.4

FLD = Frontline demonstration; IT = Improved technology; FP = Farmers' practice; EG= Extension gap; TG= Technology gap; TI= Technology Index

Table 2 Profitability of improved technologies under frontline demonstrations on sesame at farmers' field

Years	Cost of cultivation (₹/ha)		Additional cost in IT (₹/ ha)	Sale price (MSP) of seed (₹/q)	Gross returns (₹/ha)		Additional return in Demo. (₹/ha)	Effective gain (₹/ha)	B:C Ratio	
	IT	FP			IT	FP			IT	FP
2014-15	14700	13200	1500	4600	29900	22540	7360	6160	2.0	1.7
2015-16	16100	14800	1300	4700	32430	22560	9870	8820	2.0	1.5
2016-17	17000	16200	800	5000	35000	25000	10000	8840	2.1	1.5
2017-18	19500	18100	1400	5300	40810	34450	6360	5050	2.1	1.9
2018-19	20200	18600	1600	6230	49217	35511	13706	12726	2.4	1.9
Mean	3836	2696	1320	5166	37471	28012	9459	8319	2.1	1.4

IP= Improved technology; FP= Farmers practice; BCR= Benefit cost ratio

The frontline demonstrations have shown the productivity potential and profitability of improved technologies of sesame in farmers' fields. In order to upscale the adoption of technologies by large number of farmers, necessary partnerships are to be forged with the stakeholders such as agricultural department, farmers and processors. Apart from yield advantage, conducting demonstrations in farmers' fields improved the relationship between farmers and scientists and built confidence as well as rapport between them. The farmers involved demonstration acted also as primary source of information on the improved practices of sesame cultivation and also acted as source of good quality seed in their locality and surrounding area.

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Safflower as an alternate crop to chickpea under rainfed black soils of Prakasam district of Andhra Pradesh

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ABSTRACT

Chickpea is a major *rabi* season crop in Prakasam district of Andhra Pradesh but suffers from moisture stress if there is less (<350 mm) rainfall during crop growth. Safflower (*Carthamus tinctorius* L.), commonly known as kardi is one of the important *rabi* oilseed crops of the country and is expected to withstand moisture stress better with a requirement of around 250 mm rainfall. Earlier study had indicated that safflower could be an alternative crop to chickpea in Prakasam district. Under the present investigation, on-farm-trials were conducted with farmers to compare the performance of safflower improved varieties against the chickpea local variety. Two year study has indicated that safflower could be an alternate crop to chickpea in the rainfed black soils of Prakasam district. Therefore, safflower can play an important role in crop diversification in low rainfall areas and in areas like Prakasam district where *rabi* crops suffer from terminal moisture stress.

Keywords: Andhra Pradesh, Chickpea, Safflower, Performance, Rainfed

Chickpea (*Cicer arietinum* L.) is an important pulse legume cultivated and consumed across the world. India is the largest producer and consumer of chickpea in the world (Basha *et al.,* 2018). Chickpea is a major *rabi* crop grown in around 4.0-5.0 lakh ha area in Andhra Pradesh and Prakasam district is one of the important districts where chickpea is the major *rabi* crop. In Prakasam district, during 2018-19 chickpea was grown in an area of 1.09 lakh ha with a production and productivity of 0.74 lakh tonnes and 682 kg/ha, respectively. Locally farmers grow local variety JG 11, which is susceptible to wilt and moisture stress. As Prakasam district is a drought prone area, *rabi* crops suffer with terminal moisture stress which leads to reduction in yields and returns. Chickpea needs about 350-500 mm of rainfall for yielding better and therefore, in the years of deficit rainfall the crop can suffer a high yield loss with improperly filled seeds. Gopalappa (1996), based on his study in Andhra Pradesh, reported that there was scope to increase income through crop diversification. Safflower (*Carthamus tinctorius* L.), commonly known as kardi is one of the important *rabi* oilseed crops of the country (Alivelu *et al.,* 2016). Safflower (*Carthamus tinctorius* L.), a multipurpose crop, has been grown for centuries in India for the orange-red dye (carthamin) extracted from its brilliantly coloured flowers and for its quality oil rich in polyunsaturated fatty acids (78% linoleic acid) (Singh *et al.,* 2013). Keeping this in view, safflower which is hardy and tolerant to water stress conditions was introduced in Prakasam district to assess the performance of safflower over chickpea local variety under rainfed black soils.

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MATERIALS AND METHODS

On farm trial was conducted at Bodhanampadu (Kurichedu mandal, 2017-18), J. Pangaluru (J. Pangaluru mandal, 2018-19) in 2.0 ha (5 farmers' fields) each year during winter season. Farmers were provided with improved varieties of safflower (4 kg to each farmer) during each year and compared with chickpea local variety (JG 11). Average rainfall received during 2017-18 and 2018-19 was 27.8 mm and 27.7 mm, respectively with per cent deficit of 85.9 and 61.5, respectively. Soil type was black. Bodhanampadu is located at 15.90°N latitude and 79.57°E longitude. J. Pangaluru is located at12.860 N latitude and 74.840E longitude.

Plant material: The salient features of the varieties used in the present study are presented in Table 1.

Treatments:

2017-18:

T_1: Safflower improved varieties (Manjira, PBNS 12)
T_2: Chickpea (JG 11)

On farm trials were conducted with 5 farmers for each variety

2018-19:

T_1: Safflower improved variety (TSF 1) - Variety was changed as PBNS 12 is from Maharashtra and Manjira is a low yielder and we wanted to test the variety bred for local climatic conditions (either from Andhra Pradesh or Telangana).

T_2: Chickpea (JG 11)

Data recorded: During the crop season data was recorded on five characters *viz.,* plant height (cm), number of branches/plant, number of capitula/plant, number of seeds/capitula and 100 seed weight (g)

Economics: Cost of cultivation (₹/ha) was calculated considering the prevailing charges of agricultural operations and market price of inputs involved. Gross returns were obtained by converting the harvest into monetary terms at the prevailing market rate during the course of studies.

Gross return (₹/ha) = (Seed yield x price)

Net returns were obtained by deducting cost of cultivation from gross return

Net returns (₹/ha) = Gross return (₹/ha) - Cost of cultivation (₹/ha)

The benefit: cost ratio was calculated by dividing gross returns by cost of cultivation

$$\text{Benefit: Cost ratio} = \frac{\text{Gross returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

RESULTS AND DISCUSSION

Data pertaining to the yield attributes are presented in Table 2 and perusal of the data indicated that higher plant height, number of branches/plant, number of capitula per plant, number of seeds/capitula and 100 seed weight were recorded in PBNS 12.

Yield: Data presented in Table 2 show that the (equivalent) yield of safflower was higher compared to chickpea except in case of Manjira during 2017-2018. Chickpea equivalent yield was higher in PBNS 12 (940 kg/ha) followed by TSF 1 (800 kg/ha). Manjira variety recorded less yield compared to chickpea. Per cent increase in yield over control in PBNS 12 was 38.2 %. Whereas, in TSF 1 it was 17.6 per cent over chickpea JG 11. Higher yield in PBNS 12 was due to more number of branches/plant, capitula/plant, number of seeds/capitula and higher test weight. Similar results have been reported by Basha *et al*. (2018).

Lower yields in chickpea during 2017-18 and 2018-19 were due to failure of North-East monsoon during the period under study. Average rainfall received during North-East monsoon of 2017-18 and 2018-19 was 27.8 mm and 27.7 mm, respectively with per cent deficit of 85.9 and 61.5, respectively.Water requirement for chickpea is 350-500 mm whereas, safflower can be grown without irrigation. But for good yields water required is 250-300 mm. Under moisture stress conditions crop growth, number of flowers, pods and seed size were reduced in chickpea.

Economics: Data presented in Table 3 reveal that cost of cultivation was less for safflower as there were less pest and disease incidence during the period under study and plant protection measures were not taken. Gross returns, net returns and C: B ratios were higher in safflower compared to chickpea (Table 4). Among improved varieties higher gross returns were recorded in PBNS 12 with 39600 ₹/ha with net returns of 22100 ₹/ha and C: B ratio of 2.3 followed by TSF 1 with gross returns, net returns and C: B ratio of 33750, 16250 ₹/ha and 1.9, respectively. Due to failure of monsoon, chickpea farmers obtained negative returns but farmers who had grown safflower obtained 1.5-2.3 rupees income per rupee invested. Higher net returns and C: B ratio was due to higher yield and less cost of cultivation.

Chickpea equivalent yield was higher in PBNS 12 followed by TSF 1. It has been concluded that safflower can be one of the alternate crops to chickpea in the rainfed black soils of Prakasam district. Safflower can be a good alternate/replacement crop for chickpea under moisture stress situations in black soils of the district. It can play an important role in crop diversification in low rainfall areas and areas where rabi crops suffer from terminal moisture stress in Prakasam district.

Table 1 Salient features of improved varieties of safflower and local variety of chickpea

Crop/Variety	Duration (days)	Yield (q/ac)	Characteristics
Safflower			
Manjira	115-120	3-4	Yellow to orange coloured flower with white colour seed. Contains 27-30% oil.
PBNS 12	130	7.0	Suitable under irrigated conditions. Contains 30% oil.
TSF 1	135	7.0	White flowered variety with 28-30% oil. Highly tolerant wilt and leaf spot. Moderately tolerant to aphids.
Chickpea (JG 11)	90-95	7-8	Tolerant to Fusarium wilt

Table 2 Yield parameters and yield of improved varieties of safflower and local variety of chickpea

Particulars	Safflower (Manjira)	Safflower (PBNS 12)	Safflower (TSF 1)	Chickpea (JG 11)
Plant height (cm)	64.3	85.1	84.2	34.3
No. of branches/plant	13.0	16.4	15.6	14.2
No. of capitula/plant	21.5	26.0	25.0	33.4 (pods/plant)
Seeds/capitula	30.0	35.5	35.0	1-2 (seeds/pod)
100 seed weight (g)	4.6	4.7	4.6	23.7
Yield (kg/ha)	590	880	750	680
Chickpea equivalent yield (kg/ha)	630	940	800	
Per cent increase in yield over control	-7.3	38.2	17.6	

Table 3 Yield of improved varieties of safflower and local variety of chickpea

Crop/Variety	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C ratio
Safflower (Manjira)	17500	26500	9000	1.5
Safflower (PBNS 12)	17500	39600	22100	2.3
Safflower (TSF 1)	17500	33750	16250	1.9
Chickpea (JG 11)	37500	28560	-8940	0.8

Prevailing market price of safflower: ₹4500/q, chickpea: ₹4200/q

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Influence of environment on quality hybrid seed production in castor : A case study of participatory seed production

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ABSTRACT

This paper highlights the observations made regarding the influence of environmental factors on genetic purity of hybrid seed produced during the participatory seed production of two castor hybrids *viz.,* DCH 177 (DPC 9 x DCS 9) and DCH-519 (M 574 x DCS 78) in two villages of Mahabubnagar district, Telangana. Preliminary observations indicated that development of environmentally sensitive interspersed staminate flowers (ISF) on pistillate lines was influenced by their genetic nature, soil and agronomic management of crop as well as weather parameters. Higher incidence of ISF was observed in shallow and red soils irrigated by furrow method compared to medium/deep, clay loamy and black soils irrigated and fertigated by drip method, leading to higher number of selfed female plants, low genetic purity of certified hybrid seed (<85%) and rejection of seed lots during certification. Abiotic stress factors like maximum temperature (>32°C temperature) increased the number of ISF in primary spike order itself and later decreased in subsequent spike orders owing to decreased temperatures. Incidence of whiteflies and *Spodoptera* was particularly high in intensively cultivated agro-ecosystems. Small and marginal farmers depending on family labour were better suited for hybrid seed production of castor. Selection of suitable agro-ecosystem, farmers and their training, and genetic nature of parents proved to be critical requirements for hybrid seed production in castor.

Keywords: Castor, Genetic purity, Hybrid seed quality, Interspersed staminate flowers (ISF), Temperature

Castor (*Rcinus communis* L.) is an important commercial, industrial and non-edible oilseed crop suitable for both rainfed and irrigated cultivation in tropical and sub-tropical climatic conditions. Castor, a monotypic genus, with the chromosome number of 2n=20 and belongs to family Euphorbiaceae (Moshkin, 1986; Weiss, 2000). World's first castor hybrid, GCH-3, based on exotic line TSP 10 R crossed with JI 15 inbred as male, was released in 1968 at Oilseeds Research Station, Junagadh, Gujarat, India (Lavanya *et al*., 2019). Among the 22 hybrids released through active collaboration between ICAR-IIOR and State Agricultural Universities (SAUs), GCH-7, GCH-4, GAUCH-1, GCH-2, DCH-177, DCH-519, PCH-111 and YRCH-1 are prominent for their seed yield and wilt resistance (Lavanya *et al*., 2019).

Castor was cultivated in an area of 9.7 lakh hectare with a production of 16.6 lakh tonnes and 1720 kg/ha productivity (Ministry of Agriculture and Farmers Welfare, 2017-18). Major area was in Gujarat (5.9 lakh ha/72%) followed by Rajasthan (1.3 lakh ha/15.9%) and in Andhra Pradesh and Telangana together (0.58 lakh ha/7%) during the year 2017-18.

Castor is a sexually polymorphic species having multiple sex forms *viz.,* monoecious form- the plant type with female flowers at the top and staminate or male flowers at the bottom of the inflorescence; the pistillate from - plant having pistillate flowers all along the main axis of raceme with or without staminate flowers (ISF), though, with varying intensity depending on the genetic nature, order of spike, age of the plant and other environmental conditions; and revertants (Shifriss,1960; Lavanya and Solanki, 2010). The proportion of female flowers is usually high in winter months (with monthly mean temperature 29-32°C) in plants having pistillate genetic nature, when the other abiotic factors like temperature, nutrition, etc., are optimum, while the same pistillate plants tend to produce racemes with higher ISF or rarely, monoecious in summer months at >32°C and due to increased abiotic stresses (Hegde *et al.,* 2003; Lavanya, 2002). This temperature influenced nature of ISF production is utilized in hybrid seed production of castor (Lavanya *et al.,* 2006). Under this scheme, the hybrid seed production is taken up in winter months (as no ISF are produced in pistillate lines) while the maintenance of pistillate lines (ISF produced during this season can effect self-pollination of the plant) is taken up during summer. Hybrid seed production in castor is complicated due to the influence of weather parameters like temperature, humidity, soil moisture, nutrition, etc., on sex expression (Prabakaran *et al.,* 2009; Lavanya *et al.,* 2006). Any aberration in weather parameters leads to development of environmentally sensitive ISF which need to be manually removed before pollen dehiscence. Any laxity in removal of off-types or manual removal of ISF lead to selfing of female plants and ultimately rejection of seed lots due to low genetic purity (<85%). In participatory hybrid castor seed production, despite imparting skills, several other abiotic factors like soil type, soil depth, method of irrigation, etc. play a key role in quality seed production. Observations made during the participatory hybrid seed production of DCH-177 and DCH-519 in two villages of Mahabubnagar district, Telangana during 2015-16 *rabi* season, are summarized in this communication with an aim that these remarks could be considered while taking up similar programmes in future to improve the quality of seeds produced. However, the preliminary observations made in the present study require further studies for confirmation.

Participatory hybrid seed production of DCH 177 (DPC 9 x DCS 9) and DCH-519 (M 574 x DCS 78) was taken up in 42 acres in two villages; Doddigadda Tanda, Krishna Nagar, a tribal village near Shadnagar and Konkal near Shantinagar, Mahabubnagar district of Telangana state during September to February, 2015-16. Optimum dates of sowing (September 14 to October 14, 2015) were followed by all the farmers in both the villages in different soil types (Table 1 and Table 2). Most of the soils had loamy or clay texture with good fertility, drainage and nutrient availability. There were eight spells (3 to 25 mm) of rainfall from September 14 to October 14, 2015. All the seed production plots were visited regularly at 10-12 days interval from the time of farmer and land selection (August 15, 2015) to final harvesting (February 15, 2016). Data on number of ISF in different orders of the female parents was recorded by observing at least 10 random plants for each order of spikes in all the seed production plots. Weather data during September, 2015 to January, 2016 were collected from online sources (www.worldweatheronline.com). Temperatures recorded at Kurnool city were considered as it was nearly 20 km (aerial distance) away from the seed production plots in Konkal village (Table 3).

Pick-wise hybrid seed was harvested separately at maturity from the female lines, DPC-9 and M-574 in all the plots, threshed and weighed separately. Pick wise grow out test (GoT) was conducted to estimate the genetic purity as per the standards of seed technology (Ramachandram and Ranga Rao, 1988; DOR, 2009). Details of size of farmer holding, soil type, irrigation method, pick-wise yield and purity of seed in DCH-177 and DCH-519 hybrids is provided in the Table 1 and Table 2, respectively.

Best management practices indicate that deep loamy, fertile, neutral and well drained soils were best suited for hybrid seed production in castor (Ramachandram and Ranga Rao, 1988; DOR, 2009; Raghavaiah and Suresh, 2010). Castor crop cannot tolerate alkalinity but can withstand slight to moderate acidity of soil (Raghavaiah and Suresh, 2010). Our observations indicated that pistillate lines were more sensitive to problematic soils than male parents. Plant vigour and growth of both the parents was affected in shallow soils leading to higher number of ISF under nutrient and soil moisture stress (farmer 7 in Table 1).

In hybrid seed production plots, DPC-9, the female parent of DCH-177, was earlier in flowering (45-57 DAS) compared to M-574 (69 DAS), the female parent of DCH-519. Flowering in seed production plots of DCH-177 sown on September 14, 2015 in black soil near Konkal village and on September 22, 2015 in red sandy loam soil near Shadnagar, Mahabubnagar district indicated that flowering was earlier in red sandy loam (45 DAS) soils compared to that in black soils (57 DAS) though both the places received almost the same rainfall during the season.

Preliminary observations on the source of irrigation supply indicated that development of environmentally sensitive ISF was lower (<5 / spike) in female parents in drip irrigated and fertigated crop due to supply of optimum moisture and frequent supply of nitrogen, especially, just before emergence of each spike order. In case of 3rd farmer (Table 1), excess application of nitrogen (300 kg N/ha), through flood irrigation, resulted in lanky growth and lodging of particularly male parents, affecting pollen availability leading to more selfed female plants. Saran and Giri (1987) have reported that nitrogen plays an important role in expressing pistillate character in female parent as deficiency of nitrogen leads to more ISF. Ramachandram and Rangarao (1988) recommended NPK @ 60:40:0 kg/ha for varietal seed production and 80:60:0 kg/ha for female parent and hybrid seed production. In case of farmer 5 (Table 1), generation of ISF was lower (<5/spike), may be due to application of 10 tonnes/ha of farm yard manure for seed production plot.

Castor requires a moderately high temperature of 20-27°C with low humidity throughout the growing season. High temperature above 41°C at the time of flowering even for a short duration will result in bursting of flowers causing non-availability of pollen and poor seed set (Singh, 2001). Though the genetic nature of a parent is crucial in sex expression, many environmental factors such as availability of soil nutrients, day temperature (>32°C), photoperiod, age of the plant, soil moisture etc., also play an important role in it (Shifriss, 1960; Lavanya, 2002; Lavanya *et al.,* 2019). Pistillate tendency was relatively strong in primary raceme and young plants, provided other abiotic conditions were optimum (Shifriss, 1956). Ankineedu and Rao (1973) opined that pistillate character of castor is governed by homozygous recessive and environmentally sensitive gene and therefore, interspersed staminate flowers may not be confined to any particular order and are temperature dependent. Ramachandram and Ranga Rao (1980) reported that polygenes influence the pistillate character and is highly unstable and varies with crop management levels. Hegde *et al.* (2003) opined that moderate temperature of 32°C promoted female tendency while high temperature promoted male tendency and the percentage of pistillate flowers were the highest on the main raceme and it decreased gradually with subsequent raceme orders.

In the present study, the temperatures recorded high and were up to 1 to 2°C more than normal (average) maximum or minimum temperatures. The actual maximum temperatures (33-30°C), minimum temperatures (24-20°C) and actual average temperatures (28-25°C) from the month of October (2015) to January (2016) were following a decreasing trend during this period (Table 3). ISF was recorded in the primary racemes itself and were in the range of 30-40 ISF per primary raceme in DPC-9 and 15-20 in M-574 (Table 3). The secondary racemes, which emerged in the 1st and 2nd week of December on the female parent DPC-9, also had high number of ISF in the range of 25-30. The number of ISF drastically reduced to a level of zero to 5 in the third and 4th order racemes of DPC-9 and 2nd and 3rd order racemes of M-574 female parents in the month of January, 2016. The decreasing temperatures have resulted in less number of ISFs in the 2nd to 4th order spikes. The observed differences in the number of ISF could be ascribed to the differences in temperatures recorded during primordial initiation (10-15 days prior to flowering) of different orders of spikes. This indicated the influence of temperature on production of ISF. Similar observations have been reported by Ankineedu and Rao (1973) and Ramachandram and Rangarao (1980).

The proportion of male flowers in the male parents DCS-9 and DCS-78 also reduced during the months of December-January (2015-16) as the low temperatures promoted female flowers. This also contributed for female selfed seed in the third pick of the DCH-177 hybrid seed lot. Thus the selection and development of male parent having stable male expression even in cool temperatures is an important requirement in castor breeding programme. The number of ISF in M-574 was relatively less primarily due to its genetic nature and also, to some extent, due to its late sowing and late flowering (10-12 days later than DPC-9), coinciding with decreasing temperatures. The high incidence of ISF in female parents, particularly in DPC-9 female parent, even after their manual removal, had significant impact on the genetic purity of hybrid seed (Table 4). A comparative study of the pick-wise genetic purity of hybrids also indicated overall mean and range of genetic purity of hybrid seed lots from DCH-519 (98%, 92-100%) was higher than that of DCH-177 (76%, 58-92%). Cost of seed production also increased due to more labour engaged for removing the ISF in its bud stage itself. Seed lots of DCH-177 from farmers 1 to 3 (Table 1) had low genetic purity (more selfed seeds) due to dependence on hired labour and could not remove ISF in their bud stage.

Table 1 Land holding size of farmer, soil type, type of labour, yield and purity of DCH-177 hybrid seed

Farmer	Land holding size and type of labour	Soil type and irrigation method	Area (acre)	Date of sowing	Pick	Purity of seed (%)	Production (kg)	Yield/acre (kg)
1*	Medium farmer, hired labour	Black cotton soil	4.45	14.09.2015	1	48	1647	370
					2	71		
					3	74		
2*	Medium farmer, hired labour	Black cotton soil	2.03	14.09.2015	1	27	1080	532
					2	70		
					3	82		
3*	Medium farmer, hired labour	Clay-loamy soil, medium depth	3.27	14.09.2015	1	50	1451	444
					2	65		
					3	59		
4**	Medium farmer, hired labour	Clay-loamy soil, drip irrigated	2.43	22.09.2015	1	87	1940	798
					2	80		
					3	83		
5*	Small farmer, family labour	Red soil, Medium depth	0.81	22.09.2015	1	83	662	817
					2	82		
					3	72		
6*	Marginal farmer, family labour	Red soil, Medium depth	0.73	10.10.2015	1	94	240	329
					2	94		
					3	87		
7*	Marginal farmer, family labour	Red soil and shallow (<30 cm)	1.24	22.09.2015	1	79	231	186
					2	85		
8*	Medium farmer, hired labour	Clay loamy soil, Medium depth	1.96	22.09.2015	1	87	940	480
					2	84		
					3	88		
9**	Medium farmer, hired labour	Red soil, Medium depth, drip irrigated	3.58	23.09.2015	1	84	1311	366
					2	80		
					3	76		

Marginal farmer: <1 ha, Small farmer: 1-2 ha, Medium farmer: 4-10 ha, Medium depth: 45-60 cm; *Furrow/flood irrigation; **Drip irrigation and fertigation

Table 2 Land holding size of farmer, soil type, type of labour, whitefly incidence, yield and purity of DCH-519 hybrid seed

Farmer	Land holding size, type of labour and whitefly incidence	Soil type	Area (Acres)	Date of sowing	Pick	Purity of seed (%)	Production (Kg)	Yield (kg/acre)
1**	Marginal farmer, No whitefly incidence, family labour	Clay-loamy, medium depth	1	28.09.2015	1	98	488	488
					2	97		
2**	Marginal farmer, No whitefly incidence, family labour	Clay-loamy, medium depth	1	28.09.2015	1	99	390	390
					2	100		
3*	Medium farmer, depending on hired labour, severe whitefly incidence	Clay-loamy, saline and shallow to medium depth	6	30.09.2015 & 05.10.2015	1	98	882	147
					2	99		
					3	98		
4*	Marginal farmer, moderate whitefly incidence, family labour	Black cotton soil, Medium depth	1.5	30.09.2015	1	97	356	237
					2	99		
					3			
5*	Marginal farmer, severe whitefly incidence, family labour	Red soil, medium depth	2.5	30.09.2015	1	99	436	174
					2	99		
6*	Medium farmer, Severe whitefly incidence, family labour	Red coarse soil with gravels, medium depth	2	30.09.2015	1	99	462	231
					2	99		
7*	Medium farmer, low whitefly incidence, hired labour	Clay-loamy soil, Medium depth	4	01.10.2015	1	99	1632	408
					2	99		
8*	Medium farmer, hired labour, severe whitefly incidence	Black soil, Saline, Medium depth	1	06.10.2015	1&2	99	104	104
9*	Marginal farmer, moderate whitefly incidence, family labour	Red soil, coarse shallow soil	1.5	14.10.2015	1&2	97	340	227

*Farmers at Konkal village, Shantinagar with intensive cropping pattern including Bt-cotton, chillies and other vegetables, ** Farmers near Narkhoda (Non-intensive agro ecosystem), Shamshabad. All farmers followed flood irrigation method

Table 3 Temperatures, order of racemes and number of ISF

Month	Temperature (°C)				Actual Average	Departure from Avg. Max. & Min.	Raceme (spike) order and Number of ISF			
	Average (2010-2012)		Actual (2015-16)				DPC-9		M-574	
	Max.	Min.	Max.	Min.			Order	ISF	Order	ISF
September,2015	33	24	32	25	28.0	-1 to +1	-	-	-	-
October	32	23	33	24	28.0	+1 to +1	-	-	-	-
November	31	20	29	22	25.5	-2 to +2	1st	30-40	1st	15-20
December	30	18	30	20	25.0	0 to +2	2nd	25-30	2nd	0-5
January,2016	32	18	30	20	25.0	-2 to +2	3rd and 4th	0-5	3rd	0-5

Source of temperatures: average and actual temperatures from world weather online.com at Kurnool city, Andhra Pradesh

Table 4 Pick wise genetic purity of DCH-177 and DCH-519 hybrid seed

Farmers	DCH-177				DCH-519				
	1	2	3	Average	Farmer	1	2	3	Average
1	48	71	74	64	1	98	97	-	98
2	27	70	82	60	2	99	100	-	100
3	50	65	59	58	3	98	99	98	98
4	87	80	83	83	4	97	99	-	98
5	83	82	72	79	5	99	99	-	99
6	94	94	87	92	6	99	99	-	99
7	79	85	-	82	7	99	99	-	99
8	87	84	88	86	8	99	99	-	99
9	84	80	76	80	9	97	97	-	97
Average	71	79	77.6	76	Average	98.3	98.60	98.0	98.60

Selection of an agro-ecosystem for castor hybrid seed production plays an important role for its success. There was severe whitefly infestation in *rabi* season, particularly in double and triple bloom parents, in the farms (farmer 3 to 9 of Table 2) of Konkal village, near Shantinagar (Mahabubnagar Dist.). This could be due to favourable agro-ecosystem for whiteflies infestation and multiplication, resulting from intensive cropping system involving cotton, chillies and other vegetables. Further studies are required to uncover the reasons for severe whitefly infestation in this context. Date of sowing of seed production varies with region and state depending on onset and duration of winter (DOR, 2009). Sowing time needs to be adjusted so as to coincide the primordial initiation of primary spike emergence with peak winter period in December-January. In conclusion, our preliminary observations during the participatory hybrid seed production indicated that, apart from the genetic nature of parents, their maintenance and selection of favourable agro-ecosystem, farmers with their own family labour, particularly women, were better suited for hybrid castor seed production as it was difficult for timely completion of various activities depending totally on hired labour. Small and marginal farmers played very pro-active role in most of the activities of crop management and were best suited for seed production of castor. Feedback from the farmers indicated that timely removal of ISF and also management of whitefly infestation was difficult and costly involving an expenditure of up to ₹ 6000-10000 per acre. However, with an average hybrid castor seed yield of 104-798 kg and an expenditure of ₹ 15,000-25,000 per acre, most of the farmers were benefited with minimum net return of ₹.25000/acre.

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A novel, low-cost and throughput selfing technique in sesame

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ABSTRACT

Sesame (*Sesamum indicum* L.) is an oilseed crop, highly valued for its quality edible oil and direct confectionery uses. Though sesame is a self-pollinated crop, the opened flowers attract several groups of bees which promote cross pollination. Genetically pure seed obtained by ensuring self-pollination is an essential requirement for fixing the traits in genotypes, and for employing them in molecular and genomic studies. As of now, bagging technique is followed for selfing and this is not only tedious but also detrimental to the developing flowers. In order to overcome the limitations of the traditional selfing technique, a novel selfing technique has been developed using liquid glue, which is low cost, less labour intensive and high throughput method. This technique has no seasonal limitations and is applicable across any region where sesame is grown.

Keywords: Bag, Bees, Glue, Insects, Sesame, Self-pollination

Sesame (*Sesamum indicum* L.) is an Indian origin oilseed crop grown in tropical and sub-tropical regions which belongs to genus Sesamum and family Pedaliaceae. Sesame is predominantly an autogamous crop, nevertheless reported outcrossing rates are quite high ranging from 1 to 42 per cent (Pathirana, 1994; Baydar and Gurel, 1999; Anonymous, 2018) due to insect visits to the flowers (Andrade *et al*., 2014; Kumar and Lenin 2000). This wide range of cross pollination is reported to be due to local bee population as well as availability of different genotypes within the vicinity.

According to Bedigian (2010), the flower buds develop at each leaf axil within 25-40 days after sowing depending on the genotype. It takes 10-12 days from the time of visibility of the bud (size 1mm) at the tip of the apical meristem to opening of the bud (10-12 mm) to bell shaped flower (Fig.1). Flowers are generally solitary or in small fascicles in upper leaf axils, bisexual, zygomorphic, 5-merous, with 2 bracts at the base, each bract with an axillary gland; calyx with oblong lobes 4-7 mm × 1-1.5 mm, slightly fused at base, apex acute, long-hairy. The corolla is fused and lobed, white, rose-pink, lavender, or mauve, in many cultivars with dark purple interior markings. The lowest lobe is often as much as 1 cm longer than the others, and often shaded purple which is commonly referred as flower lip. The ovary is superior, oblong-quadrangular, approximately 5 mm × 2 mm, and grayish hairy. Style is 1 cm long, with 2-lobed or 3 lobed stigma covered by 4 stamens, filament is fused near the base of corolla tube and included, the upper 2 stamens are shorter than the lower 2 stamens.

Flowers open in acropetal sequence, from the base of the stem toward the apex. Flower anthesis takes place early in the morning between 6 and 9 AM, and the pollen remains viable for >24 hours while the stigma remains receptive for up to 48 hours (Bedigian 2010). Sesame is an indeterminate plant with flowering usually starting from 30-35 days after sowing in the main stem and continues until harvest. It has been observed and that in commercially cultivated varieties such as TKG-22, PHULE TIL-1, RT-346, RT-127, GT-2 etc. flowering ceases at 70-85 days after sowing. This observation is supported by the reports of earlier workers (Kumhar *et al.,* 2013; Parameshwarappa 2017). During flowering, each branch will have 2-4 opened flowers every day until bud production stops. Sesame flowers are visited by a wide group of honey bees and other insects for nectar and pollen and during this process they cause cross pollination. Longer duration of stigmatic receptivity coupled with longer pollen viability increases the window of time for cross pollination. Although honey bee pollination is encouraged during commercial cultivation of sesame, it is a disadvantage in breeding programmes where directed crossing or selfing is intended. Homozygous and homogeneous lines are required for carrying out several molecular, biochemical and genomic studies and under such conditions unintended cross pollination poses a problem. Therefore, it is essential to ensure proper selfing of plants under several situations and to meet this requirement, the development of a fool proof, easy and high throughput selfing method in sesame is advantageous. Even while maintaining the germplasm accessions through self pollination, it becomes essential to ensure that cross pollination has not occurred and genetic identity of lines is maintained. Covering the flower buds from top of the branches with butter paper is commonly followed by sesame breeders. When the branches from selected plants are covered using butter paper bag and the base of the cover is tied to the branch using a thread, the indeterminate growth of the braches poses difficulty in maintaining the butter paper bags on the branches. The flower bud as well as immature capsule drop is observed inside the bag along with fungal mycelium growth and only one or two capsules with normal seeds could be harvested. Due to these disadvantages of covering the branches, a method which can cover only individual flowers so that honey bee cannot enter inside the flower is essential. In Tamil Nadu Agriculture University, Coimbatore, smearing clay solution on tip of the mature flower bud is being practiced. We understood that this method, basically does not allow the corolla to open up on bud maturation, hence, honey bee cannot enter the flower. On perusal of this idea of smearing the clay, we communicated with the senior workers of sesame in TNAU, Coimbatore and we were informed that the clay used by them was the natural clay available particularly in their area and they also mentioned that the clay may be washed away due to rain thus allowing the corolla to open (personal communication from Dr. V. Muralidharan, former Head, Oilseeds TNAU, Coimbatore and former Director ICAR-DGR, Junagadh). Therefore, we searched for the material which is easily available, handy to use and wash proof with the capacity to hold the corolla tight without opening. We initially thought of adhesive strips (was difficult to place it on the flower buds), fevicol (costly and damages the bud tissue in 2-3 hours of application), starch solution prepared using starch powder (attracts ants and flakes out from the bud when it dries up). We identified liquid glue which is easily available, thick paste like starch but does not flake out and does not attract insects, less concentrated and odor free when compared to fevicol and liquid based which facilitates for easy application unlike adhesive tapes. This article describes, a new technique developed to ensure self-pollination using liquid glue.

In this study undertaken with popular cultivated variety SHWETA TIL, mature flower buds (Fig. 1) which were ready to open the next morning were selected and tagged using a piece of thread. Initially, liquid glue was directly used to apply on the mature flower bud so that glue holds the corolla tight without opening, but it was observed that the thick concentration was too heavy on the soft tissues of mature flower buds (tip of the bud turned brown on next day). Therefore solution was prepared using water and commercially available liquid glue in 1:1, 2:1 and 3:1 raito and these solutions were used for application on 10 flower buds. The corolla of the buds were closed upon maturity in all three solution, but there was some damage (browning of the tip) in 1:1 ratio. The buds on which 2:1 and 3:1 solution was applied resulted in normal healthy flower with closed corolla in all 10 buds. Therefore, 2:1 dilution was considered in all subsequent experiments. The mature flower buds were dipped to third of its length in the glue solution of 2:1 ratio carried in a small container (say like a cap of a bottle as shown in Fig 2 or any tiny equivalent container). The tip of the flower bud was dunked into the glue solution and it was ensured that tip of the flower bud where it opens into flower was closed with the glue solution. When the tip of the bud was covered with glue solution, the corolla gets glued up and does not open up. The following morning, it was observed that the corolla was intact due to the glue and did not open. However, the bud had grown normally and matured into flower with normal anthesis and ensured self-pollination (Fig.3). Normal seed setting and seed filling was observed in all the flower buds treated with the glue solution and there was no difference between these capsules and the capsules formed from flowers that were not treated (Fig.4). This experiment was taken up during Summer-2018. The success of capsule set on treated flower buds encouraged us to treat 20 flower bud in each of the released varieties *viz.,* E-8, GT-2, GT-4, HT-1, MT-75, PHULE TIL, RT-351, RAJESHWARI, HIMA, SWETHA TIL, TSS-6, VRI-3 and germplasm accessions *viz.,* IC-132201, IC-500472, IC-96160, IC-204618, IC-204613, IC-96227, IC-204300 and IC-204444. The selfed seeds from these capsules were collected and used for crossing during late *kharif*-2018. The new technique described above was used to self 4608 flower buds of 768 F_2 plants from the cross IS-49-1A x RT-346 during late *kharif*-2018 (August sown) crop. The selfing spanned from 10 September 2018 to 23 September 2018 using 2 women labour for this particular activity. There was normal capsule and seed setting in these treated buds which were used to raise F_3 generation. During this selfing activity there were rains on 12th September (12.4 mm) and 22nd September (4.87 mm), however, it was observed that the glue treated flowers were closed even after the rains. With this observation we were convinced that the rain does not wash away the glue on the flower bud. The three popular selfing techniques practiced by breeders to ensure selfing and the merits and demerits of each of these techniques are presented in Table 1.

Lower seed weight per capsule has been reported when selfing is ensured by covering the capsules using butter paper covers or tulle covers or nets (Das and Jha 2019). Light interception is restricted, which in turn reduces photosynthetic rate in top leaves and stem resulting in low seed weight per capsule. Green capsules in sesame are also known to be photosynthetically active and expected to contribute significantly for increased carbon fixation and seed weight (Weiss, 1983).

The simple liquid glue is available in stationery stores and the same could be diluted with water and used to dip the bud. In our experiments we found that the glue does not get easily washed out due to rain or dew. Dipping a bud in the glue solution takes just a second and so large number (up to 1000) of flower buds could be treated in less than 2 hours. This technique is less labour intensive, with no special skill requirement and is high throughput. The present method of glue application overcomes the disadvantages in other selfing techniques followed by the breeders. However, tagging of selfed buds is time consuming, which can be avoided by selfing all the available buds every day up to one week of peak flowering or as per the breeder's choice.

This technique of glue based self-pollination in sesame is currently being practiced in ICAR-IIOR, Hyderabad since summer 2018 and it is working satisfactorily, to maintain purity in germplasm as well as in advancing the generations through selfing. Based on these observations, the present method is being advocated as a simple and effective method for selfing flower buds in sesame. However, identification of selfed flower bud needs labelling of the buds and the presently followed method of tying a thread around is quite time consuming. Therefore there is a need to look for alternative ways of labeling the flower buds selfed using glue.

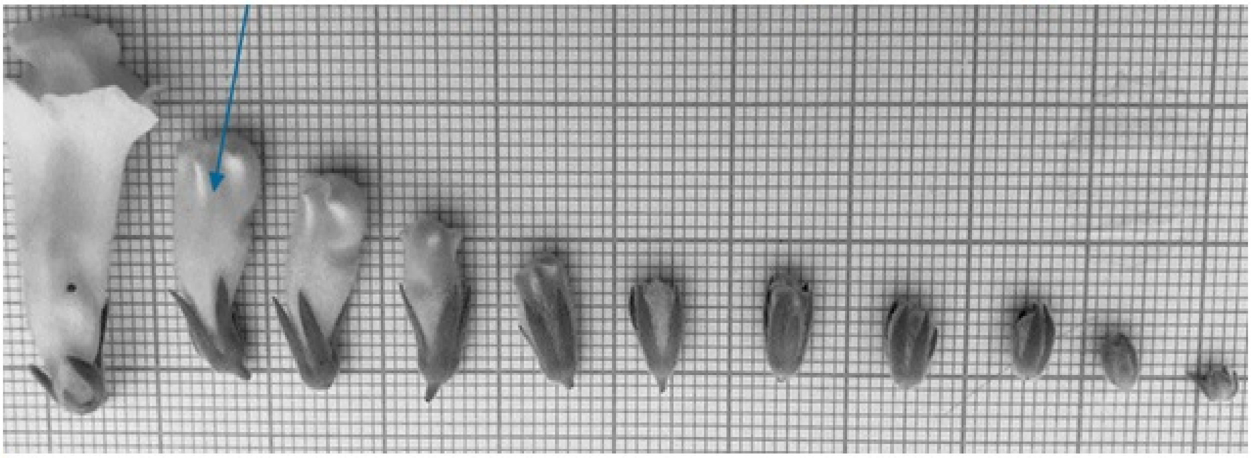

Fig. 1. Development of sesame flower bud. Mature flower bud (with arrow mark is ready to open in the next morning) is selected for treating with glue

Fig. 2. Dipping of mature flower bud (which is ready to open in the next morning) in glue solution using a small container (cap of water bottle) to carry the glue

Fig. 3 (a). Treated (with glue) flower buds matured normally but did not open for insect pollination; (b). Treated flowers dropped off after fertilization without the corolla opening; (c). Untreated flowers opened completely and then dropped off after fertilization

Table 1 Selfing techniques practiced and their merits and demerits

Selfing technique	Merits	Demerits
Covering of buds at top of branches with butter paper bags or tulle covers to protect the flowers from insect visit to ensure self-pollination.	1. Ensures selfing 2. Widely adoptable 3. Less laborious and not highly skilled.	1. Very difficult to cover individual flower bud due to fragile pedicel. Therefore, bags are placed on top of the branches which arrests further production of the buds. 2. Very few buds can be selfed, therefore less amount of selfed seeds produced 3. Humidity and temperature in the bag increases leading to dropping of the capsule before maturity as well as favours growth of saprophytic and opportunistic fungi 4. Usually leads to reduced seed set and seed weight
Coving the plots by nylon net	1. Easy and less laborious 2. Large quantity of self-seed obtained	1. Does not ensure 100% self-pollination as there are chances of insects getting inside the net resulting in cross pollination 2. Difficult for inter-cultural operations and increased humidity, reduced seed set and seed weight
Applying paste of clay on the tip of the buds and once the clay dries it prevents flower opening as it forms a tight cap preventing the corolla from opening developed by TNAU, Coimbatore (agritech.tnau.ac.in/crop_improvement/crop_improv_emasculation_oilseeds.html)	1. Individual flowers can be selfed 2. Ensured selfing 3. Good seed set 4. Selfed seeds can be obtained early by selfing early buds	1. Smearing clay with fingers on individual bud is laborious 2. Requires skill for preparing right clay consistency as well as for application. 3. Clay may wash out due to rain and dew. (Refer agritech.tnau.ac.in/crop_improvement/crop_improv_emasculation_oilseeds.html) 4. Ensuring uniformity in clay quality is difficult and varies with location and time. 5. Maintaining consistency though out the process is difficult

Fig. 4. Normal capsule maturity and seed filling from glue treated flower buds (ensured self-pollination) when compared with seeds from untreated flower buds (open pollination)

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Always conclude the article by clearly crystallizing the summary of the results obtained along with their implications in solution of the practical problems or contribution to the advancement of the scientific knowledge.

Acknowledgments (To be typed as given above, as a side-heading, well below the concluding portion of Conclusions)

The author(s) may place on record the help, and cooperation, or financial help received from any source, person or organization. This should be very brief, and omitted, if not necessary.

References (To be typed as above, as side heading below Acknowledgement)

The list of references must include all published work referred to in the text. Type with double line spacing. Do not cite anonymous as author; instead cite the name of the institute, publisher, or editor. References should be arranged alphabetically according to the surnames of the individual authors or first authors. Two or more references by the same author are to be cited chronologically; two or more in the same year by the letters a, b, c, etc. All individually authored articles precede those in which the individual is the first or joint author. Every reference cited in the article should be included in the list of References. This needs rigorous checking of each reference. Names of authors should not be capitalized.

The reference citation should follow the order: author(s), year of publication, title of the paper, periodical (title in full, no abbreviations, italics or underlined), volume (bold or double underlining), starting and ending pages of the paper. Reference to a book includes authors(s), year, title (first letter of each word except preposition, conjunction, and pronouns in capitals and underlined), the edition (if other than first), the publisher, city of publication. If necessary, particular page numbers should be mentioned in the last. Year of publication cited in the text should be checked with that given under References. Year, volume number and page number of each periodical cited under "References" must be checked with the original source. The list of references should be typed as follows:

Rao C R 1968. *Advances in Statistical Methods in Biometrical Research*, pp.40-45, John Wiley & Sons, New York.
Kanwar J S and Raychaudhuri S P 1971. *Review of Soil Research in India*, pp 30-36. Indian Society of Soil Science, New Delhi.
Mukherjee J N 1953. The need for delineating the basic soil and climatic regions of importance to the plant industry. *Journal of the Indian Society of Soil Science*, **1** : 1-6.
Khan S K, Mohanty S K and Chalam A B, 1986. Integrated management of organic manure and fertilizer nitrogen for rice. *Journal of the Indian Society of Soil Science*, **34** : 505-509.
Bijay-Singh and Yadvinder-Singh 1997. Green manuring and biological N fixation: North Indian perspective. In: Kanwar J S and Katyal J C (Ed.) *Plant Nutrient Needs, Supply, Efficiency and Policy Issues 2000-2025.* National Academy of Agricultural Sciences, New Delhi, India, pp.29-44.
Singh S, Pahuja S S and Malik R K 1992. Herbicidal control of water hyacinth and its effect on chemical composition of water *(in) Proceedings of Annual Weed Science Conference*, held during 3-4 March 1992 by the Indian Society of Weed Science, at Chaurdhary Charan Singh Haryana Agricultural University, Hisar, 127p.
AICRP on Soybean 1992. *Proceedings of 23rd Annual Workshop of All-India Co-ordinated Research Project on Soybean*, held during 7-9 May 1992 at University of Agricultural Sciences, Bangalore, Karnataka, National Research Centre for Soybean, Indore, pp.48.
Devakumar C. 1986. Identification of nitrification retarding principles in neem (*Azadirachta indica* A.Juss.) seeds. Ph D Thesis, Indian Agricultural Research Institute, New Delhi.

Reference to unpublished work should normally be avoided and if unavoidable it may be mentioned only in the text.

Short Communication

Conceptually short communication is a first report on new concept, ideas and methodology which the author(s) would wish to share with the scientific community and that the detailed paper would follow. Short Communication is akin to an advance booking for the report on the findings. Short communications may include short but trend-setting reports of field or laboratory observation(s), preliminary results of long-term projects, or new techniques or those matters on which enough information to warrant its publication as a full length article has still not been generated but the results need to be shared immediately with the scientific community. The style is less formal as compared with the "full-length" article. In the short communications, the sections on abstract, materials and methods, results and discussion, and conclusion are omitted; but the material is put concisely in the same sequence but without formal sections. The other instructions are the same as in the case of the full-length articles.

Tables

Tables should not form more than 20% of the text. Each table should be typed on separate sheet and should have on the top a table number (in Arabic numerals *viz.* 1, 2, 3 etc.) and a caption or title which should be short, but sufficiently explanatory of the data included in the table. Information in the table should never duplicate that in the text and vice versa. Symbols (asterisks, daggers, etc. or small letters, *viz.*, a, b, etc.) should be used to indicate footnotes to tables. Maximum size of table acceptable is what can be conveniently composed within one full printed page of the journal. Over-sized tables will be rejected out-right. Such tables may be suitably split into two or more small tables.

The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm±, NS (not C.D., S.E.m±, N.S.). Do not put cross-rules inside the table. Tables should be numbered consecutively and their approximate positions indicated in the margin of the manuscript. Tables should not be inserted in the body of the text. Type each table on a separate sheet. Do not use capital letters for the tabular headings, do not underline the words and do not use a full-stop at the end of the heading. All the tables should be tagged with the main body of the text i.e. after references.

Figures

Figures include diagrams and photographs. Laser print outs of line diagrams are acceptable while dot-matrix print outs will be rejected. Alternatively, each illustration can be drawn on white art card or tracing cloth/ paper, using proper stencil. The lines should be bold and of uniform thickness. The numbers and letterings must be stenciled; free-hand drawing will not be accepted. Size of the illustrations as well as numbers, and letterings should be sufficiently large to stand suitable reduction in size. Overall size of the illustrations should be such that on reduction, the size will be the width of single or double column of the printed page of the Journal. Legends, if any, should be included within the illustration. Each illustration should have a number followed by a caption typed/ typeset well below the illustration.

Title of the article and name(s) of the author(s) should be written sufficiently below the caption. The photographs (black and white) should have a glossy finish with sharp contrast between the light and the dark areas. Colour photographs/ figures are not normally accepted. One set of the original figures must be submitted along with the manuscript, while the second set can be photocopy. The illustrations should be numbered consecutively in the order in which they are mentioned in the text. The position of each figure should be indicated in the margin of the text. The photographs should be securely enclosed with the manuscript after placing them in hard board pouches so that there may not be any crack or fold. Photographs should preferably be 8.5 cm or 17 cm wide or double the size. The captions for all the illustrations (including photographs) should be typed on a separate sheet of paper and placed after the tables.

Expression of Plant Nutrients on Elemental Basis

The amounts and proportions of nutrient elements must be expressed in elemental forms e.g. for ion uptake or in other ways as needed for theoretical purposes. In expressing doses of nitrogen, phosphatic, and potassic fertilizers also these should be in the form of N, P and K, respectively. While these should be expressed in terms of kg/ha for field experiments, for pot culture studies the unit should be in mg/kg soil.

SI Units and Symbols

SI Units (System International d 'Unities or International System of Units) should be used. The SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units. To denote multiples and sub-multiples of units, standard abbreviations are to be used. Clark's Tables: Science Data Book by Orient Longman, New Delhi (1982) may be consulted.

Some of these units along with the corresponding symbols are reproduced for the sake of convenience.

Names and Symbols of SI Units

Physical Symbol for SI Unit Symbol Remarks quantity physical quantity for SI Unit

Primary Units					
length	l		time	t	
metre	m		second	s	
mass	m		electric current	I	
kilogram	kg		ampere	A	
Secondary Units					
plane angle	radian	rad	Solid angle	steradian	sr
Unit Symbols					
centimetre	cm		microgram	μg	
cubic centimetre	cm^3		micron	μm	
cubic metre	m^3		micronmol	μmol	
day	d		milligram	mg	
decisiemens	dS		millilitre	mL	
degree-Celsium	°C [=(F-32)x0.556]		minute	min	

gram	g	nanometre	nm
hectare	ha	newton	N
hour	h	pascal	Pa
joule J	(= 10^7 erg or 4.19 cal.)	second	s
kelvin	K (= °C + 273)	square centimetre	cm^2
kilogram	kg	square kilometre	km^2
kilometre	km	tonne	t
litre	L	watt	W
megagram	Mg		

Some applications along with symbols

adsorption energy	J/mol (=cal/molx4.19)	leaf area	m^2/kg
cation exchange capacity	cmol (p+)/kg (=m.e./100 g)	nutrient content in plants (drymatter basis)	µg/g, mg/g or g/kg
Electrolytic conductivity	dS/m (=mmhos/cm)	root density or root length density	m/m^3
evapotranspiration rate	$m^3/m^2/s$ or m/s	soil bulk density	Mg/m^3 (=g/cm^3)
heat flux	W/m^2	specific heat	J/kg/K
gas diffusion	$g/m^2/s$ or $m^3/m^2/s$ or m/s	specific surface area of soil	m^2/kg
water flow	$kg/m^2/s$ (or) m^3m^2s (or) m/s	thermal conductivity	W/m/K
gas diffusivity	m^2/s	transpiration rate	$mg/m^2/s$
hydraulic conductivity ion uptake	m/s	water content of soil	kg/kg or m^3/m^3
(Per kg of dry plant material)	mol/kg	water tension	kPa (or) MPa

While giving the SI units the first letter should not be in capital i.e cm, not Cm; kg not Kg. There should not be a full stop at the end of the abbreviation: cm, not cm. kg, not kg.; ha, not ha.

In reporting the data, dimensional units, viz., M (mass), L (length), and T (time) should be used as shown under some applications above. Some examples are: 120 kg N/ha; 5 t/ha; 4 dS/m etc.

Special Instructions

I. In a series or range of measurements, mention the unit only at the end, e.g. 2 to 6 cm2, 3, 6, and 9 cm, etc. Similarly use cm2, cm3 instead of sq cm and cu m.

II. Any unfamiliar abbreviation must be identified fully (in parenthesis).

III. A sentence should not begin with an abbreviation.

IV. Numeral should be used whenever it is followed by a unit measure or its abbreviations, e.g., 1 g, 3 m, 5 h, 6 months, etc. Otherwise, words should be used for numbers one to nine and numerals for larger ones except in a series of numbers when numerals should be used for all in the series.

V. Do not abbreviate litre to` l' or tonne to `t'. Instead, spell out.

VI. Before the paper is sent, check carefully all data and text for factual, grammatical and typographical errors.

VII. Do not forget to attach the original signed copy of `Article Certificate' (without any alteration, overwriting or pasting) signed by all authors.

VIII. On revision, please answer all the referees' comments point-wise, indicating the modifications made by you on a separate sheet in duplicate.

IX. If you do not agree with some comments of the referee, modify the article to the extent possible. Give reasons (2 copies on a separate sheet) for your disagreement, with full justification (the article would be examined again).

X. Rupees should be given as per the new symbol approved by Govt. of India.

Details of the peer review process

Manuscripts are received mainly through e-mails and in rare cases, where the authors do not have internet access, hard copies of the manuscripts may be received and processed. Only after the peer review the manuscripts are accepted for publication. So there is no assured publication on submission. The major steps followed during the peer review process are provided below.

Step 1. *Receipt of manuscript and acknowledgement*: Once the manuscript is received, the contents will be reviewed by the editor/associate editors to assess the scope of the article for publishing in JOR. If found within the scope of the journal, a Manuscript (MS) number is assigned and the same will be intimated to the authors. If the MS is not within the scope and mandate of JOR, then the article will be rejected and the same is communicated to the authors.

Step 2. *Assigning and sending MS to referees*: Suitable referees will be selected from the panel of experts and the MS (soft copy) will be sent to them for their comments - a standard format of evaluation is provided to the referees for evaluation along with the standard format of the journal articles and the referees will be given 4-5 week time to give their comments. If the comments are not received, reminders will be sent to the referees for expediting the reviewing process and in case there is still no response, the MS will be sent to alternate referees.

Step 3. *Communication of referee comments to authors for revision*: Once the referee comments and MS (with suggestions/ corrections) are received from the referees, depending on the suggestions, the same will be communicated to the authors with a request to attend to the comments. Authors will be given stipulated time to respond and based on their request, additional time will be given for attending to all the changes as suggested by referees. If the referees suggest no changes and recommend the MS for publication, then the same will be communicated to the authors and the MS will be taken up for editing purpose for publishing. In case the referees suggest that the article cannot be accepted for JOR, then the same will be communicated to the authors with proper rationale and logic as opined by the referees as well as by the editors.

Step 4. *Sending the revised MS to referees*: Once the authors send the revised version of the articles, depending on the case (like if major revisions were suggested by referees) the corrected MS will be sent to the referees (who had reviewed the article in the first instance) for their comments and further suggestions regarding the acceptability of publication. If only minor revisions had been suggested by referees, then the editors would look into the issues and decide take a call.

Step 5. *Sending the MS to authors for further revision*: In case referees suggest further modifications, then the same will be communicated to the authors with a request to incorporate the suggested changes. If the referees suggest acceptance of the MS for publication, then the MS will be accepted for publication in the journal and the same will be communicated to the authors. Rarely, at this stage also MS would be rejected if the referees are not satisfied with the modifications and the reasoning provided by the authors.

Step 6. *Second time revised articles received from authors and decision taken*: In case the second time revised article satisfies all the queries raised by referees, then the MS will be accepted and if not satisfied the article will be rejected. The accepted MS will be taken for editing process where emphasis will be given to the language, content flow and format of the article.

Then the journal issue will be slated for printing and also the pdf version of the journal issue will be hosted on journal webpage.

Important Instructions

- Data on field experiments have to be at least for a period of 2-3 years
- Papers on pot experiments will be considered for publication only as short communications
- Giving coefficient of variation in the case of field experiments Standard error in the case of laboratory determination is mandatory. For rigorous statistical treatment, journals like Journal of Agricultural Science Cambridge, Experimental Agriculture and Soil Use and Management should serve as eye openers.

SPECIAL ANNOUNCEMENT

In a recently conducted Executive Committee meeting of the Indian Society of Oilseeds Research, it was decided to increase the scope of the Journal of Oilseeds Research by accommodating vibrant aspects of scientific communication. It has been felt that, the horizon of scientific reporting could be expanded by including the following types of articles in addition to the Research Articles, Shor Communications and Review Articles that are being published in the journal as of now.

Research accounts (not exceeding 4000 words, with cited references preferably limited to about 40-50 in number): These are the articles that provide an overview of the research work carried out in the author(s)' laboratory, and be based on a body of their published work. The articles must provide appropriate background to the area in a brief introduction so that it could place the author(s)' work in a proper perspective. This could be published from persons who have pursued a research area for a substantial period dotted with publications and thus research account will provide an overall idea of the progress that has been witnessed in the chosen area of research. In this account, author(s) could also narrate the work of others if that had influenced the course of work in authors' lab.

Correspondence (not exceeding 600 words): This includes letters and technical comments that are of general interest to scientists, on the articles or communications published in Journal of Oilseeds Research within the previous four issues. These letters may be reviewed and edited by the editorial committee before publishing.

Technical notes (less than 1500 words and one or two display items): This type of communication may include technical advances such as new methods, protocols or modifications of the existing methods that help in better output or advances in instrumentation.

News (not exceeding 750 words): This type of communication can cover important scientific events or any other news of interest to scientists in general and vegetable oil research in particular.

Meeting reports (less than 1500 words): It can deal with highlights/technical contents of a conference/ symposium/discussion-meeting, etc. conveying to readers the significance of important advances. Reports must

Meeting reports should avoid merely listing brief accounts of topics discussed, and must convey to readers the significance of an important advance. It could also include the major recommendations or strategic plans worked out.

Research News (not exceeding 2000 words and 3 display items): These should provide a semi-technical account of recently published advances or important findings that could be adopted in vegetable oil research.

Opinion (less than 1200 words): These articles may present views on issues related to science and scientific activity.

Commentary (less than 2000 words): This type of articles are expected to be expository essays on issues related directly or indirectly to research and other stake holders involved in vegetable oil sector.

Book reviews (not exceeding 1500 words): Books that provide a clear in depth knowledge on oilseeds or oil yielding plants, production, processing, marketing, etc. may be reviewed critically and the utility of such books could be highlighted.

Historical commentary/notes (limited to about 3000 words): These articles may inform readers about interesting aspects of personalities or institutions of science or about watershed events in the history/development of science. Illustrations and photographs are welcome. Brief items will also be considered.

Education point (limited to about 2000 words): Such articles could highlight the material(s) available in oilseeds to explain different concepts of genetics, plant breeding and modern agriculture practices.

Note that the references and all other formats of reporting shall remain same as it is for the regular articles and as given in Instructions to Authors

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