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Genetic variability analyses for yield and physiological traits in groundnut (*Arachis hypogaea* L.) genotypes

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ABSTRACT

Twenty different groundnut genotypes were evaluated in a randomized block design with three replications during *kharif* 2012 to study the variability parameters, heritability, genetic advance, correlation coefficient and path analysis for ten characters. Analysis of variance revealed highly significant differences among genotypes for all the traits except stability of soil plant analytical development (SPAD) and Chlorophyll Meter Reading 45 days after sowing indicating that adequate variability was found in the genotypes studied for most of the characters. The characters like 100 kernel weight, SPAD Chlorophyll Meter Reading 75 days after sowing, specific leaf area 75 days after sowing and rust resistance had high heritability with high genetic advance as per cent of mean and medium genotypic coefficient of variation indicating greater role of additive gene effects on these traits. While pod yield had moderate genotypic coefficient of variation and heritability along with high genetic advance as per cent of mean revealed that this character is also governed by additive gene effects and selection would be effective even in the early generation. Days to maturity, shelling outturn and specific leaf area 45 days after sowing had moderate heritability accompanied with low genotypic coefficient of variation and genetic advance indicating these traits are governed by non-additive gene effects. Selection may be practiced in later generations for improving these traits. The results on genotypic correlation coefficients revealed that pod yield had significant highly positive correlation with days to maturity, 100-kernel weight, and SPAD Chlorophyll Meter Reading 45 days after sowing while it was negative and significant for days to flower initiation and rust disease. SPAD Chlorophyll Meter Reading 45 days after sowing and SPAD Chlorophyll Meter Reading 75 days after sowing had highly significant negative correlation with specific leaf area 45 days after sowing and specific leaf area 75 days after sowing. Specific leaf area 45 days after sowing had highly significant negative correlation with rust. Therefore, SPAD Chlorophyll Meter Reading value could be used to identify genotypes with low specific leaf area and rust resistance. Path analysis indicated that 100-kernel weight had high positive direct effect with highly significant positive correlation with pod yield. Hence, this character may be effective for selection of high pod yield.

Keywords: Correlation, Genotypic coefficient of variation, Groundnut, Heritability, Phenotypic coefficient of variation

Groundnut (*Arachis hypogaea* L.) is an important self-pollinated oilseed crop grown in about 5.0 million ha area with the production and productivity of 7.72 million tons and 1537 kg/ha respectively during 2015-16 to 2017-18 (Anonymous, 2018). Groundnut kernels is valued as a rich source of oil (48-50%), protein (25-28%), carbohydrates (10-20%) and provides 564 kcal of energy for every 100 g of kernels (Arya *et al.,* 2016). It is also a rich source of several micronutrients and health-enhancing components, including minerals, antioxidants, and vitamins along with some biologically active polyphenols, flavonoids, and isoflavones (Janila *et al*., 2013; Ajay *et al*., 2016). Groundnut haulm is a very important nutritious feed for animals, it is more palatable and is a rich source of protein (8-15%), lipids (1-3%), minerals (9-17%), and carbohydrates (38-45%) as compared to cereal fodder. Nutrient digestibility of groundnut haulm for animals is about 53 per cent and that of crude protein is 88 per cent. It releases energy up to 2.337 cal/kg of dry matter (Singh and Diwakar, 1993; Narendra Kumar *et al*., 2017).

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There is large gap between potential pod yield and the realized pod yield in most of the situations (Johansen and Rao, 1996; Devasena *et al.,* 2017). Under rainfed situations, groundnut is attacked by several biotic and abiotic stresses that contribute to yield gap. Among the biotic stresses, foliar fungal diseases, late leaf spot (LLS) caused by *Phaeoisariopsis personata* (Berk. & Curt.) Van Arx and rust caused by *Puccinia arachidis* Speg. are the most widespread and major production constraints in groundnut growing regions. When they come together, it causes 50 to 70 per cent reduction in pod yield depending on severity of the disease incidence besides having an adverse effect on seed quality (Subrahmanyam *et al.,* 1984; McDonald *et al.,* 1985). Physiological parameters like specific leaf area (SLA) and soil plant analytical development (SPAD) chlorophyll meter reading (SCMR), which are easy to measure, are highly correlated with each other. Both traits have considerable genetic variation in groundnut (Serraj *et al.,* 2004; Upadhyaya, 2005; Lal *et al.,* 2006).

Genetic variability for a trait in available genetic stock is the basic requirement for crop improvement. Effectiveness of selection is dependent upon the nature, extent and

magnitude of genetic variability present in the breeding material for the target trait. Heritability is an important parameter because it determines the response to selection. It is the proportion of phenotypic variance among individuals in a population that is due to heritable genetic effects known as narrow sense heritability while proportion of phenotypic variance that is attributable to an effect for the whole genotype, comprising the sum of additive, dominance and epistatic effects known as broad sense heritability (Nyquist, 1991; Falconer and Mackay, 1996). Heritability and genetic advance are very useful biometrical tools for breeders in determining the direction and magnitude of selection. High heritability alone is not enough to make efficient selection in the advanced generations and unless accompanied by substantial amount of genetic advance. Correlation measures the level of dependence among traits, but it is often very difficult to determine the actual mutual effects among traits if correlation values are similar for certain pairs of traits, direct effects for some of them and especially indirect effects via other traits can differ for some traits (Ikanovic *et al.,* 2011; Vaithiyalingan, 2016). Path coefficient analysis is very important technique for partitioning the correlation coefficient in to direct and indirect effect of independent variables on dependent variable. Path coefficient analysis takes into account the casual relationship in addition to degree of relationship (Mahajan *et al.,* 2011). The present study was undertaken using 20 diverse groundnut genotypes to estimate genetic variability parameters including genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2), genetic advance (GA), genetic advance as percentage of mean (GAM), trait associations and path coefficient for yield and physiological traits in groundnut.

MATERIALS AND METHODS

The experimental material consisted of 20 genotypes including five Spanish and 11 Virginia advanced breeding lines with four high yielding popular groundnut varieties *viz.,* GG 7, TG 37A, GG 20 and Somnath. The experiment was laid out in a randomized complete block design with three replications during *kharif* 2012 at ICAR-Directorate of Groundnut Research, Junagadh, Gujarat (Lat. 21°31' N, Long. 70°36' E) in medium black calcareous soil. The seeds of each genotype were sown in five row of 5 m length at 45 cm spacing between rows and 10 cm between plants. Recommended package of practices were followed for raising the crop. Supplementary irrigation was given as and when required to protect the crop. Chemical spraying of insecticide was done to prevent damage from insects-pests as and when required and no control measures were used to control foliar diseases. The observations were recorded on days to flower initiation, days to maturity, 100-kernel weight (g), shelling outturn (%), pod yield (kg/ha), stability of soil plant analytical development (SPAD), Chlorophyll Meter Reading (SCMR) at 45 and 75 days after sowing (DAS), specific leaf area (cm^2/g) at 45 and 75 DAS and rust incidence. Observations on SCMR and SLA were recorded on third leaflets from top on the main stem of five randomly selected competitive plants in each genotype at 45 and 75 days after sowing.

Scoring of the each genotype for rust was carried out at 105 days after sowing. Observations for rust taken through visual score on a modified 1 to 9 point scale as given by Subrahmanyam *et al.* (1995). A disease score of 1 indicates resistance with no or very little disease infection while a score of 9 indicates highly susceptible with >80% severely infected leaves and defoliation in case of LLS, whereas burning like symptoms in case of rust. Observation on yield and its component traits were recorded on ten randomly selected plants in each genotype in each replication except days to flower initiation were recorded on plot basis. The data were subjected to statistical analysis and calculated analysis of variance (Panse and Sukhatme, 1961). Genotypic variance (V_g) and phenotypic variance (V_p) were estimated for the character having significant mean square due to the genotypes. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated formula suggested by Burton (1952). Heritability (h^2) was estimated in broad sense by formula suggested by Lush (1940). Genetic gain (GAM), the per cent expected genetic advance over the population mean, was computed by formula suggested by Johnson *et al.* (1955). Phenotypic (rp) and genotypic (rg) correlations between characters were estimated using the method described by Miller *et al.* (1958). Path coefficient analysis was estimated as per method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance revealed highly significant differences among genotypes for all the traits *viz.,* days to flower initiation, days to maturity, 100-kernel weight, shelling outturn, pod yield, SCMR 75DAS, SLA 45 and 75DAS and rust incidence/resistance except SCMR 45DAS (Table 1) indicating that adequate variability was found in the genotypes studied for these characters because of diverse pedigree of the advanced breeding lines and botanical types. Variability is a pre requisite for any breeding programme for improving the yield and other characters. Therefore, information on phenotypic coefficient of variation and heritability are helpful in prediction of the possible genetic advance by selection of genotypes for a character (Bhagasara *et al.,* 2017). Wider difference and reduction in the mean value of SLA from 45DAS to 75DAS could be due to water deficit stress at this stage resulting in deposition of cuticle wax on the leaf surface that increase leaf thickness and

weight and causes reduced SLA in later stage (Kalaria *et al*., 2017).

Genotypic coefficient of variability estimate offers good implication for genetic potential in crop improvement through selection (Johnson *et al.,* 1955) and it also provides information on genetic variability present in the available genotypes. Results of phenotypic coefficient of variation (PCV) were found higher than genotypic coefficient of variation (GCV) for all the characters (Table 2) indicating the predominant role of environment in the expression of all the characters. High value of PCV than GCV for above characters was also observed by Zaman *et al.* (2011), Vasanthi *et al.* (2015), Patil *et al.* (2015), Bhargavi *et al.* (2016) and Chaudhari *et al.* (2017).

The wider difference between PCV and GCV were observed for pod yield, SCMR 45DAS, SLA 45DAS, SLA 75DAS and rust indicating that these characters were highly influenced by environmental factors. Some characters like days to flower initiation, days to maturity, 100 kernel weight, shelling outturn and SCMR 75DAS showed very low differences between phenotypic and genotypic coefficient of variation suggesting the less influence of environment on the expression of these traits and hence these characters could not be improved much by providing favourable environmental conditions and there would be an opportunity to use these characters in breeding programs for trait improvement. These results are in agreement with those reported by Zaman *et al.* (2011), Bhargavi *et al.* (2016) and Chaudhari *et al.* (2017). GCV values was found to be moderate for 100-kernel weight (19.7), pod yield (18.3), SCMR 75DAS (13.5), SLA 75DAS (12.5) and rust (15.1) while low GCV was found for days to flower initiation (8.9), days to maturity (2.3), shelling outturn (4.9), SCMR 45DAS (3.6) and SLA 45DAS (7.1). Genetic variability is a basic requirement of any breeding programme on which selection acts to evolve superior genotype. Thus, the higher the amount of genetic variation in these characters greater is the scope for its improvement through selection.

High heritability in broad sense was recorded (Table 2) for days to flower initiation (67.9), 100 kernel weight (86.4), SCMR 75DAS (73.6), SLA 75DAS (61.6) and rust (68.8) while moderate heritability was observed for shelling outturn (56.5), pod yield (39.4) and SLA 45DAS (29.8). High heritability increases when the genetic components contribute more to the variation as compared to non-genetic factors i.e., environmental conditions. High heritability of a trait does not mean that the trait is not influenced by environmental condition. Heritability can also change as a result of changes in the environment, migration, inbreeding, or the way in which heritability itself is measured in the population under study (Visscher *et al.,* 2008). Heritability gives an idea about the feasibility of selection. Therefore, high heritability for above characters indicated that genetic component is predominant with less influence by environmental effect and hence selection for these traits may lead to genetic improvement of these characters through selection.

Table 1 Analysis of variance for ten characters in different genotypes of groundnut

Source of variation	Df	DFI	DM	HKW	SOT	PY	SCMR45DAS	SCMR75DAS	SLA45 DAS	SLA75 DAS	Rust
Replication	2	4.31	26.9	26.4	19.9	431608.4	39.8	4.6	278.3	645.3	0.3
Genotype	19	18.85**	34.3*	165.9**	42.8**	399062.5**	17.4	45.7**	1109.9*	1547.8**	3.3**
Error	38	2.56	14.7	8.3	8.8	135445.2	13.6	5.1	490.9	265.2	0.4

*, ** Significant at 0.05 and 0.01 probability levels, respectively. Where, DFI- Days to flower initiation; DM-days to maturity; HKW-100 kernel weight (g);
SOT- Shelling outturn (%); PY- Pod yield (kg/ha); SCMR45 & 75DAS-SPAD Chlorophyll Meter Reading 45 and 75 days after sowing; SLA-Specific leaf area (cm^2/g).

Table 2 Genetic variability parameters for yield and other component traits in groundnut genotypes

Parameters	Mean	Range	CV (%)	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	h^2(%)	Genetic advance	GAM
Days to flower initiation	26.2	22.6-30.0	6.1	8.0	5.4	10.8	8.9	67.9	4.0	15.1
Days to maturity	112.0	104.6-116.3	3.4	21.2	6.5	4.1	2.3	30.9	2.9	2.6
100 kernel weight (g)	36.9	25.1-49.5	7.8	61.0	52.7	21.2	19.7	86.4	13.9	37.7
Shelling outturn (%)	68.8	63.2-75.1	4.3	20.3	11.5	6.6	4.9	56.5	5.2	7.6
Pod yield (kg/ha.)	1620.7	1076.9-2563.1	22.7	223323.7	87896.4	29.2	18.3	39.4	383.2	23.6
SCMR45 DAS	29.1	23.6-32.6	12.6	14.8	1.1	13.2	3.6	7.6	0.6	2.1
SCMR75 DAS	27.5	18.7-33.9	8.2	18.7	13.8	15.7	13.5	73.6	6.6	23.8
SLA45 DAS	204.4	179.3-259.1	10.8	699.3	208.2	12.9	7.1	29.8	16.2	7.9
SLA75DAS	164.8	136.1-238.1	9.8	692.6	426.4	16.0	12.5	61.6	33.4	20.2
Rust	6.5	4.0-8.0	10.1	1.4	1.0	18.2	15.1	68.8	1.7	25.7

CV-Coefficient of variation, PCV-Phenotypic coefficient of variation, GCV-Genotypic coefficient of variation,
h^2- Heritability in broad sense, GAM-Genetic advance as per cent of mean

Genetic advance as per cent of mean indicates the mode of gene action in the expression of a trait, which helps in deciding an appropriate breeding method. Genetic advance as per cent of the mean was found to be high for 100 kernel weight (37.7), pod yield (23.6), SCMR 75DAS (23.8), SLA 75DAS (20.2) and rust (25.7). It indicated that these characters are controlled by additive gene effects and selection could be effective for improvement of these characters in studied genotypes. Genetic advance is a more reliable index for understanding the effectiveness of selection for improvement of traits because these estimates are derived by heritability, phenotypic standard deviation and intensity of selection. Therefore, genetic advance along with heritability gives clear idea about the effectiveness of selection for improving characters (Mandal *et al*., 2017).

High heritability coupled with high genetic advance as per cent of mean and medium genotypic coefficient of variation was observed (Table 2) for 100 kernel weight (86.4, 37.7), SCMR 75DAS (73.6, 23.8), SLA 75DAS (61.6, 20.2) and rust (68.8, 25.7) indicating these characters are least influenced by environmental effect and hence, selection would be rewarding for improving these traits due to additive gene effects. Genetic coefficient of variance estimates along with heritability would provide the best information of the amount of advance to be expected from selection (Burton and Devane, 1953). High heritability with high genetic advance findings for 100 kernel weight was in agreement with Zaman *et al*. (2011), Bhargavi *et al*. (2016), Yusuf *et al*. (2017), Chavadhari *et al*. (2017) and for SLA it was in agreement with Sab *et al*. (2018) and for rust with Chaudhari *et al*. (2017).

High heritability accompanied with moderate genetic advance as per cent of mean was observed for days to flower initiation (67.9, 15.1) indicating that the selection for improvement of this character may be rewarding because both additive and non-additive gene actions play important role in the expression of these traits and improvement can be done through diallel selective mating followed by selection in advanced generations to exploit additive effects. Moderate heritability coupled with high genetic advance as per cent of mean was observed for pod yield (39.4, 23.6). It revealed that pod yield is governed by additive gene effects and low and moderate heritability may be due to the greater effect of environment on expression of trait and therefore selection would be rewarding for improving pod yield in studied genotypes. Results of moderate heritability with high genetic advance for pod yield are in agreement with Chavadhari *et al*. (2017). Moderate heritability accompanied with low genetic advance as per cent was recorded for days to maturity, shelling outturn and SLA 45DAS indicating these traits are highly influenced by environmental effects and governed by non-additive gene action. The traits governed by non-additive gene action can be improved by inter-mating among selected plants in early generation and selection may be practiced in later generations. It provides limited scope for improvement of these traits through selection. Moderate heritability with low genetic advance was also reported by Zaman *et al*. (2011) and Chavadhari *et al*. (2017) for days to maturity and Yusuf *et al*. (2017) and Kademani and Herakal (2017) for shelling outturn. Variability parameters helps in identifying the characters having high response to selection while characters like yield governed by several contributing traits and also have less variability in groundnut. These characters can be improved by indirect selection through identification of component traits. Hence, genotypic and phenotypic correlation coefficients are helpful in identification of these component traits.

In the present study, magnitude of genotypic correlation coefficients were higher than the phenotypic correlation coefficient (Table 3). It revealed that genes governing two traits are similar but the environmental conditions involving the expressions of these traits have a small and similar effect. Genotypic correlation was found more significant than phenotypic correlation indicating that low contribution of environment in the expression of these traits and there would be scope of improving these traits through indirect selection. The results on genotypic correlation coefficients revealed that the pod yield was significant and positive with days to maturity (0.68), 100 kernel weight (0.41), SCMR 45DAS (0.67) while it was significant and negative with days to flower initiation (-0.26) and rust incidence (-0.30). It suggested that pod yield could be improved by simultaneously selecting for long duration, high 100 kernel weight and high SCMR value in the studied groundnut genotypes. Similar findings were also reported for 100 kernel weight and days to maturity (Vasanthi *et al*., 2015; Gaikpa *et al*., 2015; Zongo *et al*., 2017), for rust (Chaudhari *et al*., 2017) and for SCMR (Nigam and Aruna, 2008).

Physiological parameters (SCMR and SLA) also play important roles in disease resistance. SLA is an indicator of leaf thickness, low SLA (thick leaves) usually having higher chlorophyll per unit leaf area and hence a greater photosynthetic capacity. The SCMR is an indicator of the photo-synthetically active light-transmittance characteristics of the leaf, which is dependent on the unit amount of chlorophyll per unit leaf area (chlorophyll density). In general genotypes having dark green leaves are more tolerant to leaf spot and rust. SLA 45DAS had highly significant negative correlation (-0.39) with rust. It revealed that higher leaf thickness reduced the rust incidence. Hence it could be used as a reliable parameter of indirect selection for rust resistance in groundnut. SCMR 45DAS had high significant negative correlation with SLA 45DAS (-0.86) and SLA 75DAS (-0.30) while SCMR 75DAS also had negative highly significant correlation with SLA 45DAS (-0.83) and SLA 75DAS (-0.41). It indicated that SCMR could be used

as a reliable parameter to identify genotypes with low SLA in groundnut. SCMR and SLA were significantly negatively correlated with each other irrespective of the time of observation and therefore can be recorded at any time after 60 days of crop growth (Nigam and Aruna, 2008) and similar findings are in agreement with those reported by Rao et al. (2001) and Upadhyaya (2005). Pod yield exhibited significant positive correlation with SCMR also reported by Sab *et al*. (2018).

Correlation coefficients quantify the associations in magnitude and direction (direct or indirect) in the sum total effects, selection based on this value alone will sometimes be misleading unless the direct effect is very high in the same direction. Study of direct and indirect effects through path analysis is a better tool for identification of component traits. Direct and indirect effects of the different characters on pod yield were worked out at genotypic level (Table 4). The variability explained by path analysis is inversely proportional to the residual effect. Residual effect (0.91) indicated that 9% variability of pod yield was explained by all the traits. Path analysis results revealed that shelling outturn (1.26) had highest positive direct effect on pod yield followed by days to flower initiation (1.0) and 100 kernel weight (0.94) while rust (-1.18) followed by days to maturity (-0.69) and SLA 45DAS (-0.49) exhibited high negative direct effects on pod yield. It clearly indicated that 100 kernel weights had high positive direct effect and highly significant positive correlation with pod yield. Therefore selection for high kernel weight may increase pod yield in studied groundnut genotypes. High positive direct effect on pod yield for shelling outturn was also reported by Zaman *et al*. (2011) and Tirkey *et al*. (2018).

Table 3 Genotypic (lower left) and phenotypic (upper right) correlation coefficient among ten characters of groundnut genotypes

Characters	DFI	DM	HKW	SOT	PY	SCMR45DAS	SCMR75DAS	SLA45DAS	SLA75DAS	Rust
DFI		0.33*	0.04	-0.53**	-0.09	0.05	0.34**	-0.11	0.10	0.00
DM	0.85**		0.31*	-0.40**	0.19	0.20	0.14	-0.19	-0.06	-0.22
HKW	0.13	0.67**		-0.08	0.19	0.39**	0.49**	-0.39**	-0.12	0.09
SOT	-0.82**	-0.47**	-0.07		0.10	0.03	-0.07	0.05	-0.18	0.29*
PY	-0.26*	0.68**	0.41**	0.13		0.20	0.08	-0.04	-0.06	-0.30*
SCMR45DAS	0.46**	1.11	1.79	-0.55**	0.67**		0.32*	-0.76**	-0.19	0.13
SCMR75DAS	0.46**	0.61**	0.57**	-0.16	0.11	1.81		-0.35**	-0.32*	0.21
SLA45DAS	-0.42**	-0.61**	-0.81**	0.55**	0.09	-0.86**	-0.83**		0.24	-0.20
SLA75DAS	0.17	-0.03	-0.17	-0.15	0.01	-0.30*	-0.41**	0.27*		-0.12
Rust	-0.05	-0.31*	0.12	0.29*	-0.40**	0.18	0.25	-0.39**	-0.14	

*, ** Significant at 0.05 and 0.01 probability levels, respectively. Where, DFI- Days to flower initiation; DM-days to maturity; HKW-100 kernel weight (g); SOT- Shelling outturn (%); PY- Pod yield (kg/ha); SCMR45 & 75DAS-SPAD Chlorophyll Meter Reading 45 and 75 days after sowing; SLA-Specific leaf area (cm^2/g).

Table 4 Direct and indirect effects at genotypic level of ten characters to determine the effect of other characters on pod yield of groundnut genotypes

Characters	DFI	DM	HKW	SOT	SCMR45DAS	SCMR75DAS	SLA45DAS	SLA75DAS	Rust	rg
DFI	**1.089**	-0.594	0.120	-1.040	-0.093	-0.012	0.205	0.009	0.055	-0.26*
DM	0.926	**-0.698**	0.627	-0.595	-0.223	-0.016	0.301	-0.001	0.363	0.68**
HKW	0.139	-0.466	**0.941**	-0.083	-0.360	-0.014	0.397	-0.009	-0.136	0.41**
SOT	-0.897	0.330	-0.062	**1.262**	0.111	0.004	-0.271	-0.008	-0.338	0.13
SCMR45DAS	0.503	-0.774	1.684	-0.695	**-0.201**	-0.046	0.423	-0.016	-0.212	0.67**
SCMR75DAS	0.500	-0.425	0.534	-0.199	-0.363	**-0.025**	0.408	-0.021	-0.294	0.11
SLA45DAS	-0.455	0.429	-0.762	0.698	0.174	0.021	**-0.490**	0.014	0.465	0.09
SLA75DAS	0.187	0.019	-0.158	-0.192	0.061	0.010	-0.130	**0.052**	0.161	0.01
Rust	-0.050	0.215	0.108	0.361	-0.036	-0.006	0.193	-0.007	**-1.181**	-0.40**

Residual effect at genotypic level= 0.91, Where, DFI- Days to flower initiation; DM- Days to maturity; HKW- 100 kernel weight (g); SOT- Shelling outturn (%); PY- Pod yield (kg/ha); SCMR45 &75DAS- SPAD Chlorophyll Meter Readings 45 & 75 days after sowing; SLA- Specific leaf area (cm^2/g), rg- Genotypic correlation

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Morphological characterization and genetic diversity of linseed (*Linum usitatissimum* L.)

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ABSTRACT

Genetic diversity among 34 linseed (*Linum usitatissimum* L.) genotypes were studied using, 18 agro-morphological traits as per the standard descriptors of DUS, UPOV 2011 at the experimental farm of the Department of Crop Improvement, CSKHPKV, Palampur. Six genotypes were found to be distinctive on the basis of morphological traits. Results revealed that sufficient genetic variability was observed for all the characters studied based on various genetic variability parameters. Principal component analysis (PCA) indicated that, out of total principal components, three PCs contributed 71.60% to the total variance amongst the genotypes assessed for nine agronomic traits. PC I contributed maximum towards the variability (36.91%) followed by PC II (22.15%) and PC III (12.54%). Cluster analysis clearly differentiated 34 genotypes into three clusters with cluster III having highest 15 genotypes. Sufficient variability was observed in the genotypes studied based on phenotypic and genotypic variance, principal component analysis and cluster analysis which could be utilized by researchers, in breeding programme and the genetic distinctiveness in the genotypes can be protected under PPVFRA.

Keywords: Characterization, Distinctiveness, *Linum usitatissimum,* PCA

Linseed (*Linum usitatissimum* L. 2n=30) also known as flax is a member of the genus *Linum* in the family Linaceae. Linseed is native to the region extending from the eastern Mediterranean to India and was probably first domesticated in the "Fertile Crescent" region of Western Asia. Two distinct morphological types, namely, flax and linseed, are recognized in this cultivated species. The flax types are primarily grown for extraction of fiber and are tall-growing with straight culms and less number of secondary branches. The linseed types which are predominantly grown in India are meant for extraction of the oil. Linseed containing about 36-40 % oil is the richest (among crop plants) source of polyunsaturated fatty acids (PUFA) essential in the human diet. The oil has drying and hardening properties which emanates from the high linolenic acid (45-60%) content, and therefore it is mostly used for industrial purposes such as manufacturing of paints, varnishes, soaps and printing inks (Wakjira 2007; Biradar *et al.,* 2016), while low linolenic acid content is necessary for its human consumption. The fibre is known for its good quality having high strength and durability, therefore, used in the manufacturing of cloth, water resistant pipes, paper and strawboard.

Despite huge benefits of linseed, it is grown in only 27.3 lakh ha of area in the world with annual production and productivity of 25.2 lakh tonnes and 923 kg/ha, respectively. In India it is grown in 3.23 lakh ha with productivity of 473 kg/ha and production of 1.5 lakh tonnes (Anonymous, 2013). The area under linseed cultivation in Himachal Pradesh is 3000 ha and production is 400 tonnes with an average yield of 225.0 kg/ha (Anonymous, 2013). In Himachal Pradesh, its cultivation is mainly concentrated in the Palam area of Kangra and Mandi districts. The low genetic variability observed in the crop necessitates strengthening of the breeding programmes through introduction of new germplasm, collection of local ecotypes and adopting interspecific hybridization. So, there is an urgent need to characterize and evaluate linseed genotypes to identify donor(s) for different traits and utilizing these genotypes in different breeding programmes. Germplasm serves as the most valuable reservoir in providing needed attributes for developing superior varieties. Characterization involves estimating existing variability across the population of individuals (Franco and Hidalgo 2003; Singh and Tewari, 2016; Singh *et al.,* 2017). Describing the characteristics of a crop species based on standard descriptors is effective for better utilization and conservation of germplasm (Diederichsen and Richards 2003; Kumari *et al.,* 2017). Moreover, morphological characterization studies play an important role in the management of crop diversity. So, it is essential not only to conserve the genotypes but also to explore the gene pool of linseed for breeding purposes. Diversity analysis is an essential process for identification of the genetic relatedness of the available genetic resources. Therefore, present study was taken up for morphological characterization studies and to identify parents to initiate crossing programme and obtain segregating population with wider variability to exercise better selection.

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MATERIALS AND METHODS

Planting material and experimental site: A total of 34 genotypes of linseed were used in the present study (Table 1). All the 34 genotypes of linseed were raised at the experimental farm of the Department of Crop Improvement,

CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.), India, during winter seasons, 2013-14, for recording various morphological characters. The experimental site is located at 1290.8 m msl and at 32°8' N latitude and 76°3' E longitude. Agro-climatically, the location represents the mid-hill zone of Himachal Pradesh (Zone-II) and is characterized by humid sub-temperate climate with high rainfall (2,693 mm). The texture of soils is clay loam to silty clay loam. The reaction of soil is acidic with pH ranging from 5.0 to 5.6.

Experimental design and layout: To characterize the germplasm and study their agro-morphological traits, field studies were conducted during the cropping season 2013-14 in a Randomized Block Design (RBD) with 3 replications. A pre-sowing irrigation was given to ensure proper germination. The experimental field was well prepared and FYM was added before sowing. The recommended dose of fertilizer (50 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha) was applied. Half dose of nitrogen and full dose of phosphorous and potash was applied as basal and the remaining half nitrogen was top dressed after 2 months of sowing. Irrigation was given whenever required and regular weeding was done to keep the trial free from weeds. Observations were recorded visually, on plot basis, in which five random plants from each line for the various linseed descriptors as per DUS UPOV 2011 (Table 2). Data were recorded on five randomly selected plants for all the agronomic traits viz., primary branches per plant, secondary branches per plant, plant height/natural height (the height of plant from the base to the tip of the main stem), technical height/systemic height (the height of the plant from the ground surface to the point from where the primary branches start) capsules per plant, SH (systemic/technical height) /NH (natural/plant height), seeds per capsules, seed weight (1000 seeds) and oil content. Nine descriptors of linseed (morphological) were also recorded i.e., plant growth habit, petal colour, flower size, flower shape, anther colour, petal aestivation, seed colour, capsule: dehiscence and capsule: shape of tip as per standard descriptors (DUS UPOV 2011; Table 2; Fig. 1).

Statistical Analysis: The data analysis for various agro-morphological traits was done as per the standard statistical procedures. Analysis of variance was done as per Panse and Sukhatme (1984); variability parameters were worked out as suggested by Burton and De Vane (1953); Johnson *et al.* (1955). Principal component analysis (PCA) and cluster analysis were performed using XLSTAT software to determine the best relationships among characters and genotypes.

Table 1 List of experimental materials used in the study

Genotype	Source/Pedigree	Genotype	Source/Pedigree
KL-213	Aoyogi × JRF-2	KL-239	Polf-27 × RL-33-4
KL-216	Polf-16 × Surbhi	KL-241	Giza-7 × KLS-1
KL-217	Flak-1× Janaki	KL-241	Gaurav × KLS-1
KL-218	RL-50-3 × RL-33-4	Him Alsi-1	Palampur
KL-219	L-1321 × Flak-1	KL-244	(RLC-29 × Jeevan) × RLC-29
KL-220	89D-2B/4	KL-245	Jeevan × KLS-1
KL-221	89-2B/5	KL-246	Him Alsi-2 × RLC-29
KL-226	Aoyogi × JRF-2	KL-247	Neelam × Nagarkot
KL-227	Flak-1 × Janaki	Jeevan	Sumit × LC-216
KL-228	Polf-22 × KL-31	Surbhi	Palampur
KL-230	Aoyogi × RL-33-4	Himani	Palampur
KL-231	Polf-16 × KL-1	Baner	Palampur
KL-232	Polf-16 × Janki	Belinka	Exotic collection
KL-233	Flax purple × Gaurav	Araine	Exotic collection
KL-234	Polf-22 × Jeevan	Nagarkot	New River × LC-216
KL-236	Jeevan × Janaki	Him Alsi-2	EC-21741 × LC-216
KL-238	Aoyogi × Nagarkot	Binwa	Palampur

Table 2 Characterization of 34 diverse linseed germplasm based on Distinctness (D),Uniformity (U) and Stability(S) as per DUS, UPOV 2011

Trait	Descriptor state	Class or scale of descriptor	Type of assessment	Distribution by classes of descriptor (%)
Plant characteristics				
Plant growth habit	Recorded considering both the angle of the basal branching and the crop canopy.	Erect	VG	7 (21%)
		Semi-erect		10 (29%)
		Spreading		17 (50%)
Plant height	The height of plant from the base, to the tip of the main stem was recorded in centimeters.	Very short (<41cm)	MS	1 (3%)
		Short (41-51 cm)		7 (21%)
		Medium (52-62 cm)		20 (59%)
		Tall (63-73 cm)		4 (11%)
		Very tall (>73cm)		2 (6%)
Technical height	The height of the plant from the base, to the point from where the primary branches start was recorded in centimeters.	Very short (< 26 cm)	MS	4 (12%)
		Short (26-36.5 cm)		28 (82%)
		Medium (36.51- 47.5 cm)		2 (6%)
		Tall (47.51-58.50 cm)		-
		Very tall (>58.5 cm)		-
SH/NH	It is recorded at the maturity time.	Oil type (< 0.75 cm)	MS	34 (100%)
		Fibre type (> 0.75 cm)		-
Primary branches per plant	The numbers of branches emerging from the main stem were counted for each plant at harvest maturity.	Some (< 7)	MS	1 (3%)
		Many (7.0- 13)		27 (79%)
		Too many (> 13)		6 (18%)
Secondary branches per plant	The numbers of branches arising from primary branches in selected plants of each genotype were recorded at harvest maturity.	No or one (Zero/1)	MS	-
		Few(1.1-3)		-
		Some (3.1-7)		1 (3%)
		Many (7.1-11)		16 (47%)
		Too many (> 11)		17 (50%)
Capsules per plant	The total numbers of capsules in the plant were counted at harvest maturity.	Low (< 30)	MS	-
		Medium (30.0–40)		7 (21%)
		High (> 40)		27 (79%)
Flower Characteristics				
Flower shape	It is recorded at the beginning of flowering time.	Funnel	VG	2 (6%)
		Star		1 (3%)
		Disk		31 (91%)
		Tubular		-
Flower size	It is recorded at the peak flowering time.	Small (<20mm)	VG	-
		Medium (20-25mm)		28 (82%)
		Large (>25 mm)		6 (18%)
Petal: colour of corolla	It is recorded at the peak flowering time.	White	VG	5 (15%)
		Light blue		-
		Lilac		-
		Blue		22 (65%)
		Light violet blue		7 (20%)
		Red-violet		-
Petal aestivation	It is recorded at the peak flowering time.	Valvate	VG	-
		Semi-twisted		-
		Twisted		34 (100%)
Anther colour	It is recorded at immediately after flower opening.	Yellowish	VS	5 (15%)
		Pinkish		-
		Greyish		-
		Bluish		29 (85%)
Seed Characteristics				
Capsule dehiscence	It is recorded at the harvest maturity time.	Dehiscent	VS	-
		Semi- dehiscent		-
		Non - dehiscent		34 (100%)
Capsule :shape of tip	It is recorded as the presence or absence of capsule tip.	Pointed	VG	34 (100%)
		Blunt		-
Seed colour	It is recorded at the harvest maturity time.	White	VG	-
		Yellow		4 (12%)
		Brown		30 (88%)
Seed weight (1000 seeds)	It is recorded at the harvest maturity time.	Very low (< 4 g)	MG	21 (61%)
		Low (4-5 g)		3 (9%)
		Medium (5-6 g)		4 (12%)
		High (6-7 g)		5 (15%)
		Very high (> 7 g)		1 (3%)
Seeds per capsule	It is recorded at the harvest maturity time.	Low (< 8)	MS	22 (65%)
		Medium (8–9)		12 (35%)
		High (> 9)		-
Oil Characteristics				
Oil content	It is recorded at the harvest maturity time.	Very low (< 35 %)	MG	2 (6%)
		Low (35–37 %)		8 (24%)
		Medium (37.01–39 %)		18 (53%)
		High (39.01–42 %)		6 (17%)
		Very high (> 42 %)		-

MG : Measurement by a single observation of a group of plants or parts of plant; MS : Measurement of a number of individual plants or parts of plants; VG : Visual assessment by a single observation of a group of plants or parts of plants; VS : Visual assessment by observation of individual plants or parts of plants.

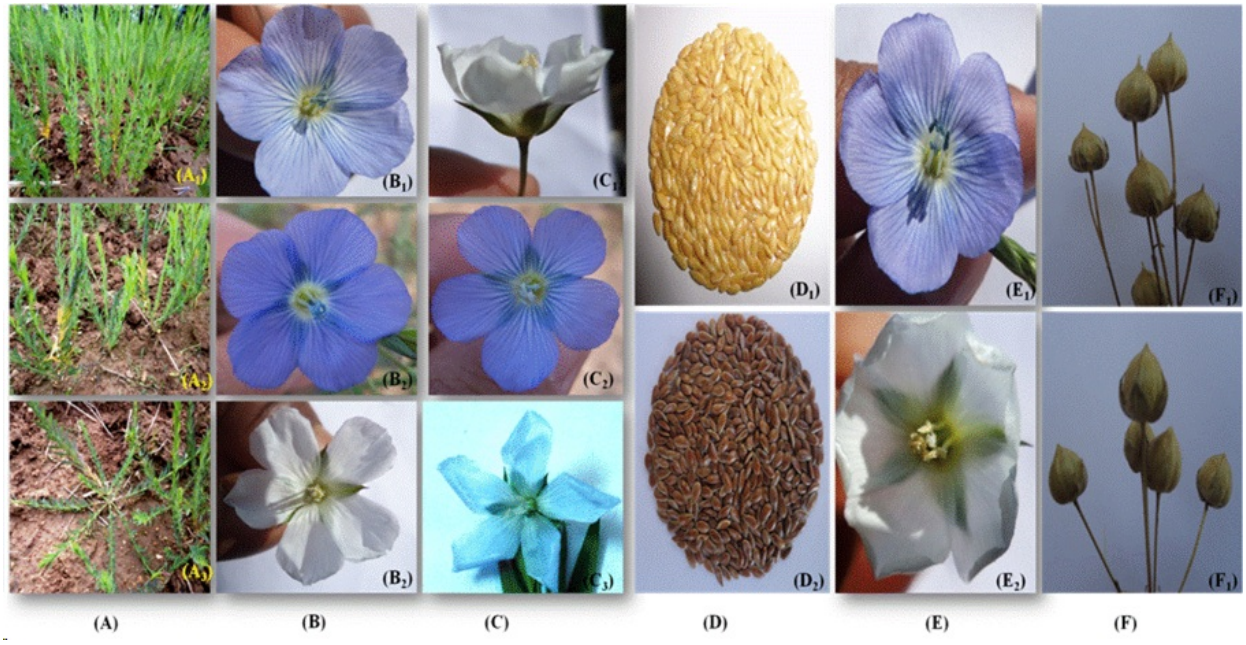

Fig. 1. Morphological characteristics of linseed genotypes

(A) Growth Habit: (A1) Erect type of growth habit; (A2) Semi-erect type of growth habit and (A3) Spreading type of growth habit, (B) Flower Petal colour: (B1) Light violet blue colour petal; (B2) Blue colour petal and (B3) White colour petal, (C) Flower Shape: (C1) Funnel shape; (C2) Disk shape and (C3) Star shape, (D) Seed colour : (D1) Yellow colour seed and (D2) Brown colour seed, (E) Anther colour: (E1) Bluish and (E2) Yellowish and (F) Shape of capsule tip: (F1) Pointed shape and (F2) Blunt shape

RESULTS AND DISCUSSION

For the maximum utilization of germplasm, the information on characterization is essential to select better germplasm. Morphological traits are considered as marker traits in the identification of linseed species and varieties (Fig. 1), which are less influenced by environmental fluctuations. The study of inheritance and linkage for various qualitative characters were carried out by Sood *et al.* (2007) revealed that the seed colour and flower colour were stable characters across the environments. To establish distinctiveness among linseed varieties, 18 traits/ characteristics have been used (Table 2) as per the UPOV 2011 test guidelines for DUS on linseed. Our study revealed that out of 34, seven (21%) linseed varieties exhibited erect whereas, 10 (29%) genotypes had semi-erect type of growth habit and rest of the 17 (35%) genotypes were having spreading type of growth habit. SH/NH ratio is very important to depict, whether the line is of oil type or flax type. From the present study it was observed that all the genotypes were oil type. The primary and secondary branches help in determining the number of capsules on the plant. Out of 34 genotypes, six (18%) and 17 (50%) lines had recorded highest number of primary and secondary branches respectively.

Crop yield depends upon number of capsules per plant. In the present investigation 27 (79%) lines had high and rest of the seven (21%) lines had medium numbers of capsules per plant. One line i.e. Him Alsi-1 had star shaped flowers, two lines i.e. Him Alsi-2 and Surbhi had funnel shaped flowers, while the remaining 31(91%) lines had disk shaped flowers. Six lines (18%) had large flower size and 28 (82%) lines showed medium flower size, indicated that the disk shape of the flower was closely associated with the medium size of the flower. White colour flower petal was observed in five (15%) lines, seven (21%) lines had light blue colour flower petals and rest of the 22 (65%) lines had blue colour flower petals. All the genotypes used in this study were found to have twisted type of petal aestivation. Most of the lines 29 (85%) had bluish anther colour and this hinted at some degree of association with the flower petal colour. Characters *viz.,* capsule dehiscence and shape of capsule tip were found closely associated. All the lines were of non dehiscence nature and had capsules with pointed tip . Thirty (88%) lines were having brown seed coat colour while of the remaining four (12%) lines showed yellow seed coat colour. Tammes (1922) and Shaw *et al.* (1931) have reported that brown seed colour is governed by three dominant genes. Barnes *et al.* (1960) reported that homozygous recessive alleles at any of the three loci were responsible for yellow colour of seed, whereas brown colour of seed was controlled by the presence of at least one dominant allele at all the three *loci*. They found that seed colour of linseed was determined by two or three pairs of complementary genes. Data on 1000 seed weight indicated that 21 (62%) lines were with low weight, three (9%) had low weight, four lines (12%) were

having medium, and five (15%) were having high weight. Only one line had very high (>7 g) weight. Twenty-two (65%) were having low, while rest of the 27 (79%) lines showed medium number of capsules per plant. Six (18%), 18 (53%), 8 (24%) and two (6%) lines had high, medium, low and very low oil content respectively.

Table 3 Characterization of the linseed (*Linum usitatissimum* L.) genotypes

Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
KL-213	S	B	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	M	Sh	Ot	Lo	H	Lo	Lo
KL-216	S	B	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	M	Sh	Ot	Lo	M	H	Lo
KL-217	E	B	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	M	M	Vl	M
KL-218	S	Lvb	M	Ds	T	Bl	Br	P	Nd	Tm	Tm	M	Sh	Ot	Lo	H	Vl	M
KL-219	S	Lvb	M	Ds	T	Yl	Br	P	Nd	Ma	Ma	M	Sh	Ot	M	M	Vl	Lo
KL-220	S	B	M	Ds	T	Bl	Y	P	Nd	Ma	Ma	Vs	Vs	Ot	M	H	H	M
KL-221	S	B	M	Ds	T	Bl	Y	P	Nd	Ma	Tm	Sh	Vs	Ot	Lo	H	Vl	H
KL-226	S	Lvb	L	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	Lo	M	H	M
KL-227	S	B	L	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	M	H	Vl	M
KL-228	S	B	L	Ds	T	Bl	Br	P	Nd	Ma	Tm	M	Sh	Ot	Lo	H	Vl	M
KL-230	S	B	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	M	Sh	Ot	Lo	H	Vl	M
KL-231	Se	B	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	M	M	Vl	Lo
KL-232	Se	B	L	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	Lo	H	H	Lo
KL-233	Se	B	L	Ds	T	Bl	Br	P	Nd	Ma	Ma	Sh	Sh	Ot	Lo	M	Vl	M
KL-234	Se	Lvb	M	Ds	T	Bl	Br	P	Nd	Tm	Ma	M	Sh	Ot	Lo	H	Vl	M
KL-236	S	B	M	Ds	T	Bl	Br	P	Nd	Tm	Tm	M	Sh	Ot	M	H	Vl	M
KL-238	Se	Lvb	M	Ds	T	Bl	Br	P	Nd	Tm	Tm	M	Sh	Ot	Lo	H	H	M
KL-239	E	B	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	Lo	H	Vl	M
KL-241	E	B	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	Lo	H	Vl	Vl
KL-242	E	B	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	Lo	H	M	Lo
Him Alsi-1	S	W	M	Ss	T	Yl	Br	P	Nd	Ma	Ma	M	Sh	Ot	M	H	Vl	M
KL-244	Se	B	L	Ds	T	Bl	Br	P	Nd	Ma	Ma	M	Sh	Ot	Lo	H	Vl	M
KL-245	Se	B	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	Sh	Sh	Ot	Lo	M	Vl	M
KL-246	S	W	M	Ds	T	Yl	Br	P	Nd	Ma	Tm	Sh	Vs	Ot	M	H	M	H
KL-247	Se	B	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	Sh	Sh	Ot	Lo	H	Vl	H
Jeevan	E	Lvb	M	Ds	T	Bl	Br	P	Nd	Ma	Ma	T	M	Ot	Lo	H	Vl	M
Surbhi	S	W	M	Fs	T	Yl	Y	P	Nd	Tm	Tm	Sh	Vs	Ot	M	H	M	H
Himani	S	B	M	Ds	T	Bl	Br	P	Nd	So	So	T	Sh	Ot	Lo	H	Vl	Low
Baner	S	B	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	M	Sh	Ot	M	H	Vl	Low
Belinka	S	W	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	Vt	M	Ot	Lo	H	M	Vl
Araine	E	Lvb	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	T	Sh	Ot	Lo	H	Lo	M
Nagarkot	Se	B	M	Ds	T	Bl	Br	P	Nd	Ma	Tm	T	Sh	Ot	M	H	Vh	H
Him Alsi-2	E	W	M	Fs	T	Yl	Br	P	Nd	Ma	Tm	T	Sh	Ot	Lo	H	Lo	M
Binwa	Se	B	M	Ds	T	Bl	Y	P	Nd	Tm	Tm	M	Sh	Ot	M	H	Vl	H

1.Plant growth habit; 2. Petal : colour of corolla; 3. Flower size; 4. Flower shape; 5. Petal aestivation; 6. Anther colour; 7. Seed colour; 8. Capsule: Shape of tip; 9. Capsule dehiscence; 10. Primary branches per plant; 11. Secondary branches per plant; 12. Plant height (cm); 13. Technical height (cm); 14. SH/NH; 15. Seeds per capsule; 16. Capsules per plant; 17. 1000 seed weight (g); 18. Oil Content (%) S = spreading, E = Erect, Se = semi-erect, B = blue, Lvb = light violet blue, W = white, M = medium, L = large, Ds = disk shape, Ss = star shape, Fs = funnel shape, T = twisted, Bl = bluish, Yl = yellowish, Br = brown, Y = yellow, P = pointed, Nd = non - dehiscent, Ma = many, Tm = too many, So = some, T = tall, Vt = Very Talll, Vs = very short, Sh = short, Ot = oil type, Lo = low, H= high, Vl = very low, Vh = very high

Parameters of variability: The analysis of variance (ANOVA) showed significant differences among the genotypes for all the characters studied (Table 4), indicating considerable amount of variation among the genotypes. Similar results were also observed by Bibi *et al.* (2013) for plant height (cm), number of branches per plant, number of capsules per plant and 1000 seed weight (g). The results of genetic variability parameters are presented in Table 5. The results revealed that phenotypic variance was higher than the genotypic variance (GV) for all the characters studied, indicating that the characters under study were influenced by the environment. Therefore, selection based on the phenotype alone cannot be effective for the improvement of these characters. The results are in accordance with the findings of Dayal *et al.* (1975); Kumar *et al.* (2012). Similar findings were also reported by Akbar *et al.* (2003). The coefficient of variation (CV) studies indicated that the wide range of CV was observed for all the traits and found to be maximum for number of capsules per plant (13.79%) followed by plant height and secondary branches per plant suggesting the scope that exists for selection for these traits. Earlier, high coefficient of variation for seed yield per plant and number of secondary branches per plant (Kumar *et al.* 2016; Kanwar *et al.,* 2014; Belete and Yohannes 2013) and seed yield (Tewari *et al.,* 2012, Chauhan *et al.,* 2012 and Nagaraja *et al.,* 2009) have been reported.

Principal component analysis: Principal factors were identified by using principal component analysis (PCA) for factor extraction. Differentiation among populations occurs in stages, or in other words in different axes of differentiation which accounts for total divergence. Theoretically as many as axes of differentiation can be envisaged as there are characters contributing to total variation, but usually that is not observed. It is possible that most of the variations is accounted for by the first two or three axes of differentiation. In the present investigation, all the three principal components showed Eigen values more than one and cumulatively they explained 71.60 % variability (Table 6). The first principal component explained 36.91% of the total variation followed by second and third principal components i.e. 22.15% and 12.54% variation, respectively. In first principal component, characters such as plant height, technical height and SH/NH had relatively higher contributions to the total morphological variability. Important contribution of first PCs in total variability was also reported by Paul *et al.* (2017) for primary branches per plant, secondary branches per plant, capsules per plant, seeds per capsule, biological yield, fiber yield and seed yield per plant. The first two principal components biplot including loadings of the various characters along with the genotypes spread over is given in Fig. 2. This figure indicates that the PCA showed a clear differentiation between most of the linseed genotypes from each others.

Cluster analysis: Cluster analysis showed 34 genotypes of linseed differentiated into three clusters (Fig. 3; Table 7). Each cluster contained genotypes that were highly similar. Cluster I consisted of 14 genotypes, cluster II of 05 and cluster III of 15 genotypes. Different clustering patterns were also reported in linseed by some earlier workers (Fulkar *et al.,* 2007; Srivastava *et al.,* 2009; Kandil *et al.,* 2011). Mean value for each cluster (Table 8) revealed that genotypes in cluster I had highest values for plant height followed by capsules per plant and oil content, cluster II showed highest values for plant height followed by capsules per plant and technical height and cluster III showed highest value for capsule per plant, plant height, oil content and technical height. Cluster analysis revealed wide range of genetic divergence, which is useful for future hybridization breeding programme for getting desirable transgressive segregants.

Table 4 Analysis of variance for various agronomic traits of linseed

Traits	Mean Squares		
	Source	Genotypes	Error
	df	33	66
Primary branches per plant		1.77**	0.29
Secondary branches per plant		1.75**	0.23
Plant height (cm)		140.34**	33.05
Technical height(cm)		55.73**	3.86
SH/NH		1.25**	0.22
Seeds per capsule		0.7**	0.05
Capsules per plant		63.81**	16.14
1000-seed weight (g)		2.04**	0.05
Oil content (%)		10.23**	0.47

**Significant at 1 per cent level

Table 5 Genetic variability for various agronomic traits in 34 linseed genotypes

Characters	Range		Mean	PV	GV	CV (%)	CD
	Min.	Max.					
Primary branches per plant	6.40	14.4	10.99	4.01	3.09	8.70	1.56
Secondary branches per plant	6.70	17.13	11.47	6.84	5.68	9.40	1.76
Plant height	40.10	75.57	57.05	79.78	50.01	9.57	8.89
Technical height	19.20	45.33	29.91	31.99	24.72	8.99	4.39
SH/ NH	0.48	0.61	0.53	0.56	0.34	8.63	0.08
Seeds per capsule	7.00	8.70	7.81	0.25	0.18	3.32	0.42
Capsules per plant	31.73	75.73	47.51	146.63	103.62	13.79	10.69
1000 seed weight	1.76	7.17	4.18	2.19	2.17	3.88	0.26
Oil content (%)	33.19	41.15	37.55	3.58	3.07	1.90	1.16

PV: Phenotypic variance; GV: Genotypic variance; CV: Coefficient of variation; CD: Critical difference

Table 6 Eigen-vectors and eigen-values of three principal components for nine traits linseed genotypes

Parameter	1 vector	2 vector	3 vector
Eigen value (root)	3.32	1.99	1.13
% Variation expected	36.91	22.15	12.54
Cumulative variation expected	36.91	59.06	71.60
Primary branches per plant	-0.32	0.31	0.22
Secondary branches per plant	-0.31	0.48	0.04
Plant height (cm)	0.35	0.47	-0.01
Technical height	0.43	0.40	0.05
SH/NH	0.46	0.09	0.13
Seeds per capsule	-0.22	-0.11	0.61
Capsules per plant	-0.26	0.45	-0.43
1000 seed weight (g)	-0.11	0.26	0.57
Oil content (%)	-0.40	0.02	-0.24

Table 7 Clustering pattern of 34 linseed genotypes

Clusters	No. of Genotypes	Genotypes
I	14	KL-216, KL-217, KL-219, KL-220, KL-226, KL-227, KL-228, KL-231, KL-233, KL-238, KL-241,KL-242, KL-245, KL-246
II	5	Him Alsi-1, Jeevan, Himani, Belinka, Him Alsi-2
III	15	KL-213, KL-218, KL-221, KL-230, KL-232, KL-234, KL-236, KL-239, KL-244, KL-247, Surbhi, Baner, Araine, Nagarkot , Binwa

Table 8 Mean values of different clusters for 9 agronomic traits

Cluster	Cluster I	Cluster II	Cluster III
Primary branches per plant	8.90	6.40	11.77
Secondary branches per plant	8.20	6.70	11.90
Plant height (cm)	53.40	64.03	58.70
Technical height	27.03	36.40	31.03
SH/NH	0.51	0.57	0.53
Seeds per capsule	8.07	7.43	7.73
Capsules per plant	42.03	45.00	59.83
1000 seed weight (g)	3.58	1.76	3.41
Oil content (%)	37.47	35.48	37.25

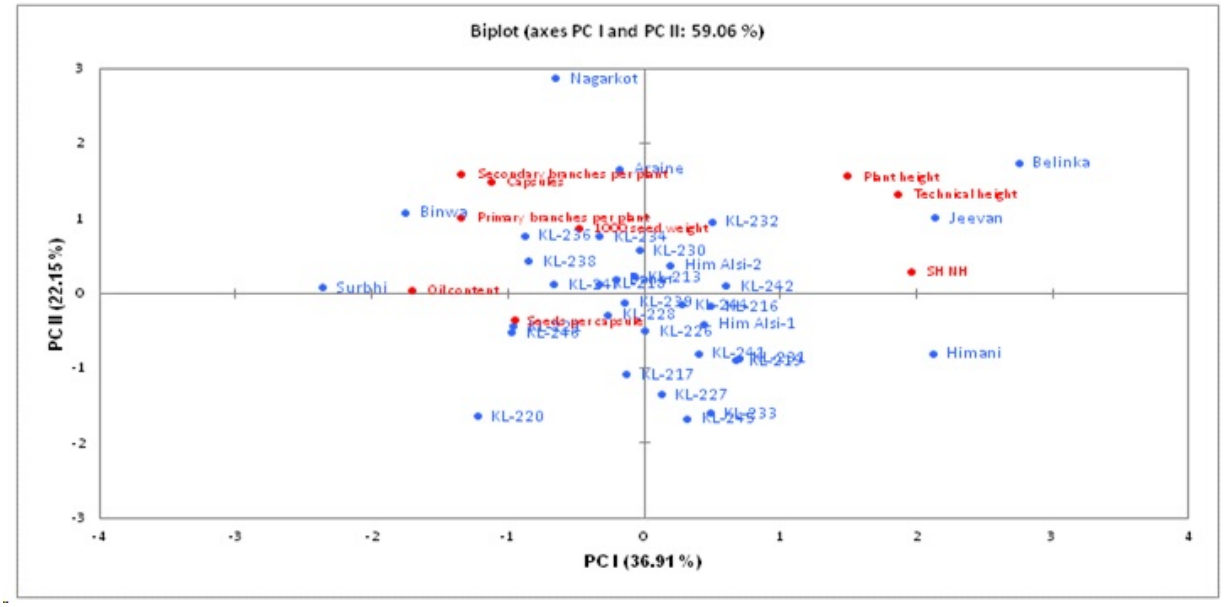

Fig. 2. Biplot of 34 genotypes of linseed on Principal Component axis I and II

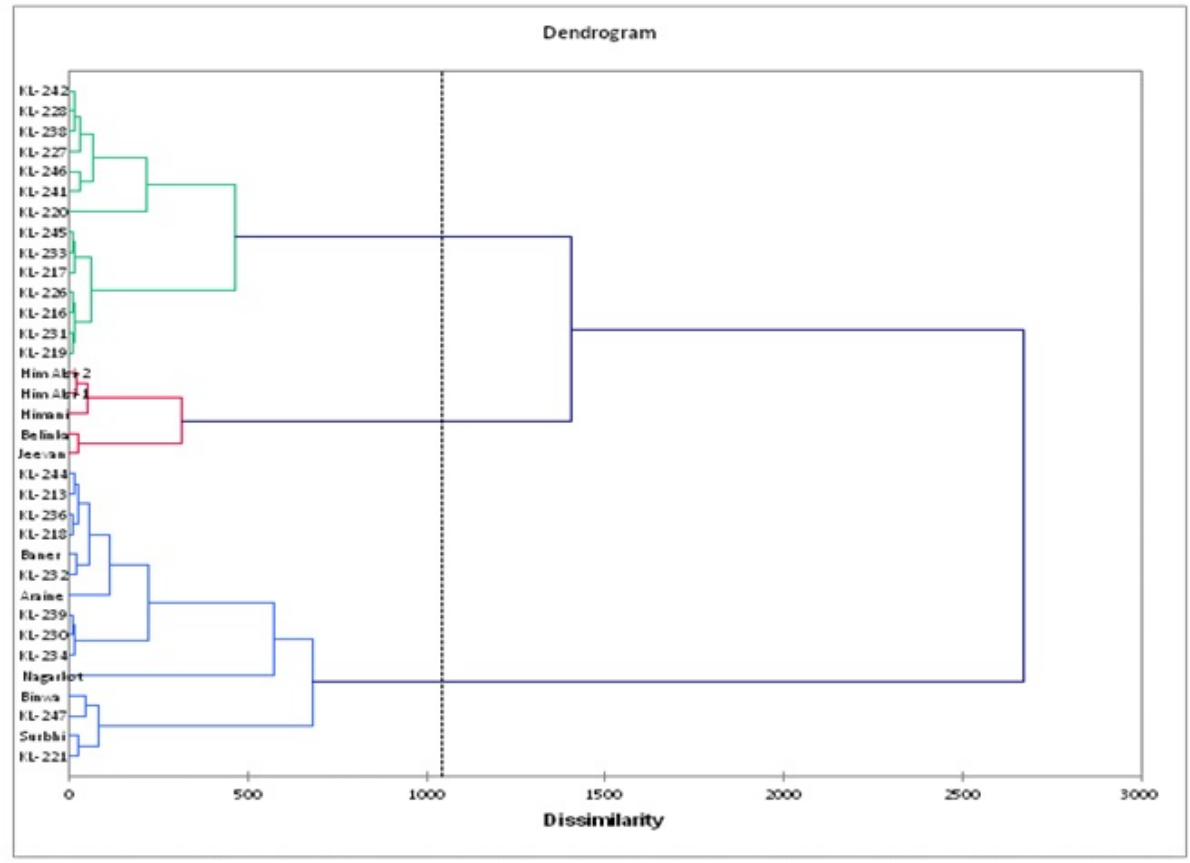

Fig. 3. Dendrogram depicting relationships among the linseed genotype for nine agronomical traits

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Effect of different sowing schedule and crop geometry on productivity and profitability of Indian mustard (*Brassica juncea* L.)

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ABSTRACT

A field experiment was conducted during three consecutive *rabi* seasons of 2014-15 to 2016-17 to study the effect of different sowing dates and crop geometry on productivity and profitability of Indian mustard (*Brassica juncea* L.) at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar in the north-Gujarat agro-climatic region. The experiment was laid out in split plot design with 3 sowing dates and 5 planting geometry replicated thrice. Results revealed that sowing of mustard crop in the second fortnight of October during all three years produced significantly higher seed yield (1882 kg/ha). Among the planting geometry, significantly higher seed yield, was recorded with 30 cm × 10 cm followed by 45 cm × 15 cm as compared to rest of the spacing. Similar trend followed for net returns and B: C ratio.

Keywords: Indian mustard, Planting geometry, Sowing dates, Yield

Rapeseed-Mustard is a major oilseed crop of the country. In India, rapeseed-mustard is grown over an area of about 6.07 million hectare with an annual production of 7.9 million tonnes during 2016-17 (Anonymous, 2017). In Gujarat, the crop is grown in an area of 0.22 million hectares with an annual production of 0.40 million tonnes (Anonymous, 2018). India occupies a prestigious position both in acreage and production of oilseed map of the world, but there is a huge gap between production potential and actual realization (Mukherjee, 2016; Chouksey *et al.,* 2016). Among the agronomic factors sowing time and spacing are well-known to play important roles in productivity (Kumar *et al.,* 2017; Vaghasia *et al.,* 2017). Therefore, the present investigation was carried out to study the appropriate sowing time with optimum planting geometry for Indian mustard in north Gujarat agro-climatic region.

MATERIALS AND METHODS

The field experiments were conducted during three consecutive *rabi* seasons of 2014-15 to 2016-17 at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India. The soil of the experimental field was sandy loam in texture, low in organic carbon, available nitrogen and potassium, and medium in phosphorus. The experiments were laid out in split plot design with three dates of sowing (Table 1) in main plots *viz*., D_1: second week of October, D_2: 10 days after first date of sowing and D_3: 10 days after second date of sowing and each main plot were further divided in five sub plots to accommodate planting geometry *viz.,* S_1: 30 × 10 cm, S_2: 30 × 20 cm, S_3: 45 × 15 cm, S_4: 45 × 30 cm and S_5: 60 × 15 cm with three replications.

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Indian mustard variety GM-3 was grown as per scheduled date and respective spacing of the treatments. The recommended dose of fertilizer of N_{50}, P_{50}, and S_{40} kg/ha for mustard crop was applied. Full dose of P and S with half dose of nitrogen fertilizers were drilled just before the sowing as a basal application through urea, DAP and elemental sulphur and remaining half dose of nitrogen were applied at 25-30 DAS after thinning operation. Need based irrigation was given. Lower to moderate infestation of mustard aphid was observed which was managed through insecticide spray. The total rainfall received during crop growth period was 628.5 mm (26 rainy days); 931.2 mm (17 rainy days) and 585.4 mm (31 rainy days) during 2014-15, 2015-16 and 2016-17, respectively. The observations pertaining to various growth parameters, yield attributes and yield were recorded at harvest on the basis of 5 randomly selected plants from every plot. Economics was computed using the prices of inputs as per prevailing local market rates and minimum support price of mustard seed. The benefit: cost ratio was calculated by using gross return divided by total cost of cultivation involved. The standard analysis of variance (ANOVA) technique prescribed for the split plot design was performed to compare the treatment means for each year separately and was pooled. Treatment means were compared at the 5% level of significance (P=0.05) using least significant difference (LSD) and hence results based on pooled analysis are presented here to draw logical inferences.

RESULTS AND DISCUSSION

Crop growth and yield attributes: The pooled analysis of the growth and yield attributes of Indian mustard was not influenced significantly due to different sowing schedule (Table 2). Only insignificant improvement was associated with second date of sowing in respect to plant height, number

of primary branches/plant, number of siliquae/plant and test weight over remaining sowing dates. However, planting geometry significantly influenced the number of primary branches/plant and number of siliquae/plant. Wider spacing of 60 × 15 cm produced 13.1% and 23.6% higher number of primary branches/plant and number of siliquae/plant over the recommended spacing of 30 cm × 10 cm. Concomitant increase in yield attributes with widening of row spacing from 30 cm to 60 cm may be due to lesser competition for resources exploitation among plants (Shivani and Kumar, 2002) which led to increased branches and siliquae/plant. These results are in accordance with the findings of Lakra *et al*. (2018). However, plant height, number of seeds/siliqua, length of siliqua and test weights remained unaffected due to planting geometry

Oil content and oil yield: Although the oil content remained the same over sowing schedules (Table 2) significantly higher oil yield was recorded in second date of sowing due to higher seed yield. However, different planting geometry showed significant influence on oil content and oil yield. Significantly higher oil content and its yield was observed under narrow spacing 30 × 10 cm over rest of the spacings but it remained statistically on par with 30 × 20 cm spacing with regard to oil content only. These results are in accordance with the findings of Singh *et al.* (2018).

Yield: Seed yield of Indian mustard was significantly influenced by various sowing schedule and planting geometry (Table 3). Sowing (D_2) 10 days after first sowing (second fortnight of October) significantly out yielded (1882 kg/ha) other dates of sowing (D_2). The higher seed yield with early sowing could be attributed to its beneficial influence on yield attributes because the crop has longer growth period and favourable soil moisture and temperature during crop growth period. The results of present study were also supported by the earlier findings of Alam *et al.* (2015) in mustard. However, mustard grown at 30 × 10 cm and 45 × 15 cm remained statistically at par with each other but maintained their significant superiority over the rest of the wider spacing treatments in respect of seed yield. These findings were in conformity with those of Khajuria *et al*. (2017) and Lakra *et al*. (2018).

Economics: Higher gross returns, net returns and benefit: cost ratio was recorded with second date of sowing (D_2). Mustard sown during second fortnight (D_2) of October earned maximum net profit of ₹ 46737/ha, which was 17.0 and 29.8% higher over the net returns values of earlier (D_1) and later sown (D_3) crop (Table 3). Mustard sown at 30 × 10 cm obtained higher gross returns, net returns and B:C ratio and it remained statistically on par with 45 × 10 cm. Similar results have also been earlier reported by Lakra *et al.* (2018) and Singh *et al.* (2018).

It could be concluded that mustard crop should be sown during second fortnight of October at a spacing of either 45 cm × 15 cm or 30 cm × 10 cm for achieving higher yield and monetary returns under North Gujarat agro-climatic region.

Table 1 Treatment wise sowing dates of mustard during three consecutive seasons

Sowing schedule	2014-15	2015-16	2016-17
D_1	10-10-2014	09-10-2015	14-10-2016
D_2	20-10-2014	19-10-2015	24-10-2016
D_3	30-10-2014	29-10-2015	03-11-2016

Table 2 Effect of date of sowing and planting geometry on yield attributes, oil content and oil yield of Indian mustard (Pooled data of 3 years)

Treatments	Plant height (cm)	No. of Primary branches per plant	No. of siliquae per plant	No of Seeds/ siliqua	Length of siliquae(cm)	Test weight (g)	Oil Content (%)	Oil yield (kg/ha)
Date of sowing (D)								
D_1: Second week of October	170	4.35	289	13.2	4.09	5.17	37.53	635.4
D_2: Subsequent date after 10 days	175	4.66	303	13.0	4.03	5.18	38.35	720.5
D_3: Subsequent date after 10 days	175	4.42	286	13.3	4.01	4.90	38.15	607.4
SEm±	2.53	0.09	5.23	0.21	0.09	0.11	0.25	17.60
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	54.22
Planting geometry (cm)								
S_1: 30 × 10 cm	170.3	4.28	260.6	13.3	4.13	5.16	38.45	726.9
S_2: 30 × 20 cm	172.1	4.33	280.2	13.1	4.05	4.94	38.16	667.1
S_3: 45 × 15 cm	173.6	4.46	298.1	13.0	4.00	5.03	37.77	683.1
S_4: 45 × 30 cm	174.6	4.49	302.7	13.1	4.02	5.28	37.80	603.9
S_5: 60 × 15 cm	176.5	4.84	322.1	13.3	4.02	5.02	37.87	591.1
SEm±	1.80	0.08	4.40	0.17	0.06	0.11	0.16	12.53
CD (P=0.05)	NS	0.22	12.41	NS	NS	NS	0.45	35.31

Table 3 Effect of date of sowing and planting geometry on yield and economics of Indian mustard (Pooled data of 3 years)

Treatments	Seed yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Date of Sowing (D)				
D_1: Second week of October	1698	62810	39929	2.74
D_2: Subsequent date after 10 days	1882	69618	46737	3.04
D_3: Subsequent date after 10 days	1592	58888	36007	2.57
SEm±	37.68	1394.0	1394.0	0.06
CD (P=0.05)	116.09	4295.4	4295.4	0.19
Planting geometry (cm)				
S_1: 30 × 10 cm	1895	70109	46448	2.96
S_2: 30 × 20 cm	1750	64742	41081	2.74
S_3: 45 × 15 cm	1810	66965	44299	2.95
S_4: 45 × 30 cm	1600	59196	36530	2.61
S_5: 60 × 15 cm	1563	57849	36098	2.66
SEm±	31.40	1161.6	1161.6	0.05
CD (P=0.05)	88.51	3274.9	3274.9	0.14

Note: B:C ratio = Gross returns / Cost of cultivation; Selling price of mustard (MSP) ₹ 37/kg

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Effect of sowing windows on growth and yield of groundnut (*Arachis hypogaea* L.) genotypes

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ABSTRACT

In general, groundnut crop is subjected to varied climatic conditions and monsoon vagaries in particular, as it is mostly grown under rainfed conditions during *kharif.* It is necessary to select a suitable groundnut genotype and sowing window as a non-monetary input to reduce the effect of climate on crop yield. Field experiment was conducted at AHRS, Bavikere, UAHS, Shivamogga, to study the influence of sowing windows on growth and yield of groundnut genotypes under rainfed conditions during *kharif,* 2017 in sandy loam soil. Four groundnut genotypes *viz.,* GKVK-5, GPBD-4, G2-52 and TMV-2 and four sowing windows *viz.,* II fortnight of June, I and II fortnights of July and I fortnight of August were selected. The experiment was laid out in Randomized Block Design with factorial concept using two factors, each with four levels replicated thrice. The experimental results revealed that, the genotype GKVK-5 recorded significantly higher pod yield (16.73 q/ha), shelling percentage and kernel yield, followed by G2-52, GPBD-4 and TMV-2. While, the crop sown during II fortnight of June recorded significantly higher pod yield, shelling percentage and kernel yield compared to other sowing windows, due to increased crop growth parameters. Delayed sowings reduced crop growth and development due to moisture stress, thereby, decreasing the pod yield. However, among the treatment combinations, genotype GKVK-5 sown during II fortnight of June recorded higher pod yield (18.07 q/ha).

Keywords: Genotype, Groundnut, Growth parameters, Sowing windows

Groundnut is an important oilseed crop grown under rainfed conditions. It is a very sensitive crop to climatic variations, especially rainfall, temperature and radiation (Banik *et al.,* 2009; Nithya and Renugadevi, 2017; Meena, 2017). As the crop is grown under rainfed conditions, adequate soil moisture is required during pegging and pod development stages to get better yield. Prathima *et al.* (2012) reported that the photosynthetic activity of the crop is severely affected under moisture stress conditions, which reduces the crop growth and development, thereby, reducing the pod yield. Further, lack of moisture during pegging and pod filling, reduces the number of pods per plant, while that during pod development produces shriveled seeds and thereby, reduces the pod yield. Variation in any of the weather parameters causes reduction in the pod yield.

Thus, it is necessary to grow the genotype which can withstand weather aberrations by adapting to varied sowing windows. Nagaeswara Rao (1992) reported that improved genotypes contribute 25 to 28 per cent to the yield increase and improved management practices contributed 30 to 32 per cent. Hence, an investigation was conducted to study the influence of sowing windows on growth and yield of groundnut genotypes.

MATERIALS AND METHODS

Field experiment was conducted at AHRS, Bavikere, UAHS, Shivamogga during *kharif,* 2017 under rainfed conditions. Soil of the experimental site was sandy loam with acidic pH (5.7), 1.73 g/kg organic carbon, 220.9:34.3:167.4 kg available N, P_2O_5, K_2O/ha. The experiment was laid out in randomized block Design with factorial concept, containing sixteen treatment combinations with three replications. Groundnut genotypes and sowing windows were the two factors, each with four levels. Four genotypes selected were GKVK-5, GPBD-4, G2-52 and TMV-2, while the four sowing windows were II fortnight of June, I fortnight of July, II fortnight of July and I fortnight of August. Nutrients were applied @ 25:50:25 kg N: P_2O_5: K_2O/ha in the form of urea, single super phosphate (SSP) and mureate of potash (MOP) respectively along with 10 tons of farm yard manure. Gypsum was applied during the time of earthing up @ 500 kg/ha. The seeds were sown at a depth of 5 cm with 30 x 15 cm spacing. Data on parameters like number of branches/plant, leaf area (dm^2/plant), total drymatter (g/plant), pod yield (q/ha), shelling percentage were recorded and leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), kernel yield were calculated from the recorded parameters. To provide an idea of edaphic factors that prevailed during the crop growth, the amount of rainfall received during the period and water requirement of the crop at different growth stages are presented in Fig. 1. The actual sunshine hours during the crop growth period and the normal sunshine hours of the research station is presented in Fig. 2.

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RESULTS AND DISCUSSION

Weather data: Weather parameters such as rainfall and sunshine are reported to play a critical role on crop growth, which in turn decides the crop yield. Apart from the total amount of rainfall received, proper distribution of rainfall throughout the crop growth period is also important as seen in Fig. 1. Crop requires 400-500 mm of total rainfall. Among the sowing windows, the crop sown during II fortnight of June received 444.5 mm of total rainfall, which was well distributed in 33 rainy days. Pod filling and pod development stages received 66 mm and 126.6 mm of rainfall, respectively. Data pertaining to the number of branches per plant, total dry matter and CGR are presented in Table 1. The genotype, GKVK-5 recorded significantly higher number of branches per plant (10), total dry matter (12.99 g/plant) and CGR (8.15 g/m/day), which might be due to better morpho-physiological characters of GKVK-5. Similar results were reported by Mohite *et al*. (2017).

Crop growth characters: Among the sowing windows, crop sown during II fortnight of June recorded significantly higher number of branches per plant (11), total dry matter (12.73 g/plant) and CGR (7.93 g/m/day). This might be due to proper distribution of rainfall during critical growth periods of the crop and long day conditions that exposed the crop to better sunlight and for longer duration resulting in more photosynthate production and increased CGR. Exposure of the crop to short day conditions reduces the vegetative growth and thereby reduces CGR (Meena *et al*., 2015). Thus, the crop sown during I fortnight of August recorded lower CGR (6.24 g/m/day). Increase in the number of branches and crop growth rate increased the total dry matter per plant when the crop was sown during II fortnight of June. With the delay in sowing, the number of branches, total dry matter and CGR decreased during I fortnight of July, II fortnight of July and they recorded lowest during I fortnight of August. This was due to moisture stress during late sown conditions. The interaction effect of genotypes and sowing windows revealed that the genotype GKVK-5 sown during II fortnight of June recorded higher number of branches (12/plant), total dry matter (14.76 g/plant) and CGR (9.41 g/m^2/day) compared to other treatment combinations. This might be due to the combination of genetic character and also the optimum weather conditions during the crop growth. Similar results were reported by Mohite *et al.* (2017).

Significantly higher leaf area and LAI (Table 2) were recorded in GKVK-5 (8.85 dm^2/plant and 1.97 respectively) followed by G2-52 (8.59 dm^2/plant and 1.91 respectively), GPBD-4 (8.36 dm^2/plant and 1.86 respectively) and TMV-2 (8.15 dm^2/plant and 1.81, respectively). Increase in leaf area was due to increase in number of branches, which increases the number of leaves per plant. Bhargavi *et al.* (2016) reported increase in leaf area with increase in number of leaves in groundnut with different spacing treatments. Increase in leaf area increases LAI, which further increases LAD and the genotype GKVK-5 recorded significantly higher LAD (60.43 days), which was on par with G2-52 (58.96 days) (Table 2).

The crop sown during II fortnight of June recorded significantly higher leaf area, LAI and LAD (9.11 dm^2/plant, 2.02 and 61.85 days respectively) (Table 2). This was followed by the crop sown during I fortnight of July (8.63 dm^2/plant, 1.92 and 58.27 days respectively), II fortnight of July (8.28 dm^2/plant, 1.84 and 56.37 days, respectively). Delayed sowings reduced the leaf area, LAI and LAD. This might be due to water stress caused by lack of rainfall which decreased from 444.5 mm during II fortnight of June to 236.2 mm during I fortnight of August. As the plant cannot intercept more radiation with shorter days due to delayed sowings, vegetative growth decreases leading to reduced leaf area and thereby, reducing LAI and LAD. Agarwal *et al.* (1996) and Kumar *et al.* (2011) reported reduced duration of vegetative growth with delay in sowings thereby, producing less number of leaves per plant and thus, decreased leaf area due to soil moisture stress than the early sown crop of Niger. Genotype GKVK-5 sown during II fortnight of June recorded higher leaf area (9.27 dm^2/plant), LAI (2.06) and LAD (63.87 days) compared to other treatment combinations.

Table 1 Influence of different sowing windows on number of branches, total dry matter and CGR of groundnut genotypes

Genotypes (G)	Sowing windows (S)														
	Number of branches/plant)					Total dry matter (g/plant)					CGR (g/m^2/day)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
G_1	11.87	10.83	10.53	8.37	1040	14.76	13.55	12.06	11.60	12.99	9.41	8.57	7.47	7.16	8.15
G_2	11.10	10.53	10.07	7.30	9.75	12.11	10.46	9.92	9.84	10.58	7.49	6.31	5.94	5.93	6.42
G_3	11.40	10.77	10.27	7.80	10.06	13.09	12.07	11.40	10.38	11.73	8.20	7.49	7.03	6.31	7.26
G_4	10.33	8.63	9.17	7.27	8.85	10.95	9.89	9.45	9.34	9.91	6.63	5.90	5.62	5.58	5.93
Mean	11.18	10.19	10.01	7.68	9.76	12.73	11.50	10.71	10.29	11.30	7.93	7.07	6.51	6.24	6.94
	SEm±		CD (p=0.05)			SEm±		CD (p=0.05)			SEm±		CD (p=0.05)		
Genotypes	0.11		0.32			0.13		0.37			0.24		0.68		
Sowing windows	0.11		0.32			0.13		0.37			0.24		0.68		
G × S	0.22		0.64			0.25		0.74			0.47		1.36		

G_1 : GKVK-5; G_2 : GPBD-4; G_3 : G2-52; G_4 : TMV-2; S_1 : II fortnight of June; S_2 : I fortnight of July; S_3 : II fortnight of July; S_4 : I fortnight of August
DAS: Days after sowing; NS: Non-significant

Table 2 Influence of different sowing windows on leaf area, LAI and LAD of groundnut genotypes

Genotypes (G)	Sowing windows (S)														
	Leaf area (dm^2/plant)					LAI					LAD (days)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
G_1	9.27	8.81	8.78	8.52	8.85	2.06	1.96	1.95	1.89	1.97	63.87	60.38	60.00	57.49	60.43
G_2	9.10	8.54	7.91	7.88	8.36	2.02	1.90	1.76	1.75	1.86	61.08	57.09	54.08	53.40	56.41
G_3	9.17	8.74	8.45	7.99	8.59	2.04	1.94	1.88	1.78	1.91	62.83	59.63	58.08	55.29	58.96
G_4	8.91	8.44	7.98	7.27	8.15	1.98	1.88	1.77	1.62	1.81	59.62	56.00	53.33	50.83	54.95
Mean	9.11	8.63	8.28	7.92	8.49	2.02	1.92	1.84	1.76	1.89	61.85	58.27	56.37	54.25	57.69
	SEm±		CD (p=0.05)			SEm±		CD (p=0.05)			SEm±		CD (p=0.05)		
Genotypes	0.07		0.19			0.01		0.04			0.59		1.72		
Sowing windows	0.07		0.19			0.01		0.04			0.59		1.72		
G × S	0.13		0.39			0.03		0.09			1.19		3.43		

G_1 : GKVK-5; G_2 : GPBD-4; G_3 : G2-52; G_4 : TMV-2; S_1 : II fortnight of June; S_2 : I fortnight of July; S_3 : II fortnight of July; S_4 : I fortnight of August
DAS: Days after sowing; NS: Non-significant

Yield and yield components: Pod yield was found to be significantly higher in the genotype GKVK-5 (16.73 q/ha) compared to G2-52 (14.29 q/ha), GPBD-4 (12.42 q/ha) and TMV- 2 (10.48 q/ha) (Fig. 3). Increase in pod yield was due to increase in the growth parameters *viz.,* number of branches, total dry matter, CGR, leaf area, LAI and LAD, better translocation of photosynthates to the sink. Thus, variation in the growth parameters varied the pod yield in the studied genotypes. Mohite *et al.* (2017) and Naik *et al.* (2018) also obtained similar results.

The pod yield decreased to 59.63 g per plant with delay in sowing from II fortnight of June to I fortnight of August. The crop sown during II fortnight of June recorded significantly higher pod yield (15.20 q/ha), which was due to favorable weather conditions that prevailed during crop growth period and similar findings were reported by Canavar and Kaynak (2008) and Bala *et al.* (2011). Chandrika *et al.* (2008) reported greater effect of rainfall on vegetative growth of the crop under late sown conditions. Canavar and Kynak (2010) also opined that short-days, lack of rainfall, delayed sowings reduce crop growth by increasing stress and thereby, reduces the pod yield. Early sowing of groundnut rarely experiences moisture stress during reproductive stage, especially pod development stage under normal rainfall distribution and was found to be more beneficial compared to delayed sowings (Patel *et al*., 2013).

Kernel yield depends on the pod yield and shelling per cent. Significantly higher kernel yield was recorded in the genotype GKVK-5 (12.17 q/ha) (Table 3) due to better shelling per cent (72.65). However, higher number of pods per plant was observed in G2-52 (13) and lower in TMV-2 (8). This might be due to the genetic variation of the genotypes (Mohite *et al*., 2017). Kernel yield was found significantly higher when the crop was sown during II fortnight of June (11.93 q/ha) (Table 3) than delayed sowing during I fortnight of August (7.69 q/ha). This was due to the higher pod yield and shelling per cent.

Table 3 Influence of different sowing windows on pod number per plant, shelling per cent and kernel yield of groundnut genotypes

Genotypes (G)	Sowing windows (S)														
	Pod numbers/plant					Shelling per cent					Kernel yield (q/ha)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
G_1	12.39	12.32	10.95	10.23	11.47	74.00	73.33	72.60	70.67	72.65	13.37	13.18	11.59	10.54	12.17
G_2	11.59	10.25	8.88	7.71	9.61	73.33	72.33	71.33	63.00	70.00	10.99	9.58	8.18	6.28	8.76
G_3	14.43	13.97	13.37	11.59	13.34	73.00	72.00	69.33	68.33	70.67	11.81	11.06	9.52	8.13	10.13
G_4	8.55	7.93	7.45	7.00	7.73	72.27	71.67	70.33	61.33	68.90	8.37	7.70	7.10	5.82	7.25
Mean	11.74	11.12	10.16	9.13	10.54	73.15	72.33	70.90	65.83	70.55	11.13	10.38	9.10	7.69	9.58
	SEm±		CD (p=0.05)			SEm±		CD (p=0.05)			SEm±		CD (p=0.05)		
Genotypes	0.19		0.55			0.80		2.31			0.14		0.40		
Sowing windows	0.19		0.55			0.80		2.31			0.14		0.40		
G × S	0.38		1.09			1.60		NS			0.28		0.80		

G_1 : GKVK-5; G_2 : GPBD-4; G_3 : G2-52; G_4 : TMV-2; S_1 : II fortnight of June; S_2 : I fortnight of July; S_3 : II fortnight of July; S_4 : I fortnight of August
DAS: Days after sowing; NS: Non-significant

Thus, it can be concluded that, early sown (II fortnight of June) crop produce higher pod yield due to better vegetative growth, better translocation of photosynthates to the sink and can escape moisture stress conditions during critical growth periods, compared to delayed sowing (I fortnight of August). The genotype GKVK-5 performed better by producing higher pod yield compared to G2-52, GPBD-4 and TMV-2.

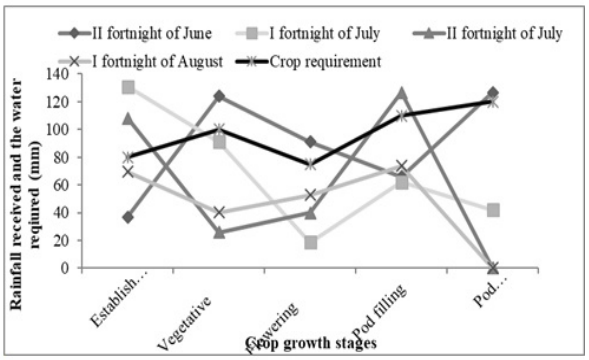

Fig. 1. Water required by the crop and the amount of rainfall received

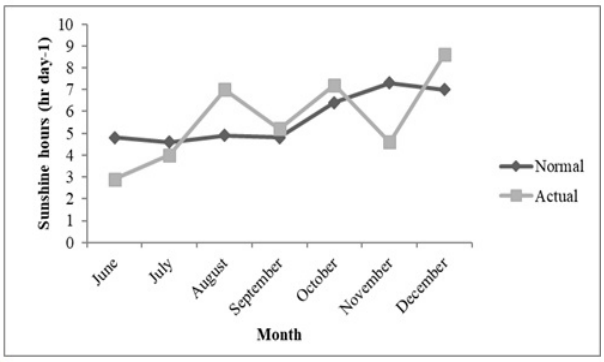

Fig. 2. Actual and normal sunshine hours during the crop growth period during different crop growth stages

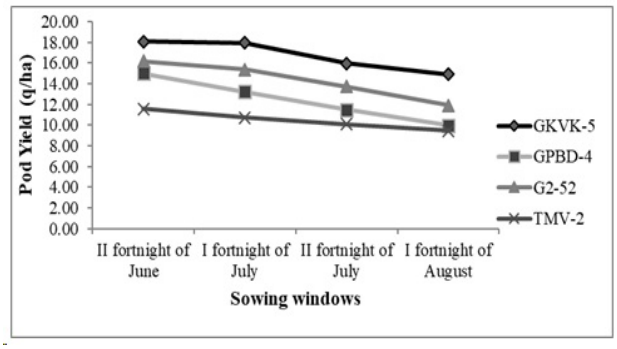

Fig. 3. Influence of different sowing windows on pod yield of groundnut genotypes

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Evaluation of groundnut (*Arachis hypogaea* L.) varieties for drought tolerance under imposed moisture stress conditions

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ABSTRACT

A field experiment was conducted to study growth and yield of groundnut as influenced by moisture stress imposed at different growth stages using rainout shelters under rainfed conditions during *kharif,* 2015-16 at Agricultural Research Station, Ananthapuramu of Andhra Pradesh. The experiment was laid out in a split plot design with four main plot treatments *viz*., M_1: Imposing moisture stress from 30-50 DAS (flowering to pegging), M_2: Imposing moisture stress from 50-70 DAS (pegging to pod formation), M_3: Imposing moisture stress from 70-90 DAS (pod filling to maturity) and M_4: Moisture stress free condition and the subplots comprised of 5 varieties *viz*., K-6, K-9, Anantha, Dharani and Harithandhra. Moisture stress from 70-90 DAS (Pod filling to maturity) recorded highest pod yield reduction followed by stress from 50-70 DAS (pegging to pod formation) and 30-50 DAS (flowering to pegging) compared to stress free condition and thus suggesting that pod filling to maturity stage is the most critical stage. Among varieties K6, Harithandra and Anantha recorded pod yield reduction of 54.0, 53.7 and 49.3 per cent, respectively. K9 and Dharani recorded 39 and 39.7 per cent pod yield reduction. The study indicated that K9 and Dharani are drought tolerant groundnut varieties.

Keywords: Groundnut varieties, Drought tolerance, Moisture stress

Groundnut in India is predominantly grown in Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Odisha and Tamil Nadu, contributing to 80 per cent of total groundnut production in India. It is extensively grown in the semi-arid tropics by resource poor farmers where many abiotic and biotic factors limit its productivity and seed quality. Anantapuram has the largest groundnut area among different districts of Andhra Pradesh. The productivity has declined from about 600 kg/ha in 1971 to 500 kg/ha in 2011. It receives the lowest rainfall of about 553 mm in the state and second lowest in the country after Jaisalmer in Rajasthan. Besides low rainfall, the variability in rainfall distribution is also very high in the district. Crop failures due to failure of monsoon, erratic and scanty rainfall are a regular phenomenon. Major abiotic factor affecting groundnut production is drought. Rainfall is the most significant climatic variable affecting groundnut production, since 70 per cent of crop area is under semi-arid tropics which is characterized by low and erratic rainfall. Efficient soil and water conservation practices have to be adopted for managing the vulnerability in agriculture caused by erratic rainfall and its distribution (Mishra *et al.,* 2002; Sharma *et al*., 2003). Some of the previous studies have shown that the pod yield of groundnut had a curvilinear relationship with rainfall and soil moisture (Anonymous, 2003; Vittal *et al*., 2003; Padmalatha *et al*., 2016; Vaghasia *et al*., 2017). Maruthi Sankar *et al*. (2010) have examined the relationships of monthly rainfall distribution and available soil moisture on different days after sowing with the groundnut pod yields attained in different years under a permanent manurial study in Alfisols. A number of improved groundnut varieties have been released to suit agro-climatic conditions of the States in India (Bhargavi *et al*., 2016). In rainfed agriculture, a need is often felt to identify suitable drought tolerant varieties in groundnut which have a better performance under changing climatic conditions. Accordingly, the present study was conducted with the objective of assessing the impact of dry spells at different growth stages on groundnut productivity and identifying a suitable drought tolerant variety for attaining maximum productivity in an arid Alfisols.

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MATERIALS AND METHODS

A field experiment was conducted to study growth and yield of groundnut as influenced by moisture stress imposed at different growth stages using rainout shelters under rainfed conditions during *kharif*, 2015-16 at Agricultural Research Station, Ananthapuramu of Andhra Pradesh. The soil of the experimental site was red sandy loam with shallow depth, low in organic carbon (0.35%) and low in available nitrogen (142 kg/ha), medium in available phosphorous (32 kg/ha) and potassium (226 kg/ha). The gross plot size of each treatment was 3.0 x 7.0 m. This experiment was laid out in split plot design and not replicated. Main plots consisted of four treatments *viz*., M_1: Imposing moisture stress from 30-50 DAS (flowering to pegging), M_2: Imposing moisture stress from 50-70 DAS (pegging to pod formation), M_3: Imposing moisture stress from 70-90 DAS (pod filling to maturation) and M_4: Moisture stress free condition and sub plots comprised of 5 varieties *viz*., K-6, K-9, Anantha, Dharani

and Harithandhra. Healthy seeds of groundnut varieties with good germination percent (95%) were used for sowing purpose. Sowing of different varieties was taken up as per the treatments. The seeds were sown by dibbling in furrows at a depth of 5 cm. The furrows were covered immediately after sowing and compacted sufficiently for better germination. The recommended dose of 20, 40 and 40 kg N, P_2O_5 and K_2O/ha was applied through urea, single super phosphate and muriate of potash respectively. Two hand weedings were done in inter rows and with hand hoes in the intra rows and all other cultural practices were normal and uniform for all treatments. An amount of 314 mm rainfall was received in 23 rainy days for K6, K9, Ananta and Harithandra when moisture stress imposed from 70-90 DAS (M_3). M_1, M_2 and M_3 treatments were imposed using rainout shelters to avoid rainfall from 30-50 (flowering to pegging), 50-70 (pegging to pod formation) and 70-90 (pod filling to maturation) DAS respectively followed by regular irrigation. In M_4 treatment, moisture stress free condition was maintained by providing irrigation for the entire crop growth period through sprinkler irrigation system whenever needed. An amount of 401 mm rainfall was received in 28 rainy days for K9 and Harithandra in moisture stress free conditions (M_4). Dry matter partitioning, leaf area index (LAI) at 20, 40, 60, 80 and 100 DAS, number of filled pods per plant, 100-pod weight, 100-seed weight, shelling percent, pod weight per plant, pod yield, haulm yield were recorded.

Repeated measures mixed ANOVA was carried out by considering periods (days) as a related factor, moisture stress levels and varieties as independent factors on dry matter partitioning in stem followed by Duncan's Multiple Range Test (DMRT) to identify homogeneous subsets among moisture stress levels and varieties. Further, a two way ANOVA is used to know the impact of moisture stress levels and varieties on number of filled pods followed by DMRT to identify homogeneous subsets among moisture stress levels and varieties with respect to pod yield.

RESULTS AND DISCUSSION

Drymatter partitioning: From the results it was observed that there was significant change in dry matter partitioning to stem at different stages of crop growth due to moisture stress at different stages (DAS) (Table 1). Further, an interaction effect of moisture stress levels at different stages also influenced the dry matter partitioning to stem. Similarly, stem weight was significantly different among five varieties during different stages which supported an interaction effect of moisture stress levels. Further it was also noticed that dry matter partitioning to stem was significantly different among four moisture stress levels in which 'moisture stress free' treatment was deviating significantly from other three levels with the highest partitioning value of 2.438 irrespective of DAS and varieties (DMRT). Among the varieties, Dharani and K9 showed high value of partitioning than that of other three varieties (DMRT). Pod dry weight and leaf area index at different stages were higher under moisture stress free conditions compared to moisture stress at other stages (Table 2). Leaf weight and TDM data are not discussed as these characters were not influenced significantly by the moisture stress.

While analyzing the pod yield data with the help of two way ANOVA, it was noticed that moisture stress levels influenced number of pods significantly at 5% level ($p<0.05$). Among them, moisture stress free and moisture stress from 30-50 DAS showed more number of filled pods than that of moisture stress from 70-90 DAS and moisture stress from 50-70 DAS. And it was observed that the variety Harithandra showed poor number of filled pods when compared to other varieties (Table 3). Moisture stress levels on different varieties of groundnut did not influence 100 pod weight, 100 kernal weight, shelling per cent and pod weight per plant significantly.

Moisture stress from 70-90 DAS (Pod filling to maturity) recorded highest pod yield reduction followed by stress from 50-70 DAS (pegging to pod formation) and 30-50 DAS (flowering to pegging) compared to stress free condition (Table 3). It indicated that pod filling to maturity stage is the most critical stage in groundnut. Among the varieties, K6, Harithandra and Ananta recorded pod yield reduction of 54.0, 53.7 and 49.3 per cent, respectively. K9 and Dharani recorded 39 and 39.7 per cent pod yield reduction. This observation indicated that K9 and Dharani are relatively drought tolerant varieties. Haulm yield of groundnut also behaved similarly with pod yield. Patel and Golakiya (1991) reported greatest yield reduction when water stress was imposed during pod development stage. Groundnut crop is more susceptible to moisture stress from70 days after sowing to harvest (pod initiation to maturity) than at 40-70 DAS (Ramachandrappa *et al*., 1992). Golakiya and Patel (1992) reported that water stress at flowering, pegging, pod development and pod maturation stages reduced the pod yields of groundnut by 26.6, 44.7, 56.3 and 60 per cent respectively. Reddy et al. (2003) observed that one or two supplemental irrigations during the critical stages would increase the pod yield significantly and provide maximum profit.

The present study clearly established that pod filling to maturity stage is the most critical stage with respect to moisture requirement in groundnut and there are genotypic differences for moisture stress tolerance. From among the varieties tested, K9 and Dharani were relatively more drought tolerant compared to K6, Anantha and Harithandra.

Table 1 Drymatter partitioning (g) per plant in leaf and stem of groundnut as influenced by moisture stress imposed during different stages

Main		Leaf dry weight per plant (g)						Stem dry weight (g)					
Moisture stress	Variety	20DAS	40DAS	60DAS	80DAS	100DAS	Mean	20DAS	40DAS	60DAS	80DAS	100DAS	Mean
Moisture stress from 30-50 DAS	K6	0.42	0.68	1.33	3.21	4.02	1.93	0.48	0.72	1.27	2.75	3.39	1.72
	K9	0.55	0.82	1.89	4.31	4.96	2.51	0.51	0.96	2.57	3.15	3.86	2.21
	Anantha	0.51	0.89	1.24	3.98	4.02	2.13	0.45	0.76	1.19	2.70	2.98	1.62
	Dharani	0.59	0.96	1.90	4.33	4.96	2.55	0.53	0.82	2.45	3.83	4.83	2.49
	Harithandra	0.46	0.71	1.21	2.67	3.15	1.64	0.39	0.67	1.05	2.51	2.86	1.50
	Mean	0.51	0.81	1.51	3.70	4.22	2.15	0.47	0.79	1.71	2.99	3.58	1.91 (b)
Moisture stress from50-70 DAS	K6	0.23	0.76	1.57	3.92	4.47	2.19	0.21	0.85	1.79	2.84	4.23	1.98
	K9	0.54	0.82	1.86	4.33	4.93	2.50	0.39	1.16	2.38	3.48	4.96	2.47
	Ananta	0.46	0.83	1.98	4.32	4.67	2.45	0.45	0.95	1.29	3.14	3.87	1.94
	Dharani	0.41	1.05	2.92	3.97	4.62	2.59	0.42	0.81	1.97	2.89	5.03	2.22
	Harithandra	0.49	0.72	0.97	3.13	3.48	1.76	0.39	0.95	1.05	2.03	2.56	1.40
	Mean	0.43	0.84	1.86	3.93	4.43	2.30	0.37	0.94	1.70	2.88	4.13	2.00 (b)
Moisture stress from70-90 DAS	K6	0.52	0.96	2.42	2.60	2.95	1.89	0.50	0.99	1.23	2.47	3.48	1.73
	K9	0.25	0.59	2.16	3.33	3.79	2.02	0.28	0.86	2.88	2.88	3.21	2.02
	Ananta	0.33	0.85	2.75	3.95	4.08	2.39	0.25	0.69	1.06	2.88	2.96	1.57
	Dharani	0.10	0.65	2.86	3.02	3.78	2.08	0.27	0.88	2.02	2.58	3.22	1.79
	Harithandra	0.21	0.76	2.21	2.69	3.95	1.96	0.19	0.67	1.05	1.96	1.97	1.17
	Mean	0.28	0.76	2.48	3.12	3.71	2.07	0.30	0.82	1.65	2.55	2.97	1.66 (b)
Moisture stress free	K6	0.37	0.82	1.42	2.84	3.65	1.82	0.35	0.66	1.97	2.91	4.21	2.02
	K9	0.56	0.68	1.13	5.69	5.96	2.80	0.42	1.13	2.33	5.65	7.66	3.44
	Ananta	0.71	0.98	2.38	5.29	4.90	2.85	0.94	1.05	1.96	4.33	4.86	2.63
	Dharani	0.39	0.64	1.28	2.57	4.65	1.91	0.36	0.73	1.05	2.25	4.71	1.82
	Harithandra	0.55	0.76	1.21	3.24	6.06	2.36	0.41	0.65	1.43	3.67	5.26	2.28
	Mean	0.52	0.78	1.48	3.93	5.04	2.35	0.50	0.84	1.75	3.76	5.34	2.44 (a)
Total	K6	0.39	0.81	1.69	3.14	3.77	1.96	0.39	0.81	1.57	2.74	3.83	1.87 (b)
	K9	0.48	0.73	1.76	4.42	4.91	2.46	0.40	1.03	2.54	3.79	4.92	2.54 (a)
	Ananta	0.50	0.89	2.09	4.39	4.42	2.46	0.52	0.86	1.38	3.26	3.67	1.94 (b)
	Dharani	0.37	0.83	2.24	3.47	4.50	2.28	0.40	0.81	1.87	2.89	4.45	2.08 (a)
	Harithandra	0.43	0.74	1.40	2.93	4.16	1.93	0.35	0.74	1.15	2.54	3.16	1.59 b

*Same alphabet indicates insignificant difference (DMRT)

Table 2 Pod dry weight(g) per plant and leaf area index (LAI) of groundnut as influenced by moisture stress imposed during different stages

Main		Pod dry weight per plant (g)					Leaf area index (LAI)				
Moisture stress	Variety	40DAS	60DAS	80DAS	100DAS	Mean	20DAS	40DAS	60DAS	80DAS	100DAS
Moisture stress from30-50 DAS	K6	0.87	0.87	1.67	1.94	1.34	0.35	0.65	1.00	1.33	2.01
	K9	1.63	1.63	1.89	2.72	1.97	0.35	0.80	1.51	1.69	2.72
	Anantha	1.06	1.06	1.76	1.98	1.47	0.33	0.75	1.21	1.54	2.15
	Dharani	1.39	1.39	2.59	3.41	2.20	0.39	0.94	1.69	1.77	2.86
	Harithandra	0.89	0.89	1.63	1.97	1.35	0.30	0.68	1.12	1.16	1.89
	Mean	1.17	1.17	1.91	2.40	1.66	0.34	0.76	1.31	1.50	2.33
Moisture stress from 50-70 DAS	K6	0.91	0.91	1.46	2.13	1.35	0.26	0.76	1.11	1.46	2.13
	K9	1.40	1.40	2.93	3.97	2.43	0.36	0.66	1.64	1.88	2.48
	Ananta	0.89	0.89	1.73	1.91	1.36	0.23	0.69	1.16	1.56	2.04
	Dharani	1.23	1.23	2.54	3.83	2.21	0.26	0.97	1.46	1.76	2.25
	Harithandra	0.91	0.91	1.04	2.15	1.25	0.27	0.71	0.92	1.34	1.80
	Mean	1.07	1.07	1.94	2.80	1.72	0.28	0.76	1.26	1.60	2.14
Moisture stress from 70-90 DAS	K6	0.87	0.87	1.34	1.54	1.16	0.34	0.71	1.40	1.25	0.56
	K9	1.08	1.08	1.22	2.45	1.46	0.15	0.50	1.53	1.30	0.72
	Ananta	1.27	1.27	2.97	3.68	2.30	0.16	0.62	1.80	1.45	0.81
	Dharani	1.90	1.90	1.98	2.55	2.08	0.11	0.54	1.76	1.31	0.72
	Harithandra	0.99	0.99	1.69	1.61	1.32	0.14	0.62	1.40	1.10	0.58
	Mean	1.22	1.22	1.84	2.37	1.66	0.18	0.60	1.58	1.28	0.68
Moisture stress free	K6	1.46	1.46	2.51	4.23	2.42	0.42	0.87	1.96	2.35	2.79
	K9	0.85	0.85	1.74	2.77	1.55	0.31	0.86	1.96	2.18	2.64
	Ananta	1.56	1.56	3.59	3.81	2.63	0.60	0.82	1.82	2.31	2.62
	Dharani	0.97	0.97	1.83	2.89	1.67	0.21	0.79	1.79	2.06	2.16
	Harithandra	1.58	1.58	3.71	3.73	2.65	0.43	0.86	1.89	2.08	2.58
	Mean	1.28	1.28	2.68	3.49	2.18	0.39	0.84	1.88	2.20	2.56
Total	K6	1.03	1.03	1.75	2.46	1.57	0.34	0.75	1.37	1.60	1.87
	K9	1.24	1.24	1.95	2.98	1.85	0.29	0.71	1.66	1.76	2.14
	Ananta	1.20	1.20	2.51	2.85	1.94	0.33	0.72	1.50	1.72	1.91
	Dharani	1.37	1.37	2.24	3.17	2.04	0.24	0.81	1.68	1.73	2.00
	Harithandra	1.09	1.09	2.02	2.37	1.64	0.29	0.72	1.33	1.42	1.71

Table 3 Yield attributes and yield of groundnut as influenced by different varieties and moisture stress periods

Main		No. filled pods/plant	100 pod weight (g)	100 kernal weight (g)	Shelling %	Pod weight per plant (g)	Pod yield (kg/ha)	Haulm yield (kg/ha)	% decrease of pod yield over control
Moisture stress	Variety								
	K6	11.0	75.7	28.7	59.0	8.5	1638.0	1904.0	-32.0
	K9	16.0	83.5	34.1	63.0	13.1	1733.0	2570.0	-17.0
Moisture Stress from 30-50 DAS	Anantha	11.0	76.8	28.8	59.0	9.2	1614.0	2380.0	-28.0
	Dharani	17.0	87.0	35.0	73.0	13.6	1842.0	2380.0	-16.0
	Harithandra	11.0	78.8	27.6	58.0	9.1	1547.0	2522.0	-27.0
	Mean	13.2 (a)	80.4	30.8	62.4	10.7	1674.8	2351.2	-24.0
	K6	10.0	75.4	24.1	64.0	8.0	1374.0	1935.0	-43.0
	K9	13.0	80.6	29.7	74.0	11.0	1671.0	2856.0	-20.0
Moisture Stress from 50-70 DAS	Ananta	10.0	78.6	21.6	63.0	9.0	1271.0	1666.0	-43.0
	Dharani	14.0	86.1	31.6	72.0	11.0	1694.0	1904.0	-22.0
	Harithandra	9.0	74.1	23.4	59.0	6.0	1123.0	2474.0	-47.0
	Mean	11.2 (b)	79.0	26.1	66.4	9.0	1426.6	2167.0	-35.0
	K6	8.0	56.4	22.0	54.0	5.0	314.0	1975.0	-87.0
	K9	10.0	59.2	21.7	58.0	5.8	412.0	1904.0	-80.0
Moisture Stress from70-90 DAS	Ananta	13.0	60.6	23.1	60.0	7.2	509.0	1428.0	-77.0
	Dharani	11.0	60.4	26.6	63.0	5.9	409.0	1666.0	-81.0
	Harithandra	5.0	54.7	21.2	45.0	3.3	276.0	1904.0	-87.0
	Mean	9.4 (b)	58.3	22.9	56.0	5.4	384.0	1775.4	-82.4
	K6	16.0	87.5	26.0	65.0	12.0	2409.0	2380.0	
	K9	15.0	72.5	28.8	66.0	10.0	2085.0	4284.0	
Moisture stress free	Ananta	18.0	82.5	24.5	53.0	11.0	2237.0	2856.0	
	Dharani	12.0	88.3	29.3	67.0	11.0	2180.0	2618.0	
	Harithandra	12.0	88.6	28.1	61.0	8.0	2110.0	3808.0	
	Mean	14.6(a)	83.9	27.3	62.4	10.4	2204.2	3189.2	
	K6	11.25	73.8	25.2	60.5	8.4	1433.8	2048.5	-54.0
	K9	13.5 (a)	73.9	28.6	65.3	10.0	1475.3	2903.5	-39.0
Total	Ananta	13.0 (a)	74.6	24.5	58.8	9.1	1407.8	2082.5	-49.3
	Dharani	13.5 (a)	80.4	30.6	68.8	10.4	1531.3	2142.0	-39.7
	Harithandra	9.3 (b)	74.1	25.1	55.8	6.6	1264.0	2677.0	-53.7

*Same alphabet indicates insignificant difference (DMRT)

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Effect of organic seed treatment and foliar spray on growth, yield and resultant seed quality in sesame (*Sesamum indicum* L.)

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ABSTRACT

Sesame (*Sesamum indicum* L.) is one of the ancient and most important oilseed crops and its seeds, contain around 50 per cent oil and 25 per cent protein. It is sixth most important oil seed crop in India and has great economic potential due to the possibilities for its exploitation in both the domestic and international markets. The usage of organic inputs is gaining importance nowadays in the context of environmental sustainability. Field experiments were carried out to study the effect of leaf extracts of four plants on seed yield of sesame under rainfed conditions. The seeds of sesame cv. TMV 3 were treated with leaf extracts of pungam (*Pongmia pinnata*), prosopis (*Prosopis juliflora*), arappu (*Albizia amara*) and moringa (*Moringa oleifera*) @ 5% along with foliar spray @10 % at vegetative and flowering stages under rainfed condition along with water sprayed control. The results revealed that pre sowing seed treatment with moringa leaf extract @ 5% + foliar spray of moringa leaf extract @ 10 % at vegetative and flowering stages recorded higher seed yield and better seed quality when compared to other treatments and control.

Keywords: Foliar spray, Leaf extract, Organic seed treatment, Seed yield, Sesame

India has 20.8 per cent of the world's area under oilseeds, but accounts for less than 10 per cent of world's production. Although India is one of the world's largest producers of oilseeds, the quantity of edible fat available is far short of the country's requirement and hence we are the second largest buyer of vegetable oil. Sesame (*Sesamum indicum* L.) is one of the oldest oilseed crops used by man, and it ranks third in area and production of all the oilseed crops in India. It is cultivated in an area of about 15.66 lakh ha with a production of 7.44 lakh tonnes and productivity of about 478 kg/ha (Agricultural Statistics at a Glance, 2017). India ranks first, both in the area and production of the world. India also happens to be one of the largest exporters of sesame (IOPEPC, 2017).

Since the chances for horizontal expansion of cultivable area is very meagre, the only option available is to sustain the crop productivity and farmers income by following improved varieties and agronomic practices (Ramesh *et al*., 2016). Even though we have achieved self-sufficiency in food grains production, particularly in rice and wheat with mounting food stocks, the productivity in pulses and oilseeds is very low leading to import of them to meet the shortages (Govindaraj *et al*., 2016; Krishna Teja *et al*., 2017).

Seed being the basic input in agriculture, production and supply of quality seeds to the farmers is very important to achieve the goal of self-sufficiency in any crop. Out of many constraints regarding low production of sesame, seed quality is of prime importance. Good quality seed is the key for successful agriculture to produce a vigorous seedling ensuring higher yield (Kishore Varma *et al*., 2017). Farmers are also interested in the best seed management practices, which are environmentally safe and sound. Seed treatments with chemicals are commonly used to ensure uniform stand establishment by improving germination and vigour and protecting against soil borne pathogens and insects.

One of the major causes for low yield in sesame is high level of flower shedding. External application of growth regulators reduce flower drop considerably and thereby increases the capsule setting and seed yield. Application of plant growth regulator regulates the excess growth and enhances the flowering and capsule setting by transporting the photosynthates to sink (Stanley and Basavarajappa, 2014). Among the naturally occurring plant growth enhancers, *Moringa oleifera* has attained enormous attention because it is considered to be rich in a variety of natural plant growth regulators such as zeatin which belongs to class of cytokinins and thus can be used as a source of cytokinins. It is also enriched with various macro-nutrients such as phosphorous and potassium along with micro-nutrients (Yasmeen, 2011). Plant growth promoters are usually used for foliar application or for seed treatment. Hence in the present study, effect of the aqueous leaf extracts of various plant leaf extracts were tried for seed treatment combined with foliar spray to evaluate their potency in seed yield and resultant seed quality in sesame cv TMV 3.

MATERIALS AND METHODS

The present study was carried out using genetically pure seeds of sesame (*Sesamum indicum* L) cv. TMV 3 obtained from the Oilseed Research Station, Thindivanam, Tamil Nadu. The experiments were conducted at the Department of Genetics and Plant Breeding, Faculty of Agriculture,

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Annamalai University, Annamalai Nagar (11 24'N latitude and 79°44'E longitude with an altitude of +5.79 mts above mean sea level) during 2016-2018. The bulk seeds were graded for uniformity using appropriate round perforated metal sieves of sizes of 5/64" and imposed with following treatments.

Treatments: There were five treatments: T_0 - Control, T_1- Seed treatment with pungam (*Pongamia pinnata*) leaf extract @ 5% + foliar spray of pungam leaf extract @ 10% at vegetative and flowering stages, T_2 - Seed treatment with prosopis (*Prosopis juliflora*) leaf extract @ 5% + foliar spray of prosopis leaf extract foliar spray @ 10% at vegetative and flowering stages, T_3- Seed treatment with arappu (*Albizia amara*) leaf extract @ 5% + foliar spray of arappu leaf extract @ 10% at vegetative and flowering stages, and T_4 - Seed treatment with moringa (*Moringa oleifera*) leaf extract @ 5% + Foliar spray of moringa leaf extract @ 10% at vegetative and flowering stages.

Preparation of leaf extract: Fresh leaves of the selected plants were collected separately and washed thoroughly using clean water. These leaves were ground well in a manual juicer to extract the leaf juice. The juice collected was filtered by passing through a muslin cloth to remove dregs. Aqueous leaf extract of plants (100%) was diluted with distilled water to prepare a solution of 5% concentration (v/v) for the treatment (Sathiya Narayanan *et al*., 2016; Hala *et al*., 2017) for seed treatment. The ratio of seed weight to solution volume was kept at 1:5 (Farooq *et al*., 2008). After hardening, seeds were given 3 washings with distilled water and re-dried to nearly their original weight under shade (Basra *et al*., 2002). These seeds were used immediately for sowing. The leaf extracts were stored at room temperature for future use.

Field experiment: Field trials were conducted adopting with Randomised Block Design (RBD) with four replications under dry land condition. The experimental plots were with 4m x 4m dimension and maintained with a spacing of 30 cm between rows and within a row. The crop was thinned after one week. Normal agronomic package of practices were followed. The seed treated plants were foliar sprayed with 10% of respective leaf extracts in the early morning with a sprayer (with 20 L vol.) twice at vegetative and flowering stages at 15 days interval (Wasif Nouman *et al*., 2012). To ensure optimal penetration into leaf tissues, 0.1% (v/v) Tween-20 was added to the foliar sprays as a surfactant. From each treatment, 10 plants were selected for taking observations.

Plant height (cm) was measured from the ground level to the tip of the plant at peak vegetative and flowering phases. Total number of branches in each treatment was counted and recorded. Total number of capsules in marked five plants in each treatment. The length and breadth (in cm) of capsule was measured in ten representative plants selected at random in each treatment. The capsules separated from five randomly selected plants were weighed separately in digital balance and the mean weight (g) of capsule/plant was considered.

Test weight (g) was recorded by taking thousand seeds collected from mature capsules. Total chlorophyll content (mg/g) was estimated as per the procedure suggested by Yoshida *et al.* (1971). The leaf area (cm2/plant) of the plants was calculated from selected five plants/plot at peak flowering stage using a portable leaf area meter-AM 300. Seeds from the five marked plants in each plot were collected manually, cleaned, dried to optimum moisture content and weighed to get the mean seed yield/plant (g). The seeds were harvested from each plot, extracted manually, cleaned, dried to optimum moisture content, weighed and expressed as kg/plot. The resultant seed quality characters i.e., germination percentage, shoot length, root length and dry matter production were estimated following the procedure of ISTA (1999), vigour index was worked out as per Abdul-Baki and Anderson (1973). All the data were analysed statistically with appropriate tools and expressed as mean values (Panse and Sukhatme, 1985). Wherever necessary, the percentage values were transformed to angular (arc sine) values, before carrying out the statistical analysis. The critical difference (CD) was worked out at 5 per cent (P = 0.05) level and wherever 'F' value was non-significant, it has been denoted by "NS".

RESULTS AND DISCUSSION

Rapid and uniform field emergence are the two essential pre-requisites to increase the yield. The present study revealed that the seed treatment with moringa leaf extract @ 5% + foliar spray of moringa leaf extract @ 10% at vegetative and flowering stages recorded higher biometric and yield traits when compared to control and other treatments (Tables 2 and 3).

Plant height is very important criterion for a crop in providing more places for flower production leading to fruit production. Increased plant height, number of capsules and yield parameters were observed in seeds treated with moringa leaf extract @ 5% + foliar sprayed with moringa leaf extract (MLE) @ 10 % at vegetative and flowering stages (Table 2). Dawson (1965) observed significant increase in plant height, number of tillers, shoot weight and yield in ragi due to seed hardening with MLE alone. The seedlings sprayed with MLE provided strong and energetic start for earlier emergence and completed the growth improvement actively (Rehman *et al.,* 2014). The effect of MLE solution may be attributed to the presence of growth-promoting substances in MLE extract that enhanced

seed germination and improved seedling growth as reported by Muhammad *et al.* (2013). Paddy seeds hardened with KCl 1% followed by pelleting with pungam leaf powder @ 200 g/kg also recorded increased growth and biometric characters (Prakash *et al*., 2013).

Table 1 Chemical constituents of moringa leaf extract (Yasmeen, 2011)

Component	Mg/g leaves
Amino acid	365.4
Proline	35.2
Total sugars	325.8
Total phenol	4.5
Total flavonoid	8.19
Ascorbic acid	8.10
Hormones (mg/100 g)	
Indole acetic acid	0.62
Gibbereline	6.09
Cytokinin - Kinetin	2.14
Benzyl adenine	0.29
Abscisic acid	0.061

Higher leaf chlorophyll, leaf area and resultant seed quality were also observed in seeds treated with moringa leaf extract @ 5% + foliar sprayed with moringa leaf extract @ 10% at vegetative and flowering stages (Table 3). Increased chlorophyll contents were observed in pungam leaf powder pelleted seeds @ 200 g/kg, due to the presence of mineral nutrients like nitrogen, potassium and calcium which plays a major role in chlorophyll synthesis (Prakash *et al*., 2013; Georgin Ophelia, 2017). The invigorative effect of botanical leaf powders helped the plants to absorb more nutrients from the soil and utilized for more chlorophyll production resulting in enhanced photosynthetic activity of treated plants (Sathiya Narayanan *et al*., 2015). Similarly, increased chlorophyll content with botanicals such as *Argemone mexicana, Calotropis procera, Solanum xanthocarpum,* and *Eichhornia echinulata* were also reported by Rose Rizvi *et al*. (2012). Results of the present study confirmed with the findings of Tetley and Thimann (1974), where they reported that presence of zeatin like cytokinin in MLE extract maintains higher leaf area for photosynthetic activity and leaf chlorophyll content. Fuglie (2000) reported that leaf extracts of *M. oleifera* accelerated growth of young plants, strengthened plants, and increased leaf area. MLE extract contains micro and macro elements and it is also rich in important phyto-hormones such as indole-3-acetic acid (IAA), gibberellins (GAs) and zeatin as a cytokinin. This diverse composition of MLE (Table. 1) indicated that this extract can be used as a plant bio-stimulant (Rehman *et al*., 2014 and Yasmeen, 2011). Presence of cytokinin in MLE solution induces cytokinin biosynthesis which encourages translocation of stem reserves to shoots, prevents premature leaf senescence and also maintains higher leaf area for photosynthetic activity which resulted in higher leaf chlorophyll content (Rady *et al*., 2015).

Higher seed yield in pungam leaf powder pelleted seeds due to the increased activity of dehydrogenase, amylase and peroxidase enzymes by the presence of growth regulators like GA_3 was reported by Shehzad *et al*. (2012). Yameogo *et al*. (2011) found that *Moringa oleifera* extract a rich source of important minerals as Ca, Mg, K, Fe, Zn, P, S, Cu, Mn, Se and Na which boosted plants to accumulate beneficial elements, thereby increased the plant nutrient status. It reflected in increasing photosynthesis and sink capacity with the supply from photo-assimilates from leaves and further translocation resulting in higher yield as reported by Thomas and Howarth (2000). Foliar application of moringa leaf extract, which contains sufficient amount of stimulant substances encouraged cell-division rate, cell-enlargement, eventually resulting in more yield (Fuglie, 2000). Azooz *et al*. (2004) reported that the different concentrations of moringa extract were capable of enhancing the photosynthetic apparatus in treated plant. These results are in agreement with those found by Palada (1996) who reported that yield of peanut, soya beans, sorghum and tomato were significantly increased when treated with foliar application of moringa leaf extract. Caceres (1999) opined that *M. oleifera* extract contains high level of elements and hormones which make it act as growth and yield enhancer. Ascorbate present in MLE helps in maintenance of tissue water contents, increase in antioxidant activities, and carbohydrate metabolism (Farooq *et al*., 2008). MLE is rich in calcium, potassium, ascorbate, zeatin, auxins, and many phenolic compounds that are responsible for enhancement of plant growth and development (Nagar *et al*., 2006).

In present investigation, seed treatment with moringa leaf extract @ 5% + foliar spray of moringa leaf extract @ 10% at vegetative and flowering stages recorded higher seed qualities such as germination, root length, shoot length, dry matter production, vigour index which were 14.47, 19.17, 59.18, 81.81 and 62.99 percentages higher than the control respectively (Table 3). MLE is a rich source of PGR hormone, zeatin, ascorbic acid, Ca, and K (Foidle *et al.,* 2001), which are involved in several plant growth and development processes. Seed priming with growth regulators improved plant vigor (Afzal *et al.,* 2012). The increase in germination per cent may be due to the modification of physiological and biochemical nature of seed embryo and its associated structures, i.e. pre-enlargement of the embryo (Austin *et al.,* 1969) and biochemical changes like enzyme activation, Gibberellin like substances (Basra *et al.,* 2002) were released during the II phase of germination which triggers the synthesis of hydrolytic enzymes that causes the early availability of high energy compounds and vital biomolecules to the germinating seedling.

These results are in complete confirmation with those of Phiri and Mbewe (2010) who observed more germination and seedling growth due to presence of cytokinin like activity. Cytokinin often plays its role by interacting with other plant hormones like auxins and abscisic acid (Iqbal *et al*., 2006). Iftikhar (2009) observed increased emergence and vigorous plant development in maize seeds primed with MLE (1:30) due to the presence of Ca, K, ascorbic acid, and cytokinin hormone. The significantly higher root length recorded by moringa leaf extract was due to the presence of various growth promoters as well as macro and micro nutrients in moringa leaf extract. This may be due to the beneficial effect of physiologically active substances which have activated the embryo and other associated structures resulting in the absorption of more water due to cell wall elasticity and development of stronger and efficient root system and that would have ultimately resulted in higher vigour index.

Yasmeen *et al*. (2013) found moringa leaf extract is quite effective in increasing the seedling growth and development of crops. These results were in consonance with the observation of Aziza *et al.* (2004) who observed that in seeds treated with MLE, there was a triggered biochemical changes such as enzyme activation, starch hydrolysis and dormancy breaking. MLE extract enhances mobilization of reserves from the storage of seed i.e., cotyledons or endosperms for partitioning to embryo or causes increase in amylase activity and reducing sugars, contributing to early vigor (Afzal *et al.,* 2012). MLE extract encourages seed germination percentage, rate and index (Muhammad, 2015). Thus, the present study revealed that seed treatment with moringa leaf extract @ 5% + foliar spray of moringa leaf extract @ 10% at vegetative and flowering stages recorded higher seed yield and resultant seed quality when compared to other treatments and control.

Table 2 Effect of organic seed treatments and foliar spray on growth and yield of sesame cv. TMV 3

Treatment	Plant height (cm)	Number of branches	Number of Capsules/plant	1000 seed weight (g)	Seed yield/plant (g)	Seed yield/plot (g)	Seed yield/ha (kg)	Oil content (%)
T_0	78	3.1	78	2.8	6.91	603	535	43.5 (39.92)
T_1	83	4.4	85	2.9	7.78	640	589	43.9 (40.10)
T_2	83	4.1	85	2.9	7.97	650	597	44.0 (40.13)
T_3	92	5.8	109	3.2	8.97	785	781	44.5 (40.31)
T_4	94	6.1	108	3.3	9.07	787	794	45.6 (40.67)
Mean	86	4.7	93	3.02	8.14	693	659	44.3 (40.23)
CD (P = 0.05)	3.771	1.16	5.946	0.08	0.15	11.14	15.103	0.28

Figures in parenthesis are arcsine transformed values

Table 3 Effect of Organic seed treatments and foliar spray on physiological and seed quality characters in sesame cv. TMV 3

Treatment	Chlorophyll content (mg/g)	Leaf area (cm^2/plant)	Germination percentage	Root length (cm)	Shoot length (cm)	Drymatter production (mg 10/seedlings)	Vigour index
T_0	1.46	618	76 (60.67)	7.3	4.9	1.1	927
T_1	1.61	661	79 (62.73)	7.8	5.5	1.5	1050
T_2	1.60	672	79 (62.73)	7.9	5.7	1.6	1074
T_3	1.95	885	86 (68.03)	8.2	7.1	1.7	1315
T_4	1.98	897	87 (68.87)	8.7	7.8	2.0	1511
Mean	1.72	746	81 (66.16)	8.0	6.3	1.6	1124
CD (P=0.05)	0.101	11.00	2.001	0.307	0.477	0.231	53.44

Figures in parenthesis are arcsine transformed values

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Standardization of procedure for assessing terminal drought stress tolerance induced by foliar spraying of potassium iodide and identification of promising castor germplasm using the developed procedure

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ABSTRACT

Castor cultivated as a rainfed crop in southern India experiences terminal drought stress with cessation of monsoon. Stem reserves act as an important source of carbon for the seeds getting filled when photosynthesis is inhibited by drought and therefore, the ability to mobilize stem reserves towards economic yield is an important trait in selection for terminal drought tolerance. Potassium iodide (KI), a chemical contact canopy desiccant induces leaf desiccation by reducing chlorophyll content and can be used to simulate the conditions of terminal drought stress. This property could be employed for assessing the genotypic variability for stem reserve mobilization trait. During *kharif* 2015-16, in RG 1826, a genotype that had been identified earlier for root and drought tolerance, KI was sprayed @ 0.2-1.0% at 50% filling of capsules on primary spikes or 1.0-3.0% at 50% filling of capsules on tertiary spikes separately as two sets of foliar sprays. KI spray @1.0% at both the stages recorded total leaf desiccation, less seed yield reduction in primary (16%) and tertiary (29%) order spikes. Hence, 1.0% KI was taken as the optimum concentration to screen castor genotypes for terminal drought stress tolerance. During late *rabi* 2016-17, 12 germplasm lines with known drought tolerance (moisture stress induced between 30 and 90 DAS) ability and better root growth characters along with two checks were sown and at 100 DAS, KI was sprayed @ 1.0%. Four genotypes, *viz.,* RG82, RG89, RG111, RG1437 with high stem reserve mobilization characterized by <30% reduction in total seed yield and <20% reduction in HI were identified as promising for terminal drought tolerance.

Keywords: Castor, Genotypic variability, Potassium iodide, Terminal drought stress

Stem reserves are an important source of carbon for grain filling when the current photosynthesis is inhibited by drought or high temperature. The genetic improvement of stem reserve storage and utilization is very important genetic mechanism (Blum, 1998) especially for terminal drought tolerance. If current photosynthesis is limited by environmental stress such as water deficit, then remobilization of previously accumulated assimilates is accelerated. Accumulated assimilates also enhance the recovery of plants after stress (Wardlaw and Eckhardt, 1987). Wide variability exists among genotypes for carbohydrate accumulation in the stems and subsequent organs. Desiccation tolerance is an important physiological mechanism for drought tolerance (Blum, 1983). Chemical desiccation of the canopy after flowering for inhibiting the current photosynthesis was developed as a tool for revealing genotypic differences in grain filling from stem reserves in the absence of current photosynthesis (Blum *et al*., 1983; 1983a). Potassium iodide (KI), a chemical contact canopy desiccant which induce leaf desiccation by reducing chlorophyll content is used to induce drought stress for assessing genetic diversity in stem reserve mobilization to sink (Tyagi *et al*., 2000).

Castor is cultivated as a rainfed crop in southern India and experiences terminal drought stress with cessation of monsoon. Selection of breeding and germplasm lines with terminal drought stress tolerance is needed to develop hybrids that can tolerate end season drought. Hence, experiments were conducted for two years between 2015 and 2017 with the dual objectives of standardization of potassium iodide (KI) concentration to induce terminal drought stress in castor and identification of germplasm lines for terminal drought stress tolerance by imposing KI induced desiccation stress.

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MATERIALS AND METHODS

Standardization of potassium iodide (KI) concentration to induce terminal drought stress in castor: The experiment, in two sets, was carried out during *kharif,* 2015-16 at Narkhoda farm of IIOR (located at an altitude of 542 m with latitude of 17° 15' 16" and longitude of 78° 18' 30") using a previously identified drought tolerant germplasm line RG 1826 (Lakshmamma *et al*., 2010, Lakshmamma, 2014). In the Ist set, KI was sprayed @ 0.2, 0.4, 0.5, 0.6, 0.8, and 1.0% at 50% filling of primary spike to select the concentration of KI that induces desiccation. Simple water spray and no-spray treatments acted as checks. Though there was desiccation in 1st set, crop recovered partially due to intermittent small showers. So concentration was increased in 2nd set. In set II, KI was sprayed @ 1.0, 1.5, 2.0, 2.5 and 3.0% at 50% filling of tertiary spikes and water spray as well as no-spray acted as control treatments. Five rows of plants taken with a spacing of 90 x 60 cm, were

sprayed with each of the treatment regimen. Data on stem dry weight of different order branches and total dry matter (TDM) was recorded 20 days after spraying as well as at harvest in both the sets of experiments. Seed yield, yield components of different order branches were recorded on 15 plants for each treatment. Partitioning coefficient was calculated for each treatment to assess stem reserve mobilization (Krishnamurthy *et al*., 2013). For measuring partitioning coefficient (p), vegetative and reproductive growth duration converted to thermal time (Cd), crop growth rate (C) and seed yield (Y) were needed and to arrive at these values following formulae were employed

Cd [thermal time]= $\sum^{n}_{t=o}[(t_{max.}+t_{min.})/2-t_b)]$

where t_{max} is mean maximum temperature during the growth, t_{min} is mean minimum temperature during the growth and t_b is the base temperature.

Base temperature for growth was taken as 19°C for castor as calculated based on the data recorded in different experiments during different seasons along with temperature data with the help of a statistician (data not presented).

C [crop growth rate (kg/ha.)]=(V+Y)/(Dv+Dr)

where, V-vegetative shoot mass (with fallen leaf) kg/ha, Y-grain mass (kg/ha.), Dv-duration of growth before the start of 50% filling of spikes (days), Dr-duration of growth after the start of 50% filling of capsules (days)

p (partitioning coefficient) =((Y/Dr)/C))

where, Y-grain mass (kg/ha), Dr-duration of growth after the start of 50% filling of capsules (thermal time), C-crop growth rate (kg/ha)

Identification of germplasm lines for terminal drought stress tolerance by imposing KI induced desiccation stress: After standardizing the concentration of KI, during late *rabi,* 2016-17, 12 germplasm lines *viz.,* RG 27, RG 72, RG 82, RG 89, RG 111, RG 298, RG 1437, RG 1494, RG 1826, RG 1941, RG 2139, RG 2797 along with two checks; 48-1, a variety, DCH-519, a hybrid with known drought tolerance (of stress between 30 and 90 DAS) selected during different years were sown in un-replicated trial with six rows at a spacing of 90 x 30 cm per treatment and screened for terminal drought stress tolerance by spraying 1% KI (identified as the ideal concentration for inducing terminal stress from both sets of experiments) at 100 DAS.

Data on stem weight and TDM at 20 days after spraying, at harvest and seed yield were recorded. HI was derived from the data on TDM and seed yield (Lakshmamma *et al*., 2017). Partitioning coefficient (p) could not be calculated as there were differences in duration of the studied genotypes and the genotypes were at different stages when terminal drought stress was imposed. 'T' test was done to see the significance among control and KI treatments.

RESULTS AND DISCUSSION

End season drought due to monsoon cessation is very common in medium and long duration castor cultivars. Selection of germplasm and breeding lines for terminal drought tolerance is needed to breed for tolerance to end season drought. Castor crop has very strong stem and stem is the major contributor to total dry matter (TDM). Genotypes with stem reserve mobilization are needed to produce under abiotic stress conditions. Due to heavy foliage and limited translocation to reproductive parts when current photosynthesis is inhibited, it results in very low HI values (≤30%) in castor. Selection for best yields often ensures indirect selection for HI. But the increase in HI should not be due to reduced reproductive duration (Krishnamurthy *et al*., 2013). Breeding for increased HI is essential for the development of varieties/hybrids with higher seed and oil yield. One of the options to increase HI is to increase stem reserve mobilization. But how much to be translocated needs to be known considering that any change made to a plant trait has potential trade-offs that needs to be found out and quantified (Denison, 2009).

Partitioning of produced biomass towards the harvested product is one of the key processes to improve WUE (Condon *et al.,* 2004). Selection for the trait 'Partitioning coefficient (p)' improves drought tolerance and yield stability. This trait possesses the best heritability surpassing the estimates for the phonological durations. Selection for this trait is easy and includes a large number of morphological and physiological contributing traits. Harvest Index (HI) is an integration of two negatively linked traits i.e reproductive duration and rate of partitioning (Krishnamurthy *et al*., 1999). Since there is a ceiling to the reproductive growth duration due to ever increasing heat and drought stress at the final stages of reproductive growth, it would be worth aiming to increase p thereby allowing the plants to escape later stress stages without compromising yield formation. Increasing the p is essential to compensate the stress induced yield gaps (Anbessa *et al*., 2007).

As castor is grown mainly as a rainfed crop in Southern India, the crop is expected to experience moisture stress at different stages of phenology depending on the rainfall distribution. Therefore, it is an important objective of breeding experiments to identify genotypes that can mitigate the effects of moisture stress through different mechanisms. Mobilizing the stored reserves from stem under drought conditions is considered to be one such mechanism. We report here, a procedure developed to induce terminal

drought at different stages of plant growth by spraying KI, a leaf desiccant and then study the ability of the genotypes to mobilize the stored reserve from stem. Initially, to identify the concentration of KI that induces terminal drought in castor, KI at different concentrations was sprayed at two stages of development on a test genotype RG 1826. This genotype had been identified as a drought tolerant one in our earlier experiments and therefore, we logically went about establishing a procedure for inducing terminal drought using KI and then using that procedure, screened a set of genotypes that had been identified for moisture stress tolerance.

Establishing the procedure for inducing terminal drought using KI

KI foliar sprayed at 50% filling of primary spikes: In this set of experiment, KI was sprayed @ 0.2, 0.4, 0.5, 0.6, 0.8 and 1% concentrations when the crop was at 50% filling of primary spike. Primary and tertiary stem weight did not show much reduction when measured 20 days after spraying, but stem weight of secondary branches showed reduction (11.3, 18.5 g/pl, respectively against 32.1 g/plant in unsprayed control) at 0.8 and 1.0% of KI. Reduction in total stem weight was more in 0.6, 0.8, 1.0% KI spray. Reduction in total dry matter was more at 1.0% KI spray at 20 days after spraying which could also be because of the reduced spike weight (Table 1). However, significant reduction in total stem weight showed that the stem reserves had been mobilized from secondary branches.

On primary and tertiary spikes, not much difference in spike characters *viz*., spike length, effective spike length (ESL) and capsule number was seen with any spray concentration (data not shown) except for reduction in primary seed yield with 1.0% KI (20.5 g compared to 24.3g in control) (Table 2). Reduced stem dry weight of secondaries at 0.8, 1.0% KI spray (Table 1) indicated translocation of stem reserves from secondary branches to primary spike. This was accompanied with reduced spike length, effective spike length (ESL), capsule number, and seed weight of secondaries (Table 2). These observations further indicated that even though the plant tried to mobilize the stem reserve from secondary branches and compensate for photosynthates, the seed yield of primaries was reduced.

KI foliar sprayed at 50% filling of tertiary spikes: Based on the results observed with KI when sprayed at 50% of primary spike filling which showed not much of stem reserve mobilization at less than 1% concentration, KI was sprayed @ 1.0% to 3.0% concentrations at 50% filling of tertiary spikes i.e. at 86 DAS, Crop completed the life cycle within 20 days of spraying with KI. Leaf dry weight reduced with increase in KI concentration (Table 3). With KI spray, no clear difference in stem reserve mobilization was observed from primary, secondary, tertiary branches as well as not much of variation was seen for total stem weight and TDM (Table 3).

Primary seed yield was not influenced by KI spray as the spike had almost matured by that time (Table 4). Though, secondary spike characters did not show reduction up to 2.0%, seed weight reduced with 2.5, 3.0% KI spray due to reduction in capsule number and test weight. Tertiary spike length and capsule number was not influenced by KI spray. But spike weight and seed yield per plant were reduced significantly and the magnitude was high with concentrations beyond 1.0%. Compared to other treatments, the tertiary seed yield reduction was less at 1.0% KI spray (Table 4). Total seed yield was reduced with KI spray at all the concentrations tested (Table 4). Plaut *et al.*, 2004 also reported reduction in duration and rate of grain filling thereby reduced kernel weight due to drought stress at anthesis stage accompanied by high temperature. In rice also, it was reported that early senescence induced by a moderate water deficit during grain filling period could enhance the remobilization of stored assimilates and accelerate the grain filling of rice (Yang *et al.*, 2001).

Table 1 Total stem weight and TDM at 20 days after spraying of KI at 50% filling of primaries

KI concentration (%)	Total stem weight (g/plant)	Spike weight (g/plant)	TDM (g/plant)
0.2	90.6	49.4	156.7
0.4	82.0	44.0	145.5
0.5	83.1	52.0	155.1
0.6	66.5	68.0	150.9
0.8	68.9	46.4	129.5
1.0	63.9	13.0	92.4
Water spray	75.2	39.0	126.4
Unsprayed	93.2	57.0	175.4

Table 2 Spike characters with KI spray at 50% filling of primary spikes

KI concentration (%)	Primary seed weight (g/plant)	Secondary spike characters			Tertiary seed weight (g/plant)	Total seed weight at harvest (g/plant)
		ESL/spike (cm)	Capsule No./spike	Seed weight (g/plant)		
0.2	22.5	24.5	27	39.7	27.6	89.7
0.4	21.8	21.9	20	39.7	34.1	95.5
0.5	25.1	21	19	34.2	32.7	89.0
0.6	22.7	21.9	20	38.6	30.1	91.4
0.8	23.4	17.2	17	33.9	34.0	91.3
1.0	20.5	17.7	14	31.6	25.3	77.4
water spray	24.1	24.5	28	42.8	22.6	89.5
unsprayed	24.3	22.5	22	50.4	22.1	96.7

Table 3 Total leaf, stem weight at 20 days after spraying of KI at 50% filling of tertiary spikes

KI concentration (%)	Leaf dry weight (g/plant)	Total stem weight (g/plant)	TDM (g/plant)
1.0	10.6	86.3	142.9
1.5	4.5	87.9	152.8
2.0	3.3	104.0	187.3
2.5	2.1	94.9	177.0
3.0	5.5	86.5	148.0
water spray	15.2	76.0	146.5
unsprayed	16.8	89.1	169.9

Table 4 Seed yield of different order spikes with KI spray at 50% filling of tertiary spikes

KI Concentration (%)	Primary seed weight (g)	Secondary seed weight (g)	Tertiary seed weight (g)	Total seed weight at harvest (g/plant)
1.0	20.7	40.8	22.4	83.9
1.5	20.4	43.9	12.4	76.7
2.0	27.6	46.9	11.2	85.7
2.5	26.9	35.8	7.4	70.1
3.0	29.4	35.3	9.9	74.5
water spray	20.1	50.5	30.1	100.6
unsprayed	28.6	50.4	31.3	110.3

As stem reserve mobilization induced by KI spray was not clearly demonstrated by the weight measurements, partitioning coefficient (p) was calculated for different concentrations and stages of spray (Table 5). When Potassium iodide (KI) was sprayed @ 0.2-1.0% at 50% filling of primary spikes, leaf desiccation, primary seed yield reduction (16%) and partitioning coefficient (p-0.50) was more in 1.0% KI concentration. with KI spray @1.0-3.0% at 50% filling of tertiary spikes, beyond 1.0% spray tertiary seed yield reduction was very high (>60%) and at 1.0%, tertiary seed yield reduction was less (<29%) and "p" was also high (0.37) compared to other concentrations. Partitioning coefficient (p - 0.33) for total seed yield was also more in 1.0% KI sprayed at 50% filling of tertiary spikes (Table 5). Strong negative relation of partitioning coefficient with percent reduction in tertiary seed yield (R^2=0.99) and total seed yield (R^2=0.57) was observed (Fig 1a & 1b). Significant correlation of grain yield with assimilate translocation rate (ATR) (R^2=0.54) was also reported in rice indicating reduction in current assimilation during reproductive stage under different KI treatments and tolerant genotypes induced an increase in stem reserve mobilization (Singh *et al.*, 2012).

Therefore, based on the observations from the two sets of experiments with KI sprayed at different concentrations at two different phonological stages, KI @1.0% was considered

as optimum for screening genotypes of castor for terminal drought stress tolerance.

Identification of castor germplasm lines for terminal drought stress tolerance by imposing KI induced desiccation stress

Twelve germplasm lines *viz*., RG 27, RG 72, RG 82, RG 89, RG 111, RG 298, RG 1437, RG 1494, RG 1826, RG 1941, RG 2139, RG 2797 along with two checks; 48-1, a variety, DCH-519, a hybrid with known drought tolerance (of stress between 30 and 90 DAS) selected during different years were grown during late *rabi*, 2016 and at 100 DAS, one bed was sprayed with KI @ 1.0% to induce terminal drought stress and 2nd bed without spraying was treated as control. When KI was sprayed, RG72, RG89, RG298, RG1437, RG1494, RG1826, RG2139 were at primary seed filling, secondary capsule formation, and tertiary spike formation stage and RG27, RG82, RG111, RG1941, RG2797 were at primary spike formation/expansion, secondary branch production stage.

Except tertiary (46.2%), reduction in stem dry weight of primary, secondary branches and total stem dry weight reduction at 20 days after KI spray was negligible. Reduction in leaf dry weight especially of secondaries and tertiaries was more with an average of 20.8% reduction in total leaf weight with KI spray as there was leaf desiccation and fall. More than 79% leaf fall was noticed in tertiary order branches (Data not shown). Spike dry weight was reduced by 21.6% while TDM was reduced by 15.7% with KI spray (Table 6). Before spraying, RG72, RG 298, RG 1826 produced tertiary branches but only RG 1826 recorded substantial spike weight reduction. Twenty days after spraying, tertiary stem weight was reduced only in RG 72, RG 89, RG 298, RG 1437, RG 1826 compared to the unsprayed control. Among different genotypes studied, >20% reduction in primary stem weight was seen in RG 72, RG111, RG298, RG1437, RG1941 at 20 days after KI spray. RG27, RG72, RG111, RG298, RG1494 showed >30% reduction in stem dry weight of secondary branches (Data not shown). TDM reduction 20 days after spray was less (<30%) and non significant in RG82, RG89, RG1437, RG 1494, RG 1826, RG 1941, RG 2139 while in RG27, RG 82, RG 89, RG111, RG1941, RG 1494 TDM reduction was significant and <25% at harvest (Table 7).

Stem dry weight at harvest showed no change in primary but exhibited more reduction in secondary (21%) and tertiary branches (77%) with KI spray. Overall, there was 24% reduction in stem dry weight with KI spray (Table 6) and the reduction was significant (p-<0.05). Total stem weight of RG72, RG111, RG298 showed >30% reduction at 20 days after spraying but was not significant (Data not shown). Genotypes that showed >30% reduction in stem dry weight at harvest included RG72, RG1437, RG1826, RG1941, and RG2797 (Table 7). Leaf weight reduction was negligible as there was leaf fall with KI spray. TDM reduction was substantial (up to 32%) due to KI spray.

Primary seed yield reduced by 28%, secondary by 47% and no seed yield was seen in tertiaries (Table 6). There was 32% reduction in total seed yield. Reduction in HI was up to 2% with KI spray (Table 8). Among different genotypes, there was <30% reduction in primary seed yield in RG82, RG89, RG1437, RG1941, RG2139. Genotypes RG72, RG89, RG111, RG298, RG1494, RG1826 recorded <35% reduction in secondary seed yield (Data not shown). There was significant difference in total seed yield with KI spray in the studied genotypes. Total seed yield reduction was less (<30%) in RG82, RG89, RG111, RG1437 with KI spray (Table 8). Genotypes with <30% reduction in HI with KI spray included: RG72, RG82, RG89, RG 111, RG 298, RG1437, RG 1494, RG1826, RG1941, RG2139. HI differences were not significant. When the genotypes were compared for seed yield up to secondaries (as there was tertiary seed yield only in control and in 3 genotypes i.e. RG72, RG298 and RG1826), the genotypes with <30% reduction in seed yield included RG82, RG89, RG111, RG1437, RG1826 and RG298 while <35% reduction in seed yield was observed in RG1494 . Genotypes selected for the study already showed drought tolerance along with good root growth. Among the genotypes, stem reserve mobilization was more in primary or secondary branches or in both the orders in RG 72, RG82, RG 298, RG111, RG1437, RG 1494 and RG 1941. Terminal drought stress reduced seed filling duration as shown by increased temperature in late sown crop of wheat and reduced remobilization to drying sinks (Fisher, 2007).

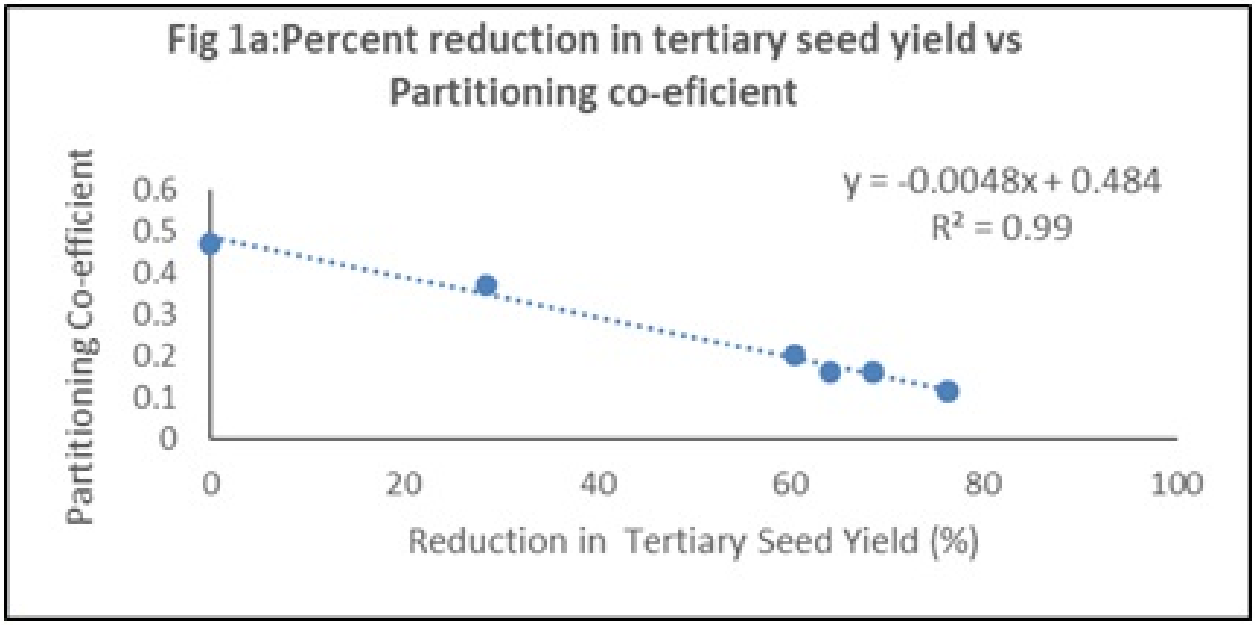
In the present study, it was established that KI@1% concentration could be used for selecting the genotypes with terminal drought stress tolerance. Using this procedure when a set of genotypes that had been identified to be drought tolerant in our earlier studies (Lakshmamma *et al*., 2010, 2014) were screened, we could identify the genotypes that could stand terminal stress. Thus we have been successful in identifying genotypes that show high HI during terminal stress. The germplasm lines, RG82, RG89, RG111, RG1437, RG1826 and RG298with more seed yield in terminal stress, less seed yield reduction with stress and with low DSI could be very useful in breeding programs aimed at developing lines with terminal stress tolerance. Selection for "p" could not be done as the genotypes were of different maturity durations and it was practically not possible to spray each genotype separately only at 50% filling of tertiary spikes. However, the data holds good for use of the selected genotypes in breeding programs. Future drought tolerance breeding programs need to incorporate partitioning coefficient (p) for better drought tolerance and yield stability.

In conclusion, leaf desiccation, primary seed yield reduction (16%) and partitioning coefficient (p-0.50) was more with 1.0% Potassium iodide (KI) spray at 50% filling of primary spikes and there was less reduction in tertiary seed yield (<30%), high partitioning coefficient (p-0.37). Induction of terminal drought stress with KI @1.0% showed <24% reduction in total seed yield with "p" 0.33. Hence, 1.0% KI was identified as the optimum concentration to screen genotypes for terminal drought stress tolerance. Genotypes RG 72, RG82, RG 298, RG111, RG1437, RG 1494 and RG 1941 were identified to have more stem reserve mobilization in primary or secondary branches or both the orders. Among the studied genotypes, RG82, RG89, RG111, RG1437, RG1826 and RG298 showed <30% reduction in seed yield, RG1494 recorded <35% reduction in seed yield. Genotypes with <30% reduction in HI with KI spray included RG72, RG82, RG89, RG 111, RG 298, RG1437, RG 1494, RG1826, RG1941 and RG2139.

Table 5 Crop growth rate and partitioning coefficient with KI spray at 50% filling of primary/tertiary spikes

KI Conc. (%)	Spray during 50% filling of primary spikes			Spray during 50% filling of tertiary spikes					
	% reduction in primary seed yield	crop growth rate (C)* (kg/ha)	Partitioning coefficient (p)**	KI Conc. (%)	% reduction in tertiary seed yield	crop growth rate (C)* (kg/ha)	Partitioning coefficient (p)**	% reduction in total seed yield	Partitioning coefficient (p)**for total seed yield
0.20	7.5	46.0	0.36	1.00	28.7	41.5	0.37	23.9	0.33
0.40	10.3	43.3	0.37	1.50	60.5	41.2	0.20	30.5	0.25
0.50	9.1	46.2	0.35	2.00	64.3	48.3	0.16	22.3	0.29
0.60	6.5	44.2	0.38	2.50	76.4	45.1	0.11	36.4	0.25
0.80	3.6	39.7	0.44	3.00	68.6	42.7	0.16	32.4	0.28
1.00	15.7	30.7	0.50						
control		49.3	0.33	control		45.4	0.47		0.39
water	0.8	39.6	0.40	water	4.0	39.3	0.53	8.8	0.42

C* = TDM/duration p**= (yield/ duration of growth after the start of 50%filling)/C



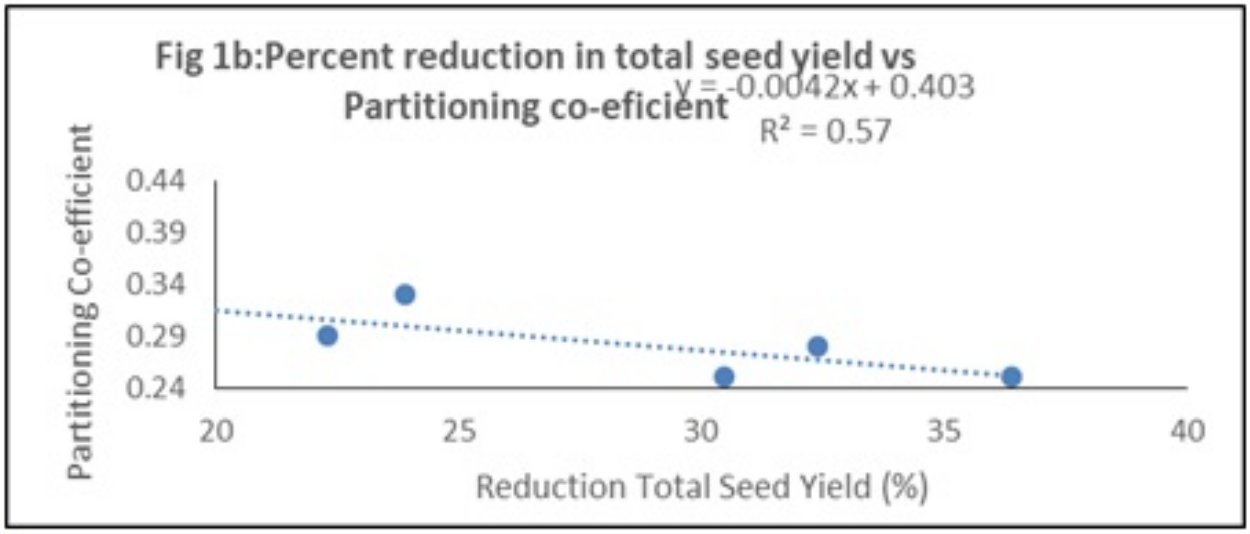


Table 6. Dry matter partitioning with KI spray at 20 days after spraying and at harvest

Character (g/plant)	20 days after spraying (g/plant)			At harvest		
	Control	KI spray	% reduction	Control	KI spray	% reduction
Total stem dry weight	45.1	44.6	1.1	65.0	47.2	24.4
Total leaf dry weight	19.7	15.6	20.8	16.5	3.5	78.8
Total spike dry weight	88	69	21.6			
TDM	153	129	15.7	240.0	149.0	32.4
Yield						
Primary seed yield				46.1	33.4	27.5
Secondary seed yield				42.2	22.5	46.7
Tertiary seed yield				5.7	0	100.0
Total seed yield				94.0	55.8	31.8
HI (%)				38.9	37.4	2.0

Table 7 Genotypic differences in stem reserve mobilization and TDM at harvest

Genotype	Stem weight (g/pl.)			TDM (g/pl.)		
	Control	KI spray	% reduction	Control	KI spray	% reduction
RG27	68.7	93.3	-35.8	277.7	169.3	24.2
RG72	89.2	36.4	59.2	329.3	160.5	52.9
RG82	44.1	40.3	8.6	152.3	162.3	-3.2
RG89	67.1	51.5	23.3	164.5	154.4	11.1
RG111	45.4	33.4	26.5	161.3	128.9	21.5
RG298	52.9	45.4	14.3	223.8	119.0	40.6
RG1437	72.1	50.2	30.4	190.6	139.0	28.0
RG1494	48.6	45.4	6.5	200.8	163.4	16.3
RG1826	44.9	30.2	32.8	233.8	130.6	42.3
RG1941	93.6	47.6	49.1	244.2	117.0	51.3
RG2139	71.6	51.9	27.5	275.4	151.2	41.5
RG2797	92.8	53.5	42.3	344.0	128.3	58.4
48-1	64.8	24.2	62.7	281.6	158.2	47.4
DCH-519	54.0	57.5	-6.5	273.3	198.4	21.8
Max.	93.6	93.3	62.7	344.0	198.4	58.4
Min.	44.1	24.2	-35.8	152.3	117.0	-3.2
Mean	65.0	47.2	24.4	239.5	148.6	32.4
		p <0.05			p <0.05	

Table 8 Genotypic differences in total seed yield and HI with KI spray

Genotype	Total seed yield (g/plant)			HI (%)		
	Control	KI spray	% reduction	Control	KI spray	% reduction
RG27	114.6	36.0	68.6	41.3	21.2	58.6
RG72	138.1	66.5	51.9	41.9	41.4	-2.3
RG82	58.9	59.7	-1.3	38.7	36.8	1.9
RG89	47.0	94.8	-101.6	28.6	61.4	-126.7
RG111	73.0	53.0	27.4	45.2	41.1	7.5
RG298	88.0	42.6	51.6	39.3	35.8	18.6
RG1437	68.3	49.2	27.9	35.9	35.4	-0.1
RG1494	78.4	52.0	33.7	39.1	31.8	20.8
RG1826	111.6	64.2	42.4	47.7	49.2	0.2
RG1941	60.8	26.1	57.0	24.9	22.3	11.8
RG2139	123.4	54.6	55.8	44.8	36.1	24.5
RG2797	146.1	32.7	77.6	42.5	25.5	46.2
48-1	96.3	72.3	24.9	34.2	45.7	-42.6
DCH-519	111.3	78.2	29.8	40.7	39.4	10.2
Max.	146.14	94.82	77.6	47.7	61.4	58.6
Min.	47.04	26.12	-101.6	24.9	21.2	-126.7
Mean	94.0	55.8	31.8	38.9	37.4	2.0
		$p < 0.05$			$p > 0.05$	

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Response of rainfed sunflower (*Helianthus annuus* L.) to varying planting geometry and fertilizer levels under different land configurations in Vertisols

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ABSTRACT

A field experiment was conducted for two consecutive rainy seasons during 2016 and 2017 at Regional Agricultural Research Station, Nandyal, Kurnool district of Andhra Pradesh under All India Coordinated Research Project on Sunflower to study the response of rainfed sunflower to varying planting geometry and fertilizer levels under different land configuration. The experiment was laid out in a split plot design with four main plot treatments *viz.,* M_1 - Flat bed sowing 60 cm x 30 cm, M_2 - Ridge and furrow sowing 60 cm x 30 cm, M_3 - Flat bed with paired row sowing 45 cm x 30 cm (90/40 cm) and M_4 - Broad bed and furrow with paired row sowing 45 cm x 30 cm and three sub-plot treatments *viz.,* S_1- 75 % RDF, S_2 - 100 % RDF (60:30:30 N, P_2O_5 and K_2O kg/ha) and S_3 - 125% RDF and replicated thrice. The results indicated that moisture use efficiency was found highest in broad bed and furrow paired row sowing (8.0 and 7.1 kg/ha-mm in 2016 and 2017, respectively) followed by ridges and furrow at 60 cm x 30 cm sowing (6.8 and 6.2 kg/ha-mm in 2016 and 2017, respectively). Highest seed yield (1632 kg/ha) was recorded with broad bed and furrow paired row 45 cm x 30 cm treatment followed by ridge and furrow 60 cm x 30 cm treatment (1398 kg/ha), which were superior to flat bed paired row 45 cm x 30 cm (1155 kg/ha). Broad bed and furrow paired row sowing at 45 cm x 30 cm recorded higher net returns (₹ 21450/-) and B: C ratio (1.82) followed by ridges and furrow sowing at 60 cm x 30 cm.

Keywords: Land configuration, Planting geometry, Soil moisture, Sunflower

Sunflower (*Helianthus annuus* L.) can be grown throughout the year. It is grown in both Alfisols and Vertisols under rainfed conditions. It is a day neutral plant and can be grown successfully in different seasons under varying conditions of day length, provided the day temperature is favorable. It grows best with clear sky and occasional rain showers during early stages. The crop requires a cool climate during germination and seedling growth and warm non-cloudy weather and high temperature from flowering to maturity. It is resistant to drought but requires continuous availability of soil moisture for optimal performance.

The productivity of sunflower in India is low (643 kg/ha) as compared to other nations and one of the major reasons for low productivity is its cultivation mainly under rainfed conditions with sub optimal crop stand, imbalanced nutrition and lack of soil moisture conservation techniques, water logging conditions in high rainfall events, thus leading to poor seed set and high percent of chaffy seed, low oil content and yield. There is a need to improve the productivity and sustainability of sunflower under rainfed conditions by improving the rainwater use efficiency with suitable moisture conservation practices and optimal input fertilizers (Sankar *et al*., 2001; Vittal *et al*., 2003). Planting geometry determines the distribution pattern of plants in a field. It affects evaporation, water use efficiency of the crop and weed intensity/ competition. Saleem *et al*. (2008) reported that proper spacing of plants in a particular area makes plant canopy more effective in intercepting the radiant energy and shading effect on weeds. Under dryland conditions, response to the applied fertilizers varies with the available soil moisture. Hence, efficient soil moisture conservation is the key for successful crop production under this situation. Reddy *et al.*, (2007) reported that application of fertilizers having nutrients *viz.,* Nitrogen, Phosphorous and Potash can increase sunflower growth and yield substantially, necessitating for balanced fertilizer application. Hence there is an immense need to study the land configuration to adapt to varying low and high moisture events during rainy season and developing optimum fertilizer requirement as per the soil moisture availability in sunflower crop.

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MATERIALS AND METHODS

A field experiment in sunflower was conducted at Regional Agricultural Research Station, Nandyal, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, situated at an altitude of 216 m above mean sea level at 15°29'19" N latitude and 78° 29'11" E longitude under rainfed conditions during rainy season of 2016 and 2017. The soil of experimental site was medium deep black (Vertisols), low in organic carbon (0.36 %), high in available P_2O_5 (45 kg/ha) and available K_2O (536 kg/ha).The experiment was laid out in a split plot design with twelve treatments (four main and three sub plots), replicated thrice. The main plots consisted of M_1 - Flat bed sowing at 60 cm x 30 cm, M_2 - Ridge and furrow sowing at 60 cm x 30 cm, M_3 - Flat bed with paired

row sowing at 45 cm x 30 cm (90/40 cm) and M_4 - Broad bed and furrow with paired row sowing at 45 cm x 30 cm (90/40cm). S_1- 75 % RDF, S_2 - 100 % RDF (60:30:30 N, P_2O_5 and K_2O kg/ha) and S_3 - 125% RDF were the sub plot treatments. Sunflower hybrid DRSH-1 was sown on 32nd standard meteorological week (SMW) and harvested on 44th SMW. Full dose of P_2O_5 and K_2O along with half of the nitrogen in all the treatments was applied as basal. The balance nitrogen was applied in two equal splits i.e. 1/4th at 30 DAS and remaining 1/4th at flowering as per the treatments. Need based plant protection measures were taken. The crop was grown completely under rainfed conditions. Rainfall during crop growth period was recorded at RARS, Nandyal meteorology unit (Table 1). Soil moisture percentage was estimated at different crop growth stages by gravimetric method. Moisture use efficiency (kg/ha-mm) was calculated by using formula.

Moisture use efficiency (MUE) (kg/ha-mm) =

$$\frac{\text{Yield (kg/ha)}}{\text{Soil moisture utilized (mm)}}$$

Soil moisture utilized (mm) = Initial soil moisture (mm) + effective rainfall received during crop growth period (mm) - run off (mm) - final soil moisture at harvest (mm)

RESULTS AND DISCUSSION

Rainfall: Rainfall distribution during the year 2016-17 (Table 1) indicates that a total rainfall amount of 405 mm was received in 14 rainy days during crop season. Most of the seasonal rainfall occurred between 34-40 SMW. This situation has the potential of causing water logging of fields. The rainfall distribution in 32-34 SMW was very erratic and caused dry spells. But during the year 2017-18, a good amount of 478.8 mm rainfall was received during crop season with well distribution in 28 rainy days. During 32-35 SMW received continuous rainfall in 3-4 rainy days in a week, which caused water logging of fields of experimental crop.

Soil moisture and moisture use efficiency: The data on soil moisture and its use efficiency indicates that land configuration techniques had no significant effect on soil moisture at root zone at initial and 30 days after sowing, but due to subsequent rainfall there was significant increase at 60 DAS and at harvest. During two years of study, BBF paired row sowing at 45 cm x 30 cm recorded significantly highest soil moisture percentage followed by ridge and furrow at 60 cm x 30 cm. This might be due to the provision of furrow holding good amount of rainfall events received during crop growth period at 35 to 40 SMW (Table 1). Patil *et al*. (2015) also reported that compartmental bunding and ridges and furrows conserved more rainwater in profile, thus producing greater sunflower seed yields varying from 22% to 28% compared to farmers' practice of flat-bed sowing.

Table 1 Actual rainfall (mm) and rainy days during crop growth period

Standard meteorological week (SMW)	2016		2017	
	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)	Rainy Days
32	1.4	0	90.8	3
33	0	0	15.6	4
34	8.2	1	74.2	4
35	206.4	3	72.6	4
36	0	0	16.2	1
37	88.4	3	58.4	2
38	76.2	3	18.2	2
39	13.2	2	8.0	1
40	13.0	2	52.6	3
41	3.2	0	46.6	3
42	0	0	25.6	1
43	0	0	0.0	0
44	0	0	0.0	0
Total	405.0	14	478.8	28

Moisture use efficiency was significantly highest in broad bed and paired row planting 45 cm x 30 cm (8.0 and 7.1 kg/ha-mm in 2016 and 2017, respectively) followed by ridges and furrow 60 cm x 30 cm planting (6.8 and 6.2 kg/ha-mm in 2016 and 2017, respectively) and flat bed paired row 45 cm x 30 cm planting method (5.6 and 4.7 kg/ha-mm in 2016 and 2017, respectively). However, flat bed 60 cm x 30 cm planting method recorded significantly lowest moisture use efficiency of 5.5 and 4.8 kg/ha-mm in 2016 and 2017, respectively. Jat *et al*. (2000) found higher water use efficiency in pigeonpea with ridges and furrows planting. Moisture use efficiency was found highest in ridges and furrow followed by opening of furrows after every two rows and lowest in flat bed in soybean (Patil *et al*., 2010). Fertilizer levels did not show significant effect on soil moisture content during both the years and throughout the crop growth period. But moisture use efficiency was highest with 125% RDF (6.8 and 6.2 kg/ha-mm in 2016 and 2017, respectively), which could be attributed to highest seed yield. Interaction effect between land configuration techniques and fertilizer levels were not significant.

Plant growth and yield attributes: Planting geometry and land configurations and fertilizer levels had no significant effect on growth parameters as indicated through plant height, but differed significantly for dry matter accumulation. However, interaction between land configuration and fertilizer levels had no significant influence on plant height and dry matter production. Among land configuration and planting geometry, broad bed and furrow paired row sowing at 45 cm x 30 cm recorded significantly highest total dry

matter at harvest (179.9 g/plant) followed by ridge and furrow 60 cm x 30 cm (173.1 g/plant). Similarly, graded level of fertilizers had exerted significant influence on dry matter accumulation. Application of 125% RDF (165.2 g/plant) produced significantly highest dry matter which was superior to 100% RDF (156.1 g/plant) and 75% RDF (145.4 g/plant).Yield attributing character exhibited through head diameter varied significantly with planting geometry, land configurations and fertilizer levels. Among planting geometry and land configurations, broad bed and furrow paired row sowing at 45 cm x 30 cm recorded significantly highest head diameter (15.1cm) followed by ridge and furrow 60 cm x 30 cm (114.4 cm). Similarly, application of 125% RDF recorded significantly highest head diameter (15.0 cm) and superior to 100% RDF (13.1 cm) and 75% RDF (12.4 cm). Number of filled seeds/head differed significantly among planting geometry and land configurations. Significantly highest number of seeds was recorded with broad bed and furrow paired row 45 cm x 30 cm (919) while, filled seed/head in flat bed paired row 45 cm x 30 cm (714) was comparable with 659. Higher no of seeds/ head under broad bed and furrow paired row 45 cm x 30 cm and Ridge and Furrow 60 x 30 cm could be attributed to the adequate availability of soil moisture over other treatments. (Table 3 and Table 4). Among the fertilizer levels, application of 125% RDF recorded significantly higher number of filled seeds/head (877) over 100% RDF (816) but 100% RDF was comparable with that of 75% RDF (813). Cumulative effect of improved growth parameter (dry matter accumulation) through efficient metabolic activity, increased photosynthetic rate and supply of photosynthates from source to sink had accommodated more number of filled seeds /head under 125% RDF. These results are in line with those of Byomkesh Let *et al*. (2014) and Pavani *et al*. (2013).

Table 2 Pooled growth, yield attributes, yield and economics of sunflower as influenced by planting geometry and land configurations under different fertilizer levels (pooled mean 2016 and 2017)

Treatments	Plant height (cm)	Total dry matter (g/plant)	Head diameter (cm)	Filled seeds/head	Seed yield (kg/ha)	Stalk yield (kg/ha)	Net returns (₹/ha)	B:C ratio
Planting geometry and land configuration(M)								
M_1- Flat bed 60 cm x 30 cm	184.2	161.3	12.7	659	1136	3713	8180	1.32
M_2-Ridge & Furrow 60 cm x 30 cm	178.6	173.1	14.4	780	1398	3812	14900	1.58
M_3-Flat bed paired row 45 cm x 30 cm	179.5	164.5	13.2	714	1155	3722	8100	1.32
M_4- Broad bed & Furrow paired row 45 cm x 30 cm	182.6	179.9	15.1	919	1632	3938	21450	1.82
SEm+	4.4	2.31	0.3	33	33	182	-	-
CD (P=0.05)	NS	6.40	1.0	112	115	NS	-	-
Fertilizer levels (S)								
S_1- 75% RDF	184	145.4	12.4	813	1231	3591	11600	1.48
S_2 - 100% RDF	184	156.1	13.1	816	1305	3635	13170	1.53
S_3 - 125% RDF	182	165.2	15.0	877	1447	3916	18530	1.74
SEm+	2.1	1.2	0.2	14	21	43	-	-
CD (P=0.05)	NS	3.4	0.6	42	63	135	-	-
Fertilizer level at same or different level of planting geometry and land configurations								
SEm+	3.4	2.3	0.7	46		91	-	-
CD (P=0.05)	NS	NS	NS	NS		NS	-	-
Planting geometry and land configurations at same or different level of fertilizer level								
SEm+	7.9	5.6	0.7	49		197	-	-
CD (P=0.05)	NS	NS	NS	NS		NS	-	-

Table 3 Soil moisture content (%) at 0-30 cm depth as influenced by planting geometry and land configurations under different fertilizer levels at different intervals during 2016

Treatments	10 DAS	30 DAS	60 DAS	At harvest
Planting geometry and land configuration(M)				
M_1- Flat bed 60 cm x 30 cm	21.7	23.3	31.2	25.5
M_2-Ridge & Furrow 60 cm x 30 cm	22.5	23.4	36.7	24.9
M_3-Flat bed paired row 45cm x 30 cm	24.5	29.4	33.5	23.5
M_4- Broad bed & Furrow paired row 45cm x 30 cm	19.5	22.9	42.8	26.4
SEm+	2.9	1.4	1.3	1.2
CD (P=0.05)	NS	NS	3.6	NS
Fertilizer levels				
S_1- 75% RDF	22.5	25.4	37.8	27.6
S_2 - 100% RDF	20.1	23.8	35.2	24.0
S_3 - 125% RDF	23.5	25.1	37.5	22.9
SEm+	2.0	1.1	3.1	1.3
CD (P=0.05)	NS	NS	NS	NS
Fertilizer level at same or different level of planting geometry and land configurations				
SEm+	3.6	1.7	0.8	3.2
CD (P=0.05)	NS	NS	NS	NS
Planting geometry and land configurations at same or different level of fertilizer level				
SEm+	2.7	3.8	0.6	2.3
CD (P=0.05)	NS	NS	NS	NS

Table 4 Soil moisture content (%) at 0-30 cm depth as influenced planting geometry and land configurations under different fertilizer levels at different intervals during 2017

Treatments	10 DAS	30 DAS	60 DAS	At harvest
Planting geometry and land configuration(M)				
M_1- Flat bed 60 cm x 30 cm	36.9	30.7	23.2	23.3
M_2-Ridge & Furrow 60 cm x 30 cm	41.4	33.9	32.8	23.9
M_3-Flat bed paired row 45 cm x 30 cm	39.9	34.3	22.4	24.3
M_4- Broad bed & Furrow paired row 45 cm x 30 cm	40.0	33.0	37.5	30.0
SEm+	1.8	2.1	1.2	1.4
CD (P=0.05)	NS	NS	3.3	3.1
Fertilizer levels				
S_1- 75% RDF	38.4	32.4	24.3	24.8
S_2 - 100% RDF	39.7	36.2	23.4	24.5
S_3 - 125% RDF	40.6	37.8	24.2	26.9
SEm+	1.4	2.5	0.3	0.7
CD (P=0.05)	NS	NS	NS	NS
Fertilizer level at same or different level of planting geometry and land configurations				
SEm+	3.2	5.2	0.5	2.8
CD (P=0.05)	NS	NS	NS	NS
Planting geometry and land configurations at same or different level of fertilizer level				
SEm+	2.9	5.1	0.6	2.0
CD (P=0.05)	NS	NS	NS	NS

Table 5 Moisture use efficiency (kg/ha-mm) as influenced by planting geometry and land configurations under different fertilizer levels during 2016 and 2017

Treatments	2016		2017	
	Seed yield (kg/ha)	Moisture use efficiency (kg/ha-mm)	Seed yield (kg/ha)	Moisture use efficiency (kg/ha-mm)
Planting geometry and land configuration(M)				
M_1- Flat bed 60 cm x 30 cm	1115	5.5	1157	4.8
M_2-Ridge & Furrow 60 cm x 30 cm	1302	6.8	1494	6.2
M_3-Flat bed paired row 45 cm x 30 cm	1165	5.6	1145	4.7
M_4- Broad bed & Furrow paired row 45 cm x 30 cm	1553	8.0	1711	7.1
SEm(±)	50	-	35	-
CD (P=0.05)	173	-	101	-
Fertilizer levels -3				
S_1- 75% RDF	1164	6.0	1298	5.4
S_2 - 100% RDF	1284	6.3	1326	5.5
S_3 - 125% RDF	1404	6.8	1490	6.2
SEm(±)	32	-	24	-
CD (P=0.05)	95	-	70	-
Fertilizer level at same or different level of planting geometry and land configurations				
SEm(±)	29	-	22	-
CD (P=0.05)	NS	-	NS	-
Planting geometry and land configurations at same or different level of fertilizer level				
SEm(±)	35	-	28	-
CD (P=0.05)	NS	-	NS	-

Seed yield: Planting geometry and land configurations and fertilizer levels had shown significant effect on seed yield. However, interaction between land configuration and fertilizer levels had no significant influence on seed yield of sunflower. Significantly highest seed yield (1632 kg/ha) was recorded with broad bed and furrow paired row 45 cm x 30 cm, which was superior to the rest of treatments. The ridge and furrow 60 cm x 30 cm recorded 1398 kg/ha of seed yield which was superior to flat bed paired row 45 cm x 30 cm (1155 kg/ha) but in turn at par with flat bed 60 cm x 30 cm (1136 kg/ha). Among the fertilizer treatments, application of 125% RDF had recorded significantly higher seed yield (1447 kg/ha) over 100% RDF (1305 kg/ha). Significantly lower seed yield was recorded when 75% RDF fertilizers were applied. Seed yield is the function of several growth parameters like plant height, dry matter accumulation and yield attributing characters *viz.,* head diameter, number of filled seeds, test weight and yield/plant. Improved growth parameters, greater head diameter due to congenial soil moisture status at star bud initiation to maturity might have led to significantly higher seed yield with broad bed and furrow paired row 45 cm x 30 cm. Adequate supply of plant nutrients under125% RDF had positively reflected with higher seed. Head diameter is the most important attributing character, which improves the seed yield by providing maximum number of florets for higher seed set. Higher seed yield under 125% RDF and 100% RDF over 75% RDF might be due to higher filled seed/head. Bharati Patil *et al*. (2010) recorded significantly higher grain yield of soybean in ridges and furrows as compared to opening of furrows after every two rows and flat bed. In contrary, Byomkesh Let *et al*. (2014) and Pavani *et al*. (2012) reported that planting geometry and land configuration had no significant effect on seed yield of sunflower but significantly higher seed yield at 125% RDF in Alfisols.

Economics: Among the treatment combinations, broad bed and furrow paired row sowing at 45 cm x 30 cm recorded higher net returns and B:C ratio (₹ 21450/ha, 1.82, respectively) followed by ridge and furrow sowing at 60 cm x 30 cm (₹ 14900/ha and 1.58, respectively). RDF at 125% recorded ₹ 18500/ha net returns and B:C ratio 1.74.

From the results it could be concluded that crop yields from rainfed sunflower in Vertisols can be improved by adopting broad bed and furrow paired row at 45 cm x 30 cm or ridge and furrow 60 cm x 30 cm with efficient soil moisture storage at root zone and duly increasing the fertilizer dose to 125% RDF.

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Evaluation of botanicals for pesticidal activity against tobacco caterpillar, *Spodoptera litura* (F.)

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ABSTRACT

Spodoptera litura (F.) (Lepidoptera: Noctuidae) is a polyphagous pest of various oilseed crops like soybean, groundnut, castor and sunflower. Usage of chemical pesticides will often lead to pest resistance, pest resurgence and environment linked problems. Hence, exploring the pesticidal potential of different botanicals for its management is an eco-friendly option. A bioassay experiment in completely randomized design was conducted to study the pesticidal activity of various botanicals (*Adhatoda vasica* L., *Calotropis gigantea* L., *Melia azedarach* Cav., *Murraya koenigii* L., *Pongamia pinnata* L. and *Vitex negundo* L.) against *S. litura* in castor. Extracts were prepared from various botanicals using acetone and methanol and evaluated against third instar larvae of *S. litura* at 24, 48 and 72 hrs with 250, 500, 750 and 1000 ppm concentrations under laboratory condition. Total phenolic contents and phytocomponents of the botanicals by GC-MS were also studied. Results of the present study indicated that the maximum percentage mortality of third instar larvae of *S. litura* was observed with methanolic extracts of *M. azedarach* and *P. pinnata* in 1000 ppm concentration after 72 hours, which was followed by *M. koenigii.* Higher total phenol content was recorded with *M. koenigii, M. azedarach* and *P. pinnata.* The GCMS study revealed the presence of squalone, a triterpenoid compound in *M. azedarach* and *P. pinnata.* This study suggests that, bio-pesticidal potential of *M. azedarach* and *P. pinnata* was due to the presence of phenolic and triterpenoid compounds resulted in higher larval mortality of *S. litura*.

Keywords: Bio-pesticidal activity, Botanicals, Castor, Phytocomponents, *Spodoptera litura*

One of the most important insect pests of agricultural crops in the Asian tropics is the tobacco caterpillar, *Spodoptera litura* F. (Manju *et al*., 2016). It is a polyphagous and most destructive pest which has about 150 host species causing heavy economic loss every year (Venkataiah *et al*., 2015). Various crops *viz.,* groundnut, castor, soybean, sunflower cole crops, castor, cotton, chilies, pulses, amaranthus, tomato were found to be voraciously fed by the larvae of *S. litura* (Yadav *et al.,* 2012; Choudhary *et al.,* 2014; Lakshman *et al.,* 2017). It is reported to be responsible for the reduction of 43.7% groundnut haulm yield (Patil *et al.,* 1996) and castor seed yield of 31.0 to 40.8 per cent (Lakshminarayana and Duraimurugan, 2014). Chemical pesticides were applied to overcome the *S. litura* problem, in general. But, insect resistance, residue contamination of human foods, mammalian toxicity and pollution to the environment were caused by the application of the pesticides (Khanna *et al.,* 2011; Chandrayudu *et al.,* 2017). In order to overcome these undesirable problems, numerous bio-pesticides are explored. Biopesticides are secondary metabolite compounds produced by plants such as phenolic compounds, alkaloids, terpenoids, and sulfur compounds. This secondary metabolite is a plant defense against pest attack, because it has a mechanism that can inhibit insect metabolism. The effects of secondary metabolite compounds which is insecticide is the occurrence of death at an early age, and the rate of growth decreases. The use of bioactive compounds derived from plants is more developed because it is safe and environmentally friendly. Hence, the present study was conducted to evaluate the pesticidal activity of six botanicals using methanol and acetone extracts against the cut worm, *S. litura.*

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MATERIALS AND METHODS

Screening for pesticidal activity: A bioassay experiment was conducted in completely randomized design by following range finding test to screen for pesticidal activity of various botanicals against *S. litura* at department of entomology in Pandit Jawaharlal Nehru College of Agriculture & Research Institute, Karaikal during January to June, 2015. Mass culturing of *S. litura* and preparation of extracts from leaves of *Adhatoda vasica.* L. (Acanthaceae), *Calotropis gigantea* L. (Asclepiadaceae), *Melia azedarach* Cav. (Meliaceae), *Murraya koenigii* L.(Rutaceae), *Pongamia pinnata* L. (Fabaceae) and *Vitex negundo* L. (Verbenaceae) was earlier discussed (Manju *et al.,* 2016).

Experiment consists of graded concentrations of botanical extracts *viz.,* 250, 500, 750 and 1000 ppm and was tested against the third instar larvae of *S. litura* for the duration of 24, 48 and 72 hour period by leaf disc bioassay method. Castor leaf of 6 cm diameter discs were used in the leaf dipping method. These leaf discs were kept individually in glass petri dishes after air drying. Pre- starved third instar larvae were released at 30 numbers with ten larvae in each petri plate and the experiment was replicated three times.

Observations were made for 72 hours with the interval of 24 hours and results were recorded. Critical difference values were calculated at 5 per cent probability level and the treatment mean values of the experiments were compared using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Determination of total phenol content: Total phenolic content (TPC) were quantified in each test sample, following the protocol of Bray and Thorpe (1954), which included the preparation of a regression curve of standard phenol (Gallic acid). Samples were diluted with distill water to give concentration of 0.4mg/ml. A 0.5 ml of each sample was added with 0.5 ml of Folin- Ciocalteu reagent and 1.0 ml of distill water. After a period of 2-5 minutes, the tubes were added with 0.5 ml of 10% Na_2CO_3. After 1-hr incubation at room temperature the absorbance was measured on a spectrophotometer UV-VIS spectrophotometer at 760 nm using distill water as a blank. Gallic acid (0-100 mg/L) dissolved in distilled water was used to prepare standard curve concentration and values were expressed as microgram of gallic acid equivalents (µg Gallic acid/g extract).

Phytocomponents analysis of botanicals by GC-MS analysis: The leaves of best performed botanicals (*M. azedarach* and *P. pinnata*) against *S. litura* were selected for phytocomponents analysis by GC-MS.

GC programme: The sample was extracted with ethanol and analysed through GC-MS for identification of different compounds. Column: Elite-5MS (5% Diphenyl/95% Dimethyl poly siloxane), 30 x 0.25 mm x 0.25 mm df,

Equipment: GC Clarus 500 Perkin Elmer, Carrier gas: 1 ml per min, Split: 10:1, Detector: Mass detector Turbo mass gold-Perkin Elmer, Software: Turbomass 5.2, Sample injected: 2 ml

Oven temperature programme: 110° C -2 min hold, Up to 200°C at the rate of 10°C/min-No hold, Up to 280°C at the rate of 5°C/min-9 min hold, Injector temperature 250°C, Total GC running time 36 min

MS programme: Library used NIST Version-Year 2005,Inlet line temperature 200°C, Source temperature 200°C, Electron energy: 70 eV, Mass scan (m/z): 45-450, Solvent Delay: 0-2 min, Total MS running time: 36 min

RESULTS AND DISCUSSION

A bioassay experiment was conducted in completely randomized design by following range finding test to screen the insecticidal activity of botanicals. The concentrations at 250, 500, 750 and 1000 ppm were tested by leaf disc bioassay method against the third instar larvae of *S. litura* with different botanical extracts for 24, 48 and 72 hour periods. Results on the percentage mortality of third instar larvae of *S. litura* with different botanical extracts indicated that there was no significant influence on the mortality of *S. litura* upto 48 hours except at 1000 ppm but larval mortality was found to increase with increase with concentration during 72 hours. Maximum larval mortality was recorded with *M. azedarach* and *P. pinnata* in methanol and acetone, and followed by *M. koenigii* in methanolic extract at 1000 ppm. Among the concentration, results of this present study indicated that the percentage mortality at 500, 750 and 1000 ppm ranged from 0.0 to 66.7, 0.0 to 93.3, and 0.0 to 100.0 per cent respectively during 72 hours (Table 1). The higher percentage of larval mortality under *M. azedarach* might be due to the presence of significant amount of tetranor-triterpenes (limonoids) in the leaves and seeds. Presence of limonoids (Carpinella *et al.,* 2003), a tetranortriterpenes in the leaves and seeds of *M. azedarach,* which act as stomach poison, found to cause damage to the midgut epithelium and high larval mortalty (Defago *et al.,* 2009). Similar effect was earlier observed by Travis and Ken (2012). *P. pinnata* found to be better biopesticidal source followed by *M. azedarach.* Methanolic extracts of *P. pinnata* showed the maximum growth reduction and higher larval mortality of *S. litura* (Prathibhav *et al.,* 2010). All the earlier findings are in conformity with the present findings.

Total phenolic content of *M. koenigii* methanolic extracts (170.00 µg of CE/g dry weight) was found to be significantly higher, which was followed by the *M. azedarach* (148.00 ?g of CE/g dry weight) and *P. pinnata* (146.33 µg of CE/g dry weight) in acetone extracts (Table 2). Presence of secondary metabolite compounds such as hydroquinone phenols, flavonoids, tannins and sterols can affect the physiology and growth of insects. Further, analysis of phytocomponents by GC-MS study conducted in the present study confirmed the presence of higher amount of phytol and appreciable amounts of squalene, a triterpenoid compounds in the leaves of *M. azedarach* (Table 3 and Fig. 1) and 1,2,3-Cyclohexanetriol and squalene in leaves of *P. pinnata* (Table 4 and Fig. 2) besides the presence of several phytocomponents. In particular, the squalene (triterpine) is a phenolic compound and that the terpines are found in latex and resines of some plants and physiological function of these compounds are generally believed to be a chemical in defense against certain pathogens causing human and animal diseases (Scortichini and Rossi, 1991). Their activity is a function of the lipophilic properties of the constituent terpines, the properties of their functional groups, and their aqueous solubility (Mahato and Sen, 1997). It was concluded that various botanicals were found to possess pesticidal activity and growth inhibition potential. In particular, *M. azaderach* and *P. pinnata* exhibited better bio-pesticidal potential due to the presence of phenols and triterpenoid compounds which helped to cause higher larval mortality of *S. litura.*

Table 1 Per cent larval mortality of *Spodoptera litura* in various concentrations of botanical extracts at 24, 48 and 72 hours

Botanical species	Extract	Per cent *S. litura* larval mortality											
		24 hours				48 hours				72 hours			
		250 ppm	500 ppm	750 ppm	1000 ppm	250 ppm	500 ppm	750 ppm	1000 ppm	250 ppm	500 ppm	750 ppm	1000 ppm
Adhatoda vasica	Methanol	6.7 (9.2)	40.0 (34.4)	60.0 (51.1)	60.0 (51.1)	26.7 (25.9)	40.0 (34.4)	60.0 (51.2)	66.7 (55.4)	33.3 (30.2)	60.0 (51.1)	66.7 (55.4)	66.7 (55.4)
	Acetone	20.0 (26.6)	13.3 (17.9)	26.7 (30.8)	33.3 (30.2)	26.7 (30.8)	33.3 (35.0)	53.3 (46.9)	66.7 (59.8)	26.7 (30.8)	53.3 (47.3)	73.3 (64.1)	73.3 (64.1)
Calotropis gigantea	Methanol	33.3 (35.0)	40.0 (34.4)	46.7 (42.7)	53.3 (46.9)	40.0 (38.9)	46.7 (43.0)	60.0 (50.7)	66.7 (59.8)	40.0 (38.9)	40.0 (38.9)	66.7 (59.8)	66.7 (59.8)
	Acetone	13.3 (17.9)	13.3 (17.9)	26.7 (25.9)	60.0 (50.8)	20.0 (26.6)	40.0 (38.9)	46.7 (42.7)	66.7 (54.9)	26.7 (30.8)	53.3 (46.9)	73.3 (59.2)	73.3 (59.2)
Melia azedarach	Methanol	26.7 (30.8)	46.7 (43.1)	46.7 (43.1)	73.3 (63.7)	46.7 (43.1)	60.0 (51.2)	73.3 (64.1)	93.3 (80.8)	46.7 (43.1)	53.3 (46.9)	93.3 (80.8)	100.0 (89.5)
	Acetone	26.7 (30.8)	33.3 (35.0)	60.0 (51.1)	80.0 (63.4)	33.3 (30.1)	53.3 (46.9)	80.0 (72.8)	93.3 (80.8)	33.3 (30.2)	66.7 (59.8)	80.0 (72.8)	93.3 (80.8)
Murraya koenigii	Methanol	13.3 (17.9)	33.3 (35.0)	60.0 (51.1)	60.0 (50.8)	46.7 (43.1)	60.0 (50.8)	66.7 (55.4)	80.0 (67.9)	46.7 (43.1)	66.7 (54.9)	80.0 (63.4)	86.7 (72.1)
	Acetone	26.7 (30.8)	33.3 (30.2)	46.7 (38.2)	73.3 (63.7)	26.7 (30.8)	46.7 (38.2)	66.7 (59.8)	73.3 (63.7)	26.7 (30.8)	46.7 (38.2)	73.3 (63.7)	73.3 (63.7)
Pongamia pinnata	Methanol	33.3 (30.2)	46.7 (42.7)	60.0 (51.1)	60.0 (50.8)	46.7 (43.1)	66.7 (55.4)	86.7 (76.6)	86.7 (76.6)	53.3 (47.3)	73.3 (64.1)	86.7 (76.6)	86.7 (76.6)
	Acetone	26.7 (30.8)	33.3 (35.0)	46.7 (43.1)	73.3 (59.2)	33.3 (35.0)	40.0 (39.2)	66.7 (59.8)	86.7 (72.1)	33.3 (35.0)	53.3 (47.3)	66.7 (59.8)	86.7 (72.1)
Vitex negundo	Methanol	26.7 (30.8)	53.3 (46.9)	60.0 (51.1)	73.3 (59.2)	53.3 (46.9)	66.7 (54.9)	73.3 (59.2)	73.3 (59.2)	46.7 (43.1)	66.7 (54.9)	80.0 (63.4)	73.3 (59.2)
	Acetone	26.7 (30.8)	20.0 (17.2)	26.7 (26.3)	46.7 (43.1)	33.3 (34.6)	46.7 (43.1)	46.7 (43.1)	80.0 (67.9)	33.3 (34.6)	46.7 (43.1)	73.3 (64.0)	80.0 (67.9)
Control	Distilled water	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)	0.0 (0.46)
CD (P=0.05)		NS	NS	NS	22.54	NS	NS	31.78	32.15	NS	30.46	34.81	29.48

Values given in parenthesis are arcsine transformed values. All values are mean of three replicates of 30 insects in each replicate

Table 2 Total phenol content (TPC) of botanical extracts

Species	Extract	Total phenol content as Catechol equivalent (µg/g)
Adhatoda vasica	Methanol	113.67
	Acetone	128.33
Calotropis gigantea	Methanol	128.00
	Acetone	115.67
Melia azedarach	Methanol	140.17
	Acetone	148.00
Murraya koenigii	Methanol	170.00
	Acetone	125.33
Pongamia pinnata	Methanol	138.33
	Acetone	146.33
Vitex negundo	Methanol	129.33
	Acetone	120.67
CD (P=0.05)		13.13

Table 3 Major phyto-components of *Melia azedarach* obtained by GC-MS

Retention time (mins)	Name of the compound	Molecular formulae	Molecular weight (g)	Peak area (%)
8.52	5-O-Methyl-d-gluconic acid dimethylamide	C9H19NO6	237	6.39
10.43	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	C20H40O	296	5.43
10.92	9-Tetradecen-1-ol, acetate, (E)-	C16H30O2	254	3.65
11.58	1,2-15,16-Diepoxyhexadecane	C16H30O2	254	1.72
12.34	Tetradecanoic acid	C14H28O2	228	30.74
13.32	Phytol	C20H40O	296	18.83
14.57	9,12-Octadecadienoic acid (Z,Z)-	C18H32O2	280	20.11
16.68	E-10-Dodecen-1-ol propionate	C15H28O2	240	2.08
18.93	Didodecyl phthalate	C32H54O4	502	0.85
20.52	7-Hexadecenal, (Z)-	C16H30O	238	0.28
22.00	Squalene	C30H50	410	1.52
23.05	Methoxyacetic acid, tridecyl ester	C16H32O3	272	0.31
25.10	7-Oxabicyclo[4.1.0]heptane, 1-methyl-4-(2-methyloxiranyl)-	C10H16O2	168	3.52
26.29	Vitamin E	C29H50O2	430	2.31
27.97	5à-Androstan-16-one, cyclic ethylene C21H34S2 mercaptole	C21H34S2	350	2.25

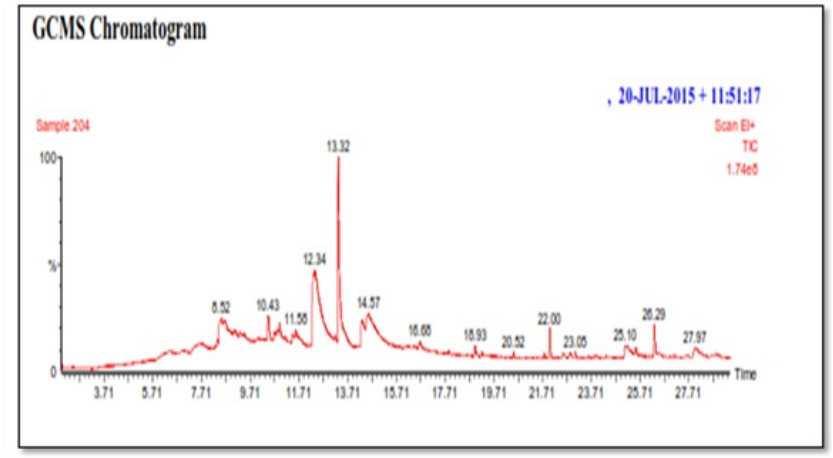

Fig. 1. GC-MS chromatogram of Melia azedarach leaves

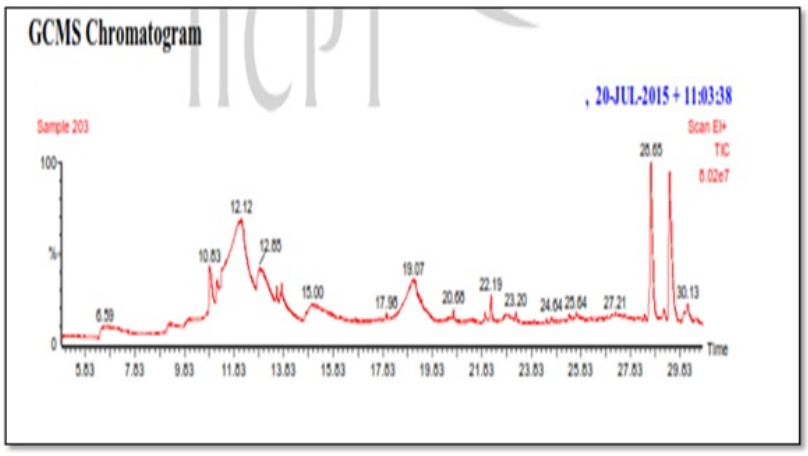

Fig. 2. GC-MS chromatogram of *Pongamia pinnata* leaves

Table 4 Major phyto-components of *Pongamia pinnata* obtained by GC-MS

Retention time (mins)	Name of the compound	Molecular formulae	Molecular weight (g)	Peak area (%)
6.59	4-Piperidinamine, N,1-dimethyl-	C7H16N2	128	4.02
10.83	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	C20H40O	296	4.58
12.12	1,2,3-Cyclohexanetriol	C6H12O3	132	42.27
12.85	9,9-imethoxybicyclo[3.3.1]nona-2,4- dione	C11H16O4	212	12.67
13.75	13,16-Octadecadiynoic acid, methyl ester	C19H30O2	290	4.84
15.00	Z-10-Tetradecen-1-ol acetate	C16H30O2	254	5.81
19.07	3-Cyclopropylcarbonyloxydodecane	C16H30O2	254	9.78
20.68	7-Hexadecenal, (Z)-	C16H30O	238	0.31
22.19	Squalene	C30H50	410	0.72
23.20	4-Cyclopropylcarbonyloxytridecane	C17H32O2	268	0.31
28.65	Urs-12-en-24-oic acid, 3-oxo-, methy ester, (+)-	C31H48O3	468	6.83
29.40	Oct-5-en-2-ol, 8-(1,4,4a,5,6,7,8,8a-octahydro-2, 5, 5, 8a-tetramethylnaphth-1-yl)-6-methyl-	C23H40O	332	7.85

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Oviposition deterrent activity of different botanicals against *Spodoptera litura* (Lepidoptera: Noctuidae) in soybean

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ABSTRACT

Tobacco caterpillar, *Spodoptera litura* (F.) is a polyphagous pest widely distributed in south east Asia which is an economically important pest as it can cause 25 to 100 per cent crop loss by defoliation. Heavy use of insecticides caused it to gain resistance over almost all groups of insecticides. Use of botanicals is a conventional approach for pest management as it is a two-tier approach by being eco-friendly and also manages the pest population. Therefore, the present study was carried out to determine the ovicidal and repellent activities of botanicals *viz.,* Datura leaf extract 5%, Annona leaf extract 5%, Marigold leaf extract 5%, Neem oil 5%, Pongamia oil 5% and Eucalyptus oil 2% against *S. litura* in soybean. The study revealed that the Eucalyptus oil 2 % was least preferred for oviposition as the number of eggs laid in this treatment were 71.20, out of which 31.50 per cent eggs hatched and it also possessed the lowest oviposition index 0.20, followed by Neem oil 5% as the number of eggs laid in this treatment were 157.20, among which 46.28 per cent eggs hatched having an oviposition index of 0.23. Hence, the results indicate that eucalyptus oil and neem oil were least preferred, hence the botanicals are reliable source for eco-friendly management of *S. litura* in soybean.

Keywords: Botanicals, Hatchability, Oviposition index, *Spodoptera litura,* Soybean

Soybean (*Glycine max* L. Merril) is the world's most important legume, which contributes to 25 % of edible oil worldwide and also nearly two-thirds of the world's protein concentrate for livestock feeding. Due to high protein content (>40%) and high oil content (>20%), soybean is considered to be an important food commodity (Mehto, 2016; Thombre *et al.,* 2017). There is a gradual reduction in the soybean yield because of various biotic interferences in crop growth in the field, such as interference by different pests and diseases. The pests on soybean attack the leaves, pods and stems. *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) is a polyphagous pest, widely distributed throughout the Asia. It has a wide range of hosts of which 40 species are known in India (Krishnaveni *et al.,* 2013; Singh *et al.,* 1998 and Paulraj, 2001; Lakshman *et al.,* 2017). *S. litura* is an economically important pest that has developed insecticide resistance in India (Chandrayudu *et al.,* 2017). It led to sporadic outbreaks of the pest and failure of the crops (Ahmad *et al.,* 2006). It has also developed manifold resistance against conventionally used insecticides. The excessive usage of chemical insecticides has resulted in serious problems like development of resistance. The growing awareness of the hazards of excessive use of pesticides globally has led researchers to search for safer and more environment-friendly alternative methods for insect pest control. Over the last three to four decades greater attention has been focused on the bioactivity of phytochemicals for their potential as pesticides against phytophagous insect parts (Sahayaraj, 2011; Anbalagan *et al.,* 2014; Manju *et al.,* 2016). On the other hand several plant species have been reported to possess insecticidal properties (Singh *et al.,* 2001; Anna Senrung, 2014). They are also responsible for affecting the food consumption and utilization by insects (Rajguru *et al.,* 2010), also their oviposition is affected (Raja *et al.,* 2003 and Jeysankar *et al.,* 2013). Therefore, the present study was carried out to screen selected botanicals for their ovicidal and repellent activities against *S. litura* in soybean.

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MATERIALS AND METHODS

Insect culture: Laboratory culture of tobacco caterpillar, *Spodoptera litura* maintained on soybean leaves (cv. JS 95-60) following Rajguru *et al.* (2010) at 27±2°C, 70±5% RH and natural photoperiod conditions was used for the experiment.

Preparation of plant extracts: Six botanicals were used out of which three were plant oils while the remaining three were leaf extracts (Table 1). The leaf extracts was prepared by collecting 500 g of fresh leaves and soaked them in 100 ml water overnight followed by macerating them using a blender and filter the extract with Whatman filter paper and preparing the solutions based on the concentrations required. The plant oils were mixed with sticker (Teepol) before they were used. The different treatments and their concentrations used for the experiment are tabulated in Table 1.

Oviposition deterrent effect of plant extracts on *S. litura*: The soybean cultivar JS 95-60 was used, its seeds were sown in pots. Fresh leaves collected along with petiole, were inserted in plastic glasses containing water. The leaves were

sprayed with the botanicals on both sides. After air drying, the treated leaves were placed in the oviposition cage and 30 pairs of healthy pupae were kept inside the cage for egg laying. Ten percent honey solution infused cotton swabs were also kept in the cage as food for adults. There were 7 treatments and replicated five times and the leaves were changed for every 48 hours. The leaves were checked on everyday basis to evaluate the number of eggs laid per day in every treatment and the hatchability of the eggs were evaluated in comparison with control plot as per the methodology followed by Raja *et al.* (2003), Baskaran *et al.* (2012) and Jeyasankar *et al.* (2013). The oviposition index and percent hatchability was calculated as per the methodology followed by Prajapati (2011).

Table 1. Treatment details of botanicals used in the experiment

T_1	Datura leaf extract (*Datura stramonium*)	5%(v/v)* (Kulkarni *et al.* , 2014)
T_2	Annona leaf extract (*Annona squamosa*)	5% (v/v) (Babu *et al*., 1998)
T_3	Marigold leaf extract (*Tagetus erecta*)	5% (v/v) (Kulkarni *et al*., 2014)
T_4	Neem oil (*Azardirachta indica*)	5% (v/v) (Sueli *et al*., 2001)
T_5	Pongamia oil (*Pongamia pinnata*)	5% (v/v) (Babu *et al*., 1998)
T_6	Eucalyptus oil (*Eucalyptus glabrous*)	2% (v/v) (Baskaran *et al*., 2012)
T_7	Control	-

$$\text{Oviposition index} = \frac{\text{No. of eggs laid in treatment}}{\text{No. of eggs laid in control}}$$

$$\text{Hatchability\%} = \frac{\text{No. of eggs hatched in treatment}}{\text{No. of eggs hatched in control}} \times 100$$

RESULTS AND DISCUSSION

Among all the seven treatments, eucalyptus oil recorded least number of eggs laid (71.20) which in turn showed very less number of hatched eggs (22.41), thereby the least hatchability per cent of 31.50 indicating that eucalyptus oil reduced oviposition by 95.24 per cent. the similar trend was followed by neem oil recording the lowest number of eggs laid after eucalyptus oil (157.20), out of which the number of hatched eggs were also few (71.92) with a hatchability per cent of 45.76 showing that neem oil reduced oviposition by 54.24 per cent, datura leaf extract showed promising results compared to other leaf extracts. Both marigold leaf extract and karanj oil recorded the number of eggs laid as 827.60 and 516.80 respectively with hatchability percentages as 63.77 and 61.84 corresponding to the reduced oviposition at the rate of 36.24 per cent and 38.15 per cent, respectively. The maximum numbers of eggs laid were recorded in the treatment Annona squamosa (1078) and control (1511.60) with higher hatchability of 83.9 per cent and 95.8 per cent showing very low effect on reducing oviposition 17.4 per cent and 7.8 per cent, respectively (Table 2) proving that anonna leaf extract is not preferable for use in pest management according to this study.

According to the results as stated in Table 3, it was found that the least oviposition index were on Eucalyptus oil (0.20) followed by Neem oil (0.23) which is at par with Datura stramonium (0.23). Maximum oviposition index was seen among the treatment Annona squamosa (0.52) and recorded in control (1.00). The treatments showing lowest oviposition index like eucalyptus oil (0.20), neem oil (0.23) and datura leaf extract (0.23) are highly suitable for use as oviposition deterrents as they reduced the oviposition proving they are least preferred. These could be integrated as one of the approaches for eco-friendly pest management.

The state of pest management today mainly focuses not on the performance of insecticide on target pest but its effect on the environment is of major importance, keeping this aspect in mind using botanical pesticides is one of the best alternative to chemical control. For lepidopteran pest oviposition deterrence, feeding deterrent activities have been reported by several researchers (Singh *et al.,* 2001). The present study proved that eucalyptus oil and neem oil can be reliable for pest management as reported by Kiran *et al.* (2006). Anurag *et al.* (2008) reported that plant extracts are acting as oviposition deterrents for *S. litura* and in similar manner datura leaf extract showed significant effect on ovipositional deterrence equally with the eucalyptus and neem oil. The present observations are corroborating with the previous findings of Rajguru *et al.* (2010), Jeysankar *et al.* (2013), Baskaran *et al.* (2012) and Kulkarni *et al.* (2014) where the oviposition deterrent activity was higher with higher concentrations of plant extracts against *S. litura* as the volatiles present in the plant oils and also in extracts deterred the pest from laying eggs and reduced hatchability. Nevertheless, in this study we found that even low concentrations of oil can cause strong antioviposition effect as in eucalyptus oil with oviposition index as low as 0.20, which is also reported to be the lowest among all the other treatments. Similarly, significant effects were obtained with higher concentrations of the other treatments (Autran *et al.,* 2009). This study was just an attempt to evaluate the different botanicals in form of plant extracts and oils for proving their oviposition deterrent activity against S. litura. The results indicate that eucalyptus oil and neem oil were least preferred, hence the botanicals are reliable source for eco-friendly management of *S. litura* in soybean.

Table 2 Per cent reduction in egg laying and effect on hatchability of *S. litura*

Treatments	No. of eggs laid	Percent reduction in oviposition	No. of eggs hatched	Percent hatchability
T_1 (*Datura stramonium*)	217.40 (14.74)#	44.46 (27.62)*	119.69 (10.93)#	54.50 (47.58)*
T_2 (*Annona squamosa*)	1078.00 (32.82)	17.40 (11.11)	903.73 (30.06)	83.90 (66.39)
T_3 (*Tagetus erecta*)	827.60 (28.75)	36.24 (11.80)	528.81 (22.97)	63.77 (53.0)
T_4 (*Azardirachta indica*)	157.20 (12.50)	54.24 (31.18)	71.92 (8.47)	45.75 (42.86)
T_5 (*Pongamia pinnata*)	516.80 (22.65)	38.15 (23.84)	319.64 (17.84)	61.84 (52.23)
T_6 (*Eucalyptus globules*)	71.20 (8.40)	95.24 (77.49)	22.41 (4.71)	31.50 (34.14)
T_7 (Control)	1511.60 (38.80)	7.80 (12.00)	1448.56 (37.98)	95.80 (78.34)
SEM±	0.675	1.968	0.574	0.888
CD @ 5%	1.966	5.730	1.671	2.578

#Figures in parentheses are square root transformed values; *Figures in parentheses are arcsin transformed values

Table 3 Effect of different botanicals on oviposition preference of *Spodoptera litura* (F.)

Treatments	No. of eggs laid	Oviposition index	Percent Hatchability
T_1 (*Datura stramonium*)	217.40 (14.74)#	0.23 (0.38)	54.50 (47.58)*
T_2 (*Annona squamosa*)	1078.00 (32.82)	0.52 (0.86)	83.90 (66.39)
T_3 (*Tagetus erecta*)	827.60 (28.75)	0.31 (0.74)	63.77 (53.0)
T_4 (*Azardirachta indica*)	157.20 (12.50)	0.23 (0.34)	46.28 (42.86)
T_5 (*Pongamia pinnata*)	516.80 (22.65)	0.28 (0.56)	62.44 (52.23)
T_6 (*Eucalyptus globules*)	71.20 (8.40)	0.20 (0.22)	31.50 (34.14)
T_7 (Control)	1511.60 (38.80)	1.00 (1.00)	95.80 (78.34)
SEM ±	0.675	0.024	0.888
CD @5%	1.966	0.071	2.578

#Figures in parentheses are square root transformed values; *Figures in parentheses are arcsin transformed values

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Screening backcross derived population of groundnut (*Arachis hypogaea* L.) for resistance to rust and late leaf spot diseases

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ABSTRACT

A set of 88 groundnut backcross derived progenies in BC_1F_2 generation of the cross CO 7 × GPBD 4 were evaluated during *kharif* 2016 against rust and late leaf spot. Field evaluation identified 19 progenies with rust and late leaf spot resistance. These backcrossed progenies may be subjected to yield assessment for further release as an improved variety.

Keywords: Backcross breeding, Groundnut, Rust and late leaf spot resistance, Screening

Rust (*Puccinia arachidis* Speg.) and late leaf spot [*Cercosporidium personatum* (Berk. & Curt.) Deighton] are the major devastating foliar fungal diseases in groundnut. These diseases damage the plant by reducing the leaf area available for photosynthesis and by stimulating the leaflet abscission leading to heavy defoliation. In India, rust and late leaf spot (LLS) generally occur together and cause not only a yield loss up to 70%, but also bring down the quality of the feed and fodder produce (Dwivedi *et al.,* 2002; Divyadharsini *et al.,* 2016). In general, disease control is possible with fungicides (4-8 sprays based on disease severity) but a majority of farmers in the semi arid tropics cannot afford them since they lack the resources and technical expertise required to use them effectively (Subrahmanyam *et al.,* 1984; Basha *et al.,* 2016; Sangeetha *et al.,* 2017). Moreover, the use of fungicides is neither a cost-effective approach nor a healthy practice for the environment and human health. Breeding for resistant variety is preferred means of managing the foliar diseases over chemical control considering the additional cost and biological safety. With this background the BC_1F_2 of CO 7 × GPBD 4 was studied for their resistance against foliar diseases in this investigation.

The rust and late leaf spot susceptible variety CO 7, a Spanish Bunch type was selected as a recipient for introgression of rust and LLS resistance traits. CO 7 is a popular, high yielding, drought tolerant and early maturing (100-105 days) cultivar with high oil content (51%). This variety, a derivative of the cross ICGV 87290 × ICGV 87846 was bred at Department of Oilseeds, TNAU, Coimbatore and released for cultivation in 2013. While GPBD 4, the leading groundnut variety in Karnataka, is high yielding as well as resistant to both the diseases and was selected as a donor parent. The parent CO 7 was crossed with GPBD4. The F_1 plants were backcrossed with recurrent parent CO 7. Promising BC_1F_1 progenies were selected and selfed. Eighty eight progenies in BC_1F_2 generation were screened for diseases.

Phenotyping for rust and LLS was carried out at Department of Oilseeds, TNAU, Coimbatore, India during *kharif* 2016. Ten seeds from each progeny were sown with 30 cm and 10 cm inter-and intra-row spacing, respectively. Both parental genotypes (CO 7, GPBD 4) were sown as controls. The genotypes were subjected to field screening for rust and LLS reaction using infector row technique (Subrahmanyam et al.,1995) in which Co Gn 4 were planted at regular interval of 10 rows and as border rows around the field to maintain sufficient inoculum load. Disease scoring for rust and LLS was done on plants at 90 days after sowing according to the modified scale of Subrahmanyam *et al.* (1995).

An attempt was made to improve elite peanut genotype CO 7 for the foliar fungal disease resistance by using GPBD 4 variety as the donor. Both CO 7 and GPBD 4 were crossed and the F_1 was backcrossed with CO 7. The BC_1F_1 generation was raised and promising plants were forwarded. A set of 88 BC_1F_2 progenies derived from cross CO 7 × GPBD 4 along with the parental genotypes were evaluated for reaction to rust and LLS during *kharif* 2016 under disease epiphytotic condition (Table 1). The mean score of parent GPBD 4 recorded 2.5 for rust and 2.0 for LLS that showed consistently lower disease incidence than CO 7, which showed scores of 7.0 and 9.0 for rust and LLS reaction, respectively. While screening back crossed progenies, a difference in severity was observed among the genotypes.

Of the 88 progenies screened for rust and LLS diseases, 30 progenies for rust and 29 for LLS showed significantly lower disease scores of 2.0 - 2.3 and 2.5 - 3.0 for rust and LLS, respectively, which were on par with GPBD 4 (Table 1). Several sources of resistance to these diseases have been identified and reported by many workers (Hossain *et al.,* 2007; Harinath Naidu *et al.,* 1997). On the other hand, screening for both the diseases led to the identification of 19

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lines possessing a disease score of 2.0 for rust and 2.5 for LLS, which is on par with the disease score observed for the donor, GPBD 4. Simultaneous evaluation of the derivatives of these progenies for yield under the disease condition should lead to development of improved variety in groundnut.

Nineteen progenies of BC_1F_2 of the cross CO 7 × GPBD 4 were identified to be carrying both rust and LLS resistance under the field screening. Therefore, these progenies could be further used for developing high yielding and foliar disease resistant variety in groundnut.

Table 1 Reaction of groundnut genotypes to rust and late leaf spot diseases

BC_1F_2 progeny	Rust (Scale)	LLS (Scale)	Susceptible or resistance	BC_1F_2 progeny	RUST (Scale)	LLS (Scale)	Susceptible or resistance
CGX16005 - 1	6.8	7.5	S	CGX16005 - 45	2.0	2.5	R
CGX16005 - 2	7.7	7.7	S	CGX16005 - 46	7.3	8.0	S
CGX16005 - 3	7.0	2.5	S	CGX16005 - 47	7.0	7.0	S
CGX16005 - 4	7.3	6.3	S	CGX16005 - 48	7.6	3.0	S/R
CGX16005 - 5	2.0	2.5	R	CGX16005 - 49	2.0	6.0	R/S
CGX16005 - 6	2.0	2.5	R	CGX16005 - 50	6.0	6.2	S
CGX16005 - 7	5.8	6.6	S	CGX16005 - 51	7.0	7.3	S
CGX16005 - 8	7.0	6.5	S	CGX16005 - 52	6.4	2.5	S/R
CGX16005 - 9	6.3	2.5	S/R	CGX16005 - 53	6.0	6.8	S
CGX16005 - 10	6.7	7.7	S	CGX16005 - 54	4.2	6.3	S
CGX16005 - 11	2.0	2.5	R	CGX16005 - 55	6.4	7.4	S
CGX16005 - 12	7.4	4.8	S	CGX16005 - 56	2.0	2.5	R
CGX16005 - 13	5.6	2.5	S/R	CGX16005 - 57	2.6	3.0	R
CGX16005 - 14	3.0	6.5	R/S	CGX16005 - 58	6.2	6.8	S
CGX16005 - 15	7.5	6.5	S	CGX16005 - 59	3.0	2.5	R
CGX16005 - 16	6.6	7.6	S	CGX16005 - 60	5.3	7.0	S
CGX16005 - 17	2.0	2.5	R	CGX16005 - 61	6.2	7.6	S
CGX16005 - 18	7.2	6.4	S	CGX16005 - 62	2.0	2.5	R
CGX16005 - 19	8.4	7.4	S	CGX16005 - 63	2.5	6.0	R/S
CGX16005 - 20	7.6	7.0	S	CGX16005 - 64	6.3	5.8	S
CGX16005 - 21	3.0	2.5	R	CGX16005 - 65	5.3	7.8	S
CGX16005 - 22	7.4	3.4	S	CGX16005 - 66	4.0	7.2	S
CGX16005 - 23	3.0	7.6	R/S	CGX16005 - 67	2.0	2.0	R
CGX16005 - 24	7.3	3.0	S/R	CGX16005 - 68	6.8	8.0	S
CGX16005 - 25	6.0	5.2	S	CGX16005 - 69	3.0	6.3	R/S
CGX16005 - 26	2.0	2.5	R	CGX16005 - 70	4.5	6.4	S
CGX16005 - 27	6.7	3.0	S/R	CGX16005 - 71	2.0	3.0	R
CGX16005 - 28	6.2	6.4	S	CGX16005 - 72	6.5	3.0	S/R
CGX16005 - 29	3.0	2.5	R	CGX16005 - 73	2.5	5.8	R/S
CGX16005 - 30	6.8	6.0	S	CGX16005 - 74	4.0	2.5	S/R
CGX16005 - 31	7.8	7.3	S	CGX16005 - 75	4.2	5.6	S
CGX16005 - 32	6.5	7.5	S	CGX16005 - 76	5.8	7.0	S
CGX16005 - 33	2.0	2.0	R	CGX16005 - 77	2.0	2.5	R
CGX16005 - 34	6.0	6.0	S	CGX16005 - 78	2.5	6.0	R/S
CGX16005 - 35	6.6	5.2	S	CGX16005 - 79	2.0	6.7	R/S
CGX16005 - 36	6.2	3.4	S	CGX16005 - 80	2.0	2.0	R
CGX16005 - 37	7.3	7.2	S	CGX16005 - 81	3.4	5.4	S
CGX16005 - 38	6.8	6.4	S	CGX16005 - 82	2.5	6.8	R/S
CGX16005 - 39	5.8	3.0	S/R	CGX16005 - 83	3.0	6.8	R/S
CGX16005 - 40	6.3	7.8	S	CGX16005 - 84	6.0	3.5	S
CGX16005 - 41	2.0	2.5	R	CGX16005 - 85	2.0	2.5	R
CGX16005 - 42	7.6	7.4	S	CGX16005 - 86	6.4	3.5	S
CGX16005 - 43	6.8	7.3	S	CGX16005 - 87	3.6	7.5	S
CGX16005 - 44	5.3	3.5	S	CGX16005 - 88	3.0	7.0	S
Susceptible control							
CO 7	7.0	9.0	S				
Resistant control							
GPBD 4	2.0	2.5	R				

S - Susceptible; R - Resistance; S/R- Susceptible to rust and resistance to LLS; R/S - resistance to rust and susceptible LLS

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Cytokinin improves the sink strength and seed yield of sunflower hybrid, KBSH-44

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ABSTRACT

Major production constraint in sunflower hybrids is the poor sink strength. Here we report a hormonal manipulation to improve sink strength and seed yield. Application of BAP (@20 g/ha) at ray floret stage, significantly improved the sink strength parameters viz., thalamus size, number of seeds per head and test weight with a reduced central sterility and resulted in increased seed yield. Additional NAA (50 g/ ha) and GA (10 g/ha) with BAP (20 g/ha) did not improve the seed yield over control. We suggest that application of BAP (@20 g/ha) at ray floret stage is beneficial to increase the sink strength and seed yield of KBSH-44.

Keywords: BAP, Sink strength parameters, LAS, Seed number, Seed yield, Sunflower

Oilseeds occupy an important position in Indian agriculture being next to food grains. Sunflower is the third largest source of oilseeds worldwide next to soybean and groundnut both in terms of area and production (Yeremenko *et al.,* 2017). Sunflower gained popularity in India for its premium oil and short growth period coupled with photo-insensitivity (Reena Rani *et al.,* 2016; Lokesh and Dandoti, 2017). The cultivated area of sunflower in India is 0.82 million hectares with a production of 0.52 million tons and productivity of 707 kg/ha. It is mainly cultivated in Karnataka, Andhra Pradesh, Maharashtra, and Tamil Nadu (FAOSTAT, 2014). Sunflower hybrid, KBSH-44 is a popular public hybrid having high biomass producing capacity and hence improvement of sink strength would enhance the productivity. Application of growth promotersis reported to improve the number of seeds per thalamus, test weight and seed yield of sunflower (Alkio *et al.,* 2003; Sawan *et al.,* 2007; Kashid, 2008; Ernst *et al.,* 2016). Hence, a field experiment was conducted to study the possibilities of improving the sink strength parameters and seed yield of sunflower hybrid (KBSH-44) using cytokinin, auxin and gibberellin.

A field experiment was conducted during rabi season 2017-18 at the All India Coordinated Research Project (AICRP) on sunflower, University of Agricultural Sciences, Bengaluru, situated at 30° North latitude, 77.35° East longitude and at an altitude of 930 meters above mean sea level. The soil of the experimental site was red sandy loam with neutral pH (6.7) and normal range of electrical conductivity (0.22 dS/mat 25°C). The available nitrogen (355 kg/ha), phosphorus (50.49 kg/ha) and potassium content (243 kg/ha) in the soil were medium.

Farm yard manure (FYM) @ 7.5 t/ha was applied 15 days prior to sowing. Recommended fertilizer dose of 60:90:60 kg N, P_2O_5, K_2O per hectare in the form of Urea, Di Ammonium Phosphate and Muriate of potash was applied. The experiment was laid out in randomized block design using a popular sunflower hybrid, KBSH-44 with six treatments and four replications. The treatments comprised of Control (water spray), BAP at star bud stage (35 DAS) and or at ray floret stage (45 DAS) and BAP in combination with NAA and GA at star bud stage (35 DAS), at star bud and ray floret stage (45 DAS). The BAP (benzyl amino purine), NAA (naphthalene acetic acid) and GA (Gibberellic acid) (99% purity) were dissolved in alcohol and stock solutions were prepared as per the treatments. From these stock solutions, spray solutions of BAP (20 g/ha in 500 L water), NAA (50 g/ha in 500 L water) and GA (10 g/ha in 500 L water) were prepared and sprayed on the plants at 35 and 45 days after sowing coinciding with star bud stage and ray floret stage respectively. Regular plant protection measures were carried out. The gross plot size of each treatment was 3 m x 3 m (9.0 m²) and the net plot size was 2.4 m x 1.8 m (4.32 m²). Five plants were selected randomly from each replication of the treatment for recording observations. The leaf area per plant was measured at 60 DAS (Nanja Reddy *et al.,* 1995) to compute the ratio of leaf area to floret (seeds per thalamus at harvest). The sterility area was computed by measuring diameter of sterile area of the thalamus, and by adopting r^2 formula. The data was subjected to statistical analyses using the statistical package, OPSTAT (Sheoran *et al.,* 1998).

Under adequate input conditions, seed yield of sunflower is primarily determined by the canopy cover, assimilation rate, sink number and sink activity. In case of high biomass producing hybrids, the productivity depends on efficient partitioning of biomass to reproductive parts. One of the approaches to improve the partitioning of biomass into thalamus, filled seed number and test weight is through external application of hormones (Sawan *et al.,* 2007; Kamil

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and Jobori, 2012). Application of BAP at ray floret stage resulted in larger head with diameter of 13.78 cm as compared to 12.20 cm in control (Table 1). Thalamus weight also increased from 13.11 g/head in control to 16.10 g in BAP sprayed at ray floret stage (Table 1). Large thalamus achieved with BAP might be due to increased cell division and cell expansion (Kothule *et al.,* 2003) which helps to accommodate higher seed number per thalamus (Gholinezhad *et al.,* 2009). Accordingly, in the present study, BAP application produced higher number of filled seeds per thalamus (652.7 with BAP applied at ray floret) as compared to 550.2 seeds per thalamus in control and resulted higher seed yield (Table 1). It appears that the endogenous cytokinin is not sufficient to meet the requirement for increasing florets production; hence exogenous application of cytokinin increased the seed number (Sitton *et al.,* 1967). The test weight did not differ significantly, although the mean test weight with BAP applied at ray floret stage was high (5.64 g per 100 seeds) compared to control (5.48g/100 seeds). Similarly, Kamil and Jobori (2012) reported no change in test weight between kinetin (200 ppm applied at star bud stage) and control.

Application of BAP at ray floret stage significantly reduced the central sterility (4.00 cm^2) as against the higher central sterility of 5.91 cm^2 in control (Table 1). The central sterility of thalamus is very critical for limiting the yield potential of sunflower and; is generally attributed to insufficient source size (Gholinezhad *et al.,* 2009). The limitation of source size can be measured by the ratio of leaf area per plant to the seed number per thalamus (LAS) (Alkio *et al.,* 2003); wherein they reported that a decrease in leaf area per seed (from 6.0 to 3.2 cm^2/seed) increased the central sterility, however even with sufficient source (LAS10 cm^2), the central sterility was not decreased below 5 to 15 per cent. Our results show that application of cytokinin at ray floret stage resulted in maximum seed yield with LAS of 6.0 and further increase in LAS to 8.85 with combination of growth promoters did not increase the seed yield (Table 1). Probably the leaf area beyond an optimum, may serve as sink for photosynthates instead of source in the high biomass producing type, KBSH-44 during seed filling period. In accordance, the seed setting was shown to be prevented by delayed senescence (Ho *et al.,* 1987; Ho and Below, 1989).Therefore, we opine that the seed yield in high biomass producing hybrid, KBSH-44 is not limited by the source size rather it could be due to poor sink strength.

Harvest Index is the ratio of seed yield to total biomass and did not increase significantly with cytokinin application (0.33) against control (0.34).However, the total biomass significantly increased with BAP treatment (109.1 g/plant) compared to control (88.2 g/plant) due to higher thalamus weight and seed weight. Therefore, the seed yield was significantly high with BAP applied at ray floret stage (36.6 g/plant) compared to control (30.0 g/plant). It is concluded that, in high biomass producing hybrid, KBSH-44, foliar application of BAP (20 g/ha) at ray floret stage enhances the sink strength (thalamus size and seed number with reduced central sterility) and seed yield.

Table 1 Effect of plant growth promoters on yield and yield attributes in sunflower hybrid (KBSH-44)

Treatments	Head diameter (cm)	Thalamus dry weight (g/plant)	Seed number/ head	100 seed weight (g)	Area of central sterility (cm^2)	LAS (cm^2 /seed)	TDM (g/plant)	HI	Seed yield (g/plant)
T_1 = Control (water)	12.20	13.11	550.2	5.48	5.91	7.30	88.2	0.34	30.0
T_2 = BAP at star bud stage	12.50	15.36	587.9	5.52	3.69	6.38	98.5	0.33	32.3
T_3 = BAP at ray floret stage	13.78	16.10	652.7	5.64	4.00	6.21	109.1	0.33	36.6
T_4 = BAP at star bud & ray floret stage	13.20	16.16	636.7	5.60	4.07	5.99	109.3	0.33	35.6
T_5 = BAP + NAA + GA at star bud stage	12.10	13.80	541.1	5.53	4.29	7.17	97.4	0.31	30.0
T_6 = BAP + NAA + GA at star bud and ray floret stage	10.85	13.80	534.6	4.75	3.74	8.85	94.7	0.27	25.5
CD @ 5%	0.99	1.75	NS	0.36	0.62	1.42	12.5	0.04	6.02
S.Em (±)	0.33	0.58	39.5	0.12	0.21	0.47	4.1	0.01	1.98
C.V. (%)	5.23	7.83	13.5	4.36	16.19	13.3	8.3	8.1	12.5

Note: Date of sowing (13-11-2017), 1st spray was given on 19-12-2017 (35 DAS, coinciding with star bud stage), 2nd spray was given on 29-12-2017 (45 DAS i.e., ray floret stage), BAP (20 g/ha), NAA (50 g/ha) and GA (10 g/ha) in 500 liters of water)

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Performance of five Mexican safflower (*Carthamus tinctorius* L.) varieties/breeding lines under Indian conditions

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ABSTRACT

Safflower (*Carthamus tinctorius* L.), a drought tolerant crop, is capable of extracting moisture from deeper layers of soil. In India, more than 80 per cent of safflower is cultivated in Vertisols of Peninsular region during post-rainy season under residual soil moisture conditions. Five Mexican varieties/breeding lines (Ciano-Lin, CCC-B4, RC-1033-L, CCC-B2 and CW-99) were evaluated in 2014-15 under irrigated conditions along with two Indian varieties (NARI-57 and PBNS-12). Significant variation was found between Mexican varieties/breeding lines and Indian varieties with respect to plant height, days to first flowering, number of capitula/plant, seed yield, biological yield, oil content and oil yield. Seed and oil yield of CCC-B2 (2259; 800 kg/ha) was on par with that of NARI-57 (2298; 719 kg/ha). The Ciano-Lin recorded significantly low seed (1266 kg/ha) and oil yield (399 kg/ha).

Keywords: Indian varieties, Mexican varieties and breeding lines, Safflower, Yield potential

Safflower (*Carthamus tinctorius* L.) is a drought tolerant crop. It has a strong tap root system which draws moisture from fairly deeper layers of the soil profile (Hussain *et al.,* 2016). In the world, India occupies second place in area after Kazakhstan and third place in production after Kazakhstan and Mexico. In India, it is being cultivated in an area of 2.11 lakh ha with a production of 1.13 lakh tons (FAO STAT, 2017) with productivity of 536 kg/ha. Average productivity of safflower in Mexico is 1260 kg/ha which has enabled Mexico to occupy the second position in production even though less area is under cultivation compared to India.

In India, safflower is basically grown in post-rainy season in Vertisols under receding soil moisture conditions. It is cultivated mainly in Maharashtra (58%), Karnataka (21%), Gujarat (12%) and to a limited extent in Telangana, Madhya Pradesh, Chhattisgarh, Odisha and Bihar (IIOR, 2016; Padmavathi *et al.,* 2017). Productivity is quite low (536 kg/ha) as the crop is being grown by resource poor farmers with poor crop management practices under biotic and abiotic stress conditions.

Safflower is thermo-sensitive crop, which needs cool temperatures (15-20°C) for root growth and rosette development and moderate temperatures of 20-32°C during crop growth, flowering and capitula formation (Shabana *et al.,* 2013). One of the drawbacks associated with safflower cultivation is very thick hull of the native varieties which adversely limits the per hectare yield of oil as well as the quantity and quality of the meal, thereby, making its cultivation less attractive. Apart from their low yield potential, all the available exotic germplasm resources with high oil content show poor adaptability to Indian conditions. Considering the importance of increasing safflower production, efforts are needed to breed cultivars with high oil yield coupled with abiotic stress tolerance there by increasing the profitability of safflower cultivation. The incorporation of alleles for low hull and/or high oil content into the genetic background of locally adapted agronomic base should form an important breeding activity in the immediate future (Kadirvel *et al.,* 2016; Kadirvel *et al.,* 2017). This study was undertaken to quantify the productivity potential, in terms of seed and oil yield, of a few Mexican varieties /breeding lines in comparison to Indian varieties.

A set of five promising varieties/breeding lines of safflower, *viz,* Ciano-Lin (EC 755688), CCC-B4 (EC 755671), RC-1033-L (EC 755687), CCC-B2 (EC 755669) and CW-99 (EC 755664), with higher seed yield potential were selected from among the lines obtained from Instituto Nacional de Investigaciones Forestales, Agricolasy Pecuarias (INIFAP), Campo Experimental Valle del Yaqui, Sonora, Mexico. These five lines along with two Indian cultivars *viz*., NARI-57 and PBNS-12 were evaluated under irrigated conditions in 2014-15. Field experiment was carried out at ICAR-Indian Institute of Oilseeds Research farm located at ICRISAT (between 17°25" latitude and 78° longitude at 545 m above sea level) during the *rabi* season of 2014-15 in deep Vertisols under irrigated conditions. Only one irrigation was given immediately after sowing. The soil was low in available nitrogen (204 kg/ha), low in P (8.1 kg/ha) and high in K (837 kg/ha). Bulk density of top 0-15 cm soil was 1.6 g/cm^3. Soil moisture content at field capacity and permanent wilting point in the upper 0-30 cm surface was 0.45 and 0.30 g/g soil respectively.

The experiment was laid out in randomized block design (RBD) with three replications. Crop was sown on ridges in the last week of October with 45 cm spacing. Thinning was done at 25 days after sowing to maintain one plant/hill of 20

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cm distance within a row. Recommended agronomic practices were followed. Entire recommended fertilizer dose (40:25:0 N:P_2O_5:K_2O kg/ha) was applied at the time of sowing. Nitrogen and phosphorus were applied in the form of urea and single super phosphate respectively and incorporated into the seedbed before sowing. Weeds were controlled mechanically and by hand-hoeing at 30 and 60 days after sowing. Aphids were controlled with chlorpyriphos 20 EC (2.5 ml/l). Safflower plants were manually harvested at physiological maturity. At maturity, data on plant height, number of capitula, weight of capitula, seed weight and 100-seed weight on main stem, primary, secondary and tertiary branches were taken in five randomly selected plants in the row next to border rows on either side of each plot without disturbing the net plot. Oil content was measured by Nuclear Magnetic Resonance (NMR) spectroscopy using 30 g of seed sample from each plot. Crop growth and yield data was analyzed using SAS9.3 (SAS Institute, Cary NC).

Growing environment of India vs Mexico: In India safflower crop matures in 120 days whereas in Mexico the crop takes 150 days to mature. In India, the crop is sown in September/October and harvested by January/February whereas in Mexico, it is sown in December/January and harvested by May/June (Padmavathi and Virmani, 2013). Mean minimum temperature during vegetative stage was 20.2°C in India and 8.6°C in Mexico. Mexican varieties/breeding lines showed lesser crop duration (~120 days) due to lesser rosette period because of warm conditions (compared to Mexican conditions) during vegetative stage of crop growth.

Soil profile (2 m) was brought into saturated condition (200 mm) with one irrigation immediately after sowing. Mean temperatures during crop growth were similar to normal temperatures and soil moisture was not a limiting factor (Table 1). Mexican varieties/breeding lines recorded seed yield of 1644 kg/ha and Indian cultivars recorded 2249 kg/ha.

Morphology and phenology: Mexican varieties /breeding lines did not differ significantly in their morphology in terms of plant height, total dry matter (g/plant) at harvest though the cultivars differed in days to first flower character (Table 2). The days to first flower variation ranged from 76 to 86 days after sowing (DAS) among the cultivars tested and 81 to 86 DAS among the Mexican varieties/breeding lines with Ciano-Lin flowering late (86 DAS), whereas Indian varieties flowered early by 7 to 10 days. Among the Mexican varieties/breeding lines, CCC-B2 flowered in 81 days which was the earliest and statistically on par with that of Indian cultivar NARI-57.

Table 1 Monthly rainfall (mm) and monthly mean of temperature (°C) and relative humidity (%) in 2014-15 during cropping period

Month	Rainfall (mm)		Mean Temperature (°C)		Relative Humidity (%)	
	2014-15	Normal*	2014-15	Normal*	2014-15	Normal*
June	42.2	116.6	30.7	29.0	58.7	63.1
July	60.3	183.4	27.4	26.6	72.4	74.3
August	101.8	222.8	27.1	25.6	75.2	78.9
September	47.6	159.3	26.0	25.9	78.3	77.7
October	47.4	98.9	25.6	25.0	68.9	71.2
November	55.8	21.3	22.8	22.5	66.5	66.7
December	0	3.1	20.4	20.5	64.7	63.6
January	4.6	7.9	20.4	21.2	62.6	62.5
February	0	6.4	23.3	23.9	54.4	54.4
Total/Mean	360	820	24.9	24.5	66.9	68.0

*Normal refers to the long-term average (44 years average)

Yield and its components: The seed yield and its components *viz.,* number of primary, secondary, tertiary and total capitula per plant varied among Mexican varieties/breeding lines and were less compared to Indian varieties. The range of variation was from 14 to 22 in primary capitula, 27 to 36 in secondary, 12 to 25 in tertiary capitula and 59 to 82 in total number of capitula/plant. Among all, Indian cultivars showed good number of secondary, tertiary capitula and total number of capitula/plant, that might have led to better seed yield in comparison to Mexican varieties/breeding lines except CCC-B2. Though the number of secondary, tertiary and total capitula/plant were less in CCC-B2 (27; 23 and 70) compared to Indian varieties NARI-57 (34; 25; 79) and PBNS-12 (36; 24; 82), the seed yield was on par with Indian varieties. This could be due to higher seed weight/capitula/plant in main stem, primary, secondary, tertiary and total seed weight in CCC-B2 (1.3; 24.8; 26.4;

9.1; 61.6 g) compared to Indian varieties NARI-57 (0.8; 20.8; 24; 8.1; 53.7 g) and PBNS-12 (1.2; 22.8; 25.7; 8.5; 58.2 g). Seed yield is known to be significantly associated with the number of capitula per plant and seed weight/capitula (Amir Hassan *et al*., 2012). Seed yield of NARI-57 was maximum (2298 kg/ha) while that of Mexican variety Ciano-Lin was minimum (1266 kg/ha) (Table 2). Yield components *viz.,* seed weight per capitula, 100 seed weight (Table 2) indicated that the seed per main stem, secondary, tertiary capitulum had better filling in CCC-B2, NARI-57 and PBNS-12, respectively compared to other Mexican lines. The 100 seed weight was maximum in CCC-B2, RC1033-L, CCC-B4 at 5.5, 4.8, 4.5 g/plant and minimum was in Ciano-Lin (3.1 g/plant).

Harvest index, oil content and oil yield: The harvest index (HI) varied from 15 to 27% among the Mexican and Indian varieties (Table 1). Genotypes CCC-B2 (from Mexico), NARI-57 and PBNS-12 (India) recorded HI of 31, 29 and 27% respectively. Higher yield with higher HI indicates better partitioning of photosynthetic substance to economic yield which can be considered as a good trait in any cultivar. Among other Mexican varieties/breeding lines, Ciano-Lin and RC-1033-L recorded significantly higher biological yield and lower HI. These results clearly indicated the poor partitioning efficiency in these two varieties/breeding lines with high biomass as compared to CCC-B2 and NARI-57.

The range of oil content varied from 23 to 35% among the cultivars tested. The CCC-B2 had maximum oil content 35.4% and PBNS-12 recorded minimum oil content 23.1%. Oil yield was significantly higher in CCC-B2 (800 kg/ha) and NARI-57 (719 kg/ha) as compared to the other four Mexican varieties/breeding lines (399; 498; 516 and 602 kg/ha) and Indian variety PBNS-12 (508 kg/ha). However oil yield was less (399 kg/ha) in Ciano-Lin though its oil content was reasonably good (31.5 %) due to lowere seed yield (1266 kg/ha) among seven entries tested.

This study established that Mexican genotype CCC-B2 was statistically on par with that of Indian cultivar NARI-57 in terms of seed and oil yield productivity.

Table 2 Productivity of Mexican varieties/breeding lines and Indian varieties of safflower

Treatment	Plant height (cm)	Days to first flower	Drymatter at harvest (g/plant)	No. of capitula/plant				Seed yield (kg/ha)	Biological yield (kg/ha)	H.I (%)	Oil content (%)	Oil yield (kg/ha)
				Primary	Secondary	Tertiary	Total					
Ciano-Lin	118	86	187	20	27	21	69	1266	8683	15	31.5	399
CCC-B4	114	85	170	14	29	21	65	1427	7078	20	34.9	498
RC-1033-L	116	85	187	19	27	12	59	1762	8354	21	34.2	602
CCC-B2	117	81	181	19	27	23	70	2259	7202	31	35.4	800
CW-99	115	84	182	18	28	20	67	1504	7325	21	34.3	516
NARI-57	112	80	176	19	34	25	79	2298	7860	29	31.3	719
PBNS-12	110	76	180	22	36	24	82	2200	8150	27	23.1	508
S.Em±	1.3	0.7	7.7	2.9	2.3	2.3	3.3	89.6	285		0.8	41.3
C.D (p≤0.05)	3.6	2	NS	NS	NS	7	10	258	820		2.4	124

Table 3 Growth and yield attributes of Mexican varieties/breeding lines and Indian varieties of safflower

Treatment	Capitula weight (g/plant)					Seed weight (g/capitula order/plant)					100-seed weight (g)				
	Main stem	Primary	Secondary	Tertiary	Total	Main stem	Primary	Secondary	Tertiary	Total	Main stem	Primary	Secondary	Tertiary	Mean
Ciano-Lin	3.5	41.3	43.3	28.4	116.5	1.1	17.9	18.7	7.0	44.7	3.1	3.6	2.9	2.6	3.1
CCC-B4	2.0	26.3	44.2	21.9	94.4	1.0	13.9	16.4	8.8	40.1	3.4	4.9	5.1	4.4	4.5
RC-1033-L	2.6	47.2	46.2	23.5	119.5	1.3	19.4	18.5	6.2	45.4	4.3	5.1	4.2	5.5	4.8
CCC-B2	2.4	39.2	44.4	27.6	113.6	1.3	24.8	26.4	9.1	61.6	4.9	5.6	5.3	6.2	5.5
CW-99	4.3	33.7	46	24.8	108.8	1.0	15.6	19.3	7.3	43.2	3.6	4.1	4.1	3.7	3.9
NARI-57	1.5	32.1	42.5	24.5	100.6	0.8	20.8	24.0	8.1	53.7	3.5	4.4	4.1	3.5	3.9
PBNS-12	1.8	30.8	46.5	26.5	105.6	1.2	22.8	25.7	8.5	58.2	4.8	4.6	3.8	3.5	4.2
S.Em±	1.2	5.9	4.1	3.0	8.4	0.13	2.7	2.2	1.5	3.5	0.45	0.5	0.6	0.56	0.42
C.D (p≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.6	1.2

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Effect of nitrogen and phosphorus levels on white rust disease of mustard [*Brassica juncea* (L.) Czern & Coss.]

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ABSTRACT

India is one of the largest oilseed economies of the world. The contribution of oilseeds to the agricultural economy of India ranks second only to food grains. An experiment was conducted to evaluate the judicious use of fertilizers against white rust disease in mustard. Susceptible plant variety JKMS-8001 was sown in 2 m x 3 m plot size with recommended spacing in a randomized block design with three replications and nine treatments *viz.,* T_1-(Control), T_2- (80 N+40 P_2O_5 kg/ha), T_3- (100 N +40 P_2O_5 kg/ha), T_4-(120 N+40 P_2O_5 kg/ha), T_5- (140 N+40 P_2O_5 kg/ha), T_6- (100 N+30 P_2O_5 kg/ha), T_7- (100 N +50 P_2O_5 kg/ha), T_8- (100 N+60 P_2O_5 kg/ha) and T_9- (100 N +70 P_2O_5 kg/ha). Minimum percent disease incidence (17.03) and maximum percent disease control (67.66) were observed in treatment in T_9 (100 kg N +70 kg P_2O_5/ha). Furthermore, maximum yield and yield attributes were found in T_9 (100 kg N +70 kg P_2O_5/h).

Keywords: Mustard, Nitrogen, Phosphorus, White rust

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is one of the major oilseed crops which is belonging to the family of Cruciferae. Rajasthan and Uttar Pradesh are the major mustard producing states in India contributing about 50 per cent of the total mustard production in the country (Kumar *et al.*, 2017). Among all the essential nutrients, nitrogen as an important limiting factor in crop productivity and it is required by the mustard crop in large quantities. Nitrogen supports the plant with rapid growth, increasing seed and fruit production and enhancing quality of leaf and oil seed crops (Allen and Morgan, 2009; Mukherjee, 2016; Chouksey *et al.,* 2016). Nitrogen management is crucial in cropping system; it is often difficult to strike between levels sufficient for normal plant growth and those that are acceptable for human consumption (Maereka *et al*., 2007). In addition Nitrogen fertilizer at the flowering stage significantly improves the seed yield and quality in most crops (Vijaya *et al*., 2011). As the highest seed yield of Mustard in Southern Alberta was achieved by the application of 95 kg N/ha, Mckenzie *et al*. (2006) opined that sufficient levels of nitrogen lead to higher yields of Mustard.

Despite considerable increased in productivity and production in Indian mustard, a wide gap exists between yield potential and yield realized at farmer's field, which is largely due to biotic and abiotic stresses that afflict this crop. Among biotic stresses, white rust caused by *Albugo candida* (Pers. ex. Lev.) and Alternaria blight caused by *Alternaria brassicae* (Berk.) Sacc. have been reported to be most wide spread and destructive fungal diseases of rapeseed-mustard throughout the world (Kolte, 1985; Sharma and Sohal, 2017). Yield losses from 23 to 54.5 per cent due to both phases (leaf and stag head) of white rust and from 17 to 48 per cent due to Alternaria blight have been reported from India (Saharan *et al.,* 1984; Saharan, 1991). Races of the white rust pathogen, Albugo candida, infect crucifers. Wherever, these crops grow. White rust was given its name due to the white pustules that form on the underside of infected leaves (Reddy, 1996).

To study effect of nitrogen and phosphorus levels on white rust disease in mustard, an experiment was conducted during 2017 at the experimental site (IFTM University) is situated at Moradabad, Uttar Pradesh at the banks of Ram-Ganga River. The geographical co-ordinates of the experimental site is longitude 78°4′ to 79° East and latitude lies between 28°21′ to 28°16′ North at altitude of 193.23 meters above mean sea level in the heart of the Indo-gangetic plains of North India. The climate of this place is tropical to sub-tropical and of slightly semi-arid in nature and is characterized by very dry summer, moderate rainfall and very cold winter. The normal rainfall is about 1407 mm (10 years average) which is uni-mode type mostly precipitating during middle of June to middle of October, where potential evaporation transpiration is lower than the precipitation. Susceptible plant variety JKMS-8001 was sown in 2x3 m plot size with normal spacing in randomized block design with three replications and nine treatments *viz.,* T_1- (absolute control - no fertilizers), T_2- (normal RDF -80 N+40 P_2O_5 kg/ha), T_3- (100 N +40 P_2O_5 kg/ha), T_4-(120 N+40 P_2O_5 kg/ha), T_5-(140 N+40 P_2O_5 kg/ha), T_6-(100 N+30 P_2O_5 kg/ha), T_7-(100 N +50 P_2O_5 kg/ha), T_8-(100 N+60 P_2O_5 kg/ha) and T_9-(100 N +70 P_2O_5 kg/ha). Half dose of nitrogen and full dose of phosphorus was applied as basal dose and remaining half dose of nitrogen at 40 DAS after first irrigation. Observations of disease severity on leaves were recorded 60 days after sowing (DAS) using revised rating scale (0-9) of Anonymous (2011).

$$\text{Disease control (\%)} = \frac{C - T}{C} \times 100$$

Where,

C = Per cent disease incidence in untreated plot

T = Per cent disease incidence in treated plot

Gross income was worked out by multiplying grain and straw yield separately under various treatment combinations with their added together in order in archives gross income (₹/ ha).

Gross income = Total income from grain and straw yield

Net income was calculated by subtracting the cost of cultivation from the gross return of the individual treatments combination.

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

Harvest index is the ratio of the grain yield to total biological produce expressed in percentage. It was calculated with the help of following equation:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Total biomass yield}} \times 100$$

The cost of cultivation was worked out by considering all the expenses gross return was worked out by multiplying grain and straw yield by its price prevailing in the market on per hectare basis under various treatments. The money value of grain and straw yields was added together. Net returns were calculated by subtracting the cost of cultivation from the gross return of the treatment.

The maximum biological yield was observed in treatment T_9- [100 kg N +70 kg P_2O_5/ha (94.00 q/ha)] and followed by T_5- [140 kg N+40 kg P_2O_5/ha (89.33 q/ha)]. Maximum seed yield was recorded in treatment T_9- [100 kg N +70 kg $P2O_5$/ha (23.66 q/ha)]. These results are similar with Tahir *et al.* (2003), Jasmin *et al.* (2014) and Singh *et al.* (2018), they reported that various yield components such as number of pods/plant, seeds/pod and 1000-seed weight were affected significantly by different levels of N, P and K. The highest seed yield and net income was obtained in treatment with 100-60-50 kg NPK/ha may be due to optimum improvement in components of yield.

Nutrient management significantly influenced the economics of mustard cultivation. Maximum gross returns were recorded in T_9 (₹ 89933.08). Most effective treatment was T_9- [100 kg N +70 kg P_2O_5/ha (₹ 64493.60)]. Maximum benefit: cost ratio was observed in T_9 (2.53) with the application of 100 kg N +70 kg P_2O_5/ha followed by T_8- (2.34), T_4-(2.18), T_7-(2.09), T_5-(1.96), T_3- (1.98), T_6-(1.98), T_2- (1.73) and T_1- (0.98). The similar finding was reported by Singh *et al.* (2017) and Kumar *et al.* (2017).

Table 1 Effect of nitrogen and phosphorus on yield, economics, PDI and PDC of mustard

Treatments	Biological yield (q/ha)	Seed yield (q/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	PDI	PDC
T_1-Control	51.33	11.00	41800.00	20750.00	0.98	52.73 (46.55)	0.00 (00)
T_2-80 N + 40 P_2O_5 kg/ha	74.56	17.11	65233.68	41346.91	1.73	30.67 (33.65)	41.83 (40.28)
T_3-100 N + 40 P_2O_5 kg/ha	77.89	18.94	72200.00	48026.93	1.98	21.37 (27.56)	59.48 (50.48)
T_4-120N + 40 P_2O_5 kg/ha	78.56	20.44	77900.00	53439.96	2.18	20.03 (26.56)	62.00 (51.94)
T_5-140 N + 40 P_2O_5 kg/ha	89.28	19.33	73466.54	48719.53	1.96	28.97 (32.58)	45.03 (42.13)
T_6-100 N + 30 P_2O_5 kg/ha	75.28	18.72	70933.08	47181.99	1.98	31.63 (34.20)	39.97 (39.23)
T_7-100 N + 50 P_2O_5 kg/ha	79.78	20.06	76000.00	51404.82	2.09	27.00 (31.31)	48.79 (44.51)
T_8-100 N + 60 P_2O_5 kg/ha	82.72	21.94	83600.00	58588.29	2.34	25.07 (30.07)	52.47 (46.43))
T_9-100N + 70 P_2O_5 kg/ha	94.00	23.72	89933.08	64493.60	2.53	17.03 (24.35)	67.66 (55.37)
SEm±	0.59	0.23	-	-	0.41	0.41	0.71
CD at 0.0 5%	1.78	0.69	-	-	1.23	1.23	2.13

Data presented in Table 1 indicate the significant effects of all the treatments on management of white rust disease of mustard. In control plot, the gradual increase in disease incidence was recorded (52.73%). On the other hand, the treatment applied with 100 kg N + 70 kg P_2O_5/ha recorded minimum disease incidence 17.03 per cent. The maximum per cent disease control (67.66 per cent) was recorded in treatment T_9-(100 kg N +70 P_2O_5 kg/ha) followed by treatment where 120 kg N + 40 kg P_2O_5 (62.00%) had been applied. Nitrogen is the most important nutrient for plant growth but has also been shown to influence diseases in many crops (Bhaduri *et al.,* 2014; Agrawal and Gupta, 1977). There are several reports of the effect of N on disease development that are inconsistent and contradict each other,

and the real causes of this inconsistency are poorly understood (Hoffland *et al.,* 2000).

In conclusion, our studies have indicated that the combined application of nitrogen and phosphorus influences the soil environment/microclimate, yield, development of pathogen and sporulation of pathogen.

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INDIAN SOCIETY OF OILSEEDS RESEARCH
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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 $\pm$, NS (not C.D., S.E.m $\pm$, 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.

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.

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