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SEED VIGOUR AND GERMINATION BASED GENETIC VARIABILITY AND ASSOCIATION STUDIES IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

The objective of this study was to determine the genetic divergence of sunflower germplasm lines and to estimate variability, genetic advance, heritability and correlation with respect to seed physiological characters like seed vigour and germination with yield and its components. The study was conducted at ICAR-Indian Institute of Oilseeds Research, Hyderabad, India, with latitude of 17° 22' 31'' N and longitude 78° 28' 27'' E. to evaluate 76 elite germplasm line of sunflower along with four checks *viz.,* DRSF-113, DRSF-108, Phule Bhaskar and KBSH-44 during *Kharif* 2023 in Randomized Complete Block Design (RCBD) with two replications. The phenotypic and genotypic coefficient of variation were high for seed yield per plant with 51.28% and 49.72%, respectively. The traits with highest genotypic variance were plant height at harvest (cm) (468.83) and the lowest value was registered by 100 seeds weight (g) (4.52). High heritability (94.30) and high genetic advance (99.72%) were exhibited by seed yield per plant. The traits seed vigour and seed germination showed high heritability and high genetic advance of mean. The results revealed that seed yield has high significant positive correlation with germination and other traits like head diameter and plant height at harvest suggesting that these traits are valuable indicators for enhancing sunflower yield. As limited studies are available related to variability, heritability and association of seed vigour, germination and plant height30th day,the study was conducted to see the impact of early seed characters on seed yield and oil content. Overall, the significant relationships identified among various characters support the notion that strategic selection based on correlated traits can effectively increase seed yield in sunflower cultivation, ultimately aiding in the development of superior sunflower varieties.

***Key words*:** sunflower, heritability, genetic advance, correlation, variance

Introduction

Sunflower (*Helianthus annuus* L.), a native of Central America, belongs to family Asteraceae. Sunflower is one of the important oilseed crops grown all over the world next to soybean, groundnut, rapeseed and mustard. Sunflower is the largest source of vegetable oil in the world and is valued for its good quality oil with low cholesterol content. Sunflower seeds contain 25 to 35 per cent oil and its oil is generally considered as premium oil as compared to other vegetable oils. Sunflower oil contains 20-25% essential vitamins like A, D, E and K. In India, sunflower was introduced in commercial cultivation around 1969 and within a short span it has reached a level of 2.1 million ha with the annual production of 1.3 mt. of seed. The crop became popular in India due to its wide adaptability and high yield potential.

In India, according to Directorate of Economics and Statistics (DES), 2023, sunflower recorded a production of 2.79 lakh tonnes from 2.69 lakh ha with average productivity of 1037 kg/ha. The primary objective of sunflower breeding is to create genotypes that are resistant to both biotic and abiotic stresses and have high seed production and oil content (Dudhe *et al.*, 2009). Identification of various genotypes benefited greatly from research on the genetic variability of germplasm collections (Siddiqi *et al.*, 2012). One of the requirements for a successful breeding program in selecting genotypes with desirable features is knowledge about the kind and extent of variability and heritability in a population (Dudley and Moll, 1969). For this reason, understanding the heritability of the agronomical traits is crucial for breeders to efficiently increase crop yield. Heritability value alone may not provide clear predictability of the breeding value. Heritability in conjugation with genetic advance over mean (GAM) is more effective and reliable in predicting the resultant effect of selection (Patil *et al.*, 1996; Ramanjinappa *et al.*, 2011; Ramesh *et al.*, 2013).

The amount of variation in sunflower breeding material has frequently been assessed using phenotypic and genotypic variation, heritability and genetic advance. The yield is determined by the interaction of a number of characters among themselves and with the environment. Hence, understanding how different traits relate to yield and themselves will help to determine the criteria for indirect selection using yield-enhancing components. The goal is to determine the genetic divergence of germplasm lines and to estimate variability, genetic advance, heritability and character association for yield and its components.

Material and Methods

Experimental material, site and design

The present investigation was conducted at the ICAR-Indian Institute of Oilseeds Research, Hyderabad, India, with latitude of 17° 22' 31'' N and longitude 78° 28' 27'' E. to evaluate 76 elite germplasm lines of sunflower along with four checks *viz.*, DRSF-113, DRSF-108, Phule Bhaskar and KBSH-44 during *Kharif* 2023 in Randomized Complete Block Design (RCBD) with two replications. The germplasm lines were planted at 60 × 30 cm row on ridges and furrow bed. Hand-weeding and normal management practices were followed. Data collection was done on randomly selected 5 plants and observations were recorded on seed vigour, germination on 10th day, plant height at 30th day, days to maturity (DM), plant height at harvest (PH), head diameter (HD), 100-seed weight (SW) and seed yield per plant (SY). The seed vigour, germination and oil content were measured in per centage, plant height and head diameter measured in centimetres and 100-seed weight and seed yield per plant were measured in gram.

Statistical analysis

Variance analysis was performed on replicated data (RBD) for each trait following standard statistical protocols (Panse and Sukhatme, 1985). The significance was evaluated by consulting the "F" table values (Fisher and Yates, 1963).

$$Y_{ij} = \mu + g_i + r_j + e_{ij}$$

The genotypic and phenotypic coefficients of variation for all traits were determined using the formulas provided by Burton and De Vane (1953).

The genotypic and phenotypic variance was determined using the formulas provided by Burton and De Vane (1953).

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{Mg - Me}}{\text{Number of replications}}$$

(i) Environmental variance ($\sigma^2 e$) = Me

(ii) Phenotypic variance ($\sigma^2 p$) = ($\sigma^2 g$) + ($\sigma^2 e$)

(iii) Phenotypic Coefficient of Variation (PCV)

$$\text{PCV} = \frac{\text{Phenotypic standard deviation } (\sigma^2 g)}{\text{General mean (x)}} \times 100$$

(iv) Genotypic coefficient of variation (GCV)

$$\text{GCV} = \frac{\text{Genotypic standard deviation } (\sigma^2 g)}{\text{General mean (x)}} \times 100$$

Heritability in the broad sense represents the ratio of genotypic variance to the overall observed variance within the entire population as given by Allard (1960).

$$h^2(b) = \frac{\text{Genotypic variance } (\sigma^2 g)}{\text{Phenotypic variance } (\sigma^2 p)} \times 100$$

In order to visualize the relative utility of genetic advance among the characters, genetic advance as per cent of mean was computed.

$$\text{GAM} = \frac{\text{GA}}{\bar{X}} \times 100$$

Where,

GA = Genetic Advance

$\bar{X}$ = General mean of the character

These coefficients were determined at phenotypic level using the formulas proposed by Falconer (1981).

$$\text{Phenotypic coefficient of correlation } (r_p) = \frac{\text{Cov. (xi - xj) p}}{\sqrt{\text{v (xi)p . v (xj)p}}}$$

Results and Discussion

The mean sum of squares for the traits under study *i.e.*, seed vigour (%), germination (%), plant height at 30th day, plant height at harvest (cm), days to maturity, head diameter (cm), seed yield per plant (g), 100 seed weight (g) and oil content (%) are presented in the Table 1. The analysis of variation showed that there is a significant difference between mean sum of squares for each genotype and all the nine characters under study. It suggests that there was a significant amount of variation

Table 1: Analysis of variance for yield and quality parameters in eighty germplasm lines of sunflower.

Source of Variation	df	Mean sum of squares								
		Seed vigour (%)	Germi-nation (%)	Plant height at 30th day (cm)	Days to maturity	Plant height at harvest (cm)	Head diameter (cm)	Seed yield per plant (g)	100 seed weight (g)	Oil content (%)
Replications	1	490.00***	113.90	68.08***	0.05	2620.75***	203.28***	38.08***	0.02	0.001
Genotypes	79	324.41***	427.37***	77.05***	31.81***	792.02***	15.07***	47.57***	8.69***	19.05***
Error	79	14.51	35.10	1.12	11.25	145.64	1.50	1.4	0.35	0.72
Total	80	171.48	230.50	39.27	21.39	482.37	9.51	24.57	4.49	9.82

*, **, *** Significance at 5%, 1% and 0.1% levels probability, respectively

for each attribute across all genotypes. The calculated genotype and error mean sum of squares were used to further analyse genotypic and phenotypic variance.

Genetic variability, Heritability and Genetic advance as per cent of mean

For different traits under study, the phenotypic and genotypic coefficients of variability, heritability estimates in broad sense and genetic advance as per cent of mean estimates are given in Table 2. The phenotypic and genotypic coefficient of variation, heritability and genetic advance as per cent of mean were represented graphically in Fig. 1 and 2.

Components of variance

Among the nine characters under study, the phenotypic variance ranged from 4.52 (100 seed weight) to 468.83 (plant height at harvest) and the genotypic variance from 4.17 (100 seed weight) to 323.18 (plant height at harvest). In comparison to genotypic variance, wide range of variation was seen in phenotypic variance. The trait with highest phenotypic variance was plant height (468.83) followed by germination (231.24), seed vigour (169.46) and the least value was recorded by 100 seed weight (4.52).

The trait with highest genotypic variance was plant height at harvest (323.18) followed by germination (196.13), seed vigour (154.94) and the trait, 100 seed weight (4.17) recorded the least value. The results of phenotypic and genotypic variance for plant height, days to maturity, head diameter, seed yield per plant, 100 seed weight and oil content are in accordance with Rani *et al.*, (2017) and Thakur *et al.*, (2022).

Coefficient of variation, heritability and genetic advance

The phenotypic and genotypic coefficient of variation for seed vigour were high *i.e.*, 39.75 and 38, respectively. Seed vigour exhibited high heritability (91.4%) along with high genetic advance as per cent of mean (74.86%). The phenotypic and genotypic coefficient of variation were high for germination % this trait with 20.45 and 22.2, respectively. Germination % showed high heritability (84.8%) with high genetic advance as per cent mean (38%). The findings suggest that the trait is controlled by additive gene action hence, direct selection of the genotypes would be efficient. The phenotypic and genotypic coefficient of variation were high for Plant height at 30th day this character *i.e.*, 28.46 and 28.05, respectively. Plant height at 30th day showed high heritability (97.1%) with high genetic advance as per cent mean (56.95%).

The phenotypic and genotypic coefficient of variation for seed yield per plant (g) were high with 51.28% and 49.72%, respectively. Seed yield per plant (g) recorded

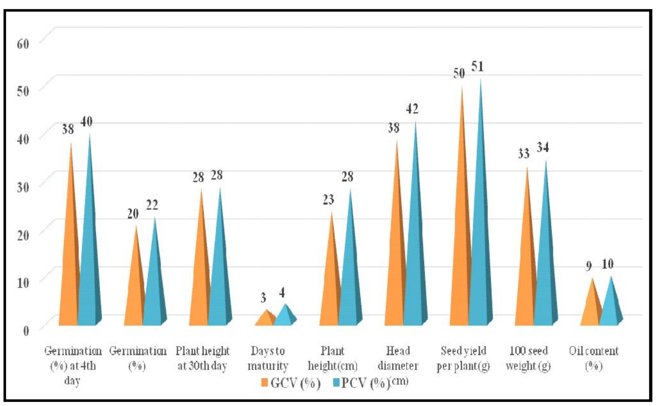

Fig. 1: Graph depicting Genotypic and Phenotypic coefficient of variation for yield and quality traits of eighty sunflower genotypes.

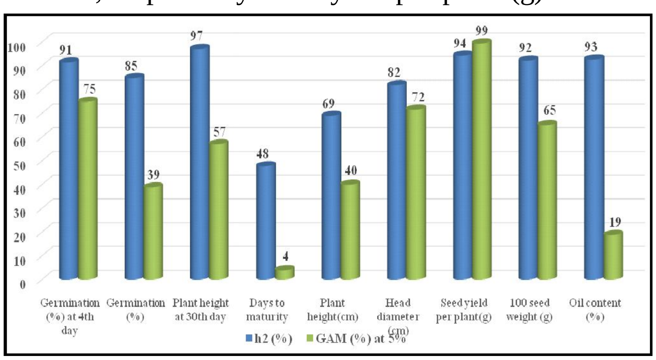

Fig. 2: Graph depicting heritability and genetic advance as per cent of mean for yield and quality parameters of sunflower germplasm lines.

Table 2: Genetic parameters for yield components and quality traits in eighty genotypes of sunflower.

S. No.	Trait	Mean ± SEm	Variance		Coefficient of Variation		h^2 (%)	GAM (%) at 5%
			Genotypic	Phenotypic	GCV (%)	PCV (%)		
1.	Seed vigour	32.75 ± 2.69	154.94	169.46	38.00	39.75	91.40	74.86
2.	Germination (%)	68.46 ± 4.21	196.13	231.24	20.45	22.20	84.80	38.80
3.	Plant height at 30th day (cm)	21.96 ± 0.75	37.96	39.08	28.05	28.46	97.10	56.95
4.	Days to maturity	115.05 ± 2.37	10.28	21.53	2.78	4.03	47.70	3.96
5.	Plant height at harvest (cm)	76.93 ± 8.53	323.18	468.83	23.36	28.14	68.90	39.96
6.	Head diameter (cm)	6.79 ± 0.87	6.78	8.29	38.35	42.37	81.80	71.54
7.	Seed yield per plant (g)	9.66 ± 0.84	23.08	24.49	49.72	51.28	94.30	99.45
8.	100 seed weight (g)	6.20 ± 0.42	4.17	4.52	32.89	34.26	92.20	65.05
9.	Oil content (%)	32.00 ± 0.60	9.17	9.89	9.46	9.82	92.70	18.77

high heritability (94.3%) with high genetic advance as per cent mean (99.45%). High variability, heritability and genetic advance as percent of mean were observed for seed yield indicating additive gene action governing the trait. The results are in consistence with Supriya *et al.* (2016), Rani *et al.*, (2017) and Varalakshmi *et al.*, (2020).

The phenotypic and genotypic coefficient of variation were high for 100 seed weight (g)with 51.28% and 49.72%, respectively. The results were in accordance with Rani *et al.*, (2017) and Varalakshmi *et al.*, (2020). Hundred seed weight (g) recorded high heritability (92.2%) with high genetic advance as per cent mean (65.05 %). Similar results for heritability and genetic advance as mean were reported by Rani *et al.*, (2017)

The phenotypic and genotypic coefficient of variation observed for oil content (%) were low *i.e.,* 9.82% and 9.46%. Similarly low PCV and GCV was reported by Sree *et al*,. (2021) and Varalakshmi *et al.*, (2020). High heritability (92.7%) with moderate genetic advance as per cent of mean (18.77) was recorded for oil content % suggesting that this character can also be improved. Supriya *et al.,* (2016), Divya *et al.*, (2019), Varalakshmi *et al.,* (2020) and Reavanth *et al.,* (2022) also reported similar findings. The closeness of the PCV and GCV values suggested that the environment had less impact on the trait's phenotypic expression.

The phenotypic variance was slightly higher than the genotypic variance for seed vigour, seed germination, days to maturity, plant height at harvest, it indicates that the observed variations in traits are more influenced by environmental factors rather than genetic differences.

For characters plant height at 30th day, head diameter, seed yield per plant, hundred seed weight and oil content the range of differences between the genotypic and phenotypic coefficients of variations was narrow, suggesting that genetic factors dominated the phenotypic expression of the characters and that environmental influences were less significant.

High heritability values indicate that the characters under study are less influenced by environment in their expression. Therefore, the plant breeder may make his/her selection safely on the basis of phenotypic expression of these characters in the individual plant by adopting simple selection methods. Genetic advance as percentage of mean (GAM) which coincide with high heritability is very useful than heritability alone in predicting the resultant effect during selection of best individual genotype, which was revealed in present study. High heritability characters coupled with moderate genetic advance in per cent of mean offered scope of the traits for improvement through selection, so these characters could be improved more easily than the other characters (Singh *et al.*, 2016).

A combination of high heritability and genetic advance was observed for germination, plant height, test weight, seed yield per plant and head diameter which showed that these characters can be further improved by phenotypic selection, particularly through mass selection. Such values of high heritability and genetic gain might attribute to additive gene effect (Panse, 1957). Thus, direct selection could be employed for improving these traits. High heritability coupled with moderate genetic advance was observed for oil content indicating the prevalence of narrow range of variability suggesting that these characters could also be considered for improvement through selection as these were more likely to be controlled by additive gene action.

The character days to maturity alone recorded moderate heritability and low genetic advance (Sudrik *et al.*, 2014, Supriya *et al.*, 2016 and Neelima *et al.*, 2016 and Baraiya *et al.*, 2018) suggesting that the role of favourable environment rather than the genotype and the selection is not rewarding.

Studies have shown that seed yield per plant is a crucial trait contributing to genetic diversity in sunflower

Table 3: Phenotypic correlation for yield and yield contributing traits in Sunflower.

Character	Seed vigour (%)	Germi-nation (%)	Plant height 30th day (cm)	Days to maturity	Plant height at harvest (cm)	Head diameter (cm)	100 seed weight (g)	Oil content (%)	Seed yield per plant (g)
Seed vigour (%)	**1.000**	0.468***	0.376***	-0.190	0.123	0.159*	0.085	-0.144	0.153
Germination (%)		**1.000**	0.277***	-0.260***	0.321***	0.166*	-0.205**	-0.132	0.205
Plant height 30th day (cm)			**1.000**	-0.135	0.272***	0.329***	0.178*	-0.153	-0.074
Days to maturity				**1.000**	-0.058	-0.102	0.148	0.101	-0.044
Plant height at harvest (cm)					**1.000**	0.475***	-0.058	0.167*	0.322
Head diameter (cm)						**1.000**	0.426***	-0.053	0.495
100 seed weight (g)							**1.000**	-0.217**	0.304
Oil content (%)								**1.000**	0.082

*, **, *** Significance at 5%, 1% and 0.1% levels probability, respectively

(*Helianthus annuus* L.). This trait, along with oil content and 100-seed weight, has been emphasized for its high heritability and genetic advance, making it a significant factor in breeding programs aimed at improving sunflower yield and quality. Research on sunflower genetic variability has consistently highlighted these traits as primary contributors to overall genetic divergence in the crop (Dudhe *et al.,* 2020).

Phenotypic correlation coefficient

Phenotypic correlation among the nine characters is depicted in Table 4. Seed yield per plant showed highly significant and positive correlation with head diameter (0.495) followed by, plant height at harvest (0.321), hundred seed weight (0.304), germination (0.205), seed vigour (0.153) and positive non-significant association was found between seed yield and oil content (0.08). Days to maturity (-0.044) and plant height at 30th day (-0.074) showed negative non-significant correlation with seed yield. Similar results were reported by Machikowa *et al.,* (2008) for plant height and head diameter. Results for plant height at harvest, hundred seed weight and oil content were in conformity with Gangavati and Kulkarni. (2021), Tyagi *et al.,* (2013). Non-significant negative correlation of seed yield with days to maturity was observed by Venkanna *et al*., (2021). Hence selection for any of the significantly associated characters under study would be effective in enhancing the seed yield in sunflower.

Seed vigour exhibited highly significant positive association with germination (0.468) followed by plant height at 30th day (0.277), head diameter (0.159), plant height at harvest (0.123) and hundred seed weight (0.085). Days to maturity (-0.190) showed negative association with seed vigour.

Germination (%) showed highly significant and positive correlation with plant height (0.321) followed by plant height at 30th day and head diameter (0.166). Days to maturity (-0.260) and hundred seed weight (-0.205) recorded negative significant association with germination (%) whereas oil content (-0.132) showed negative non-significant correlation. The results for 100 seed weight were in accordance with Radic *et al.,* (2013) who found negative correlation between germination and seed weight and stated that smaller and medium-sized seeds may germinate more readily than large seeds in some years. However, larger seeds have more reserve in their cotyledons than smaller seeds, according to Grieve and Francois (1992). Given that a quantity of reserves has a direct bearing on the development of the embryo, they also found that larger seeds require more energy to germinate than smaller ones.

Plant height at 30th day showed positive significant association with head diameter (0.329) followed by plant height at harvest (0.272) and hundred seed weight (0.178). Oil content (-0.153) and days to maturity (-0.135) exhibited negative association with plant height at 30th day.

Days to maturity exhibited positive non-significant association with hundred seed weight (0.148) and oil content (0.101). Germination % (-0.260) showed highly significant negative correlation whereas plant height at harvest (-0.058), head diameter (-0.102) and plant height at 30th day showed negative non-significant association with days to maturity. The results for plant height are in accordance with Rikkala *et al.,* (2024). Similar results for head diameter and oil content were reported by Singh *et al.,* (2018).

Plant height at harvest recorded highly significant positive correlation with, head diameter (0.47), germination (0.32) and oil content (0.1). Days to maturity (-0.05) and hundred seed weight (-0.05) showed negative non-significant association with plant height at harvest. The results for head diameter, oil content and hundred seed weight were in conformity with Singh *et al.,* (2018). Similar results for head diameter and test weight were reported by Yasin *et al.,* (2010).

Highly significant positive correlation of head diameter was observed with plant height at harvest (0.47), hundred seed weight (0.42) and germination (0.16). Days to maturity (-0.10) and oil content (-0.05) showed negative non-significant association with head diameter. The results for all the characters except days to maturity are in conformity with Riaz *et al.,* (2019). Similar results for plant height, hundred seed weight and oil content were given by Machikowa *et al.*, (2008).

Hundred seed weight showed highly significant positive association with head diameter (0.42). Days to maturity exhibited positive non-significant correlation whereas germination % (-0.20) and oil content has negative significant correlation. Plant height at harvest showed negative non-significant association. The results for head diameter, hundred seed weight and plant height were in accordance with Yasin *et al.*, (2010). Similar results for oil content were reported by Riaz *et al.,* (2019).

Oil content showed significant positive correlation with plant height at harvest (0.16). Germination and days to maturity showed non-significant positive association. Highly significant negative association was observed for hundred seed weight and non-significant negative correlation with head diameter. The results obtained were in line with Riaz *et al.,* (2019). Gangavati and Kulkarni (2021) reported similar results for hundred seed weight and plant height.

Conclusion

It can be concluded that the broad range of variation was exhibited for both GCV and PCV values for all the characters. Out of which the traits like seed yield per plant head diameter and plant height at harvest recorded high phenotypic and genotypic coefficients of variation. Traits exhibiting high heritability combined with significant genetic advance percentages suggest promising prospects for improvement through selection. Specifically, traits such as seed yield per plant, germination and head diameter highlight an opportunity for advancement through direct selection strategies, given their strong additive gene effects. The association studies indicate that seed yield per plant has highly significant positive correlations with several traits, including head diameter (cm) and plant height at harvest (cm), hundred seed weight (g), germination (%) and seed vigour (%) suggesting these traits are valuable indicators for enhancing sunflower yield. The study further highlights that traits such as germination percentage and hundred seed weight (g) also show significant associations, illustrating their potential as selection criteria in breeding programs. Moreover, negative correlations with days to maturity, particularly in relation to seed yield (g) and germination (%), suggest that earlier maturing varieties may be more beneficial in achieving higher yields. Overall, the significant relationships identified among various characters support the notion that strategic selection based on correlated traits can effectively increase seed yield in sunflower cultivation, ultimately aiding in the development of superior sunflower varieties.

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Conflicting Interests

Author states that there is no conflict of interest.

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