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Assessment of Genetic Variability and Character Associations in Sunflower (*Helianthus annuus* L.) Yield Related Traits

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Authors' contributions

This work was carried out in collaboration among all authors. Author VVK designed the study and corrected the draft, Author NM performed the statistical analysis, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Authors MS, BVT and Poornima managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate yield and yield related characteristics for variability and association studies in fifty-two powdery mildew differentials of sunflower.
Study Design: Augmented block design.
Place and Duration of Study: Main agricultural Research station, University of Agricultural Science, Raichur, Karnataka between November 2022 and February 2023.

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Methodology: Study included 52 powdery mildew differentials of sunflower studied factors such as genetic variability, heritability, and genetic advance in characters such as head diameter, seed filling percent, test weight, number of seeds per head, volume weight, oil content and seed yield. Correlation and path analysis was also done.
Results: Findings revealed significant differences among the traits, especially in seed yield per plant, head diameter, seed filling percent, test weight, and number of seeds per head which conclude that there is variability present in the studied character and there is scope for crop improvement. Correlation coefficients showed positive connections between seed yield per plant and traits like head diameter, test weight, seed filling percentage, and number of seeds per head. However, volume weight had a negative correlation. Path coefficient analysis helped us understand the direct and indirect impacts of these traits on seed yield per plant. Head diameter, seed filling percentage, test weight, and number of seeds per head had positive direct effects on seed yield per plant. In contrast, volume weight had a negative direct effect.
Conclusion: The study contributes to the understanding of the genetic architecture of sunflower traits related to yield and provides a foundation for developing targeted breeding strategies. These insights can guide sunflower breeding programs in selecting traits for improved yield.

Keywords: Sunflower; genetic variability; correlation; path analysis.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) holds a significant position in the world as a major oilseed crop which belongs to the genus Helianthus, encompassing 67 species [1]. Renowned for its versatile utility, sunflower seeds contain 40-54 per cent oil and 16 per cent proteins. This oil, with its low saturated fatty acid content and elevated concentrations of polyunsaturated and monounsaturated fatty acids, is widely employed in various applications, from culinary use to the production of margarine and biodiesel. Beyond its culinary uses, sunflower oil has been acknowledged for its potential health benefits and its application as a dermo-protectant. Globally, sunflower is the second most cultivated oilseed crop, trailing only behind soybeans, while sunflower meal ranks third in oilseed meal consumption [2,3].

Russia leads the world in sunflower seed production, followed by Ukraine,Russia and Argentina [4]. In the context of India, sunflower production contributes 2.5 lakh tonnes, with Karnataka emerging as the leading producer, followed by Andhra Pradesh and Maharashtra [5] with an area of 1.62 lakh ha. As yield is a complicated trait, its inheritance is dependent on several characters, many of which are polygenic in nature and heavily influenced by environmental variables. The correlation coefficient is used to determine the degree (strength) of the mutual relationship between different plant characters and the component character on which selection can be based to genetically improve yield. Interrelationships between yield and its components are inevitable for an efficient selection program. Path analysis calculates the impact that different independent characters have, both directly and indirectly, on a dependent character. Therefore, the present investigation was undertaken to determine association among different traits in sunflower and their direct and indirect effects on yield by using path coefficient analysis.

2. MATERIALS AND METHODS

2.1 Experimental Material

The experimental material comprised 52 sunflower powdery mildew differentials sourced from AICRP on Sunflower, MARS (University of Agricultural Sciences, Raichur), ICAR-Indian Institute of Oilseeds Research (Hyderabad), and Tamil Nadu Agricultural University (Coimbatore). KBSH 44 and PM-81 served as checks for present study.

2.2 Experimental Design and Planting

An augmented block design was employed for the cultivation of the 52 powdery mildew sunflower differentials, with the check planted after every 10 genotypes. Each line was sown in rows of four and a half meters, containing 15 plants per row. The planting configuration involved a row-to-row distance of 60 cm and a plant-to-plant distance of 30 cm for each genotype. Seeds were sown using the dibbling method, placing 2-3 seeds per hill. At the four to six-leaf stage, hand thinning was conducted to retain one healthy plant per hill, following recommended agricultural practices.

2.3 Observations and Traits Studied

Observations on yield characters were recorded for five randomly selected plants in each genotype and check. The traits studied included Head diameter (cm), Seed filling percentage (%), Number of seeds per head, Volume weight (g/100 ml), 100 seed weight (g), Seed yield per plant (g), and Oil content (%).

2.4 Statistical Analysis

The mean values of quantitative traits for all 52 sunflower genotypes and check entries were computed. Analysis of variance, following an augmented design [6], was performed to partition the total variation. Phenotypic correlation coefficients were calculated using the method outlined by Johnson et al. [7]. Path coefficient analysis, as suggested by Dewey and Lu [8], was employed to estimate the direct and indirect effects of seven component traits on seed yield per plant. Statistical analyses were conducted using the R software program.

3. RESULTS AND DISCUSSION

Analysis of Variance (ANOVA) was conducted to evaluate the statistical distinctions among the seven traits related to yield and its attributes. The mean sum of squares for each trait was computed and presented in Table 1. The significance of the mean sum of squares across all the examined traits indicates the presence of variability in the traits under investigation. This variability suggests a focus on these traits for potential improvements.

Genetic variability plays a crucial role in improving crops, as it forms the foundation for selecting suitable parents and genotypes in breeding programs. It's essential to grasp the various components of genetic variability. To assess variability, genotypic variance (σ^2g), phenotypic variance (σ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, and genetic advance as a percentage of the mean were examined. These metrics aid in the selection of traits for improvement.

The range of variation, as well as genotypic and phenotypic co-efficient of variations were high for seed yield per plant, head diameter, seed filling percent, test weight and number of seeds per head indicating the scope of improvement through simple selection procedure for obtaining high yield. The results obtained are in confirmatory with the findings of Sudrik et al. [9], Baraiya et al. [10] and Varalakshmi et al. [11]. Volume weight registered moderate phenotypic and genotypic co-efficient of variation. Supriya et al. [12] and Reavanth et al. [13] reported similar results. Low variability was observed for oil

Table 1. Analysis of variance for seed yield and its component characters in sunflower genotypes

Source of variation	Degree of freedom	Mean sum of squares						
		HD	SFP	TW	NSH	VW	YPP	OIL
blocks (ignoring treatments)	4	28.57**	794.78**	4.35 **	22116.78**	29.68**	160.95**	11.08**
Treatment(eliminating blocks)	51	8.97**	396.87**	1.30**	54409.81**	36.91**	117.08**	14.02**
Checks	1	18.01**	2.13**	0.09**	165407.21**	1.41**	1027.19**	95.72**
Checks+Var vs. Var.	50	5.54**	228.03**	1.06**	20643.10**	26.12**	56.33**	8.07**
Block (Eliminating Check+Var.)	4	0.25	1.66	0.02	70.13	0.23	0.03	0.21
Entries (ignoring blocks)	51	11.19**	459.07**	1.64**	56138.96**	39.22**	129.7**	14.87**
Varieties	49	7.60**	297.38**	1.44**	19488.46**	29.03**	49.66**	7.16**
Checks V/S varieties	1	18.01**	2.13	0.09	165407.21**	1.41	1027.19**	95.72**
Error	4	0.06	0.57	0.01	67.28	0.28	0.09	0.17

** Significant at 5 per cent* *** Significant at 1 per cent*

Note: HD- Head diameter (cm), NSH- Number of seeds per head, SFP- Seed filling percent (%), TW- Test weight (g), VW-Volume weight (g/100ml), OIL- Oil content (%), YPP- Seed yield per plant(g)

content. This is in line with the results of Varalakshmi et al. [11] This is due to the presence of both positive and negative alleles for these characters in the material (Table 2.).

High heritability estimates were observed for all the characters studied. These results are in confirmatory with the findings of Supriya et al. [12], Varalakshmi et al. [11] and Shyam et al. [14]. This indicated that these characters were least influenced by the environment and generally, selection based on phenotypic observation would be effective. Heritability in conjunction with genetic advance would give more reliable index of selection value (Johanson et al. 1955). A combination of high heritability and genetic advance was observed for seed yield per plant, head diameter, seed filling percent, test weight, number of seeds per head and volume weight which showed that these characters were amenable for improvement by phenotypic selection, particularly through mass selection (Ashok et al. 2000). Such values of high heritability and genetic gain might contribute to additive gene effect. Thus, direct selection could be employed for improving these traits. These findings are consistent with Supriya et al. [12] and Shyam et al. [14]. 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 which aligns with the results of Supriya et al. [12] and Varalakshmi et al. [11].

Seed yield and oil content are two important characteristics in sunflower. It is desirable to evolve hybrids with high seed yield coupled with high oil per cent. High variability, heritability and genetic advance as percent of mean were observed for seed yield indicating additive gene action controlling the trait. While the character oil content showed low variability, high heritability and moderate genetic advance as per cent of mean.

The correlation coefficient between yield and yield attributing traits among them were estimated at phenotypic level. The phenotypic correlation coefficients between seed yield per plant and six contributing traits are given in Table 3. Head diameter displayed a statistically significant positive correlation of 0.612 with test weight, 0.508 with seed filling percentage, and 0.468 with the number of seeds per head. Conversely, it exhibited a high and significant negative correlation of -0.461 with volume weight. These findings are consistent with prior research conducted by Baraiya et al. [10], Riaz et al. [15], Lakshman et al. [16] and Gangavati et al. [2]. Hence, selecting for larger heads automatically leads to greater test weight and a higher number of filled seeds per head. However, it's important to note that head diameter showed a negative correlation with volume weight, so choosing larger heads may result in lower volume weight.

Seed filling per cent recorded significant positive correlation with head diameter (0.508) and number of seeds per head (0.340) at phenotypic level, these findings were in accordance with Ghodke et al. [17]. This indicates that a greater number of filled seed will automatically leads to larger heads and seeds with higher test weight. But as we go for genotypes with higher seed filling per cent it will leads to lower volume weighted seeds with low oil content. Whereas test weight demonstrated a strong and statistically significant positive correlation of 0.612 with head diameter and a significant positive correlation of 0.490 with seed filling

Table 2. Estimation of Mean, Range, Heritability (h^2), Genetic advance (GA) and Genetic advance as per cent of mean (GAM)

Trait	Mean	Std. Error	Std.Deviation	Range		GCV	PCV	h^2	GA	GAM
				Min	Max					
HD (%)	12.16	0.39	2.83	5.52	17.82	22.58	22.67	99.24	5.64	46.42
SFP (%)	64.04	2.50	18.01	23.53	94.83	26.90	26.93	99.81	35.51	55.44
TW (g)	3.40	0.17	1.20	0.50	5.79	35.17	35.32	99.16	2.45	72.26
NSH	370.07	22.68	163.57	88.08	923.00	37.66	37.72	99.65	287.00	77.55
VW (g/100ml)	36.68	0.76	5.47	25.28	52.54	14.62	14.69	99.03	11.01	30.01
OIL (%)	31.87	0.41	2.98	25.68	40.71	8.30	8.40	97.64	5.39	16.92
YPP (g)	14.38	1.12	8.06	1.74	42.82	48.94	48.99	99.81	14.51	100.87

Note: HD- Head diameter (cm), NSH- Number of seeds per head, SFP- Seed filling percent (%), TW- Test weight (g), VW-Volume weight (g/100ml), OIL- Oil content (%), YPP- Seed yield per plant(g)

Table 3. Estimation of phenotypic correlation between seed yield and its component characters in sunflower powdery mildew differentials.

	HD	SFP	TW	NSH	VW	OIL	YPP
HD	1.000	0.508**	0.612**	0.468**	-0.461**	-0.044	0.601**
SFP		1.000	0.490	0.341*	0.574**	-0.275*	0.450**
TW			1.000	0.145	-0.348*	0.107	0.656**
NSH				1.000	-0.068	0.063	0.702**
VW					1.000	0.380**	0.340*
OIL						1.000	0.135
YPP							1.000

** Significant at 5 per cent ** Significant at 1 per cent*

Note: HD- Head diameter (cm), NSH- Number of seeds per head, SFP- Seed filling percent (%), TW- Test weight (g), VW-Volume weight (g/100ml), OIL- Oil content (%), YPP- Seed yield per plant(g)

percentage. Conversely, it showed a significant negative correlation of -0.348 with volume weight. Which indicates that seeds with higher test weight will automatically leads to large headed genotypes with high seed filling per cent. These findings are consistent with earlier research conducted by Chambó et al. [18], Abu et al. [19], Ghodke et al. [17] and Gangavati et al*.* [2].

Number of seeds per head displayed a strong and statistically significant positive correlation of 0.468 with head diameter and a significant positive correlation of 0.341 with seed filling percentage. This highlights that opting for the selection of a greater number of seeds per head naturally leads to both increased head diameter and a higher number of filled seeds per head. These findings are consistent with previous research conducted by Pandya et al. [20], Chambó et al. [18] and Riaz et al. [15]. Oil content exhibited a strong and statistically significant positive correlation of 0.380 with volume weight, while it showed a significant negative correlation of -0.275 with seed filling percentage. Consequently, selecting lines with higher volume weight can result in lines with increased oil content. These findings are consistent with previous research conducted by Radić et al. [21], Ghodke et al*.* [17] and Gangavati et al*.* [2].

Volume weight displayed significant positive correlations with oil content (0.380) and seed filling percentage (0.574). Conversely, it exhibited a strong negative correlation with head diameter (-0.461). Therefore, selecting for higher volume weight proves to be an effective strategy for achieving greater seed filling percentage and oil content. These findings align with prior research conducted by Radić et al*.* [21], Gangavati et al*.* [2] and Lakshman et al*.* [16].

Path coefficient analysis, a statistical tool initially developed by Wright in 1921, serves as a valuable method for dissecting correlation coefficients into their direct and in direct effects on a dependent variable by independent variables. Dewey and Lu [8] introduced a modified version of path coefficient analysis that offers a more practical foundation for assigning appropriate importance to various attributes when designing a realistic program for yield improvement. The results including phenotypic path coefficients are presented in Table 4.

Table 4. Estimation of phenotypic path co-efficients between seed yield and its component characters in sunflower powdery mildew differentials

	HD	SFP	TW	NSH	VW	OIL	YPP
HD	-0.154	-0.078	-0.094	-0.072	0.071	0.007	0.601**
SFP	-0.074	-0.146	-0.072	-0.050	0.084	0.040	0.450**
TW	0.380	0.304	0.620	0.090	-0.216	0.066	0.656**
NSH	0.333	0.243	0.103	0.712	-0.049	0.045	0.702**
VW	0.120	0.149	0.090	0.018	-0.260	-0.099	0.340
OIL	-0.003	-0.021	0.008	0.005	0.029	0.075	0.135

Residual effect=0.392

Note: HD- Head diameter (cm), NSH- Number of seeds per head, SFP- Seed filling percent (%), TW- Test weight (g), VW-Volume weight (g/100ml), OIL- Oil content (%), YPP- Seed yield per plant(g)

Head diameter, with a negative direct effect of -0.154, had an adverse influence on seed yield per plant (0.601). These findings are consistent with the results reported by Abdelsatar et al. [22] and Lakshman et al. [16]. Moreover, head diameter exhibited a positive in direct effect on seed yield per plant through test weight (0.380), the number of seeds per head (0.333) and volume weight (0.120). Conversely, it displayed a negative in direct effect through seed filling percentage (-0.074) and oil content (-0.003), which align with the findings of studies conducted by Baraiya et al. [10], Riaz et al. [15] and Lakshman et al. [15]. This result indicates that head diameter has a direct affect in seed yield of the plants in a negative manner but it indirectly affects seed yield per plant positively via test weight, number of seeds per head and volume weight.

Seed filling percentage, with a negative direct effect of -0.146, exhibited a detrimental impact on seed yield per plant (0.450), which is consistent with the findings reported by Lakshman et al. [15]. Furthermore, this particular trait demonstrated a positive in direct effect on seed yield per plant through test weight (0.304), volume weight (0.149) and the number of seeds per head (0.243). However, it displayed a negative in direct effect through head diameter (-0.078) and oil content (-0.021), findings that are in line with the results from studies conducted by Sowmya et al. [23], Lakshman et al. [24] and Shyam et al. [14]. This indicates that seed filling per cent has a negative direct effect on seed yield per plant and it has a positive in direct effect on seed yield via test weight, volume weight and the number of seeds per head.

Test weight, with a direct effect of 0.620, displayed a positive impact on seed yield per plant (0.656). These findings are in line with previous studies conducted by Sowmya et al. [23], and Lakshman et al. [16]. Furthermore, this trait exhibited positive in direct effects on seed yield per plant through the number of seeds per head (0.103), volume weight (0.090), and oil content (0.008). Conversely, it showed an in direct negative effect on seed yield per plant through head diameter (-0.94) and seed filling percentage (-0.072). These indirect effects are consistent with the results reported in studies conducted by Lakshman et al. [24], Arshad et al. [25], Abdelsatar et al. [22] and Lakshman et al. [16]. Which gives an information that test weight shows a direct effect on seed yield and it indirectly affects the seed yield positively via number of seeds per head, volume weight and oil content.

The number of seeds per head, with a direct effect of 0.712, exhibited a positive impact on seed yield per plant (0.702). These findings are consistent with those reported in studies by Baraiya et al. [10], Lakshman et al. [24] and Lakshman et al. [16]. Additionally, this trait demonstrated a positive in direct effect on seed yield per plant through volume weight (0.018), test weight (0.090) and oil content (0.005). Conversely, it displayed a negative in direct effect through head diameter (-0.072) and seed filling percentage (-0.050). These in direct effects align with the results reported in studies conducted by Baraiya et al. [10], Riaz et al. [15], Abdelsatar et al. [22], Lakshman et al. [16] and Shyam et al. [14]. This gives us a picture that number of seeds per head directly impact seed yield per plant in a positive manner and indirectly it impacts via volume weight, test weight and oil content.

The oil content, with a direct effect of 0.075, had a positive influence on seed yield per plant (0.135), which is consistent with findings from previous studies conducted by Sowmya et al. [23], Lakshman et al. [24] and Arshad et al. [25]. Moreover, this trait exhibited positive in direct effects on seed yield per plant through head diameter (0.007), seed filling percentage (0.040), test weight (0.066) and the number of seeds per head (0.045). Conversely, it displayed an in direct negative effect on seed yield per plant through volume weight (-0.099), which is in line with results reported in studies conducted by Sowmya et al. [23], Arshad et al. [25], Riaz et al. [15] and Gangavati et al. (2021). This tells us that oil content has a direct impact on seed yield per plant and it shows an in direct impact on seed yield per plant positively through head diameter, seed filling percentage, test weight, and the number of seeds per head.

The volume weight, with a direct effect of -0.026, had a negative impact on seed yield per plant (-0.340). This finding aligns with previous studies conducted by Binod et al. (2008) and Lakshman et al. [16]. Additionally, this particular trait exhibited positive in direct effects on seed yield per plant through head diameter (0.071), seed filling percentage (0.084) and oil content (0.029). Conversely, it showed in direct negative effects on seed yield per plant through test weight (-0.216) and the number of seeds per head (-0.049). These results are consistent with the findings of other studies conducted

Gangavati et al. [2], Ghodke et al. [17] and Lakshman et al. [16]. Therefore, volume weight directly affects seed yield per plant negatively and indirectly via head diameter, seed filling percentage and oil content positively.

In the current study, the residual effect observed was 0.392, signifying its significance in measuring the influence of unexamined independent variables on the dependent variable at the phenotypic level. This study highlights that there is a combined impact of both direct and in direct effects, accounting for 0.392 in total. However, it is advisable to consider the inclusion of additional component variables to enhance the accuracy and reliability of the path analysis in assessing both direct and in direct effects at the phenotypic level. Furthermore, it's worth noting that a moderate level of residual effects in the present study can still contribute valuable insights for drawing genetic conclusions based on the interplay of direct and indirect effects.

4. CONCLUSION

In conclusion, the study revealed that several traits, including seed yield per plant, number of seeds per head, 100-seed weight, seed filling percent, head diameter, and volume weight, exhibit high heritability and significant potential for improvement through selection. The positive correlations between seed yield and the number of seeds per head, 100-seed weight, and head diameter further highlight the importance of these traits in achieving higher sunflower yields. Path coefficient analysis reinforced the central role of the number of seeds per head in directly influencing seed yield per plant. These findings provide valuable guidance for sunflower breeding programs, emphasizing the need to prioritize traits such as the number of seeds per head, head diameter, and seed filling percent for achieving improvements in yield. The study contributes to the understanding of the genetic architecture of sunflower traits related to yield and provides a foundation for developing targeted breeding strategies. Further research and validation of these findings across diverse environments and genotypes will be crucial for the successful implementation of breeding programs aimed at enhancing sunflower productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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