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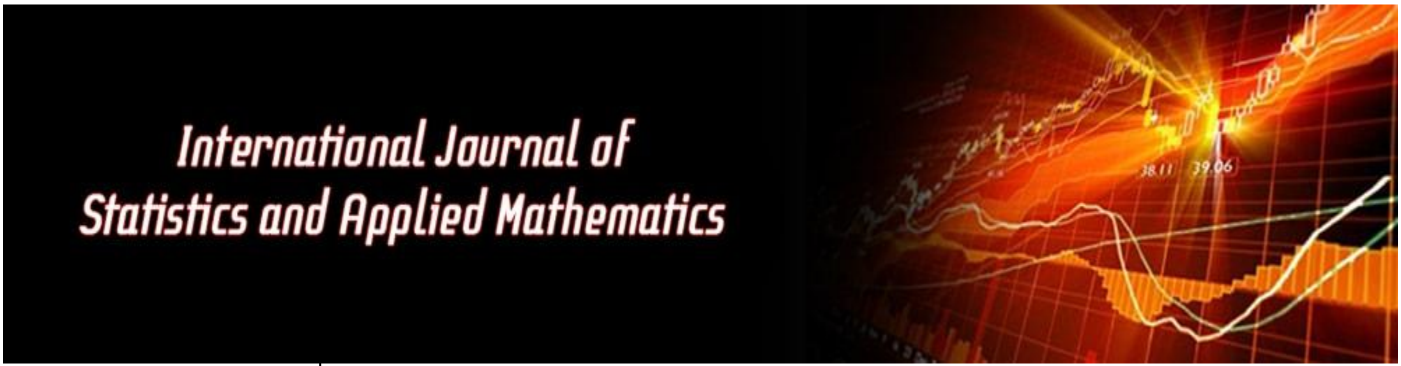

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Correlation and path coefficient analysis of the components of yield in sunflower genotypes (*Helianthus annuus* L.)

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Abstract
Present investigation “Correlation and path analysis of the Components of Yield in Sunflower Germplasm” was carried out during *Kharif* season (2024-25) in Randomized Block Design at Botany Research farm, College of Agriculture, Pune. Sunflower (*Helianthus annuus* L.) is an oilseed crop valued for its high content of polyunsaturated fatty acids, particularly linoleic and oleic acids, which contribute to cardiovascular health by lowering cholesterol levels. The primary objective in sunflower breeding is to develop cultivars with high yield. Yield in sunflower is a complex trait, influenced by various component traits and environmental factors, understanding the traits interaction among themselves and with the environment is very essential in planning successful crop improvement program. The study included 32 genotypes including 2 checks. Correlation study reported highly significant positive association of seed yield per plant with seed filling percentage, followed by head diameter, and 100 seed weight and negative association with hull content at genotypic level. Among the characters studied seed filling percentage had the highest positive direct effect on seed yield per plant followed by head diameter and genotypic correlation between hull content and seed yield per plant was strongly negative, while its direct effect was positive at genotypic level. Therefore, direct section for characters seed filling percentage and head diameter would be useful in developing high yielding genotypes in sunflower.

Keywords: Sunflower, correlation, path analysis

Introduction
The domestication history of sunflower traces back over 5,000 years to Native American cultures in present-day southwestern United States and Mexico (Blackman *et al*. 2011) [5]. Following its introduction to Europe in the 16th century, systematic breeding efforts in Russia and Ukraine during the 19th century established sunflower as a major global oilseed crop. Contemporary sunflower cultivation spans temperate, subtropical, and tropical regions worldwide, with recent USDA (2025) reports indicating that it is cultivated as an oilseed crop across an area of 28.23 million hectares globally, yielding a production of 52.45 million metric tons and achieving a productivity rate of 1.85 metric tons per hectare during the 2024-2025 agricultural year. In India, during the same period, sunflower was cultivated over an area of 0.18 million hectares, resulting in a production of 0.11 million metric tons and a productivity of 0.63 metric tons per hectare.

Seed yield remains the primary objective in sunflower breeding programs and is strongly influenced by environmental factors. Yield improvement can be achieved by selecting for key yield-contributing traits such as head diameter, seed weight and seed number per capitulum (Göksoy & Turan 2007) [7]. In this context, correlation studies aid in the selection of traits that are positively associated with yield, while also identifying and managing the negative influences of certain traits. Path analysis further supports this by partitioning the correlation coefficients into direct and indirect effects. The current study aims to help in the selection of positively associated traits with yield via correlation and path analysis.

Materials and Methods
The experiment consisted of 32 genotypes including 2 checks (DRSF 108 and Phule Bhaskar). The experiment was laid out in a randomize block design with three replications during 2024-25. Each genotype was sown in the 4.5meter length of rows. The genotypes along with the checks were sown by keeping row to row distance of 60 cm and plant to plant distance of 30 cm for each genotype. The observations on days to 50 percent flowering, days to maturity, plant height, head diameter, 100 seed weight, seed filling percentage volume weight, seed yield per plant, hull content and oil content were recorded on five randomly selected plants. Genotypic and phenotypic correlation coefficients were calculated using the method given by Singh and Chaudhary (1977). The direct and indirect effects of seven component traits on seed yield per plant were estimated by path coefficient analysis as suggested by Dewey and Lu (1959).

Results and Discussion
Correlation study
Genotypic correlation coefficients are represented in Table 1. Seed yield per plant demonstrated highly significant positive genotypic correlations with seed filling percentage (0.964), head diameter (0.903), and 100-seed weight (0.636), while showing a significant negative correlation with hull content (-0.781). Non-significant positive associations were observed with volume weight (0.145), days to maturity (0.159), days to 50% flowering (0.110), and oil content (0.111). These findings align with previous studies: Tahir *et al*. (2002) [14] for seed filling and head diameter, Sujatha *et al*. (2013) [13] for seed weight and head size, Adeel *et al*. (2019) [1] for seed filling percentage, head diameter, and 100 seed weight.

Days to 50% flowering exhibited highly significant positive genotypic correlations with days to maturity (0.989), plant height (0.373), volume weight (0.355 g/100 mL), 100-seed weight (0.225), and head diameter (0.197). Non-significant positive associations were observed with hull content (0.145), oil content (0.142), and seed filling percentage (0.062).

Days to maturity showed significant positive correlations with plant height (0.424), volume weight (0.360 g/100 mL), 100-seed weight (0.260), and head diameter (0.217). Nonsignificant positive associations were observed with oil content (0.132), hull content (0.124), and seed filling percentage (0.097).

Plant height showed a highly significant positive correlation with 100-seed weight (0.375). Non-significant positive associations were observed with hull content (0.159), volume weight (0.115 g/100 mL), and oil content (0.081), while non-significant negative correlations were found for head diameter (-0.018) and seed filling percentage (-0.004).

Head diameter exhibited highly significant positive correlations with seed filling percentage (0.818), 100-seed weight (0.608), and volume weight (0.212 g/100 mL). A nonsignificant positive association was observed with oil content (0.148). Notably, head diameter showed a strong negative correlation with hull content (-0.892).

Volume weight (g/100 mL) showed highly significant positive correlations with 100-seed weight (0.443,) and oil content (0.223). Non-significant associations were observed with seed filling percentage (0.098) and hull content (-0.149).

100-seed weight showed significant positive correlations with seed filling percentage (0.615) and oil content (0.229), while exhibiting a significant negative correlation with hull content (-0.406).

Seed filling percentage showed significant positive correlation with oil content (0.236,) and significant negative correlation with hull content (-0.736,). Hull content exhibited a nonsignificant negative association with oil content (-0.164). Previous studies support these findings: Binod *et al*. (2007) [4] further confirmed strong positive associations between head diameter and volume weight. Arshad *et al*. (2010) [3] reported significant positive correlations between head diameter and 100-seed weight, while Sujatha *et al*. (2013) [13] documented similar relationships between plant height and days to maturity and Lakshmi *et al*. (2021) reported significant positive relationship of plant height with 100 seed weight. Hammad *et al*. (2023) [8] also reported strongest correlation of seed yield per plant with seed filling percentage and head diameter.

Path analysis
The path analysis treated seed yield per plant as the dependent variable influenced by eight independent variables: days to 50% flowering, plant height, head diameter, seed filling percentage, 100-seed weight, hull content, oil content, and volume weight. Table 2 presents both the direct and indirect phenotypic path effects of these component traits on seed yield.

The genotypic correlation between days to 50% flowering and seed yield per plant was weakly positive but non-significant (0.110). Path analysis revealed a strong negative direct effect (-1.213) on yield. Indirect effects occurred through multiple pathways: (1) strongly negative via days to maturity (-1.200) and plant height (-0.452), (2) moderately negative via 100-seed weight (-0.273) and head diameter (-0.239), and (3) weakly negative via hull content (-0.176), oil content (-0.172), and seed filling percentage (-0.076). The positive indirect effect through volume weight (0.430) partially offset these negative influences.

Days to maturity showed a weak, non-significant positive genotypic correlation with seed yield per plant (0.159), but exerted a strong positive direct effect (1.171). Indirect effects occurred through three distinct pathways: (1) strongly positive via plant height (0.496) and volume weight (0.421 g/100 mL), (2) moderately positive via 100-seed weight (0.305) and head diameter (0.254), and (3) weakly positive via oil content (0.154), hull content (0.146), and seed filling percentage (0.113).

Plant height showed a non-significant negative genotypic correlation with seed yield per plant (-0.040), with a modest negative direct effect (-0.108). The trait exhibited two distinct indirect effect pathways: (1) weakly positive through head diameter (0.002) and seed filling percentage (0.0004), and (2) weakly negative through days to maturity (-0.046), 100-seed weight (-0.041), days to 50% flowering (-0.040), hull content (-0.017), and volume weight (-0.013 g/100 mL). The indirect effect via oil content (-0.009) was negligible.

Head diameter demonstrated a strong positive genotypic correlation with seed yield per plant (0.903**)** and exerted a substantial direct effect (0.627). The analysis revealed three categories of indirect effects: (1) strongly positive via seed filling percentage (0.513) and 100-seed weight (0.381), (2) moderately positive through days to maturity (0.136*)* and volume weight (0.133 g/100 mL), and (3) weakly positive via days to 50% flowering (0.124) and oil content (0.093). Significant negative effects occurred through hull content (-0.559), while plant height showed minimal negative influence (0.011).

Volume weight showed a non-significant positive genotypic correlation with seed yield per plant (0.145), with a minimal direct effect (0.036). Indirect positive effects occurred through 100-seed weight (0.016), days to maturity (0.013), and days to 50% flowering (0.013), while negligible contributions came via oil content (0.008), head diameter (0.008), and seed filling percentage (0.004). A slight negative indirect effect was observed through hull content (-0.005).

100-seed weight showed a highly significant positive genotypic correlation with seed yield per plant (0.636), but exhibited a minimal negative direct effect (-0.019) in the path analysis. Negative direct effects of 100-seed weight and indirectly positively via plant height, oil content and indirectly negatively through days to 50 percent flowering, days to maturity and head diameter to a limited extent on seed yield per plant were recorded by Alba and Greco (1979) and Lakshman (1983). In most of the studies on sunflower path analysis showed 100-seed weight of sunflower having positive direct effect on seed yield per plant. The negative direct effect of test weight on seed yield per plant in the present investigation is limited and it can be compensated by its highly significant positive association with seed yield and also via its indirect positive association with component traits. Also, similar result was recorded by Lakshmi Gangavati and Vikas V. Kulkarni (2021).

Seed filling percentage showed a strong positive genotypic correlation with seed yield per plant (0.964**)** and exerted a high direct effect (0.650). Significant positive indirect effects occurred through head diameter (0.532**)** and 100-seed weight (0.400), while weaker positive contributions came via oil content (0.153), volume weight (0.064 g/100 mL), days to maturity (0.063), and days to 50% flowering (0.040). The trait demonstrated substantial negative indirect effects through hull content (-0.478**)** and minimal effects via plant height (-0.003).

The genotypic correlation between hull content and seed yield per plant was strongly negative (-0.781**),** while its direct effect was surprisingly positive (0.291). Indirect effects occurred through multiple pathways: (1) weak positive contributions via plant height (0.046), days to 50% flowering (0.042), and days to maturity (0.036); (2) strong negative effects through head diameter (-0.259**)** and seed filling percentage (-0.214); and (3) moderate negative influences via oil content (-0.043) and volume weight (-0.043). The 100-seed weight pathway showed a minor negative effect (-0.118).

Oil content showed a weak, non-significant positive genotypic correlation with seed yield per plant (0.111), but exhibited a slight negative direct effect (-0.064). The trait demonstrated minimal positive indirect effects through hull content (0.011), while all other pathways showed negligible negative influences on yield.

These findings align with previous research: Farhatullah *et al*. (2006) [6] regarding the positive direct effects of head diameter on seed yield. Similar confirmations were reported by Sridhar *et al*. (2005) [12] for both head diameter and seed filling percentage, and by Patil (2011) [11] for volume weight and head diameter relationships. The results further corroborate findings from Neelima *et al*. (2012) [10] concerning seed filling percentage and plant height, Varalakshmi *et al*. (2019) [16] and Anusha *et al*. (2024) [2] indicated that seed yield per plant had strongest association with seed filling percentage, 100 seed weight and head diameter. Seed filling percentage, head diameter, days to maturity, hull content, and volume weight (g/100 mL) demonstrated significant positive direct effects on seed yield per plant. These findings suggest that targeted selection for these traits would be effective for enhancing yield in sunflower breeding programs.

Conclusion

In conclusion, correlation analysis revealed that the information of positive and negative associations of yield component traits on seed yield could be used to predict the superior cross combinations and to identify traits for ideal plant type and aid in indirect selection to get higher yield. Based on correlation values, it was observed that selection for seed filling percentage, head diameter, and 100 seed weight will be rewarding in developing high yielding genotypes in sunflower. Path analysis studies reported significant positive direct effect of seed filling percentage, and head diameter on seed yield per plant. While, 100 seed weight recorded significant negative direct effect on seed yield per plant. The direct selection for genotypes with high seed filling percentage, larger head and 100 seed weight coupled with early maturity would be effective in sunflower improvement.

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