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Research Article

# Genetic Variability Analysis and Trait Interrelationship in *Helianthus annuus* l. across Two Growing Years

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## ABSTRACT

Edible oil consumption is increasing day by day while its production is stagnant. In Pakistan, there is huge gap between consumption and production. Cottonseed is contributing majorly to local production followed by Brassica and sunflower. Although sunflower is non-conventional crop, but it has great potential to fulfill then gap between consumption and production of edible oil. Sunflower is cross-pollinated crop and has highest genetic variation. There is dire need to explore the genetic potential of cultivated sunflower accessions. Assessment for genetic variability is the main component for effective selection. Achene yield is a complex trait influenced by genetic and environmental factors. Understanding the interrelationship among yield and its contributing attributes is the foundation for effective breeding strategies. This scientific inquiry focuses on accessing genetic variability and interrelationship among key traits across two years 2022 & 2023. Experiment was conducted at the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The study involved 80 sunflower accessions from diverse sources i.e. national and international organizations grown by using Randomized Complete Block Design with three replications. Data were recorded on achene yield and its related traits for further analysis. Recorded data were subjected to analysis of variance, mean comparison test, and correlation coefficient analysis. The results revealed significant differences among accessions for all the studied traits, suggesting effective selection from germplasm. Among 80 sunflower accessions, Line 48, 49 and 50 had maximum means values for most of the traits. Traits number of leaves, leaf area, and head diameter are selected as selection criteria for improving the oil and achene yield in sunflowers. The study's results provide a solid foundation for breeding programs aimed at improving sunflower yield and productivity across diverse growing seasons.

**Keywords:** Sunflower, Oilseeds, Genetic Variability, Achene and Oil Yield, Correlation Coefficient.

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## INTRODUCTION

The agriculture sector is confronted with the continual challenge of meeting the domestic demand for edible oil. During the year 2023-24, Pakistan imported 2.71 million tonnes of edible oil at a total cost of US $3.562 billion, whereas local production is projected to remain at 0.471 million tonnes. The estimated total edible oil availability for 2024, combining both imports and domestic production, is 3.18 million tons (Economic Survey of Pakistan, 2023-24). Bridging this gap requires the adoption of advanced cultivation strategies, the use of non-conventional crops like sunflower and soybean, and policy-driven initiatives to enhance local oilseed production. In the context of global oilseeds, sunflower is ranked as the third most important crop, largely due to its oil-rich seeds. While oilseeds are critical to the

agricultural economy, domestic production in Pakistan has been unable to sufficiently address the rising demand, relying heavily on the import of oilseeds to cover the supply deficiency. Sunflower (*Helianthus annuus* L.), a biennial crop, is primarily cultivated for its high-quality oil. With a rapid growth cycle of 90 to 110 days, sunflowers serve as a strategically important oilseed crop, enabling its incorporation into existing cropping rotations without adversely impacting major cash crops (Ilahi *et al*., 2009). Sunflower oil is a healthy choice for human consumption because it is rich in oleic and linoleic acid. The oil content in sunflower achene typically ranges from 28-53% and about 20% protein. Its oil is regarded as premium due to its light color and high smoke point (Razzaq *et al*., 2014). It is valued for its key nutritional components, including essential fatty acids, vitamins A, D, E, and K, tocopherols, antioxidants, remarkable health benefits, and oxidative stability.

Sunflower is cultivated in diverse agro-climatic regions; the growing seasons are crucial for determining its crop productivity (Georgieva *et al*., 2024). It can be grown on various types of soil and needs very low input. It can be extensively grown on marginal and polluted lands. One of the most remarkable benefits of sunflowers lies in their ability to extract heavy metals and radioactive pollutants from contaminated soils through the process of phytoremediation (Muller *et al.,* 2011).

Achene yield is a polygenic character, so there is a need to determine the relationship between yield and its related traits. The relationship among yield-related traits plays a pivotal role in breeding strategies aimed at increasing achene yield. These traits, including plant height, head size, branch number, seed number, and seed size, exhibit significant genetic variability that can be harnessed through selection (Habib *et al.,* 2007; Arif *et al.,* 2024).

Analyzing genetic diversity and establishing linkages within sunflower populations is fundamental to unlocking the potential of the crop for yield enhancement and improving oil content (Alam *et al.,* 2023). The genetic variation present within sunflower genotypes offers breeders an opportunity to identify and propagate favorable traits, thereby optimizing both productivity and oil quality. This reinforces the importance of genetic research, particularly in linking phenotypic characteristics to their molecular determinants, for advancing sunflower breeding strategies (Salgotra and Chauhan, 2023).

Correlation coefficient analysis is essential for identifying relationships among various traits, which is crucial for optimizing sunflower yield through the simultaneous selection of key characteristics. This research paper aims to explore the interrelationship between various yield-related characters in sunflowers, focusing on their genetic variability effects on achene yield.

This study aims to achieve the following objectives: to determine genetic variation among yield and its related traits and development of selection criteria based on interrelationship among traits. These objectives will collectively contribute to the development of more productive and resilient sunflower genotypes.

## MATERIALS AND METHODS

### Experimental conditions

The experiment was conducted in the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan, where the semi-arid climate is characterized by seasonal temperature fluctuation and variable rainfall. Faisalabad is located in North Eastern Punjab where latitude and longitude are 73°-60°, and 26°-30°.

### Experimental layout

A total of 80 sunflower accessions were collected from the Oilseeds Research Laboratory, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The source of these accessions is diverse. Twenty accessions were collected from national organizations, i.e., NARC, forty were from USDA, and twenty were from Australia.

The land was prepared after two ploughings, and recommended practices were applied. Ridges were maintained for sowing. Thirty seeds of each accession per replication were sown under field conditions by following a randomized complete block design during the year 2022-23. Row to row and plant to plant distance was maintained at 75cm and 25cm, respectively. All the agronomic practices were followed uniformly for both years. A total of four irrigations were applied at critical stages. Ten plants from each accession per replication were randomly tagged to maintain uniform sampling.

### Data recording

Data was recorded in both years (2022-23) on the following traits:

Plant Height (cm)*:* Plant height was measured from ground level to the base of the head in centimeters.

Head diameter ($cm^2$): Head diameter was measured across the widest part of the capitulum from edge to edge in cm. To ensure accuracy, three measurements per head were recorded at different orientations, and the average was calculated.
Number of leaves per plant: Fully expanded leaves at the flowering stage were counted.
Achene yield per plant (g): With the use of an electronic balance (Setra BL - 410S), the seeds were weighed in grams from each head of each replication.
Leaf area ($cm^2$): Leaf area was measured by multiplying leaf length and width using a measuring scale, and the average was calculated. Measurements were taken in the flowering stage to ensure consistency.
Oil contents (%): Oil content was determined using the Soxhlet extraction method, and the extracted oil percentage was calculated.
Flower Initiation: Flower initiation was recorded as the number of days from sowing to the appearance of the first flower in the main stem in each accession.

**Statistical analysis**

The dataset was statistically analyzed using an analysis of variance (Steel *et al.,* 1997). Correlation coefficient analysis was used to determine the strength of the relationship among traits (Dewey and Lu, 1959).

## RESULTS AND DISCUSSION

**Genetic variability across two seasons**

The results from the analysis of variance demonstrate substantial genetic variation among sunflower accessions for yield-related traits across two years (2022-23), which is critical for sunflower breeding programs (Table 1).

Table 1. Mean square values from analysis of variance for yield-related traits in sunflower accession (**Bold values**=Year 2022).

| SOV | DF | AYPP | FI | HD | LA | NL | OC | PH |
|---|---|---|---|---|---|---|---|---|
| Replications | 2 | **47.27** | **78.38** | **99.01** | **338.06** | **39.09** | **143.92** | **140.79** |
| | | 44.61 | 92.36 | 97.12 | 397.40 | 62.50 | 151.51 | 123.11 |
| Accessions | 79 | **83.76**** | **171.12**** | **26.13**** | **886.42**** | **106.09**** | **143.38**** | **1365.19**** |
| | | 84.70** | 179.58** | 26.17** | 892.39** | 103.69** | 142.30** | 1372.88** |
| Error | 158 | **8.02** | **18.41** | **0.89** | **74.73** | **7.87** | **13.44** | **98.04** |
| | | 7.98 | 19.01 | 0.92 | 73.83 | 10.11 | 13.45 | 97.57 |

** highly significant differences at α=0.01
SOV: Sources of Variation, DF: Degrees of Freedom, AYPP: Achene Yield Per Plant, FI: Flower Initiation, HD: Head Diameter, LA: Leaf Area, NL: No. of Leaves Per Plant, OC: Oil Contents, PH: plant Height

The findings of Memon *et al*. (2014). revealed that significant mean squares for genotypes indicate that genetic factors play a dominant role in trait expression. The reproducibility of significant differences over two years confirms the stability of trait expression under varying environmental conditions. The sustained phenotypic expression across seasons is crucial for characterizing reliable genotypes for breeding purposes (Lamichhane *et al.,* 2022).
Achene yield is influenced by environmental and genetic factors as well as the contribution of other yield-related traits like seed weight, plant height, and head diameter (Delen *et al.,* 2024; Kaya *et al.,* 2007 and Goksoy and Turan, 2007).
The high genetic variability observed for traits like achene yield and head diameter suggest that these traits can be effectively improved through selection. Traits that have high variability and heritability are preferred targets for breeding programs as they show significant responsiveness to selection pressure (Kost *et al.,* 2015).
The findings are consistent with earlier investigations as Blackman et al. (2011), demonstrated that plant height, flowering time, and oil content exhibit significant heritability, making them suitable targets for selection. Genetic variability among sunflower accessions for key traits across different seasons revealed the potential for yield improvement through selective breeding.
Genetic diversity studies have shown that selecting for superior genotypes based on agro-morphological traits can lead to significant improvements in oil quality and achene yield (Fig. 1). The comprehensive analysis of yield-related traits in sunflower accessions focused on key traits influencing yield, including Number of Leaves (NL), Leaf Area (LA), Plant Height (PH), Head Diameter (HD), Flower Initiation (FI), Oil Content (OC), and

Average Yield per Plant (AYPP) among the genotypes.

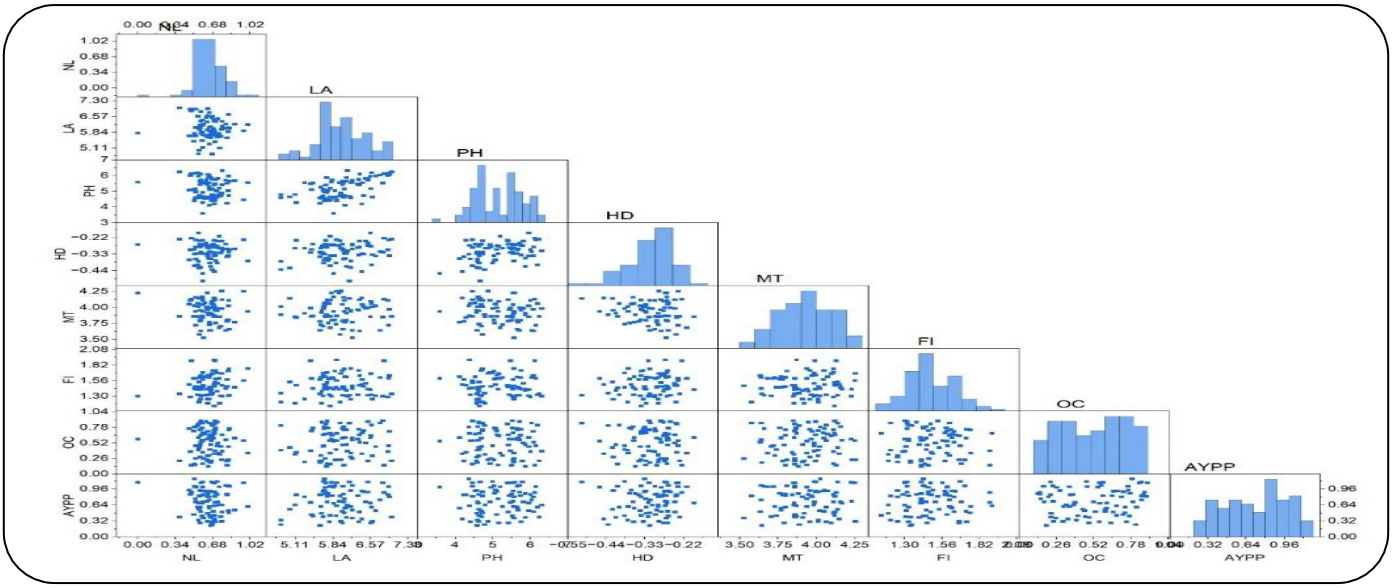


Figure 1. Scatterplot matrix showing trait correlations in *Helianthus annuus* L.

Among 80 sunflower lines, UAF A-48, 49 and 50 demonstrated superior performance across most of the traits evaluated. The identification of high-performing lines provides valuable insights for sunflower breeding programs. These lines can be used as parental materials to enhance yield-related traits in future generations, leveraging their genetic potential to improve sunflower productivity. The results align with previous studies that have emphasized the importance of genetic diversity in sunflower accessions for improving yield and related traits (Delen *et al.,* 2024; Singh and Chander, 2018; Rikkala *et al.,* (2024).

The correlation analysis identifies key associations among traits, providing critical insight for crop improvement. Figure 2 shows the correlation coefficient among traits across both years (2022-23).

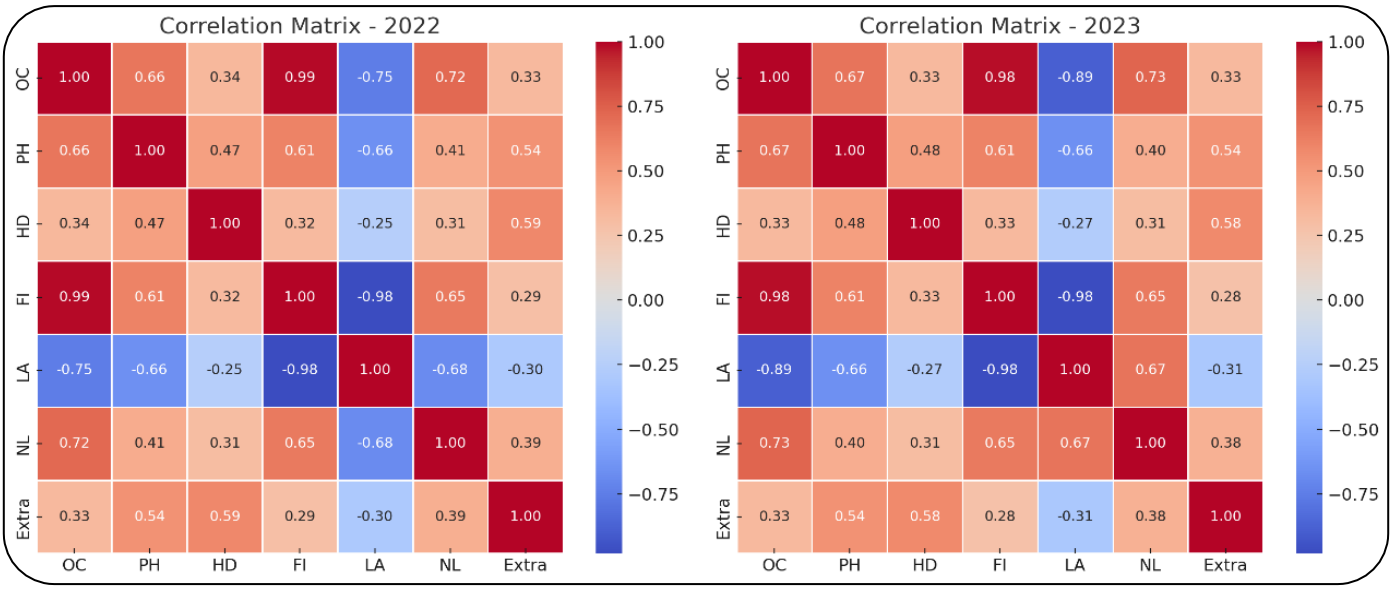


Figure 2: Correlation matrix heat map for 2022 and 2023, showing relationships among different traits.

A strong positive correlation was observed between head diameter and achene yield per plant for the two years. This implies that choosing to prioritize a larger head diameter can effectively improve yield. Plant height exhibits a moderate positive correlation with leaf area and achene yield, implying that taller plants tend to develop broader leaves and increase yield (Gangavati and Kulkarni, 2021). The substantial negative correlation between flower initiation and head diameter suggests that early flowering plants allocate fewer resources to head development and consequently compromise yield potential.

Correlation coefficient analysis showed that yield per plant is strongly positively correlated with achene number, leaf area, head diameter, 1000 seed weight, and plant height, supporting the observation of Goksoy and Turan (2007) Singh and Chander (2018) Memon et al. (2014).

Yasin and Singh (2010) highlighted the importance of considering plant height in breeding programs aimed at improving the oil yield. A strong negative relationship was discovered between the initiation of flowering and head diameter also in seed yield and head diameter, under the studies conducted by Hladni *et al*. (2016) and Ghaffari and Hoseinlou (2013).

Different sowing seasons significantly impact different parameters, as observed by Rauf (2008) and Tahir et al. (2002), with the most notable reduction in yield per plant, leaf area, and 1000 achene weight

According to the investigation of Baraiya et al. (2018), the number of seeds per plant, days to 50% flowering, head diameter, and plant height positively influence seed yield per plant.

## CONCLUSION

The study provides a comprehensive assessment of genetic variability and trait interrelationship in *Helianthus annuus* L. across two distinct growing seasons. Studied germplasm showed maximum genetic variation for all the traits that shows that leads towards the effective selection. Among 80 entries, UAF A-48, 49 and 50 had maximum mean values for most of the traits respectively. Correlation coefficient analysis confirmed that traits such as head diameter and seed weight have a strong influence on achene yield. The findings suggest that target selection for yield-attributing traits can be an effective strategy for improving sunflower productivity. Future research should focus on enhancing selection efficiency and improving achene yield potential in diverse climatic conditions, thereby leveraging genetic diversity to optimize sunflower productivity and adaptability.

## AUTHOR CONTRIBUTIONS

**Humera Razzaq**: Conducted research and translated into paper. **Noreen Amjad**: Data Analysis and write up. **Zeeshan Ishfaq Bukhary**: Critical Analysis on import of oilseeds and gap between consumption and production. **Waqar ul Hassan**: Helped in Data analysis and translation into graphical presentation. **Muhammad Nouman Khalid**: Helped in write up.

## COMPETING OF INTEREST

The authors declare no competing interests.

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