Original Research Article

Assessment of Genetic diversity and Characterization of Sunflower Inbreds for breeding improvement

.

ABSTRACT

|  |
| --- |
| **Aims:** To assess the genetic diversity and characterize sunflower inbred lines based on morphological and quantitative traits, with the objective of identifying superior genotypes for future breeding programs and varietal improvement.  **Study design:** Randomized block design.  **Place and Duration of Study:** Oilseeds Research Station, Latur during *kharif*-2024.  **Methodology:** Study included 42 sunflower genotypes along with two checks. The diversity analysis carried out by using Mahalonobis D2 statistic and characterization of sunflower accession by using DUS descriptors and IBPGR guidelines.  **Results:** The evaluation of 40 sunflower inbred lines and 2 checks revealed significant genetic variability across all morphological and yield-related traits. ANOVA showed highly significant differences for key traits, including days to 50% flowering, plant height, head diameter, 100-seed weight, seed filling percentage, and oil content. Cluster analysis grouped the genotypes into seven distinct clusters, with the highest genetic divergence observed between Clusters VI and VII. Head diameter contributed most to the genetic divergence, followed by oil content, volume weight, and seed filling percentage. Cluster VII genotypes were superior for early flowering and yield-contributing traits. Broad morphological variation was noted for leaf traits, ray floret number, seed length, and shape, indicating potential for diverse breeding applications.  **Conclusion:** The study revealed significant genetic variability among 40 sunflower inbreds and 2 checks, identifying promising lines for key yield traits. The observed diversity offers valuable potential for hybrid development and future breeding programs aimed at enhancing productivity and sustainability. |

Keywords: DUS descriptors, Genetic diversity, Inbred lines, Morphological traits, Cluster analysis.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a day-neutral, oilseed crop valued globally for its adaptability, short duration, high yield potential, and superior oil quality. Its insensitivity to photoperiod and temperature makes it a versatile crop for diverse agro-climatic conditions. Introduced in India in 1969 as a "crop for all seasons," sunflower belongs to the family Asteraceae (Compositae) and is a diploid species with 2n = 34 chromosomes. The genus name is derived from the Greek words *helios* (sun) and *anthos* (flower). In India, it is commonly known as "Suraj Mukhi."

Sunflower is one of the four major global oilseed crops alongside soybean, mustard, and safflower. The crop originated in southern regions of the USA and Mexico. It was widely cultivated in the USSR during the 19th century before its introduction into Indian agriculture. The plant height typically ranges from 50 to 300 cm, with a rough, hairy stem and ovate, serrated leaves. Its inflorescence is a capitulum composed of sterile ray florets on the periphery and fertile disc florets in the center. The crop exhibits protandry, encouraging natural cross-pollination.

Sunflower seeds contain 42–46% edible oil, considered premium due to its light-yellow color, high smoke point (107°C), high linoleic acid (55–60%), and PUFA content. The oil’s low cholesterol nature and high vitamin content (A, D, E, K) make it beneficial for human health (Khan *et al*.2015). Globally, during 2024–25, sunflower was cultivated on 28.14 million hectares, producing 52.02 million metric tons with a productivity of 1.85 MT ha⁻¹. In India, cultivation covered 0.18 million hectares with a productivity of 0.63 MT ha⁻¹. Maharashtra contributed 1.24 thousand tonnes from 2.51 thousand hectares with a productivity of 494 kg ha⁻¹. Major sunflower-growing states include Karnataka, Andhra Pradesh, Maharashtra, and Tamil Nadu.

Despite its importance, the sunflower area in India has declined due to limited availability of quality hybrids. To overcome this constraint, exploiting the existing genetic diversity becomes crucial for identifying superior genotypes (Reddy *et al*.2024). The selection of genetically diverse and agronomically superior parents is fundamental to a successful hybrid breeding programme (Arunachalam, 1981). Genetic divergence, especially measured through Mahalanobis’s D² statistic, serves as a reliable tool for quantifying diversity among genotypes and guiding parent selection. Information on the nature and extent of variability present in a population due to genetic and non-genetic factors served as a critical prerequisite for any systematic breeding programme (Rao, 2012).

The D² analysis helps in grouping genotypes based on genetic distances, identifying promising combinations for heterosis and variability (Murty 1965). Greater divergence between parents increases the likelihood of obtaining heterotic hybrids with wider segregation. Genetic divergence estimates also help in understanding the structure of genetic variation within a population. Several studies (e.g., Murty and Arunachalam, 1966; Singh and Choudhary, 1979; Punitha *et al*., 2010) have supported the use of D² statistics for parent selection in crop improvement.

In the current study, 40 sunflower inbred lines along with 2 checks were evaluated for morphological and yield-related traits. Characterization was done using IBPGR descriptors and UPOV guidelines. Traits studied included hypocotyl pigmentation, leaf shape, color, serration, ray and disc floret characteristics, bract shape, plant branching, pigmentation, flowering time, maturity, plant height, and head diameter. Such characterization enables the identification, selection, and classification of genetically distinct lines, which is vital for effective conservation and utilization of genetic resources in breeding programmes.

This study aimed to explore genetic variability, quantify divergence, and identify superior inbred lines for hybrid development, ultimately contributing to the improvement and sustainability of sunflower production.

2. material and methods

The present investigation was carried out during the *kharif* season of 2024 at the Oilseeds Research Station, Latur, affiliated with Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra), India. The primary objective of the study was to evaluate and characterize 40 sunflower (*Helianthus annuus* L.) inbred lines along with two standard checks, LSF-08 and SS-2038, for both morphological and agronomic traits.

The experiment was laid out in a Randomized Block Design (RBD) with two replications, maintaining a spacing of 60 × 30 cm between and within rows, respectively. Each plot consisted of a single row with 15 plants, and all standard agronomic practices were followed uniformly throughout the growing season to ensure healthy crop establishment and optimal plant performance.

For the assessment of quantitative traits, observations were recorded on five randomly selected competitive plants from each genotype per replication, including the checks. The data were collected on Days to 50% flowering, Days to maturity, Plant height (cm), Head diameter (cm), Hull content (%),100-seed weight (g), Seed filling percentage (%), Volume weight (g/100 ml), Oil content (%), Seed yield per plant (g).

Analysis of variance, following randomized block design was performed to partition the variation carried out as per the standards of Panse and Sukhatme, 1985. The genotypic and phenotypic components of variance based on analysis of variance were estimated by using formula proposed by Johnson *et al*. (1955). The genotypic and phenotypic coefficient of variation proposed by the Burton’s (1952) formula. Heritability and genetic advance were computed according to Johnson et al. (1955). Genetic divergence among the genotypes was estimated using Mahalanobis’s D² statistical method (Mahalanobis, 1936), which is a multivariate approach for assessing genetic diversity based on multiple quantitative traits. The clustering of genotypes was performed based on D² values to determine inter- and intra-cluster distances, aiding in the identification of genetically diverse parents for hybridization.

In addition to quantitative characterization, the genotypes were also evaluated for qualitative traits based on internationally accepted guidelines. Morphological characterization was conducted following the IBPGR Descriptors for Sunflower (1985) and Protection of Plant Varieties and Farmers’ Rights Authority (PPV&FRA), India (2009), under the framework of Distinctiveness, Uniformity, and Stability (DUS) testing.

A total of 24 qualitative traits were recorded, including: hypocotyl pigmentation, leaf shape, leaf colour, leaf blistering, leaf serration, leaf angle of lateral veins, the orientation of blade, leaf petiole pigmentation, stem pigmentation, ray floret number, ray floret colour, ray floret shape, disk floret colour, pollen colour, bract shape, bract pigmentation, plant natural position of closest lateral head to the central head, head attitude, head shape, plant branching, seed length, seed shape, seed coat strips and colour of seed coat stripes.

These traits were chosen for their relevance in sunflower breeding and utility in varietal identification, classification, and selection of diverse parental lines. The data collected were statistically analysed to estimate the extent of variability and to identify superior and genetically divergent genotypes suitable for inclusion in breeding programs.

3. results and discussion

Plant breeders aim to assess genetic variation in germplasm using quantitative and morphological traits, as the evaluation of morphological traits is relatively straightforward and does not require advanced techniques or costly equipment. In the present study, analysis of variance (ANOVA) revealed highly significant differences among the genotypes for all the traits evaluated, indicating substantial genetic variability in the experimental material (Table 1). A wide range of variation was observed for most of the traits studied. The quantitative traits analyzed included days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), hull content (%), seed filling percentage, 100-seed weight (g), volume weight (g/100 ml), oil content (%), and seed yield per plant (g), all of which showed significant genotypic differences. Similar observations were recorded by Dudhe *et al*. (2019) which supports the present findings.

The estimates of phenotypic coefficient of variation (PCV) were high for head diameter (28.31%), 100-seed weight (27.83%), and seed yield per plant (19.06%), followed by hull content (18.56%) and volume weight (14.89%) (Table 2). Similarly, genotypic coefficient of variation (GCV) was also high for head diameter (28.22%) and 100-seed weight (27.45%), followed by seed yield per plant (18.38%) and hull content (17.11%). In all the traits studied, PCV values were higher than their corresponding GCV values, indicating the influence of environmental factors on trait expression. The narrow gap between PCV and GCV for most traits suggested low environmental interference, particularly for traits like head diameter and 100-seed weight.

High heritability estimates were recorded for all traits, with head diameter (99.4%), oil content (98.94%), seed filling percentage (97.71%), volume weight (97.58%), and 100-seed weight (97.25%) exhibiting very high heritability. High heritability coupled with high genetic advance as percent of mean was observed for seed yield per plant (36.52%), head diameter (57.96%), 100-seed weight (55.76%), and hull content (32.49%), indicating that these traits are largely governed by additive gene action and can be effectively improved through selection. Moderate genetic advance as percent of mean was observed for volume weight (29.94%), oil content (23.74%), and seed filling percentage (20.10%). Low estimates were recorded for traits such as days to 50% flowering (11.51%) and days to maturity (10.46%), suggesting limited scope for improvement through direct selection

**Genetic diversity analysis**

The genetic divergence among 42 sunflower genotypes was assessed based on ten quantitative characters using Mahalanobis's D² statistic (Mahalanobis,1936). The genotypes were grouped into distinct clusters following Tocher's method of clustering as outlined by Rao (1952) (Table 3). This multivariate technique enables effective classification of genotypes based on the degree of genetic diversity and assists in identifying genetically diverse parents for hybridization programs. The clustering pattern provides valuable insight into the extent of variability present in the germplasm and helps in selecting promising genotypes from divergent clusters to exploit heterosis and enhance genetic gain in sunflower breeding programs.

**Intra and Inter clusters distance**

D² analysis is considered as one of the most effective methods to quantify the degree of genetic divergence among genotypes at both intra- and inter-cluster levels. In the present investigation, genetic divergence among 42 sunflower genotypes was assessed using Mahalanobis’s D² statistic and clustering was done using Tocher’s method. The results revealed that the inter-cluster distances were generally higher than intra-cluster distances (Table 4.), indicating the existence of substantial genetic variability among the genotypes studied. The intra-cluster D² values ranged from 12.13 to 20.92. The highest intra-cluster distance was recorded in Cluster V (20.92), followed by Cluster II (14.98), Cluster III (16.63), Cluster IV (17.28), Cluster I (13.54), and Cluster VI (14.65). The lowest intra-cluster distance was found in Cluster VII (12.13), indicating less genetic diversity within that cluster.

Among the inter-cluster distances, the maximum average divergence was observed between Cluster VI and Cluster VII (51.90), indicating the presence of maximum genetic divergence between genotypes of these two clusters. This was followed by Cluster I and Cluster VII (45.39), Cluster III and Cluster VII (44.09), and Cluster II and Cluster VI (43.62). The minimum inter-cluster distance was recorded between Cluster III and Cluster IV (31.11), suggesting that the genotypes in these clusters are genetically more similar.

**Cluster-wise Intra and Inter cluster Divergence Summary**:

1. Cluster I showed maximum divergence with Cluster VII (45.39), followed by Cluster II (36.76), Cluster IV (32.27), Cluster V (27.47), Cluster III (18.18), and minimum with Cluster VI (17.03).
2. Cluster II exhibited highest divergence with Cluster VI (43.62), followed by Cluster I (36.76), Cluster IV (32.96), Cluster V (32.01), Cluster III (22.87), and lowest with Cluster VII (23.98).
3. Cluster III had highest divergence with Cluster VII (44.09), followed by cluster II (32.96), Cluster IV (31.11), Cluster V (23.92), Cluster VI (21.54), and lowest with Cluster I (18.18).
4. Cluster IV displayed maximum divergence with Cluster V (37.75), followed by Cluster VI (36.03), Cluster I (32.27), Cluster III (31.11), Cluster VII (27.94) and minimum with Cluster II (22.87).
5. Cluster V showed highest divergence with Cluster VII (43.28), followed by Cluster IV (37.75), Cluster VI (34.81), Cluster II (32.01), Cluster I (27.47) and minimum with Cluster III (23.92).
6. Cluster VI exhibited maximum divergence with Cluster VII (51.90), which was also the highest inter-cluster distance overall, followed by Cluster II (43.62), Cluster IV (36.03), Cluster V (34.81), Cluster III (21.54) and minimum with Cluster I (17.03).
7. Cluster VII had its highest divergence with Cluster VI (51.90), followed by Cluster I (45.39), Cluster III (44.09), Cluster V (43.28), Cluster IV (27.94), and lowest with Cluster II (23.98).

**Contribution of different characters to genetic diversity in sunflower genotypes**

The number of times that each of yield component characters appeared in first rank and its respective percentage contribution towards genetic divergence is presented in (table 5). The result showed that head diameter contributed highest towards genetic divergence (46.11%) by taking 397 times ranking first, followed by oil content (27.87%) by taking 240 times, volume weight (11.96%) by taking 103 times, seed filling percentage (6.27%) by taking 54 times,100 seed weight (3.83%) by taking 33 times, seed yield per plant (2.44%) by taking 21 times, plant height (0.58%) by taking 5 times, days to maturity and hull content each (0.35%) by taking 3 times and days to 50 per cent flowering (0.23%)by taking 2 times.

**Morphological Characterization**

The distinctiveness, uniformity and stability (DUS) study evaluated 26 morphological traits to determine their variation among 42 genotypes taken for analysis (Table 6.). At the seedling stage, only 1 genotype exhibited strong hypocotyl anthocyanin pigmentation, 24 had medium pigmentation and rest 17 showed no pigmentation. Out of 42 genotypes 6 genotypes showed large leaf size, 20 was recorded as medium size and 16 have small leaf size. For leaf shape 39 genotypes identified as rounded leaf shape and remaining 3 genotypes have lanceolate shaped leaves. Leaf colour of 19 have light green colour, 13 genotypes recorded for dark green colour and remaining 8 genotypes have green coloured leaf. Coarse leaf serration was predominant found in 33 genotypes, medium serration was seen in 6 genotypes, while only one genotypes showed fine leaf serration. Among the 42 sunflower genotypes evaluated, the majority (30 genotypes) exhibited an acute angle of lateral veins and the remaining 12 genotypes showed an obtuse angle of lateral veins. Out of the 42 genotypes evaluated, 32 genotypes exhibited a drooping leaf blade orientation and remaining 10 genotypes showed an erect leaf blade orientation. A large majority of the genotypes 38 out of 42 showed absence of pigmentation on the leaf petiole and remaining four genotypes exhibited pigmentation on the leaf petiole. For stem pigmentation 38 genotypes showed absence of pigmentation and remaining 4 genotypes showed the presence of stem pigmentation. Variation in ray floret number was recorded among the genotypes, medium number of ray florets (30–40) was observed in 23 genotypes, higher number of ray florets (>40) was recorded in 17 genotypes and only two genotypes showed a lower number of ray florets. Ray floret colour was predominantly yellow, noted in 31 genotypes and for light yellow colour 11 genotypes was observed. Ray floret shape varied distinctly among the genotypes. For ray floret shape elongated ray florets were observed in 28 genotypes indicating a predominance of this shape. In contrast, ovate-shaped ray florets were recorded in 14 genotypes. Ray floret shape determines the overall appearance and pollination efficiency. In disc floret colour Yellow colour were uniformly observed across all 42 sunflower genotypes evaluated reinforcing the uniformity of this trait among cultivated sunflower lines. A majority of the genotypes 38 out of 42 exhibited absences of pigmentation in disc florets while strong pigmentation was observed in only four genotypes. All 42 sunflower genotypes uniformly exhibited yellow pollen colour indicating a genetically stable and non-variable trait among the sunflower lines studied. All 42 genotypes showed elongate round bract shape this uniformity suggests limited variation for this trait, which influences head protection and seed cover during development. None of the genotypes exhibited pigmentation on the bracts, showing a total absence of this character across all 42 genotypes. This suggests pigmentation is not a common trait in cultivated sunflower lines studied. In 32 genotypes, the position of the closest lateral head was found to be above the central head. In contrast, 10 genotypes showed the lateral heads positioned below the central head. This trait reflects plant architecture and potential for branching. A majority of the genotypes 39 out of 42 exhibited a half-turned down head orientation indicating that this is the predominant head attitude among the studied genotypes while, only three genotypes exhibited a vertical head orientation. Head attitude affects seed filling and protection from sun or birds. Convex head shape was predominantly observed in 39 genotypes, making it the most common head shape among the studied genotypes. In contrast, only three genotypes exhibited a concave head shape. Head shape can influence water retention and seed development. Branching was absent in 29 genotypes, indicating a predominantly non-branching growth habit. In contrast, 13 genotypes exhibited branching. This trait is important for seed yield and plant structure. Seed length showed considerable variation among the genotypes, a total of 26 genotypes exhibited short seed length, 15 observed for medium seed length and only 1 exhibited for long seed length. Seed size influences market preference and oil content. Variation in seed shape was observed among the sunflower genotypes. A total of 12 genotypes exhibited elongated seed shape, ovoid-elongated seeds were found in 11 genotypes and the remaining 19 genotypes exhibited ovoid-wide seed shape. Seed shape is an important market and breeding trait. Absence of seed coat stripes was recorded in 24 genotype and remaining 18 genotypes exhibited the presence of seed coat stripes. Striped seeds are often preferred in confectionery sunflower. Grey-coloured seed coat stripes were observed in 11 genotypes and White stripes were recorded in six genotypes. Stripe colour influences seed marketability and classification.

4. Conclusion

The present study revealed significant genetic variability among sunflower inbred lines for key agronomic and quality traits. Several superior genotypes were identified for traits such as early flowering, seed yield, oil content, and head diameter, which can serve as valuable parents in future breeding programs. High heritability coupled with high genetic advance for most traits indicates the predominance of additive gene action, suggesting effective improvement through direct selection. Morphological characterization showed wide diversity, and cluster analysis grouped genotypes into seven distinct clusters with maximum genetic divergence between Cluster VI and VII, indicating potential for heterosis breeding. These findings provide a strong foundation for genetic enhancement and hybrid development in sunflower.

References

Khan S, Choudhary S, Pandey A, Khan MK, Thomas G. 2015. Sunflower oil: Efficient oil source for human consumption. *Emerging Life Sciences Research*, **1**(1): 1–3.

USDA. 2025. *World Agricultural Production*. Circular Series, WAP 3-20. United States Department of Agriculture, Washington, D.C.

Reddy YPK, Reddy BVRP, Shanthi P, Amma KV. 2024. Study on genetic diversity in 45 elite sunflower inbred lines (*Helianthus annuus* L.). *Journal of Scientific Research and Reports*, 30(9): 551–559.

Arunachalam V. 1981. Genetic divergence in plant breeding. *Indian Journal of Genetics and Plant Breeding*, 41(2): 226–236.

Mahalanobis PC. 1936. On the generalized distance in statistics. *Proceedings of the National Institute of Sciences of India*, 2: 49–55.

Rao VT. 2012. Variability studies for yield and yield components in sunflower (*Helianthus annuus* L.). *International Journal of Applied Biology and Pharmaceutical Technology*, **3**(2): 208–210.

Murty BR, Arunachalam MV. 1966. The nature of divergence in relation to breeding systems in some crop plants. *Indian Journal of Genetics and Plant Breeding*, 26(A): 188–198.

Singh RK, Chaudhary BD. 1979. *Biometrical Methods in Quantitative Genetic Analysis*. New Delhi: Kalyani Publishers, pp. 229–231.

Punita B, Vindhiyavarman P, Manivannan N. 2010. Genetic divergence study in sunflower (*Helianthus annuus* L.). *Electronic Journal of Plant Breeding*, 1(4): 426–430.

Anonymous. (1985). *Descriptors for cultivated and wild sunflower*. Rome: International Board for Plant Genetic Resources (IBPGR), p. 53.

Panse, V. G. & Sukhatme, P. V. (1985). *Statistical Methods for Agricultural Workers*, 4th ed., ICAR, New Delhi

Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soybean. AGRON J. 1955a; 47:314-318.

Burton GW, DeVane EM. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal*, 45: 478–481.

PPV & FRA. Guidelines for conduct of DUS test for distinctness, uniformity and stability on sunflower (Helianthus annuus L.). GOI, New Delhi; 2009.

Rao CR**.** 1952. *Advanced Statistical Methods in Biometrical Research*. New York: Wiley and Sons, pp. 357–363.

Dudhe MY, Sujatha M, Meena HP, Ranganatha ARG, Varaprasad KS, Reddy AVV. 2019a. Genetic variability, diversity and identification of trait-specific accessions from the conserved sunflower germplasm for exploitation in the breeding programme. *Agricultural Research*, 9: 9–22.

**Table 1.** Analysis of variance of randomized block design for ten characters in Sunflower

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Characters** | **Mean Sum of Squares** | | |
| **Replication** | **Treatment** | **Error** |
| **1** | Days to 50 per cent flowering | 0.583 | 29.2395\*\* | 3.096 |
| **2** | Days to maturity | 3.048 | 45.819\*\* | 2.096 |
| **3** | Plant height (cm) | 393.300 | 235.79\*\* | 9.530 |
| **4** | Head diameter (cm) | 41.062 | 21.726\*\* | 0.066 |
| **5** | Hull content (%) | 62.820 | 31.947\*\* | 2.593 |
| **6** | 100 seed weight (g) | 3.823 | 2.3127\*\* | 0.033 |
| **7** | Seed filling (%) | 325.700 | 86.62\*\* | 1.000 |
| **8** | Volume weight (g/100ml) | 178.209 | 66.753\*\* | 0.818 |
| **9** | Oil content (%) | 10.822 | 28.8848\*\* | 0.155 |
| **10** | Seed yield per plant (g) | 64.313 | 50.853\*\* | 1.837 |

\* Significance at 5 % level and \*\* significance at 1% level

**Table 2.** Mean, range, variability, heritability (Broad sense), genetic advance and genetic advanced as per cent mean for ten characters of 42 Sunflower genotypes.

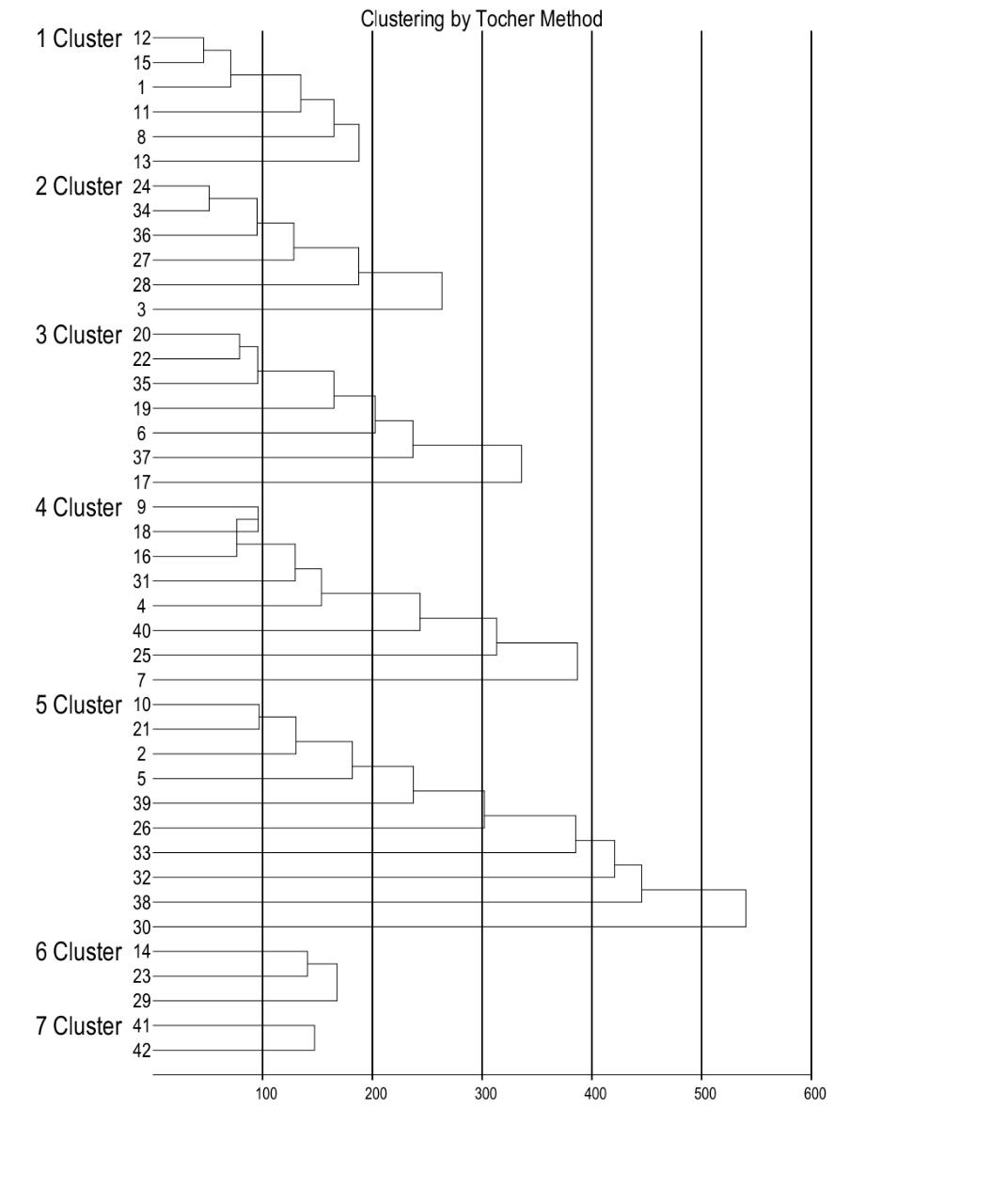
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Characters** | **Mean** | **Range** | | **Genotypic variance** | **phenotypic variance** | **Environmental variance** | **GCV (%)** | **PCV (%)** | **ECV (%)** | **Heritability in broad sense (H2) (%)** | **Genetic Advance** | **Genetic Advance as % of mean** |
| **Min** | **Max** |
| **Days to 50 per cent flowering** | 58.48 | 50 | 67 | 13.07 | 16.16 | 3.09 | 6.21 | 6.91 | 3.02 | 80.85 | 6.69 | 11.51 |
| **Days to maturity** | 79.00 | 78 | 97 | 21.86 | 23.95 | 2.09 | 5.31 | 5.56 | 1.64 | 91.25 | 9.20 | 10.46 |
| **Plant height (cm)** | 123.91 | 102 | 172 | 113.13 | 122.66 | 9.52 | 8.48 | 8.83 | 2.46 | 92.23 | 21.04 | 16.78 |
| **Head diameter (cm)** | 11.43 | 7 | 17 | 10.82 | 10.89 | 0.06 | 28.22 | 28.30 | 2.20 | 99.40 | 6.75 | 57.95 |
| **Hull content (%)** | 22.58 | 14 | 32 | 14.67 | 17.26 | 2.59 | 17.10 | 18.55 | 7.19 | 84.99 | 7.27 | 32.49 |
| **100 seed weight (g)** | 3.75 | 2 | 7 | 1.14 | 1.17 | 0.03 | 27.44 | 27.83 | 4.62 | 97.25 | 2.16 | 55.76 |
| **Seed filling (%)** | 65.90 | 53 | 79 | 42.81 | 43.81 | 0.81 | 9.80 | 9.98 | 1.51 | 97.71 | 13.32 | 20.10 |
| **Volume weight (g/100ml)** | 44.15 | 24 | 48 | 32.96 | 33.78 | 0.81 | 14.71 | 14.89 | 2.31 | 97.58 | 11.68 | 29.93 |
| **Oil content (%)** | 33.65 | 23 | 40 | 14.36 | 14.51 | 0.15 | 11.58 | 11.65 | 1.20 | 98.94 | 7.76 | 23.74 |
| **Seed yield per plant (g)** | 30.18 | 17 | 40 | 24.50 | 26.34 | 1.83 | 18.38 | 19.05 | 5.03 | 93.03 | 9.83 | 36.52 |

|  |  |  |
| --- | --- | --- |
| **Cluster** | **Total Genotypes** | **Inbred lines** |
| **Cluster I** | 6 | RCB-5,25-2, RCR-63,64,65,68 |
| **Cluster II** | 6 | RCB-5, RCMS-34B, USDA-42,63,126,128 |
| **Cluster III** | 7 | RCB-19-25, RCR-71,74,75, RCMS-16B, USDA-126,164 |
| **Cluster IV** | 8 | RCB-11,23-1,32, RCR-70,72, RCMS-96B, USDA-94, DRSF-113 |
| **Cluster V** | 10 | RCB-6,16,47, RCMS-8B, USDA-8,65,104,110,188, PI-599977 |
| **Cluster VI** | 3 | RCR-67, RCMS-76B, USDA-63 |
| **Cluster VII** | 2 | LSF-08, SS-2038 |

**Table 3.** Composition of 42 inbred lines including two checks into seven clusters

**Table 4.** Intra and Inter cluster distances (D)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Cluster** | **Cluster**  **I** | **Cluster**  **II** | **Cluster**  **III** | **Cluster**  **IV** | **Cluster**  **V** | **Cluster**  **VI** | **Cluster**  **VII** |
| **Cluster I** | 13.54 | 36.76 | 18.18 | 32.27 | 27.47 | 17.03 | 45.39 |
| **Cluster II** |  | 14.98 | 32.96 | 22.87 | 32.01 | 43.62 | 23.98 |
| **Cluster III** |  |  | 16.63 | 31.11 | 23.92 | 21.54 | 44.09 |
| **Cluster IV** |  |  |  | 17.28 | 37.75 | 36.03 | 27.94 |
| **Cluster V** |  |  |  |  | 20.92 | 34.81 | 43.28 |
| **Cluster VI** |  |  |  |  |  | 14.65 | 51.90 |
| **Cluster VII** |  |  |  |  |  |  | 12.13 |



**Fig 1.** Clustering pattern of 42 genotypes in sunflower by Tocher’s method.

**Table 5.** Contribution of different character to genetic diversity in sunflower genotypes.

|  |  |  |  |
| --- | --- | --- | --- |
| **Sr. No.** | **Traits** | **No. of times appearing 1st in ranking** | **Contribution % towards Divergence** |
| **1** | **Days to 50 per cent flowering** | 2 | 0.23% |
| **2** | **Days to maturity** | 3 | 0.35% |
| **3** | **Plant height (cm)** | 5 | 0.58% |
| **4** | **Head diameter (cm)** | 397 | 46.11% |
| **5** | **Hull content (%)** | 3 | 0.35% |
| **6** | **100 seed weight (g)** | 33 | 3.83% |
| **7** | **Seed filling (%)** | 54 | 6.27% |
| **8** | **Volume weight (g/100ml)** | 103 | 11.96% |
| **9** | **Oil content (%)** | 240 | 27.87% |
| **10** | **Seed yield per plant (g)** | 21 | 2.44% |

**Fig 2.** Contribution of each character towards divergence

|  |  |  |  |
| --- | --- | --- | --- |
| **No.**  **Table 6.** Morphological characterization of sunflower genotypes | **Characteristics** | **Category** | **No. of genotypes** |
|  |  | Absent | 15 |
| 1 | Hypocotyl: Anthocyanin Pigmentation | Medium | 22 |
|  |  | Strong | 1 |
|  |  | Lanceolate | 2 |
| 2 | Leaf size | Small | 16 |
|  |  | Medium | 19 |
|  |  | Large | 6 |
| 3 | Leaf: Shape | Lanceolate | 3 |
|  |  | Rounded | 37 |
| 4 | Leaf: Color | Light green | 19 |
|  |  | Green | 8 |
|  |  | Dark green | 13 |
| 5 | Leaf: Blistering | Absent | 42 |
|  |  | Medium | 0 |
|  |  | Strong | 0 |
| 6 | Leaf: Serration | Fine | 1 |
|  |  | Medium | 6 |
|  |  | Coarse | 33 |
| 7 | Leaf: Angle of lateral veins | Acute (<90) | 29 |
| Obtuse (>90) | 11 |
| 8 | Leaf: Orientation of blade | Erect | 10 |
| Drooping | 30 |
| 9 | Leaf: Petiole anthocyanin pigmentation | Absent | 38 |
| Present | 4 |
| 10 | Stem: Pigmentation | Absent | 38 |
| Present | 4 |
|  |  | Elongated | 26 |
| 11 | Ray floret: Shape | Ovate | 13 |
|  |  | Rounded | 0 |
|  |  | Light yellow | 31 |
| 12 | Ray floret: Color | Yellow | 11 |
| Orange | 0 |
|  |  | Purple | 0 |
| 13 | Ray floret number | Medium | 20 |
|  |  | Many | 13 |
| 14 | Disk floret: Color | Yellow | 42 |
| 15 | Disk floret: Anthocyanin pigmentation of stigma | Absent | 38 |
|  |  | Medium | 0 |
|  |  | Strong | 4 |
| 16 | Disk floret: Pollen colour | White | 0 |
| Yellow | 42 |
| 17 | Bract: Shape | Elongated | 42 |
| Rounded | 0 |
| 18 | Bract: Anthocyanin pigmentation | Absent | 42 |
| Present | 0 |
| 19 | Plant: Natural position of closest lateral head to the central head (end of flowering- branched) | Above | 32 |
| Below | 10 |
| 20 | Head: Attitude | Inclined | 0 |
|  |  | Vertical | 3 |
| Half turned down | 39 |
|  |  | Turned down | 0 |
| 21 | Head: Shape of the grain side | Concave | 3 |
|  |  | Flat | 0 |
| Convex | 39 |
|  |  | Irregular | 0 |
| 22 | Plant: Branching | Absent | 29 |
| Present | 13 |
|  |  | Basal | 0 |
| 23 | Seed length | Short | 26 |
|  |  | Medium | 15 |
|  |  | Long | 1 |
| 24 | Seed: Shape | Elongated | 12 |
|  |  | Ovoid elongated | 11 |
|  |  | Ovoid wide | 19 |
|  |  | White | 0 |
| 25 | Seed coat: Stripes | Absent | 24 |
| Present | 18 |
| 26 | Seed coat: Color of Stripes | White | 6 |
|  |  | Grey | 11 |
| Brown | 0 |
|  |  | Black | 0 |