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UNLOCKING MORPHOLOGICAL DIVERSITY IN SUNFLOWER (*Helianthus annuus* L.) INTERSPECIFIC DERIVATIVES THROUGH DUS PROFILING

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ABSTRACT

Sunflower (*Helianthus annuus* L.) is an important oilseed crop valued for its high-quality edible oil and wide adaptability. The present study evaluated the morphological diversity of forty six advanced BC_2F_6 interspecific derivatives along with four checks using twenty seven DUS descriptors. Considerable variability was observed among the genotypes for most seedling, vegetative, floral, head, plant architectural and seed traits. Out of the twenty seven traits studied, only one character i.e., disk floret pollen colour was monomorphic, whereas the remaining descriptors exhibited two or more states of expression. Most genotypes were early flowering (96%) and predominantly exhibited triangular leaves (62%), yellow ray florets (86%), orange disk florets (74%), small head diameter (88%), medium plant height (48%), ovoid elongated seeds (72%) and medium 100-seed weight (94%). Seed coat base colour showed limited variation, with black seed coats in 49 genotypes (98%) and a brown seed coat in RHA 1-1 (2%). Rare expression states for ray floret shape, head attitude, plant height, seed weight and seed coat stripes were useful in identifying distinct genotypes. The observed morphological diversity provides valuable genetic resources for sunflower breeding and germplasm documentation.
Keywords **:** Morphological characterization, DUS descriptors, Sunflower· Interspecific derivatives.

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops cultivated worldwide due to its high-quality edible oil and wide adaptability to diverse agro-climatic conditions. The crop is valued for its high content of polyunsaturated fatty acids, particularly linoleic and oleic acids, which contribute to improved human health. Despite its economic importance, sunflower productivity in India remains relatively low compared to the global average, largely due to the narrow genetic base of cultivated germplasm. Therefore, broadening the genetic base through the effective utilization of diverse genetic resources has become a key strategy in sunflower breeding programmes.

Wild *Helianthus* species constitute an important source of genetic variability and have been extensively utilized in sunflower improvement programmes. Interspecific hybridization has facilitated the transfer of desirable traits such as enhanced seed and oil yield, disease resistance, and adaptation to diverse environments. Among wild sunflower species, diploid annual species are highly valuable because of their cross-compatibility with cultivated sunflower (Sujatha *et al*., 2008). The incorporation of these valuable genes into cultivated backgrounds has resulted in the development of interspecific derivatives with enhanced breeding potential.

However, the effective utilization of these interspecific derivatives requires systematic characterization to identify promising genotypes and to understand the extent of available variability. The success of any crop improvement programme depends on the availability and effective utilization of genetic variability. Characterization of germplasm is essential for identifying diverse and trait-specific genotypes that can serve as potential donor sources in breeding programmes.

Being signatory to the General Agreement on Trade and Tariffs (GAAT), Government of India has enacted its Sui generis system, Protection of Plant Varieties and Farmers' Right Act (PPV&FRA), 2001 for providing protection to plant varieties based on Distinctiveness, Uniformity and Stability (DUS) test, apart from novelty. Therefore, the characterization of a line or inbred is a prerequisite and identification of plant varieties of common knowledge is essential for the protection of new plant varieties and determining varietal purity.

The uniqueness of a variety from existing varieties is to be established by following standard DUS testing guidelines. Morphological characterization based onDUS descriptors provides a standardized and reliable approach for varietal identification, assessment of genetic diversity and elimination of duplicate germplasm as prescribed by the PPV&FRA guidelines for sunflower (Muktha *et al*., 2009). Qualitative descriptors are particularly valuable because they are generally stable across environments and generations (Dhillon *et al*., 2011). Several studies have demonstrated the effectiveness of DUS descriptors in characterizing sunflower germplasm and identifying distinct genotypes (Cuk *et al*., 2020 and Kumar *et al*., 2023).

Therefore, the present investigation was undertaken to characterize interspecific derivatives of sunflower (*Helianthus annuus* L.) using 27 DUS descriptors to identify distinct, uniform, and stable genotypes for their effective utilization in future sunflower breeding programmes.

Material and Methods

The present investigation was conducted during *Rabi*, 2025–26 at the Agricultural Research Station, Tornala, Siddipet district, Telangana, India. The experimental material comprised of 50 genotyopes which includes 46 BC_2F_6 interspecific derivatives of sunflower (*Helianthus annuus* L.) developed from crosses involving cultivated sunflower and wild *Helianthus* species (*H. petiolaris* and *H. debilis*), along with four checks.Toevaluate the morphological characteristics of these genotypes under field conditions, the experiment was laid out in a Randomized Block Design (RBD) with two replications. Each genotype was grown in two rows of 4.5 m length with a spacing of 60 cm × 30 cm. All the recommended agronomic practices were followed throughout the crop growth period to ensure uniform crop establishment and optimum plant growth and development.

Morphological characterization of the genotypes was carried out using 27 DUS descriptors as prescribed in the guidelines for sunflower developed by the Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), Government of India (Muktha *et al.,* 2009). The descriptors studied included hypocotyl anthocyanin pigmentation, days to 50 per cent flowering, leaf size, leaf shape, leaf colour, leaf blistering, leaf serration, leaf blade orientation, petiole anthocyanin pigmentation, stem pigmentation, ray floret shape and colour, disk floret colour and pollen colour, head attitude, head diameter, head shape of grain side, plant height, branching habit, type of branching, seed length, seed shape, 100-seed weight, seed coat base colour, seed coat stripes, hull content and oil content.

Qualitative descriptors were recorded based on the expression of the entire plot; whereas quantitative observations were recorded from five randomly selected competitive plants in each genotype in each replication. Based on the observations recorded, each genotype was classified into the appropriate states of expression as specified in the DUS guidelines. The frequency distribution of genotypes under each descriptor category was subsequently computed to determine the pattern of variation.

Results and Discussion

Morphological characterization of fifty sunflower genotypes, including interspecific derivates and checks, was carried out using twenty seven DUS (Distinctness, Uniformity and Stability) descriptors in accordance with the national DUS test guidelines for sunflower. The frequency distribution of all the traits under study was presented in Table 1. The study revealed substantial variability among the genotypes for most of the qualitative and quantitative traits, indicating the presence of considerable genetic diversity within the experimental material across the seedling, vegetative, floral, head, plant architectural and seed characters. Among the 27 descriptors studied, only disk floret pollen colour was monomorphic, whereas the remaining descriptors exhibited two or more states of expression.

The observed variability may be attributed to the diverse genetic background of the interspecific derivatives and highlights their potential for broadening the genetic variability available in sunflower breeding programmes. Similar findings on morphological diversity and the effectiveness of DUS descriptors for the characterization and differentiation of sunflower genetic resources have been reported by Sujatha *et al.* (2008), Dhillon *et al*. (2011), Meena *et al*. (2017), Cuk *et al*. (2020), Kumar *et al.* (2023), Sasikala *et al*. (2025) and Sonawane *et al*. (2025).

Seedling, flowering and vegetative characters exhibited considerable variation. Hypocotyl anthocyanin pigmentation differentiated the genotypes into three classes, with pigmentation being absent in thirty one genotypes (62%), medium in thirteen (26%) and strong in six (12%) genotypes. Strong pigmentation was observed in PB-1234, PB-1603, PB-1602, PB-1612, DRSF-113 and RHA 1-1.

Flowering time showed limited variation, with forty eight genotypes (96%) were classified as early flowering and only PB-1609 and PB-1646 as medium flowering duration, while no genotype belonged to the late flowering group. Similar observations were reported by Dhillon *et al.* (2011), Abu (2020) and Kumar *et al.* (2023).

Leaf characters provided reliable criteria for genotype differentiation. Small size leaves (< 15 cm) were recorded in twenty six genotypes (52%) and medium size (15-25 cm) leaves in twenty four (48%), whereas large leaves (> 25 cm) were absent. Triangular leaves predominated with thirty one genotypes (62%), while nineteen (38%) entries possessed cordate leaves. Green leaf colour was observed in twenty seven genotypes (54%) and dark green leaf colour was expressed by twenty three (46%) genotypes. Medium leaf blistering was predominant (66%), followed by absent (20%) and strong blistering (14%). Fine serration was most frequent (54%), followed by medium (34%) and coarse (12%).Erect leaf orientation occurred in 44 genotypes (88%), whereas DRSF-113, PB-1627, PB-1603, PB-1617, ARM 243B and PB-1647 exhibited drooping leaves. Petiole anthocyanin pigmentation was absent in thirty genotypes (60%) and present in 20 (40%), while stem pigmentation occurred in only seven genotypes (14%). These vegetative descriptors proved useful for establishing the morphological identity of sunflower genotypes. Similar variability was reported by Dhillon *et al*. (2011), Vikas Kulkarni *et al.* (2015), Cuk *et al.* (2020), Kumar *et al.* (2023) and Sonawane *et al.* (2025).

Floral characters also exhibited appreciable diversity. Ray floret shape was elongated in 56%, ovate in 40% and rounded in 4% of the genotypes. Rounded ray florets were confined to PB-1233-1 and PB-1580, making this trait a useful diagnostic character. Yellow ray florets predominated (86%), whereas light-yellow and orange ray florets occurred in 6% and 8% of the genotypes, respectively. Disk floret colour was predominantly orange (74%), followed by yellow (26%), while disk floret pollen colour was monomorphic with all genotypes exhibiting yellow pollen. These floral traits contributed significantly to genotype distinctness and served as reliable morphological markers for varietal identification. Similar observations were reported by Tan *et al*. (2013), Sudrik*et al*. (2014), Cuk *et al.* (2020),Abu (2020) and Kumar *et al*. (2023).

Head morphology and plant architectural traits also displayed considerable diversity. Vertical head attitude was predominant (44%), followed by turned down (34%), half turned down (20%) and inclined (2%), with inclined head attitude observed only in genotype PB-PB-1574. Small head diameter was recorded in forty four genotypes (88%), whereas PB-1624, PB-1616, PB-1614, PB-1603, PB-1602 and PB-1661 exhibited medium head diameter. The grained side of the head was predominantly flat (48%), followed by convex (42%) and concave (10%).

Plant height varied from very short (<80 cm) to tall (141-170 cm), with medium height (111-140 cm) genotypes predominating (48%), followed by short (30%), tall (18%) and very short (4%).Genotypes PB-1468-1 and PB-1580 were identified as very short. Branching was absent in twenty nine genotypes (58%) and present in twenty one (42%) genotypes, of which eleven showed overall branching and ten entries exhibited apical branching. The diversity observed in head and plant architectural traits provides useful phenotypic variation for genotype characterization and breeding. Similar findings were reported by Kanwal *et al*. (2019), Dudhe*et al.* (2020), Cuk *et al*. (2020) and Kumar *et al*. (2023).

Seed characters exhibited moderate to high variability. Medium seed length (1-1.5 cm) predominated in forty one genotypes (82%), while nine genotypes (18%) possessed short seeds (<1 cm). Ovoid elongated seeds were observed in thirty six genotypes (72%) and ovoid wide seeds in fourteen (28%). Based on 100-seed weight, forty seven genotypes (94%) were classified as medium (4-6 g) and three genotypes namely, PB-1245, PB-1234-1 and PB-1616 (6%) have high seed weight (> 6 g). Seed coat base colour showed limited variation, with forty nine genotypes (98%) possessing black seed coats and only one entry RHA 1-1 (2%) exhibited brown seed coat. Seed coat stripes were present in five genotypes (10%), namely PB-

1240, PB-1247-1, PB-1334, RHA 1-1 and DRSF-113, while the remaining forty five genotypes (90%) lacked stripes. Hull content was classified into low (< 25 %) with eleven genotypes, twenty four entries possessed medium (25-30 %) hull content, while remaining fifteen genotypes had high (>30%) hull content. Seed oil content was low (< 35 %) in twenty five genotypes, medium (35-40 %) in twenty four genotypes, COSF 6 B recorded high oil content (40-43 %). Although seed coat base colour exhibited limited variation, the unique brown seed coat of RHA 1-1 and the presence of seed coat stripes in a few genotypes contributed to their morphological distinctness, while seed shape, seed weight, hull content and oil content proved useful for genotype characterization. Similar variability for seed-related traits has been reported by Cuk *et al.* (2020), Dudhe*et al*. (2020), Kumar *et al*. (2023) and Sasikala *et al.* (2025).

Conclusion

To meet the continuously expanding needs of varietal improvement, the assemblage, evaluation, preservation and characterization of the entire existing germplasm are essential to more rewarding breeding efforts. The DUS based characterization revealed substantial morphological variability among the sunflower interspecific derivatives, enabling effective differentiation of the genotypes. Out of the twenty seven DUS characters recorded, disk floret pollen colour was mono morphic, where as traits *viz*., time of 50% flowering (days), leaf size, leaf shape, leaf colour, leaf orientation of blade, leaf petiole anthocyanin pigmentation, stem pigmentation, disk floret colour, head diameter, plant branching, type of branching, seed length, seed shape, seed weight, seed coat base colour and seed coat stripes expressed dimorphic state. Tri morphic expression was observed for hypocotyl anthocyanin pigmentation, leaf blistering, leaf serration, ray floret shape, head shape of grain side, hull content (%) and oil content (%). Two characters namely head attitude and plantheight were showed four states of expression. The identified diversity provides valuable information for genotype identification, germplasm documentation, and the selection of superior trait-specific donor lines. These findings underscore the potential of the evaluated sunflower genotypes as important genetic resources for future breeding programmes aimed at developing high-yielding, adaptable, and improved sunflower cultivars and hybrids.

Table 1: Frequency distribution of interspecific derivatives of sunflower for various DUS characters

S. No	Character	States of expression	No. of genotypes	Frequency (%)	Genotypes
1	Hypocotyl: Anthocyanin pigmentation	Absent	31	62	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1334, COSF 6B, PB-1234-1, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, PB-1645-1, PB-1627, PB-1616, PB-1609, ARM 243B, PB-1607-1, PB-1661, PB-1647, PB-1620, PB-1458, PB-1480-1,PB-1574, PB-1569, PB-1468-1 and PB-1580
		Medium	13	26	PB-1331, PB-1243, PB-1233-1, PB-1235, PB-1624, PB-1621, PB-1614, PB-1617, PB-1624-3, PB-1603-1, PB-1643-1, PB-1646 and PB-1611
		Strong	6	12	PB-1234, DRSF-113, PB-1603, PB-1602, PB-1612, and RHA 1-1
2	Days to 50 % flowering (Days)	Early	48	96	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1616, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		Medium	2	04	PB-1609 and PB-1646
3	Leaf: Size	Small	26	52	PB-1239, PB-1240, PB-1245, PB-1331, PB-1233-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1609, PB-1617, PB-1607-1, PB-1624-3, PB-1643-1, PB-1611, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1 and PB-1580
		Medium	24	48	PB-1242, PB-1247-1, PB-1247-4, PB-1249, PB-1334, PB-1243, COSF 6B, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1624,

S. No	Character	States of expression	No. of genotypes	Frequency (%)	Genotypes
					PB-1627, PB-1616, PB-1621, PB-1614, PB-1603, PB-1602, ARM 243B, PB-1612, PB-1603-1, PB-1661, PB-1646and PB-1647
4	Leaf: Shape	Cordate	19	38	PB-1239, PB-1240, PB-1245, PB-1247-1, PB-1247-4, PB-1331, PB-1334, COSF 6B, PB-1233-1, PB-1238-1, DRSF-113, PB-1624, PB-1609, ARM 243B, PB-1607-1, PB-1603-1, RHA 1-1, PB-1458andPB-1468-1
		Triangular	31	62	PB-1242, PB-1249, PB-1243, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1645-1, PB-1627, PB-1616, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, PB-1624-3, PB-1612, PB-1643-1, PB-1661, PB-1646, PB-1611, PB-1647, PB-1620, PB-1480-1, PB-1574, PB-1569andPB-1580
5	Leaf: Colour	Green	27	54	PB-1239, PB-1242, PB-1245, PB-1247-1, PB-1249, PB-1331, PB-1334, COSF 6B, PB-1233-1, PB-1237, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1621, PB-1617, ARM 243B, PB-1607-1, PB-1624-3, PB-1643-1, PB-1646, PB-1611, PB-1620, PB-1574, PB-1569, PB-1580andPB-1647
		Dark green	23	46	PB-1240, PB-1247-4, PB-1243, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237-1, PB-1238, PB-1238-1, PB-1616, PB-1609, PB-1614, PB-1603, PB-1602, PB-1612, PB-1603-1, PB-1661, RHA 1-1, PB-1458, PB-1480-1andPB-1468-1
6	Leaf: Blistering	Strong	7	14	PB-1239, PB-1240, PB-1331, PB-1334, PB-1243, PB-1621and PB-1603
		Medium	33	66	PB-1242, PB-1245, PB-1247-1, PB-1247-4, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238-1, PB-1645-1, PB-1624, PB-1616, PB-1609, PB-1614, PB-1617, PB-1602, ARM 243B, PB-1607-1, PB-1603-1, PB-1643-1, PB-1646, PB-1647, PB-1620, RHA 1-1, PB-1480-1, PB-1574, PB-1569andPB-1468-1
		Absent	10	20	PB-1249, PB-1238, DRSF-113, PB-1627, PB-1624-3, PB-1612, PB-1661, PB-1611, PB-1458and PB-1580
7	Leaf: Serration	Coarse	6	12	PB-1239, PB-1240, PB-1249, PB-1331, PB-1334and PB-1647
		Medium	17	34	PB-1242, PB-1245, PB-1247-1, PB-1247-4, COSF 6B, PB-1234-1, DRSF-113, PB-1627, PB-1603, PB-1602, ARM 243B, PB-1624-3, PB-1643-1, PB-1646, RHA 1-1, PB-1569and PB-1580
		Fine	27	54	PB-1243, PB-1233-1, PB-1234, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, PB-1645-1, PB-1624, PB-1616, PB-1609, PB-1621, PB-1614, PB-1617, PB-1607-1, PB-1612, PB-1603-1, PB-1661, PB-1611, PB-1620, PB-1458, PB-1480-1, PB-1574andPB-1468-1
8	Leaf: Orientation of blade	Erect	44	88	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, PB-1645-1, PB-1624, PB-1616, PB-1609, PB-1621, PB-1614, PB-1602, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1611, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		Drooping	6	12	DRSF-113, PB-1627, PB-1603, PB-1617, ARM 243Band PB-1647
9	Leaf: Petiole anthocyanin pigmentation	Absent	30	60	PB-1239, PB-1240, PB-1245, PB-1247-1, PB-1249, PB-1243, COSF 6B, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1609, PB-1621, PB-1614, ARM 243B, PB-1624-3, PB-1603-1, PB-1643-1, PB-1646, PB-1647, PB-1458, PB-1468-1and PB-1580
		Present	20	40	PB-1242, PB-1247-4, PB-1331, PB-1334, PB-1233-1, PB-1234, PB-1234-1, PB-1616, PB-1603, PB-1617, PB-1602, PB-1607-1,

S. No	Character	States of expression	No. of genotypes	Frequency (%)	Genotypes
					PB-1612, PB-1661, PB-1611, PB-1620, RHA 1-1, PB-1480-1, PB-1574andPB-1569
10	Stem: Pigmentation	Absent	43	86	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1243, COSF 6B, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1627, PB-1616, PB-1609, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, ARM 243B, PB-1624-3, PB-1612, PB-1603-1, PB-1661, PB-1646, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1andPB-1580
		Present	7	14	PB-1334, PB-1233-1, PB-1234, PB-1234-1, PB-1624, PB-1607-1and PB-1643-1
11	Ray floret: Shape	Ovate	20	40	PB-1239, PB-1240, PB-1242, PB-1249, PB-1334, PB-1243, PB-1237-1, PB-1645-1, PB-1624, PB-1627, PB-1621, PB-1603, PB-1617, PB-1602, PB-1603-1, PB-1643-1, PB-1647, PB-1574, PB-1569 and PB-1468-1
		Elongated	28	56	PB-1245, PB-1247-1, PB-1247-4, PB-1331, COSF 6B, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1238, PB-1238-1, DRSF-113, PB-1616, PB-1609, PB-1614, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1661, PB-1646, PB-1611, PB-1620, RHA 1-1, PB-1458 and PB-1480-1
		Rounded	2	4	PB-1233-1 and PB-1580
12	Ray floret: Colour	Yellow	43	86	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1616, PB-1621, PB-1614, PB-1603, PB-1602, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1647, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569 and PB-1468-1
		Light yellow	3	6	PB-1233-1, PB-1627 and PB-1611
		Orange	4	8	PB-1237, PB-1609, PB-1617and PB-1580
13	Disk floret: Colour	Orange	37	74	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1243, COSF 6B, PB-1234, PB-1234-1, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, DRSF-113, PB-1645-1, PB-1616, PB-1609, PB-1621, PB-1603, PB-1617, PB-1602, PB-1607-1, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		Yellow	13	26	PB-1249, PB-1331, PB-1334, PB-1233-1, PB-1235, PB-1238-1, PB-1624, PB-1627, PB-1614, ARM 243B, PB-1624-3, PB-1646 and PB-1458
14	Disk floret: Pollen colour	Yellow	50	100	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1616, PB-1609, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1 and PB-1580
15	Head: Attitude	Vertical	22	44	PB-1239, PB-1240, PB-1331, PB-1233-1, PB-1234, PB-1234-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238-1, PB-1645-1, PB-1614, PB-1617, PB-1624-3, PB-1612, PB-1661, PB-1646, PB-1611, PB-1458, PB-1480-1, PB-1569 and PB-1580
		Turned	17	34	PB-1242, PB-1247-1, PB-1247-4, PB-1334, PB-1243, COSF 6B,

S. No	Character	States of expression	No. of genotypes	Frequency (%)	Genotypes
		down			PB-1235, PB-1235-1, PB-1627, PB-1616, PB-1609, PB-1603, PB-1602, ARM 243B, PB-1607-1, PB-1603-1 and RHA 1-1
		Half turned down	10	20	PB-1245, PB-1249, PB-1238, DRSF-113, PB-1624, PB-1621, PB-1643-1, PB-1647, PB-1620 and PB-1468-1
		Inclined	1	2	PB-1574
16	Head diameter (cm)	Small	44	88	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1627, PB-1609, PB-1621, PB-1617, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1646, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		Medium	6	12	PB-1624, PB-1616, PB-1614, PB-1603, PB-1602, PB-1661
17	Head: Shape of the grained side	Convex	21	42	PB-1239, PB-1240, PB-1242, PB-1245, PB-1249, PB-1243, PB-1235, PB-1235-1, PB-1235-2, PB-1238, PB-1238-1, PB-1645-1, PB-1624, PB-1616, PB-1602, PB-1624-3, PB-1661, PB-1646, PB-1647, PB-1569 and PB-1580
		Flat	24	48	PB-1247-1, PB-1247-4, PB-1331, PB-1334, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1237, PB-1237-1, DRSF-113, PB-1627, PB-1609, PB-1621, PB-1603, PB-1617, PB-1607-1, PB-1612, PB-1603-1, PB-1611, PB-1620, PB-1458, PB-1480-1and PB-1574
		Concave	5	10	PB-1614, ARM 243B, PB-1643-1, RHA 1-1and PB-1468-1
18	Plant height (cm)	Medium	24	48	PB-1239, PB-1240, PB-1242, PB-1245, PB-1249, PB-1331, PB-1334, COSF 6B, PB-1234, PB-1235-1, PB-1235-2, PB-1238, PB-1645-1, PB-1627, PB-1621, PB-1603, PB-1602, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1458 and PB-1480-1
		Tall	9	18	PB-1247-1, PB-1247-4, PB-1243, PB-1234-1, PB-1235, DRSF-113, PB-1624, PB-1609and ARM 243B
		Short	15	30	PB-1233-1, PB-1237, PB-1237-1, PB-1238-1, PB-1616, PB-1614, PB-1617, PB-1607-1, PB-1624-3, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1574 and PB-1569
		Very short	2	4	PB-1468-1and PB-1580
19	Plant: Branching	Absent	29	58	PB-1239, PB-1242, PB-1245, PB-1247-1, PB-1243, COSF 6B, PB-1233-1, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237-1, DRSF-113, PB-1645-1, PB-1624, PB-1616, PB-1609, PB-1621, PB-1614, PB-1603, ARM 243B, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1647, PB-1574 and PB-1468-1
		Present	21	42	PB-1240, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1234, PB-1237, PB-1238, PB-1238-1, PB-1627, PB-1617, PB-1602, PB-1607-1, PB-1646, PB-1611, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1569 and PB-1580
20	Plant: Type of branching	Apical	10	20	PB-1240, PB-1247-4, PB-1234, PB-1238, PB-1627, PB-1602, PB-1607-1, PB-1611, PB-1620 and PB-1569
		Overall	11	22	PB-1249, PB-1331, PB-1334, PB-1237, PB-1238-1, PB-1617, PB-1646, RHA 1-1, PB-1458, PB-1480-1and PB-1580
21	Seed length (cm)	Short	9	18	PB-1239, PB-1240, PB-1331, PB-1233-1, PB-1237-1, PB-1602, PB-1611, PB-1458 and PB-1480-1
		Medium	41	82	PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1334, PB-1243, COSF 6B, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1616, PB-1609, PB-1621, PB-1614, PB-1603, PB-1617, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1647, PB-1620, RHA

S. No	Character	States of expression	No. of genotypes	Frequency (%)	Genotypes
					1-1, PB-1574, PB-1569, PB-1468-1and PB-1580
22	Seed: Shape	Ovoid elongated	36	72	PB-1239, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1616, PB-1609, PB-1621, PB-1614, ARM 243B, PB-1607-1, PB-1624-3, PB-1643-1, PB-1611, PB-1647, PB-1620, PB-1458, PB-1574 and PB-1580
		Ovoid wide	14	28	PB-1240, PB-1233-1, PB-1237-1, PB-1603, PB-1617, PB-1602, PB-1612, PB-1603-1, PB-1661, PB-1646, RHA 1-1, PB-1480-1, PB-1569 and PB-1468-1
23	100-seed weight (g)	Medium	47	94	PB-1239, PB-1240, PB-1242, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1609, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1611, PB-1647, PB-1620, RHA 1-1, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		High	3	6	PB-1245, PB-1234-1and PB-1616
24	Seed coat: Base colour	Black	49	98	PB-1239, PB-1240, PB-1242, PB-1245, PB-1247-1, PB-1247-4, PB-1249, PB-1331, PB-1334, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1616, PB-1609, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1611, PB-1647, PB-1620, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		Brown	1	2	RHA 1-1
25	Seed coat: Strips	Absent	45	90	PB-1239, PB-1242, PB-1245, PB-1247-4, PB-1249, PB-1331, PB-1243, COSF 6B, PB-1233-1, PB-1234, PB-1234-1, PB-1235, PB-1235-1, PB-1235-2, PB-1237, PB-1237-1, PB-1238, PB-1238-1, PB-1645-1, PB-1624, PB-1627, PB-1616, PB-1609, PB-1621, PB-1614, PB-1603, PB-1617, PB-1602, ARM 243B, PB-1607-1, PB-1624-3, PB-1612, PB-1603-1, PB-1643-1, PB-1661, PB-1646, PB-1611, PB-1647, PB-1620, PB-1458, PB-1480-1, PB-1574, PB-1569, PB-1468-1and PB-1580
		Present	5	10	PB-1240, PB-1247-1, PB-1334, DRSF-113andRHA 1-1
26	Hull content (%)	Medium	24	48	PB-1239, PB-1247-1, PB-1249, PB-1331, PB-1243, COSF 6B, PB-1234, PB-1234-1, PB-1235-1, PB-1238, DRSF-113, PB-1645-1, PB-1624, PB-1627, PB-1621, PB-1614, PB-1602, PB-1624-3, PB-1612, PB-1646, PB-1480-1, PB-1569, PB-1468-1and PB-1580
		High	15	30	PB-1240, PB-1247-4, PB-1334, PB-1233-1, PB-1235-2, PB-1237, PB-1616, PB-1609, PB-1603, PB-1617, PB-1643-1, PB-1611, PB-1647, RHA 1-1 and PB-1574
		Low	11	22	PB-1242, PB-1245, PB-1235, PB-1237-1, PB-1238-1, ARM 243B, PB-1607-1, PB-1603-1, PB-1661, PB-1620 and PB-1458
27	Seed: Oil Content %	Medium	24	48	PB-1239, PB-1245, PB-1331, PB-1334, PB-1243, PB-1233-1, PB-1234, PB-1235, PB-1235-1, PB-1235-2, PB-1645-1, PB-1609, PB-1603, PB-1617, ARM 243B, PB-1607-1, PB-1612, PB-1643-1, PB-1661, PB-1611, PB-1480-1, PB-1574, PB-1468-1and PB-1580
		Low	25	50	PB-1240, PB-1242, PB-1247-1, PB-1247-4, PB-1249, PB-1234-1, PB-1237, PB-1237-1, PB-1238, PB-1238-1, DRSF-113, PB-1624, PB-1627, PB-1616, PB-1621, PB-1614, PB-1602, PB-1624-3, PB-1603-1, PB-1646, PB-1647, PB-1620, RHA 1-1, PB-1458 and PB-1569
		High	1	02	COSF 6B

Cordate Triangular

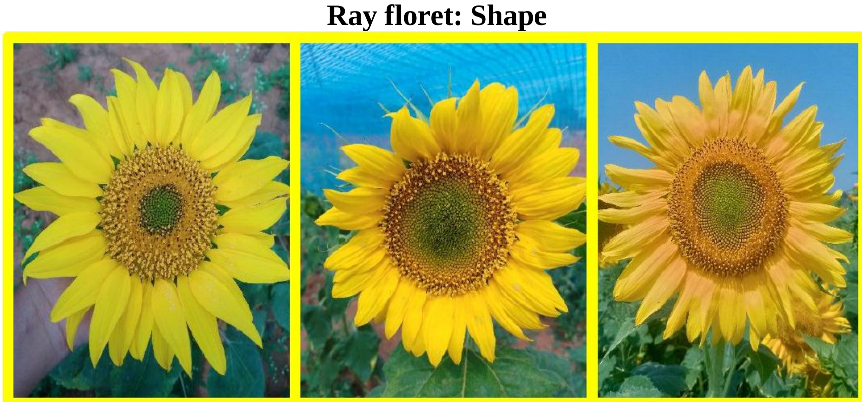
Leaf: Shape

Absent Medium Strong

Leaf: Blistering

Elongated Ovate

Ray floret: Shape



Light yellow Yellow Orange

Ray floret: Colour

Figure 1: Variability observed for various DUS characters

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