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Morphological Characterization of Linseed (*Linum usitatissimum* L.) Germplasm using DUS Descriptors

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ABSTRACT

Linseed or flax (*Linum usitatissimum*) is a versatile crop grown in various atmospheres for food, fiber, feed and industry. The characterization and evaluation of diverse germplasm of utmost importance to understand the potential of linseed in agriculture. The current study was carried out on agro-morphological traits to identify the superior germplasm that can be used as potential donors for future exploitation in the selection and breeding of linseed. The present study was carried out to observe the DUS characterization of 109 linseed germplasm lines. A great number of linseed germplasm is available with more similarity in their plant structure along with for blue flower, so at this real use of DUS is very much applicable. Therefore, looking to these facts present study was based on DUS characterization of 109 diverse line including exotic and indigenous accessions of linseed were carried out at Research Farm of AICRP on Linseed, College of Agriculture, Nagpur (MH), India during *rabi* 2020-21. As per DUS, UPOV 2011, observations were recorded. The results indicated the variety of traits which can be exploited in breeding lines appropriate for smallholder and commercial farmers in producing a sustainable, secure, high-value crop meeting, agricultural economic and cultural needs. Thus, the present study clearly indicated the use of the PPV & FRA descriptors for the purpose of registration, maintenance and protection of linseed lines.

Keywords Linseed, Flax, Diversity, Germplasm, DUS.

INTRODUCTION

Linseed (*Linum usitatissimum*) is a diploid (2n=30), self-pollinated and annual plant species. In the Indian subcontinent near the Mediterranean Sea, the domestication of flax was observed hence for genus *Linum,* this area is identified to have great biological diversity (Fu 2005 and Kaur *et al.* 2018). The oldest flax wild form cultivated possibly is *Linum bienne* Mill. (= *L. angustifolium* Huds.). Cultivation of *Linum bienne* for fiber and seeds is supposed to have led to the development of *L. usitatissimum* L., the modern cultivated flax (McDill *et al.* 2009). As linseed have various nutritious features such as it is a rich source of ω-3 fatty acid: α-linolenic acid (ALA), soluble and insoluble fibers, phyto estrogenic lignans, short

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chain polyunsaturated fatty acids (PUFA), proteins and an array of antioxidants (Ivanova *et al*. 2011 and Alhassane and Xu 2010). By keeping this in mind, there is a consistent need to increase the genetic potential for seed yield. The main constraints for its low productivity are limited competitiveness due to the narrow genetic base of released cultivars, cultivation under low input conditions (Sood *et al.* 2012) and sensitivity to fungal diseases.

Genetic diversity is the main support of biodiversity. In the agricultural production systems, crop diversity is vital component which ensure food security. The crosses between maximum genetically divergent parents are generally the most responsive for genetic improvement (Arunachalam 1981). The future accomplishment of world agriculture will rest on its capability to alter and while maintaining increased productivity to feed a growing world population, crops will have to be modified to sustainable forms of agriculture. However, it is necessary to screen and characterize the germplasm for the nature and extent of genetic diversity to know the traits present in the selected parental genotypes. To develop new and improved cultivars with desirable characteristics, crop diversity provides an opportunity for plant breeders by selecting suitable parents and to examine the nature and magnitude of genetic variation existing in the germplasm (Govindaraj *et al.* 2015). Hence, the current study was carried out on agro-morphological traits to identify the superior germplasm that can be used as potential donors for future exploitation in the selection and breeding of linseed.

MATERIALS AND METHODS

One hundred and nine germplasm lines including exotic and indigenous accessions of linseed were evaluated for various DUS characterization in Randomized Block Design (RBD) with two replications at All India Co-ordinated Research Project on Linseed, College of Agriculture, Nagpur (MS) India during *rabi* 2020-2021. Each entry has two rows of three meter length spaced 30 cm apart with the plant to plant distance of 10 cm. The crop was raised by using the package of practices of All India Crop Research Project on Linseed, Nagpur.

A representative sample of five plants was taken randomly from each plot for recording the observations. Observations for eleven quantitative characters viz., plant height (cm), flower size (mm), days to 50% flowering, capsule size (mm), seed size (mm), number of capsule plant^{-1}, number of branches plant^{-1}, seed yield plant^{-1} (g), 1000 seed weight (g), % bud fly infestation, % alternaria blight infestation and ten qualitative traits viz., Plant growth habit, Flower shape, Flower color, Flower petal aestivation, Flower venation color, Anther colour, Stamen: Filament colour, Capsule dehiscence, Seed color, Capsule: Shape of tip were used in this study for grouping of germplasm into various groups. Observation on traits Days to 50% flowering (DF) and Days to maturity (DM) was recorded on a plot basis. As per DUS, UPOV 2011, observations were recorded. As per Distinctiveness, Uniformity and Stability (DUS) guidelines, the morphological traits were evaluated.

RESULTS AND DISCUSSION

Characterization is the description of plant germplasm showed in which is showed in Tables 1-2. It defines the expression of highly heritable characters ranging from morphological or agronomical features. Germplasm characterization is essential to provide information on different characters of particular accessions for the maximum exploitation of the germplasm collection to the breeder. For the improvement of cultivated plants, the role of germplasm has been well recognized yet, the use of germplasm collection is still restricted in spite of this wide recognition. Once the collection has been properly evaluated and its characteristics become known to breeders, it has more practical use. In present study, one hundred and nine diverse lines including exotic and indigenous accessions were regularly observed for two seasons at different growth stages, off types are roughed out. Qualitative characters were examined using measurements from a single plant or its part, or from groups of plants or their parts, visual assessments from single plant or its part, or from groups of plants or their parts depend on the element used to characterize the accession. All morphological descriptors showed remarkable differences in their distribution and amount of variations within them.

Table 1. Characterization of 109 diverse linseed germplasm based on Distinctness (D), Uniformity (U) and Stability (S) as per DUS,UPOV 2011.

Trait	Descriptor state	Categorization	Genotypes
Plant height	It is recorded as height of plant from the base, to the top of the main stem and it is recorded in centimetres.	Dwarf (<50 cm)	CI-1924, CI-2006, CI-2260, E20 X NATURAL, EC -1386, EC -1424, EC-1474, EC-1628, EC-1645, EC-41623, EC-41628, EC-41659, EC-41741, EC-51904, EC-98994, ES-1440, ES-1456, ES-15889, EX-3, EX-53-98, EX-313-23, FR-11, FRW-6, Fatehpur,FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-36, GS-40, GS-41, GS-43, GS-51, GS-52, GS-54, GS-61,GS-64, GS-82,GS-100, GS-105, GS-108, GS-109, GS-128, GS-129, GS-130, GS-134,GS-139, GS-145, GS-148pp GLC-1-1, GIF- White, Indira Alsi -2, Indira Alsi -32, BAU-14-19, Shekhar, T-397, Divya, A 429, RLC-6, Binwa, GF-3-3, RAC-6, TL 99, OL-10-15, Priyam, UPN-15, GS-55, Mutent 2, Mutent 4, Mutent 5, NL-97
		Medium (50-70 cm)	EI – 5611, EC-15888, EC-14539, EC-99001, ES-165-36, ES-1444, ES-1531, ES-1534, ES-14230, ES-14600, ES-15890, EX-16, FR-15, FRW-12, GS-42, GS-49, GS-69, GS-85, GS-111, GS-121, GS-187, GS-410, GLC-11-1, Gewargi -1-2, JSL-95, Kiran, R 552, Parvati, Padmini, PKV -NL-260
		Tall (>70 cm)	--
Flower size	It is recorded when the experimental field is in peak flowering	Small (<15 mm)	CI-1924, CI-2006, CI-2260, EI – 5611, E20 X NATURAL, EC -1386, EC-1628, EC-1645, EC-41628, EC-41659, EC-51904, EC-98994, EC-99001, ES-165-36, ES-1440, ES-1444, ES-1456, ES-1531, ES-1534, ES-14230, EX-3, EX-16, EX-53-98, EX-313-23, FR-11, FR-15, FRW-6, FLAX-16, Fatehpur, GF-3-3-NO-3,GS-4, GS-15, GS-20, GS-27, GS-30, GS-36, GS-40, GS-41, GS-42,GS-43, GS-49, GS-51, GS-52, GS-54, GS-61, GS-64, GS-69, GS-82, GS-85, GS-100, GS-105, GS-108, GS-109, GS-130,GS-145, GS-148pp, GS-187,GS-410,GF-3-3, RAC-6, Priyam, Parvati, UPN-15, GS-55, Mutent 2, Mutent 4
		Medium (15-20 mm)	EC -1424,EC-1474, EC-15888, EC-41623, EC-41741, ES-14600, ES-15889, ES-15890, FRW-12, FX-16, GS-111, GS-121, GS-128, GS-129, GS-134, GS-139, GLC-1-1, GLC-11-1, GIF- White, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32, Shekhar, NL -356, T-397, JSL-95, Divya, A 429, RLC-6, Binwa, Meera, Kiran, TL 99, OL-10-15, R 552, NL-97 Padmini, PKV -NL-260
		Large (720 mm)	
Days to 50% flowering	It was recorded as how many days a plant needs for 50 % flowering from the day of sowing	Early (<50 days)	ES-1463, ES-1534, ES-14600, FR-15, GS-4, GS-15, GS-30, GS-85, GS-100, GS-105, GS-121,GS-148pp, BAU-14-19, GF-3-3
		Medium (50-60 days)	EC -1386, EC -1424, EC-1474, EC-41628, EC-51904, EC-98994, ES-1440, ES-14230, EX-3, EX-313-23, FRW-12, FLAX-16, GS-27, GS-36, GS-40, GS-41, GS-52, GS-54, GS-61, GS-69,GS-130, GS-134 GS-139, GS-410, GLC-1-1, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32, Shekhar, JSL-95, A 429, RLC-6, OL-10-15, R 552, Priyam, UPN-15
		Late (>50 days)	CI-2006, CI-2260, E20 X NATURAL, EC-1628, EC-1645 EC-15888, EC-41659, EC-99001, ES-165-36, ES-1456, ES-15890, EX-16, EX-53-98, FR-11,FRW-6, Fatehpur, GS-20, GS-42, GS-49, GS-51, GS-82, GS-108, GS-109, GS-111, GS-128, GS-129, GS-187, GLC-11-1, NL -356, T-397, Divya, RAC-6, Meera, Kiran, TL 99, Parvati, Mutent 4, Mutent 5, NL-97, Padmini
Capsule size	It is recorded when a capsule is fully developed	Small (<7mm)	CI-2260, EI – 5611, EC -1386, EC -1424, EC-1474, EC-1628, EC-41741, ES-1531, ES-15890, EX-3, EX-53-98, FR-11, FLAX-16, GS-4, GS-41, GS-42, GS-43, GS-51, GS-52, GS-61, GS-64, GS-85, GS-109, GS-128, GS-130,GS-134, GS-139, GS-145, GS-148pp, GS-187, GS-410, GIF- White, Indira Alsi -2, NL -356, T-397, JSL-95, Divya, A 429, Meera

Table 1.. Continued.

Trait	Descriptor state	Categorization	Genotypes
		Medium (7-8 mm)	CI-2006, EC-1066, EC-15888, EC-14539, EC-41623, EC-98994, ES-165-36, ES-1444, ES-1456, ES-1534, ES-14230, ES-15889, FR-15, FRW-6, FRW-12, FX-16, GF-3-3-NO-3, GS-15, GS-20, GS-27, GS-30, GS-36, GS-49, GS-54, GS-69, GS-82, GS-100, GS-105, GS-108, GS-121, GS-129, GLC-11-1, Gewargi -1-2, BAU-14-19,Shekhar, Binwa, GF-3-3, Kiran, TL 99, R 552, Parvati, UPN-15, Mutent 4
		Bold (>8mm)	CI-1924, E20 X NATURAL, EC-1645, EC-51904, EC-99001, EX-16, Fatehpur, GLC-1-1, RLC-6, RAC-6, Priyam, Mutent 2, Mutent 5, NL-97, Padmini, PKV-NL-260
Seed size	It is recorded as the longitudinal dimension measured as the distance from the base to the tip of the seed	Small (<4.5 mm)	CI-1924, ES-1444, ES-1531, ES-14600, ES-15889, ES-15890, EX-3, EX-53-98, FR-15, FLAX-16, Fatehpur, GS-4, GS-15, GS-20, GS-30, GS-40, GS-42, GS-43, GS-49, GS-51, GS-54, GS-61, GS-64, GS-69, GS-82, GS-100, GS-105, GS-111, GS-121, GS-128, GS-129, GS-134, GS-139, GS-145, GS-148pp, GS-187, GS-410, GLC-1-1, GIF- White, Mutent 2, Mutent 4
		Medium (4.5-5.5 mm)	EI – 5611, E20 X NATURAL, EC-1066, EC -1386, EC -1424, EC-1474, EC-1628, EC-1645, EC-15888, EC-41623, EC-41628, EC-41659, EC-41741, EC-98994, EC-99001, ES-165-36, ES-1440, ES-1456, ES-1534, FRW-12, FX-16, GF-3-3-NO-3, GS-41, Indira Alsi -2, Shekhar, T-397, JSL-95, GF-3-3, RAC-6, Meera, Priyam, Parvati, UPN-15, NL-97, PKV -NL-260
		Bold (>5.5 mm)	--
No. of capsules/ plant	It is recorded as total number of good healthy capsules to a	More (>50)	EI – 5611, EC -1386, ES-1444, Gewargi -1-2, BAU-14-19, NL -356, T-397, Mutent 2, Mutent 4
		Less (<50)	EC -1424, EC-1474, EC-15888, EC-41623, EC-51904, EC-99001, ES-165-36, ES-1440, ES-1456, ES-1463, ES-1531, ES-14230, ES-14600, ES-15889, ES-15890, EX-16, EX-53-98, EX-313-23, FR-11, FR-15, FRW-6, FRW-12, FLAX-16, GS-15, GS-30, GS-36, GS-40, GS-42, GS-43, GS-49, GS-51, GS-52, GS-54, GS-61, GS-64, GS-69, GS-85, GS-100, GS-105, GS-108, GS-109, GS-111, GS-121, GS-128, GS-129, GS-130, GS-134, GS-139, GS-145, GS-148pp, GS-187, GLC-1-1, RLC-6, GF-3-3, R 552
No. of branches/ plant	It is recorded visually simply by counting the number of primary branches of an individual plant	Less (<5)	CI-1924, CI-2006, CI-2260, EI – 5611, E20 X NATURAL, EC-1066, EC -1386, EC -1424, EC-1474, EC-1628, EC-1645, EC-15888, EC-14539, EC-41623, EC-41628, EC-41659, EC-41741, EC-51904, EC-98994, EC-99001, ES-165-36, ES-1440, ES-1456, ES-1463, ES-1531, ES-1534, ES-14230, ES-14600, ES-15889, ES-15890, EX-3, EX-16, EX-53-98, EX-313-23, FR-11, FR-15, FRW-6, FRW-12, FLAX-16, Fatehpur, FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-36, GS-40, GS-41, GS-42, GS-43, GS-49, GS-51, GS-52, GS-54, GS-61, GS-64,GS-69, GS-82, GS-85, GS-100, GS-105, GS-108, GS-109, GS-111, GS-121, GS-128, GS-129, GS-130, GS-134, GS-139, GS-145, GS-148pp, GS-187, GS-410, GLC-1-1, GLC-11-1, GIF- White, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32, BAU-14-19, Shekhar, NL -356, T-397, JSL-95, Divya, A 429, RLC-6, Binwa, GF-3-3, RAC-6, Meera, Kiran, TL 99, OL-10-15, R 552, Priyam, Parvati, UPN-15, GS-55, Mutent 2, Mutent 4, Mutent 5, NL-97, Padmini PKV -NL-260
		More (>5)	--
Seed yield /plant	Seed yield of an individual plant after harvest	High (>1.5 g)	EC -1386, EC-14539, FRW-6, FRW-12,GS-49, GS-51, GS-105, T-397, TL 99, NL-97, Padmini, PKV -NL-260

Table 1. Continued.

Trait	Descriptor state	Categorization	Genotypes
		Low (<1.5 g)	EC -1424, EC-1474, EC-1628, EC-41628, EC-41741, EC-98994, EC-99001, ES-165-36, ES-1440, ES-1456, ES-1531, ES-1534, ES-14600, ES-15889, ES-15890, EX-3, EX-16, EX-53-98, EX-313-23, FR-15, Fatehpur, GF-3-3-NO-3, GS-15, GS-20,GS-27, GS-30, GS-36, GS-41, GS-42, GS-43, GS-69, GS-82, GS-85, GS-100, GS-109, GS-111, GS-121,GS-128, GS-129, GS-130, GS-134, GS-139, GS-145, GS-148pp, GS-187, GS-410, GLC-1-1, GLC-11-1,GIF- White, Indira Alsi -2, Indira Alsi -32, Shekhar, NL -356, JSL-95, Divya, A 429, RLC-6, GF-3-3, RAC-6, Meera, OL-10-15, R 552, Priyam, Parvati, GS-55, Mutent 2, Mutent 4
1000 seed weight	Weight of 1000 well developed grains collected from the bulk of plants selected was recorded and expressed in grams	Low (<6gm)	EC -1424, EC-41741, EC-51904, EC-98994, ES-1456, ES-14230, ES-15889, EX-3, EX-53-98, GS-36, GS-85 GS-129, JSL-95, Divya, GF-3-3
		Medium (6-8)	CI-1924, CI-2260, EC-41628, EC-99001, ES-165-36, ES-1440, ES-1444, ES-1463, ES-1534, ES-15890, FR-11, FR-15, FRW-6, Fatehpur, FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-30, GS-43, GS-51, GS-54, GS-69, GS-82, GS-108, GS-109, GS-130, A 429, Binwa, RAC-6, Meera, OL-10-15, Priyam, Parvati, GS-55, Mutent 2
		High (78 g)	EC-15888, EC-41623, ES-1531, EX-16, FLAX-16, GS-40, GS-41, GS-42, GS-61, GS-111, GS-145, GLC-1-1, GLC-11-1, Gewargi -1-2, BAU-14-19, Shekhar, RLC-6, NL-97 Padmini, PKV -NL-260, EC -1386, EC-14539, EX-313-23, FRW-12, GS-49, GS-105, GS-148pp, TL 99
Bud fly %	The bud fly infestation was recorded at dough stage on five plants per entry by counting total number of floral buds as well as infested buds, which was converted into % bud infestation.	Resistant (upto 10%)	Indira Alsi -2
		Moderately resistant (10.01%-25%)	CI-1924, CI-2260, EI – 5611, E20 X NATURAL, EC -1386, EC-1474, EC-1628, EC-1645, EC-15888, EC-41623, EC-41659, EC-41741, EC-51904, EC-98994, EC-99001, ES-1440, ES-1444, ES-1456, ES-1463, ES-1531, ES-15889, EX-3, EX-16, EX-313-23, FR-15, Fatehpur, GS-30, GS-36,GS-40, GS-41, GS-42, GS-43, GS-49, GS-52, GS-54, GS-64, GS-69, GS-82, GS-100, GS-108, GS-109, GS-111, GS-121, GS-128, GS-130, GS-134, GS-139, GLC-11-1, Shekhar, JSL-95, Binwa, GF-3-3, RAC-6, Meera, Kiran, TL 99, OL-10-15, Priyam, Parvati, UPN-15, Mutent 2, Mutent 5, NL-97, Padmini
		Moderately susceptible (25.01%-50%)	FLAX-16, GS-27
Alternaria blight %	The bud fly infestation was recorded at dough stage.	Resistant (upto 10%)	EC-1066, EC-1628, ES-1444, FRW-12, FX-16, GS-30, GS-41, GS-43, S-82, GS-100, GS-105, GS-108, GS-109, GS-121, GS-134, GS-139, GS-187, GLC-11-1, GIF- White, JSL-95, Divya, RLC-6, GF-3-3, TL 99, GS-55, NL-97, PKV -NL-260
		Moderately resistant (10.01%-25%)	CI-1924, CI-2006, CI-2260, EI – 5611, EC-41659, EC-41741, EC-99001, ES-165-36, ES-1456, ES-1531, ES-1534, ES-14600, ES-15889, EX-3, EX-16, EX-313-23, FR-11, FR-15, FRW-6, FLAX-16, Fatehpur, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-36, GS-40, GS-42, GS-49, GS-52, GS-64, GS-69, GS-85, GS-111, GS-128, GS-129, GS-130, GS-145, GS-148pp, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32, Shekhar, NL 356, T-397, A 429, Binwa, Meera, Kiran, OL-10-15, Parvati, UPN-15, Mutent 4, Mutent 5

The height of plant was recorded in centimetres from the base to the tip of the main stem. It has divided into three classes namely, Dwarf (<50 cm), Medium (50-70 cm) and Tall (>70 cm). A total of seventy four germplasm lines are categorized as dwarf whereas, thirty lines were categorized as medium in height (Table 1). Flower size (mm) is recorded in peak flowering, measured as the distance from petal to petal recorded in millimeter. This character was categorized into three classes, viz. small (< 15 mm), medium (15-20 mm) and large (> 20 mm). Out of one hundred and nine lines, sixty six lines having small flower size and thirty eight lines were showed medium flower size. There was no genotype with large flower size (Table 1). Time of flowering means for each genotype, how many days it took for 50% flowering from the day of sowing to the day on which 50% of the plants showed flowering was recorded. It has classified into three classes namely, Early (<50 days), Medium (50-60 days) and Late (>50 days). Out of one hundred and nine diverse germplasm, fourteen lines were showed early flowering, thirty six lines were medium and fourty lines were late in 50% flowering. No genotype found to be late (Table 1).

Capsule size (mm) is recorded of fully developed capsule in millimeter. It is classified into three groups viz. Small (<7mm), Medium (7-8 mm) and Bold (>8 mm). Thirty nine germplasm lines were with small capsule size, forty three were with medium and sixteen were with bold capsule size (Table 1). Seed size in mm is measured as longitudinal dimension measured as the distance from the base to the tip of the seed .On the basis of size it is categorized into 3 classes as, bold (>5 mm), medium (4-5 mm), small (<4 mm). There were fourty one genotypes which had small seed size, thirty five genotypes were with medium seed size and not a single genotype was with bold seed size (Table 1). Total number of capsules per plant was recorded as total number of good healthy capsules. It was divided into two categories viz., more (>50) and less (<50). There were nine genotypes which showed more number of capsules and fifty five genotypes showed less number of capsules per plant (Table 1). Total number of primary branches of an individual plant were counted and divided into two categories viz., less (<5) and more (>5). All hundred and nine genotypes were categorized in less category (Table 1). Seed yield per plant is recorded as yield of a single plant in gram and categorized into two categories viz., low yielder (<1.5 g) and high yielder (>1.5 gm). Sixty seven germplasm lines found to be low yielder and twelve lines were high yielder (Table 1).

1000-seed weight is recorded as weight of 1000 well developed grains collected from the bulk of plants selected was recorded and expressed in grams. According to weight, it is grouped in three classes viz. low (< 6 g), medium (6-8 g) and high (>8 g). Fifteen lines were showed low seed weight, thirty six lines having medium seed weight and twenty eight lines grouped into high seed weight (Table 1).

Bud fly infestation (%): The bud fly (*Dasyneura lini*) infestation was recorded at dough stage on five plants per entry by counting total number of floral buds as well as infested buds, which was converted into % bud infestation. It was divided into three categories viz., Resistant (upto 10), Moderately Resistant (10.01-25), Moderately Susceptible (25.01-50), Susceptible (50.01 to 75.00) and Highly Susceptible (>75). Among one hundred and nine germplasm lines, only one genotype found resistant, sixty four genotypes were categorized into moderately resistant and two genotypes were classified as moderately susceptible. Not a single genotype is classified as susceptible and highly susceptible (Table 1).

Alternaria blight (%): Infected buds by *Alternaria lini* were counted in each plant and percentage was taken from the total number of buds. It was divided into three categories viz., Resistant (upto 10), Moderately Resistant (10.01-25), Moderately Susceptible (25.01-50), Susceptible (50.01 to 75.00) and Highly Susceptible (>75). 27 genotypes were under resistant category and fifty four genotypes were moderately resistant (Table 1).

Plant growth habit was recorded considering both the angle of the basal branching and the crop canopy. It was divided into three categories viz., bushy, semi-erect and erect. There are four genotypes which were bushy in nature, seventy seven genotypes were categorized as semi-erect and twenty seven genotypes were erect in nature (Table 2). Flower shape must be recorded before noon. Flower shape grouped in three

Table 2. Qualitative characters of 109 diverse linseed germplasm based on Distinctness (D),Uniformity (U) and Stability (S) as per DUS,UPOV 2011.

Trait	Descriptor state	Categorization	Genotypes
Plant growth habit	Recorded considering both the angle of the basal branching and the crop canopy.	Bushy	E20 XNATURAL, GS-49, GS-108, T-397
		Semi-erect	CI-1924, CI-2006, CI-2260, EC-1066, EC-1474, EC-1645, EC-15888, EC-14539, EC-41623,EC-41628, EC-41659, EC-41741, EC-51904, EC-98994,EC-99001,ES-165-36,ES-1440,ES-1444, ES-1463, ES-1531, ES-14230,ES-14600, ES-15889, EX-3,EX-16, EX-53-98,FR-11,FR-15,FRW-6,FX-16,GF-3-3-NO-3,GS-4,GS-15,GS-20,GS-27, GS-30, GS-40,GS-41, GS-42, GS-43,GS-52,GS-54, GS-61,GS-69, GS-82,GS-85,GS-100,GS-105,GS-128,GS-129,GS-130,GS-134,GS-187,GLC-1-1,GLC-11-1,GIF-White, Gewargi-1-2,Indira Alsi-2,Indira Alsi -32,BAU-14-19, Shekhar,NL-356, JSL95,Divya,A 429, Binwa,GF-3-3,RAC-6, Meera, Kiran,TL99,R 552,Priyam,Parvati, UPN-15, NL-97, Padmini
		Erect	EI–5611, EC -1386, EC -1424,EC-1628, ES-1456, ES-1534, ES-15890, EX-313-23, FRW-12,FLAX-16,Fatehpur,GS-36,GS-51,GS-64,GS-109,GS-111,GS-121,GS-139,GS-145, GS-148pp, GS-410, RLC-6,OL-10-15, GS-55, Mutent 2, Mutent 4, Mutent 5
Flower shape	It must be recorded before noon.	Funnel	CI-1924, CI-2006, EC-1066, EC -1386, EC-41741, EC-51904, ES-165-36,ES-1440, ES-1444, ES-1456, ES-1531, ES-1534, ES-14230, ES-15889, ES-15890, EX-3,EX-16, EX-53-98,FRW-6, FRW-12, FLAX-16, FX-16, GF-3-3-NO-3, GS-15, GS-20, GS-27, GS-41, GS-42,GS-51, GS-52, GS-54, GS-69, GS-105, GS-109, GS-128, GS-129, GS-130, GS-139, GS-145, GLC-1-1, GLC-11-1, GIF- White, NL -356, Divya, A 429, GF-3-3, RAC-6, Meera, Kiran, TL 99, OL-10-15, R 552, Priyam, GS-55, Mutent 2, Mutent 4, Mutent 5, NL-97, Padmini, PKV -NL-260
		Star	CI-2260, EI – 5611, EC -1424, GS-49, GS-82, GS-100, GS-121, GS-134, GS-148pp, Gewargi -1-2, JSL-95
		Disk	E20 X NATURAL, EC-1474, EC-1628, EC-1645, EC-15888, EC-14539, EC-41623, EC-41628, EC-41659, EC-98994, EC-99001, ES-1463, ES-14600, EX-313-23, FR-11, FR-15, Fatehpur, GS-4, GS-30, GS-36, GS-40, GS-43, GS-61, GS-64, GS-85, GS-108, GS-111, GS-187, GS-410, Indira Alsi -2, Indira Alsi -32, BAU-14-19, Shekhar, T-397, RLC-6, Binwa, Parvati, UPN-15
Flower color	It scored in fully opened flower by visual observation	White	EI – 5611, EC -1424, ES-1444, ES-1534, EX-16, GS-40, GS-49, GS-69, GS-82, GS-100, GLC-1-1, GLC-11-1, GIF- White, Gewargi -1-2, Priyam
		Violet	CI-1924, CI-2006, CI-2260, E20 X NATURAL, EC-1066, EC -1386, EC-1474, EC-1628, EC-1645, EC-15888, EC-14539, EC-41623, EC-41628, EC-41659,EC-41741, EC-51904, EC-98994,EC-99001,ES-165-36, ES-1440, ES-1456, ES-1463,ES-1531, ES-14230, ES-14600, ES-15889, ES-15890, EX-3, EX-53-98, EX-313-23, FR-11, FR-15, FRW-6, FRW-12, FLAX-16, Fatehpur, FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-36, GS-41, GS-42, GS-43, GS-51, GS-52,GS-54,GS-61, GS-64, GS-85, GS-105, GS-108, GS-109, GS-111, GS-121, GS-128, GS-129, GS-130, GS-134, GS-139, GS-145, GS-148pp, GS-187, GS-410, Indira Alsi -2, Indira Alsi -32, BAU-14-19, Shekhar, NL -356, T-397, JSL-95, Divya, A 429, RLC-6, Binwa, GF-3-3, RAC-6, Meera, Kiran,TL-99,OL-10-15,R-552,Parvati,UPN-15, GS-55,Mutent 2, Mutent 4, Mutent 5, NL-97, Padmini, PKV -NL-260

Table 2. Continued.

Trait	Descriptor state	Categorization	Genotypes
Flower petal aestivation	It is recorded as arrangement of petals	Twisted	E20 X NATURAL, EC-1066, EC-1645, EC-15888, EC-14539, ES-1463, ES-15889 GS-43, GS-105, GS-128 GS-130, GS-145, GS-187, BAU-14-19, Shekhar, T-397, Kiran
		Semi-twisted	CI-1924, CI-2006, EI – 5611, EC -1386, EC -1424, EC-1474, EC-1628, EC-41623, EC-41628, EC-51904, EC-98994, EC-99001, ES-165-36, ES-1440, ES-1444, ES-1456,ES-1531, ES-1534, ES-14230, ES-14600, ES-15890, EX-3, EX-16, EX-313-23, FR-11, FRW-6, Fatehpur, FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-36, GS-40, GS-41, GS-42, GS-52, GS-54, GS-61, GS-64, GS-69, GS-85, GS-108, GS-111, GS-129, GS-139, GS-410, GLC-1-1, GLC-11-1, GIF- White, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32, NL -356, A 429, RLC-6, Binwa, GF-3-3, RAC-6, Meera, TL 99, OL-10-15, Priyam, Parvati, UPN-15, GS-55, Mutent 2, Mutent 4, Mutent 5, NL-97, Padmini, PKV -NL-260
		Valvate	CI-2260, EC-41659, EC-41741, EX-53-98, FR-15, FRW-12,FLAX-16, GS-49, GS-51, GS-82, GS-100, GS-109, GS-121, GS-134, GS-148pp, JSL-95, Divya, R 552
Flower venation color	It is recorded in fully developed flower	White	EI – 5611, EC -1424, ES-1444, ES-1534, EX-16, GS-40, GS-49, GS-69, GS-82, GS-100, GLC-1-1, GLC-11-1, GIF- White, Gewargi -1-2, Priyam
		Violet	CI-1924, CI-2006, CI-2260, EC-1066, EC -1386, EC-1474, EC-1628, EC-1645, EC-15888,EC-14539, EC-41623, EC-41628, EC-41659, EC-41741, EC-51904,EC-98994, EC-99001, ES-165-36, ES-1440, ES-1456,ES-1463, ES-14230, ES-14600, ES-15889, ES-15890, EX-3, EX-53-98, EX-313-23, FR-11, FRW-6, FRW-12, FLAX-16, Fatehpur,FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-36, GS-41, GS-42, GS-43, GS-51, GS-52, GS-54, GS-61, GS-64, GS-85, GS-105, GS-108, GS-109, GS-111, GS-121, GS-128, GS-129, GS-130, GS-134, GS-139, GS-145, GS-187, GS-410, Indira Alsi -2, Indira Alsi -32, BAU-14-19, Shekhar, NL -356, T-397, JSL-95, Divya, A 429, RLC-6, Binwa, GF-3-3, RAC-6, Meera, Kiran, TL 99, OL-10-15, R 552, Parvati, GS-55, NL-97, Padmini, PKV -NL-260
		Blue	E20 X NATURAL, ES-1531, FR-15, GS-148pp, UPN-15, Mutent 2, Mutent 4, Mutent 5
Anther color	Immediately after flower opening	Cream	EI – 5611, EC-14539, ES-165-36, ES-1440, ES-1444, GS-49, GS-51, GS-69, GS-82, GS-100, GS-121, GIF- White, Gewargi -1-2, JSL-95, Priyam
		Grey	EC-15888, EC-41628, EC-41659, GS-30, GS-43, GS-85, GS-139, GLC-1-1
		Violet	CI-1924, CI-2006, CI-2260, EC -1386, EC-41623, EC-99001, ES-1456, ES-1463, ES-15890, EX-16, EX-53-98, EX-313-23, FR-15, FRW-6, GF-3-3-NO-3, GS-27, GS-36, GS-40, GS-105, GS-108, GS-128, GS-410, GLC-11-1, Indira Alsi -32, BAU-14-19, Shekhar, Divya, RLC-6, RAC-6, TL 99, OL-10-15, NL-97, Padmini, PKV -NL-260

Table 2. Continued.

Trait	Descriptor state	Categorization	Genotypes
		Blue	EC-41628, EC-41659, EC-41741, EC-98994, EC-99001, FRW-12, Fatehpur, FX-16, GS-15, GS-49, GS-51, GS-52, GS-54, GS-410, NL -356, OL-10-15, Mutent 2, Mutent 4, Mutent 5
Capsule dehiscence	It is recorded at the maturity time	Semi dehiscent	CI-1924, EC-1628, EC-41628, EC-41659, ES-165-36, ES-1440, EX-3, EX-16, Fatehpur, GS-36, GS-54, GS-85, GS-105, GS-109, GS-145, GS-187, GS-410, GLC-1-1, GF-3-3, Mutent 2, Mutent 4, Mutent 5
		Non dehiscent	CI-2006, CI-2260, EI – 5611, E20 X NATURAL, EC-1066, EC -1386, EC -1424, EC-1474, EC-1645, EC-15888, EC-14539, EC-41623, EC-41741, EC-51904, EC-98994, EC-99001, ES-1444, ES-1456, ES-1463, ES-1531, ES-1534, ES-14230, ES-14600, ES-15889, ES-15890, EX-53-98, EX-313-23, FR-11, FR-15, FRW-6, FRW-12, FLAX-16, FX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-40, GS-41, GS-42, GS-43, GS-49, GS-51, GS-52, GS-61, GS-64, GS-69, GS-82, GS-100, GS-108, GS-111, GS-121, GS-128, GS-129, GS-130, GS-134, GS-139, GS-148pp, GLC-11-1, GIF- White, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32, BAU-14-19, Shekhar, NL -356, T-397, JSL-95, Divya, A 429, RLC-6, Binwa, RAC-6, Meera, Kiran, TL 99, OL-10-15, R 552, Priyam, Parvati, UPN-15, GS-55, NL-97, Padmini, PKV -NL-260
Capsule: Shape of tip	It is recorded as the presence or absence of tip.	All are Pointed	CI-1924, CI-2006, CI-2260, EI – 5611, E20 X NATURAL, EC-1474, EC-1628, EC-1645, EC-15888, EC-14539, EC-51904, ES-1440, ES-1444, ES-1456, ES-1463, ES-1531, ES-1534, ES-14230,ES-14600, ES-15889, ES-15890, EX-3, EX-16, FR-11,FR-15, GS-4, GS-27, GS-40, GS-43, GS-64, GS-69, GS-82, GS-85, GS-100, GS-108, GS-128, GS-129, GS-134, GS-145, GS-148pp, GS-187, GLC-1-1, GLC-11-1, GIF- White, Gewargi -1-2, Indira Alsi -2, BAU-14-19, Shekhar, JSL-95, GF-3-3, Priyam, EC-41628, EC-41659, EC-41741, EC-98994, EC-99001, FRW-12, Fatehpur, FX-16, GS-15, GS-49, GS-51, GS-52, GS-54, GS-410, NL -356, OL-10-15, Mutent 2, Mutent 4, Mutent 5, EC-1066, EC -1386, EC -1424, EC-41623, ES-165-36, EX-53-98, EX-313 -23, FRW-6, FLAX-16, GF-3-3-NO-3, GS-20, GS-30, GS-36, GS-41, GS-42, GS-61, GS-105, GS-109, GS-111, GS-121, GS-130, GS-139, Indira Alsi -32, T-397, Divya, A 429, RLC-6, Binwa, RAC-6, Meera, Kiran, TL 99, R 552, Parvati, UPN-15, GS-55, NL-97, Padmini, PKV -NL-260
Seed color	It is recorded as visual observations	Light brown	EI – 5611, E20 X NATURAL, EC-15888, EC-41623, EC-41659, EC-99001, ES-1456, ES-1463, FR-15, FRW-12, Fatehpur, FX-16, GS-51, GS-69, GS-108, GS-111, GS-139, GS-145, GS-148pp, GS-187, GIF- White, Gewargi -1-2, Indira Alsi -2, Indira Alsi -32,Divya RAC-6, OL-10-15, R 552, Mutent 2, Mutent 4, Mutent 5, Padmini
		Brown	CI-1924, CI-2006, CI-2260, EC-1066, EC -1386, EC -1424, EC-1474, EC-1628, EC-1645, EC-41628, EC-51904, EC-98994, ES-165-36, ES-1440, ES-1444, ES-1531, ES-14230, ES-14600, ES-15889, ES-15890, EX-3, EX-16, EX-53-98, EX-313-23, FRW-6, FLAX-16, GF-3-3-NO-3, GS-4, GS-15, GS-20, GS-27, GS-30, GS-36,GS-40, GS-41, GS-42, GS-43, GS-49, GS-52, GS GS-54, GS-61, GS-64, GS-82, GS-85, GS-100, GS-105, GS-109,

Table 2. Continued.

Trait	Descriptor state	Categorization	Genotypes
			GS-121, GS-128, GS-129, GS-130, GS-134, GS-410, GLC-1-1, GLC-11-1, BAU-14-19, Shekhar, NL -356, JSL-95, A 429, RLC-6, Binwa, GF-3-3, Meera, Kiran, TL 99, Priyam, Parvati, UPN-15, GS-55, NL-97, PKV -NL-260
		Dark brown	EC-41741, ES-1534, FR-11, T-397

groups namely, funnel, star and disk. Sixty germplasm lines were with funnel shape, eleven lines showed star shape and a total of thirty eight lines showed disk shape (Table 2). Flower color scored in fully opened flower by visual observation. It is classified into two groups as white and violet. Fifteen lines showed white flower colour and ninety six lines had violet color (Table 2). Flower petal aestivation is recorded as arrangement of petals. According to this, it is grouped into three classes viz. twisted, semi twisted and valvate. Out of one hundred and nine lines, seventeen lines showed twisted aestivation, seventy four lines were grouped in semi twisted and eighteen lines were falls under valvate aestivation (Table 2).

Flower venation color is recorded in fully developed flower. It is grouped into three classes as, white, violet and blue. Fifteen lines included in white color, eighty six lines were grouped into violet and only eight lines showed blue flower venation colour (Table 2). Anther color showed a continuous range of color variation as, cream, grey, violet and blue. fifteen lines were cream colour, eight lines were under grey color, thirty four were violet and fifty two were blue color (Table 2).

Stamen Filament color is recorded after flower opening. On the basis of filament color, it is grouped into three categories viz. white, violet, blue. Out of one fifty lines, fifty one lines white colour, thirty nine lines were included under violet and nineteen lines were showed blue filament colour (Table 2). Capsule dehiscence is recorded at the maturity time. It is grouped into two classes as, Semi Dehiscent and Non Dehiscent. Out of one hundred and nine lines, twenty two lines were grouped under semi dehiscence and eighty seven having non dehiscence nature (Table 2). Capsule: Shape of tip is recorded as the presence or absence of pointed and blunt tip. All the one hundred and nine lines were found to have pointed tip (Table 2). Seed colour is recorded as visual observations. It is grouped in three categories viz. light brown, brown and dark brown. Thirty two lines showed light brown colour, seventy three were brown and only four lines grouped under dark brown (Table 2).

According to Joshi and Dhawan (1986) germplasm diversity was essential to meet different purposes of the crop such as increased yield, wider adaptation, desirable quality, pest and disease resistance (Begum *et al*. 2007). Various researchers (Mounika *et al.* 2020, Dhirhi *et al.* 2017, Bhajantri *et al*. 2017) have done DUS characterization of linseed germplasm. Information on the degree and nature of interrelationship among different traits help in framing effective scheme of several character selection. Further, knowledge of the naturally occurring diversity in a population helps in identifying diverse groups of genotypes (Tadesse *et al.* 2009). For understanding linseed domestication, these findings are significant and also useful in classifying intra specific diversity of cultivated linseed. It can be accomplished by establishing a core subset of the linseed collection and exploring new sources of genes for linseed improvement (Fu 2005). Adugna *et al*. (2006), Savita (2006), Fulkar *et al.* (2007), Fu *et al.* (2011), Sinha and Wagh (2013) reported wide range of genetic diversity in linseed.

CONCLUSION

In conclusion, there are considerable morphological differences within the linseed germplasm. Thus, the present study indicated the importance of morphological characterization using DUS descriptors for the registration, maintenance and protection of genotypes.

Results from the present study indicate that several genes interact for development of different characters. In the selection of distinguishable, uniform and stable traits, measurements of morphological variation will be helpful. It will be much useful at the time of seed production and monitoring program of linseed. Along with that for breeding programme suitable parents may be used by making diallel among diverse parents. They would provide good transgressive segregants for oil, linen and dual purpose integrated with value addition. In this way the linseed crop diversity can be exploited for reaching the goals regarding the area, production and productivity in future.

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