Pak. J. Bot., 53(1): 203-209, 2021. DOI: http://dx.doi.org/10.30848/PJB2021-1(45)

AGRO-MORPHOLOGICAL EVALUATION OF LINESEED (*LINUM USITATISSIMUM* L.) GERMPLASM FROM PAKISTAN

RIZWAN TAJ KHAN[1*] ASMA HAMEED[1], SANIA BEGUM AND SYED RIZWAN ABBAS[3*]

[1]*Department of Botany, University of Azad Jammu and Kashmir*
[2]*Scientific Officer, NARC Islamabad, Pakistan*
[3]*Department of Biological Sciences, Hunza Campus, Karakorum International University, Gilgit. Pakistan*
[*]*Corresponding Authors: drrizwantajkhan@gmail.com*

Abstract

The information about the diversity of the crop for different attributes is important for their effective utilization in the breeding programs. The present investigation was carried out to characterize the 42 linseed (*Linum usitatissimum* L) genotypes by qualitative and quantitative agro-morphological traits and to describe the genetic variation. Eleven agro-morphological traits (germination days, initiation of flowers, days to maturity, height of plant, primary branches, number of capsules per plant, number of seeds per capsules per plant, seed yield of each plant, thousand seeds weight, seed size and seed color) were recorded to evaluate phenotypic variations among linseed genotypes. Three genotypes viz., 020885, 020890 and 020870 contributed noteworthy results on the basis of morphological traits. The diverse and significant trait was obtained from genotype 021200 (Pak) among total genotypes; having maximum number of primary branches per plant (10) as well as maximum number of seeds per capsule (10.3). Whereas, genotype 020885(Pak) contributed for the maximum weight of seeds per plant and for maximum weight of 1000 seeds among all the genotypes. The results also showed that agro-morphological attributes grouped genotypes belonged to different regions grouped together in same clusters. Out of 42 genotypes, 39 genotypes were clustered in 4 clusters and remaining 3 genotypes viz., 021160, 021200 and 035127 did not place in any cluster as they found to be most phenotypically diverse from all other genotypes. The information on the diversity and relationship with agro-morphological attributes will be helpful in the selection of populations in the breeding programs.

Key words: Lineseed, Genotypes, Agro-morphology, Genetic Diversity, Attributes.

Introduction

Flax (*Linum usitatissimum* L) is also known as linseed or common flax, annual herb and known to be the third largest fiber crop and fifth major oil crop in the world (Deng *et al.,* 2011). Linseed is winter season crop and of temperate zone (Rastogi *et al.,* 2013) and according to 2011 data, the total production of *Linum usitatissimum* L. in the world is about 1.6 million tons. In Pakistan *Linum usitatissimum* L. is grown at 4.7 thousand hector areas and its yearly production is about 2.71 thousands tones whose average yield is 573 kg ha-[1] (Anon., 2001). *Linum usitatissimum* L., is of great importance in human nutrition due to the presence of active and beneficial components and its seeds can be used by human beings as either crushed and powdered it to add in bakery products or in oil form (Bernacchia *et al.,* 2014). Its seeds are considered to be the healthy source of oil which contain digestible proteins, poly-unsaturated fatty acids (α-linolenic acid, omega-3 and omega-6 rich oil) and lignin (Akhtar *et al.,* 2013). It possess numerous components that have anti-carcinogenic, antioxidant, hypoglycemic, anti-platelet and anti-inflammatory properties (Bloedon & Szapary, 2004; Verghese *et. al.,* 2011). The oil is used for varnishes, linoleum, putty and for leather preparation. It is in local medicines as demulcent, emollient and laxative, and is taken orally in bronchial infection and diarrhea (Gul *et al*., 2016). Cellulosic and lignified material remaining after extraction of fiber or oil is used for manufacture of paper and straw board, and for animal feed or bedding. The study about the extent and distribution of genetic diversity in crop plants is important for their breeding programs (Rahman *et al*., 2016; Khan *et al*., 2005). Genetic diversity is known as genetic variations present within species. It provides some chemical outlining of its fatty acids which help breeder to select the accession for improved genotype of linseed (Siddique *et al.,* 2016). The assessment of genetic diversity can be identified through morphological, molecular and biochemical parameters (Mohammadi & Prasanna, 2003; Sudre *et al.,* 2007; Goncalves *et al.,* 2009). The present study was aimed to assess morphological traits diversity among *Linum usitatissimum* L. germplasm which will be helpful in selection of agro-morphologically important genotypes for breeders.

Materials and Methods

The present research was carried out in National Institute for Genomics and Advanced Biotechnology at National Agriculture Research Center (NARC) Islamabad Pakistan.

Plant material: The seeds of linseed (*Linum usitatissimum* L.) genotypes were collected from Plant Genetic Research Institute (PGRI), department of National Agricultural Research Centre (NARC), Islamabad Pakistan. Total 42 genotypes of *Linum usitatissimum* L. were used, of which 32 genotypes were from Pakistan and 10 from America. The seeds of 42 genotypes of *Linum usitatisimum* L. were grown at (NIGAB) NARC Islamabad. Fertilizers were added in its soil to make it fertile and good land for the field experimentation. During entire crop season its soil was kept moist. Seeds were sown at 2 centimeter depth of prepared soil. After an interval of a week, weeds were being removed for better growth of plants. Eleven agro-morphological traits (germination days, initiation of flowers, days to maturity, height of plant, primary branches, number of capsules per plant, number of seeds per capsules per plant, seed yield of each plant, thousand seeds weight, seed size and seed color) were recorded to evaluate phenotypic variations among linseed genotypes. Morphological diversity among linseed

germplasm was explained through frequency histograms, cluster analysis and ANOVA. By using UPGMA method, dendrograms were generated to assess genetic associations among linseed genotypes.

Results

The analysis based on 11 agro- morphological traits revealed significant genetic variability.

Days to germination: There was non-significant variation in germination days of selected linseed genotypes. The germination days of linseed genotypes varied from 3 to 9 days (Fig. 1). The average days of genotypes' germination ranged from 3-7 days with the exception of 4 genotypes viz., 020900 (Pak), 035881 (Pak), 035880 (Pak) and 035151 (USDA) which germinated after 8 and 9 days of their sowing, respectively (Fig. 1).

Days to initiation of flower (DFI): The average range of DFI of all genotypes ranged from 74-99 days. Two genotypes, 020891 (Pak) and 035151 (USDA) were recorded to produce primary flower very earlier (74 days), followed by 2 genotypes 021570 (Pak) and 035880 (Pak) produced primary flowers after 78 days from their germination, and genotype 021195 was recorded to produce vary initiation of flowers after 99 days from their germination (Fig. 1).

Days to 100% maturity: Genotype 031538 took minimum days (138 days) for its maturation followed by 2 genotypes viz., 031539 (Pak) and 031541 (Pak) took 139 days for their maturation while late maturation (147 days) was only observed in genotypes 035127 (USDA) and 035125 (USDA) (Fig. 1). The maximum genotypes (22) took 140-141 days for their maturation.

Plant height: The maximum plant height (105cm) was observed in genotype 0350127 (USDA) while minimum plant height (44cm) was observed in genotype 021200 (Pak), followed by genotype 021160 (Pak) (55.6cm) as shown in table 1. According to histogram, maximum genotypes have their plant height at the range of 70cm-79cm (Fig. 1).

Branches per plant (PB/P): The maximum number of primary branches (10) were observed in genotype 021200 (Pak) followed by 6 genotypes that had 9 PB/P while lowest primary branches (5) were observed in genotype 035146 (USDA) (Fig. 1).

Number of capsules per plant (C/P): The maximum numbers of capsules per plant (33) were observed in genotype 035127 (USDA) followed by genotype 021195 (Pak) and 021245 (Pak) showed 31 and 30 (C/P) whereas minimum number of capsules (13.5) were identified in genotypes 021400 (Pak) followed by genotypes 035147 (USDA), 031951 (Pak), 021425 (Pak) and 021200 (Pak) showed 15.5 C/P (Fig. 1).

Seeds per capsules: The average number of seed per capsule in genotypes ranged from 5 to 10 seeds. The maximum numbers of seeds per capsules (10.3) were recorded in genotype 021200 while minimum (5.6) in genotype 031538 (Fig. 1).

Seeds yield per plant: The maximum seed yield per plant (8g) was obtained by genotype 020885 and minimum weight (4g) was gained by genotype 035016 (Table 1). According to frequency distribution data maximum genotypes (17) yield was 6g (Fig. 1).

Thousand seeds weight (TSW): Maximum TSW was recorded Genotype 020885 (Pak) and 020870 (Pak) showed maximum weight (2.4g) of 1000 seeds while minimum weight (1.6g) was observed in 028359, followed by genotypes 020900 (Pak) and 035011 (USDA) 1.8g TWS (Fig. 1).

Seed sizes: 19 genotypes have large sized seed; four genotypes produced small sized seeds while 19 genotypes showed medium sized seeds (Fig. 1).

Seed color: According to frequency distribution histograms, maximum (18) genotypes produced brown color seeds (1), followed by 14 genotypes showed dark brown color while 9 genotypes showed light brown color and only 1 genotype 035146 (USDA) showed golden color.

The recorded data of eleven morphological traits were used to construct a dendrogram by UPGMA method, comprised of two main A and B groups (Fig. 2). According to cluster analysis, each group A-1 and A-2 has 1 genotype of Pakistan origin; 021160 and 021200 respectively. The genotype 021200 showed the minimum plant height (44cm) from total genotypes, followed by genotype 021160 of 55.6cm. The genotype 021200 showed the minimum plant height (44cm) from total genotypes, followed by genotype 021160. Group B-1 holds only 1 genotype 035127 (USDA) and the more the diversity was obtained in it. The cluster B-2-1-1 grouped two genotypes 021195 (Pak) and 021245 (Pak). The genotype 21195 showed the maximum days for flowering (99 days) and the later produced maximum number of capsules (31) and seeds per capsules (9.3) among the total genotypes. The correlation coefficients (Fig. 3) between agro-morphological traits calculated from 42 lineseed genotypes. The positive correlation was shown between different agro-morphological traits. The circles with greater size show a positive correlation while the circles with smaller size have low correlation. The number of branches has positive correlation with plant height and days for flower initiation have positive correlation with days taken for germination for each genotype. The Fig. 4 shows the genotypes by- traits-biplot analysis which can be used to evaluate the genotypes based on multiple traits and to identify the genotypes based on specific groups. In biplot a vector is drawn from its origin to the trait to facilitate the visualization of relationship between trait and genotype. The genotype 35880 which has taken maximum days for germination. The genotype 21195 showed a different response for all traits studied so it occupies a different position. It has taken 9 maximum days for germination, plant height 70cm and 41 days 100% maturity. The genotype 20890 is also separated on number of capsules 27 and 141 days taken for maturity. The germination days are the main source of variation and the plant height and number of capsules per plant also contributed significantly.

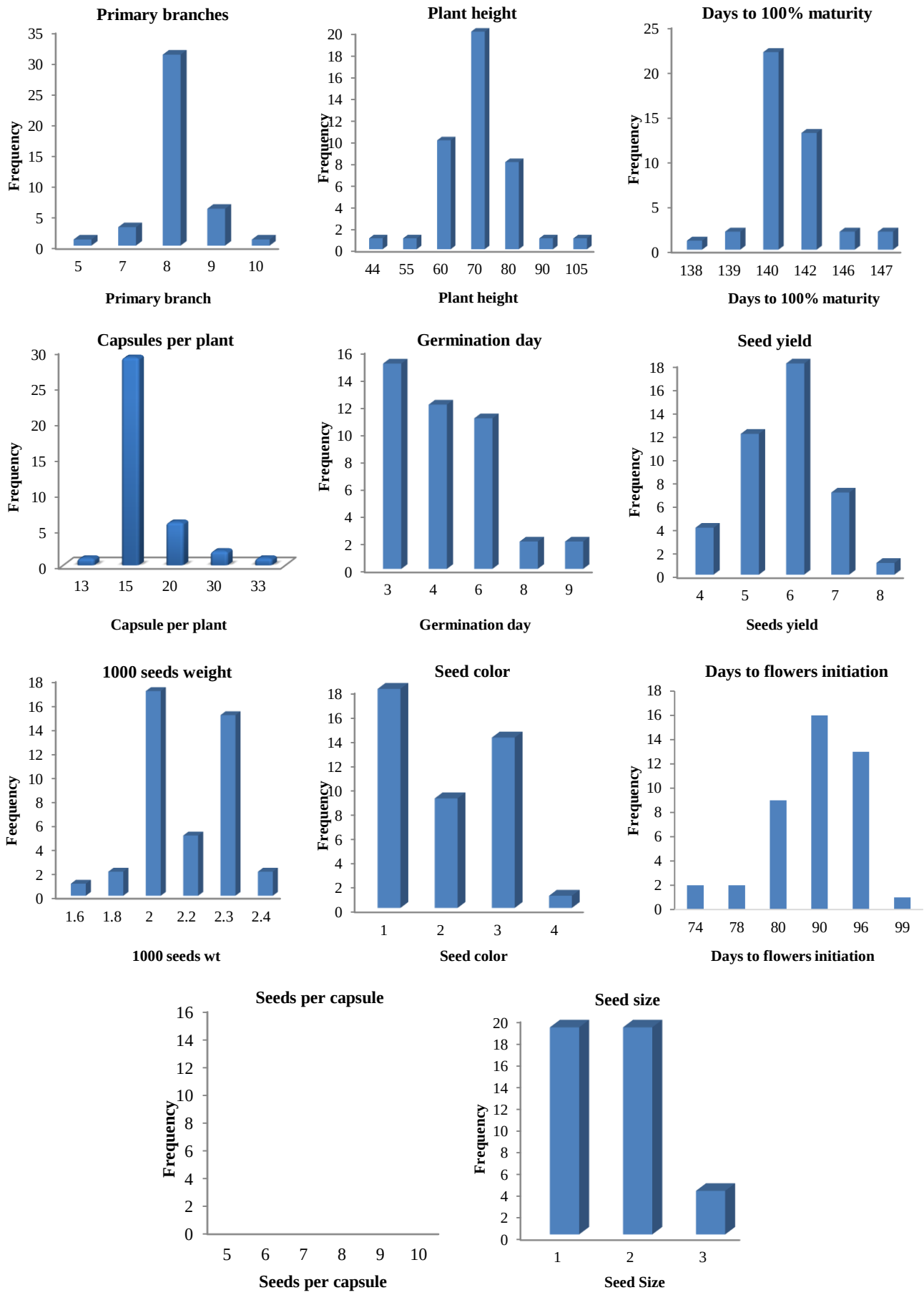

Fig. 1. Histogram showing frequency distribution of 42 genotypes of linseed regarding variations in different agro-morphological characters.

Table 1. List of *Linum usitatissimum* L. genotypes used for the assessment of genetic and morphological diversity.

Sr. No.	Genotypes	Genus	Species	Origin	Location
1.	020870	*Linum*	*usitatissimum*	Pakistan	Lahore
2.	020885	*Linum*	*usitatissimum*	Pakistan	Islamabad
3.	020886	*Linum*	*usitatissimum*	Pakistan	Islamabad
4.	020887	*Linum*	*usitatissimum*	Pakistan	Islamabad
5.	035151	*Linum*	*usitatissimum*	Exotic	USDA
6.	020889	*Linum*	*usitatissimum*	Pakistan	Islamabad
7.	020890	*Linum*	*usitatissimum*	Pakistan	Islamabad
8.	020891	*Linum*	*usitatissimum*	Pakistan	Islamabad
9.	020893	*Linum*	*usitatissimum*	Pakistan	Islamabad
10.	035126	*Linum*	*usitatissimum*	Exotic	USDA
11.	021160	*Linum*	*usitatissimum*	Pakistan	Faisalabad
12.	021195	*Linum*	*usitatissimum*	Pakistan	Faisalabad
13.	021200	*Linum*	*usitatissimum*	Pakistan	Faisalabad
14.	021245	*Linum*	*usitatissimum*	Pakistan	Jhang
15.	021310	*Linum*	*usitatissimum*	Pakistan	Jhang
16.	021400	*Linum*	*usitatissimum*	Pakistan	Muzaffargarh
17.	021425	*Linum*	*usitatissimum*	Pakistan	Attock
18.	021570	*Linum*	*usitatissimum*	Pakistan	T.T. Singh
19.	021750	*Linum*	*usitatissimum*	Pakistan	Karachi
20.	021890	*Linum*	*usitatissimum*	Pakistan	Sargodha
21.	021920	*Linum*	*usitatissimum*	Pakistan	Lahore
22.	022305	*Linum*	*usitatissimum*	Pakistan	Rawalpindi
23.	035011	*Linum*	*usitatissimum*	Exotic	USDA
24.	035147	*Linum*	*usitatissimum*	Exotic	USDA
25.	035031	*Linum*	*usitatissimum*	Exotic	USDA
26.	035032	*Linum*	*usitatissimum*	Exotic	USDA
27.	035037	*Linum*	*usitatissimum*	Exotic	USDA
28.	035146	*Linum*	*usitatissimum*	Exotic	USDA
29.	035016	*Linum*	*usitatissimum*	Exotic	USDA
30.	035127	*Linum*	*usitatissimum*	Exotic	USDA
31.	020888	*Linum*	*usitatissimum*	Pakistan	Islamabad
32.	031951	*Linum*	*usitatissimum*	Pakistan	Hasilpur 5
33.	035880	*Linum*	*usitatissimum*	Pakistan	Hunza
34.	031542	*Linum*	*usitatissimum*	Pakistan	Sheikhupura
35.	020900	*Linum*	*usitatissimum*	Pakistan	Lahore
36.	031538	*Linum*	*usitatissimum*	Pakistan	Hasilpur 1
37.	036756	*Linum*	*usitatissimum*	Pakistan	Ghizer
38.	031540	*Linum*	*usitatissimum*	Pakistan	Hasilpur 3
39.	028359	*Linum*	*usitatissimum*	Pakistan	Mianwali
40.	031539	*Linum*	*usitatissimum*	Pakistan	Hasilpur 2
41.	031541	*Linum*	*usitatissimum*	Pakistan	Hasilpur 4
42.	035881	*Linum*	*usitatissimum*	Pakistan	Hunza

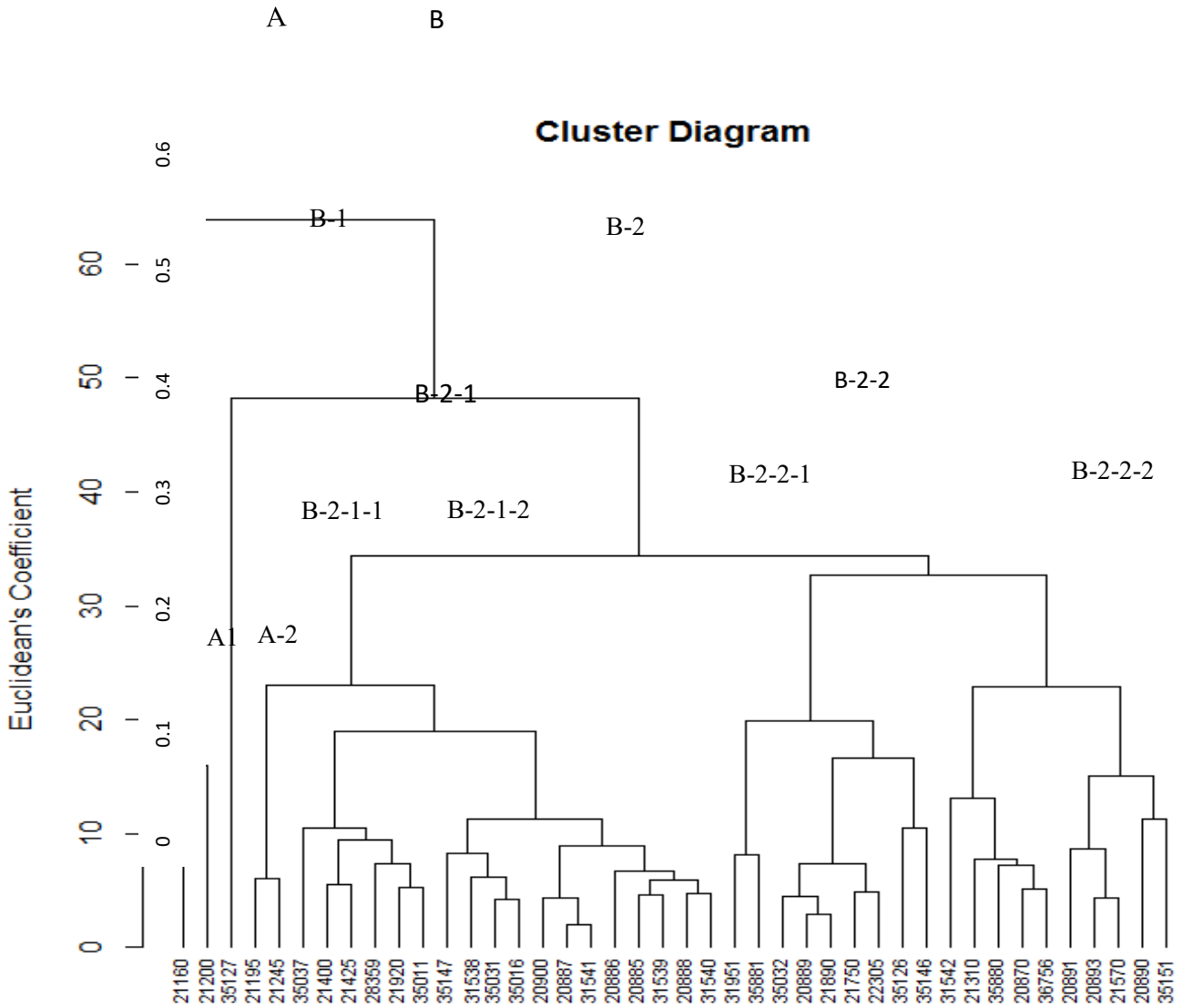

Fig. 2. Cluster analyses of genotypes of linseed through dendrogram based on their morphological traits.

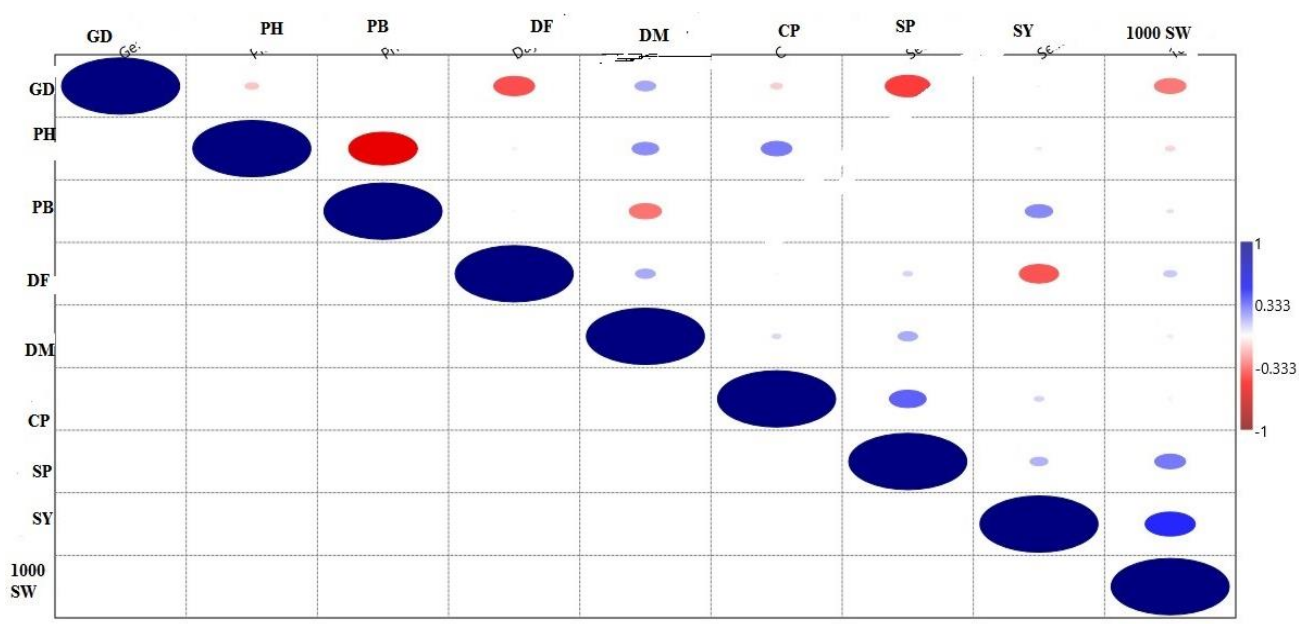

Fig. 3. Pearson's Correlation coefficients between agro-morphological traits calculated from 42 Lineseed genotypes. GD= germination days, PH= Plant height, PB= Primary branches, DF= Flower initiation days, DM= Days for 100% maturity, CP= Capsules per Plant, SP=Seeds per plant, SYP= Seeds yield per plant, 1000SW= 1000 seed weight.

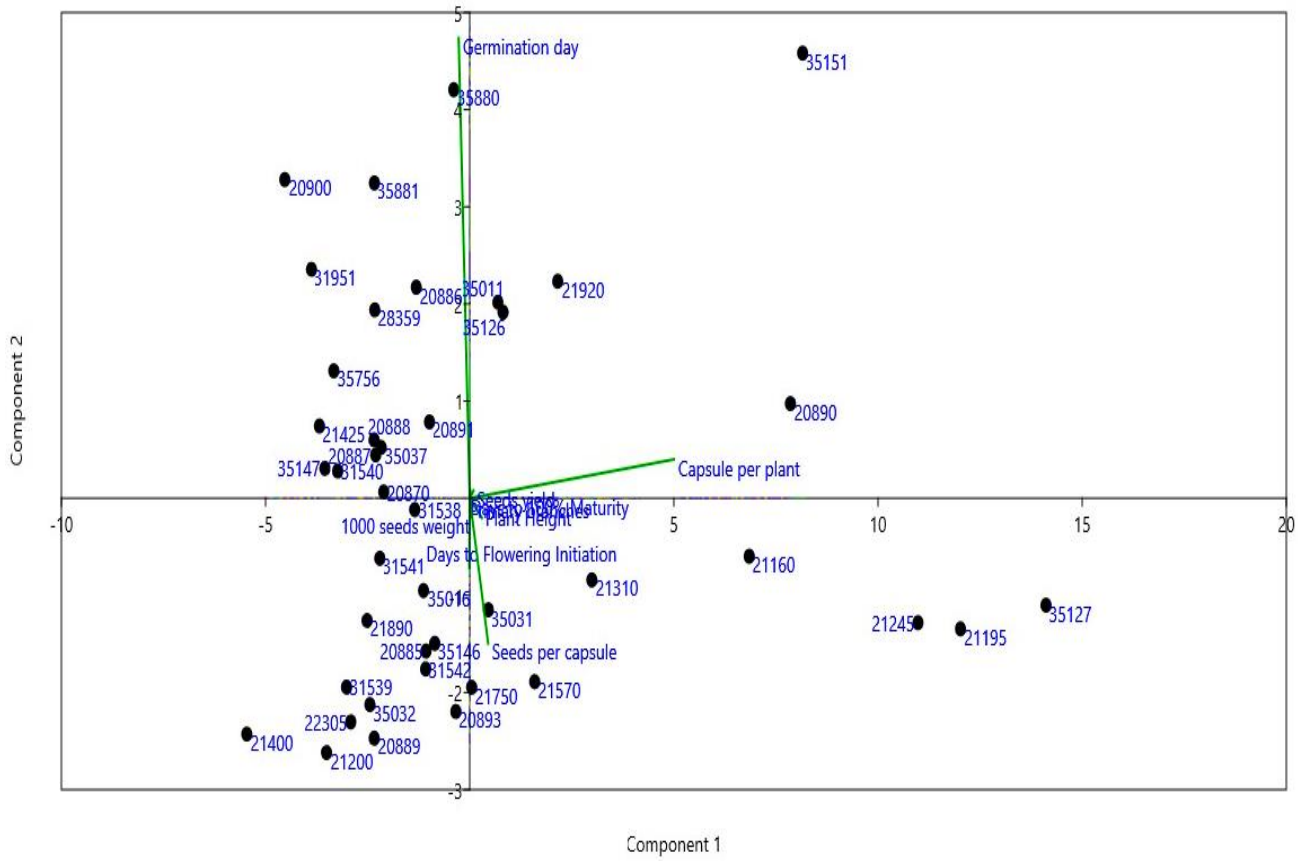

Fig. 4. Biplot showing the interrelationship among all measured traits for 42 lineseed genotypes.

Discussion

The present study was focused to evaluate the 42 linseed (*Linum usitatissimum* L.) genotypes based on the agro-morphological attributes which were both from Pakistan and America and are cultivated in different agro-environmental conditions. This crop is cultivated due to its multiple beneficial aspects like nutritional, medicinal and industrial. It is found to be difficult to explain that the crop is preferred to cultivate either for its seeds or fibers (Kislev *et al.,* 2011). All the genotypes evaluated for different characters in present study showed different results. No single genotype that performed best for all the selected screened traits. Similar results were provided by Siddiqui *et al.,* 2016, who reported that all selected linseed genotypes did not show significant performances for different characters. The days taken for germination is the important character studied for these 42 genotypes of linseed which were both Pakistan and America based. The maximum 9 days were taken by 035880 and 035151. Worku *et al.,* 2015 reported that some genotypes were late in germination up to 7 days. Such findings were also reported by Lu *et al.,* 2004. In present work, significant results were recorded for the character of the days to initiate the flowers which ranged from 74 to 99 days. Two genotypes viz., 020891 and 035151 showed very early DFI (74 days) while only one genotype 021195 (Pak) showed too late DFI (99 days). Similar results of wide ranged and continuous variations in DFI of linseed genotypes were reported by (Worku *et al.,* 2015; Bibi *et al.,* 2013). The genotype 021200 (Pak) and maximum plant height (105cm) by genotype 035127 (USDA). In western countries linseed is mostly being grown for its fiber regarding its remarkable mechanical properties having flexibility and strength (Fernandez, 2016). So genotype of USDA is preferable to grow for fiber purposes. Low variation was recorded for the character seeds per capsule among 42 selected genotypes. The genotype 021200 (Pak) contributed for maximum number of seeds per capsule (10.3). Similar results of less diversity for this trait were reported by Shipra *et al.,* 2016. Similar outcomes were provided by Alem and Tadesse, 2014 who described the effect of environment and its interaction with genotypes regarding number of seeds per capsules. This study revealed that a significant variation was recorded for the seed yield. Many genotypes which were American based show less yield which may be the effect of different agro environmental conditions or due to their fiber yielding character. Such seed yield results were also shown by Shipra *et al.,* 2016. Maximum seed yield (8g) was contributed by genotype 020890 (Pak) while genotypes 35016 (USDA) and 035756 (Pak) contributed minimum seed yield (4g each). The climatic factors highly contribute for the productivity of the crops and these factors also affect the growth and development of the crops (Agalave, 2017; Alem & Tadesse, 2014 and Hussain *et al.,* 2015). Similar findings for seed yield variation among genotypes was provided by Siddique *et al.,* 2016 who reported that when same genotypes of linseed were grown in different areas their productivity was affected as due to difference in agro-climatic conditions these genotypes experienced different selection pressure.

The low productivity rate of linseed is due to unavailability of best varieties that survive in different agro-climatic conditions. But due to its global commercial demand linseed breeders started work on different techniques to develop varieties of best productivity (Rastogi *et al.,* 2013). This study also compared the agro-morphological attributes of Lineseed genotypes from Pakistan and America under irrigated conditions. The data recorded for the both the germplasm resources showed wide range of diversity for agro-morphological traits. This investigation will also help in the choosing of precious genotypes for breeding programs. Results recorded for genotypes classification revealed that genotypes grouped together in each cluster belonged to different countries which indicate that there was no clear relationship among the genotypes and geographical diversity. Therefore there should be more emphasis on the genotypes rather than on the geographical level as a source of diversity. This type of results were also reported by several studies in different crops like white clover (Jahufer *et. al.,* 1997), durum wheat (Annicchiarico *et al.*, 2000), safflower (Jaradat & Shahid, 2006; Khan *et al.* 2008) and watermelon (Szamosi *et al.*, 2009). The present investigation was an attempt to investigate the 42 lineseed germplasm through morphological traits which showed high level of variation among these genotypes as these genotypes were from both Pakistan and America based. The most divergent genotypes in morphological evaluation may be used as parents in breeding programs to develop new linseed varieties with desirable characteristics.

Conclusion

Three genotypes viz., 020885, 020890 and 020870 contributed noteworthy results on the basis of morphological traits. The diverse and significant trait was obtained from genotype 021200 (Pak) along total genotypes; having maximum number of primary branches per plant (10) as well as maximum number of seeds per capsule (10.3). Whereas, genotype 020885(Pak) contributed for the maximum weight of seeds per plant as well as for maximum weight of 1000 seeds among all the genotypes.

Acknowledgements

The authors are thankful to the Director General NARC Islamabad Pakistan for providing the seeds of 42 lineseed genotypes and research facilities.

References

Agalave, H. R. 2017. Effect of environmental factors on productivity of crop. *Int. J. Bot. Stud.,* 2 (1): 14-16.

Akhtar, S., T. Ismail and M. Riaz. 2013. Flaxseed-a miraculous defense against some critical maladies. *Pak. J. Pharm. Sci.*, 26(1): 199-208.

Alem, C. and D. Tadesse. 2014. Study on genotype environment interaction of seed yield, oil content, fatty acid profile and stability analysis of yield related trait in linseed (*Linum usitatissimun* L.) in North Western Ethiopia. *Int. J. Plant Breed. Genet.*, 8(2): 66-73.

Annicchiarico, P., L. Pecetti, G. Boggini and M.A. Doust. 2000. Repeatability of large-scale germplasm evaluation results in durum wheat. *Crop Sci*., 40: 1810-1814.

Anonymous. 2001. Agricultural Statistics of Pakistan. Government of Pakistan, Ministry of Food, Agriculture and Livestock, Economic Wing, Islamabad: 67-80.

Bernacchia, R., R. Preti and G. Vinci. 2014. Chemical composition and health benefits of flaxseed. *Aust. J. Nut. Food. Sci*., 2(8): 1045.

Bibi, T., T. Mahmood, Y. Mirza and T. Mahmood. 2013. Correlation studies of some yield related traits in linseed, *Linum usitatissimum. J. Agri. Res.,* 51(2): 121-132.

Bloedon, L.T. and P.O. Szapary. 2004. Flaxseed and cardiovascular risk. *Nutr. Rev.*, 62(1): 18-27.

Deng, X., S.S. Long, D. He, X. Li, Y. Wang, D. Hao and X. Chen. 2011. Isolation and characterization of polymorphic microsatellite markers from flax (*Linum usitatissimum* L.). *Afr. J. Biotech.*, 10(5): 734-739.

Fernandez, J.A., N. Le Moigne, A.S. Caro-Bretelle, R. El Hage, A. Le Duc, M. Lozachmeur and A. Bergeret. 2016. Role of flax cell wall components on the microstructure and transverse mechanical behavior of flax fabrics reinforced epoxy biocomposites. *Ind. Crops Prod.*, 85: 93-108.

Gul, S., A.A. Rajper, F.A. Kalhoro, S.A. Kalhoro, A. Ali, F.A. Shah and M. Ahmed. 2016. Screening selected linseed (*Linum usitatissimum* L.) genotypes for yield performance in Sindh, Pakistan. *Nat. Sci.,* 8(02): 53.

Hussain, F., J. Iqbal, M. Rafiq, Z. Mehmood, M. Ali and N. Ramzan. 2015. Genetic improvement in linseed (*Linum usitatissimum* L.) through variability heritability and genetic advance. *J. Agri. Res.*, 53(4): 507-512.

Jahufer, M.Z.Z., M. Cooper and B.D. Harch. 1997. Pattern analysis of the diversity of morphological plant attributes and herbage yield in a world collection of white clover (*Trifolium repens* L.) germplasm characterised in a summer moisture stress environment of Australia. *Genet. Resour. Crop Evol*., 44: 289-300.

Jaradat, A.A. and M.A. Shahid. 2006. Patterns of phenotypic variation in a germplasm collection of (*Carthamus tinctorius* L.) from the Middle East. *Genet. Resour. Crop,* 53(2): 225-244.

Khan, M.B., T.A. Yasir, T.A. and M. Aman. 2005. Growth and yield comparison of different linseed (*Linum usitatissimum* L.) genotypes planted at different row spacing. *J. Agri. Biol.*, 7: 515-517.

Kislev, M.E., O. Simchoni, Y. Melamed and L. Maroz. 2011. Flax seed production: evidence from the early Iron Age site of Tel Beth-Shean, Israel and from written sources. *Veg. Hist. Archaeobot.*, 20(6): 579.

Lu, X., X. Chen and C. Cui. 2004. Germination ability of seeds of 23 crop plant species after a decade of storage in the National Gene Bank of China. *Plant Genet. Resour. Newslett,* 139: 42-46.

Rastogi, A., A. Siddiqui, B.K. Mishra, M. Srivastava, R. Pandey, P. Misra and S. Shukla. 2013. Effect of auxin and gibberellic acid on growth and yield components of linseed (*Linum usitatissimum* L.). *Crop Breed. & Appl. Biotech.*, 13(2): 136-143.

Shipra, S., R. Sohan, B. Shanti and A. Ekhlaque. 2016. Genetic variability, heritability and genetic advance of yield and quality traits in linseed (*Linum usitatissimum* L.). *Int. J. Plant Sci.,* 11(2): 270-274.

Siddiqui, A., S. Shukla, A. Rastogi, A. Bhargava, A. Niranjan and A. Lehri. 2016. Relationship among phenotypic and quality traits in indigenous and exotic genotypes of linseed. *Pesquisa Agropecuária Brasileira*, 51(12): 1964-1972.

Szamosi, C., I. Solmaz, N. Sari and C. Barsony. 2009. Morphological characterization of Hungarian and Turkish watermelon (*Citrullus lanatus* (Thunb.) Matsum. et Nakai) genetic resources. *Genet. Resour. Crop Evol*., 56: 1091-1105.

Verghese, M., J. Boateng and LT. Walker. 2011. Flax seed (*Linum usitatissimum*) fatty acids. In: (Eds.): Preedy, V., R. Watson & V. Patel. Nuts and seeds in health and disease prevention. *Acad. Press:* 487-498.

Worku, N., A. Zemede and Y. Haileselassie. 2005. Variation and association analyses on morphological characters of linseed (*Linum usitatissimum* L.) in Ethiopia. *Sinet.*, 28(2): 129-140.

(Received for publication 15 March 2019)