MAS Journal of Applied Sciences Uygulamalı Bilimler Dergisi ISSN: 2757-5675 masjaps.com

OPEN ACCESS

DOI: http://dx.doi.org/10.5281/zenodo.10004214

Araştırma Makalesi / Research Article

Determination of Yield and Quality Properties of Different Flax (*Linum usitatissimum* L.) Genotypes in Eskisehir Ecological Conditions

Nimet KATAR[1], Mustafa YAŞAR[2*], Arzu KÖSE[3], Duran KATAR[4]

[1]Eskisehir Directorate of Provincial Agriculture and Forestry, Eskisehir

[2]Muş Alparslan University, Faculty of Applied Sciences, Department of Plant Production and Technologies, Muş

[3]Transitional Zone Agricultural Research Institute, Eskisehir

[4]Eskisehir Osmangazi University, Faculty of Agriculture, Ali Numan Kirac Campus, Eskisehir

*Corresponding author: mustafa.yasar@alparslan.edu.tr

Received: 02.07.2023 **Accepted**: 06.08.2023

Abstract

This research was conducted to determine the performance of different flax (*Linum usitatissimum* L.) genotypes (Sari-85, Clli 1351, Clli 1370, Clli 1400, Clli 1412, Clli 1423, Larnaka, Milas, NewTurk and Dillman) in terms of the plant height, first branch height, number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight, the seed yield, oil content, oil yield and fatty acid composition. The mean values of the plant height, first branch height, number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight, the seed yield, oil content and oil yield were determined as 62.80 cm, 35.93 cm, 3.51 number, 28.40 number, 11.73 number, 5.80 g, 1.75 t ha^{-1}, 34.84% and 0.61 t ha^{-1}, respectively. α-Linolenic (51.90-58.93%), oleic (16.08-21.78%), linoleic (12.90-16.00%), palmitic (5.70-6.31) and steraric (4.41-5.67%) fatty acids were determined in flax genotypes. The linen genotypes used in the study have been found to have linolenic acid content which is too high to be used as edible oil. Therefore, new genotypes with less than 3% α-linolenic acid content for edible oil production should be developed by breeding programs/biotechnology.

Keywords: Flax, fatty acids, genotypes, oil content, seed yield, yield components

1. Introduction

More than 300 species of *Linum* genus were recorded in the world (Reddy et al., 2013). One of them is the *Linum usitatissimum* L., which is an annual plant and produced 3.4 million tons in the world. (Umer et al., 2017; Yaşar and Yetişsin, 2023). Flax (*Linum usitatissimum* L.) or wild species have generally spread in the Mediterranean countries, the Balkans and Turkey. Flax is a plant cultivated for many years in many countries of the world because of its fibers obtained from its stems and its oils obtained its seeds (Konukgil and Bahadir, 2004). Flax is one of the oldest crops that has been cultivated since the dawn of civilization (Goyal et al., 2014). Flax is produced and consumed for its oil and fiber, and intensively used in several sectors. It is important industrial plants with several uses (Zuk et al., 2015; Yaşar, 2023). It had been mainly grown only for the utilization of fibers for years (Elayan Sohair et al., 2015). In the following years, synthetic fibers have become widespread in the markets due to their production and price advantages. In the same time period, the cultivation of crops such as flax and hemp has gradually declined worldwide (Zając et al., 2012). The negative effects of synthetic fiber industry on the environment and the use of these fibers on human health have been observed. With the emergence of this negative impact on the environment and human health, the trends to green and health oriented products have created new opportunities for flax and hemp in the last two decades (Goyal et al., 2014). In addition, the use of linen oils with high alpha linolenic acid content as functional foods and the development of Solin genotypes that contain less than 3% alpha linolenic acid and can be used in edible oil production has also increased the demand for flax plants. With this period, the cultivation of plants such as flax and hemp began to attract attention again (Yildirim and Arslan, 2013). On the other hand, there are many different ways of use of oil obtained from the seeds of the linen plant. This has led to an increase in the production of linen as well as increasing the scientific research carried out on linens (Konukgil and Bahadir, 2004; Yildirim and Arslan, 2013). The oil content of linseeds varies between 30-45% (Umer et al., 2017). Linolenic acid (omega-3) content, which is the main component of linen oil, varies between 40-60% (Yildirim and Arslan, 2013, Ghanbari-Odivi et al., 2013). The oxidative stability of linolenic acid that is a triple-unsaturated essential fatty acid is low. Since linolenic acid shortens the shelf life of the oil, it is not desirable to have a high level of this fatty acid in flaxseed oil (Ali et al., 2016). In addition, linen oil, which has a high iodine value (160-200), is considered to be one of the drying oils. These properties of linen oil restrict the use of conventional oil as a edible oil. Linen oil, which is one of the drying oils, is widely used for the manufacture of paints, varnish, linoleum, oil cloth, currency paper, patent leather, printer ink, enamels, plastics, stickers, tarpaulins, soaps (Popa et al., 2012). In addition, linseed oil, an important vegetable source of omega-3, is increasingly being used as a food supplement. Linseeds containing different secondary metabolites are used in the treatment of many disorders. Linseeds are known as analgesic, anti-estrogenic, anti-inflammatory, cardiotonic, demulcent, emollient, expectorant, laxative, nervine, pectoral, purgative, resolvent (Yildirim and Arslan, 2013, Gallardo et al., 2014). Recently, new linen types with linolenic acid ratio less than 3% and linoleic acid ratio higher have been developed with the breeding studies carried out on the flax plant (İsleroglu et al., 2005). The new linen genotype, named as Solin, have produced high quality edible double-unsaturated oil similar to sunflower oil (Konukgil and Bahadir, 2004). These new genotypes of flax have been developed by genetic mutations (Gallardo et al., 2014). These low linolenic acid mutants have a high level (65-76%) of linoleic acid. The decrease in the ratio of linolenic acid significantly

increased the oxidative stability of the oil (Maurya et al., 2017). The genetic modification of the activity of desaturase enzymes prevents the conversion of linoleic acid (C18:2) to linolenic acid (C18:3) at the stage of seed formation. After oil is extracted from linola seeds, the remaining meal is a valuable protein source in ruminants feeding. In addition, the milled linola seeds promise an important future as a functional food component of flour to increase the quality and shelf life of bread. The seed contains mucilage, which has a lowering effect on blood cholesterol, and is an important source of lignans with anti-carcinogenic effect (Ali et al., 2016). Linseed is produced in the arid and semi-arid regions of the world. In the regions that are not have a very hard winter, alternative or absolute winter varieties are sown in autumn and are produced as winter sowing with higher yield compared to summer sowing (Yildirim and Arslan, 2013). One of the most important agronomic applications to increase the yield and quality in agricultural production is to determine the appropriate genotypes for the region. Therefore, it is necessary to determine the performance of the different genotypes of the crop, which will to be cultivated in any region, firstly. For this purpose, field experiments have been carried out and appropriate genotypes have been recommended for the region considering the data obtained. The same is true for flax plant and adaptation experiments have been carried out in many parts of the world to determine the appropriate genotypes (Tuncturk, 2007; Chauhan et al., 2008; Yildirim and Arslan, 2013; Andruszczak et al., 2015; Maurya et al., 2017). The aim of this study was to determine the yield and quality characteristics of different flax genotypes in Eskisehir ecological condition.

2. Materials nnd Methods

2.1. Material

The study was carried out at the experimental fields of Eskisehir Osmangazi University Agricultural Faculty during crop growing period of 2017 and 2018. The plant materials used in the experiment were obtained from Translational Zone Agricultural Research Institute. The properties of the experimental soils were given in Table 1. Soil characteristics in 2017 and 2018 were: loamy, pH 7.22 and 7.33, lime 5.26% and 7.33%, salt 0.03 ds m^{-1}% and 0.04 ds m^{-1}, organic matter 2.51% and 2.68%, phosphorus 54.9 kg ha^{-1} and 58.7 kg ha^{-1} and potassium 2195.3 kg ha^{-1} and 2574.0 kg ha^{-1}.

Table 1. Some physical and chemical properties of soils in experimental fields

Structure	Lime (%)	Salt (ds m^{-1})	Available Phosphorus (P2O5)(kg ha^{-1})	Available Potassium (K_2O) (kg ha^{-1})	pH	Organic Matter
Loamy (2017)*	5.26	0.03	54.9	2195.3	7.22	2.51
Loamy 2018)**	5.12	0.04	58.7	2574	7.33	2.68

**The analyze was carried out in Eskisehir Osmangazi University, Faculty of Agriculture, Soil Analysis Laboratory.*
*** Soil analyze was carried out in Transitional Zone Agrıcultural Research Institute Soil-Plant-Water analysis and Physiology laboratories.*

Temperature and precipitation and total and mean values of these meteorological data were presented in Table 2. Total annual precipitation in long-term period was 338.8 mm, whereas this value was lower both in 2017 (374.4 mm) and in 2018 (411.8 mm). Likewise, the average temperature for long-term period was lower than the average temperature values for both 2017 and 2018. Mean temperature in 2017 and 2018 were 11.29 °C and 12.50 °C respectively.

Table 2. Meteorological data of the experiment years*

	Climatic factors					
	Total Precipitation (mm)*			Mean Temperature (°C)		
	Years			Years		
Months	2017	2018	1970-2011 (Long years)	2017	2018	1970-2011 (Long years)
January	33.00	30.00	30.6	-2.00	1.40	-0.2
February	9.20	28.80	26.1	1.90	5.60	0.9
March	16.20	49.80	27.6	7.60	8.90	4.9
April	62.00	16.80	43.1	9.60	13.60	9.6
May	50.80	72.00	40.0	14.40	16.40	14.9
June	44.80	60.60	23.7	19.10	19.30	19.1
July	13.40	42.00	13.1	23.10	21.90	22.1
August	31.40	19.30	9.2	22.00	22.70	21.8
September	3.00	3.80	18.1	19.60	18.30	16.7
October	46.60	30.10	32.8	10.80	13.00	11.7
November	27.80	18.60	34.0	5.50	7.40	5.6
December	36.20	40.00	40.5	3.90	1.7	1.7
Total/Mean	374.40	411.80	338.8	11.29	12.50	10.7

**Data were taken from Eskisehir Regional Meteorological Service.*

2.2. Method

Ten different linseed genotypes used in the experiment were Sari-85, Clli 1351, Clli 1370, Clli 1400, Clli 1412, Clli 1423, Larnaka, Milas, NewTurk and Dillman. The experimental design was a randomized complete block design with three replications. Seeds were sown by hand, with 15 cm row spacing on plots of 3 m^2 harvest area (0.6 m width x 5 m length) on 28 March of 2017 and 23 March of 2018. In order to obtain a crop stand of 400 plants per m^2, seeding was performed with a seeding rate of 45 kg ha^{-1}. Weed control was made by hand when needed. No irrigation was applied. The experimental plots were fertilized with a dose of 80 kg N and 50 kg P_2O_5 per ha. A row was removed from both sides of the plots as side effect and then the plants in the plots were harvested by hand on 3 July 2017 and 9 July 2018. The seed samples were properly ground and the oil extracted with n-hexane in a Soxhlet extractor for 4 h. Recovered crude oils were taken to dry out on a rotator evaporator at 35 ^oC. Fatty acids were esterified as methyl esters and analyzed by Agilent 6890N Network with equipment with DB-23 capillary column (JW Scientific 122-2362 DB-23; 60.0 m x 250 μm x 0.25 μm) GC and FID detector. Helium was used as carrier gas at a flow rate of 1 mL/min. Injector and detector temperature were 260 ^oC and 240 ^oC, respectively. Column temperature was kept at 220 ^oC for 69 min. Samples of 0.5 uL was injected by hand and in the split mode (20:1). FAMEs were identified by comparison of their retention times with those of reference standards. The content of fatty acids was calculated from corresponding integration data.

2.3. Statistical Analysis

With randomized complete block design, analytical data collected with three replications of each treatment were subjected to analysis of variance using SAS statistical software program, and differences between mean values were compared via the LSD (Least Significant Difference) test (Acikgoz, 1993).

3. Result and Discussion

3.1. Yield and yield components

As is known, the yield and yield components are determined by genotype, environment and genotype x environment interaction (Reddy et al., 2013). As in other oilseed crops, seed and oil yield in flax plants are also under control of some yield components (Mirza et al., 2011). The main yield components affecting seed and oil

yield in linseed are the number of primary branches of each plant, the number of capsules per plant, the number of seeds in each capsule, thousand seed weight and the oil content (Ibrar et al., 2016). Therefore, knowledge of the main yield components and their inheritance is of great importance in determining the performance of genotypes (Katar et al., 2016). In order to determine the performances of different linseed genotypes, the combined values obtained from the field experiments carried out in 2017 and 2018 were given in Table 3. Except for number of branches plant^{-1}, 1000 seed weight and oil content (%), genetic make-up differences among the genotypes revealed highly significant ($P<0.01$) differences for all studied parameters. The traits evaluated manifested various levels of variability among the genotypes studied (Table 3). Plant height, first branch height, branches number per plant, number of capsules per plant, number of seeds per capsule, 100 seed weight, seed yield, oil content and oil yield varied between 59.93-72.52 cm, 33.44-43.54 cm, 3.08-4.11 number, 23.51-30.38 number, 9.05-14.43 number, 5.61-6.11 g, 1.09-2.12 (t ha^{-1}), 33.76-36.15% and 0.37-0.77 (t ha $^{-1}$), respectively (Table 3). Differences among genotypes in the parameters examined can be explained by the genetic and genomic diversities in total genetic make-up of examined genotypes (Ibrar et al., 2016). It is known that the genetic diversity among genotypes encompasses all the variability that occurs among different genotypes (Bhandari et al., 2017). As a result, the variation expressing itself in the form of altered morphology, anatomy, physiological behavior or biochemical properties in heritable characters of genotypes caused different performances of genotypes (Terfa and Gurmu, 2020). The highest plant height and first branch height were obtained from New Turk genotype as 72.52 cm and 43.54 cm, respectively. The highest number of capsules plant^{-1} and the highest number of seeds capsules^{-1} were obtained from Milas (30.38) and Larkana (14.43) genotypes, respectively. In the study, it was determined that the average values of the genotypes for the number of branches per plant, 1000 seed weight and oil content were 3.51, 5.80 g and 34.84%, respectively. The highest seed and oil yield were determined as 2.12 t ha^{-1} and 0.77 t ha^{-1} in the New Turk genotype, respectively. The highest oil content was obtained from New Turk genotype at 36.15%. Although the highest yields were obtained from the New Turk genotype in terms of seed and oil yields, this genotype was statistically in the same group with the other four genotypes (Clli 1423, Larkana, Milas and Dillman) (Table 3). It is known that the number of capsules per plant, which is one of the yield components in flax plant, has the greatest positive effect on seed yield. Similarly, primary branches of each plant, 1000 seed weight, and number of seeds per capsule have a positive direct effect on seed yield (Mirza et al., 2011; Ibrar et al., 2016; Bağci et al., 2023). In the study, it was determined that in the genotypes (Clli 1423, Larkana, Milas, NewTurk and Dillman) with high seed yield, the number of primary branches per plant, the number of capsules per plant, the number of seeds per capsule and the weight of 1000 seeds were also high. The high seed yield obtained from some of the examined genotypes can be explained by the high genetic potential of these genotypes to produce higher yielding components (Terfa and Gurmu, 2020). Since there is no significant difference between the oil ratios of flax genotypes, the increase in oil yield in some flax genotypes can be explained by the increase in seed yield detected in these genotypes. It is known that the yield and yield components of flax are affected by genetic makeup of flax cultivars, environmental factors and cultural practices (Reddy et al., 2013). The differences between genotypes obtained in the study can be explained by the genotypic difference of plant materials. Our plant height, the first branch height, the number of seeds per capsule and 1000 seed weight were consistent with those reported by

Yildirim and Arslan (2013). Our oil content values were in line with the reported values by Reddy et al., 2013). When all of the phenotypic criteria examined in the study were evaluated together and compared with the phenotypic criteria reported by Smykal et al. (2011), it can be said that the genotypes used in this study are in intermediate type/transitional forms (convar. *usitatissimum*).

Table 3. Results of yield and yield components on flax varieties

Genotypes	Plant height	First branch height	Number of branches plant^{-1}	Number of capsules plant^{-1}	Number of seed capsule^{-1}	1000 seed weight	Seed yield (t ha^{-1})	Oil Content (%)	Oil Yield (t ha^{-1})
Sari-85	60.90 B	33.79 C	3.21	27.91 A	10.57BCD	5.61	1.56 B	35.06	0.55 B
Clli 1351	61.93 B	36.58BC	3.28	23.51 B	9.05 D	5.86	1.09 C	33.87	0.37 C
Clli 1370	65.05 B	35.53 C	3.55	28.04 A	10.54BCD	5.62	1.48 B	35.18	0.52 B
Clli 1400	61.26 B	34.27 C	3.56	27.88 A	10.27 CD	6.11	1.50 B	33.76	0.51 B
Clli 1412	61.36 B	34.35 C	3.55	27.92 A	10.27 CD	5.74	1.51 B	34.62	0.53 B
Clli 1423	59.93 B	33.44 C	3.08	30.14 A	12.17ABC	5.80	2.16 A	34.05	0.74 A
Larkana	61.09 B	34.61 C	3.59	29.35 A	14.43 A	5.72	1.94 A	34.83	0.68 A
Milas	61.11 B	34.54 C	3.59	30.38 A	14.36 A	6.06	2.09 A	35.47	0.74 A
NewTurk	72.52 A	43.54 A	3.61	30.12 A	13.09 AB	5.78	2.12 A	36.15	0.77 A
Dillman	61.80 B	38.67 B	4.11	28.76 A	12.56ABC	5.66	2.01 A	35.39	0.71 A
Mean	**62.70**	**35.93**	**3.51**	**28.40**	**11.73**	**5.80**	**1.75**	**34.84**	**0.61**
	**	**	ns	**	**	ns	**	ns	**
C.V.(%)	7.93	10.26	16.03	11.69	21.78	5.55	23.09	7.71	26.35

3.2. Fatty acid composition

Vegetable oils are used for different purposes such as pharmacology, industry and biodiesel besides being used in human nutrition. Fatty acid composition is the most important factor in determining the purpose for which vegetable oils are used (Katar, 2013). For this reason, it is of great importance to determine the composition of fatty acids in order to ensure that vegetable oils can be used for the right purposes and that the breeding programs to be prepared can be directed accordingly. In this study, levels of fatty acids (palmitic acid, palmitoleic acid, stearic acid, linoleic acid, arachidic acid, behenic acid, oleic acid, lignoceric acid and α-linolenic acid) in different flax genotypes were analyzed by GC and GC-MS. As a result of the analysis, the determined fatty acids composition in different flax genotypes was given in Table 4. As shown in Table 4, 9 different fatty acids were identified in oils of 10 different linen genotypes. Linolenic, oleic, linoleic, stearic and palmitic acid were found as main fatty acids in different linen genotypes. The first three of these main fatty acids were unsaturated fatty acids while the other two are saturated fatty acids. The ratios of saturated fatty acids in total fatty acids varied between 10.11-12.10%. When the fatty acid composition of the different linen genotypes used in the study was examined, it was determined that α-linolenic acid content had changed between 51.9-58.9% (Table 4). While the lowest α-linolenic acid content was being determined in Clli 1423 genotype, the highest content was found in yellow-85 genotype. In terms of α-linolenic acid content, other genotypes showed a value between these two genotypes. These values also indicated us that the genotypes had a variation in α-linolenic acid. α-Linolenic acid values of flax genotypes used in this study were approximately parallel to the values reported by Reddy et al. (2013), Yildirim and Arslan (2013) and Ghanbari-odivi et al. (2013). Another important fatty acid in flax genotypes was oleic acid (omega-9). In the flax genotypes,

the oleic acid content varied between 16.08-21.78% (Table 4). The highest oleic acid value (21.78%) was obtained from larkana genotype while the lowest value (16.08%) was found in Sari-85 genotype. The oleic acid values of the genotypes was consistent with the values (12-30%) reported by Umer et al. (2017). Linoleic acid, a polyunsaturated fatty acid and one of two essential fatty acids for humans, was important in terms of quality of vegetable oil (Demir and Tasan, 2019). The flax genotypes used in the study differed in terms of linoleic acid contents (Table 4). The highest linoleic acid value (17.9%) was obtained from New Turk genotype while the lowest value (12.9%) was found in larkana genotype. Our linoleic acid values belonging to the genotypes was in harmony with the values reported by Isleroglu et al. (2005). When the fatty acid compositions of the studied genotypes were evaluated collectively, the fatty acid compositions obtained were in accordance with the composition of the fatty acids reported by Umer et al. (2017). In this study, α-linolenic acid ratio of flax genotypes changed between 51.90-58.90% and it is over 3%. This situation showed us that the genotypes used in the experiment did not belong to the newly developed Solin types. As it is known, Solin type genotypes are used as edible oil because they have less than 3% linolenic acid and higher ratio of linoleic acid. As a result, the oils obtained from the conventional flax genotypes used in this study are among the drying oils. This type of oil can be used only as a food supplement in human nutrition and for industrial purposes in the production of paints, varnish, linoleum, oil cloth, currency paper, soap etc. In addition, linseeds containing different secondary metabolites is used in the treatment of many diseases due to analgesic, anti-estrogenic, anti-inflammatory, cardiotonic, demulcent, emollient, expectorant, laxative, nervine, pectoral, purgative, resolvent activities (Gallardo et al., 2014). Considering the fatty acid composition of the flax genotypes used in this study, it is seen that the fat obtained from these genotypes is not suitable for use as edible oil.

Table 4. Fatty Acid Composition in Different Flax Genotypes (*Linum usitatissi*umum) in 2018

	Genotypes									
Fatty Acid	Sari-85	Clli 1351	Clli 1370	Clli 1400	Clli 1412	Clli 1423	Larkana	Milas	New Turk	Dillman
Palmitic acid	5.70	5.99	6.17	6.21	6.43	6.24	5.89	6.31	5.95	5,93
Palmitoleic acid	0.07	0.07	0.08	0.07	0.07	0.09	0.06	0.09	0.06	0,08
Stearic acid	5.28	5.67	5.18	5.25	5.32	5.11	5.62	5.52	4.41	5,40
Linoleic acid	13.2	15.5	13.5	14.9	15.8	16.0	12.9	13.9	17.9	14,2
Arachidic acid	0.38	0.37	0.37	0.36	0.34	0.34	0.35	0.30	0.28	0,37
Behenic acid	0.15	0.16	0.16	0.14	0.21	0.13	0.16	0.15	0.11	0,16
Oleic acid	16.08	18.67	18.40	18.29	18.62	19.97	21.78	18.5	18.7	17,63
Lignoceric acid	0.09	0.08	0.09	0.09	0.10	0.09	0.09	0.08	0.06	0,09
α-Linolenic acid	58.93	53.37	55.97	54.58	52.98	51.90	53.06	55.1	52.4	55,76
Unidentified	0.08	0.08	0.09	0.13	0.14	0.10	0.09	0.07	0.11	0,09
Total	100	100	100	100	100	100	100	100	100	100

4. Conclusion

The results obtained from the study carried out for two years using ten different linen genotypes in Eskisehir ecological conditions showed that Clli 1423, Milas, NewTurk, Dillman and Larnaka varieties were suitable for the production of flaxseed, respectively. These varieties produced higher seed and oil yields compared to others in our region. These genotypes (Clli 1423, Milas, NewTurk, Dillman and Larnaka), which have high seed and oil yield, are recommended to be produced for use in functional food and oleo-chemical industry in Eskisehir ecological conditions due to their high level of alpha linolenic acid. Since all the genotypes studied contain high levels of alpha linolenic acid, these genotypes are not suitable for use in edible oil production.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

References

Acikgoz, N. 1993. Research and trial methods in agriculture. *Ege University Faculty of Agriculture Publications*, İzmir, Turkey.

Ali, M., F.U. Hasan, M. Afzal. 2016. Response of Linola (*Linum usitatissimum* L.) to different spacings under rainfed conditions. *Cercetari Agronomice in Moldova.* 2(166): 87-96.

Andruszczak, S., U. Gawlik-Dziki, P. Kraska, E. Kwiecińska-Poppe, K. Różyło and E. Pałys. 2015. Yield and quality traits of two linseed (*Linum usitatissimum* L.) cultivars as affected by some agronomic factors. *Plant Soil Environment.* 61(6): 247-252.

Bağci, M., Arslan, Y., Yaşar, M., İşler, B., Ünal, S. 2023 Investigation of yield and yield components of some flax (*Linum usitatissimum* L.) varieties in ankara ecological conditions. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 9(2), 252-261.

Bhandari, H.R., Bhanu, A.N., Srivastava, K., Singh, M.N., Shreya, S., Hemantaranjan, A., 2017. Assessment of genetic diversity in crop plants an overview. *Advances in Plants & Agriculture Research* 7(3): 279-286.

Chauhan, D.V.S., Lodhi, M.D., Verma, N.K.2008. Effect of sowing dates, varieties and number of irrigations on yield attributes, yield and quality of linseed (*Linum usitatissimum* L.) under Bundelkhand condition of Uttar Pradesh. *Agricultural Science Digest,* 28(4): 271-273.

Demir, B.A., Tasan, M., 2019. Fatty acid profiles of selected industrial foods with zero trans fatty acids claim. *Journal of Tekirdag Agriculture Faculty*, 6(1): 23-33.

Elayan Sohair, E.D., Abdallah Amany, M. Nemat, A.N., Doaa, I.M., 2015. Effect of sowing date on yield, fiber and seed quality of eight flax genotypes. *American-Eurasian Journal of Agricultural & Environmental Sciences.* 15(5): 886-895.

Gallardo, M.A., Milisich, H.J. Drago, S.R., González, R. J. 2014. Effect of cultivars and planting date on yield, oil content, and fatty acid profile of flax varieties (*Linum usitatissimum* L.). *International Journal of Agronomy.* Article ID 150570, p: 7.

Ghanbari-Odivi, A., Safari, A. Tahmasebi, B.K. Farroki, M., Bahrampour, B., 2013. Effect of delaying in sowing date on growth, yield, yield components and oil content of two genotypes of Flaxseed (*Linum usitatissimum*). *Advances in Environmental Biology.* 7(6): 1014-1018.

Goyal, A., Sharma, V., Upadhyay, N., Gill, S., Sihag, M. 2014. Flax and flaxseed oil: an ancient medicine & modern functional food. *Journal Food Science Technology*, 51(9): 1633–1653.

Isleroglu, H., Yildirim, Z., Yildirim, M. 2005. Flaxseed as a functional food. *GOU Journal of the Faculty of Agriculture*. 22(2): 23-30.

Katar, D. 2013. Determination of fatty acid composition on different false flax (*Camelina sativa* (L.) Crantz) genotypes under Ankara ecological conditions. *Turkish Journal of Field Crops.* 18(1): 66-72.

Katar, D., Arslan,Y., Kodas, R., Subasi, I., Katar, N. 2016. Determining of performances on different characteristics in safflower (*Carthamus tinctorius*) genotypes under organic and conventional production systems. *Biological Diversity and Conservation.* 9(1): 172-181.

Konukgil, B., Bahadir, O., 2004. *Linum usitatissimum* L. and its chemical constituents and biological activities. *Journal of Ankara Pharmacy Faculty*. 33(1): 63-84.

Maurya, A.C., Raghuveer, M. Gozwami, G., Kumar, S. 2017. Influences of date of sowing on yield attributes and yield of linseed (*Linum usitatissimum* L.) varieties under dryland condition in eastern Uttar Pradesh. *International Journal of Current Microbiology and Applied Sciences.* 6(7): 481-487.

Mirza, M.Y., Khan, M.A. Akmal, M., Mohmand, A.S., Nawaz, M.S. Navaz, N., Ullah, N. 2011. Estimation of genetic parameters to formulate selection strategy for increased yield in linseed. *Pakistan Journal of Agricultural Research*. 24(1-4):19-24.

Popa, V.M., Gruia, A., Raba, D.N., Dumbrava, D., Moldovan, C., Bordean, D., Mateescu, C. 2012. Fatty acids composition and oil characteristics of linseed (*Linum usitatissimum* L.) from Romania. *Journal of Agroalimentary Processes and Technologies.* 18(2):136-140.

Reddy, M.P., Reddy, B.N., Arsul, B.T., Maheshwari, J.J., 2013. Genetic variability, heritability and genetic advance of growth and yield components of linseed (*Linum usitatissimum* L.). *International Journal of Current Microbiology and Applied Sciences*, 2(9): 231-237.

Smykal, P.N., Bacˇova´-Kerteszova, N., Kalendar, R. Corander, J., Schulman A.H., Pavelek, M., 2011. Genetic diversity of cultivated flax (*Linum usitatissimum* L.) germplasm assessed by retrotransposon-based markers. *Theoretical and Applied Genetics*, 122:1385–1397.

Terfa, G.N., Gurmu, G.N., 2020. Genetic variability, heritability and genetic advance in linseed (*Linum usitatissimum* L) genotypes for seed yield and other agronomic traits. *Oil Crop Science*, 5(3): 156-160.

Tuncturk, M. 2007. Determination of yield and some yield components of some linens (*Linum usitatissimum* L.) cultivars in Van ecological conditions. *Ankara University Faculty of Agriculture Journal of Agricultural Sciences.* 13(4): 365-371.

Umer, K.H., Zeenat, F., Ahmad, W., Ahmad, I., Khan, A.V., 2017. Therapeutics, phytochemistry and pharmacology of Alsi (*Linum usitatissimum* Linn): An important Unani drug. *Journal of Pharmacognosy and Phytochemistry*. 6(5): 377-383.

Yaşar, M., 2023. Sensitivity of different flax (*Linum usitatissimum* L.) genotypes to salinity determined by GE biplot. *Saudi Journal of Biological Sciences,* 30(4): 103592.

Yaşar, M., Yetişsin, F. 2023. Determination of Tolerances of Some Flax Varieties to Different Doses of Salt Concentrations in Early Development Period. *MAS Journal of Applied Sciences*, 8(1): 144-157.

Yildirim, M.U., Arslan, N. 2013. Comparing the various characters of the selected flax (*Linum usitatissimum* L.) lines. *Journal of Field Crops Central Research Institute.* 22(2): 59-68.

Zając, T., Oleksy, A., Klimek-Kopyra, A., Kulig, B. 2012. Biological determinants of plant and crop productivity of flax (*Linum usitatissimum* L.). *Acta Agrobotanica.* 65(4): 3-14.

Zuk, M., Richter, D., Matuła, J., Szopa, J. 2015. Linseed, the multipurpose plant. Industrial *Crops and Products*, 75: 165-177.

To Cite: Katar, N., Yaşar, M., Köse, A., Katar, D. 2023. Determination of Yield and Quality Properties of Different Flax (*Linum usitatissimum* L.) Genotypes in Eskisehir Ecological Conditions. *MAS Uygulamalı Bilimler Dergisi*, 8(Special Issue): 955–964.
DOI: http://dx.doi.org/10.5281/zenodo.10004214.