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Research Article

DETERMINATION OF YIELD CHARACTERS OF SOME LINSEED (*Linum usitatissimum*) CULTIVARS UNDER RAINFED CONDITION IN EASTERN MEDITERRANEAN

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ABSTRACT. Cultivar selection plays an important role in the production of linseed, which is produced and used for various purposes. This study aimed to determine the yield and yield components of 10 linseed (*Linum usitatissimum*) cultivars in the Eastern Mediterranean ecological conditions. In this experiment, which was established with 3 replications according to the randomised complete block design, all cultivars were produced as winter crop. While the differences among the cultivars were statistically significant in terms of plant height, first branch height, number of branch, number of boll and seed yield, the seed number per boll, 1000 seed weight, biological yield, straw yield and harvest index were insignificant. When the data were examined, it was determined that all cultivars were suitable for dual-purpose (oil, fibre) production, yet it was concluded that Sarı-85 cultivar was more prone to production for oil purposes due to its superiority in terms of the number of branch and boll and its short plant height. The NewTurk cultivar showed compliance with the ecological conditions for fibre production, and the cv. Milas proved its advantage in terms of yield and yield components aimed at production for dual purposes. Determination of the yield and yield components of *Linum usitatissimum* cultivars, which can be produced for dual-purposes due to the strategic importance of fibre and oil production, in the Eastern Mediterranean ecological conditions will shed light on next studies and production plans.

Keywords: *Linseed, cultivar, Linum usitatissimum, yield, dual-purpose.*

INTRODUCTION

Linseed is one of the oldest plants cultivated by mankind. The success of linseed in the service of humanity for centuries is its use for a wide variety of purposes as fibre and seed. Its fibres are mainly used in clothing, bed sheet, towel, tablecloth, drapery, furniture upholstery, non-woven twine, rope, waist belt, bag cover, cartridge belt, tarpaulin, tent, composites (in plastic and concrete reinforcement), paper, cement, in packaging, coating material (automotive sector and fiberglass) and wicker production. Its seeds are used for food, medicine and various industrial purposes (paint, varnish, lacquer, linoleum printing and printer ink, soap and some waterproof items) [1]. Linseed is an important plant for different industrial areas with its high oil content. Due to the high Omega-3 fatty acids in linseed oil and the high protein content of its seed, it has been added to diets in human nutrition in recent years. Therefore, the main expectation in linseed production and breeding is high yield [1, 2].

Current developments and forecasts for the future show that the demand for linseed, both as a seed and as a fibre, will increase in the short and long term. The health benefits of linseed, the increasing use of its fibres in the textile and plastic industries, and even the increasing demand for linseed in pet food are all signs of this trend. The fiber content in dry stems varies between 17-37%, depending on the variety and growing conditions [3]. At the same time, the seeds contain 25-36% protein and 33-47% oil [4]. The Covid-19 pandemic that broke out two years ago disrupted the linseed supply chain in the international market and the demand for linseed increased due to the health awareness among the producers during this pandemic.

As a result of these trends, there has been an increase in linseed fibre and seed production in the world in recent years. As a matter of fact, according to FAO data, approximately 823 thousand tons of fibre and 2 million tons of seed production in 2000 increased to approximately 976 thousand tons of fibre and 3.3 million tons of seed production in 2020 [5]. While linseed fibre and seed production increased in the world, this was not the case in our country in the same period. According to the estimation data of the Turkish Statistical Institute (TUIK), 0.5 ton of seed and 6 tons of fibre were produced in Turkey in 2021 [6]. In our country, linseed is produced in the coastal zone of the Black Sea Region, around Kocaeli Province in the Marmara Region and in some inner transitional zones, albeit a little. Linseed is generally a temperate climate plant [1]. The fiber-type prefers conditions with higher relative humidity than the oil-type [7]. While the sun has a positive effect on the yield in the oil type, it is not suitable for the fiber type to be exposed to excessive sun [1]. For linseed cultivation, the soil reaction (pH) is required to be between 6.5-8.0 [8].

Linseed cultivation and weaving dates back to as early as 2000 BC in Anatolia [9]. During the Ottoman Empire period, important developments were experienced in this regard. Before the World War I, there was a considerable linen fabric trade along the Black Sea coast from Şile to Rize [9]. After the war, weaving declined and linseed farming decreased to a level that could only fulfill family needs. Due to the abandoned linseed cultivation, a sustainable source of livelihood in the regions where it is produced has disappeared, and handicrafts are on the verge of disappearing. Re-producing this plant, a natural agricultural product that is on the verge of extinction, will benefit local family business and regional fibre processing handicrafts will be encouraged again.

Linseed should be included in crop rotation systems because it can adapt to weak soils, does not tire the soil too much, leaves a good field for the plant to be grown after it, is not very sensitive to diseases and pests, is a fast growing plant that can reach maturity in usually 100 days. In particular, the cultivation possibilities of linseed outside the usual production areas, especially in the Mediterranean Region, should be investigated.

Both the fibre and seed productivity of this plant depend on the cultivar, environment and growing conditions and their interactions. In recent years, significant successes have been achieved in the development of new linseed cultivars in the world and in our country. There is a serious shortage of vegetable oil in our country. In order to meet this need, the cultivation of oil crops is important. Therefore, it is necessary to propound alternative areas for the cultivation of oil crops. With the decision to support the effective use of agricultural lands in our country, it has been reported that grant support will be given to projects aimed at improving the production of oilseed plants. The same support program also evaluates the issue of reintroducing idle lands to agriculture. This study was carried out in order to determine the compatibility of domestic and foreign cultivars of *Linum* *usitatissimum* with the Amik Plain conditions, as a winter crop without reducing the main product cotton cultivation.

MATERIALS AND METHODS

Material

In the study, 10 cultivars belonging to *Linum usitatissimum* were used. The information about the cultivars used is given in Table 1.

Table 1. *Cultivars used in the study and some of their characteristics*

Cultivar	Flower Colour	Seed Colour
Sarı-85	White	Yellow
Clli 1351	Blue	Light Brown
Clli 1370	Blue	Brown
Clli 1400	Blue	Brown
Clli 1412	Light Blue	Brown
Clli 1423	Blue	Brown
Larkana	Blue	Dark Brown
Milas	Blue	Light Brown
NewTurk	Blue	Dark Brown
Dillman	Blue	Brown

The field trial was carried out in Hatay Mustafa Kemal University research and application field. The climate data of the region were obtained from the Hatay Meteorology Directorate. During the growing season, the temperature values were very close to the long-term average (LTA) values, while the precipitation amounts were quite low compared to the long-term monthly averages except for January (Figure 1).

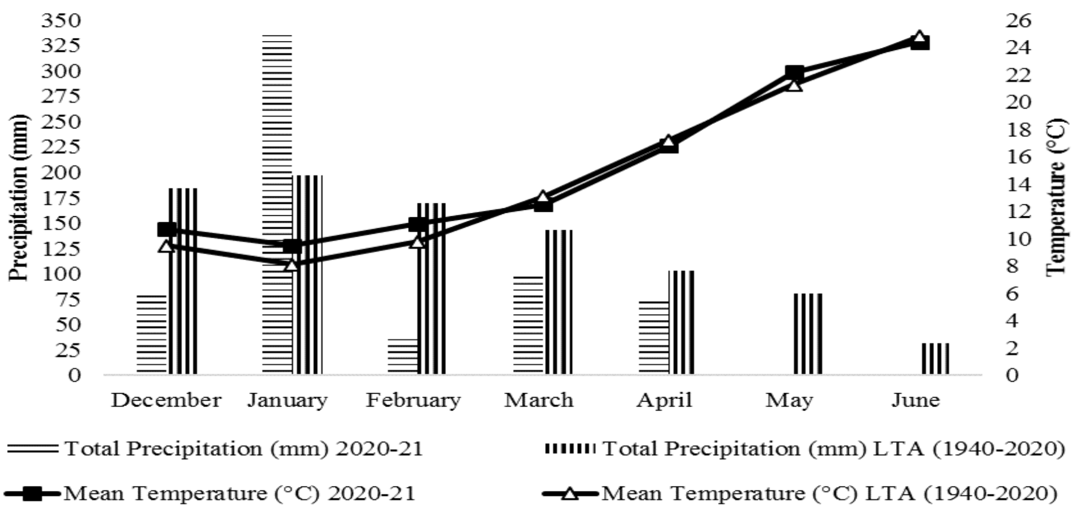

Fig. 1. *Climatic data of the growing season in which the study was carried out and the long-term average (LTA)*

Method

The study was carried out according to the randomized blocks experimental design with 3 replications. The sowing process was done manually in the first week of December 2020. The plots were established in 5 rows with 20 cm row spacing and sowing was done according to the 3 kg da^{-1} sowing norm [10]. 10 kg da^{-1} N and 6 kg da^{-1} were applied to each plot [11, 12]. Half of the nitrogen fertilizer was applied at sowing and the other half performed during the stem extension period [1]. During the cultivation period, weed control was carried out once with herbicide with Quizalofop-p-ethyl active ingredient and once manually. Before harvest, plant height, first branch height (technical stem length), number of branch and number of boll were recorded. Irrigation was not applied in the experiment carried out under precipitation conditions and harvesting was done in June 2021. In the harvest made by removing the edge effects, the plants were cut 5 cm height from the soil surface. After the harvest, seed per boll, 1000 seed weight, seed yield, stem yield and biological yield values were measured and the harvest index value was calculated.

The obtained data were subjected to variance analysis by the IBM SPSS Statistics 24 program, and as a result of these analyses, the averages were grouped with the LSD multiple range test.

RESULTS AND DISCUSSION

Plant height in linseed can vary depending on the plant type (fibre type, oil type), the amount of nitrogen fertilizer and growth regulators, the air temperature, the day length, the amount of irrigation water and especially the genotype of the plant [1, 13, 14]. It is not a desirable character for linseed to have a long length in cultivation for seed purposes. Lodging occurs especially in linseed with very long plant heights. In linseed, which is sensitive to lodging [15], the elongation of the plant is not a desirable situation for seed yield.

When the data obtained in the study were examined, statistically significant differences were observed between plant height values. Except for the Sarı-85 cultivar, all cultivars had plant heights higher than 80 cm. According to Kymäläinen et al. [13], depending on the environment and growing conditions, plant heights vary between 25-80 cm in oil-type linseed and 80-120 cm in fibre-type. It was concluded that the Sarı-85 cultivar, with its 76.90 cm plant height, showed the lowest plant height value and represented oil-type character since it was much shorter than the other oil type linseed cultivars. The highest plant height was observed in NewTurk cultivar with 102.07 cm (Table 2).

According to Aydın [2], the plant height values obtained by planting the same cultivars in Eskişehir conditions differed between cultivars. While this supports our work on the diversity of cultivars, the variations that occurred were different from each other. Similarly, there are studies reporting that different linseed genotypes show statistically significant differences in plant heights [2, 16, 17, 18, 19]. However, plant height values in the mentioned studies are considerably lower than the values in this study. This situation can be explained by the different day length, precipitation regime and other ecological conditions of this study. The reason is that linseed does not tend to bloom in short day conditions [1], maintains vegetative growth and increases in its plant height. Indeed, Kurt et al. [20] obtained plant heights in the range of 78.50-97.08 cm in their study to determine the winter cultivars suitable for Samsun ecological conditions.

***Table 2.** Mean values of some yield parameters of linseed cultivars*

Cultivar	Plant Height (cm)	First Branch Height (cm)	Number of Branch (unit plant^{-1})	Number of Boll (unit plant^{-1})	Seed Yield (kg da^{-1})
Clli 1423	87.90±1.55 ^{abc}	68.60±1.73 ^{ab}	6.40±0.38 ^{b}	20.47±0.39 ^{b}	147.78±21.37 ^{abc}
Larkana	95.10±1.57 ^{ab}	70.70±2.34 ^{ab}	5.53±0.28 ^{b}	20.00±1.60 ^{b}	162.53±29.3 ^{ab}
Milas	96.13±0.75 ^{ab}	73.23±1.72 ^{ab}	5.73±0.09 ^{b}	20.57±2.40 ^{b}	172.92±24.51 ^{a}
NewTurk	102.07±3.89 ^{a}	80.77±3.68 ^{a}	6.23±0.29 ^{b}	22.73±1.42 ^{b}	98.19±3.25 ^{cd}
Dillman	82.60±3.08 ^{bc}	62.27±4.45 ^{bc}	5.67±0.24 ^{b}	18.90±1.68 ^{b}	146.94±40.63 ^{abc}
Sarı-85	76.90±2.40 ^{c}	52.17±3.58 ^{c}	8.63±0.46 ^{a}	46.22±6.44 ^{a}	58.33±0.42 ^{d}
Clli 1351	92.87±2.18 ^{ab}	73.20±3.10 ^{ab}	5.60±0.25 ^{b}	16.87±2.68 ^{b}	111.25±16.08 ^{bcd}
Clli 1370	94.13±4.07 ^{ab}	74.67±1.80 ^{ab}	5.80±0.30 ^{b}	19.67±1.64 ^{b}	141.53±22.44 ^{abc}
Clli 1400	90.37±2.44 ^{abc}	69.20±3.38 ^{ab}	5.97±0.43 ^{b}	17.80±0.45 ^{b}	125±14.33 ^{abc}
Clli 1412	92.53±4.14 ^{ab}	70.07±3.20 ^{ab}	5.57±0.19 ^{b}	22.10±2.26 ^{b}	129.58±25 ^{abc}
F	6.71 ***	6.82 ***	12.60 ***	11.84 ***	2.56 *
LSD	15.32	16.40	1.46	13.71	56.34
SEM	1.46	1.58	0.18	1.65	8.32
Coef.Var.	8.8	12.43	16.42	40.16	34.00

*: p<0.05. ***: p<0.001

The first branch height refers to the technical stem length from which the fibres are obtained in fibre-type and this value shows a high correlation with fibre length, fibre fineness, fibre ratio and fibre yield [2, 21]; it shows a high correlation with seed yield in oil-type [22]. In many studies, fruiting zone length was mentioned by subtracting the technical stem length from the plant height, and Kulpa and Danert [23] easily categorized linseed as fibre-type, oil-type and both purposes by proportioning this value to plant height.

When the results of the analysis of variance were examined, the difference between the cultivars in terms of first branch height was found to be statistically significant. The highest first branch height was recorded in cv. NewTurk (80.77 cm) and the lowest in cv. Sarı-85 (52.17 cm). Plant height had an effect on the first branch height [17] and the first branch heights showed parallelism with the plant heights (Figure 2). However, Larkana and Milas cultivars, which have higher plant heights, have lower first branch heights compared to cv. Clli 1370. The same situation emerges as a result of comparing the Larkana and Milas cultivars with the Clli 1351 cultivar when examined proportionally. This can be explained by categorizing the cultivars according to Kulpa and Danert [23], resulting from the genotype of the plant. In other studies, significant differences in the first branch height of the linseed genotypes were stated [2, 16, 17, 18, 19]

Branching in linseed is a desirable character for seed yield. The reason is that the branches end with boll and a significant correlation has been reported between the number of branch and the number of boll and seed yield [2]. When the results of the analysis of variance were examined, the differences between the cultivars in terms of number of branch were significantly different. While the highest number of branch (8.63 unit plant^{-1}) was observed in the cv. Sarı-85, this cultivar showed that it was superior to the others in this regard. Differences among other cultivars were non-significant, and they were all included in the same group (Table 2). The lowest number of branch was in cv. Larkana with 5.53 plant^{-1}.

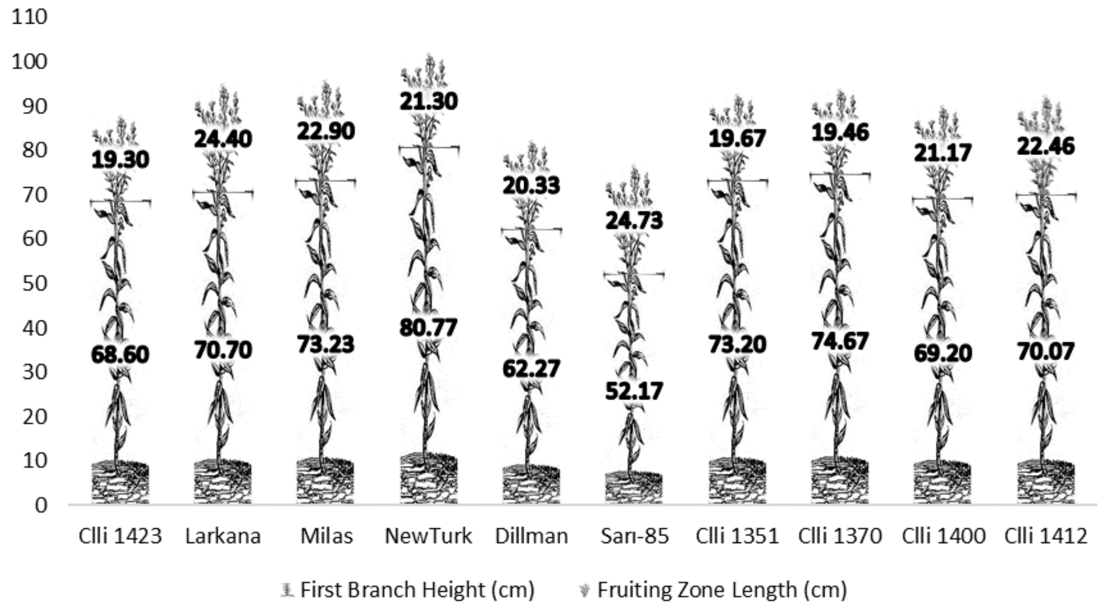

Fig. 2. *First branch height and fruiting zone length of linseed cultivars*

Aslan and Sarıhan [19] reported that 21 linseed genotypes formed 7 statistical groups in terms of the number of branch, and the highest branch number value belonged to 7.7 unit plant^{-1} and Sarı-85 cultivar. On the other hand, Örs and Öztürk [18] stated the superiority of the cv. Sarı-85 in terms of the number of side branch among 13 linseed cultivars. Similarly, in other research the number of branch in linseed were significantly different among genotypes [2, 16, 17].

Boll/capsule are the names given to the fruits that contain seeds in linseed. The branches usually end with a boll, but since the flowering and fruit formation period is long in this plant, the vegetation period of the plant may not be sufficient for boll formation and/or maturation in all branches. The number of boll has a linear relationship with the seed yield per plant [2, 16].

When the variance analysis results were examined, the differences between the cultivars in terms of the number of boll were significantly different. While the cv. Sarı-85 had the highest boll number with 46.22 unit plant^{-1}, the differences between the other cultivars did not produce significant results. The lowest boll number value was recorded with 16.87 unit plant^{-1} in cv. Clli 1351. Except for the cv. Sarı-85, there was no variation in the number of boll, and the cultivars were in the same statistical group (Table 2). This is due to the genetic structure of the Sarı-85 cultivar, as well as the inability to reach the desired plant density in this cultivar. Berglund and Zollinger [24] stated that the seedling viability of linseed with yellow seeds was low. On the other hand, according to Gabiana [25], the number of boll increases as the plant density decreases in linseed. While some studies show that the number of boll is affected by the genotype [18, 19], there are also studies reporting results to the contrary [2, 16, 20].

According to the results obtained in this study, the differences between the cultivars used in terms of seed yield were significantly different. While the highest seed yield was 172.92 kg da^{-1} in cv. Milas, the lowest seed yield was 58.33 kg da^{-1} in cv. Sarı-85. Some researchers stated that the difference between genotypes in terms of seed yield is statistically significant in their studies [2, 16, 17, 18, 19]. Kurt et al. [20] obtained a high variation (109.67-263.67 kg da^{-1}) among genotypes in winter sowing, but these differences were found to be statistically insignificant.

Seed number per boll, boll number per plant and seed weight are important factors that make up the seed yield. For high seed yield, the number of seeds in boll is as important as the number of boll per plant. As a result of the analysis of variance, it was revealed that the differences between the cultivars in terms of the seed number per boll were statistically non-significant (Table 3). The lowest value in terms of seed number per boll was observed in cv. NewTurk with 7.33 unit boll^{-1}, and the highest value was observed in Dillman and Clli 1400 cultivars with 8.63 unit boll^{-1}. While there are studies reporting that the seed number per boll is affected by the genotype [2, 18, 19], there are also studies with opposite results [16, 20]. Tunçtürk [17] did not find statistically significant differences in the seed number per boll among cultivars in 2002 under Van ecological conditions, but reported that this difference was significant in 2003. For this reason, it was concluded that the differences in the seed number per boll may vary according to the genotype, ecological conditions and cultivation practices.

Table 3. *Mean values of some yield parameters of linseed cultivars*

Cultivar	Seed Number per Boll (unit boll^{-1})	1000 Seed Weight (g)	Biological Yield (kg da^{-1})	Straw Yield (kg da^{-1})	Harvest Index (%)
Clli 1423	7.67±0.34	5.82±0.06	916.67±83.10	768.89±80.31	16.25±2.27
Larkana	7.90±0.46	5.44±0.50	901.39±104.21	738.85±80.68	17.92±1.75
Milas	8.03±0.23	5.60±0.26	957.64±80.46	784.72±56.66	17.87±1.23
NewTurk	7.33±0.37	5.67±0.40	924.31±164.36	826.11±161.33	11.13±1.43
Dillman	8.63±0.50	5.58±0.09	818.06±156.99	671.11±116.4	17.17±2.06
Sarı-85	8.60±0.23	5.32±0.16	418.75±154.17	360.42±154.58	16.16±6.05
Clli 1351	8.30±0.12	5.56±0.12	800.00±105.76	688.75±94.71	14.05±1.41
Clli 1370	8.03±0.23	5.59±0.07	851.39±140.44	709.86±118.17	16.66±0.28
Clli 1400	8.63±0.47	5.60±0.02	842.36±134.23	717.36±121.15	15.07±0.92
Clli 1412	8.20±0.26	4.94±0.38	750.00±94.84	620.42±76.00	17.13±1.83
F	1.57 ns	0.83 ns	2.09 ns	1.82 ns	1.07 ns
LSD					
SEM	0.12	0.08	40.41	34.82	0.63
Coef.Var.	7.95	7.99	26.16	26.79	21.30

ns: non-significant

As an indicator of seed size, thousand-grain weight is an important yield factor, especially for plants that benefit from seeds. Aydın [2] and Çopur et al. [26] reported significant correlations between 1000 seed weight and seed yield. It was concluded that the differences among the cultivars used in this study in terms of 1000 seed weight were statistically non-significant (Table 3). The lowest 1000 seed weight was 4.94 g in Clli 1412 cultivar, and the highest value was 5.82 g in Clli 1423 cultivar. According to some research there were statistically significant differences among genotypes in terms of 1000 seed weight [2, 16, 17, 18, 19], but Kurt et al. [20] reported that 1000 seed weight values varying between 3.71-6.40 g did not create statistically significant differences.

Biological yield is obtained as a result of harvesting and weighing the above-ground parts of linseed. Whether the biological yield is high or low has varying degrees of importance in *Linum usitatissimum* according to the production purpose. Biological yield, especially for harvests made before seed maturation, is much more closely related to stalk yield and therefore fibre yield, but it would be more accurate to examine this value together with the harvest index in oil type.

Considering the results of variance analysis, there was no statistically significant difference in biological yield among linseed cultivars (Table 3). The lowest biological yield was 418.75 kg da^{-1} in cv. Sarı-85, and the highest biological yield was 957.64 kg da^{-1} in Milas cultivar. Aydın [2] and Yıldırım [16] mentioned the statistical importance of genotypic differences in terms of biological yield, but the general average of biological yield values seen in these studies was found to be quite low compared to that of our study (279.70 and 347.16 kg da^{-1}, respectively). It can be argued that these differences are the result of the fact that our study was carried out in winter in the ecological conditions of the Amik Plain, where the Mediterranean climate is dominant. The reason is that linseed, which does not tend to bloom in short day conditions [1], will continue its vegetative growth and reach higher plant height, technical stem length and therefore higher biological yield values.

Straw yield is an important yield component especially in fibre-type linseed, but Aydın [2] reported a high linearity between straw yield and seed yield. This is sufficient to explain that straw yield is also a yield component in oil type. The differences between the stem yield values varying between 360.42 and 826.11 kg da^{-1} were found to be statistically non-significant (Table 3). On the contrary, according to Aydın [2] and Yıldırım [16], it has been reported that the variations with less straw yield among different genotypes are statistically significant. Straw yield is much more considerable in fibre production.

Harvest index is a yield component obtained by the ratio of seed yield to biological yield. The differences among the cultivars in terms of harvest index were found to be statistically non-significant (Table 3). The lowest harvest index value was recorded in cv. NewTurk with 11.13%, and the highest was in Larkana cultivar with 17.92%. It is a desirable character to have a high harvest index in all plants produced for seed purposes.

CONCLUSION

When all the results for seed yields were evaluated, cv. Sarı-85 and cv. NewTurk gave lower results than others. However, it was concluded that NewTurk cultivar may be suitable for fibre production in regional conditions with its high plant height (102.07 cm), technical stem length (80.77 cm) and straw yield (826.11 kg da^{-1}). Milas cultivar, on the other hand, was determined as the most promising cultivar for production for both purposes, with the highest seed yield (172.92 kg da^{-1}), as well as a remarkable plant height (96.13 cm), first branch height (73.23 cm) and straw yield (784.72 kg da^{-1}). When the results of the study were evaluated according to Kulpa and Danert [19], it was revealed that there was no oil-type cultivar, and all cultivars were suitable for both purposes. According to this scale, Clli 1370 was the closest to fibre-type, and Sarı-85 was the closest to oil-type. The results were found to be positive for this plant production for both purposes, although it is required that other studies examine fibre yields in Amik Plain conditions.

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Conflict of Interest. "The authors declared that there is no conflict of interest."

Authorship Contributions. Concept: Y.Z.A., M.M., Design: Y.Z.A., M.M., Data Collection or Processing: Y.Z.A., M.M., Analysis or Interpretation: Y.Z.A., M.M., Literature Search: Y.Z.A., M.M., Writing: Y.Z.A., M.M.

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