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Evaluation of Earliness and Yield-Related Traits in Advanced Cotton Cultivars (*Gossypium Hirsutum* L.)

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ABSTRACT

Cotton is an important fiber crop and used to produce fibers and oil. Evaluating morphologic traits of cotton is very important and can be used for the selection of better cultivars. This study was conducted in the Moghan Agricultural Research Station affiliated with the Ardabil Agricultural and Natural Resources Research and Training Center, Iran. In this study, 35 cultivars of cotton were evaluated for fiber-and yield-related traits during two consecutive years. We found that fiber quality and seed cotton traits were significantly affected by plots and cultivars over two years. Among the cultivars, the highest number of the bolls, boll weight, first picking yield, total yield, fiber strength, fiber traction, and fiber percentage were 24.5 g, 6.30 g, 3454 kg/ha, 5431 kg/ha, 34.5 g/tex, 7.30%, and 45.80% observed in cultivar Shayan, while the second picking yield, earliness percentage, and fiber fineness were 2323.3 kg/ha, 73.5%, and 4.55 µg/in obtained in cultivars Varamin, Avangard, and Armaghan, respectively. Based on the ward's cluster analysis, the cotton cultivars were grouped into three different clusters. The cultivars in Cluster 3 including Nazilli, No.228, No.200, B557, Armaghan, Golestan, and Shayan are superior in terms of their number of the boll, boll weight, earliness percentage, fiber percentage, fiber length, fiber fineness, fiber strength, fiber traction, and yield performance.

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1-Introduction

Cotton (*Gossypium hirsutum* L.) has been cultivated in different countries of the world for thousands of years, and its fiber is used in the textile industry to produce clothes and its seeds are used to make oil [1]. Cotton is known as white gold because of its importance and one of the main factors in increasing the national economy and is a strategic approach to prevent poverty. Although there are different cotton genotypes around the world, there is no comprehensive information about their genetic diversity, heritability, and morphological characteristics [2-3]. In many countries, the quality of fiber and seed yield of cotton is low and the main goal is to increase these properties. Therefore, selecting superior lines with an appropriate genetic complement can be helpful. Given the importance of cotton and the increasing demand, it is necessary to provide cotton varieties with high quality fibers and yields [4].

Many producers are dependent on cotton, and irreparable damage will result if production is significantly reduced. Therefore, it is necessary to provide figures that, in addition to meet a high demand, have the desired quality. Scientists have studied the genetic, physiological, and morphological factors that affect performance and have identified various characteristics [5]. Morphological and physiological features are used for classical selection. For example, plant height plays an important role in the sustainable management of cotton pests, assessing the diversity, and heritability of this trait may be essential to ensure its stability. Assessing genetic diversity is the first step in selecting parents to produce suitable genotypes [2].

The phenotypic properties of the plant are influenced by the interaction of genotype and environment. Therefore, it is important to investigate the cause of genetic and environmental changes [6-7]. The yield of cotton seeds depends on various morphological features and is affected by them [8-9]. Various researchers have reported that cotton yields have a high heredity and its evaluation along with phenotypic and genotypic variance can be very beneficial [10-11]. Cotton genotypes have a limited genetic basis that limits genetic diversity and access to alleles. In previous studies, the genetic diversity of different cotton genotypes in terms of morphology and fiber quality has been investigated and showed that domesticated cotton has few genetic polymorphisms [12-14]. To improve yield and identify desirable genotypes, a variety of cotton germplasm can be used. Therefore, various traits such as fiber quality and seed quality are used. These qualitative traits are called morphological markers that are stable in different environments and are reliable [15-16]. To use genetic resources and determine evolutionary relationships, it is essential to determine the genetic diversity. Investigating changes in morphological features in different germplasms is a key tool. Accurate assessment of genetic diversity of cotton genotypes, parental selection, estimation of heritability, and heterosis is very important [17-14]. According to the importance of cotton, the present study was conducted to investigate the difference of 35 cultivars of cotton in terms of fiber and yield traits and selecting the superior cultivar.

2-Materials and Methods

2-1- Plant material and field trials

This study was conducted in the Moghan Agricultural Research Station affiliated with the Ardabil Agricultural and Natural Resources Research and Education Center, located in the north of Ardabil province in Iran. The seeds of 35 cultivars of cotton including Sk-G (A-14), 4-s-4, Armaghan, Avangard, B557, Bakhtegan, BC244, Beliizov, GKTB113, Golestan, K8801, K8802, Khordad, Khorshid, Latif, Mehr, N2G80, Nazilli, No.200, No.228, NSK847, NSKB23, O10, Oltan, Opal, Sahel, Sajedi, Shayan, Shirpan533, Shirpan6.3, SKSH249, SKT133, Tabladil, Tashkand, and Varamin of cotton obtained from Cotton Research Institute. In the winter of the first (2018) and the second year (2019), the land was plowed for the first time. The second plowing was done in the spring and the disc and trowel were used. The 200 kg/ha urea fertilizer and 200 kg/ha ammonium phosphate fertilizer were added to the land and the second disc was applied. Before planting, 3 L/ha Sonalan (Giah company,Iran) herbicide was used, and finally farrowing and planting operations were performed.

2-2- Data collection

At crop maturity, the data for eleven traits were recorded including the number of the bolls, boll weight, the first and the second picking yield, total yield, earliness percentage, fiber fineness, fiber strength, fiber traction, and fiber percentage.

2-3- Cluster analysis

Cluster analysis was performed by Ward's method to create a dendrogram and grouped the cultivars based on yield, fiber, and morphological traits.

2-4- Statistical analysis

The analysis of variance of collected data from the two years was performed as and factorial experiment based on a randomized complete plot design with three replicates. The years and cultivars were used as factors. The means were compared by using Duncan's multiple range test at 5% probability with IBM SPSS 26.0 statistical software [9].

3-Results

3- 1- Number of the bolls

Compared with other traits, the number of the bolls is highly correlated with a high yield. Cotton grain yield is also directly related to the number of the bolls. The ANOVA results showed that plot, year, cultivar, and interactions of year and cultivar had a significant effect on the number of the bolls (Table 1). The results revealed that there was non-uniformity in the field and the first plot had more bolls than the second and third plots. The number of the bolls in the first plot was 20.8, which was 1.06- and 1.02-fold higher than the second and the third plots (Figure 1a). In the first year of cultivation, the number of the bolls was 1.10-fold higher than the second year (Figure 2a). According to the variation between cultivars, the number of the bolls ranges varied from 17.8 to 24.5, where cultivar Shayan followed by Bakhtegan, Sahel, and Varamin displayed the maximum amount of the number of the bolls while cultivars N2G80 and Shirpan533 revealed the lowest number of the bolls (Figure 3a). In general, the highest number of the bolls was obtained in the second year of cultivation of cultivar Shayan which was 1.33-fold higher than the first year (Table 2).

3-2- Boll weight

The boll weights of cultivars were recorded at crop maturity. The ANOVA analysis results demonstrated that the plot, year, and cultivar had a significant effect on boll weight (Table 1). Like the number of the bolls, in the boll weight in the first plot had more boll weight compared with the other plots, which was 1.08- and 1.06-fold higher than the second and the third plots, respectively (Figure 1b). Likewise, in the second year, the boll weight was significantly lower than the first year (Figure 2b). The average boll weight for each cultivar is depicted in Figure 1b. The best bolls weight was 6.30 g in cultivar Shayan followed by Golestan (6.00 g). The boll weights of these two cultivars were statistically significant. The data showed that the lowest mean bolls weight was obtained in cultivar Shirpan 6 (4.60 g) followed by 4.70 g in cultivar Shirpan533. Therefore, the boll weight in cultivar Shayan was 1.37-fold higher than the cultivar Shirpan 6 (Figure 3b).

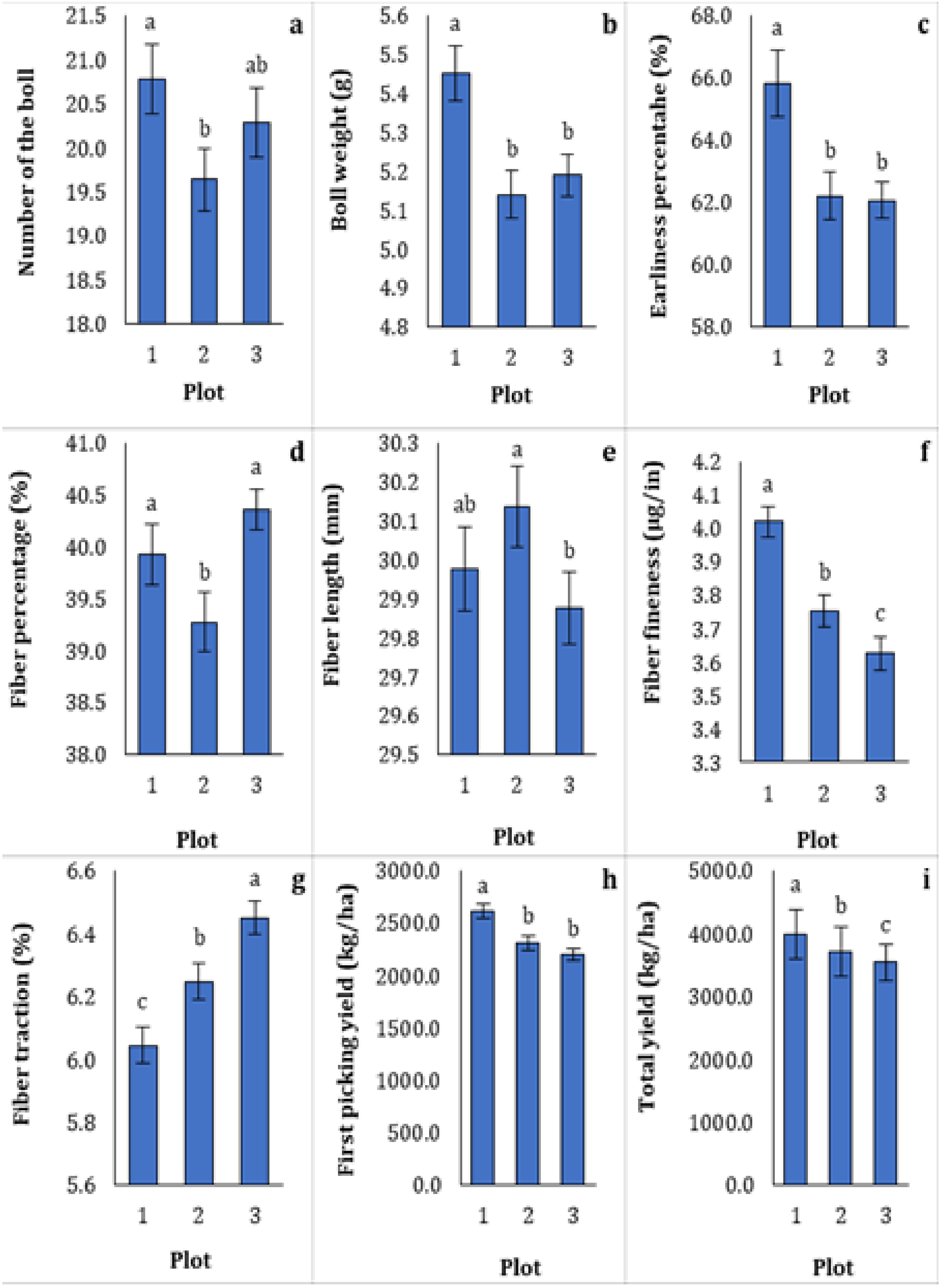

Fig. 1. Effect of plot on number of the bolls (a), boll weight (b), earliness percentage (c), fiber percentage (d), fiber length (e), fiber fineness (f), fiber traction (g), first picking yield (h), and total yield (i) in cotton culture

Table 1. ANOVA analysis of yield, fiber, and morphological traits of different cultivars of cotton

S.O.V	Df	Mean of Square										
		No. of the bolls	Boll weight	Earliness percentage	Fiber percentage	Fiber length	Fiber fineness	Fiber strength	Fiber traction	First picking yield	Second picking yield	Total yield
Plot	2	22.976*	1.958**	314.600**	20.869**	1.228**	2.835**	2.680^{ns}	2.881**	3218927.92**	47404.75^{ns}	3508183.56**
Year	1	202.076**	1.962**	0.012^{ns}	8.280^{ns}	4.032**	0.091^{ns}	5.217^{ns}	0.139^{ns}	17811.22^{ns}	20424.01^{ns}	76381.07^{ns}
Cultivar	34	12.875*	0.816**	150.130**	17.186**	3.232**	0.486**	21.896**	0.879**	1144230.42**	626031.58**	2545652.63**
Cultivar × Year	34	13.831**	0.154^{ns}	6.653^{ns}	1.369^{ns}	0.111^{ns}	0.056^{ns}	1.614^{ns}	0.032^{ns}	11490.73^{ns}	19696.26^{ns}	28568.57^{ns}
Error	138	7.377	0.144	33.519	2.724	0.239	0.112	3.570	0.105	143634.19	62699.207	194126.70
CV%		13.42	7.21	9.14	4.14	1.63	8.80	6.75	5.18	15.93	18.23	11.74

Table 2. Effect of year and cultivar interaction on number of boll in cotton culture

Year	Cultivar	No. of boll	Year	Cultivar	Number of boll
First	(A-14) S	21.67 ± 3.06 $^{b-j}$	Second	(A-14) S	16.00 ± 1.00 ^{jk}
	4-s-4	20.00 ± 3.00 $^{b-k}$		4-s-4	17.67 ± 2.08 $^{f-k}$
	Armaghan	19.67 ± 0.58 $^{b-k}$		Armaghan	19.67 ± 3.79 $^{b-k}$
	Avangard	21.33 ± 2.08 $^{b-j}$		Avangard	20.00 ± 4.36 $^{b-k}$
	B557	22.00 ± 2.00 $^{b-i}$		B557	19.67 ± 1.53 $^{b-k}$
	Bakhtegan	24.67 ± 3.21 ^{abc}		Bakhtegan	20.67 ± 5.03 $^{b-k}$
	BC244	21.67 ± 5.03 $^{b-j}$		BC244	18.67 ± 5.03 $^{d-k}$
	Beliizov	21.00 ± 1.00 $^{b-k}$		Beliizov	16.33 ± 1.15 ^{ijk}
	GKTB113	22.67 ± 1.53 $^{b-h}$		GKTB113	20.00 ± 0.00 $^{b-k}$
	Golestan	20.33 ± 4.04 $^{b-k}$		Golestan	23.00 ± 3.61 $^{a-g}$
	K8801	21.33 ± 1.15 $^{b-j}$		K8801	18.67 ± 2.31 $^{d-k}$
	K8802	20.33 ± 3.06 $^{b-k}$		K8802	19.33 ± 0.58 $^{b-k}$
	Khordad	23.00 ± 2.65 $^{a-g}$		Khordad	20.33 ± 1.53 $^{b-k}$
	Khorshid	19.67 ± 2.52 $^{b-k}$		Khorshid	16.33 ± 2.08 ^{ijk}
	Latif	21.67 ± 4.73 $^{b-j}$		Latif	20.00 ± 3.61 $^{b-k}$
	Mehr	21.33 ± 0.58 $^{b-j}$		Mehr	20.33 ± 2.08 $^{b-k}$
	N2G80	17.67 ± 3.21 $^{f-k}$		N2G80	18.00 ± 2.65 $^{f-k}$
	Nazilli	20.00 ± 4.00 $^{b-k}$		Nazilli	20.33 ± 0.58 $^{b-k}$

No.200	20.33 ± 3.51 b-k	No.200	20.33 ± 2.08 b-k
No.228	21.33 ± 3.21 b-j	No.228	20.00 ± 1.00 b-k
NSK847	21.00 ± 3.61 b-k	NSK847	18.33 ± 1.53 e-k
NSKB23	19.00 ± 1.00 c-k	NSKB23	18.00 ± 1.00 f-k
O10	22.00 ± 3.46 b-i	O10	18.00 ± 2.65 f-k
Oltan	22.33 ± 4.04 b-h	Oltan	16.00 ± 1.73 jk
Opal	24.00 ± 2.65 a-e	Opal	18.33 ± 2.52 e-k
Sahel	23.33 ± 1.15 a-f	Sahel	21.33 ± 1.53 b-j
Sajedi	19.33 ± 0.58 b-k	Sajedi	20.00 ± 1.00 b-k
Shayan	21.00 ± 3.61 b-k	Shayan	28.00 ± 1.00 a
Shirpan5	18.67 ± 1.53 d-k	Shirpan533	17.00 ± 0.00 h-k
Shirpan6	25.00 ± 3.61 ab	Shirpan603	15.33 ± 1.53 k
SKSH249	18.67 ± 4.04 d-k	SKSH249	18.33 ± 2.08 e-k
SKT133	20.33 ± 6.11 b-k	SKT133	19.33 ± 4.04 b-k
Tabladil	22.67 ± 0.58 b-h	Tabladil	17.33 ± 0.58 g-k
Tashkand	23.33 ± 3.06 a-f	Tashkand	19.00 ± 1.73 c-k
Varamin	20.33 ± 3.21 b-k	Varamin	24.33 ± 1.53 a-d

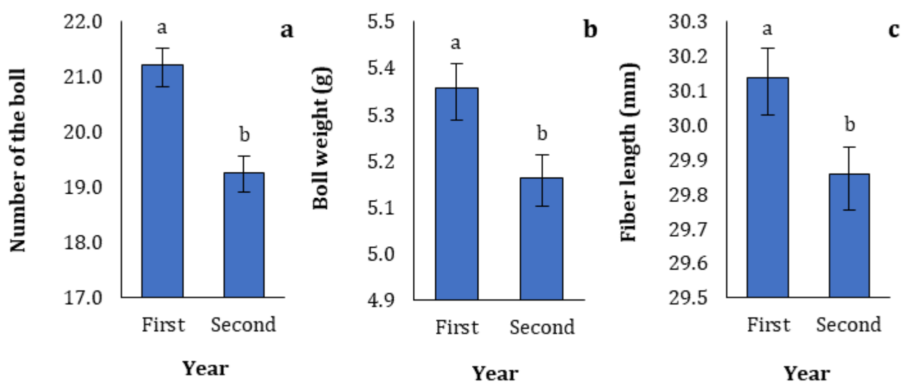

Fig. 2. Effect of year on number of the bolls (a), boll weight (b), and Fiber length (c) in cotton culture

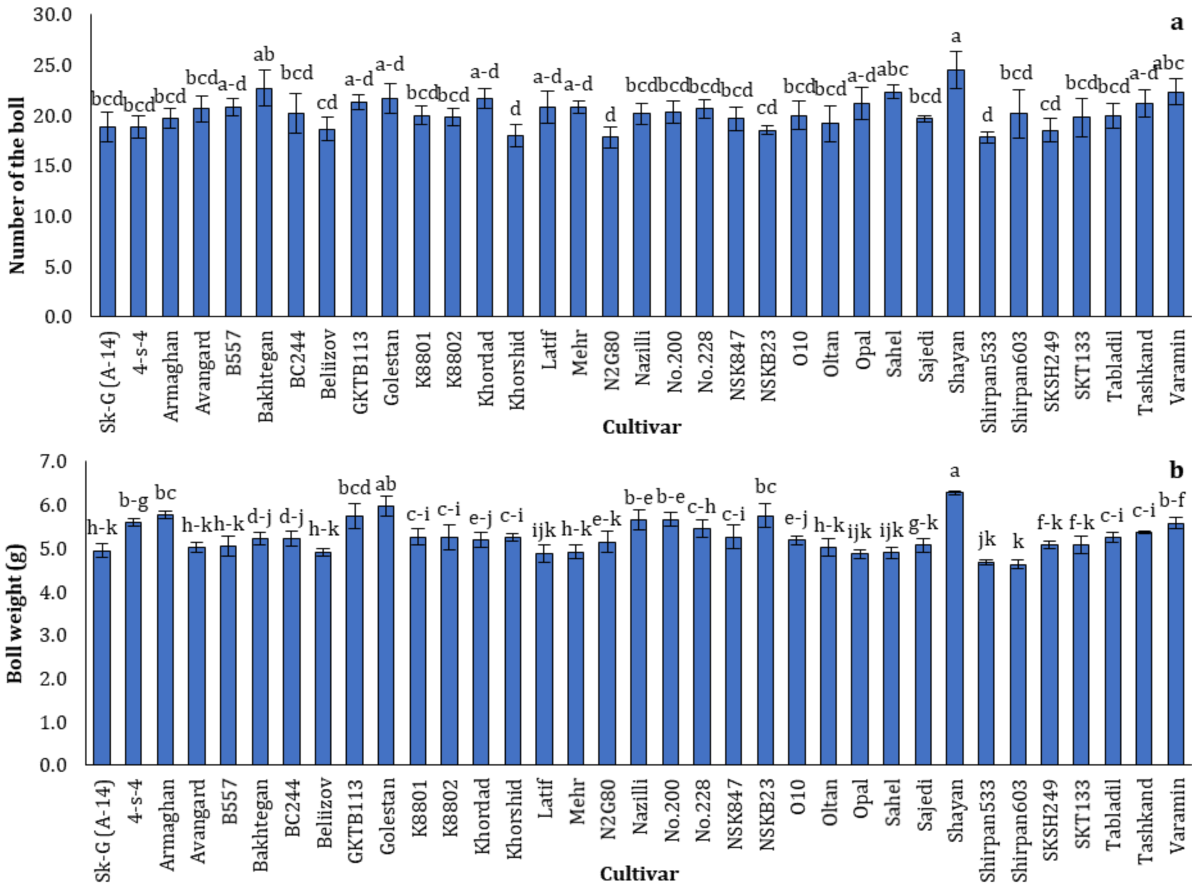

Fig. 3. Effect of cultivar on number of the bolls (a) and boll weight (b) in cotton culture

3.3- Earliness percentage

Based on ANOVA analysis results, the earliness percentage significantly affected by plot and cultivar (Table 1). Among the three plots used in this study, the first plot with 65.8 % has the highest earliness percentage which was 1.06- and 1.059-fold higher than the second and the third plots, respectively (Figure 1c). Among 35 different cultivars, the cultivar Avangard had the highest earliness percentage (73.5 %) followed by cultivars Opal and Oltan. Based on the results, the lowest earliness percentage was 46.4% was seen in cultivar Varamin. Statistically, there were significant differences in cultivar Avangard and other cultivars genotypes in terms of earliness percentage (Figure 4a).

3-4- Fiber percentage

The fiber percentage is a polygenic trait and is affected by environmental conditions. The fiber percentage highly depends on fiber weight and affected seed yield. ANOVA results revealed significant differences among the plots and cultivars (Table 1). The third plot showed the highest fiber percentage followed by the first plot. However, these two plots were not statistically significant difference. In the third plot, the fiber percentage was 40.4 % (Figure 1d). Furthermore, it was observed that the cultivar Shayan gave the significantly highest fiber percentage (45.80 %) followed by Sahel (43.40 %), while cultivar K8802 gave the lowest fiber percentage (36.90%). The present results indicated that cultivars Shayan and Sahel could be utilized in the breeding program to improve the fiber percentage (Figure 4b).

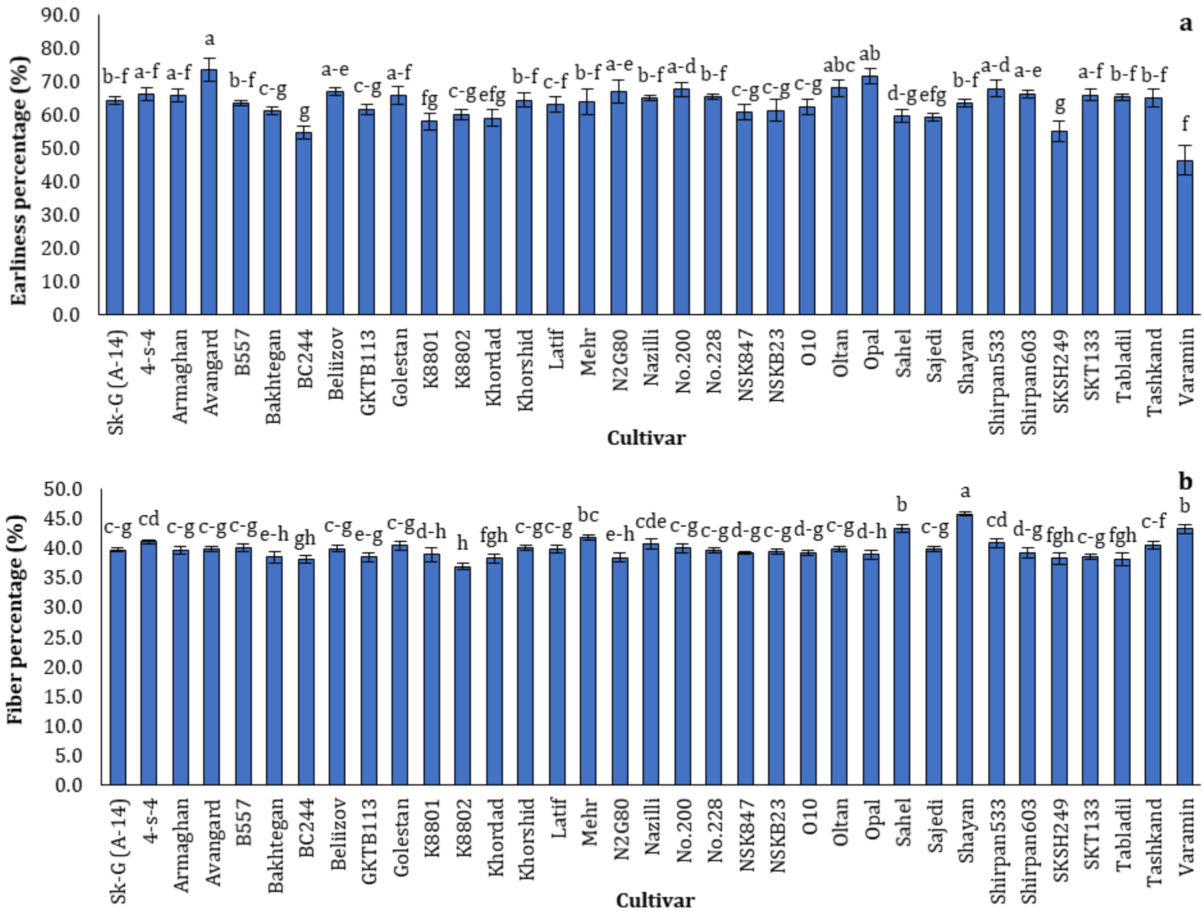

Fig. 4. Effect of cultivar on Earliness percentage (a) and fiber percentage (b) in cotton culture

3-5- Fiber length

Length is one of the most important properties of cotton fiber. Longer fiber is finer and stronger than a shorter fiber. The fiber length depends on genetic factors and determines the textile processing conditions. The results indicated that the plot, year, and cultivar had a significant effect on fiber length. Based on the results, the second plot produced the highest fiber length (30.10 mm) which was 1.003- and 1.04-fold higher than the first and third plots, respectively (Figure 1e). Moreover, the first year showed higher fiber length (30.10 mm) compared with the second year (29.90 mm). This difference among the years was statistically significant (Figure 2c). The overall length of fiber between different cultivars ranged from 29.10 mm to 32.20 mm. Cultivar Shayan showed maximum fiber length as compared with all other tested cultivars. Varamin, Armaghan, and Golestan have appropriate lengths in the range of 31.10-31.80 mm (Figure 5a).

3.6- Fiber fineness

The results showed that fiber fineness was significantly affected by plot and cultivar (Table 1). Between the three plots, the highest fiber fineness was 4.00 μg/in obtained in the first plot which was 1.05- and 1.11-fold higher than the second and third plots, respectively (Figure 1f). The results of fiber fineness of cultivar Armaghan showed 4.55 μg/in followed by Golestan. In addition, Cultivars Shayan, Nazilli, and Varamin have appropriate fiber fineness in the range of 4.19-4.42 μg/in (Figure 5b).

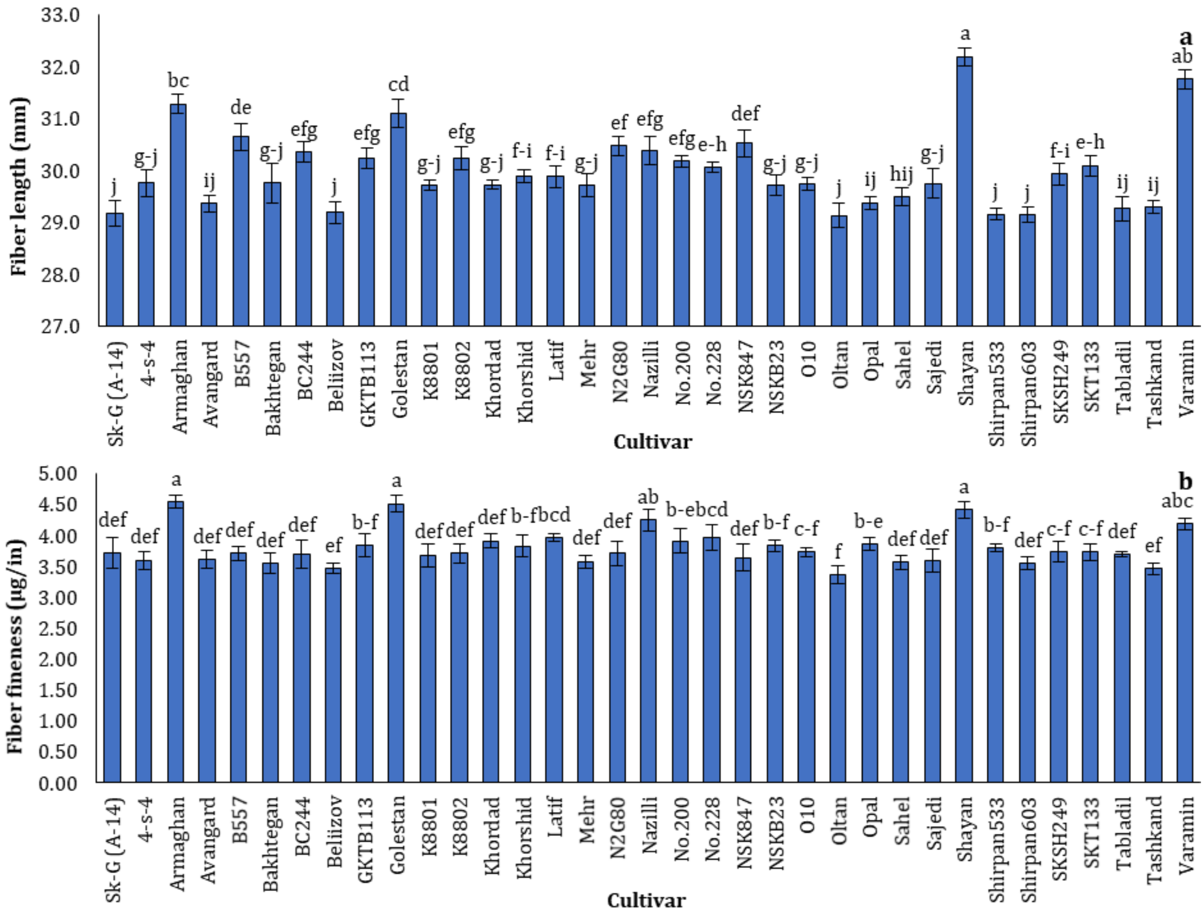

Fig. 5. Effect of cultivar on fiber length (a) and fiber fineness (b) in cotton culture

3.7- Fiber strength

Fiber strength is one of the main properties of cotton, which is shown by its ability to resist stretch. This trait is determined by cotton quality that should be of long-staple and is highly twisted. In this study, the fiber strength was determined for all 35 cultivars of cotton. ANOVA analysis showed that the fiber strength of cotton is dependent on the cultivar and various cultivars have different fiber strength (Table 1). The cultivar Shayan proclaimed 34.50 g/tex fiber strength. On the other hand, cultivars Golestan and Varamin fabricated 31.70 g/tex and 31.30 g/tex strength, respectively. The remaining cultivars were in the range of 25.02- 30.30 g/tex of fiber strength measures (Figure 6a).

3.8- Fiber traction

The results indicated that the plot and cultivars had a significant effect on fiber traction (Table 1). Among different plots, the maximum amount of fiber traction was 6.5% obtained at the third plot, which was 1.08- and 1.05-fold higher than the first and second plots (Figure 1g). The maximum fiber traction (7.30 %) was obtained in Shayan followed by 7.00 % in Varamin, while other cultivars followed in the range of 5.70 % to 6.80 %. The present results demonstrated that cultivar NSK847 produced 5.70 % fiber traction (Figure 6b).

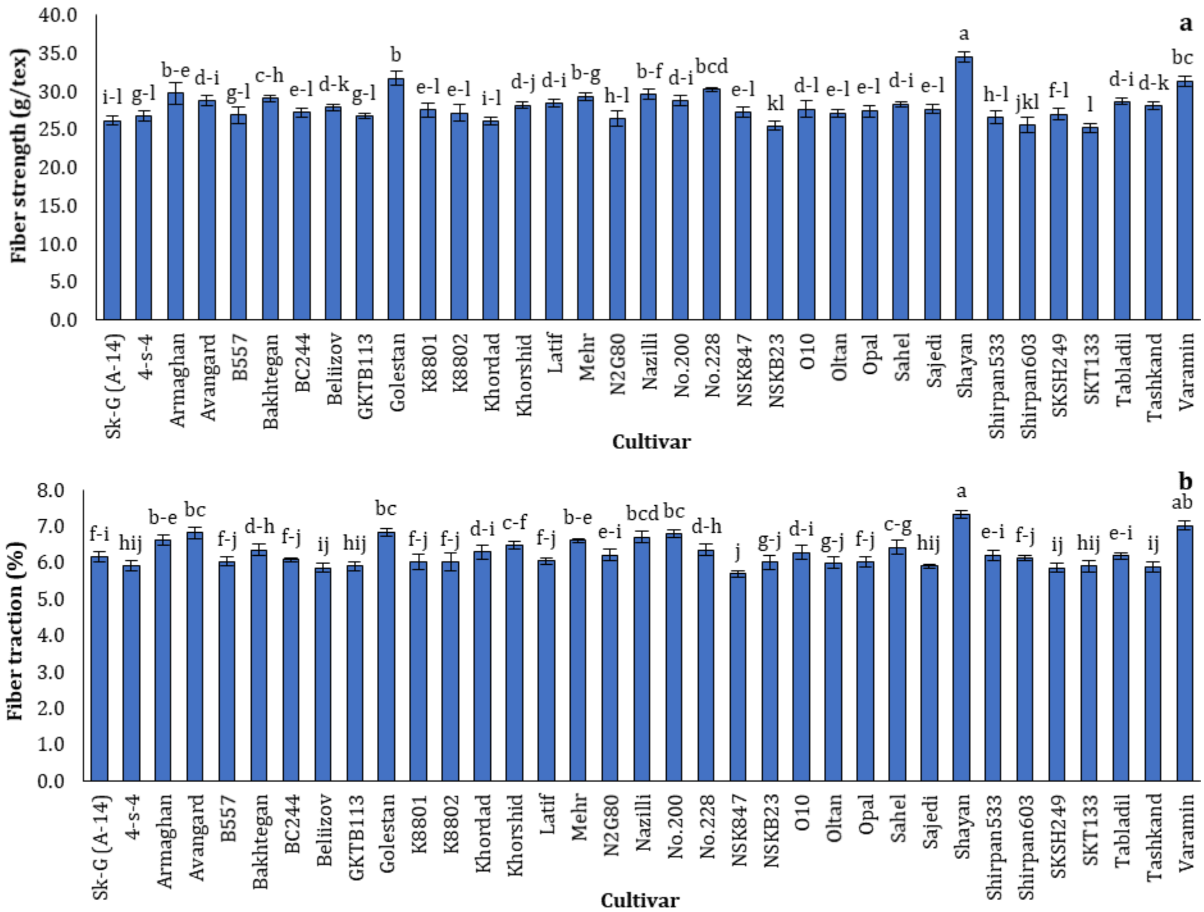

Fig. 6. Effect of cultivar on fiber strength (a) and fiber traction (b) in cotton culture

3.9- First picking yield

The results revealed that the first picking yield was significantly affected by field condition (Plot) and cultivar (Table 1). The first picking yield of all three plots was 2618 kg/ha, 2316.10 kg/ha, and 2203.20 kg/ha, respectively. Therefore, the highest first picking yield was obtained at the first plot which was 1.13- and 1.19-fold higher than the second and third plots (Figure 1h). The maximum first picking yield was measured by Shayan (3454 kg/ha) which was not significantly different with cultivar Armaghan with the first picking yield of 3301.30 kg/ha. In the other cultivars, the first picking yield was in the range of 1733.7 kg/ha to 3224 kg/ha. The lowest first picking yield was 1733.7 kg/ha observed in cultivar 4-s-4. (Figure 7a).

3.10- Second picking yield

The results indicated that the second picking yield significantly affected the cultivar (Table 1). The variation among cultivars regarding the second picking yield ranged 873.3 to 2323.3 kg/ha, while cotton cultivar Varamin presented the maximum (2323.3 kg/ha) for this feature, whereas cultivar Avangard displayed the lowest second picking yield (873.3 kg/ha) (Figure 7b).

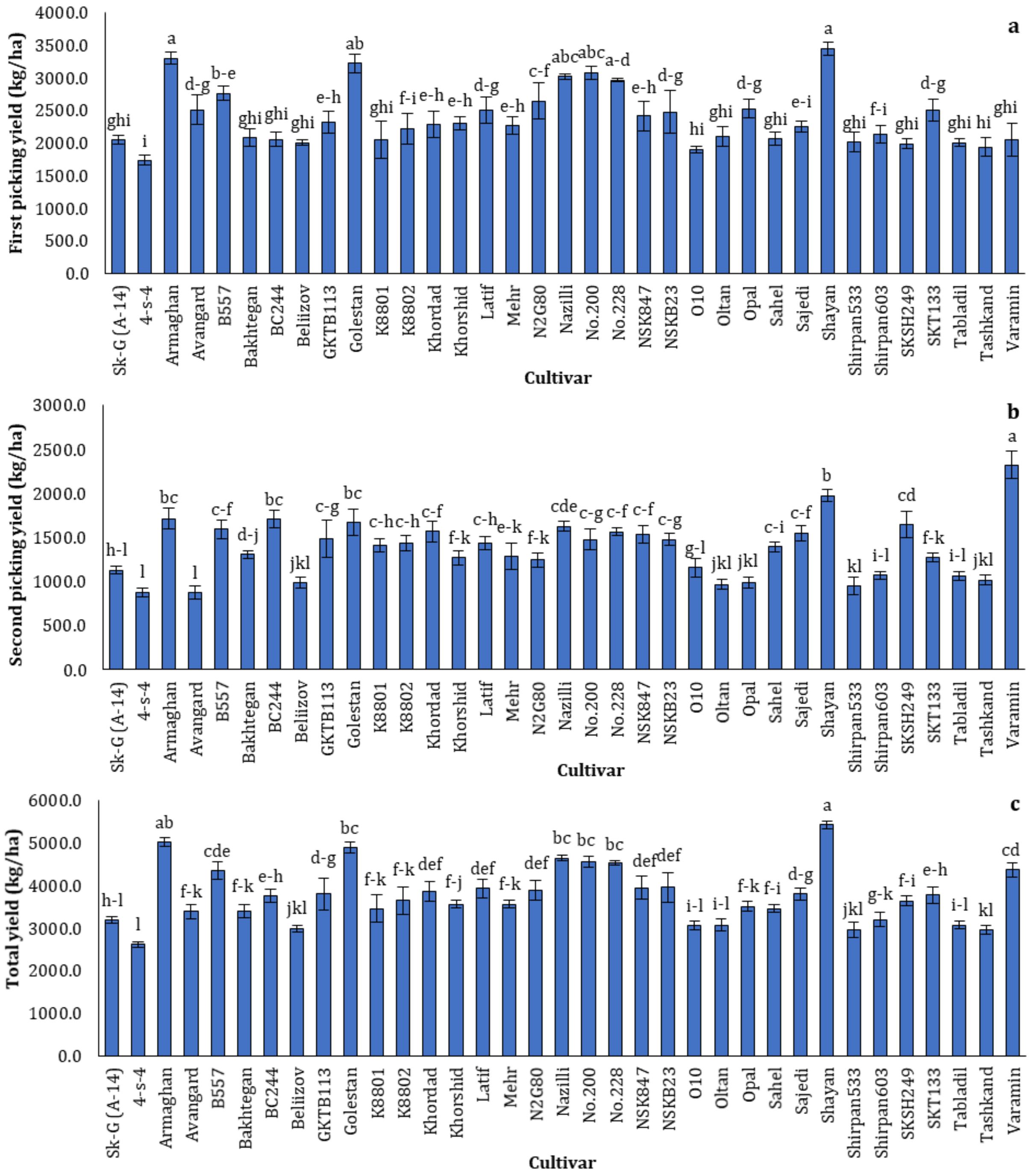

Fig. 7. Effect of cultivar on the first (a), and the second (b), as well as picking yield and total yield (c) in cotton culture

3.11- Total yield

In this study, the total yield is significantly affected by plots and cultivars (Table 1). The maximum total yield obtained in the first plot which was 1.04- and 1.12-fold higher than other plots, respectively (Figure 1i). The studied cultivars unfold a range of variation for total yield in kg/ha, and minimum to maximum yield were 2613.2 to 5431 kg/ha, respectively. This indicates that the total yield has reasonable diversity among the studied cultivars, where the cultivar Shayan expressed the highest yield

(5431 kg/ha) followed by Armaghan (5016.5 kg/ha) and Golestan (4898.5 kg/ha), while the cotton cultivar 4-s-4 revealed the minimum yield (Figure 7c).

3.12- Cluster analysis

Ward's cluster analysis was performed for the classification of different cotton cultivars used in this study. A dendrogram from cluster analysis of 35 cultivars based on yield, fiber, and morphological traits was drawn (Figure 8). Based on this classification, cotton cultivars were grouped into three different clusters. In the first cluster, there were nineteen cultivars including K8801, Sahel, Bakhtegan, Khorshid, Mehr, K8802, BC244, SKSH249, Avangard, Opal, N2G80, SKT133, Khordad, Sajedi, GKTB113, Latif, NSKB23, NSK847, and Varamin, while cluster two collected nine cultivars named Sk-G (A-14), Shirpan6.3, O10, Tabladil, Beliizov, Shirpan533, Tashkand, Oltan and 4-s-s, the third cluster was composed of seven cultivars i.e., Nazilli, No.228, No.200, B557, Armaghan, Golestan, and Shayan. The cultivars in Cluster 3 are superior in terms of their number of the boll, boll weight, earliness percentage, fiber percentage, fiber length, fiber fineness, fiber strength, fiber traction, and yield performance (Table 3).

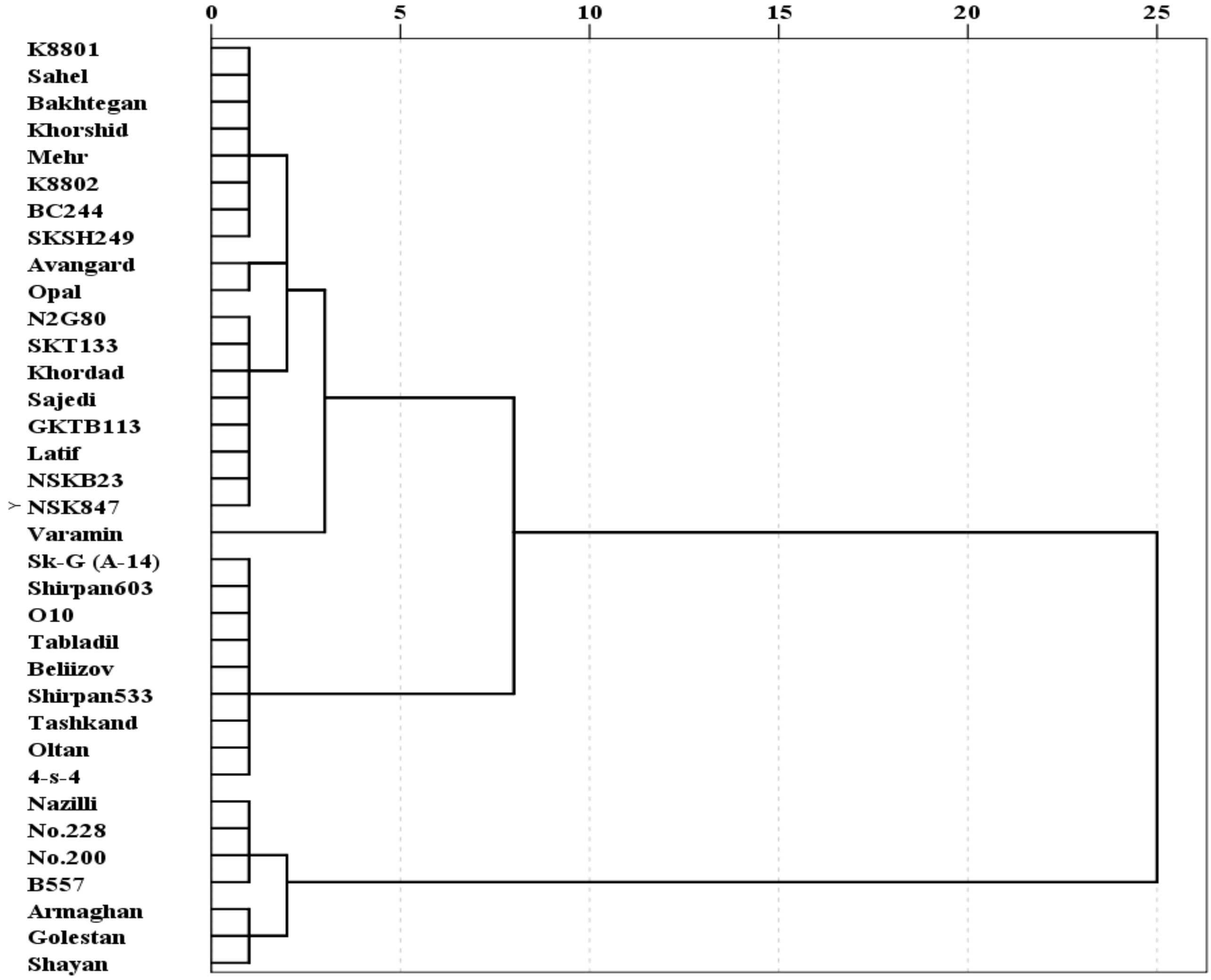

Figure 8. Ward's linkage cluster analysis of cultivars based on morphological traits

Table 3. Cluster analysis of yield, fiber, and morphological traits of different cultivars of cotton

Traits	Clusters		
	1	2	3
Number of the bolls	20.30	19.41	21.13
Boll weight (g)	5.21	5.08	5.73
Earliness percentage (%)	61.44	65.9	65.33
Fiber percentage (%)	39.48	39.88	40.88
Fiber length (mm)	30.01	29.34	30.86
Fiber fineness (µg/in)	3.75	3.60	4.19
Fiber strength (g/tex)	27.57	27.16	30.2
Fiber traction (%)	6.19	6.08	6.66
The first picking yield (kg/ha)	2292.25	1988.87	3116.7
The second picking yield (kg/ha)	1432.12	1025.88	1661.31
Total yield (kg/ha)	3724.38	3014.73	4778.03

The use of morphological markers accelerate the selection and reduces the time required for it [18]. To identify the superior lines and improvement their genetic, it is essential to know about their variability and heritability [19]. The results of this study showed that the 35 genotypes studied were different in terms of morphological characteristics. Based on the results of this study, it should be possible to select cotton cultivars with morphological traits including the number of the bolls, boll weight, the first and the second picking yield, total yield, earliness percentage, fiber fineness, fiber strength, fiber traction, and fiber percentage. The obtained information could help breeders to produce improved cultivars. In various studies, there is sufficient evidence about the positive effects of morphological traits and their use in indirect selection and increasing selection efficiency. In the next step, this selection with morphological markers is complemented by molecular markers and used to analyze genetic diversity, identify ancestors, and cultivars [20]. Our results showed that the fiber traits and yield performance have variation in different cultivars. Among the 35 cultivars, the highest number of the bolls, boll weight, the first picking yield, total yield, fiber strength, fiber traction, and fiber percentage were 24.5, 6.30 g, 3454 kg/ha, 5431 kg/ha, 34.5 g/tex, 7.30%, and 45.80% observed in cultivar Shayan, respectively, while the second picking yield, earliness percentage, and fiber fineness were 2323.3 kg/ha, 73.5% and 4.55 µg/in obtained in cultivars Varamin, Avangard, and Armaghan, respectively. The difference among cultivars might have been due to difference in the genetic potential. Significant difference between cultivars of cotton has been reported by scientists such as Ashokkumar and Ravikesavan [21] and Bhatti *et al.* [5]. In previous studies, the early maturity with a high number of the boll, boll weight, and yield observed in hybrids CIM-506 × CIM-554, CIM-473 × CIM-554, CIM-554 × CIM-496, CIM-554 × CIM-707, and CIM-446 × CIM-554 [22-23]. In studies on the different cotton genotypes, the boll weight was 3 g [24]. The early maturing cotton often has smaller and larger bolls as well as a higher yield, so a large number of the bolls are harvested in the early stages compared with the late maturing cultivars [25]. In a study by Batool *et al.* [26], it was reported that CIM-506 cultivar is the early maturity and its boll weight is medium and has high yield. Dhivya, Amalabalu, Pushpa, and Kavithamani [27] and Khan [28] observed varying values for fiber percentage in upland cotton genotypes, and least seed cotton yield in the early maturing parental cultivars and their progenies. Nazir, Mahmood, and Khan [3] found a significant difference in cotton genotypes in term of fiber length, fiber strength, and fiber fineness. Similar results observed in Bolek, Cokkizgin, and Bardak [29] studies on the upland cotton. Hussain *et al.* [30]observed the best fiber strength, fiber fineness, and fiber uniformity in CIM-707, FH-1000 and LA-17801 genotypes, respectively. Shahzad *et al.* [31] s howed that the yield traits except fiber percentage were mainly controlled by genetic and environment interaction effects, whereas fiber percentage and fiber quality traits were determined by the main genetic effects. Ahuja and Dhayal [32] selected the CCH-526612 for boll weight, CITH-77 for the number of open bolls per plant, CNH-36 for seed cotton yield, CCH-526612 for fiber strength and fiber elongation, and AKH-9618 for fiber strength and fiber elongation.

4- Conclusion

The results of the fiber quality traits evaluations of the cotton cultivars showed a wide range of variation. Among different cotton cultivars, Shayan is a better on terms of the number of the bolls, boll weight, the first picking yield, total yield, fiber strength, fiber traction, and fiber percentage. Therefore, this cultivar can be used as the best cultivar for breeding.

Acknowledgments

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