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The Effect of Planting Dates and Planting Methods on Cotton Quantitative and Qualitative Traits in Moderate and Humid Climatic Conditions

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ABSTRACT

Cotton is one of the most important crops in Golestan Province, Iran. The planting and harvesting date interferes with autumn crops such as wheat. A delay in planting cotton causes a decrease in yield. Transplanting cultivation can help to solve this problem. For this purpose, an experiment was carried out during two crop years in 2017 and 2018 in Iran, Golestan Province, Gorgan city, research station of Iraqi Mahlah in the form of a split plot based on randomized complete blocks design in four replications. Experimental treatments including planting dates at three levels including; Planting dates were May 27, June 16 and July 7 and planting methods were in seven levels (6 treatments using Transplanting and direct seeding methods). Quantitative traits including plant height, number of bolls per plant, lint weight per boll, lint yield and biological yield were measured along with cotton qualitative traits such as fiber length, stretch percentage, fiber fineness, fiber strength and uniformity index. Based on the results, the simple effect of planting dates, planting methods, as well as the interaction effect of planting dates × planting methods on all quantitative and qualitative traits were significant. Also, the interaction effect of year × planting date × planting method on the number of bolls per plant and biological yield was significant. The average lint yield in transplanting methods was 2256 kg per hectare and showed an increase of about 37% compared to direct seeding cultivation method. The best cultivation method it was that one with one seedling transplanted, the distance between the rows=75 cm and the distance on the rows=40 cm, the yields being higher as compared to other treatments. In general, the lint yield in direct seeding was much lower than the lint yield in transplanting cultivation. Also, the quality traits were affected by planting dates and planting methods, and in most cases, cotton quality traits were improved in the transplanting cultivation method. Therefore, if the cost of producing and transporting seedlings is economical, cotton transplanting is preferable to direct seeding cultivation.

Keywords: fiber fineness, fiber length, fiber strength, lint yield, planting date.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is one of the most important industrial products that is widely used in the textile industry (Spakota et al., 2023). Cotton production has a long history in Iran. According to the FAO (2021), the area under cotton cultivation was about 77832 hectares with an average yield of about 2.155 tons per hectare in Iran in 2021, so that, about 3000 hectares belong to rain-fed cotton production. Golestan, Khorasan Razavi, Fars and Ardabil Provinces are the most important cotton producers in Iran (FAO, 2021; Iran's Ministry of Agriculture, 2021). Golestan Province has been one of the cotton regions in Iran, but, its cultivation level has decreased in recent years due to the interference of the planting time with the end of the wheat growing season and the interference of the cotton harvesting time with the planting of autumn crops. The transplanting method and changing the planting date have been proposed as a solution to solve this problem (Soleimanzadeh et al., 2020).

The cotton plant is very responsive to environmental conditions, so that abiotic factors such as temperature, precipitation, and soil moisture are the main factors that determine the cotton yield and quality (Guo et al., 2023). Planting date, as one of the main strategies used worldwide in crop management, can lead to differences in crop growth environment (Baum et al., 2019; Cao et al., 2022). Planting date significantly affects leaf area expansion, internode length, dry matter

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production and distribution in cotton, and thus leads to differences in yield and fiber quality (Guo et al., 2023).

In general, early and timely planting dates often lead to higher yields, but too early planting date results the poor establishment due to adverse weather conditions such as cool soil temperatures and high moisture (Hunt et al., 2019). Morphological and physiological effects of low temperatures can affect the rice grain yield during germination, emergence, and early seedling growth phases (Reddy et al., 2017).

In general, in delayed planting, fiber length and strength, growth period length, harvest index, yield and Leaf Area Index (LAI) will be decreased. In return, vulnerability to pests and diseases will be increased (Wang et al., 2021). Direct planting of cotton seeds causes the seeds to be placed at different depths and far from accessible nutrients, and as a result, causes non-uniform greening. On the other hand, the amount of water loss and weeds invasion increase. Finally, the final yield decrease (Khozaei et al., 2020; Suleiman et al., 2023). Also, due to the fact that in some areas it is not possible to plant cotton on time, this plant may be planted late, which will reduce the yield. In order to make better use of climatic and soil factors, as well as to compensate for the decrease in growth in delayed cotton crops, cotton transplanting cultivation has been proposed (Khajeh Mozaffari et al., 2019).

Transplanting method has an effective role in improving the use of inputs such as seeds per unit area. Also, reducing the cultivation period length and growth period length can increase the efficiency of using inputs such as water and thus reduce the production costs (Khozaei et al., 2020; Suleiman et al., 2023).

Wang et al. (2019) stated that the unfavorable climate in the early growing season, including continuous rain, low temperature, and low radiation, makes superior to direct seeding in terms of boll number. Mehrabadi (2017) also reported that cotton yield was affected by the planting method, and cotton transplanting cultivation increased the fiber yield by 33.9% compared to the direct seeding method. They attributed this improvement to the longer flowering period and earlier cotton growth. In another experiment, Ahmad et al. (2018) after conducting a research on cotton yield on direct seed and transplanting cultivations in Pakistan, reported that the highest yield (4039 kg/ha) was related to the transplanting method, which compared to direct seeding increased the cotton yield by 29%. During a survey, it was found that cotton seeding on the conventional planting date causes the crop to ripen in about 27 to 38 days, while direct seeding on this planting date caused interference in the cultivation of the next crop (Salmani et al., 2021). In an experiment, Jafari (2020) found that the water use efficiency increased by 47% in the seedling cultivation compared to the direct seeding in cotton production.

Considering the favorable effect of well-timed planting date, which is possible with seedling cultivation, in this research, the effects of planting date and seedling planting method compared to direct seeding cultivation on the quantitative and qualitative traits of c.v. Golestan cotton were investigated.

MATERIAL AND METHODS

This experiment was conducted at the Iraqi Mahalle Research Station (affiliated to the Ministry of Agricultural Jihad) located in Gorgan, Iran in 2017 and 2018. The longitude and latitude are 54°25′ E and 36°54′ N, respectively, and its height is 5.5 m.a.s.l. The average of minimum temperature in the coldest month of the year is more than 5°C. The annual rainfall is between 500 and 600 mm and the 15 years' average temperature is 17.1°C. The amount of rainfall in the cotton growing season (May to October) in 2017 and 2018 was reported 133.3 and 122 mm, respectively. The long-term statistics of rainfall in the cotton growing season was 207.8 mm, according to these statistics, the amount of rainfall has decreased in recent years compared to the long-term statistics of 30 years. Before conducting the experiment, soil samples were taken from a 30 cm depth and the soil physicochemical characteristics were determined (Table 1).

Table 1. Physical and chemical soil characteristics at the experimental site (0-30 cm depth)

Soil texture	Organic carbon (%)	pH	EC (ds m^{-1})	Total nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)	Clay (%)	Silt (%)	Sand (%)
Silt-loam	1.25	7.74	1.12	0.12	13.2	294	21	67	12

This experiment was carried out in the form of a split plot based on randomized complete blocks in four replications during the years 2017 and 2018. Experimental treatments included planting dates in three levels (1- planting date May 27, 2- planting date June 16, 3- planting date July 7) and planting method in seven levels (Table 2).

Table 2. Treatments of direct seeding and transplanting method along with treatment codes and plant densities

Treatments	Planting arrangement	Plant density (1000/ha)
T1	Direct seeding: The distance between the rows=75 cm, the distance on the row=20 cm	65
T2	Transplanting: one seedling, the distance between the rows=75 cm, the distance on the row=20 cm	65
T3	Transplanting: two seedlings, the distance between the rows=75 cm, the distance on the row=20 cm	65
T4	Transplanting: one seedling, the distance between the rows=75 cm, the distance on the row=40 cm	32.5
T5	Transplanting: one seedling, on both sides of an irrigation tape, the distance between the rows=100 cm, the distance on the row=31 cm, the distance between irrigation tapes=10	65
T6	Transplanting: one seedling, on both sides of an irrigation tape, the distance between the rows=100 cm, the distance on the row=61 cm, the distance between irrigation tapes=10	32.5
T7	Transplanting: two seedlings, on both sides of an irrigation tape, the distance between the rows=100 cm, the distance on the row=61 cm, the distance between irrigation tapes=10	65

To prepare the required soil for the seed bed, three parts of agricultural soil, one part of fertilizer and one part of sand were mixed. In both years of the experiment (2017 and 2018), c.v. Golestan cotton seeds were planted in the treasury on April 26. First, the prepared soil, which is economical and easily available, was poured into the seedling trays (seedling trays made of special plastic material with dimensions of 3×3 with a depth of 5 cm) and then one seed was placed in some of each tray houses. In other tray houses, two seeds were planted. Then, a thin layer of the prepared soil was poured on the seeds. Their surface was covered with hemp sacks to preserve moisture, and they were sprinkled with water in the first cultivation days before emergence.

Necessary care was taken in the treasury for 30 days until the seedlings reached the stage of three to four leaves. Immediately, while preparing the main land, the seedlings were transferred to the main land and cultivated manually after 30 days on the 26th of May of the same year (in both years the treasury and planting dates were the same). Cultivation of each treatment was done in the form of three rows of five meters long inside the plots. The required fertilizers were used based on the soil test as recommended by the Soil and Water Research Institute. Phosphorous fertilizers and one third of nitrogen fertilizer along with potash fertilizer were given to the plant at the time of planting and the rest of the nitrogen fertilizer was applied to the plant in the beginning of flowering. During the growing season, weeds were manually removed. The studied traits included plant height, number of bolls per plant, lint weight per plant (g), lint yield and biological yield (kg/ha), fiber length, stretch percentage, fiber fineness, fiber strength, and uniformity index.

Ten plants were marked from each sub-plot and traits such as plant height, number of bolls per plant, and lint weight per boll at the end of the plant growth period were recorded. To measure the lint and biological yields, the plants located in the middle two rows were harvested, taking into account the marginal effect in each plot. To determine the cotton quality traits such as fiber length, stretch percentage, fiber fineness, fiber strength and uniformity index, 100 g sample of each treatment was prepared and sent to the quality analysis laboratory of Cotton Research Institute of Golestan Province for relevant measurements. The traits were determined according to the relevant instructions with the help of HIV device, ART model.

To analyze the data, in order to assume variance homogeneity of the treatments in the experimented years, Bartlett's test was performed for the variances uniformity, and then, combined analysis was performed. Data analysis was done using SAS software (SAS Institute Inc, 1989). The means comparison was performed using Least Significant Difference (LSD) test at 5% level. Excel 2013 software was used to draw the graphs.

RESULTS AND DISCUSSION

Plant height

Variance analysis indicated that the effect of planting date, planting method and interaction effect of planting date × planting method on plant height was significant (P≤0.01) while other factors on this trait were not significant (Table 3). Also, the mean comparison showed that the lowest plant height was 87.25 cm on the 27th May and the T3 planting method (Transplanting: two seedlings, the distance between the rows= 75 cm, the distance on the row=20 cm, density=65,000 plants per hectare), and the highest plant height was 135 cm on June 16 and planting method T3 was observed (Table 4). However, the average plant height on the 16th June planting date was higher than the other two planting dates.

Table 3. Combined analysis of cotton plant height, yield and yield components traits under the influence of planting date and method in 2017 and 2018

S.O.V.	df	Plant height	Number of bolls per plant	Lint weight per boll	Lint yield	Biological yield
(Y) Year	1	417.06^{ns}	0.28^{ns}	0.01^{ns}	16424.3^{ns}	1746.8^{ns}
(Y) R	6	452.3	0.13	0.02	110511.6	3867.6
(P) Planting date	2	11741**	10.16**	6.06**	61618829**	794981.8**
P × Y	2	65.2^{ns}	5.8**	0.04^{ns}	651898^{ns}	18355**
Error a	12	409.8	0.10	0.18	205040.7	4150.07
(P) Planting type	6	429.6**	4.98**	4.95**	1743534**	66279.9**
B × Y	6	1.87^{ns}	0.19^{ns}	0.25ns	102296.2^{ns}	14416.0**
P × B	12	548.1**	1.03**	1.67**	227264.3*	29627.15**
P × B × Y	12	3.5^{ns}	0.74**	0.13^{ns}	185518.7^{ns}	14257**
Error b	108	129.15	0.16	0.38	112199.3	3980
C.V.	-	10.39	12.35	14.05	15.45	18.23

Number of bolls per plant

The results illustrated that the effects of planting date, year × planting date, planting method, planting date × planting method, and year × planting date × planting method on the number of bolls per plant were significant (P≤0.01) while other factors on this trait were not significant (Table 3). The range of changes in the number of bolls per plant in the first year of the experiment on the planting dates of 27 May, 26 June and 7 July respectively between 13.10 (planting method T3) to 20.90 (planting method T4), between 11.25 (planting method T7) to 22.25 (T1 seeding method) and between 12.70 (T7 planting method) to 18.55 (T4 seeding method). But in the second year, the number of bolls per plant change ranges on 27th April were between 15.45 (planting method T3 and T5) to 23.15 (planting method T4); On June 6, between 16.0 (T3 planting method) and 23.40 (T4 planting method) and on July 7 between 14.95 (T7 planting method) and 14.70 (T1 planting method) were recorded (Table 5).

Lint weight per boll

Variance analysis showed that the effect of planting date, planting method, and the interaction effect of planting date × planting method on lint weight per boll was significant (P≤0.01) (Table 3). The mean comparison indicated that the planting methods T1 and T4 had the lowest and highest lint weight per boll on the May 27 and June 16 planting dates, respectively. While on the planting date on July 7, the lowest and highest lint weight per boll were observed in T7 and T5 planting methods (3.72 g and 5.46 g), respectively (Table 4).

Table 4. Mean comparison of height, lint weight per boll and lint yield in the different planting date and planting methods

Planting date	Planting method	Plant height (cm)	Lint weight per boll (g)	Lint yield (kg/ha)
27th May	T_1	104.9^{a}	3.46c	2408.7c
	T_2	97.95^{ab}	4.07b	3196.68b
	T_3	87.25^{b}	4.03b	3243.5a
	T_4	99.0^{a}	5.45a	3451.67a
	T_5	91.97^{b}	4.01b	3324.2a
	T_6	90.9^{b}	5.22a	3329.06a
	T_7	90.32^{b}	4.0b	3192.6b
16th June	T_1	127.23^{ab}	3.66c	1893.0b
	T_2	132.16^{ab}	4.19abc	1998.1b
	T_3	135.01^{a}	4.07bc	1893.3b
	T_4	123.5^{bc}	4.7a	2538.2a
	T_5	108.5^{d}	3.96bc	2429.2a
	T_6	124.4abc	4.4ab	2492.1a
	T_7	114.0cd	4.10bc	2639.2a
7th July	T_1	106.1bc	4.12c	614.4b
	T_2	103.9bc	5.11ab	1028.02a
	T_3	102.4d	5.22ab	1077.8a
	T_4	114.6ab	4.81b	1241.2a
	T_5	112.7bc	5.46a	1177.5a
	T_6	124.3a	5.07ab	1225.25a
	T_7	104.25b	3.72c	1150.47a

Lint yield per hectare

Variance analysis showed that the effect of planting date, planting method, and the interaction effect of planting date × planting method on the lint yield were significant (P≤0.01) (Table 3). Also, the mean comparisons indicated that the highest and lowest yield were observed in T4 and T1 planting methods in all three planting dates, respectively (Table 4).

Biological yield

The results revealed that the all main effect and interaction effects including planting date, year × planting date, planting method, year × planting method, planting date × planting method, and year × planting date × planting method on biological yield were significant (P≤0.01) (Table 3). Also, planting methods T4 and T7 had the highest and lowest biological yields on the planting dates of May 27 and June 16 in the first year, respectively. While no significant difference was observed between the planting methods on the July 7 planting date. Also, the highest and lowest biological yields were observed in T1 and T3 planting methods on the planting date of May 27 in the second year, respectively. However, there was no significant difference between the planting methods on 7th July, so that most of the treatments were in the same statistical group, however, the range of this trait varied from 5758 (T2 method) to 3668 (T5 method) kg/ha. As in the first year of the experiment, no significant difference was observed between the planting methods in the third planting date in the second year (Table 5).

Table 5. The triple interaction effect of year × planting date × planting method on the bolls number per plant and biological yield in 2017 and 2018

Planting date	Planting method	Bolls number per plant		Biological yield	
		First year	The second year	First year	The second year
May 27	T_1	15.25b	17.25b	2500.0b	6184.5a
	T_2	13.77b	16.30b	2271.7b	3540.7bc
	T_3	13.10b	15.45b	2036.2b	2042.7d
	T_4	20.90a	23.15a	4348.0a	4212.0b
	T_5	13.5b	15.45b	2417.2b	2420.0d
	T_6	20.85a	23.10a	3596.0a	2994.5cd
	T_7	13.50b	15.55b	2081.7b	2206.7d
June 16	T_1	22.05a	19.10bc	4847.2b	4622.2ab
	T_2	15.15c	21.05ab	5650.5a	5758.0a
	T_3	14.75d	16.0d	4702.0b	4675.0a
	T_4	18.75bc	23.40a	5574.0a	5499.5a
	T_5	20.75ab	15.25cd	3757.5c	3668.0b
	T_6	14.75d	21.55ab	5323.0ab	5223.0a
	T_7	11.25e	16.05cd	3761.0c	3761.0b
July 7	T_1	16.75ab	14.80a	2379.2a	2250.7a
	T_2	15.65abc	11.90bcd	2527.5a	2462.5a
	T_3	14.05bc	10.95cd	2518.0a	2518.7a
	T_4	18.55a	13.05abc	2671.7a	2621.7a
	T_5	14.25bc	14.20ab	2790.2a	2740.2a
	T_6	17.70a	11.65bcd	2447.0a	2422.0a
	T_7	12.70c	9.95d	2299.0a	2204.2a

Qualitative traits (the second year only)

The results showed that all the qualitative traits studied were influenced by planting date, planting methods and the interaction of these treatments (P≤0.01) (Table 6).

Table 6. Variance analysis of cotton qualitative traits in the second year (2018)

S.O.V.	df	Fiber length (mm)	Strength (g/tex)	Uniformity index	Stretch (%)	Fiber fineness
Replication	3	0.16	3.1	0.47	0.03	0.33
Planting date (A)	2	17.6**	14.32**	251.6**	0.08**	14.64**
Error (A)	6	0.25	1.62	1.58	0.02	1.43
Planting method (B)	6	8.43**	9.5**	122.7**	0.51**	1.69**
A × B	12	8.4**	19.98**	129.9**	0.7**	0.87**
Error (B)	54	0.33	1.98	1.69	0.02	0.31
C.V.	-	2.0	4.7	1.55	2.38	13.19

ns, * and **, are non-significance and significance at p<0.05 and p<0.01, respectively.

The results of the mean comparison showed that no significant difference was observed between the planting methods in fiber length on May 27 planting date. Also, planting method T3 had the lowest fiber length compared to other planting methods on the planting date of June 16. In other words, it was statistically significantly different from other planting methods (Table 6). In total, shorter fibers were formed in direct seeding method. Also, the average fiber length was 29 and 29.7 mm on the planting date of May 27 and June 16, respectively, and 28 mm on the planting date of July 7, which can be concluded that the length of cotton fibers decreases with delay in planting (Table 7). Also, according to the mean comparison results in Table 7, the lowest strength was related to the planting date of July 7 and planting method T1. Other planting dates and planting methods had almost similar strength.

Table 7. The interaction effect of planting date × planting method (3 planting dates and 7 planting methods) on cotton quality traits (the second year only)

Planting date	Planting method	Fiber length (mm)	Strength (g/tex)	Uniformity index	Stretch percentage	Fiber fineness (micron)
May 27	T_1	29.07a	30.30a	85.7a	6.65a	4.2a
	T_2	29.11a	29.02ab	84.75a	6.60a	4.85a
	T_3	29.10a	30.17a	84.8a	6.60a	4.74a
	T_4	29.22a	30.87a	85.25a	6.72a	4.5a
	T_5	28.92a	30.47a	85.5a	6.60a	4.51a
	T_6	28.47a	29.7ab	84.7a	6.57a	4.57a
	T_7	29.15a	28.30b	86.37a	6.60a	4.95a
June 16	T_1	29.66a	31.8a	86.07a	6.75a	4.74a
	T_2	29.6a	31.0ab	85.65ab	6.62a	4.91a
	T_3	28.76b	29.02b	84.4b	6.55a	3.89b
	T_4	29.84a	31.17a	85.77ab	6.60a	4.85a
	T_5	29.86a	30.95ab	87.02a	6.67a	4.73a
	T_6	30.14a	31.62a	85.45ab	6.65a	4.97a
	T_7	30.26a	29.75b	86.45a	6.55a	4.72a
July 7	T_1	22.7d	22.25c	58.4c	4.77b	1.88d
	T_2	28.87bc	30.75ab	83.57b	6.60a	3.22bc
	T_3	29.05abc	30.20ab	83.30b	6.55a	3.04bc
	T_4	28.24c	29.07b	83.47b	6.57a	4.13a
	T_5	29.30ab	31.10ab	83.97ab	6.57a	3.43ab
	T_6	29.05abc	30.30ab	84.57ab	6.57a	4.05ab
	T_7	29.83a	31.82a	85.45a	6.67a	4.14a

In each group, the treatments that are similar in at least one letter have no statistically significant difference at the five percent level.

Mean comparisons of uniformity index indicated that no significant difference was observed between planting methods on the planting date of May 27. While on June 16, planting method T3 and on July 7, planting method T1 had the lowest uniformity index compared to other planting methods (Table 7). However, there was no statistically significant difference between the planting methods in stretch percentage on the planting dates of May 27 and June 16.

While on the planting date of July 7, except for T1 planting method with 4.7%, which recorded the lowest amount compared to other planting methods, no significant difference was observed between other planting methods (Table 7). Also, the fibers fineness did not reveal a significant difference between the planting methods on the planting date of May 27, but on the planting date of June 16, only the T1 planting method with the lowest (3.89 micron) fibers fineness had a significant difference with other planting methods. This was despite the fact that the variety of fiber fineness in planting methods was high on the date of planting on July 7, so that the lowest and highest fiber fineness were observed in T1 (1.88 micron) and T7 (4.14 micron), respectively (Table 7).

According to the results, planting dates and planting methods had an effect on plant height up to 35%, so that the maximum plant height was observed on the planting date of May 7 with the high density cultivation method and two-row planting method. One of the reasons is competition in high densities among the plants. In the study of Wenqing et al. (2019), the reason for the increase in plant height with the increase in plant density was the increase in competition between plants. Also, in the study of Ahmad et al. (2018), the transplanted cotton plants had a higher height than the plants obtained from direct seeding cultivation method.

In general, the lint yield decreased in all planting methods with a delay in planting.

Also, the lint yield was 20-37% higher than direct seeding in transplanting methods. T4 treatment (transplanting method with a density of 32000 plants per hectare) was higher than direct seeding method and other methods. Since in the current study, different planting methods were different in terms of plant distance on the row and density (planting arrangement), so some of the lint yield changes were related to the planting arrangement in addition to the planting dates and methods. Planting arrangement is effective in increasing yield because it has an effective role in light distribution in the plant canopy and photosynthesis rate (Chapepa et al., 2020). Also, in transplanting cultivation, the sensitive period of plant growth is spent in more favorable conditions than in direct seeding cultivation, it has used enough environmental conditions and available nutrients for photosynthesis, and as a result, it has increased the cotton yield (Khozaei et al., 2020; Suleiman et al., 2023). In a study, the reason for the increase in the yield of transplanting cultivation compared to direct seeding cultivation was related to the phenological stages. On the other hand, in direct seeding, some bolls flowered late and did not open due to the autumn cold, and this led to a decrease in cotton yield. (Khajeh Mozaffari et al., 2019). The findings of this research were similar to the results obtained by Khajeh Denglani et al. (2018) on cotton. These researchers reported that the transplanting method had a higher yield compared to the direct seeding cultivation method (24.4%). They reported 2354 kg/ha lint yield in transplanting cultivation but 1892 kg/ha in direct seeding cultivation. This increase in yield in transplanting cultivation was due to the faster occurrence of phenological stages compared to direct seeding cultivation, which ultimately increased the lint yield.

According to the results in both experimental years, in terms of the number of bolls per plant, it was significant between the planting methods on the timely planting date (May 27) and no difference was observed between the planting methods in delayed planting (Table 5). Also, transplanting cultivation was better than direct seeding cultivation in most planting dates. Therefore, it can be concluded that the photosynthetic system is more efficient and the leaf area index is more in transplanting cultivation compared to the direct seeding cultivation system. In hence, more fertile bolls were formed in appropriate densities. But at higher densities, the possibility of boll formation decreased and the fewer number of open bolls was recorded due to the lack of space and reduced penetration of radiation into the plant canopy.

Wang et al. (2021) also stated that adverse weather in the early growing season, including continuous raining, low temperature, and low radiation, resulted in superiority of transplanting method compared to direct seeding in terms of boll number. In the study of Ahmad et al. (2018), the number of bolls per plant that were cultivated by transplanting method was more than that of direct seeding cultivation. By reducing the plant distance, the competition between plants to absorb water, nutrients and light increases and less photosynthetic assimilates is produced in the plant (Chen et al., 2022). This problem causes the fall of reproductive organs and the reduction of bolls in cotton, and as a result, the number of bolls per plant decreases, but this decrease is compensated by increasing the number of plants per unit area and more bolls are produced, this increase in the number of bolls per unit area is accompanied by the boll weight, it compensates for the decrease in lint yield in the plant and increases it per unit area (Khosravi and Mousavi; 2019). In the study of Jafari (2020), the planting date and planting method were significant on the number of bolls and boll weight. In his study, the delay in transplanting caused a reduction in the growth period and finally the number of bolls per plant decreased.

The length of the fibers along with the fibers fineness and strength are the three main traits of cotton fiber qualities for textile industries. The results showed that the biggest difference in quality traits between planting methods was observed in delayed cultivation, while there was no difference in the other two planting dates (Table 7). Fiber strength is an effective factor in yarn strength, and after length and fineness, it is the most important quality factor of cotton fiber technology (Hamidi et al., 2022). Fiber strength is determined in terms of grams per tex unit, the linear density measurement unit, and in terms of grams per 1000 meters of cotton thread length. Fibers which strength index is less than 24 and more than 30 g/tex are fibers with weak and strong strength, respectively, and strength more than 26 g/tex is desirable (Raper et al., 2019). Therefore, apart from the planting method T1 on the planting date of 16 days, in which the fiber strength is 22.25 g/tex and has weak fibers, considering that the fiber strength of other treatments was between 28.30 and 31.82 g/tex. Therefore, it can be said that in this experiment, the range of strength of the fibers was between optimal and strong. In hence, it can be concluded that the cotton fibers strength is mostly under genetic control, although it may also be affected by the environmental and nutritional conditions of the plant (Hamidi et al., 2022).

The uniformity index indicates the ratio of the average length of the fibers to the average length of the upper 50% of the fibers and indicates the length of the fibers longer than 50%. Uniformity index with values of 77>, 77-80, 81-84, 85-87, and 87< percent are classified as very low, low, medium, high, and very high, respectively (Mitra and Majumdar, 2023). Therefore, according to the mean comparison results, except for the T1 method on the planting date of July 7, in which the uniformity index is 58.4% and is placed in a very low class, the range of the uniformity index in other treatments is between 83.30 (T3 planting method on July 7 planting date) was up to 87.02% (T5 planting method on May 27 planting date), so the treatments are in the medium to high class of uniformity index (Table 7). The uniformity of fiber length in textile is very important, so it is necessary to identify the factors that influence the uniformity index. In Mehrabadi's study (2017), planting date did not have a significant effect on the fibers strength and uniformity, but the transplanting method was superior to the direct seeding method.

Fiber stretch is an indicator of the flexibility of fibers against stretching, and the increase in fiber length due to stretching until the breaking stage is called the degree (percentage) of fiber stretch, and the higher stretch is the more favorable for producing yarn and fabric (Hamidi et al., 2022). In general, the results of this research indicated that planting date and planting method have no significant effect on fiber stretch.

More fiber fineness indicates that there is more fiber per unit diameter of the yarn and the yarn will be stronger. Less fiber fineness leads to the production of low-quality yarns. The international standard range of fiber fineness is 3.5 to 4.9. Lower the fiber fineness, the fibers are finer and more desirable. The fiber fineness of 7.3 to 2.4 is desirable, and fibers less than 3.7 are known as fine fibers and higher than 4.7 are known as rough fibers (Hamidi et al., 2022). Therefore, the fibers fineness is in the optimal range according to the results of most planting methods in the different planting dates. The results of Mehrabadi (2017) the cotton fibers fineness was affected by the planting date (April 19, May 5 and 15 and June 5) and it reached from 4.63 on the first planting date to 4.17 on the fourth delayed planting date. They reported that the filling period length reduction in delayed cultivation has reduced the fibers fineness.

CONCLUSIONS

According to the results of this study, it was found that transplanting cultivation improved the quantitative and qualitative cotton traits and yield compared to the direct seeding system. The average lint yield in transplanting methods was 2256 kg per hectare and showed an increase of about 37% compared to direct seeding cultivation. The best cultivation method it was T4 (transplanting method with one seedling, the distance between the rows=75 cm and the distance on the row=40 cm), which produced a higher yield compared to other treatments. In general, the lint yield in direct seeding method was much lower than the lint yield in transplanting method. Also, the quality traits were affected by planting dates and planting methods, and in most cases, cotton quality traits were improved in the transplanting cultivation method. Therefore, if the cost of producing and transporting seedlings is economical, cotton transplanting is preferable to direct seeding cultivation.

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