Effect of Different Plant Density and Nitrogen Doses on Cotton Yield and Quality

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Abstract: This study was carried out to determine the effects of different nitrogen doses and plant density on cotton yield, fiber quality criteria and some physiological properties.

A field experiment was conducted according to the split plots design in randomized blocks with 4 replications and 4 different nitrogen doses (6, 12, 18 and 24 kg da^{-1} N) were formed in the main plots and plant density (5, 10 and 15 cm) in the sub plots. In the study, it was determined that there were significant statistical differences between applications in terms of seed cotton yield, number of sympodial, monopodial branches and number of nodes. It was determined that plant density had a significant effect on seed cotton yield and number of sympodial branches, nitrogen doses had a significant effect on the number of monopodial branches and number of nodes, and the interaction of nitrogen dose x plant density was effective on plant height.

The results showed that the highest seed cotton yield was obtained from 5 cm intra-row and the highest number of sympodial branch was obtained from 15 cm plant density. Among the nitrogen doses, it was determined that the highest number of monopodial branches and number of nodes were obtained at the nitrogen dose of 6 kg da^{-1}.

As a result of the study, in the light of this information, it was concluded that the Olivia cotton variety can be recommended because it has the highest yield when planted in 5 cm intra-row and also has the highest monopodial and sympodial branches when a nitrogen dose of 6 kg da^{-1} is applied.

Keywords: Nitrogen, Plant density, Quality, Cotton, Yield, Physiology.

INTRODUCTION

The main purpose in cotton farming is to obtain more and higher quality products from a unit area. The amount and quality of product to be obtained from a unit area are determined by the genetic potential of the variety cultivated, the environmental conditions in which it is located, the cultivation technique applied to it and the interactions between them [1]. Seed cotton yield varies depending on the genetic structure of the variety used, the genetic yield potential of the variety, the maintenance processes applied by the producers who are effective in the emergence of this potential and the environmental conditions of the region where it is grown.

Rational plant density is important for high yield. A suitable plant density can provide a beneficial microenvironment (canopy temperature, relative humidity and light transmittance) for the plant canopy in the formation of high yield along with the growth and development of the plant [2]. A suitable plant density can not only maximize cotton yield and fiber quality, but also reduce cost inputs by minimizing seed use without reducing yield [3].

While some researchers stated that they did not determine significant differences in total seed cotton yield due to changes in plant density [4-5]. Some researchers stated that there were decreases in yield with excessive or inadequate plant densities [6]. Studies have shown that fiber yield increases with increasing plant density per unit area [7] and that plant density has a positive effect on yield increase (40.7%) [3], while some studies reported that plant density weren't effected on yield [8].

Planting when the most suitable climatic conditions occur positively affects yield and quality. On the other hand, it has been stated that genotypes tolerant to climatic changes such as temperature and CO_2 increase will have shorter height and this situation will negatively affect the development and weed competition in the early development period. It is recommended to increase plant density to minimize these negativities [9].

In order for plants to grow and develop, the application of macro and micro nutrients in the required doses and on time is necessary to increase the optimum yield and quality of cotton. It is known that six macro nutrients (N, P, K, S, Ca, Mg) are necessary for plants to grow and develop [10]. Nitrogen is one of the most important elements and is an element that makes

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a significant contribution to plant physiology [11]. One of the necessary fertilizers for plants, perhaps the most important, is nitrogenous fertilizers. Nitrogen is a highly needed and generally limiting element by plants and plays an important role in many basic processes such as photosynthesis, protein synthesis, carbon balance, as well as enzyme and hormone activity. The role of N in plant life is very important because it enters the structure of proteins [12].

Nitrogen, which the cotton plant uses more than other nutrients, is an important element that affects yield and quality. Nitrogen affects different developmental periods and physiological processes of the plant, nitrogen deficiency limits dry matter accumulation in leaves, stems and bolls, dry matter weight and leaf area index decrease significantly in nitrogen deficiency, and despite these negativities, photosynthesis, transpiration and stomatal conductance are not affected by nitrogen deficiency in the upper leaves of the canopy [13].

While appropriately increasing nitrogen fertilizer can increase dry matter accumulation and chlorophyll content, excessive nitrogen doses cause imbalance in carbon and nitrogen metabolism, excessive vegetative growth, late maturation, and can reduce yield and nitrogen use efficiency [14].

Plant density and nitrogen doses are the most important applications in cotton production and are necessary research topics for an economical production planning and input management, and the optimum level of these applications should be ensured by the research to be conducted. Although there are many studies examining plant density and nitrogen doses, research findings examining nitrogen doses at different plant densities are limited.

This study was conducted to examine the yield, yield components, fiber quality criteria and some physiological performances of plants by applying different nitrogen doses at different plant densities.

MATERIALS AND METHODS

Experimental Site

The field trial was carried out in the experimental area of Siirt University Faculty of Agriculture department of field crops in 2022. The experiment was conducted in randomized blocks according to the split plot design with 4 replications. In the experiment, nitrogen doses (6, 12, 18 and 24 kg da^{-1}) formed the main plots and plant densities (5, 10 and 15 cm) formed the sub-plots.

Orion cotton variety was used as plant material which was supplied by the private sector. Orion cotton variety is a late maturing variety and its leaves are less hairy [15].

The experimental area is located in the center of Siirt province, in the Kezer campus, in the Siirt University experimental area, at 37°58' North latitude, 41°51' East longitude and 930 m above sea level.

The climate in this region, summers are hot and dry, while winters are very cold and generally partly cloudy. Temperatures normally vary between -2°C and 37°C throughout the year. While winters can drop below -8°C, summers can exceed 40°C. There is usually no precipitation between June and October. The temperature difference between night and day is high.

The minimum, maximum and average temperature for the year 2022 and long-terms are given in Figure **1**, precipitation (mm) and relative humidity (%) values for the year 2022 and long- term are given in Figure **2**.

When Figure **1** is examined, it is seen that the maximum temperature in 2022 is higher than in long-term, the highest temperature was 42 °C in July and is 5 °C higher than the long-term average temperature, and the minimum temperature is similar to the long-term average temperature.

In Figure **2**, it is seen that the precipitation in April is quite low compared to long-term according to the monthly precipitation amount of 2022. This shows that the soil contains less groundwater in 2022.

The agricultural land where the experiment was carried out consists of flat and medium deep soils. Due to the high amount of clay minerals contained in the soil, it expands and swells in winters, and in summers, cracks deepening to depths of 70-80 cm from the surface occur due to high temperatures and drought. Before planting, soil samples were taken from the experimental area and analyzed for soil properties and nutrient element content. The results of analysis are given in Table **1**.

As shown in Table **1**, the soil had a slightly calcareous structure, with little organic matter, the pH was slightly alkaline, and the soil texture was clayey.

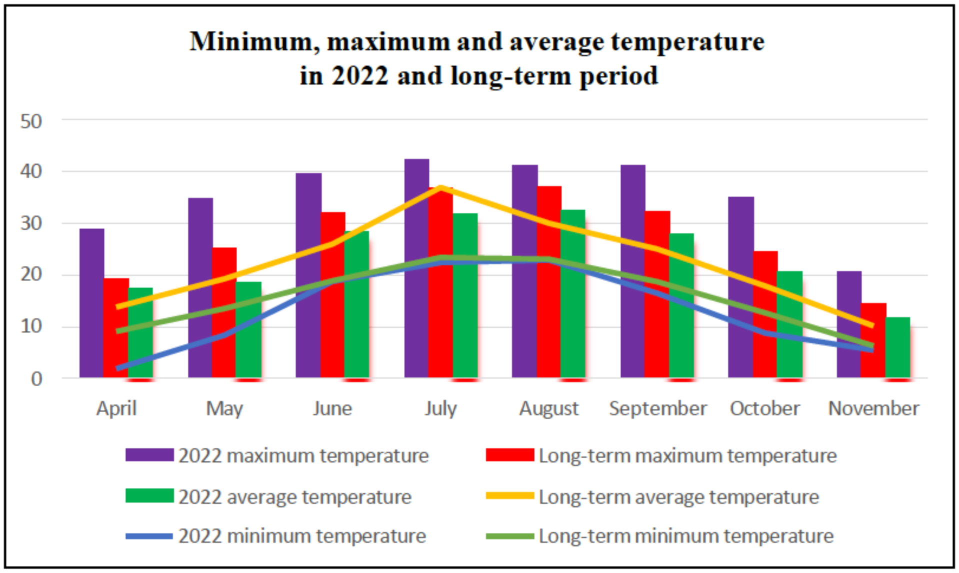

Figure 1: Minimum, maximum and average temperature during 2022 and long-term period.

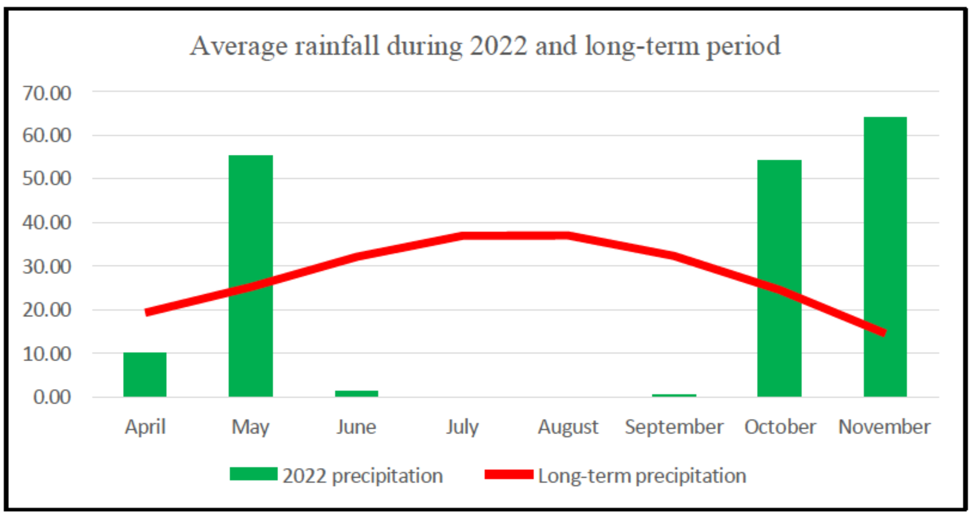

Figure 2: Average rainfall during 2022 and long-term period.

The electrical conductivity was unsalted. The amount of nitrogen in the soil was low, available phosphorus was very low and available potassium was adequate.

Table 1: Some Important Soil Properties of the Experimental Area

Analysis	Results of Analysis	Evaluation
pH	7.70	Slightly alkaline
EC	0.09 dS/m	Unsalted
Lime	%2.55	Slightly calcareous
Soil texture	Sand: %27.3 Silt: %20.0 Clay %52.7	Clayey
Organic matter	%0.94	Very low
Available phosphorus	2.96 kg/da	Very low
Available potassium	136.65 kg/da	Adequate
Nitrogen	%0.099	Low

Field Experiment

The trial area was plowed deeply with a plow in the autumn and then surfaced with a cultivator before planting in the spring. Before planting, the field was dug twice and the trial area was made ready for planting. After the land was prepared for planting, the plot was done according to the trial plan and the boundaries of the plots were determined. The planting operations in the trial were carried out with a trial drill on May 13, 2022.

Each parcel was composed of 16.8 m^2, 2.8 m wide and 6 m long parcels with 4 rows. The distance between the rows was kept constant at 0.7 m during planting, and 2 m space was left between the blocks. The intra-row spacing was determined by measuring with a ruler and thinning, with 5, 10 and 15 cm space between the plants when the plants had 3-4 leaves.

During planting, half of the nitrogen doses was applied as ammonium sulfate form and 8 kg da^{-1} P_2O_5 was applied in the form of triple super phosphate to the band, the remaining half of the N doses (6, 12, 18 and 24 kg da^{-1} N) were applied in the form of urea in the period before the first irrigation, the specified nitrogen doses were weighed separately for each plot and applied 10 cm to the rows with the help of a hoe and then covered.

The experiment was irrigated with using the drip irrigation method. Irrigations were determined according to the water demand of the cotton plant and the water needs of the plant were met regularly. The first irrigation was applied during the squaring period and irrigation was completed at 10% boll opening period. During the trial period, hand hoeing was done twice and machine hoeing was done twice, and both weed control and soil aeration were provided with hoeing operations. Weed and pest controls were done at certain periodic intervals. Harvesting operations were done by hand and completed twice harvest. The first harvest was carried out during the 60% boll opening period, and the remaining cotton was collected at the second harvest.

Data Collection

Plant height, number of monopodial and sympodial branches, number of bolls, number of node of first fruiting branch, number of nodes, height to node ratio (HNR) were measured from five selected plants from each plot and 50 bolls were collected in the 1st position between the 1st and 5th fruit branches from each plot for determining boll weight, seed cotton boll weight, number of seeds in the boll, ginning percentage.

Chlorophyll content (SPAD value) was measured with the Minolta SPAD 502 chlorophyll meter in 10 randomly selected plants during the flowering period. The top five newly opened and fully grown leaves of the plant were measured according to Johnson and Sounders, 2003 [16].

NDVI value (Normalized difference vegetative index) was determined using a Trimble brand GreenSeeker instrument. NDVI values were recorded by holding the sensor 76 to 91 cm above the plant canopy [17, 18].

Fiber Analysis

After ginning fiber samples determined for quality properties with High Volume Instrument (HVI).

Statistical Analysis

The results obtained from the research were evaluated with the help of the JUMP 7.0 (JMP®, Version 7.0. SAS Institute Inc., Cary, NC, 1989-2019) statistical program in accordance with the experimental design used, and the LSD $_{(0.05)}$ test was used to compare the means.

RESULTS AND DISCUSSION

The differences between investigated agronomic and physiological traits and fiber technological traits and LSD $_{(0.05)}$ test results are given in Table **2**-**4**.

It can be observed from Table **2** that no significant statistical differences were obtained between nitrogen doses in terms of seed cotton yield, however the differences between plant densities were significant at the $p \leq 0.01$ probability level, and interaction between the nitrogen doses and plant densities were not significant.

In the study, seed cotton yield values varied between 273.85 and 287.32 kg da^{-1} at different nitrogen doses, but no significant statistical difference was obtained between the applications.

It is observed that the seed cotton yield values varied between 257.57 and 314.82 kg da^{-1} at different plant densities, and the highest yield was obtained from 5 cm plant density (314.82 kg da^{-1}) and this application constituted group a. It is seen that the lowest yield was obtained from 15 cm plant density (257.57 kg da^{-1}) and this application was in the same group as 10 cm plant density (in group b) and the general average value of the trial was 281.78 kg da^{-1}.

In the study, it was determined that plant density had a significant effect on seed cotton yield, the highest yield was obtained from 5 cm plant density and this application was followed by 10 cm plant density. The obtained results are parallel to those of [19-23] who reported that increasing the number of plants per unit area caused an increase in seed cotton yield, but they

Table 2: Average Values and Groups of Yield and Yield Contributing Agronomic Traits

Treatment	Seed Cotton YIELD	Monopodial Branches	Sympodial Branches	Boll Number	Boll Weight	Seed Cotton Weight Per Boll	Number of Seeds in the Boll
Nitrogen							
6 kg da^{-1}	273.85	2.24 a	9.31	10.70	5.53	4.03	24.11
12 kg da^{-1}	285.05	1.32 b	10.05	9.13	5.50	3.93	25.46
18 kg da^{-1}	280.90	1.16 bc	9.69	9.35	5.52	4.01	24.37
24 kg da^{-1}	287.32	0.60 c	9.44	8.33	5.51	3.99	25.84
Plant Spacing							
5 cm	314.82 a	1.28	8.78 b	8.91	5.40	3.91	25.12
10 cm	272.95 b	1.30	9.63 ab	9.17	5.64	4.09	25.54
15 cm	257.57 b	1.41	10.45 a	10.05	5.50	3.97	24.17
Mean	**281.78**	**1.33**	**9.62**	**9.38**	**5.51**	**3.99**	**24.94**
CV (%)	15.59	7.36	16.11	32.5	6.35	7.76	7.89
LSD $_{(0,05)}$ Nitrogen	Ns	0.70 **	ns	ns	ns	ns	ns
LSD $_{(0,05)}$ Plant Spacing	31.99 **	ns	1.13*	ns	ns	ns	ns
LSD $_{(0,05)}$ N×PS	ns	ns	ns	ns	ns	ns	ns

* and ** Significant at the 0.05 and 0.01 probability level, respectively

differ from those of [5, 24], who reported that the effect of plant density on seed cotton yield was not significant.

Kubde and Lakhdive (1993) [25], McConnell *et al*. (1993) [26], Godoy *et al*. (1994) [27], Bibi *et al*. (2011) [28] and Hassan *et al*. (2003) [29] revealed that increasing nitrogen dose increased seed cotton yield, while Tomar *et al*. (1989) [30] reported that the difference in yield between 80 and 120 kg ha^{-1} N was not significant. It is seen that similar results were obtained with Tomar *et al*. (1989) [30] in the study. Devi *et al*. (2018) [31] reported that they obtained the most suitable plant density and nitrogen amount from 60 x 10 cm density and 15 kg da^{-1} N nitrogen level, while [32] reported that they obtained the highest yield value from 165 kg ha^{-1} nitrogen application with 33 cm plant density. On the other hand, [33] suggested that reducing nitrogen by 20-30% did not reduce the seed cotton yield.

Number of Monopodial Branches

The average values obtained for the applications in terms of number of monopodial branches are shown in Table **2**.

It can be observed from Table **2** that there are statistical differences at 1% significance level between nitrogen doses in terms of number of monopodial branchs, plant density does not have a significant effect on number of monopodial branches, and the interaction between nitrogen dose x plant density is not significant.

It can be observed from Table **2** that number of monopodial branches at different nitrogen doses vary between 0.60 and 2.24 number plant^{-1} and the differences between the applications are significant at 1% level. It is observed that the highest number of monopodial branch was obtained from 6 kg/da N dose (2.24 number plant^{-1}), while the lowest value (0.60 number plant^{-1}) was obtained from 24 kg da^{-1} N dose. Increasing nitrogen dose caused a decrease in the number of monopodial branches. It is observed that the number of monopodial branches varies between 1.28 and 1.41 number plant^{-1}at different plant densities, but the differences obtained are not found to be statistically significant, and there is no significant interaction between nitrogen dose x plant density.

Gençer and Oğlakçı (1983) [34] reported that nitrogen doses do not affect the number of monopodial branches, [19] reported that increasing the number of plants per unit area does not affect the number of monopodial branches, while [35] stated that the number of monopodial branches decreases as plant density decreases. It is seen that different results are obtained in the study. This situation may be due to the difference in the materials used in the study, the application period and application dose of nitrogen, and the differences in cultural processes.

Number of Symopodial Branches

There is no statistically significant difference between nitrogen doses in terms of the number of sympodial branches, a statistically significant difference of 5% was obtained between plant densities, and no interaction was observed between nitrogen doses x plant density.

It can be observed from Table **2** that the number of sympodial branches vary between 9.31 and 10.05 number plant^{-1}at different nitrogen doses, but the differences between the applications are not significant. It is seen that the number of sympodial branches obtained at different plant densities is 8.78 and 10.45 number plant^{-1}, the highest sympodial branch number is obtained from 15 cm plant density, the lowest number of sympodial branch is obtained from 5 cm plant density and the general average value of the experiment was 9.62 number plant^{-1}.

In the study, it is seen that the number of sympodial branches is affected by plant density, and the increasing distance between plants leads to an increase in the number of sympodial branches. Çopur *et al*. (2002) [22] reported that the number of sympodial branches increases with the increase in the row distance. Similar findings were also reported by [23]. Kumar *et al*. (2017) [36] stated that higher number of sympodial branch is obtained at normal plant density. Liaqat *et al*. (2018) [32] reported that plant density and nitrogen dose had significant effects on the number of sympodial branches in their study with three plant densities and four nitrogen doses. It is seen that the research findings differ from the findings of [37] indicating that increasing nitrogen dose increases the number of sympodial branches.

Boll Number

It can be observed from Table **2** that there is no statistically significant difference between nitrogen doses and plant densities in terms of boll number, and the interaction between nitrogen doses x plant density is not significant.

Table **2** shows that the boll number values obtained by applying different nitrogen doses varied between 8.33 and 10.70 number plant^{-1}, the boll number values were 8.91 and 10.05 number plant^{-1}at different plant densities and the general average value of the experiment was 9.38 number plant^{-1}. In the study, it was observed that the boll number was not affected by nitrogen doses and plant densities at a statistically significant level and the difference between the applications was not significant. Cawley *et al*. (1998) [35] stated that the boll number increased as the plant density increased, [22] stated that the boll number increased with the increase in the distance in the row, and [21] stated that the plant density affected the boll number. It was observed that the research findings differed with the findings of [29] indicating that increasing nitrogen dose increased the boll number. This situation may be due to differences in cotton varieties used in the study, cultural practices and climate factors, as well as differences in nutrient elements in the soil and differences in application times. The findings obtained in the study are similar to those of [34], who reported that nitrogen doses did not have a significant effect on the number of bolls.

Boll Weight

Table **2** shows that no statistically significant difference was found between nitrogen doses and plant densities in terms of boll weight, and there was no significant interaction between nitrogen doses x plant densities.

It can be observed from Table **2** that the boll weight values obtained at different nitrogen doses varied between 5.50 and 5.53 g, and the boll weight values at different plant densities varied between 5.40 and 5.64 g, nitrogen doses and plant densities did not have a significant effect on boll weight, and the interaction between nitrogen dose x plant densities was not significant in terms of this traits. The findings obtained in the study were similar to [22, 38, 39] who reported that boll weight was not affected by plant densities, but differed from [28], who stated that boll weight increased with nitrogen dose.

Seed Cotton Weight Per Boll

Nitrogen doses and plant densities do not have a significant effect on the seed cotton weight per boll, and the nitrogen dose x plant density interaction is also not significant.

Seed cotton weight per boll values obtained at different nitrogen doses varied between 3.93 and 4.03 g, and that the seed cotton weight per boll values at different plant densities varied between 3.91 and 4.09 g that nitrogen doses and plant densities did not have a significant effect on the seed cotton weight per boll, and that the nitrogen dose x plant densities interaction was not significant in terms of this feature.

The findings are consistent with those of [34] who stated that nitrogen dose has no effect on seed cotton weight per boll, and [19] who stated that plant density has no significant effect on seed cotton weight per boll.

Number of Seeds in the Boll

Table **2** shows that there is no statistically significant difference between nitrogen doses and plant densities in terms of number of seeds in the boll, and the nitrogen dose x plant densities interaction is not significant for this feature.

It is observed from Table **2** that the number of seeds in the boll obtained at different nitrogen doses varied between 24.11 and 25.84, the number of seeds in the boll varied between 24.17 and 25.54 at different plant densities, the general average value of the experiment was 24.94, nitrogen doses and plant densities did not have a significant effect on the number of seed in the boll, and the nitrogen doses x plant densities interaction was also not significant in terms of this traits. It was stated by [40, 41] that plant density did not affect the number of seeds in the boll and this was similar to the research findings. It is seen that different results were obtained with [3] who reported that the number of seeds in the boll increased as the plant density decreased.

Plant Height

It is observed from Table **3** that nitrogen doses and plant density do not have a significant effect on plant height and the interaction between nitrogen doses x plant densities was significant at the 1% level.

From the Table **3**, it can be observed that plant height values vary between 63.88 and 69.08 cm at different nitrogen doses, and between 65.55 and 67.28 cm at different plant densities, but the differences between the applications are not statistically significant. It is seen that the interaction between nitrogen doses x plant density is significant at the 1% level. The fact that the nitrogen dose x plant density interaction is significant shows that nitrogen dose may change at different plant densities. While it is seen that the highest plant height value is obtained at 10 cm plant density and 6 kg da^{-1} nitrogen dose, the lowest value is obtained at 5 cm plant density and 24 kg da^{-1} nitrogen dose as shown in Figure **3**. Cawley *et al*. (1998) [35] stated that plant height increases as plant density increases, [32] stated that plant density and nitrogen dose have significant effects on plant height, and [37]

Table 3: Average Values and Groups of some Investigated Agronomic and Physiological Traits

Treatment	Plant Height	Number of Node of First Fruiting Branches	Number of Nodes	Height/ Node Ratio	First Picking Percentage	Ginning Percentage	Chlorophyll (SPAD Value)	NDVI
Nitrogen								
6 kg da^{-1}	69.08	7.67	17.35 a	3.98	95.86	45.43	48.61	0.66
12 kg da^{-1}	66.91	6.41	16.33 b	4.10	96.33	47.30	47.85	0.66
18 kg da^{-1}	65.38	6.58	15.87 b	4.14	95.60	46.11	48.69	0.66
24 kg da^{-1}	63.88	6.38	16.24 b	3.94	95.41	45.21	48.01	0.65
Plant Spacing								
5 cm	66.12	6.93	16.02	4.13	96.10	45.75	48.20	0.67
10 cm	67.28	7.07	16.47	4.10	96.01	45.49	47.78	0.66
15 cm	65.55	6.28	16.86	3.89	95.29	46.79	48.89	0.64
Mean	**66.31**	**6.76**	**16.45**	**4.04**	**95.80**	**46.01**	**48.29**	**0.66**
CV (%)	4.76	14.49	8.44	7.17	2.42	6.36	5.07	6.49
LSD $_{(0,05)}$ Nitrogen	ns	ns	0.98 *	ns	ns	ns	ns	ns
LSD $_{(0,05)}$ Plant Spacing	ns	ns	ns	ns	ns	ns	ns	ns
LSD $_{(0,05)}$ N×PS	4,60 **	ns	ns	ns	ns	ns	ns	ns

* and ** Significant at the 0.05 and 0.01 probability level, respectively.

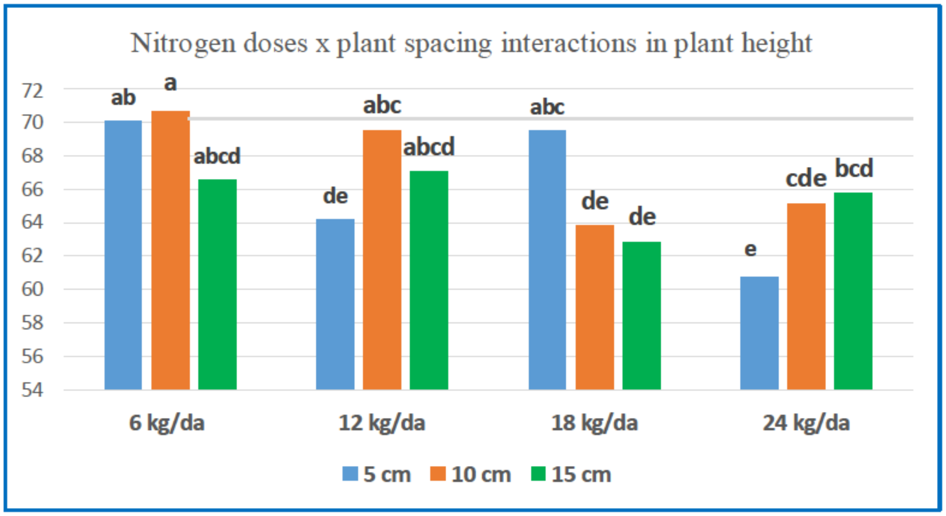

Figure 3: Nitrogen doses and plant spacing interactions in plant height.

stated that plant height increases with increasing nitrogen dose.

Number of Node of First Fruiting Branch

As shown in Table **3** that there is no significant statistical difference between nitrogen doses and plant densities in terms of the number of node of first fruiting branch, and the nitrogen dose x plant density interaction is not significant for this feature.

Table **3** shows that the values of the number of node of first fruiting branch obtained at different nitrogen doses vary between 6.38 and 7.67, and the values of the number of first fruiting branch nodes vary between 6.28 and 7.07 at different plant densities, and the general average value of the experiment is 6.76, and nitrogen doses and plant densities do not have a significant effect on the number of first fruit branch nodes, and the interaction between nitrogen doses x plant densities is not significant for this feature.

The results of the study are similar to the findings of [40,42] who stated that the number of first fruiting branch nodes is not affected by the distance in the row. Similar results were obtained with [43] who reported that increasing nitrogen dose did not have a significant effect on the number of first fruit branch nodes.

Number of Node

Table **3** shows that there are statistical differences at the 5% significance level between nitrogen doses in terms of node number, plant densities are not significant, and nitrogen doses x plant density interaction is also not significant.

Table **3** shows that the node number values obtained at different nitrogen doses vary between 15.87 and 17.35 and the differences between nitrogen doses are significant at 5% level. It was determined that the lowest node number value (15.87) was obtained from the 18 kg da^{-1}dose among nitrogen doses, while the highest value (17.35) was obtained from 6 kg da^{-1}nitrogen dose. It was observed that plant densities did not cause a significant difference in node number values, and the nitrogen dose x plant densities interaction was not significant in terms of this feature.

Azizpour *et al*. (2005) [23] stated that plant density has a significant effect on the node number in the plant, [32, 44] stated that plant density and nitrogen dose have significant effects on the node number in the main stem.

It was determined that the applied nitrogen doses have a significant effect on the node number feature in the plant. The findings are similar to those reported by [45, 46, 32] that increasing nitrogen dose affects the number of nodes in the plant.

Height/Node Ratio

Nitrogen doses and plant densities do not cause a significant difference in height/node ratio, and the nitrogen dose x plant density interaction is also not significant.

It is seen that the height/node ratio value obtained at different nitrogen doses varies between 3.94 and 4.14 and the height/node ratio varies between 3.89 and 4.13 at different plant densities, but the differences between nitrogen doses and plant densities are not statistically significant (Table **3**). Karataş and Karademir (2022) [43] reported that increasing nitrogen dose did not have a significant effect on the height/node ratio. It is seen that similar results were obtained in the study.

First Picking Percentage

It is observed from Table **3** that nitrogen doses and plant densities do not have a significant effect on the first picking percentage, and the nitrogen doses x plant density interaction is not significant in terms of this character.

It is observed from Table **3** that the first picking percentage value obtained at different nitrogen doses varies between 95.41 and 96.33%, and the first picking percentage value varies between 95.29 and 96.10% at different plant densities, but the differences between the applications do not lead to a significant difference in the first picking percentage. Şahin (1994) [47] reported that earliness decreases with increasing nitrogen, [36] reported that the first-hand seed ratio is high at high plant density, and it is seen that different results are obtained in the research.

Ginning Percentage

It is observed from Table **3** that nitrogen doses and plant densities do not have a significant effect on ginning percentage, and the nitrogen doses x plant density interaction is also not significant.

From Table **3**, it is seen that the ginnig percentage obtained at different nitrogen doses varies between 45.21 and 47.30%, and varies between 45.49 and 46.79% at different plant densities, but the differences between nitrogen doses and plant densities are not statistically significant in terms of ginning percentage. It is seen that similar findings were obtained with [40, 48] who reported that the decrease in plant density did not have a significant effect on ginning percentage. Vireshwar *et al*. (1989) [49] stated that increasing the nitrogen rate did not have a significant effect on ginning percentage, and [50] stated that ginning percentage decreased as the amount of nitrogen increased.

Chlorophyll Content

It is observed from Table **3** that nitrogen doses and plant density do not have a significant effect on leaf chlorophyll content, and nitrogen dose x plant density interaction is not significant in terms of this feature.

It is observed that the chlorophyll content value obtained at different nitrogen doses varied between 47.85% and 48.69%, and the chlorophyll content value varied between 47.78% and 48.89% at different plant densities, but the differences between the applications did not cause a significant difference in the chlorophyll content value.

While the findings of [51] indicating that the chlorophyll content value in the leaf is not affected by plant density are parallel to the research findings, the research findings differ from [52] who determined a higher chlorophyll content value in dense planting. It is seen that different results are obtained with [43] who reported that the effects of nitrogen doses on chlorophyll content are important and that they obtained the highest value from 12 kg da^{-1} nitrogen dose. Niu *et al*. (2021) [14] who stated that chlorophyll content increases with the appropriate increase of nitrogen fertilizer.

This situation may be due to the difference in the plant materials used in the study, the application period and application dose of nitrogen, and the differences in cultural practices.

NDVI Value

It is observed from Table **3** that nitrogen doses and plant densities do not have a significant effect on the NDVI value, and the nitrogen doses x plant densities interaction is not significant in terms of this feature.

From same Table, it is observed that the NDVI value obtained at different nitrogen doses varies between 0.65 and 0.66, and the NDVI value varies between 0.64 and 0.67 at different plant densities, but the differences between the applications do not cause a significant difference in the NDVI value. It has been determined that different results were obtained with [53, 54] who reported that the NDVI value is affected by plant densities. It is seen that different results were obtained with [55, 56, 43] who reported that the NDVI value is affected by nitrogen doses. The findings of [57] who stated that the GreenSeeker sensor is sensitive to nitrogen and can be used to detect the nitrogen status of the product and to determine the nitrogen requirement of the product, differ with the research results. This situation may be due to the difference in the material and method used in the research and the difference in the time of measuring the NDVI value.

Fiber Fineness

Nitrogen doses and plant density do not have a significant effect on fiber fineness, and the nitrogen doses x plant density interaction is not statistically significant. From Table **4** it is seen that the fiber fineness value varies between 4.04 and 4.15 micronaire (mic.). at different nitrogen doses, and the fiber fineness varies between 4.03 and 4.15 mic. at different plant densities, and the general average value of the trial is 4.09 mic. It was determined that the fiber fineness was not affected by nitrogen doses and plant densities at a statistically significant level.

Afzal *et al*. (2018) [58] reported that high plant density requires proportionally less nitrogen and that high plant density does not improve fiber quality properties. Boquet (2005) [59] stated that fiber fineness decreases with increasing plant density, [22] stated that plant density does not affect fiber fineness. Bridge *et al*. (1972) [60] reported that plant density reduces fiber fineness value. Vireshwar *et al*. (1989) [49] reported that increasing nitrogen rate increases fiber fineness, while [34] stated that nitrogen dose does not affect fiber fineness. In the study, it is seen that some results are consistent with some literatures and different results are obtained with some literatures.

Fiber Length

Nitrogen doses and plant density do not have a significant effect on fiber length, and the nitrogen doses x plant density interaction is also not significant.

Table **4** shows that fiber length values vary between 28.44 and 28.81 mm at different nitrogen doses, and fiber length values vary between 28.50 and 28.67 mm at different plant densities, and the overall average value of the experiment is 28.58 mm. It was determined that fiber length was not affected by nitrogen doses and plant densities at the level of statistical significance. Afzal *et al*. (2018) [58] stated that high plant density did not affect fiber quality. While it was reported that increasing the nitrogen rate increased fiber length [50, 49, 61]. El- Dababi *et al*. (1995) [62] reported that fiber quality was not affected by increasing nitrogen. Kubde and Lakhdive (1993) [25] stated that fiber length was not affected by nitrogen dose and plant density. The results obtained in the study are in accordance with [62, 58].

Fiber Strength

It was observed that nitrogen doses and plant density do not have a significant effect on fiber

Table 4: Average Values and Groups of Investigated Fiber Technological Traits

Treatment	Fiber Fineness (mic.)	Fiber Length (mm)	Fiber Strength (g/tex)	Fiber Elongation (%)	Fiber Uniformity (%)	Reflectance (RD)	Yellow Ness (+b)	Spinning Consistency Index
Nitrogen								
6 kg da^{-1}	4.15	28.57	27.70	5.57	82.45	81.19	8.47	128.91
12 kg da^{-1}	4.04	28.44	27.45	5.51	81.75	81.07	8.51	125.33
18 kg da^{-1}	4.10	28.81	27.94	5.41	82.59	81.52	8.29	131.33
24 kg da^{-1}	4.07	28.52	27.88	5.55	82.33	81.57	8.55	129.77
Plant Spacing								
5 cm	4.03	28.59	27.94	5.54	82.54	81.42	8.40	131.18
10 cm	4.15	28.67	27.30	5.49	82.11	81.47	8.47	126.40
15 cm	4.09	25.80	28.00	5.50	82.18	81.12	8.50	128.94
Mean	**4.09**	**28.58**	**27.74**	**5.51**	**82.28**	**81.33**	**8.45**	**128.83**
CV (%)	5.28	2.66	7.03	4.21	1.26	0.85	2.79	7.58
LSD $_{(0,05)}$ Nitrogen	ns	ns	ns	ns	ns	ns	ns	ns
LSD $_{(0,05)}$ Plant Spacing	ns	ns	ns	ns	ns	ns	ns	ns
LSD $_{(0,05)}$ N×PS	ns	ns	ns	ns	ns	ns	ns	ns

* and ** Significant at the 0.05 and 0.01 probability level, respectively.

strength, and the interaction of nitrogen dose and plant density is also not significant (Table **4**).

Table **4** shows that fiber strength values at different nitrogen doses vary between 27.45 and 27.94 g tex^{-1}, and that fiber strength values at different plant densities vary between 27.30 and 28.00 g tex^{-1}, and the overall average value of the trial is 27.74 g tex^{-1}. It was determined from the study that fiber strength was not affected by nitrogen doses and plant densities at a statistically significant level. The results obtained are in line with [47, 62] who stated that fiber quality is not affected by nitrogen dose, while they differ from [49] who reported that increasing the nitrogen rate reduces fiber strength. It is observed that similar results were obtained with [58] who stated that the effect of plant density on fiber quality is not significant and [60] who reported that plant density does not affect fiber strength.

Fiber Elongation

Fiber elongation values vary between 5.41 and 5.57% at different nitrogen doses, and vary between 5.49 and 5.54% at different plant densities, and the general average value of the experiment is 5.51%. It was determined that fiber elongation is not affected by nitrogen doses and plant densities at a statistically significant level and also interactions.

It is also supported by [60, 63, 58] that fiber elongation is not affected by plant density. It is observed that similar results were obtained with [47, 64, 62, 65, 66, 67] who stated that fiber quality is not affected by nitrogen doses.

Fiber Uniformity

Table **4** shows that the fiber uniformity ratio values vary between 81.75 and 82.59% at different nitrogen doses, and the fiber uniformity ratio values vary between 82.11 and 82.54% at different plant densities, and the overall average value of the experiment is 82.28%. It was determined that the fiber uniformity ratio was not affected by nitrogen doses and plant densities at the level of statistical significance. For fiber uniformity nitrogen doses x plant spacing interactions were found non-significant. It is seen that similar results were obtained with [47] and [58] in the study.

Fiber Reflectance

It can be observed from Table **4** that nitrogen doses and plant density do not have a significant effect on the fiber reflectance, and the interaction of nitrogen dose and plant density is not significant for this trait.

Fiber reflectance values vary between 81.07 and 81.57% at different nitrogen doses, and fiber reflectance values vary between 81.12 and 81.47% at different plant densities, and the overall average value of the experiment is 81.33%. It was determined that fiber reflectance value was not affected by nitrogen doses and plant densities at a statistically significant level. It is seen that the research results are similar to the findings of [68] who stated that plant density does not affect fiber quality characteristics, and [69] who stated that fiber reflectance not affected by plant density. Similar results were obtained with the findings of [43] who stated that fiber reflectance is not affected by nitrogen doses.

Fiber Yellowness

It can be observed from Table **4** that nitrogen doses and plant density do not have a significant effect on the fiber yellowness value, and the interaction of nitrogen doses and plant density is not significant for this feature.

Table **4** shows that fiber yellowness values vary between 8.29 and 8.55 at different nitrogen doses, and vary between 8.40 and 8.50 at different plant densities, and the overall average value of the experiment is 8.45. It was determined that the fiber yellowness value was not affected by nitrogen doses and plant densities at a statistically significant level. It is seen that similar results were obtained with [43] who reported that nitrogen doses were not important on the fiber yellowness value, and [54] who stated that plant density did not affect the fiber yellowness value.

Spinning Consistency Index

It can be observed from Table **4** that nitrogen doses and plant density do not have a significant effect on the spinning consistency index, and the interaction of nitrogen dose and plant density is not significant for this feature.

Table **4** shows that the spinning consistency index values vary between 125.33 and 131.33 at different nitrogen doses, and vary between 126.40 and 131.18 at different plant densities, and the overall average value of the experiment is 128.83. It has been determined that the spinning consistency index value, known as an important quality criterion, is not affected by nitrogen doses and plant densities at a statistically significant level. While [54] reported that plant density does not have a significant effect on the spinning consistency index, it is seen that similar results were obtained by [43] and [67] who stated that the effect of nitrogen doses on this trait is non-significant.

CONCLUSION

In the study, it was determined that significant statistical differences were obtained in terms of seed cotton yield, number of monopodial and sympodial branches and number of nodes. It was determined that no significant statistical difference was obtained in the number of bolls, boll weight, seed cotton weight per boll, number of seeds in boll, number of node of first fruiting branch, height/node ratio, ginning percentage, leaf chlorophyll content (SPAD value), first picking percentageo, NDVI value and fiber quality criteria such as fineness, length, strength, elongation, uniformity, reflectance, yellowness and spinning consistency index. It was observed that nitrogen doses x plant density interaction was significant in plant height trait.

It was observed that plant density was effective on the yield of cotton and the number of sympodial branches, and it was determined that the highest yield was obtained from 5 cm plant density, and the lowest yield was obtained from 15 cm plant density. It was determined that the highest number of sympodial branches were obtained from 15 cm plant density, and the lowest number of sympodial branches were obtained from 5 cm plant density.

It was observed that nitrogen doses caused a significant difference in the number of monopodial branches and the number of nodes, and it was determined that the highest number of monopodial branches and the number of nodes were obtained at 6 kg da^{-1} nitrogen dose, and the nitrogen doses x plant density interaction was effective on plant height.

In the study, it was observed that all the fiber quality characteristics determined with the help of the HVI instrument were not affected by different plant density and nitrogen doses, and no significant statistical difference could be determined between the applications. This situation shows that the response of the Orion cotton variety used as material in the study to different agronomic applications such as nitrogen and plant density is stable.

The fact that the study was conducted as a single-year study using the Orion cotton variety and therefore the results obtained reflect the genetic performance of the variety and that similar results can be obtained by growing the variety in the same ecology. The study results show that the number of monopodial branches and the number of nodes may change depending on the nitrogen dose when the Orion variety is planted at a plant density of 5 cm or grown without thinning, and the plant height of the variety may differ at different nitrogen doses and plant density.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest between the authors in this study.

AUTHORS' CONTRIBUTION

EK contributed to the design of the research, obtaining the data, analyzing and interpreting the data, performing statistical analyses, preparing the visuals and writing the article, and OI conducting the study and obtaining the data. Both of authors contributed to the final version of the manuscript.

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REFERENCES

[1] Karademir E, Karademir Ç, Ekinci R, Sevilmiş U. Determination of Yield and Fiber Quality Properties in Advanced Generation Lines in Cotton (Gossypium hirsutum L.) Turkish Journal of Agricultural Research, 2015; 2(2): 100-107. https://doi.org/10.19159/tutad.60964

[2] Yang G, Luo X, Nie Y, Zhang X. Effects of plant density on yield and canopy micro environment in hybrid cotton. Journal of Integrative Agriculture, 2014; 13(10): 2154-2163. https://doi.org/10.1016/S2095-3119(13)60727-3

[3] Zhi XY, Han YC, Li YB, Wang GP, Du WL, Li XX, Mao SC, Lu FENG. Effects of plant density on cotton yield components and quality. Journal of Integrative Agriculture 2016; 15(7): 1469-1479. https://doi.org/10.1016/S2095-3119(15)61174-1

[4] Jones MA, Wells R. Dry matteral location and fruiting patterns of cotton grown at two divergent plant populations. Crop Science 1998; 37: 797-802. https://doi.org/10.2135/cropsci1997.0011183X003700030017x

[5] Bednarz CW, Bridges DC, Brown SM. Analysis of cotton yield stability across population densities. Agronomy Journal 2000; 92(1): 128-135. https://doi.org/10.2134/agronj2000.921128x

[6] Smith WC, Waddle BA, Ramery HHJr. Plant spacings with irrigated cotton. Agronomy Journal 1979; 71: 858-860. https://doi.org/10.2134/agronj1979.00021962007100050035x

[7] Mao L, Zhang L, Evers JB, Werf W, Liu S, Zhang S, Wang B, Li Z. Yield components and quality of intercropped cotton in response to mepiquat chloride and plant density. Field Crops Research 2015; 179: 63-71. https://doi.org/10.1016/j.fcr.2015.04.011

[8] Ren X, Zhang L, Du M, Evers JB, Werf W, Tian X, Li Z. Managing mepiquat chloride and plant density for optimal yield and quality of cotton. Field Crops Research 2013; 149: 1- 10. https://doi.org/10.1016/j.fcr.2013.04.014

[9] Hall AE, Ziska LH, Reddy KR, Hodges HF. Crop breeding strategies for the 21st century, In: Reddy KR, Hodges HF, eds. Climate Change and Global Crop Productivity, Oxon: CABI, 2000, 407-423. https://doi.org/10.1079/9780851994390.0407

[10] Rochester IJ, Constable GA, Oosterhuis DM, Meredith E. Nutritional requirements of cotton during flowering and fruiting Chapter 4, Ed. Oosterhuis DM, Cothren JT. Flowering and Fruiting in Cotton The Cotton Foundation 2012; 35-50.

[11] Bloom AJ. The increasing importance of distinguishing among plant nitrogen sources. Current Opinion in Plant Biology 2015; 25: 10-16. https://doi.org/10.1016/j.pbi.2015.03.002

[12] Karaman MR. Plant Nutrition. Gübretaş Guide Book Series 2012; 2, Ankara.

[13] Wullschleger SD, Oosterhuis DM. Canopy development and photosynthesis of cotton as influenced by nitrogen nutrition. Journal of Plant Nutrition 2008; 13(9): 1141-1154. https://doi.org/10.1080/01904169009364140

[14] Niu L, Gui H, Iqbal A, Zhang H, Dong Q, Pang N, Wang S, Wang Z, Wang X, Yang G, Song M. N-Use Efficiency and yield of cotton (Gossypium hirsutum L.) are improved through the combination of N-Fertilizer reduction and N-efficient cultivar. Agronomy 2021; 11 (1): 55. https://doi.org/10.3390/agronomy11010055

[15] Anonymous, Cotton Variety Catalog. T.C. Minister of Agriculture and Forestry 2022; https://www.tarimorman.gov.tr/BUGEM/TTSM/Belgeler/Yay%C4%B1nlar/%C3%87e%C5%9Fit%20Katologlar%C4%B1/2022/End%C3%BCstri%20Bitkileri/2022_Pamuk_cesit_%20katalogu.pdf

[16] Johnson JR, Saunders JR. Evaluation of chlorophyll meter for nitrogen management in cotton. Annual Report, 2002; 162-163.

[17] Gwathmey CO, Tyler DD, Yin X. Prospects for monitoring cotton crop maturity with NDVI. Agronomy Journal 2010; 102(5): 1352-1360. https://doi.org/10.2134/agronj2010.0148

[18] Gwathmey CO, Leib BG, Main LC. Lint yield and crop maturity responses to ırrigation in a short-season environment. The Journal of Cotton Science 2011; 15: 1-10.

[19] Incekara F, Turan ZM. 1977. Ekim sıklığının dört pamuk çeşidinde bazı agronomik karakterlere ve değişik yöntemlere göre analiz edilen erkencilik üzerine etkisi, Ege Üniversitesi Ziraat Fakültesi Yayınları, 303. Bornova-İzmir, 69.

[20] Kaynak MA, Unay A, Ozkan D, Akdemir H, Gurel A. Effect of Different Planting Densities on Agronomic and Technological Characteristics in Some Cotton (Gossypium hirsutum L.) Varieties with Colored Fibers and Okra Leaves. Türkiye II. Field Crops Congress, Ondokuz Mayıs University Faculty of Agriculture Department of Field Crops Samsun 1997; 320-324.

[21] Silva PT, Macedo FG, Camacho MA, Santos C, Santi A, Krause W, Rambo JR. Spacing and plant density effect on reproductive development of herbaceous cotton. Scientia Plena 2012; 8(5): 1-8.

[22] Çopur O, Gur MA, Ozel A, Demir U. Harran Ovası Koşullarında Farklı Sıra Mesafelerinin İki Pamuk (G. hirsutum L.) Çeşidinde Verim ve Verim Unsurlarına Etkisi Üzerinde Araştırmalar. Harran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü, Tübitak Tarp- 1962 (Proje Raporu) 2002; Şanlıurfa.

[23] Azizpour K, Shakiba MR, Moghadan M, Elah NN, Elah EE. Effects of plant density on morphological characteristics and yield of two cotton cultivars at Varamin Region. Journal of Agricultural Science 2005; 15(1): 137-151.

[24] Bozbek T, Ünay A. The effect of sowing time and plant density on cotton yield. Anadolu 2005; 15(1): 34-43. https://doi.org/10.3923/ja.2006.122.125

[25] Kubde KJ, Lakhdive BA. Effect of nitrogen, phosphorus and spacing on yield, quality and nutrient uptake of hirsutum cotton. Research Journal 1993; 17(2): 232-232.

[26] McConnell JS, Baker WH, Frizzell BS, Varvil JJ. Nitrogen fertilization of three cotton cultivars, Special Report Agricultural Experiment Station, Division of Agriculture University 1993; 162: 154-158.

[27] Godoy AS, Chavez FG, Palomo GA. Nitrogen fertilization of Cian 95 a new variety fort he Comarca Lagunera. Proceedings Beltwide Cotton Conferences, January 5-8, San Diego, California, USA, 1994; 1568-1569.

[28] Bibi Z, Khan N, Mussarat M, Khan MJ, Ahmad R, Khan IU, Shahen S. Response of Gossypium hirsutum genotypes to various nitrogen levels. Pakistan Jounal of Botany 2011; 43(5): 2403-2409.

[29] Hassan M, Muhammed T, Nasrullah M, Iqbal M, Nasir A, Haq I. Cotton response to split application of nitrogen fertilizer. Asian Journal of Plant Sciences, 2003; 2(6): 457-460. https://doi.org/10.3923/ajps.2003.457.460

[30] Tomar SPS, Tomar SS, Shrivastava UK. Response of cotton nitrogen and plant protection measures. Indian Journal of Agronomy 1989; 34(2): 254-255.

[31] Devi B, Bharathi S, Rekha MS, Jayalalitha K. Nutrient uptake and economics of cotton in high density planting system under varied plant spacing and nitrogen levels. Journal of Research ANGRAU 2018; 46(1): 26- 29.

[32] Liaqat W, Jan MF, Ahmadzai MD, Ahmad H, Rehan W. Plant spacing and nitrogen affects growth and yield of cotton. Journal of Pharmacognosy and Phytochemistry 2018; 7(2): 2107-2110.

[33] Luo Z, Liu H, Li W, Zhao Q, Dai J, Tian L, Dong H. Effects of reduced nitrogen rate on cotton yield and nitrogen use efficiency as mediated by application mode or plant density. Field Crops Research 2018; 218: 150-157. https://doi.org/10.1016/j.fcr.2018.01.003

[34] Gençer O, Oğlakçı M. 1983. Farklı sıra arası uzaklığı ve azot gübrelemesinin, pamuk bitkisinin (G. hirsutum L.) verim ve kalite unsurlarına etkisi üzerine araştırmalar. Çukurova Üniversitesi Ziraat Fakültesi Yıllığı 1983; (3-4): 179-194.

[35] Cawley N, Edmisten KL, Stewart AM, Wells R. Evaluation of Ultra Narrow Row Cotton in North Carolina. Reprinted from the Proceedings of the Beltwide Cotton Conference 1998; 2: 1402-1403.

[36] Kumar A, Karunakar AP, Nath A, Meena BR. The morphological and phenological performance of different cotton genotypes under different plant density. Journal of Applied and Natural Science, 2017; 9(4): 2242 -2248. https://doi.org/10.31018/jans.v9i4.1518

[37] Haliloğlu H. 1999. A research of the effects of different nitrogen rates on flowering and fruiting pattern, yield, yield components in cotton (Gossypium hirsutum L.) in the Harran plain conditions. Phd thesis Harran University Department of Field Crops Şanlıurfa, 162.

[38] Iqbal M, Ahmad S, Nazeer, Muhammad T, Khan MB, Hussain M, Mehmoud A, Tauseed M, Hameed A, Karim A. High plant density by narrow plant spacing ensures cotton

productivity in elite cotton (Gossypium hirsutum L.) genotypes under severe cotton leaf curl virus (CLCV) infestation. African Journal of Biotechnology 2012; 11(12): 2869-2878. https://doi.org/10.5897/AJB11.3259

[39] McCarty J, Jenkins J, Hayes R, Wubben M. Effects of plant density on boll retention and yield of cotton in the mid-south, American Journal of Plant Sciences 2017; 8: 891-906. https://doi.org/10.4236/ajps.2017.84060

[40] Akbar HM, Akram M, Hassan MW, Hussain A, Rafay M, Ahmad I. Growth, yield and water use efficiency of cotton (Gossypium hirsutum L.) sown under different planting techniques. Custos e @gronegócio on line 2015; (11): 1, 142-160.

[41] Mahil EIT, Lokanadhan S. Yield and yield components of winter cotton (Gossypium hirsutum L.) genotypes influenced by plant spacings. International Journal of Plant & Soil Science 2017; 20(6): 1-6. https://doi.org/10.9734/IJPSS/2017/38591

[42] Wang X, Hou Y, Mingwei D, Xu D, Lu H, Tian X, Li Z. Effect of planting date and plant density on cotton traits as relating to mechanical harvesting in the Yellow River valley region of China. Field Crops Research 2016; 198: 112-121. https://doi.org/10.1016/j.fcr.2016.09.010

[43] Karataş M, Karademir E. Management of nitrogen stress in cotton (Gossypiun hirsutum L.) using greenseeker technology. Journal of Applied Life Sciences and Environment, 2022; 55(4): 441-456. https://doi.org/10.46909/alse-554075

[44] Zaman I, Ali M, Shahzad K, Tahir MS, Matloob A, Ahmad W, Alamri S, Khurshid MR, Qureshi MM, Wasaya A. Effect of plant spacings on growth, physiology, yield and fiber quality attributes of cotton genotypes under nitrogen fertilization. Agronomy 2021; 11: 2589. https://doi.org/10.3390/agronomy11122589

[45] Bondada BR, Oosterhuis DM, Norman RJ, Baker WH. Canopy photosynthesis, growth, yield, and boll 15N accumulation under nitrogen stress in cotton. Crop Science 1996; 36: 127- 133. https://doi.org/10.2135/cropsci1996.0011183X003600010023x

[46] El-Zahi ES, Arif SA, Jehan BA, El-Dewy MHM. Inorganic fertilization of cotton field- plants in relation to sucking insects and yield production components of cotton plants. Journal of American Science 2012; 8(2): 509-517.

[47] Şahin A. Nitrogen Requirement of Nazilli-84, Nazilli-87 and Nazilli-M-503 Cotton Cultivars, Nazilli Cotton Research Institute 1994; Publication No: 44, Nazilli.

[48] Sawan ZM. Plant density; plant growth retardants: Its direct and residual effects on cotton yield and fiber properties. Cogent Biology 2016; 2, 1234959: 1-12. https://doi.org/10.1080/23312025.2016.1234959

[49] Vireshwar S, Nagwekar SN, Singh V. Effect of weed control and nitrogen levels on quality characteristics in cotton. Journal of the Indian Society for Improvement 1989; 14(1): 60-64.

[50] Oruçoğlu H, Boyacı S, Paşaoğlu T, Öztürk Z. Cotton Research Abstract (1967-1989), Akdeniz Agricultural Research Institute 1989; Publication No, 12, Antalya.

[51] Janat M, Khalout AR. Evaluation of drip-ırrigated cotton grown under different plant population densities and two ırrigation regimes. Communications in Soil Science and Plant Analysis 2011; 42: 741-752. https://doi.org/10.1080/00103624.2011.550373

[52] Xie T, Su P, An L, Shan L, Zhou Z, Chai Z. Physiological characteristics of high yield under cluster planting: photosynthesis and canopy microclimate of cotton. Plant Production Science 2016; 19(1): 165-172. https://doi.org/10.1080/1343943X.2015.1128088

[53] Ramirez MB, Allen PB, Freeland RS, Wilkerson JB. Cotton Canopy NDVI: Reducing the Ground Exposure Effect. Transactions of the ASABE 2017; 60(2), 293-301. https://doi.org/10.13031/trans.10950

[54] Altundağ R, Karademir E. Plant spacing and its effect on yield, fibre quality and physiological parameters in cotton. Journal of Applied Life Sciences and Environment, 2021; 2(186): 200-215. https://doi.org/10.46909/journalalse-2021-018

[55] Porter W. Sensor Based Nitrogen Management for Cotton Production in Coastal Plain Soils. Msc Thesis, Clemson University 2010; 1-109.

[56] Arnall DB, Abit MJM, Taylor RK, Raun WR. Development of an NDVI-based nitrogen rate calculator for cotton. Crop Science 2016; 56(6): 3263-3271. https://doi.org/10.2135/cropsci2016.01.0049

[57] Foote W, Edmisten K, Wells R, Collins G, Roberson G, Jordan D, Fisher L. Influence of nitrogen and mepiquat chloride on cotton canopy reflectance measurements. The Journal of Cotton Science 2016; 20: 1-7. https://doi.org/10.56454/WJHN3394

[58] Afzal MN, Tariq M, Ahmad M, Mubeen K, Khan MA, Afzal MU, Ahmad S. Dry matter, lint mass and fiber properties of cotton in response to nitrogen application and planting densities. Pakistan Journal of Agricultural Research 2018; 32(2): 229-240. https://doi.org/10.17582/journal.pjar/2019/32.2.229.240

[59] Boquet DJ. Cotton in ultra-narrow rows pacing: plant density and nitrogen fertilizer rates. Agronomy Journal 2005; 97(1): 279-287. https://doi.org/10.2134/agronj2005.0279

[60] Bridge RR, Meredith WR, Chism JF. Influence of planting method and plant population on cotton (Gossypium hirsutum L.). Agronomy Journal 1972; 65(1): 104-109. https://doi.org/10.2134/agronj1973.00021962006500010032x

[61] Mukundan S, Janardhanam KV, Reddy BM, Reddy AS. Effect of nitrogen and phosphorus on fibre quality of cotton. Field Crop Abstracts 1992; 45(4): 314.

[62] El-Dababi, AS, Hammam GY, Nagib MA. Effect of planting date, N and P applications levels on seed index, lint percentage and technological characters of Giza-80 cotton cultivar. Annals of Agricultural Science, Moshtocor, 1995; 33(2): 455-464.

[63] Stephenson DO, Barber LT, Bourland FM. Effect of twin-row planting pattern and plant density on cotton growth, yield, and fiber quality. The Journal of Cotton Science 2011; 15: 243-250.

[64] Wankhade ST, Deshpande RM, Kene HK. Effect of different forms of fertilizer on yield of cotton. PKV Research Journal 1994; 18(1): 33-34.

[65] Karademir C, Karademir E, Doran I, Altıkat A. The Effect of Different Nitrogen and Phosphorus Doses on Cotton Yield, Yield Components and Some Earliness Criteria. Journal of Agricultural Science 2006; 12(2): 121-129.

[66] Saleem MF, Bilal MF, Awais M, Shahid MQ, Anjum SA. Effect of nitrogen on seed cotton yield and fiber qualities of cotton (Gossypium hirsutum L.) cultivars. The Journal of Animal & Plant Sciences 2010; 20(1): 23-27.

[67] Hernandez-Cruz AE, Sánchez E, Preciado-Rangel P, García-Bañuelos ML, Palomo-Gil A, Espinoza-Banda A. Actividad de la Nitrato Reductasa Biomasa, Rendimiento y Calidad en Algodón en Respuesta a la Fertilización Nitrogenada, Revista Internacional De Botanica Experimental 2015; 84: 454-460.

[68] Hawkins BS, Peacock HA. Influence of row width and population density on yield and fiber characteristics of cotton. Agronomy Journal 1973; 65(1): 47-51. https://doi.org/10.2134/agronj1973.00021962006500010014x

[69] Kayış MA. 2018. The effect of normal, narrow and twin row planting pattern on cotton (Gossypium hirsutum L.) yield and yield components under the Harran Plain conditions. MSc thesis, Harran University Department of Field Crops, Şanlıurfa, 1-74.

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