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Optimizing Cotton Production: Impact of Varied Plant Densities on Yield and Fiber Quality

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A R T I C L E I N F O

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A B S T R A C T

This study investigates the impact of varying planting densities on cotton plants' morphological traits and yield. As planting density increases, there is a reduction in monopodial and sympodial branches, resulting in a more compact plant structure. The study highlights the highest yield achieved with specific planting densities, endorsing the viability of both holl and row planting methods. It suggests adopting narrow or ultra-narrow row systems to enhance yield and economize input costs. The study was conducted in 2017 at the experimental field of Aydın Adnan Menderes University in the Faculty of Agriculture's Department of Field Crops. The material used in this study was the widely cultivated cotton variety "Gloria" in the Aegean region. The investigation was conducted using a randomized block design with 4 replications. In evaluating cotton yield and related parameters, it was observed that D1 and D2 (14.285 plants/da) achieved the highest yield concerning plant density, emphasizing the viability of both holl and row planting methods. The study concluded that augmenting the number of plants within a specific area of production significantly contributes to higher seed cotton yields. To enhance yield and economize cotton input costs, the adoption of a narrow or ultra-narrow row production system is suggested as an alternative strategy to conventional methods.

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Introduction

Cotton is an important source of raw material in the textile industry. Cotton fibre has many uses other than textiles. In our country, cotton is mostly grown in the Southeastern Anatolia Region, followed by the Aegean and Mediterranean Regions. Increasing fibre yield and quality is one of the main problems. Because of this reason, different agronomic practices are being experimented.

Plant productivity can be influenced by genetic, environmental conditions and cultivation processes. Cotton production can be affected by plant density and other various cultivation techniques. In addition, optimal climatic conditions during cultivation have a positive impact on both the yield and quality of cotton crops. Hall and Ziska (2000) suggest that climate change has a negative impact on plant height, which can impede early development and weed competition. Plant density is adjustable one of the methods to address these issues.

According to Delaney (2006), the optimal planting time for Aydın region ranges from mid-April to late May. Planting cotton after this time period results in decreased yields. Additionally, the study indicates the importance of the relationship between planting time and plant density (19cm, 38cm, 76cm and 102cm) row spacing and three different plant densities (9884, 18532 and 29650 plants/da)

Jost and Cothren's (2000) study on cotton production discovered that ultra-narrow row production could reduce costs by increasing plant density. The study tested four-row spacings (19cm, 38cm, 76cm, and 102cm) and three plant densities (9884, 18532, and 29650 plants/da). The results showed that 50% of the harvestable bolls were formed on the first ten internodes. Increasing plant density led to maturity. Akhtar et al. (2002) identified the optimal plant density for achieving maximum cotton yield. They found that the highest number of bolls and weight were observed at 30 cm and 20 cm spacings. However, Bozbek and Ünay (2005) reported that plant density has an insignificant effect on seed cotton yield, while ginning percentage directly affects yield. İncekara and Turan (1977) discovered that increasing the number of plants per unit area correspondingly increased seed cotton yield.

Akçar and Gençer (1987) found that plant density has no impact on cotton seed weight and 100 seed weight. Düven (1992) conducted a study under Çukurova conditions and showed a decrease in the number of monopodial branches, sympodial branches and number of bolls, as well as a decrease in boll weight and seed cotton yield with a decrease in plant density. Moreover, Gerik (1999) suggested that the utilization of narrow-row planting could improve cotton production by 40 to 100%.

In a study conducted by Hawkins and Peacock (1971), Bridge et al. (1973) and Baker (1976), the relationship between "fiber length, fiber strength, and fiber elongation" and plant density was examined. The results indicated that plant quality was not significantly affected by plant density. Kaynak et al. (1994) discovered that reducing the spacing between rows (raising plant density) resulted in higher seed cotton output, earlier maturity, and increased weight of 100 seeds. Nevertheless, there was a decrease in plant height, number of monopodial branches, sympodial branches, number of bolls, boll weight, ginning percntage fiber length and strength. In a study conducted by Heithold (1995), narrow-row cultivation was compared to traditional farming. The results indicated that narrow-row cultivation had the capacity to improve boll number and fiber yield. Jost et al. (1998) established that ultra-narrow row cotton cultivation is a viable farming technique, as there is no noticeable disparity in fiber yield between different row spacing regimens. According to Jones and Wells (1998), an increase in plant density is associated with a decrease in fiber fineness.

The main goal of this study was to systematically investigate the effects of different planting densities on cotton production, yield components and fiber characteristics. Identifying alternative planting techniques that account for plant density adjustment is critical to prevent adversities due to sowing delay.

Materials and Methods

The study was conducted in 2017 at the experimental field of Aydın Adnan Menderes University in the Faculty of Agriculture's Department of Field Crops. The material used in this study was the widely cultivated cotton variety "Gloria" in the Aegean region. The investigation was conducted using a randomized block design with 4 replications. Figure 1 displays the design of experiment involving five distinct sowing densities with a row spacing of 70 cm. These densities were labeled as follows: D1 with density of 10 cm, D2 with density of 5 cm, S3 with a row spacing of 30 cm and three plants per hole, S4 with a row spacing of 30 cm and six plants per hole, and S5 with no treatment (Table 1). Each plot area, comprising of 4 rows with a row spacing of 70 cm and a length of 10 m, was assessed to be 28 m^2 at the time of harvest.

Parameters Investigated

Seed cotton yield (kg/da), number of bolls per plant (number/plant), boll weight (g), Plant height (cm), Number of days to first boll opening (day), irrigation water use efficiency (IWUE), ginning percentage (%), Fiber quality properties a. Fiber length (mm), b. Fiber fineness, c. Fiber strength (gr/tex), d. Elongation (%) and e. The uniformity index was determined. The parameters were measured from random 10 plants from each row.

Cultural Treatments Applied in the Experiment

The experimental area was treated with a disc harrow for 3 times for soil preparation, and then the seedbed was prepared by dragging the roller 2 times. According to the soil analysis results, 40 kg of 20-20-0 compound fertilizer (8 kg Nitrogen, 8 kg Phosphorus per decare), 20 kg (4.4 kg Nitrogen per decare) 21% Ammonium Sulphate and 30 kg (6.3 kg Nitrogen per decare) 21% Ammonium Sulphate fertilizers were used before flowering. The trial area was hoeed 2 times between the rows with a machine, 1 time by hand, and drip irrigation was applied 6 times. The trial area was sprayed 10 times for empoasca, aphid, whitefly and green worm pests. Harvesting was done manually on 14.10.2017. During harvesting, 2 rows were harvested from the middle of the plots, leaving one meter from the beginning and end of each plot and one row from the edges. Before harvesting, 50 single boll samples were taken from each parcel to represent the parcel for laboratory analysis.

Table 1. Sowing densities and plant densities applied in the experiment

Density (D)	Row	Plant Density (plants/da)
D1	10 cm in row	14.285
D2	30 cm holl	14.285
D3	5 cm in row	28.571
D4	30 cm holl	28.571
D5	No treatment has been applied to the sowing	47.619

Figure 1. A: 10 cm in row sowing 14.285 plants/da; B. 30 cm in row sowing 14.285 plants/da; C. 30 cm in row sowing 28.571 plants/da; D. 5 cm in row sowing 28.571 plants/da; E. No treatment sowing 47.619 plants/da.

Table 2. Variance analysis results of applied sowing density

SV	df	MB	SB	BN	BW	GP	YD	FL	FS	FF
Rep	3	0.33	1.73	0.71	2.2	1.36	8493.4	1.09	0.05	0.30
Density	4	0.87*	6.88**	11.4**	0.13	0.6	1773.6**	0.211	0.12	0.234
Error	12	0.21	0.44	0.21	0.57	0.47	344.99	1.05	0.14	0.82

SV: Source of Variance; * MB: Monopodial branch, SB:Sympodial branch, GP: Ginning percentage, BW: Boll weight, YD: Cotton seed yield FF: Fiber fineness, FS: Fiber strength, FL: Fiber length, ,FS: Fiber strength

Tablo 3. Means and LSD of the parameters affected by plant density application

Plant density	MB	SB	BN	YD
D1	1 A	9.25 A	8.37 A	542.97 A
D2	0.75 A	9 AB	7.37 AB	528.53 AB
D3	0.75 A	8.25 AB	6.63 B	513.1 BC
D4	0 B	8 AB	5.31 C	508.6 BC
D5	0 B	7.5 B	4.31 C	494.98 C
$Lsd_{(0.05)}$	0.828	1.954	1.244	28.88

Result and Discussion

The results of analysis of variance for yield and yield component traits of cotton genotypes cultivated at different planting densities are presented in Table 2. There is a statistically significant difference in terms of number of monopodial branches, sympodial branches, number of boll and seed cotton yield characteristics; it was found that there were no statistically significant differences in terms of boll weight per plant, ginning percentage, fiber length, fiber strength and fiber fineness.

The number of monopodial branches varied between 1-0 pieces/plant according to plant density. The highest average number of monopodial branches was obtained at plant density D1 (14.285 plants/da) and the lowest average number of monopodial branches was obtained at plant densities S4 and S5; in general, as plant density increased, monopodial branch values tended to decrease (Table 3). At low plant densities, the number of monopodial branches and sympodial branches increases, and plants get a wide habitus appearance with more internodes (Bednarz et al., 2000; Meng et al., 2016). Ulaş et al., (2023) was determined that the number of monopodial branches decreased as the plant density increased.

It was determined that plant densities statistically affected the number of sympodial branches of cotton plants. The highest number of sypmodial branches was obtained at plant density of 14.285 plants/da (D1) with 9.25 plants/piece and the lowest number of sypmodial branches was obtained at plant density of 47.619 plants/da (D5) with 7.5 plants/piece, and it was determined that the number of sypmodial branches decreased as the plant density increased (Table 3). This result can be explained by the finding that as the plant density increases, plant height increases in the first developmental stage of cotton plant; there is no change in the later stages and high plant densities may affect yield by reducing the number of internodes on the main stem (Kaggwa-Asiimwe et al., 2013). As a result, as plant density increased, plant height decreased and the number of sympodial branches decreased accordingly. The findings obtained are in parallel with Karataş (2007) and Ulaş et al. (2023) who reported that the number of branch nodes decreased as plant density increased and contradictory with the findings of Bednarz et al. (2000) who reported that the number of nodes with the first sympodial branch was not related to plant density.

The highest number of bolls (8.37 pieces/plant) was observed at plant density S1 (14.285 plants/da) and the lowest number of bolls (4.31 pieces/plant) was observed at plant density S5 (47.619 plants/da) (Table 3). The results of the study are in agreement with the findings of the studies indicating that the number of bolls decreases with increasing plant density (Akthar et al., 2002; Boquet (2005); Siebert (2005); Beyyavaş et al. (2018); Sadık and Kaynak (2017); Ulaş et al., 2023).

When plant densities were compared in terms of boll weight, it was found that boll weight was irregularly distributed with plant density (Figure 1D). The highest average boll weight value was observed at plant density S4 (28,531 plants/da) with 3.9 g and the lowest boll weight value was observed at plant density S5 with 3.1 g (Figure 2D). The findings of the study were different from the results of Fowler and Ray (1977), Kaynak (1995), Jones and Wells (1998), Bednarz et al. (2000), Akhtar et al. (2002), McCarty et al. (2017) who reported that boll weight decreased with increasing plant density.

When plant densities were compared in relation to ginning percentage, it was found that there was an irregular distribution with plant density (Figure 2H). This study is in parallel with the study of Ulaş et al. (2023) in which they reported that ginning percentage was not statistically affected by plant density, but in conflict with the studies (Bednarz et al., 2005; Darawsheh et al., 2009) which reported that ginning percentage decreased with increasing plant density. It is believed that the reason why the ginning percentage is not affected by sowing density is because it is a trait with high heritability. In fact, studies have found that cotton ginning percentage is a trait with high heritability and is less affected by environmental and growing conditions (İlker et al., 2008; Reddy and Sarma, 2014).

When considering the effect of planting density on seed cotton yield, the highest yield value was obtained at D1 (14.285 plants/da) with 542.97 kg/da. However, as the planting density increased, the yield value decreased and the lowest yield value was observed at S5 planting density (47.619 plants/da) with 494.98 kg/da (Table 3).

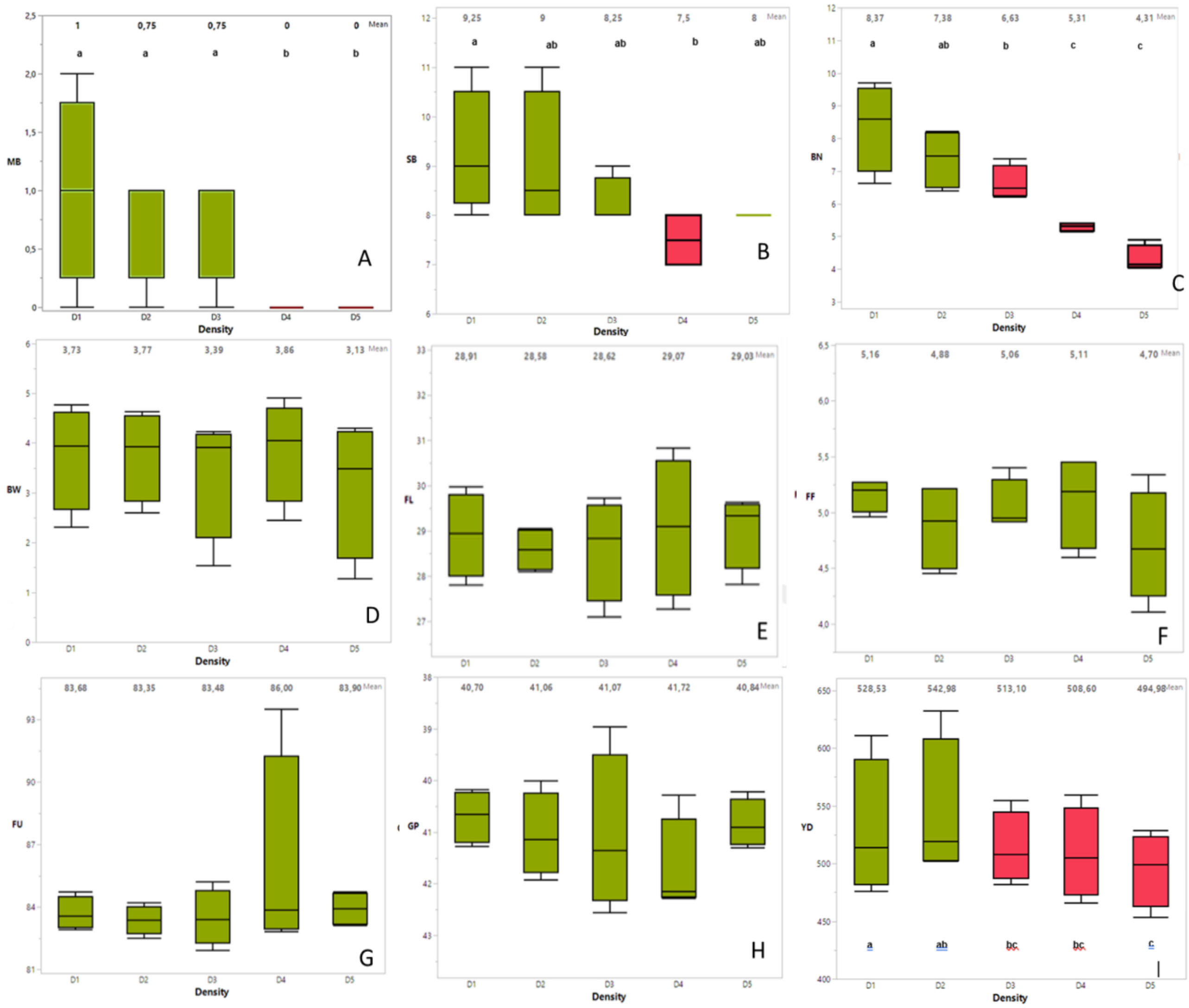

Figure 2. Mean values of measured traits according to plant densities. * A: Monopodial branch, B:Sympodial branch, C:Boll Number, D:Boll weight, E: Fiber length F: Fiber fineness, G: Fiber uniformite H: Ginning percentage, I: Cotton seed yield

High plant density significantly reduces leaf characteristics such as stomatal number, length, width, pore perimeter, and thickness (Khan et al., 2019). As the plant density per unit area increases, the average net assimilation rate decreases, and the amount of dry matter produced also decreases (Bednarz et al., 2000). Therefore, while the number of plants per unit area increases, the average yield initially increases, but then shows a decreasing trend.

There was no statistical difference in fiber quality parameters in terms of plant density. The highest fiber length value was obtained at D4 (28.531 plants/da) plant density (29.07 mm), while the lowest fiber length value was obtained at D2 (14.285 plants/da) plant density (28.58 mm) (Figure 2E). In terms of fiber elongation, the lowest value was obtained at D1 (14.285 plants/da) plant density (5.77%) and the highest value was obtained at D3 (28.531 plants/da) plant density (6.23%). When plant densities were compared in terms of fiber fineness, it was determined that the finest fiber was obtained from S5 plant density with 4.7 mic and the coarsest fiber was obtained from D1 plant density with 5.15 mic. It was determined that the fiber fineness value increased statistically as the plant density increased (Figure 2F).

Conclusion

The study revealed substantial impacts of varying planting densities on the morphological characteristics of cotton plants. As planting density increased, a discernible reduction in monopodial branch numbers and a more compact plant structure were observed. Additionally, the study demonstrated a noteworthy influence of plant density on sympodial branch numbers, which exhibited a decrease with the corresponding increase in planting density. The study extended its focus to key parameters, including boll number, boll weight, ginning percentage, and seed cotton yield.

In evaluating cotton yield and related parameters, it was observed that D1 and D2 (14.285 plants/da) achieved the highest yield concerning plant density, emphasizing the viability of both holl and row planting methods. The study concluded that augmenting the number of plants within a specific area of production significantly contributes to higher seed cotton yields. To enhance yield and economize cotton input costs, the adoption of a narrow or ultra-narrow row production system is suggested as an alternative strategy to conventional methods.

Furthermore, the study is fiber characteristics are predominantly influenced by genetics. Hence, the selection of appropriate varieties is important for maximizing fiber quality, with the secondary consideration of managing plant density to either maintain or amplify genetic potential.

These findings not only enhance our comprehension of the impacts of planting density on morphological traits and yield in cotton cultivation but also underscore the critical role of logicaly selecting and applying appropriate planting densities as a strategic approach to augmenting yield in cotton production.

Data Availability statements

The data used in this study are available upon reasonable request from the corresponding author.

Founding statements

This research was conducted with no external funding. All expenses related to this study were covered by the authors themselves, and no specific funding was received for the design, execution, analysis, interpretation of results, or writing of this manuscript.

Conflict of interest disclosure statement

The authors declare that they have no conflicts of interest relevant to this research.

Contribution of Authors

Dr. Hatice Kübra GÖREN, Corresponding Author Planning of the work, field and laboratory analysis, writing and revising manuscript. Dr. Uğur TAN, Statistical analysis, interpretation of the analysis results and help with writing and revising the manuscript.

Ethics approval statements

Ethical approval was not sought for this study, as it did not involve human subjects or patient data.

Patient consent statements

No patient consent was required for this study, as it did not involve human subjects or patient data.

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Clinical trial registration

This study does not involve a clinical trial, and therefore, clinical trial registration is not applicable.

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