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Research Article

Influence of Plant Density on Maize (*Zea mays* L.) Yield and Yield-Related Traits in the Amik Plain

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ABSTRACT

This study was conducted to determine the effects of different plant densities on yield and yield components of maize under main crop conditions in the Amik Plain. The maize cultivar P1541 was used, and the experiment was established at Mustafa Kemal University Agricultural Research and Application Center in Hatay, following a randomized complete block design with three replications. Six different plant density levels (7,519; 8,071; 8,606; 9,276; 9,990; and 10,989 plants da^{-1}) were applied. The evaluated traits included plant height, stalk diameter, ear insertion height, ear length, ear diameter, number of kernels per ear, ear weight, kernel weight, 1000-kernel weight, and grain yield. Most morphological characteristics did not show statistically significant differences. However, plant density had a significant effect ($P < 0.01$) on grain yield, with the highest yield obtained at 10,989 plants da^{-1}. These findings indicate that optimal plant density can enhance maize productivity under Amik Plain conditions.

Keywords: Maize, plant density, yield components, grain yield, P1541 cultivar.

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1. INTRODUCTION

Maize (*Zea mays* L.) ranks among the most important cereal crops for addressing global and national food security challenges posed by increasing population demands [1,2]. This versatile crop serves dual purposes in both human nutrition (processed into oil, starch, glucose, and snacks) and animal feeding systems (utilized as silage, green forage, and grain). As a C4 photosynthetic plant, maize exhibits exceptional solar energy utilization efficiency, resulting in a short growth cycle, high grain yield per ear, and remarkable adaptability to diverse climatic conditions[3,4]. These agronomic advantages enable its cultivation as both a primary and secondary crop, establishing maize as a strategic global commodity.

The optimization of maize productivity requires careful consideration of plant density alongside cultivar selection appropriate for regional agro-climatic conditions [5]. Plant density directly influences interplant competition dynamics, potentially creating either favorable or restrictive growth environments. While increased planting density has been associated with higher per-area yield potential[6], it induces complex physiological responses. Sher et al.[7] demonstrated that elevated densities reduce ear length and kernel filling percentage due to light competition during critical growth stages, while simultaneously increasing ear number per plant, resulting in net yield gains. This density-yield relationship has been further corroborated by Assefa et al.[8] and Tang et al.[9], who emphasized the interaction between genetic potential and planting density. Sönmez [10] additionally reported significant modifications in morphological characteristics and yield components under varying density regimes.

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This study aims to examine the effects of different planting densities on yield and yield components of a commonly cultivated maize variety under Amik Plain conditions, and to determine the optimal planting density.

2. EXPERIMENTAL

2.1. Materials

In this study, the maize cultivar P1541 was used as the plant material.

2.2. Methods

The experiment was conducted with three replications using a randomized complete block design (RCBD) at the Telgaliş Research and Application Field, affiliated with the Agricultural Research and Application Center of Hatay Mustafa Kemal University (36°15'N, 36°30'E, altitude up to 94 m above sea level). Each plot consisted of four rows, with an inter-row spacing of 70 cm. Intra-row spacings were set at 13.0, 14.3, 15.4, 16.6, 17.7, and 19.0 cm, respectively, to establish different plant density levels. The corresponding plant densities are presented in Table 1.

Table 1. Plant densities used as the research factor (plants da^{-1}).

Intra-row Spacing (cm)	Plant Density (plants da^{-1})
13	10,989
14.3	9,990
15.4	9,276
16.6	8,606
17.7	8,071
19.0	7,519

The plots were 2.8 meters wide and 5 meters long. The plant density treatments were randomly assigned within each block to represent different replications. Sowing was carried out on March 25, 2024, and harvesting took place on August 10, 2024.

According to the soil analysis, the soil texture was classified as clay-loam, with a low organic matter content of 1.93%, a moderate lime level of 6.45%, and a slightly alkaline pH of 7.12. Based on these results, a basal fertilizer (15-15-15) was applied at a rate of 20 kg nitrogen, 8 kg phosphorus, and 8 kg potassium per decare. Additionally, when the plants reached approximately 40–50 cm in height after emergence, a topdressing of nitrogen was applied using urea fertilizer (46% N) at a rate of 12 kg per decare. Weed control was carried out manually, and irrigation was performed at 20-day intervals.
The climatic data obtained from the nearest meteorological station to the experimental site are presented in Figure 1.

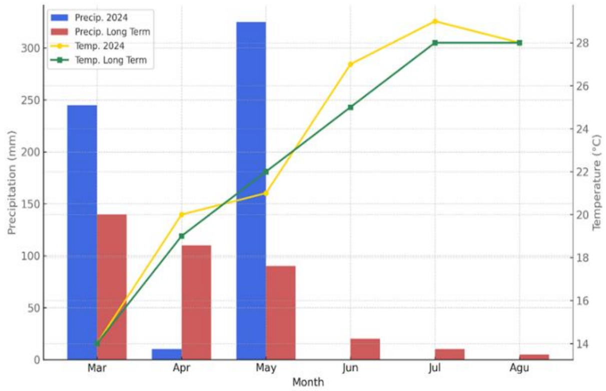

Figure 1. Climatic data obtained from the meteorological station closest to the experimental site.

As shown in Figure 1, precipitation levels in 2024 were high at the beginning of spring but dropped significantly toward late spring and early summer, indicating an almost completely dry profile. This pattern reflects an increasing irregularity in rainfall distribution and highlights the growing risks of drought and stress conditions.

Temperature data for 2024 reveal that temperatures during the spring months were consistently above the long-term averages, potentially leading to early evaporation and a reduction in soil moisture. Overall, the climatic conditions in 2024 deviated from typical patterns, with rainfall showing considerable imbalance in both timing and quantity. When evaluated together, the increase in temperature and decrease in rainfall suggest a heightened risk of drought and potential stress on agricultural productivity.

The following traits were examined for yield and yield components:

- **Plant Height (cm):** The height of 15 randomly selected plants per plot was measured from the soil surface to the top of the plant using a measuring tape.
- **Stem Diameter (mm):** The diameter was measured at the midpoint between the first and second internodes of 15 randomly selected plants per plot using a digital caliper, and expressed in millimeters.
- **First Ear Height (cm):** The height from the soil surface to the first ear node was measured in 15 randomly selected plants per plot using a measuring tape.
- **Ear Length (cm):** After harvesting, the ears from 15 randomly selected plants per plot were measured with a ruler and expressed in centimeters.

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- **Ear Diameter (mm):** The diameter of the ears from 15 randomly selected plants per plot was measured using a digital caliper and expressed in millimeters.

- **Number of Kernels per Ear:** The number was calculated by multiplying the number of rows by the number of kernels per row on each of 15 randomly selected ears per plot.

- **Single Ear Weight (g):** Each of the 15 randomly selected ears per plot was individually weighed on a scale and expressed in grams.

- **Grain Weight per Ear (g):** The kernels were removed from the ears of 15 randomly selected plants per plot and weighed individually, with results expressed in grams.

- **Thousand Kernel Weight (g):** For each plant density, seeds were counted in sets of 100 kernels with four replications, weighed, and converted into thousand-kernel weight, expressed in grams.

- **Grain Yield (kg ha^{-1}):** The grain yield obtained from each plot was calculated and expressed on a per-hectare basis.

All numerical data obtained from the study were subjected to analysis of variance (ANOVA) using the JMP 13.0 statistical software based on the randomized complete block design (RCBD). For the traits that were found to be statistically significant, Tukey's Honestly Significant Difference (HSD) test was applied for mean separation.

3. RESULTS and DISCUSSION

The effects of different plant densities on plant height (PH), stem diameter (SD), first cob height (FCH), cob length (CH), and cob diameter (CD) in main-season maize were found to be statistically non-significant (Table 3).

When PH values were examined, the effect of plant density was not significant, and the values ranged between 272.20 cm and 258.07 cm. The highest PH was observed at a plant density of 9,276 plants da^{-1}, while the lowest was recorded at 10,989 plants da^{-1}. El-Sobky and El-Naggar[11] reported that plant density had no significant effect on plant height; however, they noted through combined analysis that increased density could significantly influence plant elongation. Bayram et al.[12], in their study on silage maize, observed that increasing plant density led to longer internode distances and consequently taller plants, reporting these effects as significant. Similarly, Konuşkan et al.[13] stated that plant height increased with plant density and that this effect was statistically significant. These findings, however, are not in agreement with the results of our study.

For SD, although the highest value (26.66 mm) was recorded at a density of 8,606 plants da^{-1} and the lowest (24.75 mm) at 9,276 plants da^{-1}, the differences among plant densities were not statistically significant. Bayram et al.[12], in a study conducted on second-crop silage maize in Bursa, reported that stem diameter was significantly affected by plant density, noting that increased density reduced stem thickness. In contrast, Öztürk et al.[14] found that plant density did not significantly affect stem diameter in silage maize, indicating that SD remained relatively constant across densities-supporting our findings.

For FCH, the highest value was recorded at a density of 9,276 plants da^{-1}, and the lowest at 8,606 plants da^{-1}, with the values ranging from 69.93 cm to 58.40 cm. However, these differences were also found to be non-significant. Bengisu and Baytekin[15], in their study under Harran Plain conditions, reported no significant differences in FCH over two experimental years or in combined averages, and their results are consistent with ours.

Regarding CH and CD, the highest CH (19.53 cm) was observed at 9,276 plants da^{-1}, while the lowest (18.70 cm) was recorded at 7,519 plants da^{-1}. For CD, the highest value (53.57 mm) was obtained at 9,990 plants da^{-1} and the lowest (51.98 mm) at 8,071 plants da^{-1}. Nevertheless, these differences were not statistically significant, and CH and CD values were found to be relatively close across all plant densities. Mandic et al.[16] reported that cob length tended to increase with higher plant densities, but also noted that the effect varied across different cultivars and plant densities, influencing yield outcomes. Although cob diameter was reported to be influenced by plant density in some cases, our results indicate that plant density had no significant effect on CD, supporting the findings in the current study.

In main-season maize, while the effects of different plant densities on the number of kernels per cob (NS), cob weight (CW), seed weight per cob (SW), and thousand seed weight (TSW) were found to be statistically non-significant, the effect on seed yield (SY) was found to be significant (Table 4).

For NS, no consistent increase was observed with increasing plant density, and some fluctuations were recorded. The highest NS value was found at a density of 8,071 plants da^{-1} (734.40), while the lowest was recorded at 10,989 plants da^{-1} (664.67); however, these differences were statistically insignificant. Similarly, SW values exhibited slight fluctuations across densities, with the highest value (1,194.67 g) observed at 8,606 plants da^{-1} and the lowest (1,041.00 g) at 9,276 plants

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da⁻¹. No distinct trend was observed in TSW values based on plant density. The highest TSW (395.00 g) was recorded at 10,989 plants da⁻¹, and the lowest (354.17 g) at 9,990 plants da⁻¹. Bengisu and Baytekin [15], in their study conducted in the Harran Plain, reported that sowing density affected NS, while the highest SW and TSW values were obtained under low-density conditions and the lowest under high-density conditions—findings that are consistent with our results.

Regarding CW, although the values varied, the differences were not statistically significant. The highest CW was recorded at 8,606 plants da⁻¹ (1,429.33 g), and the lowest at 9,276 plants da⁻¹ (1,242.67 g). Mandic et al.[16] reported a reduction in CW with increasing plant density. While their results do not fully align with our findings, some similarities were observed.

When SY was evaluated, plant density had a statistically significant effect on yield. However, an increase in density did not result in a proportional increase in yield. The highest SY (122.42 t/ha) was obtained at 10,989 plants da⁻¹, while the lowest (81.43 t ha^{-1}) was recorded at 7,519 plants da⁻¹. Turhal [17], in a study conducted under Eskişehir conditions with different maize hybrids, reported that increasing plant density had a significant effect on yield. Similarly, Akgün et al. [18], in their study on sweet corn under Isparta conditions, found that the highest yield was achieved at the highest plant density—results that support the findings of our study.

Table 3. Effects of different plant density on properties of PH, SD, FCH, CH and CD.

Plant density (plant da^{-1})	PH (cm)	SD (mm)	FCH (cm)	CH (cm)	CD (mm)
7,519	264.33±2.66	25.63±0.71	66.33±0.64	18.70±0.67	52.54±0.54
8,071	261.70±4.94	24.89±0.89	64.07±2.07	18.92±0.54	51.98±0.59
8,606	269.33±0.87	26.66±0.70	58.40±2.10	19.17±0.27	53.57±0.17
9,276	272.20±3.82	24.75±1.23	69.93±5.68	19.53±0.09	52.63±0.63
9,990	262.77±2.86	24.90±1.60	69.13±5.20	18.72±0.22	53.07±0.79
10,989	258.07±3.59	25.98±0.94	64.40±3.00	19.45±0.26	52.58±0.85
P values	0.083^{ns}	0.8001^{ns}	0.4013^{ns}	0.5477^{ns}	0.6999^{ns}
CV values (%)	2.05	6.91	8.10	3.12	1.96

ns: not significant, CV: coefficient of variance, PH: Plant height, SD: Stem diameter, FCH: First cob height, CH: Cob height, CD: Cob diameter

Table 4. Effects of different plant density on properties of NS, CW, SW, TSW and SY.

Plant density (plant da^{-1})	NS (piece cob^{-1})	CW(g $plant^{-1}$)	SW(g cob^{-1})	TSW(g)	SY(t ha^{-1})
7,519	670.93±51.81	1276.00±61.91	1083.00±52.25	366.67±15.30	$81.43±3.93^{b}$
8,071	866.00±55.13	1289.00±24.03	1098.67±20.22	385.00±24.66	$88.67±1.63^{b}$
8,606	734.40±32.29	1429.33±30.23	1194.67±27.95	387.50±17.74	$102.81±2.41^{ab}$
9,276	699.10±20.58	1242.67±148.51	1041.00±118.58	375.83±7.95	$96.56±11.00^{ab}$
9,990	725.87±52.61	1291.00±66.20	1093.33±52.52	354.17±9.61	$109.22±5.25^{ab}$
10,989	664.67±61.27	1333.67±47.01	1114.00±40.72	395.00±11.46	$122.42±4.48^{a}$
P values	0.1471^{ns}	0.6583^{ns}	0.6991^{ns}	0.449^{ns}	0.0091^{**}
CV values (%)	10.94	8.50	8.33	6.61	8.33

**: P≤0.01, ns: not significant SW: Steam Weight, NS: number of seed, CW: con weight, SW: steam weight, TSW:1000-seed weight, SY: seed yield.
$^{a-b}$: Values indicated with different characters in same column differ from each other.

4.CONCLUSION

In this study, the effects of different plant densities on yield and selected morphological characteristics of the P1541 maize cultivar grown under main-season conditions in the Amik Plain were investigated. The results indicated that there were no statistically significant differences among plant densities in terms of the examined traits. Although variations were observed in yield components such as the number of kernels per ear, ear weight, seed weight per ear, and thousand seed weight, these differences were not statistically significant. The most notable finding was the significant effect of plant density on seed yield; the highest yield was obtained at the density of 10,989 plants per decare. These results are consistent with findings in the literature and demonstrate that optimal planting densities can enhance yield. However, since the study was conducted over a single growing season, repeating the experiment for a second year is recommended to confirm the findings and support their consistency for regional recommendations.

Conflict of Interest

There is no conflict of interest with any person, institution, company, etc.

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