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Determination of the effects of different sowing times and densities under ıı. product conditions on the yield and components of maize varieties belonging to two different maturity groups

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Abstract
This study was conducted using maize (*Zea mays* L.) varieties from two different maturity groups (DKC5747 (FAO 500) and PR31P41 (FAO 650)) under II—product conditions. The effects of different sowing times (June 1, June 20, July 10) and planting densities (800, 900, 1000, and 1100 plants per hectare) on these varieties' yield and yield components were investigated. The objective was to determine the optimal maturity group, sowing time, and planting density for achieving the highest yield in maize (*Zea mays* L.). The features analyzed included plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), single corn grain weight (mg/corn grain), and grain yield per cob (g/cob). The results showed that sowing time significantly influenced all features examined. The highest values for cob length, weight, corn grain number per cob, and grain yield per cob were obtained at the second sowing time (June 20), while the lowest values were recorded at the third sowing time (July 10). The optimal planting density was determined to be 900–1100 plants/ha for the DKC5747 variety and 800 plants/ha for the PR31P41 variety. For the Amik Plain, the most suitable sowing time for second-crop maize cultivation was June 20, with an optimal planting density of 900–1100 plants/da. The most appropriate varieties were those in the short maturity group. In maize cultivation as a second crop under the conditions of the Amik Plain in Hatay, it is crucial to prioritize the selection of maize varieties in the short maturity group (FAO 500 maturity group) to achieve high grain yields. When longer maturity varieties are selected, it should be noted that while the plants may produce higher biomass, their capacity to convert dry matter into grain may be insufficient, potentially leading to reduced grain yields.
Keywords: Planting time, Planting density, Maturity group

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INTRODUCTION

Maize is among the most widely cultivated crops globally in terms of cultivation area, production, usage, and trade. Corn is widely used both as human food and animal feed (silage, green feed, and concentrated feed) because it grows quickly and produces plenty of grain and stalk in a short time (Kara, 2022). Considering the continuous increase in the global population and the reduction in arable land, enhancing the productivity of agricultural lands and utilizing these crops more efficiently is crucial for meeting human food needs and animal feed requirements. As a C4 plant, maize efficiently utilizes solar energy. It produces the highest dry matter per unit area, making it one of the leading crops capable of achieving high yields from shrinking agricultural areas (Yılmaz, 2016).

Maize (*Zea mays* L.), commonly grown in Turkey and worldwide, belongs to the *Maydeae* subfamily of the *Poaceae* (Gramineae) family. Its high adaptability allows it to be cultivated in various regions of the world (Yorgancılar et al., 2019). Maize is a warm-season cereal requiring an 8–10 °C germination temperature, with optimal germination occurring above 18 °C. The ideal temperature range for maize growth is 25–30 °C, while temperatures below 15 °C slow initial growth, resulting in yield losses (Sönmez, 2019).

In maize cultivation, sowing time plays a critical role in realizing the yield potential of a variety, as temperature fluctuations significantly impact maize growth. Variations in sowing time alter climatic factors such as temperature, light intensity, and humidity during the plant's different growth and development stages. These climatic variations affect dry matter assimilation and growth parameters, consequently influencing grain yield. Changes in sowing time can expose plants to harmful high or low temperatures during critical periods of development (e.g., seedling and grain filling stages), leading to yield reductions (Sönmez et al., 2013). For this reason, determining the optimal sowing time based on the maturity group (cobly or late varieties) is vital for achieving the highest yields in maize cultivation.

Plant density, another cultivation technique, significantly affects grain yield by influencing the living space available to each plant. Increased plant density can reduce grain yield due to limited living space per plant. In high-density plantings, plants may not receive sufficient sunlight, notably lower leaves, which remain shaded for extended periods. This shading adversely affects CO_2 assimilation—a key determinant of photosynthesis—and ultimately reduces plant yield (Jia, 2018). Determining the optimal seed rate per unit area ensures that plants efficiently utilize available soil water, nutrients, and sunlight energy (Jia, 2018). Several studies have demonstrated that row spacing significantly impacts maize yield, with excessive density and sparseness limiting yield (Bruns et al., 2012; Eskandarnejad et al., 2013; Jia, 2018).

This study aims to evaluate the combined effects of maturity group, sowing time, and plant density to achieve the highest yields in maize under second cropping conditions.

MATERIALS AND METHODS

This research was conducted in 2017 under the ecological conditions of the Amik Plain, using two dent corn varieties with different maturity durations: DKC5747 (FAO 500) and PR31P41 (FAO 650).

ClimaticCharacteristics

The climatic data for the trial cob and long-term averages are presented in Table 1. According to long-term average data, no rainfall occurred in the trial area during June–September. The precipitation for October in the trial cob and the long-term average were 24.6 mm and 29.5 mm, respectively. The average temperatures for the June–September period were 26.6 °C for the trial cob and 25 °C for the long-term average. Relative humidity for the same period was 57.1% in the trial cob and 62.1% in the long-term average (Table 1).

In the trial cob, average temperatures were consistently higher than the long-term averages except for August. Total relative humidity in October during the trial cob exceeded the long-term average.

Table 1. Climatic data for the trial cob and long-term averages*

Climate data	Cobs	Months					Averages
		June	July	August	September	October	
Average temperature (°C)	2016	26.4	30.1	24.4	29.3	22.7	26.6
	long years (1940-2016)	25.2	27.7	25.8	28.8	21.4	25.8
Total humidity (%)	2016	54.4	49.6	61.3	57.1	62.8	57.1
	long years (1940-2016)	63.2	64.0	63.2	61.0	59.2	62.1
Precipitation amount (mm)	2016	0	0	0	0	24.6	
	long years (1940-2016)	1.5	0.1	0.1	9.9	29.5	

* MGM Hatay İl Müdürlüğü, 2016

Soil Characteristics

The soil of the experimental area is essential (pH: 8.22), has a high lime content (23.42%), has a low organic matter content (1.39%), and is clayey (59%).

Establishment of the Study

The study was conducted at the Tel-Kaliş Rescobch and Application Center of the Department of Field Crops, Faculty of Agriculture, Hatay Mustafa Kemal University. It was arranged using a split-split plot design in randomized blocks with three replications. Sowing time was assigned to the main plots, sub-plot varieties, and sub-sub-plot plant densities.

The first sowing date was June 1, followed by subsequent sowings on June 20 and July 10. Each plot consisted of five rows, each 10 meters long. Planting was performed with a planting frame at densities of 800, 900, 1000, and 1100 plants per hectare.

At sowing, 15-15-15 compound fertilizer was applied to provide 8 kg/da of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). Thinning was carried out when plants reached the three-leaf stage.

When plants were at the five-leaf stage, urea fertilizer equivalent to 20 kg N/da was applied as a top dressing and incorporated into the soil using a ridging hoe. Harvesting was performed manually by collecting cobs from the middle three rows of each plot.

The maize varieties used in the study were measured for the following features: plant height (cm), cob length (cm), cob weight (g), corn grain number per cob (corn grains/cob), single corn grain weight (mg/corn grain), and grain yield per cob (g/cob).

Table 2. Abbreviations used in the study and their equivalents.

Abbreviations	Meanings	Abbreviations	Meanings
DKC5747	Dekalb	**PH**	Plant Height
PR31P41	Pioneer	**CL**	Cob Length
EZ-1	1. Planting Time (1st June)	**CW**	Cob Weight
EZ-2	2. Planting Time (20th June)	**CGNPC**	Corn Grain Number Per Cob
EZ-3	3. Planting Time (10th July)	**CCGY**	Cob Corn Grain Yield
S1	Plant Density (800 plants per hectare)	**SCKW**	Single Corn Grain Weight
S2	Plant Density (900 plants per hectare)	**DF**	Degree of Freedom
S3	Plant Density (1000 plants per hectare)	**SV**	Source of Variation
S4	Plant Density (1100 plants per hectare)		

Statistical Analysis of Data

The study's data were analyzed using the MSTAT-C statistical program. The analysis of variance (ANOVA) was performed according to the split-plot design in randomized blocks, and mean comparisons were carried out using the Least Significant Difference (LSD) test.

RESULTS

Table 3 presents the combined analysis of variance results for the yield and some yield components of maize (*Zea mays* L.) varieties from different maturity groups under second-crop conditions, based on sowing time.

Table 3. Results of combined variance analyses for yield and some yield components of varieties based on planting time.

Source of Variation	DF	Characteristics					
		PH	CL	CW	CGNPC	CCGY	SCKW
Replication	2	772,3	2,9	3,0	420,3	61,4	0.70
Planting Time (A)	2	4572,75*	28,0*	5965,1***	97548,6***	14760,5**	7344,7***
Error-1	4	1004,7	4,6	23,7	1458,3	396,1	12,5
Variety (B)	1	42,0	0,3	5848,2***	169168,1***	630,1*	4960,1***
AxB	2	636,4	44,8***	1468,7***	4321,5**	2814,3**	431,1***
Error-2	6	659,5	7,3	17,6	809,7	303,5	15,7
Plant Density (C)	3	234,8	33,0***	1092,4***	53970,8***	1654,4*	2008,3***
AxC	6	334,5	68,8***	1416,9***	39802,6***	2049,9	1476,6***
BxC	3	346,3	31,3***	3771,1***	41589,4***	6430,3***	3332.0***
AxBxC	6	201,5	45.8***	998,8***	10108,4	857,5	220,9***
General Error	36	3044,2	37,8	116,3	735,9	5646,7	88,8
SV		5,9	10,0	2,5	8,3	7,8	3,0

***): p≤0,0001; **): p≤0,001 ve *): p≤0,05

When examining the effects of different sowing times, variety, and plant density factors, as well as their interactions, on some plant characteristics (plant height, cob length, cob weight, corn grain number per cob, single corn grain weight, and grain yield per cob), it was found that plant height showed statistically significant results only for sowing time, with no significant statistical differences for other factors. Among all the examined features, cob length showed no significant interaction with the variety factor, and single corn grain weight did not exhibit significant results with the interactions of sowing time x density and sowing time x variety x density. For all other features except the plant's characteristics mentioned above, all factors and their interactions were found to be statistically significant.

In the second-crop conditions, the average values for plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), single corn grain weight (mg/corn grain), and grain yield per cob (g/cob) of maize (*Zea mays* L.) varieties from different maturity groups, under different sowing times and varying plant densities, as well as the groups formed by the Least Significant Difference (LSD) comparison test, are presented in Table 4.

Table 4. Average values of plant height (cm), cob length (cm), cob weight (g/cob), number of corn grains per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) for two different maize varieties from different maturity groups, at different planting times and varying plant densities, and the groups formed according to the LSD comparison test.

Application / Investigated Properties	PH (cm)	CL (cm)	CW (g/cob)	CGNPC (corn grains/cob)	EKY (mg/corn grain)	SCKW (g/cob)
Planting Time (A)						
June 1	167 **a**	14,1 **b**	62,7 **c**	321 **b**	149 **b**	48,8 **b**
June 20	149 **b**	15,6 **a**	84,1 **a**	373 **a**	181 **a**	67,2 **a**
July 10	152 **b**	14,6 **b**	67,9 **b**	283 c	153 **b**	43,7 **c**
Variety (B)						
DKC 5747	155	14,7	80,6 **a**	374 **a**	164	61,5 **a**
PR31P41	175	14,8	62,6 **b**	277 **b**	158	44,9 **b**
Plant Density (C)						
800	154	15,9 **a**	78,2 **a**	372 **a**	168 **a**	62,0 **a**
900	158	14,6 **b**	70,7 **b**	319 **b**	163 **ab**	52,6 **b**
1000	157	14,2 **b**	68,8 **c**	312 **b**	157 **b**	50,1 **c**
1100	154	14,3 **b**	68,6 **c**	300 **b**	156 **b**	48,2 **d**

Regarding plant height, the tallest plants were found in the first sowing time (June 1) with a height of 167 cm, while the shortest plants were found in the second sowing time (June 20) with a height of 149 cm. When analyzed by variety, the DKC 5747 variety had a plant height of 155 cm, 20 cm shorter than the PR31P41 variety (175 cm); however, this difference was not statistically significant. Regarding plant density, plant heights were found to be 154 cm for 800 plants/hectare, 158 cm for 900 plants/hectare, 157 cm for 1000 plants/hectare, and 154 cm for 1100 plants/hectare, with these differences being statistically insignificant.

For cob length, the plants sown on June 20 (second sowing time) had the longest cobs (15.6 cm), while those sown on July 10 (third sowing time) had intermediate lengths (14.6 cm), and those sown on June 1 (first sowing time) had the shortest cobs (14.1 cm). The cob length for DKC 5747 was 14.7 cm, while for PR31P41, it was 14.8 cm, with both varieties having statistically insignificant and similar values. In terms of plant density, the cob length was longest (15.9 cm) for 800 plants/hectare, while the lengths for 900, 1000, and 1100 plants/hectare were 14.6 cm, 14.2 cm, and 14.3 cm, respectively, and these differences were statistically insignificant.

Cob weight was highest for the plants sown on June 20 (84.1 g) and lowest for those sown on June 1 (62.7 g). The DKC 5747 variety had a cob weight of 80.6 g, significantly higher than the PR31P41 variety, which had a cob weight of 62.6 g. Regarding plant density, the cob weight was highest for 800 plants/hectare (78.2 g), followed by 70.7 g for 900 plants/hectare, and the lowest values of 68.8 g and 68.6 g were found for 1000 and 1100 plants/hectare, respectively. However, the differences between 1000 and 1100 plants/hectare were statistically insignificant.

For corn grain number per cob, the highest value (373 corn grains) was found in the plants sown on June 20 (second sowing time), while the lowest value (283 corn grains) was found in the plants sown on July 10 (third sowing time). The DKC 5747 variety had 374 corn grains per cob, while the PR31P41 variety had 277 corn grains per cob, which is statistically significant. The highest corn grain number was observed in plants sown at 800 plants/hectare (372 corn grains), while plants sown at 900, 1000, and 1100 plants/hectare had 319, 312, and 300 corn grains, respectively, and the differences between these three densities were statistically insignificant.

Regarding single corn grain weight, the highest value (181 mg) was found for plants sown on June 20, while the lowest value (149 mg) was found for those sown on June 1. The single corn grain weight for plants sown on July 10 (153 mg) fell between the two sowing times. The values for DKC 5747 (164 mg) and PR31P41 (158 mg) were very similar, and the difference was not statistically significant. For plant density, the highest single corn grain weight (168 mg) was observed for 800 plants/hectare, with 900 plants/hectare yielding 163 mg, 1000 plants/hectare yielding 157 mg, and 1100 plants/hectare yielding 156 mg.

For grain yield per cob, the highest value (67.2 g) was observed for the plants sown on June 20, while the lowest value (43.7 g) was found for those sown on July 10. The DKC 5747 variety (61.5 g/cob) had a higher grain yield per cob than the PR31P41 variety (44.9 g/cob). As plant density increased, grain yield per cob decreased regularly, with the highest yield (62 g/cob) observed at 800 plants/hectare, followed by 52.6 g, 50.1 g, and 48.2 g for 900, 1000, and 1100 plants/hectare, respectively.

DISCUSSION

The values of plant height (cm), cob length (cm), cob weight (g/cob), number of corn grains per cob (corn grains/cob), corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) of maize varieties planted under second crop conditions and belonging to different maturity groups, based on different planting times, are presented in Figure 1.

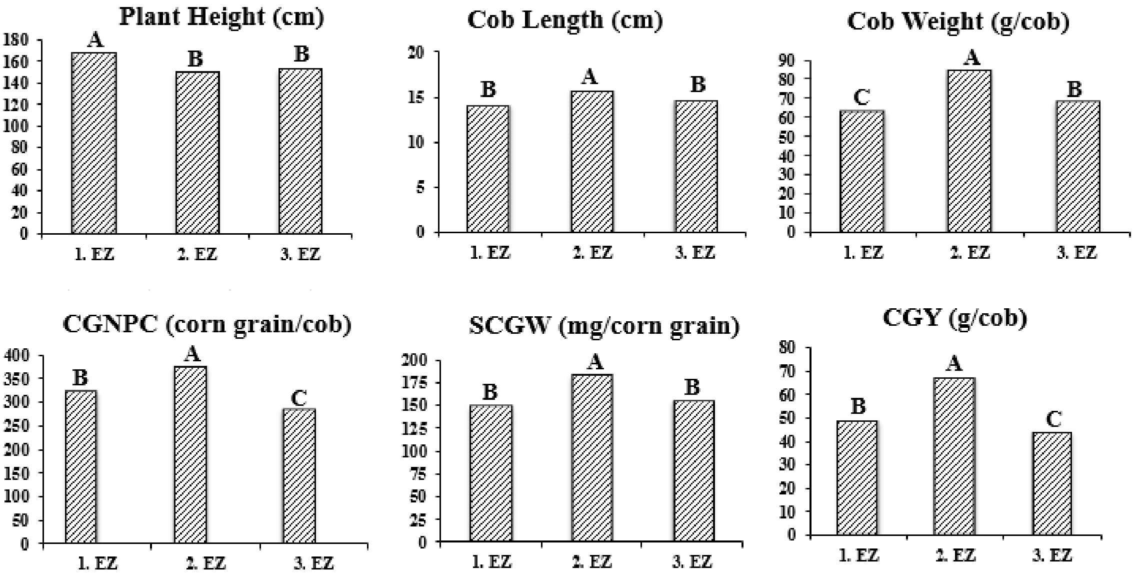

Figure 1. Average values of plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) for two different corn varieties at different sowing times, along with the groups formed according to the LSD comparison test.

Planting time is an essential factor in determining the yield potential of a maize variety. To obtain the highest yield level from the cultivated plants, the planting time should be selected in which the environmental factors such as climate, soil, and temperature required by the plants are ideal. The study also shows that planting time affects plant characteristics (see Table 1). Early or late planting hinders the potential of the plants and reduces yield. Among the plant characteristics examined in this study, plant height reached the best values at the first planting time, while all other characteristics performed best at the second planting time. It is thought that this is because the plants at the first planting time use most of their energy for height growth and thus will have less energy available for cob formation and development, leading to a reduction in cob length, cob weight, corn grain number per cob, corn grain weight, and consequently cob corn grain yield. Güney et al. (2010), Kuşvuran et al. (2015), Seydoşoğlu and Saruhan (2017) reported that environmental changes caused by different ecological conditions resulted in significant differences in plant height, similar to the results of our study. Gürses (2010), Kuşvuran et al. (2014), Çakar (2015), Han (2016), Saygı et al. (2017), Doğanlar (2018), and Bueno and Lima (2020) found that, although cob length is a genetic feature, it shows variability depending on environmental factors and the period it is grown (planting time). Additionally, similar to the results of this study, many studies have reported that cob weight changes with planting time (Cesurer, 1995; Sencar et al., 1997; Sönmez et al., 2013; Özlem et al., 2011) and that there is a relationship between planting time and corn grain number per cob (Alan et al., 2011). In addition, while Sönmez et al., (2013) stated that there is a relationship between planting time and yield, contrary to the study results, there are also studies indicating that there is no difference in yield per decare between planting times (Cesurer, 1995; Sencar et al., 1997).

The values of plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) of maize varieties planted under second crop conditions and belonging to different maturity groups, based on different planting densities, are presented in Figure 2.

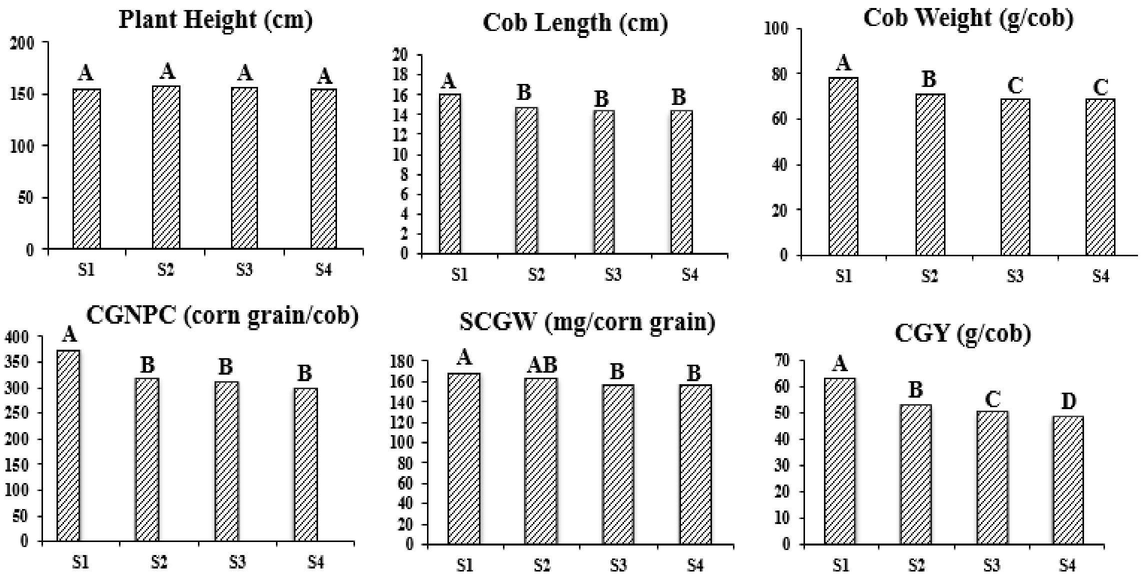

Figure 2. Average values of plant height (cm), cob length (cm), cob weight (g/cob), number of corn grains per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) for two different corn varieties at different planting densities, along with the groups formed according to the LSD comparison test.

Plant density is one of the important factors affecting yield, particularly in reducing or increasing the living space per plant. An increase in plant density reduces the living space per plant, decreasing yield. In dense plantings, the inability of the plants to fully utilize sunlight, especially the extended duration during which the lower leaves remain shaded, negatively affects CO_2 assimilation, one of the critical determinants of photosynthesis, and consequently reduces plant yield (Jia, 2018). Determining the amount of seed to be sown per decare ensures that plants make the most efficient use of favorable water, nutrients, and light energy in the soil. The data from this study support these facts, showing a decrease in all the plant characteristics examined as plant density increased (see Table 2).

An increase in planting density is expected to cause competition among plants and result in taller plants in dense plantings. However, in this study, plant height values did not show statistically significant differences or a consistent trend (see Table 4). This situation is thought to have been caused by the fact that the densest plant plots were directly exposed to the wind, as the density variation in the experimental design changed from east to west while the wind direction was from west to east. During the plant's vegetative period, wind speed ranged from 5 to 10 km/h and continued at similar speeds throughout the day. Many studies have presented similar and different results. Sönmez et. Al., (2013) noted that planting density had no significant effect on plant height, supporting the findings of this study, while Gözübenli et al. (2004), Pagano and Maddonni (2007), Bukhsh et al. (2008), and Yılmaz et al. (2008) reported longer and statistically significant plant heights at higher planting densities. As mentioned earlier, cob length is related to plant height, and changes in plant height affect cob length. Although no statistically significant differences were found in plant heights due to planting densities in this study, values for cob length, cob weight, corn grain number per cob, corn grain weight, and cob corn grain yield showed a consistent decrease in dense plantings (see Table 4). Dense plantings cause plants to shade each other, preventing them from utilizing sunlight effectively, impairing their photosynthetic activity, and negatively affecting cob characteristics, leading to decreased plant productivity. The study's results support these findings, as decreases in all cob characteristics were observed with increased planting density (see Table 2).

At the same time, there are many studies indicating that increases in planting density cause a decrease in ear weight (Şirikçi, 2006), grain number per ear (Öktem et al., 2001; Alıcı, 2005; Yılmaz et al., 2005) and ear grain yield (Andrade et al., 2002; Widdicombe and Thelen, 2002; Alıcı, 2005; Liu et al., 2004; Stahl and Bau, 2009; Bruns et al., 2012; Eskandarnejad et al., 2013).

The values for plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) of maize varieties planted under second crop conditions and belonging to different maturity groups, based on planting time x variety interactions, are presented in Figure 3.

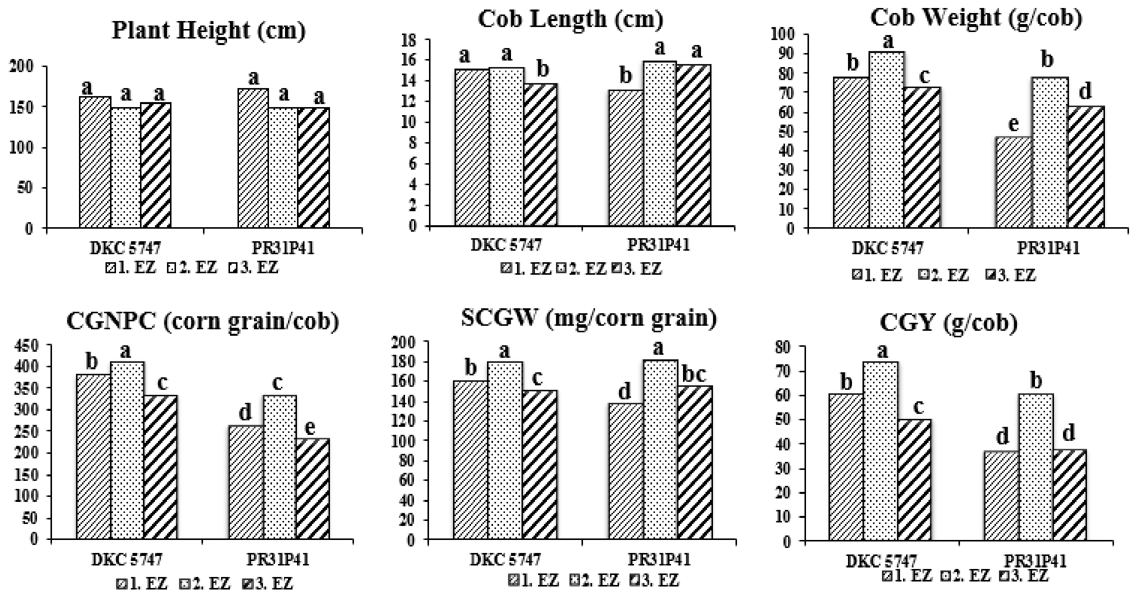

Figure 3. Average values of plant height (cm), cob length (cm), cob weight (g/cob), number of corn grains per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) for two different corn varieties at different planting times x variety interaction, along with the groups formed according to the LSD comparison test.

In second-crop conditions, the maturity groups of maize varieties and planting time are critical. Maturity groups define the speed of maturation and development stages of the plant from planting to harvest. Therefore, in second-crop conditions, varieties that mature and develop faster, particularly under late planting conditions, are preferred. This study used two varieties from both long and short-maturation groups, and their responses to changes in planting time were evaluated. Overall, the highest values were obtained from the DKC5747 variety, which belongs to the short maturity group, and from the second planting time (June 20). The PR31P41 variety, which belongs to the long maturity group, could not adapt to changing environmental factors (temperature, sunlight duration, etc.) during its development and yielded lower results than the variety in the short maturity group. Contrary to expectations, the plant height feature did not show statistically significant differences against the variety x density interaction.

In the study, cob lengths, like plant heights, showed values almost close to each other. The DKC 5747 variety in the early maturation group exhibited lower values as the planting time was delayed, and the PR31P41 variety in the long maturation group exhibited lower values at early planting time.

Although the cob length values were quite similar regarding planting time x variety interactions, cob weight, corn grain number per cob, corn grain weight, and cob corn grain yield values were different from cob length and showed similar results. The highest results in cob weight, number of grains on the cob, and cob grain yield values were obtained from the DKC 5747 variety in the early maturity group and from the 2nd planting times. In contrast, unlike the mentioned characteristics, the single-grain weight values were statistically the same and had the highest values in both varieties.

This is because cob length is directly related to corn grain yield in maize. Although the cob length values for varieties were broadly similar according to planting time, it is thought that the PR31P41 variety from the late maturity group was unable to complete its vegetative development during the late planting times, causing the cobs to fail to set corn grains, resulting in lower values for cob weight, corn grain number per cob, and cob corn grain yield. It is thought that the reason why single grain weight reaches the same level of importance, especially at the 2nd sowing time and in both varieties, is this feature. However, it varies depending on the varieties, environmental conditions, and genetic factors, allowing the small number of grains in the cob to access more nutrients and water, thus increasing the single grain weight.

Supporting our findings, many studies have shown that comply-maturing varieties and comply planting times in second-crop conditions have a positive impact on cob length (Jia, 2018), cob weight (Akgün et al., 2017), corn grain number per cob, and cob corn grain yield (Jia, 2018).

The values for plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) of maize varieties planted under second crop conditions and belonging to different maturity groups, based on planting time x density interactions, are presented in Figure 4.

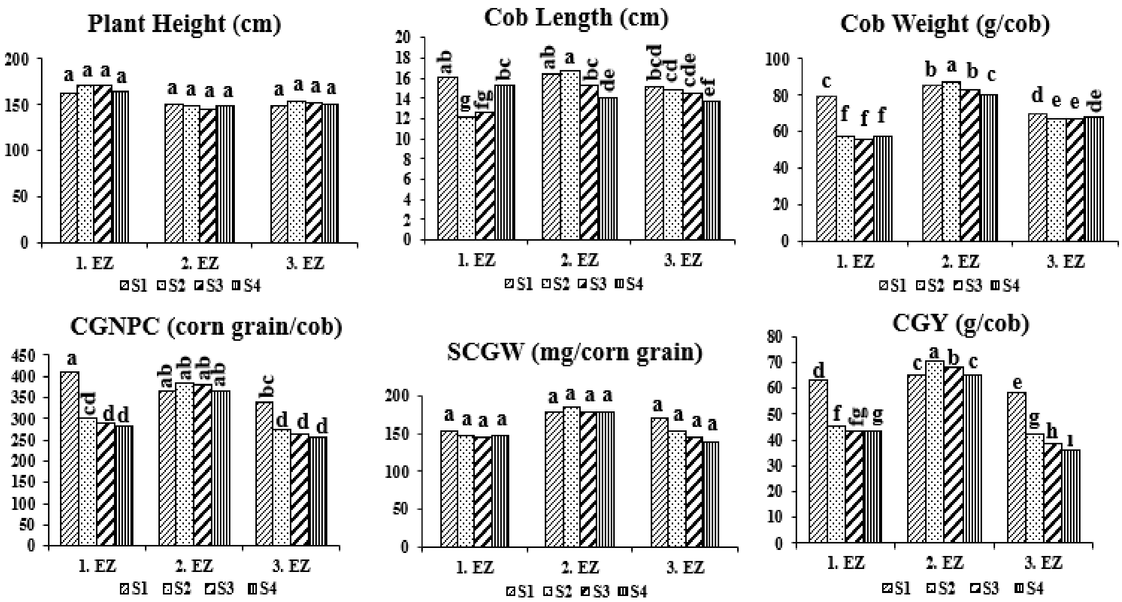

Figure 4. Average values of plant height (cm), cob length (cm), cob weight (g/cob), number of corn grains per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) for two different corn varieties at different planting times x variety interaction, along with the groups formed according to the LSD comparison test.

In the study, except for the corn grain number per cob, the highest values for all the features were obtained from the second planting time and the 800-900 plants per hectare planting densities. The interaction between planting time and density is critical in managing plant competition and determining the optimal planting time. Combining planting time and appropriate planting density is crucial for better plant development and higher yields.

The study observed no significant difference in plant height between the planting time and density treatments. Although many studies (Kara and Kırtok, 2006) have reported significant differences in plant height due to varying planting times and densities, the results of this study align with other research that reports no significant differences in plant height based on these factors (Güler, 2001).

Statistically significant differences were observed in cob length, which varied based on the interaction between planting time and density. Particularly, at the second planting time and with a planting density of 900 plants per hectare, the highest cob length was achieved, while the lowest values were found at the third planting time and with 1100 plants per hectare. These results support the idea that increased competition at higher planting densities reduces nutrient access, negatively impacting cob development.

Ear weight showed significant changes depending on planting time and density, and especially in the second planting time and S1 (900 plants per hectare), higher ear weight was achieved, while in the first planting time and S3 (1000 plants per hectare) and S4 (1100 plants per hectare) planting densities, ear weight generally decreased. These findings align with studies suggesting that the timing and appropriate planting density are critical factors influencing cob weight (Atasever, 2018; Kılınç, 2018).

The corn grain number per cob reached its highest value at the first planting time and the S1 density, but the values for the other densities at this planting time were much lower than the other planting times. No statistical differences were found between planting densities at the second planting time, and the values at the third planting time, except for the S1 density, were the lowest in the study. This situation is consistent with the literature indicating that competition between plants can reduce grain number, and lower densities can increase this parameter (Bozkurt and Karadoğan, 2017). Furthermore, the general decrease in corn grain number as planting time advances emphasizes the importance of planting time on yield.

No significant differences were observed for single corn grain weight based on planting time and density combinations, similar to the results for plant height. Corn grain weight showed similar results across all planting times and densities.

Cob corn grain yield showed significant changes due to the interaction between planting time and density, with the highest values obtained at the second planting time and the S2 density. This result was consistent with the values of cob weight and cob grain number and was similar to studies suggesting that more appropriate planting time and density could increase cob grain yield (Özlem et al., 2011; Sönmez et al., 2013).

The values for plant height (cm), cob length (cm), cob weight (g/cob), corn grain number per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) of maize varieties planted under second-crop conditions and belonging to different maturity groups, based on variety x density interactions, are presented in Figure 5.

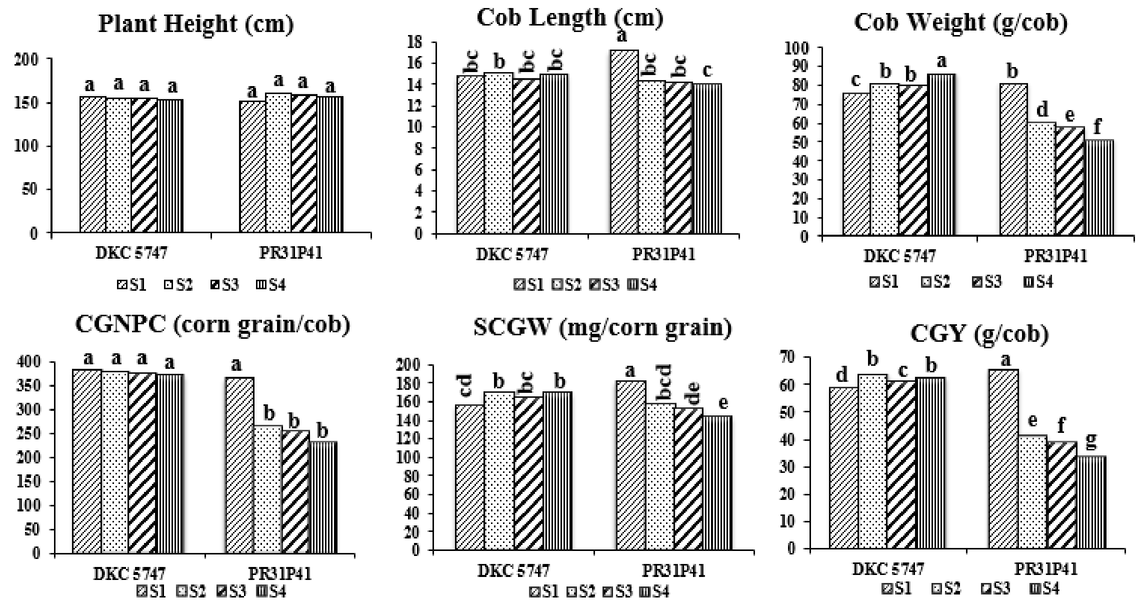

Figure 5. Average values of plant height (cm), cob length (cm), cob weight (g/cob), number of corn grains per cob (corn grains/cob), single corn grain weight (mg/corn grain), and cob corn grain yield (g/cob) for two different corn varieties at different variety x planting density interaction, along with the groups formed according to the LSD comparison test.

In the study, when the variety x density combination values were examined, the highest results were obtained from S1 planting density based on frequency. In contrast, contrary to expectations, the PR31P41 variety, which is in the long maturity group, showed the highest results. The reasons for this situation are,

- Although the PR31P41 variety is in the long maturity group, it may have a genetically high yield potential,
- Since plants generally have a longer growth period in long maturity groups, the photosynthetic activity periods of these varieties are longer. This may result in the PR31P41 variety accumulating more carbon over a longer period and directing it to the grain-filling process,
- The PR31P41 variety may be more resistant to stress by using water and nutrient resources per plant more efficiently under low-density conditions,
- The PR31P41 variety may have adapted better to the environmental conditions (soil structure, climate, water management) under which the study was conducted than the DKC 5747 variety,
- At low density (S1), air circulation and microclimate conditions between plants are improved. This may contribute to the better development of varieties with long growth periods, especially the long maturity group,

Although plant heights did not reveal statistically significant results, cob length, cob weight, number of grains per cob, single grain weight, and cob grain yield values exhibited compatible results.

A regular decrease in cob length was observed with increasing density, especially in the PR31P41 variety, and this was associated with increased competition between plants. Similar to the study results, the literature reports that cob length decreases with increasing density (Özata et al., 2016). While cob grain number, single grain weight, and cob grain yield values also show results compatible with cob length, cob weight showed the highest results in DKC 5747 variety and S4 density. This situation is thought to be because plants can produce heavier cobs with more resource use at lower density levels. At low density, plants have a larger root area and receive more nutrients and water, which can increase cob weight.

CONCLUSION

A study conducted on second-crop maize cultivation in the Amik Plain has thoroughly examined the effects of agricultural practices such as sowing time, planting density, and variety selection on yield, providing significant findings. The study demonstrated that sowing time and planting density created statistically significant differences in traits such as plant height, ear length, ear weight, number of grains per ear, and grain yield. However, the effects of maize varieties on plant height and ear length were statistically limited, whereas they played a significant role in all other traits. This highlights the importance of variety selection, particularly regarding critical production parameters such as grain yield.

According to the findings, using varieties from the short maturity group (FAO 500 maturity group) is a fundamental requirement for achieving high grain yield in second-crop maize production. These varieties converted the produced dry matter into grain more effectively than those with extended maturity periods. In varieties with longer maturity periods, although plants produce high biomass, significant losses in grain yield were observed due to insufficient biomass conversion into grain. This indicates that short-maturity group varieties are more suitable for second-crop maize cultivation, where the harvest period is limited.

The most suitable sowing date for the region was determined to be around June 20. Sowing at this time ensures that plants benefit from optimal environmental conditions during their growth and development stages, thus achieving high yield potential. Later sowing dates could negatively impact yield due to shortened growth periods and low temperatures encountered during harvest.

Planting density was identified as another critical factor influencing yield. The study concluded that a density of 90,000 to 110,000 plants per hectare, combined with short maturity group varieties, is optimal for achieving high grain yield. Lower or higher planting densities could reduce yield due to increased competition or insufficient growing space.

In conclusion, the following recommendations can be made to producers who aim to cultivate second-crop maize in the Amik Plain:

- Varieties belonging to the short maturity group (FAO 500 maturity group) that are compatible with the region's climate and soil conditions should be preferred.
- Sowing should be done around June 20 to optimize plant development and yield potential.
- Planting density should be carefully managed, with a target of 90,000 to 110,000 plants per hectare.

These practices will significantly improve the efficient use of regional resources and productivity, thereby increasing farmers' income levels. This study's findings also serve as a valuable guide for developing region-specific agricultural management strategies.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The authors have no conflict of interest to declare.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the text, figures, and tables are original and that they have not been published before.

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