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Effects of Hybrid and Double Cross Maize Planting on Yield and Yield Components under Amik Plain Conditions

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ABSTRACT: This study presents a field parameters conducted under the conditions of the Amik Plain, focusing on the commonly cultivated P1541 maize variety. The parameters examined different planting models involving hybrid and double cross maize types. Five distinct planting models were used: hybrid (H), double cross (DC), and three hybrid-double cross mixtures at varying ratios (25% DC + 75% H, 50% DC + 50% H, 75% DC + 25% H). The experiments were laid out in a randomized block design with three replications. Yield-related traits such as plant height, stem diameter, first cob height, cob heigh, cob diameter, number of grain per cob, cob weight, grain weight per cob, and thousand-grain weight were evaluated. While significant variations were observed in some parameters (cob diameter, cob weight, and grain weight), differences in other parameters such as stem diameter, cob height, and thousand-grain weight were found to be statistically insignificant. According to field data and statistical analyses, the PH and 25% DC + 75% H combinations demonstrated superior performance in terms of plant height, cob weight, and overall yield. Notably, the 25% DC + 75% H combination provided balanced and high results across key yield components. In conclusion, combining double cross plantings with suitable genetic combinations may significantly improve maize yield and help make up for the high cost of hybrid seeds. To establish definitive recommendations, these studies should be conducted over a two-year period.

Keywords: double cross, hybrid, maize, P1541.

INTRODUCTION

With the continuously growing global population, the demand for food is also increasing each year. This growing demand, coupled with industrialization and the expansion of human settlements, has led to a significant reduction in available agricultural land. To meet the rising food needs and maintain low production costs, maximizing yield from existing farmland has become a critical objective. Accordingly, the development of various agricultural strategies is essential. Today, increasing crop production, reducing input costs, and utilizing agricultural land more efficiently are of great importance (Kırılmaz and Marakoğlu, 2018). Among cereal crops, maize stands out as a C4 plant with the highest yield potential and the most efficient use of solar energy. Due to its high productivity, excellent energy storage capacity, and wide range of uses, maize has become one of the key crops in the industrial sector (Kün, 1985; Kırtok, 1998). Additionally, maize cultivation is well-suited to mechanized agriculture, requiring relatively less manual labor. Moreover, its ability to be grown as both a main and a second crop, along with easier and more cost-effective control of diseases, pests, and weeds compared to other crops, makes maize highly marketable. These advantages are among the main reasons why farmers prefer maize cultivation (Akan and Kılıç, 2021). However, the high cost of hybrid maize seeds has prompted producers to seek more efficient planting methods. This raises the question of whether seeds derived from hybrids previously cultivated on the same land—such as those resulting from double crosses—can be effectively used (Kırılmaz and Marakoğlu, 2018).

Mixing double cross seeds with hybrid maize during planting may help reduce seed costs. In this way, the high cost of hybrid seeds can be balanced, providing economic advantages for producers (Kırılmaz and Marakoğlu, 2018). Özata et al. (2013), in a study conducted with hybrid maize varieties developed at the Black Sea Agricultural Research Institute, reported that the yields obtained were superior to those achieved by other planting methods. Similarly, Bozdağ and Soylu (2019), in their research under the ecological conditions of Konya, found that among the traits examined, hybrid seed combinations yielded significantly higher grain output compared to the parent lines. Yıldırım and Soylu (2019) also conducted studies in Konya and reported that four different hybrid combinations produced statistically significant and distinct results compared to other combinations. Our findings are in parallel with previous international trails demonstrating that hybrid mixtures under medium to high plant density resulted in improved Lal, photosynthetic activity and grain yield increases of 7-10%, as reported by Hu et al. (2019). Similarly, Rasheed et al (2017) showed that double cross hybrids exhibited yield performance comparable to their parental single cross hybrids across diverse environmental conditions. Furthermore, a recent study from Germany revealed a yield gap of approximately 5 t/ha-1 between defferent double cropping systems, indicating that mixed planting models offer clear advantges in yield stability (Frontiers, 2023).

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This study was conducted under the conditions of the Amik Plain to evaluate the effects of mixed planting ratios of double cross and hybrid maize—based on a commonly cultivated hybrid variety in the region—on yield and yield components. This study not only addresses regional challenges but also aims to contribute to global discussions on cost-effective maize cultivation models under climate stress conditions.

MATERIALS AND METHODS

In this experiment, the maize variety P1541 was used as the plant material. The parameters was conducted at the Telgalis Research and Application Area of the Agricultural Research and Application Center, affiliated with Hatay Mustafa Kemal University (36°15'N, 36°30'E, elevation up to 94 m), using a randomized block design with three replications. Each plot consisted of four rows, with 70 cm between rows and 20 cm between plants within rows. Five planting models were implemented: hybrid (H), double cross (DC), and mixed plantings of 25% DC + 75% H, 50% DC + 50% H, and 75% DC + 25% H. Each plot measured 2.8 meters in width and 5 meters in length, covering a total area of 14 m². The mixtures were randomly assigned to the plots within each block to ensure proper replication. Sowing was carried out on March 25, 2024, and harvesting took place on August 10, 2024.

The soil at the experimental site was classified as clay-loam, with low organic matter content, moderate lime levels, and a slightly alkaline pH. Based on these characteristics, fertilizers were applied at a rate of 20 kg nitrogen, 8 kg phosphorus, and 8 kg potassium per decare. Of this, 8 kg of nitrogen and all of the phosphorus and potassium were applied before sowing in the form of a 15-15-15 compound fertilizer. When the plants reached approximately 40–50 cm in height, an additional 12 kg of nitrogen per decare was applied as urea. Weed control was managed using cultural practices. Throughout the vegetation period, the hybrid, double cross, and mixed maize crops grown under main season conditions were irrigated via flood irrigation eight times, based on the water needs of the crop.

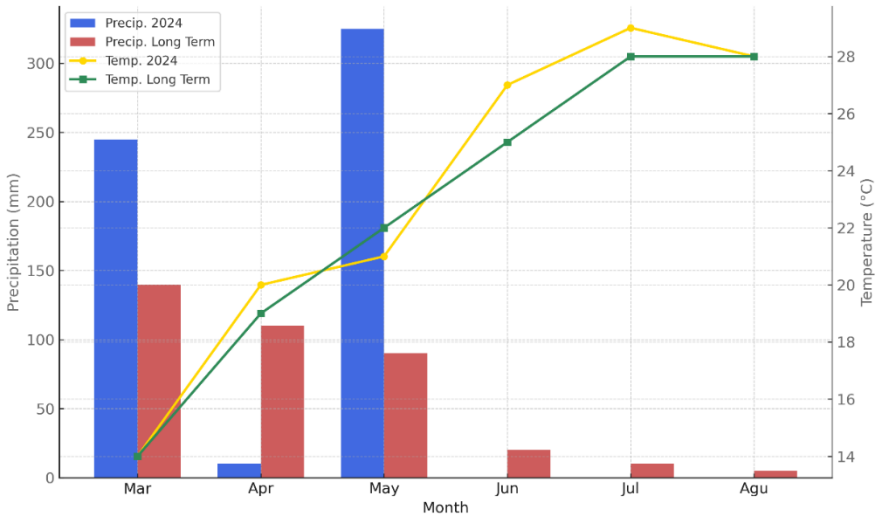

Figure 1. *Total Cases of Covid-19 from 2019 to 2021*

As reported by the Hatay Provincial Directorate of Meteorology, an analysis of the 2024 precipitation data (Figure 1) reveals that the early spring period of the vegetation season experienced relatively high rainfall. However, a marked drought trend was observed from late spring into early summer.This pattern indicates an irregular seasonal distribution of precipitation, which in turn suggests an increase in drought and associated stress conditions. Temperature data for the same period show that April, June, and July recorded values above the long-term averages. Such elevated temperatures may lead to early soil moisture loss and increased evaporation rates. Overall, the 2024 climate data demonstrate deviations from typical seasonal climate patterns. When the rise in temperatures and decline in rainfall are considered together, it can be concluded that the risk of drought and stress potential for agricultural production may have increased.

The traits examined for yield and yield components, along with the methods used for their measurement, are outlined below:

Plant Height (cm): The height from the soil surface to the apex of the plant was measured with a measuring tape on 10 randomly selected plants per plot.

Stem Diameter (mm): Using a digital caliper, the diameter was measured at the midpoint between the first and second internodes on 10 randomly selected plants from each plot.

First Cob Height (cm): The distance from the soil surface to the point where the first cob emerged was measured with a measuring tape on 10 randomly selected plants.

Cob Height (cm): The height of 10 randomly harvested cobs from each plot was measured using a ruler.

Cob Diameter (mm): The diameter of 10 randomly selected cobs was measured at the midpoint using a digital caliper.

Number of Grain per Cob: The total number of grains was estimated by multiplying the number of rows by the number of grains per row on each cob.

Single Cob Weight (g): Ten randomly harvested cobs per plot were weighed using a precision scale.

Grain Weight per Cob (g): Grains separated from the harvested cobs were weighed using a precision scale.

Thousand Grain Weight (g): Grains from each sample were divided into four replicates of 100 seeds, counted and weighed, then converted to thousand grain weight.

RESULTS AND DISCUSSION

Table 1 presents the results of the variance analysis and mean comparison test for plant height (PH), stem diameter (SD), first cob height (FCH), and cob weight (CW). The mixed sowing of hybrid and double cross maize had a statistically significant effect on plant height and first cob height, while it did not significantly affect the other traits.

Table 1. *Effect of double cross maize hybrids on propertions PH, SD, FCH and CH.*

Planting Model	PH (cm)	SD (mm)	FCH (cm)	CH (cm)
25 DC+75 H	248.60 ± 6.26^{b}	25.15 ± 0.34^{a}	62.10 ± 1.63^{b}	20.49 ± 0.97^{a}
50 DC+50 H	259.23 ± 2.39^{b}	26.18 ± 0.28^{a}	62.80 ± 1.34^{b}	18.95 ± 0.41^{a}
75 DC+25 H	259.90 ± 1.97^{b}	24.94 ± 0.61^{a}	60.43 ± 1.59^{b}	18.85 ± 0.26^{a}
DC	224.07 ± 6.35^{c}	27.33 ± 1.59^{a}	53.63 ± 6.37^{b}	18.47 ± 0.82^{a}
H	286.27 ± 0.38^{a}	26.08 ± 0.33^{a}	82.93 ± 4.47^{a}	18.71 ± 0.24^{a}
P values	0.0001**	0.2595^{ns}	0.0093*	0.1383^{ns}
CV values (%)	8.48	5.65	17.87	6.11

*: 0.01< P ≤0.05 **: P≤0.01, ns: not significant PH:plant height, SD:stem diameter, FCH:first cob height, CH:cob height

An examination of PH values reveals that, among the hybrid–double cross mixture treatments, the highest and lowest values ranged from 286.27 cm to 224.07 cm. The highest value was recorded in the hybrid (H) planting, whereas the lowest was observed in the double cross (DC) planting. For the other treatments, the PH values in mixed sowings of hybrid and double cross maize were found to fall within the same statistical group, while hybrid and double cross sowings belonged to distinct subgroups. Regarding FCH, the highest value (82.93 cm) was observed in the H treatment, while the lowest (53.63 cm) was recorded in the DC treatment. However, variance analysis indicated that, apart from the H model, all other treatments belonged to the same statistical group. Uysal and Soylu (2019), in their study on hybrid maize, reported that differences in PH values were significant, whereas FCH values showed insignificant negative effects in 9 hybrid lines and insignificant positive effects in 11 lines. Similarly, Pekbağrıyanık et al. (2020), in their work with dent corn and sweet corn genotypes and hybrids, found that both PH and FCH values were statistically non-significant. On the other hand, Özata and Öz (2014), in their study with various maize genotypes, reported no significant differences in PH values, but significant variation in FEH across genotypes. These findings are consistent with the results of the present study.

For cob height (CH), the highest value was recorded as 20.49 cm in the 25DC + 75H treatment, while the lowest value of 18.47 cm was observed in the double cross (DC) treatment. All sowing models fell within the same statistical group, and the differences were considered statistically insignificant. Pekbağrıyanık et al. (2020), in their study on hybrid maize, reported that hybrid maize did not affect CH, and the obtained values were statistically insignificant. Conversely, İdikut et al. (2020), conducting their study with hybrid maize during the second crop season in Kahramanmaraş, found that CH values formed different subgroups and were statistically significant.

Table 2 presents the results of variance analysis and mean comparison tests for cob diameter (CD), cob weight (CW), number of grain per cob, grain weight per cob, and thousand-grain weight. The mixed planting of hybrid maize and double cross maize had a significant effect on cob diameter, cob weight, and grain weight per cob, while it did not affect the other traits.

Table 2. *Effect of double cross maize hybrids on propertions CD, CW, NS, CGW and TSW.*

Planting Model	CD (mm)	CW (g/plant)	NS (piece/cob)	CGW (g)	TSW(g)
25 DC+75 H	52.49±0.64^{a}	1366.67±58.17^{a}	713.73±21.57^{a}	1152.33±60.84^{a}	376.67±10.83^{a}
50 DC+50 H	50.38±0.62^{a}	1179.33±83.45^{ab}	700.00±131.21^{a}	971.00±62.08^{ab}	374.17±8.33^{a}
75 DC+25 H	51.54±0.73^{a}	1273.00±31.80^{a}	714.40±34.84^{a}	1047.67±19.47^{a}	382.50±24.11^{a}
DC	45.07±0.62^{b}	908.67±67.53^{b}	541.87±81.34^{a}	771.33±50.11^{b}	366.67±7.95^{a}
H	50.72±1.17^{a}	1315.33±72.07^{a}	763.33±98.74^{a}	1095.00±60.10^{a}	365.83±13.64^{a}
P values	0.003**	0.0082*	0.1095^{ns}	0.0095*	0.9138^{ns}
CV values (%)	5.83	15.96	21.22	15.61	5.86

*: 0.01< P ≤0.05 **:P≤0.01, ns:not significant, CD:cob diametri, CW: cob weight, NS:number of seed, CWG:cob grain weight, TSW: 1000-seed weight.

When examining the cob diameter (CD) values, the highest and lowest values ranged between 51.54 mm and 45.07 mm, respectively. The highest value was recorded in the 75DC+25H treatment, while the lowest value was observed in the double cross (DC) treatment. Although statistical analysis divided the values into two different subgroups, all treatments except the DC planting model were grouped within the same subgroup. While Aygün (2012) reported no statistically significant differences in CD values in double cross maize planting, Turgut and Duman (2014), in their study on dent corn, found that CD values in hybrid maize combinations were significantly different compared to pure lines. Their findings support the results of our study.

For cob weight (CW), the highest value was recorded as 1366.67 g in the 25DC+75H treatment, while the lowest value of 908.67 g was observed in the double cross (DC) treatment. The results showed the formation of two distinct groups: the 25DC+75H, 75DC+25H, and H treatments were grouped together, whereas the DC treatment formed a separate subgroup. The 50DC+50H treatment was found to fall into both groups, indicating the significance of the observed values. Aygün (2014), in his study on single, triple, and double cross hybrid maize, reported significant differences in cob weight among double cross hybrids, supporting the findings of our study.

When examining the number of grains per cob (NS), the numerical differences between values were minimal. The highest NS value was 714.40 in the 75DC+25H treatment, while the lowest was 541.87 in the double cross (DC) treatment. However, based on the variance analysis and mean comparison tests, these values were grouped within the same statistical group, indicating that the mixture ratios did not have a significant effect on NS. Although Akan and Kılıç (2021), in their study conducted under Muş conditions, reported significant differences between the highest and lowest NS values, their findings do not support our results.

Regarding the cob grain weight (CGW), the highest value of 1152.33 g was observed in the 25DC+75H treatment, while the lowest value of 971.00 g was in the 50DC+50H treatment. The H, 75DC+25H, and 25DC+75H treatments were grouped together statistically, while the double cross treatment formed a separate group. The 50DC+50H treatment fell into both groups. These results suggest that hybrid maize cultivation with varying double cross hybrid ratios, as well as hybrid cultivation, can yield optimal results. Özata and Öz (2014) reported differences among genotypes for CGW, which are important for grain yield per unit area. Similarly, İdikut et al. (2020) found statistically significant differences in CGW among hybrid maize varieties.

A recent study from Germany (Frontiers, 2023) indicated that mixed planting models could reduce yield variability by mitigating environmental stress effects, reinforcing our conclusion that such combinations may buffer the impacts of irregular rainfall and temperature increases in regions like the Amik Plain. A recent study from Germany (Frontiers, 2023) indicated that mixed planting models could reduce yield variability by mitigating environmental stress effects, reinforcing our conclusion that such combinations may buffer the impacts of irregular rainfall and temperature increases in regions like the Amik Plain.

Similarly, Rasheed et al. (2017) reported that double cross hybrids exhibited performance levels comparable to their parental single-cross hybrids under diverse environmental conditions, supporting the feasibility of using double cross seeds in combination with hybrids. Similarly, Rasheed et al. (2017) reported that double cross hybrids exhibited performance levels comparable to their parental single-cross hybrids under diverse environmental conditions, supporting the feasibility of using double cross seeds in combination with hybrids.

Additionally, studies conducted by Hu et al. (2019) demonstrated that hybrid mixtures under various planting densities improved grain yield by up to 10%, which aligns with our observation that the 25DC+75H model produced superior cob and grain weight. Additionally, studies conducted by Hu et al. (2019) demonstrated that hybrid mixtures under various planting densities improved grain yield by up to 10%, which aligns with our observation that the 25DC+75H model produced superior cob and grain weight.

For the thousand seed weight (TSW), the highest value of 382.50 g was recorded in the 75DC+25H treatment and the lowest value of 365.83 g in the H treatment. Although numerical differences were observed, variance and mean comparison tests indicated no significant difference, with all treatments belonging to the same group. Khan et al. (2012) reported in their study in Pakistan that TSW was highest in single-cross hybrids, followed by double cross hybrids, with the differences being statistically significant. İdikut et al. (2020), in their study under second crop conditions, observed significant differences in TSW among hybrid maize varieties, but their results do not align with ours.

CONCLUSION

This study, conducted under the conditions of the Amik Plain, evaluated the effects of different hybrid maize planting models on yield and yield components, with a particular focus on the impact of double cross planting systems. The hybrid (H) and the 25% double cross + 75% hybrid (25DC+75H) combinations showed superior performance in key traits such as plant height, first cob height, cob weight, and grain yield. The data indicate that these two treatments resulted in statistically significant and agriculturally efficient outcomes. Although some evaluated traits did not show significant differences between groups, these traits have limited direct correlation with yield. However, parameters directly related to yield, such as cob diameter, cob weight, and grain weight per cob, formed the basis for yield-enhancing strategies and exhibited significant differences.

Overall, the results suggest that genetic variation and the appropriate planting model considerably influence the yield potential in hybrid maize production. The double cross planting method is recommended as an economically efficient strategy, especially when using costly hybrid seeds. The application of the 25% double cross + 75% hybrid ratio offers a promising alternative for achieving high yield. While the findings of this study provide valuable insights for local producers and researchers, repeating the experiment under different ecological conditions and soil types will offer more comprehensive information regarding the adaptability of the maize variety. Moreover, these findings emphasize that selecting the optimal planting ratio—especially the 25DC+75H model—not only ensures high productivity but also balances seed cost and yield efficiency, which are crucial in regions facing economic and climatic constraints.

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CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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