

# The Impact of Climate Change on the Main and Second Crop Production of Different Corn Varieties in the Continental Climate Zone

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## ABSTRACT

Under changing climatic conditions, identifying crop varieties with different maturity characteristics has become increasingly important to ensure yield stability and efficient use of production periods. The study was conducted in 2021-2022 at the research fields of the Department of Field Crops, Faculty of Agriculture, Van Yüzüncü Yil University, across four periods covering both main and second cropping seasons. Corn varieties representing different FAO maturity groups - early (FAO 300), medium-early (FAO 400), medium (FAO 500-600), and medium-late (FAO 680) - were evaluated using a randomized complete block design with three replications. Measured traits included plant height (PH), forage yield (TF), dry matter (DM), dry matter ratio (DMR), number of leaves (NL), leaf weight (LW), cob weight (CW), and stem diameter (ST). In the main crop, medium and medium-late varieties showed the highest PH and DM, while CW and ST were also greatest in these groups. In the second crop, early and medium-early varieties performed better in PH, CW, and DM. Forage yield (TF) was highest in medium varieties during the main crop, but medium-early varieties were superior in the second crop. These results indicate that each maturity group adapts differently to seasonal conditions, providing specific advantages under varying production periods. Overall, these results demonstrate that the strategic use of different maturity groups according to seasonal conditions not only enhances yield performance but also supports sustainable and resilient forage corn production under variable climate conditions.

**Keywords:** climate change, corn, main cropping season, second cropping season.

## INTRODUCTION

Climate change, one of the most pressing global issues, has led to a temperature increase of about 1.1°C from 1850-1900 to 2010-2019, with projections suggesting it will exceed 1.5°C by 2030 (IPCC, 2022). These changes threaten agricultural productivity, as shifts in temperature and soil conditions directly affect crop yield and quality. Given its role in employment, income, nutrition, and trade, agriculture faces significant economic and social losses due to global warming (Huang et al., 2011; Stevanović et al., 2016). The impacts of climate change vary regionally: while some areas experience yield reductions, others may benefit (Acharya and Bhatta, 2013). This variability underscores the importance of developing adaptive strategies to sustain production under changing conditions (Karaer et al., 2021). One effective adaptation approach is second-crop cultivation, which

allows farmers to utilize fallow lands and achieve two harvests in a season. Silage maize, with its high yield potential and adaptability, is commonly preferred after cereal or legume harvests in suitable climatic and irrigated regions (Ağırağaç and Zorer Çelebi, 2022). However, yield and quality depend on the compatibility between variety and environment, making regional adaptation studies essential. The availability of maize varieties with differing maturity levels provides flexibility: early varieties ensure safer production in risky areas, while late varieties offer higher yields in water-abundant regions (Cairns et al., 2013; Gökkuş et al., 2016; Loučka et al., 2018).

This study aims to emphasize the need to revise regional production patterns in response to global climate change by determining maize varieties best adapted to continental conditions and evaluating their performance as both main and second crops.

## MATERIAL AND METHODS

The research was carried out in the Research and Practice Field of the Faculty of Agriculture, Van Yüzüncü Yıl University (38°34'18.8" N, 43°17'17.5" E), during 2021-2022 in both main and second crop cycles. Climatic data for the experimental years are shown in Figure 1. Total annual rainfall was 206.2 mm in 2021 and 272.9 mm in 2022, below the long-term average of

406 mm. The annual mean temperatures were 11.7°C and 10.9°C, slightly above the long-term average of 10°C. Soil samples from 0-20 cm and 20-40 cm depths were analyzed before sowing. The soil is generally sandy-loam-loamy, slightly alkaline (pH 7.61-7.72), low in salinity (0.07-0.09%), with 18-19% lime and 1.21-1.44% organic matter. Sand content ranges from 44% to 49%, indicating a well-drained, suitable environment for crop cultivation.

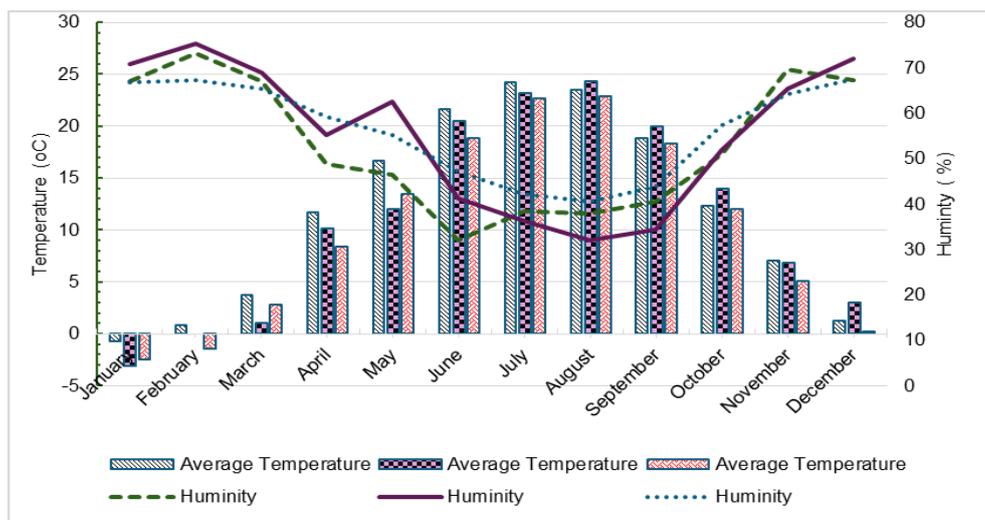


Figure 1. Average temperature and relative humidity chart (2021, 2022, Long-Term Average) (WU, 2023)

The study used nine corn varieties from different FAO maturity groups, supplied by May and KWS, in a randomized block design with three replications. Plots measured 3 m in length, with 1 m between plots and 2 m between blocks; sowing was done in 4 rows with 70 cm row spacing and 12 cm plant spacing. First and second crops were sown and harvested in 2021 (Apr 24-Sep 5 and Jun 23-Oct 15) and 2022 (May 1-Sep 12 and Jun 27-Oct 20). Fertilization included DAP and ammonium sulfate, applying 20 kg N and 8 kg P per decare. Irrigation was via sprinklers, and weed control, thinning, and top dressing were applied at appropriate growth stages. Measured parameters included plant height (PH), forage yield (TF), dry matter yield (DM), dry matter ratio (DMR), number of leaves (NL), leaf weight (LW), cob weight (CW), and stem diameter (ST). PH was averaged from 10 plants per plot; TF from 2.8 m<sup>2</sup> of cut area; DM from samples dried at 70°C. Data were analyzed

with ANOVA and Duncan's test (SPSS), and Pearson correlations were calculated using R.

## RESULTS AND DISCUSSION

In the first crop, maize variety significantly affected all measured traits at the 1% level. The year effect was generally significant, except for leaf weight (LW), which was not, and cob ratio (CR), significant at 5%. The variety × year interaction was significant for all traits except plant height (PH). For the second crop, variety effects were significant at 1% for all traits, the year effect was significant for all except stem diameter (ST), and the variety × year interaction was significant for all traits. Overall, across both planting periods, variety, growing period, and their interaction significantly influenced all measured parameters (Table 1).

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Table 1. Analysis of variance table explaining the effect of growing periods on yield parameters of different corn varieties

Crop Period	Year	Variable	PH	TF	DM	DMR	LW	NL	CW	ST
Main Crop	2021-2022	Variety	24.06 **	626.81 **	416.45 **	166.01 **	18.28 **	83.98 **	172.48 **	239.14 **
		Year	8.98 **	27.23 **	97.95 **	82.20 **	0.06 **	77.65 **	120.56 **	6.40 **
		Variety*Year	1.65 **	27.22 **	25.56 **	21.71 **	6.53 **	3.28 **	19.52 **	8.26 **
Second Crop	2021-2022	Variety	83.22 **	287.95 **	151.40 **	77.41 **	25.86 **	107.65 **	292.73 **	126.55 **
		Year	45.02 **	351.09 **	62.18 **	10.88 **	9.00 **	128.26 **	133.88 **	0.02
		Variety*Year	6.52 **	13.03 **	27.21 **	25.02 **	7.25 **	5.73 **	5.70 **	7.83 **
Main Crop - Second Crop		Variety	6.84 **	66.26 **	42.90 **	20.09 **	9.97 **	22.45 **	6.04 **	127.44 **
		Crop Period	799.73 **	16303.89 **	5147.06 **	1548.16 **	192.31 **	867.76 **	1495.87 **	696.98 **
		Variety* Crop Period	39.29 **	106.08 **	56.83 **	24.26 **	10.23 **	28.56 **	53.69 **	37.14 **

Significant differences in plant height (PH) were observed among varieties across years and sowing periods. In the first crop, the highest PH in 2021 was recorded for Koloseus (236.2 cm) and in 2022 for Bodega (232.4 cm), while the lowest values were observed in Simpatico and KB8392. For the second crop, Simpatico (2021) and KB8392 and K\*B6451 (2022) had the highest PH, whereas Koloseus had the lowest in both years (194.8 cm in 2021; 198.6 cm in 2022) (Figure 2). The variety  $\times$  sowing period interaction showed that PH was generally higher in the main crop, with Koloseus and

Bodega reaching 233.5 cm and 233.1 cm, respectively, while the lowest was Koloseus in the second crop (196.7 cm, a 15.7% decrease). Early-maturing varieties like Simpatico showed minimal reduction (1.18%) in the second crop, emphasizing their suitability for second-crop cultivation. These differences are attributed to the distinct FAO maturity groups of the varieties. PH is an inherited trait affected by environmental and management conditions, and higher PH is key for maximizing forage yield (Ağırağaç and Zorer Çelebi, 2022; Ağırağaç, 2024).

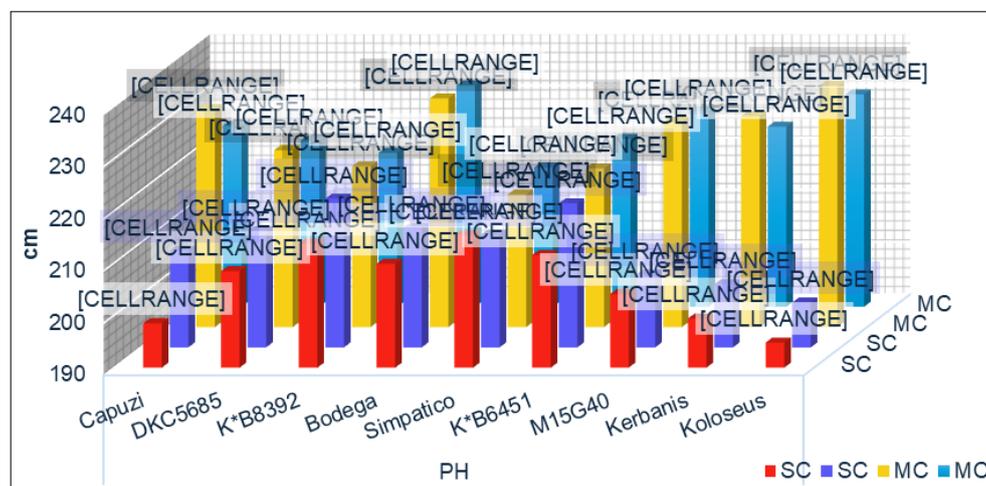


Figure 2. Comparison of PH values of corn varieties during the main and second product sowing periods in 2021 and 2022 (p<0.5)

In the main crop, the highest fresh forage yield (TF) in 2021 was recorded for Bodega (7.49 t/da) and Kerbanis (7.43 t/da), while in 2022, Kerbanis led with 7.50 t/da. The lowest TF in 2021 was observed in DKC5685, KB8392, and KB6451, and in 2022 in KB8392 (6.33 t/da). For the second crop, TF was generally lower than the main crop. In 2021, KB6451 had the highest TF (5.23 t/da), while in 2022, K\*B8392 led with 5.29 t/da. Koloseus had the lowest TF in both years (4.90-4.93 t/da) (Figure 3). The variety ×

sowing period interaction showed the highest TF in Kerbanis (7.47 t/da) and Bodega (7.40 t/da) in the main crop, and the lowest in Koloseus (4.92 t/da) in the second crop (Figure 10). Overall, varieties performed better in the main crop due to the longer growing period and cumulative temperature, highlighting the importance of selecting appropriate varieties to maximize green biomass in silage corn production (Safdarian et al., 2014; Demiray, 2013).

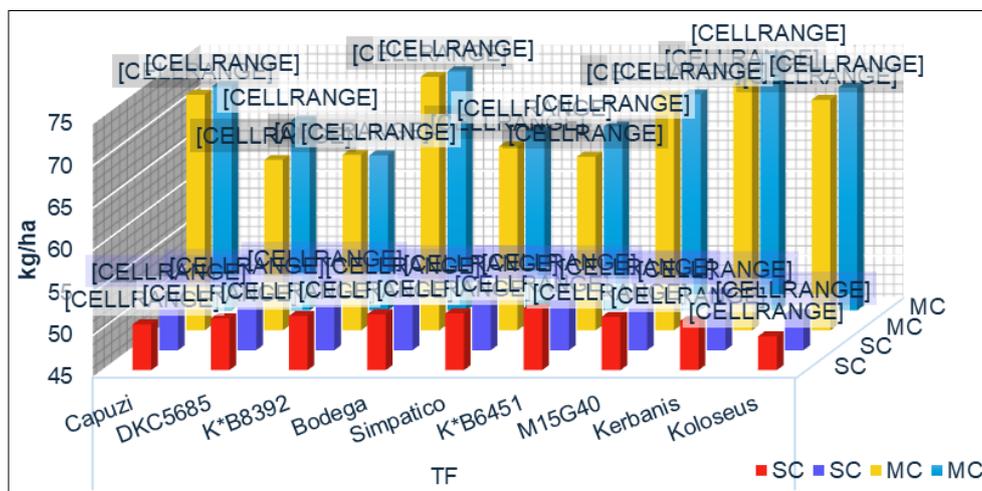


Figure 3. Comparison of corn varieties' fresh forage yield (TF) in the main and second product sowing periods for the years 2021 and 2022 (p<0.5)

Dry matter (DM) was higher in the main crop than the second crop. In 2021, Bodega had the highest DM (2.28 t/da), while in 2022, Kerbanis (2.14 t/da) and Bodega (2.13 t/da) led. The lowest DM was in KB6451 (2021) and KB8392 (2022). In the second crop, DM was higher in 2022, with K\*B6451 (2021) and Bodega (2022) highest, and Koloseus lowest both years

(0.90-1.02 t/da) (Figure 4). Late-maturing varieties like Koloseus underperformed in the second crop due to shorter growth and lower temperatures, highlighting the advantage of early-maturing varieties. Differences in DM reflect genetic and phenological traits, consistent with prior studies (Geren et al., 2003).

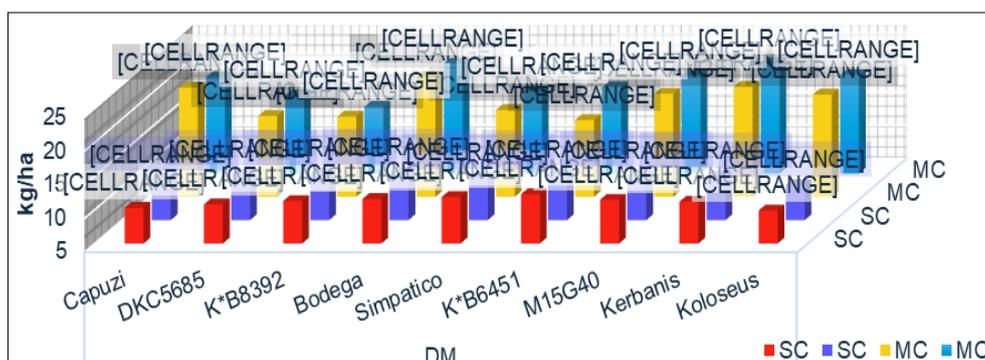


Figure 4. Comparison of dry matter (DM) content of maize varieties during the main and second crop planting periods in 2021-2022 (\*p<0.05)

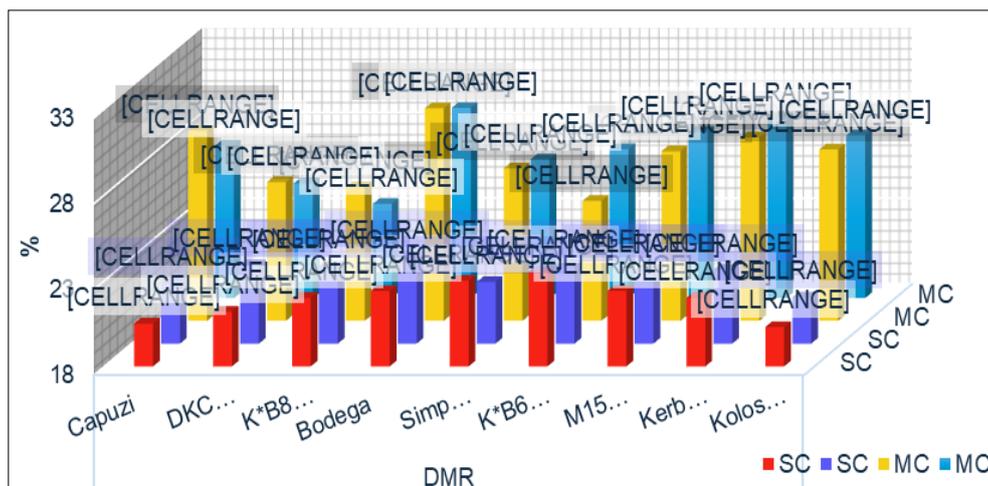


Figure 5. Comparison of dry matter ratio (DMR) of maize varieties during the main and second crop planting periods in 2021-2022 (\* $p < 0.05$ )

In the main crop, the highest dry matter ratio (DMR) was observed in Bodega (30.4% in 2021; 29.1% in 2022) and Kerbanis (28.5% in 2022), while the lowest was in KB6451 (25%) in 2021 and KB8392 (23.5%) in 2022. In the second crop, K\*B6451 (23.5% in 2021) and Bodega (23.1% in 2022) had the highest DMR, whereas Koloseus had the lowest in both years (20.3-20.7%) (Figure 5). The variety  $\times$  sowing period

interaction showed the highest DMR in Bodega during the main crop (29.8%) and the lowest in Koloseus (20.5%) and Capuzi (21%) in the second crop (Figure 10). Overall, varieties performed better in the first crop. DMR, calculated from the ratio of dry to fresh forage (Ağırağaç, 2024), is an important indicator of forage quality, with higher values reflecting greater nutrient content (Budak et al., 2014).

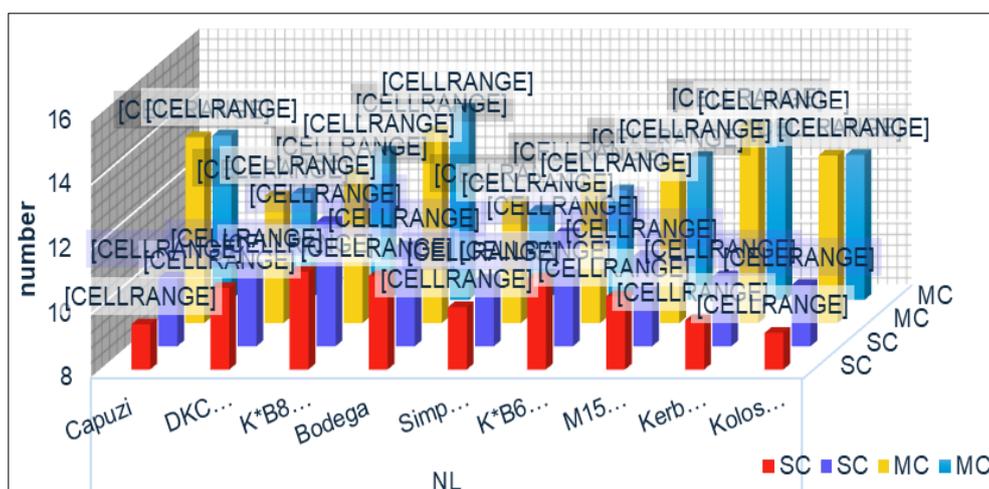


Figure 6. Comparison of the number of leaves (NL) of maize varieties during the main and second crop planting periods in 2021-2022 (\* $p < 0.05$ )

In the main crop, the highest number of leaves (NL) in 2021 was recorded in Kerbanis (14.1), Bodega (14), and Capuzi (13.8), while in 2022, Bodega led with 13.9 leaves/plant. The lowest NL was observed in DKC5685 and Simpatico (2021) and

DKC5685 and KB6451 (2022). For the second crop, KB8392 (11 in 2021; 11.9 in 2022), Bodega, and KB6451 had the highest NL, while Koloseus had the lowest in both years (Figure 6). The variety  $\times$  sowing period interaction showed that NL was highest in

Bodega (14) and Kerbanis (13.7) during the main crop, and lowest in Koloseus (9.5), Capuzi (9.8), Kerbanis (9.8), and Simpatico (10) in the second crop (Figure 10). Differences in NL are influenced by FAO maturity groups and temperature, as late-

maturing varieties like Kerbanis performed best in the main crop but poorly in the second. These results align with previous studies showing the importance of variety and FAO group in leaf development (Sun, 2004).

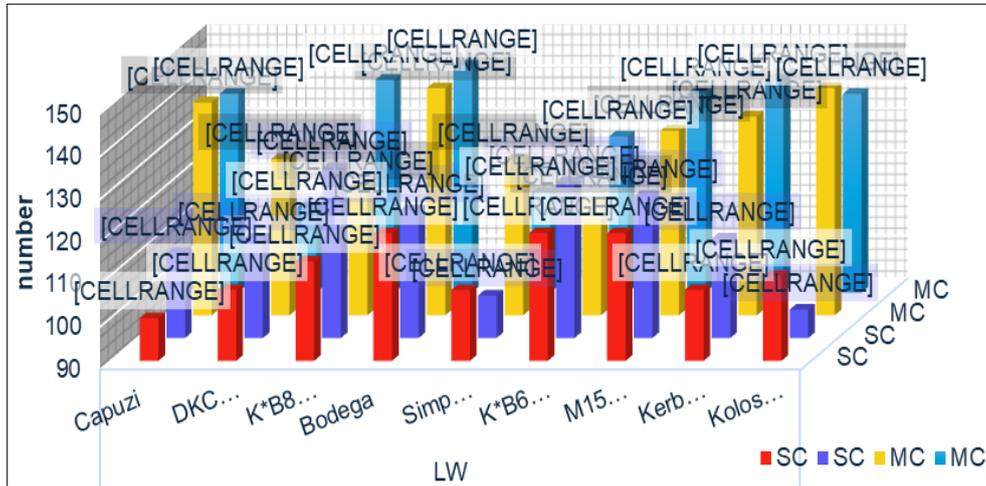


Figure 7. Comparison of leaf width (LW) of maize varieties during the main and second crop planting periods in 2021-2022 (\*p<0.05)

In the main crop, leaf weight (LW) was highest in Capuzi, Bodega, M15G40, Kerbanis, and Koloseus (133-143 g/plant) and lowest in KB6451, KB8392, and DKC5685 (107-127 g/plant). In the second crop, LW decreased, with Koloseus and Capuzi showing the lowest values (100-110 g/plant) and was positively correlated with leaf number. Cob weight (CW) was highest

in Koloseus, Capuzi, and Kerbanis (235-250 g/plant) in the main crop, while late-maturing Koloseus had the lowest CW in the second crop (141-153 g/plant) (Figure 7). Early-maturing varieties like Simpatico and K\*B8392 performed better in second-crop conditions, highlighting their importance for silage quality.

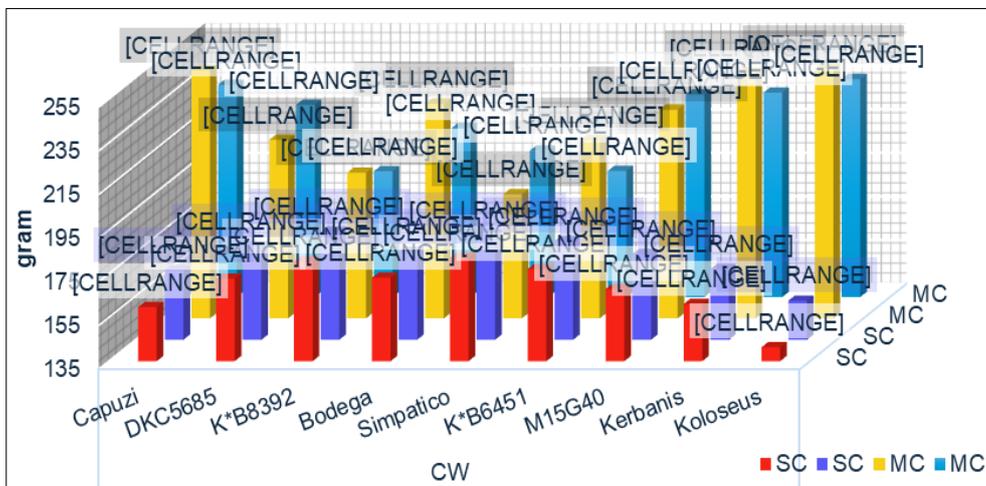


Figure 8. Comparison of corn varieties' CW during the main and second crop sowing periods in 2021-2022 (\*p<0.5)

In 2021, the highest stem diameter (ST) in the main crop was observed in Bodega (21.9 mm), and in 2022 in Kerbanis (22 mm) and Bodega (21.7 mm). The lowest ST was recorded in KB6451 (18-18.1 mm) and Simpatico (18.2 mm) in 2021, and KB6451 (18 mm) in 2022. For the second crop, the highest ST in 2021 was in M15G40 (20 mm) and Bodega (19.9 mm), while in 2022, Bodega (20 mm), Kerbanis (19.9 mm), and M15G40 (19.7 mm) led. The lowest values in the second crop were KB8392 (17.5 mm) in

2021 and Simpatico/KB6451 (17.5-17.6 mm) in 2022 (Figure 9). The variety × sowing period interaction showed the highest ST in Bodega during the main crop (21.8 mm) and the lowest in KB8392, KB6451, and Simpatico during the second crop (17.8-18 mm) (Figure 10). Overall, the first crop generally resulted in higher ST. ST is a key trait for plant development and resilience, supporting upright growth and the bearing of leaves and reproductive organs (Geren and Kavut, 2009).

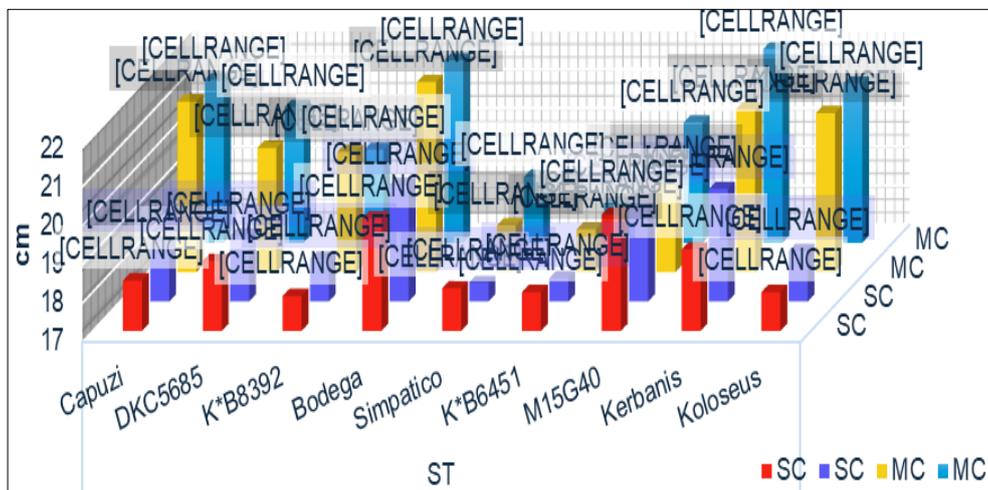
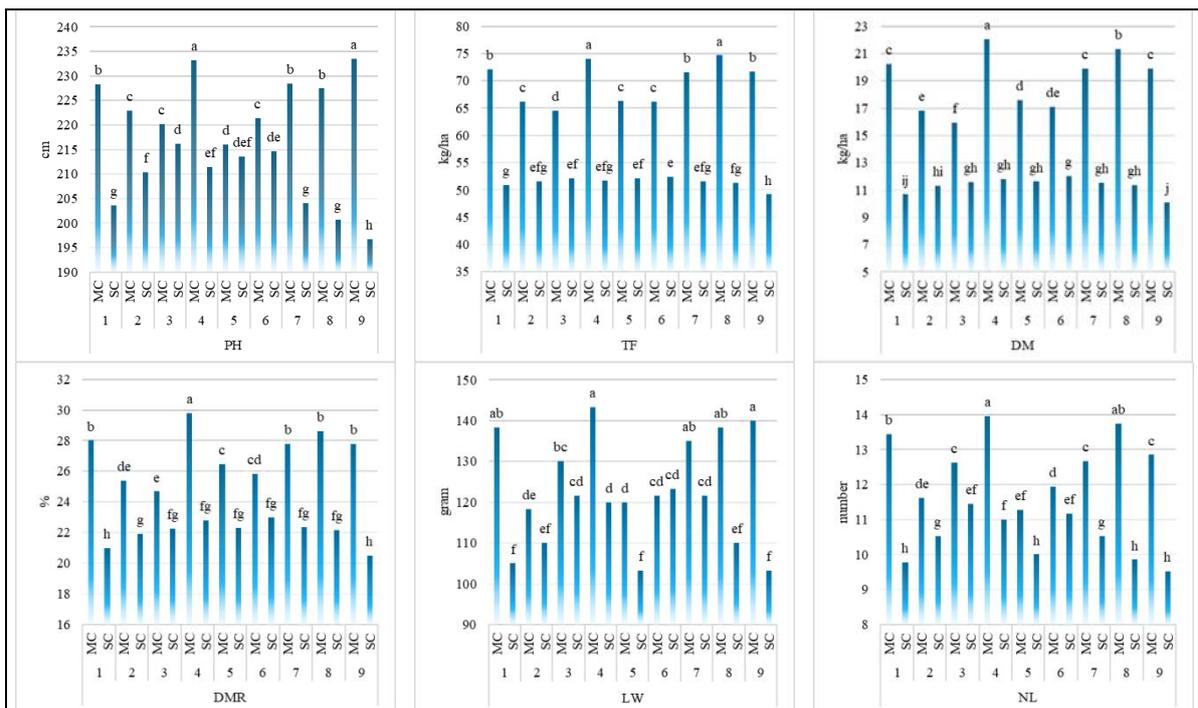


Figure 9. Comparison of corn varieties' ST during the main and second crop sowing periods in 2021-2022 (\*p<0.5)



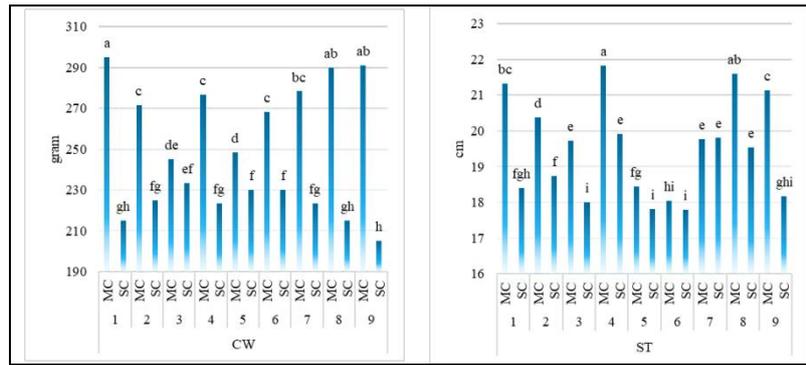


Figure 10. Results of the cultivation period and variety interaction, and the resulting groups (two-year average)

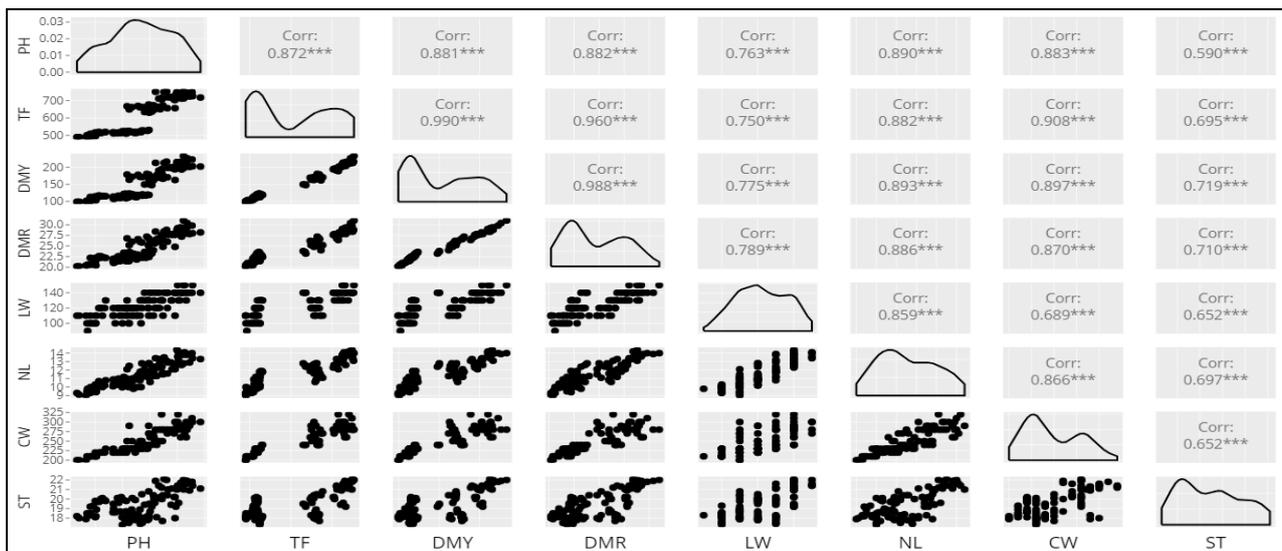


Figure 11. Correlation graph of the dependent variables of the varieties

When examining the provided correlation matrix, particularly high correlation coefficients were observed between PH and other measured parameters (Figure 10). High correlations were found between PH and TF (DMY) at 0.811, DMR at 0.882, NL at 0.890, and CW at 0.883. An increase in TF is associated with dry matter yield, DMR, and LW. Notably, there is a strong 99% correlation between DM and TF.

Climate change strongly affects agriculture, creating both biotic and abiotic stresses that reduce productivity (Luck et al., 2011; Challinor et al., 2014; Rosenzweig et al., 2014; Thornton et al., 2014; Raza et al., 2019). However, it also offers opportunities, such as cultivating crops in previously unsuitable areas and developing drought- and heat-tolerant, early-maturing varieties to sustain production (Audsley et al., 2006; Acharya and Bhatta, 2013; Malhi et al.,

2021). Maximizing crop yield requires selecting suitable varieties adapted to regional ecological conditions, while animal production depends on high-quality, cost-effective feed, with corn being the most important silage crop due to its yield and nutritional value (Ağırdoğan, 2024). Regional climate - temperature, solar radiation, CO<sub>2</sub> levels, and water availability - regulates plant metabolism (Chaves et al., 2003; Lucier, 2006; Pidwirny and Jones, 2006). Therefore, analyzing local climate and choosing compatible varieties are essential to ensure high-quality silage and optimal yields, as mistakes in variety selection cannot be compensated by other cultivation practices (Challinor et al., 2014; Sariyerli and Soylu, 2016; de Oliveira et al., 2017). Variety selection in maize is strongly influenced by the maturation period, classified by FAO maturity groups (Bahan et al., 2022). In this

study, nine varieties from early (FAO 300), semi-early (FAO 400), medium (FAO 500-600), and late-maturing (FAO 680) groups were used. Plant height (PH) is a key parameter for silage yield, affected by temperature, rainfall, and humidity (Araújo et al., 2012; Anwar et al., 2013; Hatfield and Prueger, 2015; Sharma et al., 2016). In the main crop, longer vegetative periods and favorable temperatures lead to higher PH, with medium and late-maturing varieties outperforming early types. Conversely, in the second crop, early and semi-early varieties show higher PH due to shorter growing periods and lower temperatures. Plant height positively correlates with number of leaves (NL) and leaf weight (LW), which are also influenced by FAO group, variety characteristics, and regional adaptation (Güney et al., 2010; Korkmaz et al., 2019; Akgün et al., 2021). Crop yield and quality depend on genotype, environment, and their interaction ( $G \times E$ ) (Heslot et al., 2014). The selection of appropriate varieties and planting dates is critical, as ear yield contributes around 50% of green mass and 70% of nutritional value in silage corn (Ososanya and Olorunnisomo, 2015). Tassel emergence varies with maturity: 3-4 days in early, 5-7 days in medium, and 9-10 days in late-maturing varieties (Kaya, 2020). Two-crop cultivation can enhance production efficiency, particularly in the context of climate change and increasing global food demand (Liu et al., 2021; Baig et al., 2022; Neupane et al., 2022). Corn varieties reach the ear formation stage at different times depending on their FAO rating and temperature requirements (TDÖ, 2010). Medium and late-maturing varieties have development periods of 110-130 days, while early types develop in 70-90 days. Optimal temperatures for ear formation and growth are 19-23°C and 25-30°C, respectively, with temperatures below 14°C prolonging ear development (Shahini et al., 2023). In the main crop, medium and late-maturing varieties show higher cob weight (CW) due to favorable August temperatures (23.9°C) that allow uniform maturation. Late-maturing

varieties generally provide higher yield potential (Ağırağaç and Zorer Çelebi, 2022). In the second crop, early and semi-early varieties perform better because sowing occurs later, and ear formation coincides with lower temperatures (~13°C), which are still suitable for maturation (Geren et al., 2003). Early-maturing varieties offer advantages in regional adaptation and climate resilience, but generally have lower yield potential (Braden and Smith, 2004; Bölek et al., 2007). Stalk thickness (ST) is positively correlated with total forage yield (TF), which is a key determinant of silage quantity (Açıkgöz et al., 2011; Ağırağaç and Zorer Çelebi, 2022; Ağırağaç, 2024). In this study, medium-maturity varieties showed the highest ST in both crop periods, while the early-maturing K\*B6451 had the lowest. TF depends on plant weight - including ear, leaf, and stalk - and is influenced by PH, NL, CW, plant density, and environmental conditions (İptaş, 2002; Kördikanlıoğlu, 2022). Medium-maturity varieties had the highest TF in the main crop, whereas semi-early varieties stood out in the second crop. Late-maturing varieties underperformed in the second crop due to a shorter effective growing period, resulting in lower CW, PH, and NL/LW. Dry matter (DM) values followed a similar pattern, with medium-maturity varieties performing best in the main crop and medium to semi-early varieties in the second crop. DM is strongly correlated with TF ( $r = 0.99$ ) and influenced by PH, NL, and ST (Aygün, 2021). The dry matter ratio (DMR) was calculated as the proportion of DM to TF (Neto et al., 2004). During vegetative growth (up to tasseling, VT), only 40% of total dry matter accumulates, while 60% accumulates during the generative phase (R1-R6), with 50% stored in grains and 50% in other plant parts (Bender et al., 2013; Kaya, 2020). Early-maturing varieties reach yield potential faster, explaining their dominance in second-crop conditions and the lower DMR in medium and late-maturing varieties that did not complete the generative phase (Poehlman et al., 1995).

## CONCLUSIONS

Global climate change necessitates adapting agricultural practices to regional conditions. This study assessed corn varieties of different FAO maturity groups as main and second crops under continental climates. Early-maturing varieties were best for second crops, while medium and semi-late varieties performed better as main crops due to longer vegetative periods and favorable temperatures. Selecting climate-adapted varieties optimizes silage corn yield and quality, enables multiple harvests per season, and promotes sustainable production. Conducting regional trials is essential to identify the most effective varieties and management practices, there by enhancing productivity and contributing to food security.

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