Corn kernel and corn fodder yield in four maize varieties in the humid tropics of Mexico

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ABSTRACT

In southeastern Mexico, maize is planted for its corn kernel. Additionally, its bracts are used for *tamales* and handicrafts, its cobs are used as vegetables for human consumption, and its fodder is used to feed cattle.

Objective: To evaluate the growth and yield of maize planted for corn kernel and fodder production in Loma Bonita, Oaxaca, Mexico.

Design/Methodology/Approach: The DK7500, H-520, A7573, and VS-536 maize genotypes were used as treatments for the production of corn kernel and fodder, using a randomized blocks design with three replications. Several variables were measured: plant height, stem diameter, chlorophyll, leaf length, leaf width, and leaf area. Finally, the corn kernel and fodder yields were estimated (kg ha^{-1}) at the time of harvest.

Results: The genotypes under study showed significant differences ($P \leq 0.05$) in plant height, stem diameter, leaf length, leaf width, and leaf area. The A7573 genotype recorded the highest corn kernel yield (20,409 kg ha^{-1}), while fodder yield was statistically the same in the four genotypes.

Study Limitations/Implications: An analysis of different environments in a multi-year period would help to verify the information obtained.

Findings/Conclusions: A7573 maize had the highest corn kernel yield (20,409 kg ha^{-1}): 15.5% higher than that of H-520 and 12.5% higher than VS-536 (control). Fodder yield was statistically similar between genotypes, ranging from 40,529 kg ha^{-1} (H-520) to 42,104 kg ha^{-1} (VS-536).

Keywords: *Zea mays* L., Poaceae, Papaloapan area.

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INTRODUCTION

Maize (*Zea mays* L.) has been planted for thousands of years. Maize remains were found at the Guilá Naquitz caves in Oaxaca, Mexico, dating back 5,400 years (Serratos, 2009). This Poaceae has provided various civilizations with grain, leaves (bracts) for *tamales*, and fodder to feed cattle. Moreover, its kernels can be consumed in soups, roasted, boiled, or used to make bread (Rojas-Polanco *et al.*, 2022).

In 2021, 68,937 ha of maize were sown in Mexico to produce corn kernel, generating 1,059,260 t (average yield: 15.37 t ha^{-1}). The main producing states were Puebla (15,714 ha), Morelos (9,789 ha), San Luís Potosí (8,906 ha), Jalisco (7,999 ha), and the State of

Mexico (4,973 ha) (SIAP, 2023). Corn kernels are used as a fresh vegetable in their milk stage, which occurs 20 to 22 days after pollination (Mehta *et al.*, 2020). The grains contain 18-20% carbohydrates, 5-6% sugars, and 2.1-4.5% proteins; additionally, they have a $<$70% moisture content. The remaining fodder is used to feed livestock (Revilla *et al.*, 2021).

Ortiz-Torres *et al.* (2013) determined the yield and quality of corn kernel production in Tehuacán Puebla, Mexico. Their study determined that the corn kernel yield of the TEH77 maize variety, reached 9,576 kg ha^{-1}, with 11.3 °Brix and 30.7 grains per row. TEH77 also stood out in cob length and width.

Another study conducted in Chiapas, Mexico, found that the plants of native varieties were late grower, reaching a notable height and producing longer and wider corn ears than the control hybrids (Coutiño *et al.*, 2015). Some attributes to consider in corn kernel production include: sweet flavor (up to 13.8 °Brix), associated with the starch content of the endosperm; outstandingly long corn ears and adequate sanitary appearance, with no physical damage; larger, sweeter pieces of corn which consumers are willing to pay a premium for; and, preferably, an organic production system (Fernández-González *et al.*, 2018; Rojas-Polanco *et al.*, 2022).

In Loma Bonita, Oaxaca, 1,384 ha are sown with maize for corn kernel production (SIAP, 2023). These plants are commercial hybrids or native varieties with white or colored (yellow, red, or blue) grains. Producers frequently sell large corn ears by the piece or the ton and use the leftover plants as fertilizer, stubble, or silo material, to help their livestock endure the dry season. The objective of this research was to conduct an analysis of the growth and yield of commercial maize used to produce corn kernel and fodder in Loma Bonita, Oaxaca, Mexico.

MATERIALS AND METHODS

Location of the study site

This research was conducted at the Universidad del Papaloapan, in Loma Bonita, Oaxaca, Mexico (18° 06' N, 95° 52' W, and 25 m.a.s.l.). The climate is warm and humid, with summer rains, an annual precipitation of 1,845 mm, and an average temperature of 24.7 °C (INEGI, 2005).

Land preparation, treatments, and experimental design

Land preparation consisted of fallowing, harrowing (twice), and plowing. Subsequently, the DK7500, A7573, VS-536, and H-520 maize genotypes sown were and used as treatments in a random block design with three replications. The experimental unit (EU=16 m^2) consisted of five 4-m long rows. The separation between rows was 0.8 m and between plants 0.2 m, resulting in a 62,500-plants ha^{-1} density.

General crop management

Weeds were controlled by hand and the crop was fertilized with two applications of the 120-60-20 NPK formula: the first on day 20 and the second on day 45. Foliar fertilizer (Bayfolán forte, 0.75 L ha^{-1}) was sprinkled weekly to correct microelement deficiencies. Chlorpyrifos ethyl (0.75 L ha^{-1}) was used to control fall armyworms.

Variables under study

Plant height (Ph, cm) was measured weekly in five plants per EU, from the base of the plant to the growth point. A digital vernier was used to measure stem diameter (Std, cm). Leaf chlorophyll (Chlo) was measured in SPAD units in the foliar laminae of the intermediate leaves of the plant using the Minolta® SPAD-502 chlorophyll determinant. The following variables were measured: number of total leaves per plant (Tol), leaf length (Ll, cm) and leaf width (Lw, cm). The leaf area per plant (La, cm^2) was calculated with the following formula: $La=Ll \times Lw \times 0.75$. After the morphological components of the plant were separated, an Ohaus Scout SPX2201 digital scale ($2{,}200 \pm 0.1$ g) was used to calculate the fodder yield (Foy, kg ha^{-1}) and the corn kernel yield, including bracts (Cly, kg ha^{-1}).

Statistical analysis

A variance analysis was conducted using Proc ANOVA and the means were compared with Tukey's test ($P \leq 0.05$). The SAS statistical package (SAS, 2013) was used in both instances.

RESULTS AND DISCUSSION

Growth characterization

As a result of the accelerated growth, A7573 and DK7500 recorded a much greater plant height (Ph) than VS-536, during the first stages of development and until the third sampling (Figure 1A). However, no Ph differences were recorded from the fourth to the eighth sampling. In the last three stages, A7573 recorded the lowest plant height (180 cm) among all the other genotypes. From November 2022 to February 2023, rainfall levels were low. These conditions may have affected the growth of A7573 plants, since this maize variety blooms early (at 52 d), while VS-536 blooms at 58 days, with a Ph of 201 cm (Estrada, 1998). Sierra-Macías *et al.* (2010) recorded a Ph of 229 cm and 234 cm for A7573 and VS-536, respectively, in the state of Veracruz, Mexico. The disparities between both studies can be explained by time of the year in which each study took place: spring-summer (Sierra-Macías) and autumn-winter (this study). In Campeche, Mexico, A7573 reached a Ph of 183 to 221.5 cm, which Rivera-Hernández *et al.* (2009) attributed to changes in the soil water regime. This information does not contradict prior findings.

Stem diameter (Std) present statistical differences ($P \leq 0.05$) between treatments on sampling dates 1 to 11, except on sampling dates 3, 5, and 10 (Figure 1B). From the beginning until the eighth sampling, stems were thicker in DK7500 (2.6 cm) and A7573 (2.56 cm). These figures are similar to those recorded by Rivera-Hernández *et al.* (2009), who reported a Std of 2.7 cm in A7573 maize.

The number of leaves per plant did not vary between genotypes ($P > 0.05$) (Figure 1C), except at 56 and 73 d. When kernels develop an important demand for photoassimilates, leaves specialize in the capture of photosynthetically active light, which is crucial for the CO_2 fixation process (Taiz *et al.*, 2017). This phenomenon explains increases in leaves per plant. Throughout the samplings, the length and width of the leaves were always different ($P \leq 0.05$) for each of the genotypes (Figure 2A and 2B). Given its precocity, the Ll and Lw of A7573 were statistically lower ($P \leq 0.05$) than the remaining genotypes in the last two

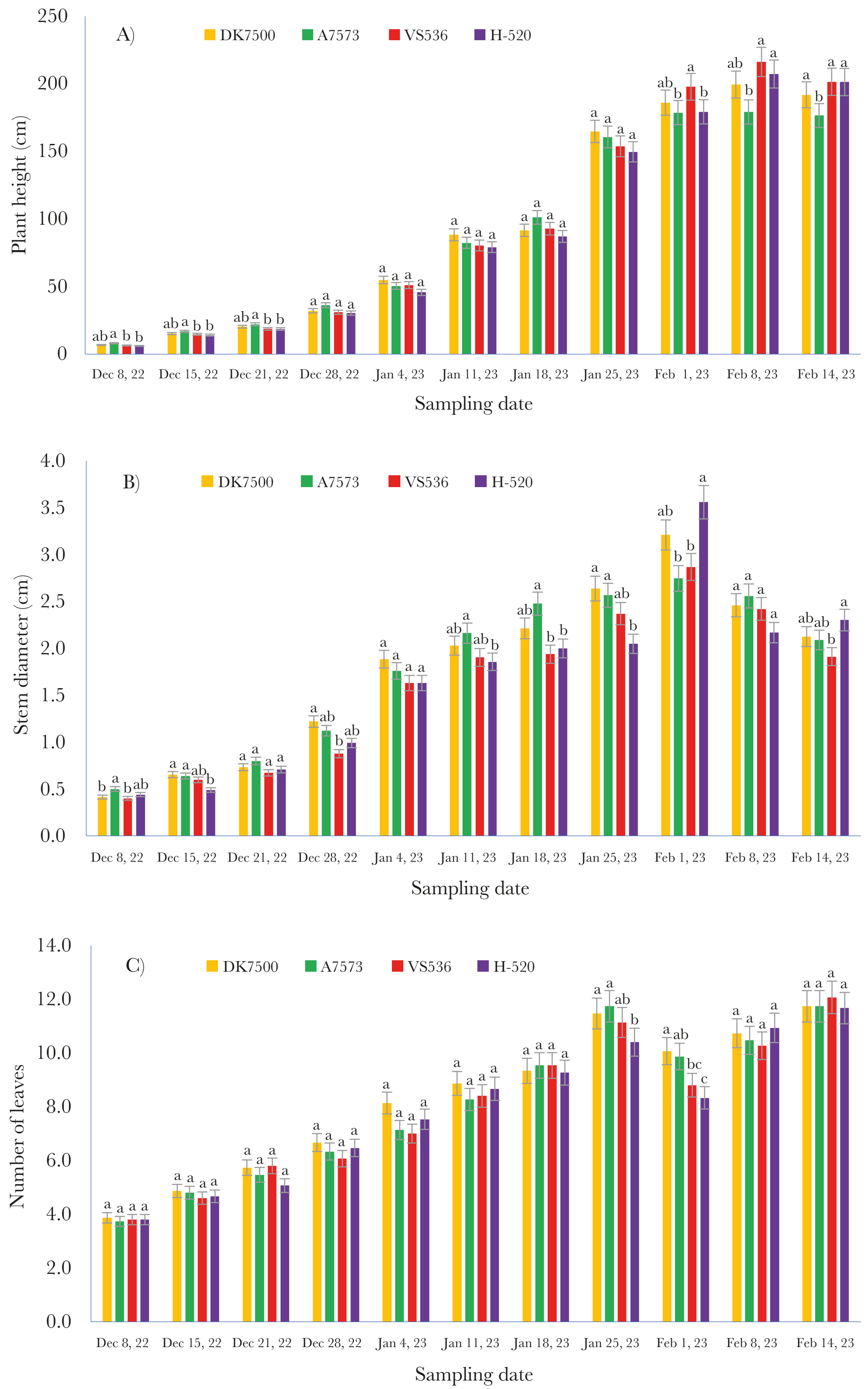

Figure 1. A) Plant height (cm), B) stem diameter (cm), and C) number of leaves in DK7500, A7573, VS-536, and H-520 maize varieties.

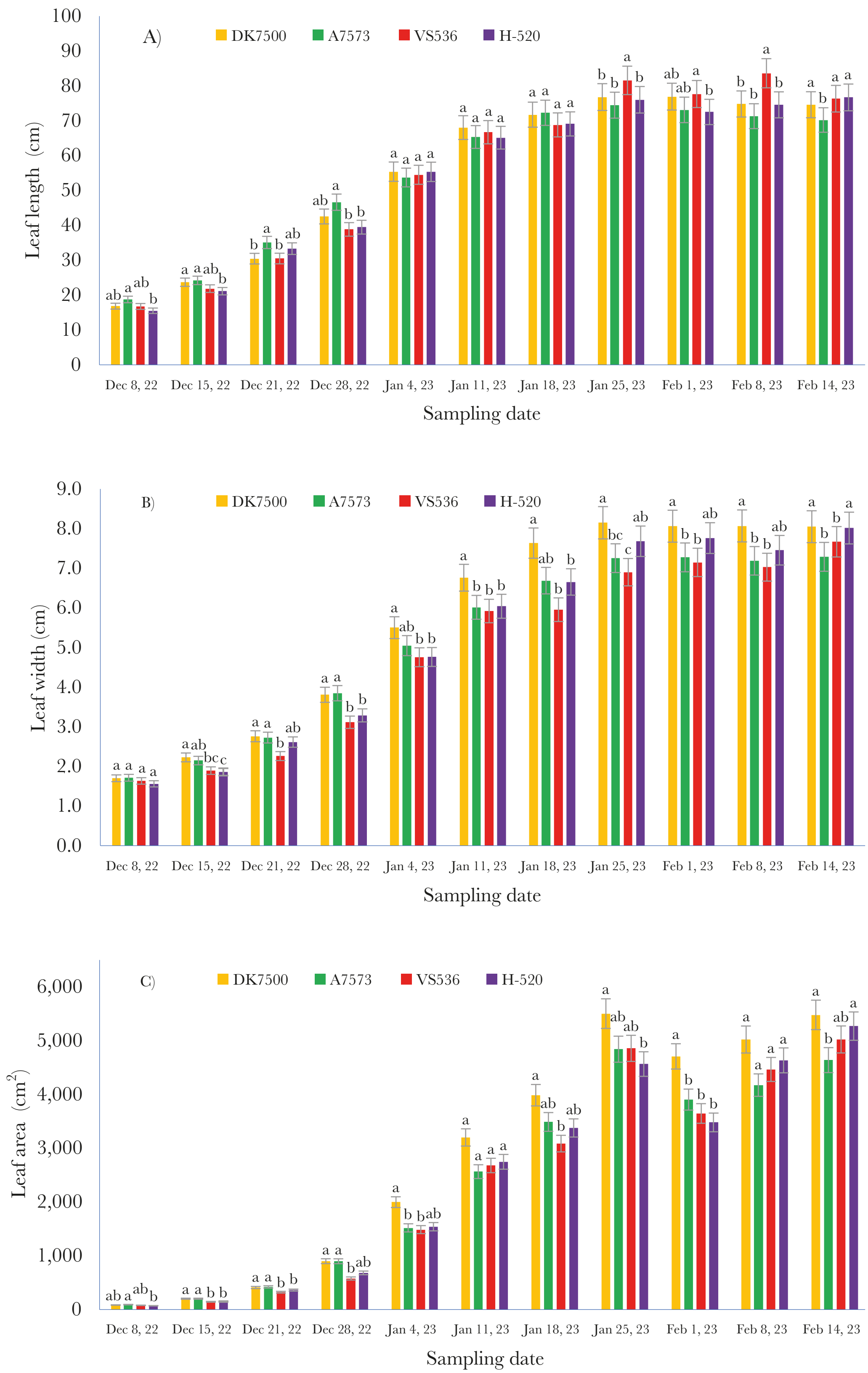

Figure 2. A) Leaf length (cm), B) leaf width (cm), and C) leaf area (cm^2) in DK7500, A7573, VS-536, and H-520 maize varieties.

samplings. Additionally, Ll and Lw were helpful to calculate the leaf area per plant, which is essential to determine important dry matter values. Leaf area per plant was higher in DK7500 (Figure 2C). However, on the last sampling date, the said genotype reached a La of 5,479 cm^2, a statistically similar result to that of H-520 and VS-536.

In the final stages, A7573 had a reduced leaf area (4,638 cm^2); these results matched the minimum leaf width and length values for this genotype. The control variety (VS-536) reached a La of 5,022 cm^2, which is similar to the results reported by Sánchez *et al.* (2021), for VS-536: a La of 4,510 cm^2 at 85 days, in maize apt for fodder production. Chlorophyll in leaves varied significantly ($P \leq 0.05$) in the first four sampling dates and in the ninth and tenth sampling dates (Figure 3). It was lower in H-520 in the first two samplings, since this hybrid maize could require more nitrogen.

In samplings five to eight (35 to 56 days) and the last sampling, there were no variations in chlorophyll between genotypes; during this vegetative stage, values of 52.9 to 54.9 SPAD units were recorded (Figure 3). Rincón and Ligarreto (2010) indicated that chlorophyll in maize ranges from 50 to 54 SPAD units. They also stated that, to obtain adequate yields in corn, chlorophyll in leaves must exceed 50 SPAD units.

The highest corn kernel yield occurred in A7573 (20,409 kg ha^{-1}), while H-520 showed the lowest production (17,233 kg ha^{-1}) (Figure 4). In a study conducted in Campeche, Mexico, Rivera-Hernández *et al.* (2009) registered a corn kernel yield of 16,680 kg ha^{-1} in A7573 maize, which was 18.3% lower than the result obtained in the present study.

Andrés-Meza *et al.* (2017) evaluated corn hybrids with corn kernel production potential in Amatlán de los Reyes, Veracruz, during spring and summer, and reported a corn kernel yield of 14,909 kg ha^{-1} in A7573 maize. These findings corroborate the results obtained in this research.

However, fodder yield was statistically the same in the four genotypes. H-520 recorded 40,529 kg ha^{-1}, while the value of VS-536 (the control variety) rose to 42,104 kg ha^{-1}. On this matter, Sánchez *et al.* (2019) estimated the fodder yield of maize in Loma Bonita,

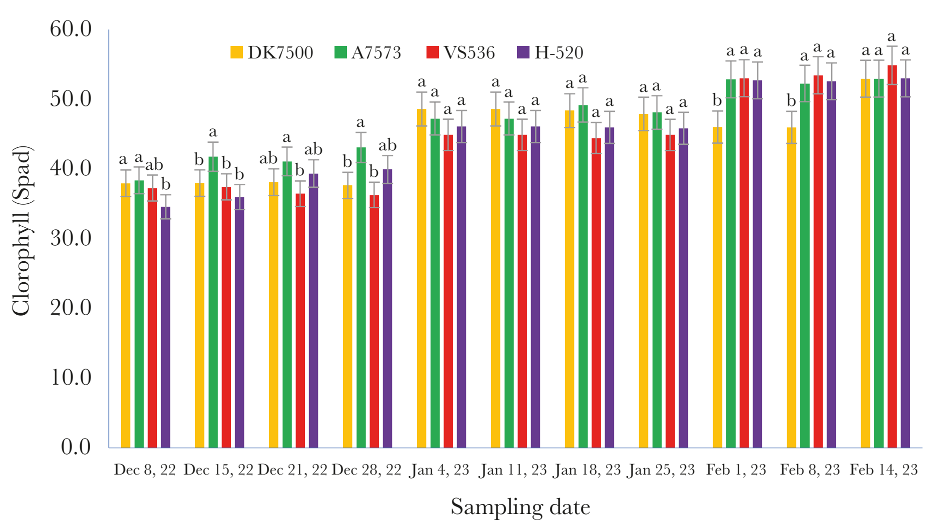

Figure 3. Chlorophyll in leaves (SPAD Units) in the DK7500, A7573, VS-536, and H-520 maize varieties.

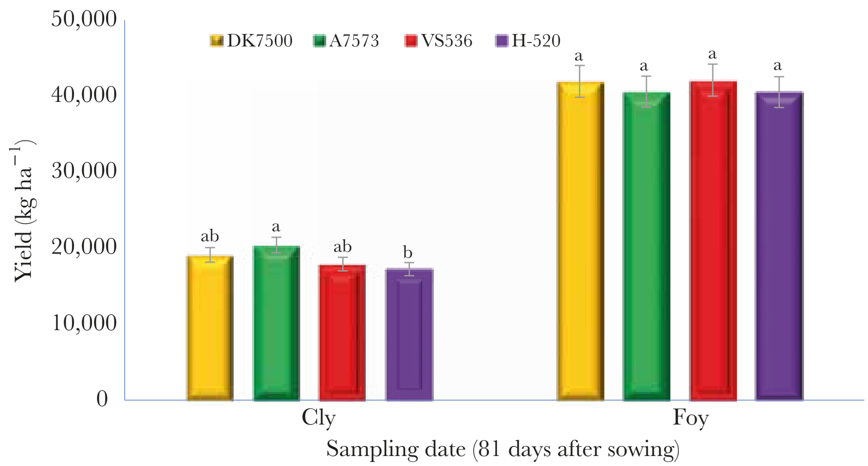

Figure 4. Corn kernel with leaf yield (Cly, kg ha^{-1}) and fodder yield (Foy, kg ha^{-1}) in the DK7500, A7573, VS-536, and H-520 maize varieties.

Oaxaca, and found that VS-536 produced 38,800 kg ha^{-1} of green fodder, while the H-520 hybrid produced only 33,300 kg ha^{-1}. Compared to the results of this study, these figures are 7.8% and 17.8% lower for VS-536 and H-520, respectively. Therefore, the maize varieties under study have the potential to produce corn kernels and fodder.

CONCLUSIONS

The A7573 maize variety produced the highest corn kernel yield (20,409 kg ha^{-1}). However, green fodder yield was similar for all genotypes, ranging from 40,529 kg ha^{-1} (H-520) to 42,104 kg ha^{-1} (VS-536). In its initial growth stages, DK7500 maize stood out regarding plant height, stem diameter, leaves per plant, leaf length, leaf width, and leaf area.

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