Colegio de Postgraduados

Use of native corn (*Zea mays* L.) from two edaphoclimatic regions of Veracruz with potential as hydroponic green forage

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ABSTRACT
Objective: To evaluate native corn from two different edaphoclimatic regions, with potential as hydroponic green forage (HGF) without nutrient solution.
Design/Methodology/Approach: A completely randomized experimental design was used with 5 treatments and 3 repetitions each: T1 hybrid (HR), T2 Almolonga (ALF), T3 Coyutla (CPC), T4 Coyutla (CFJ), and T5 Coyutla (CMJ).
Results: The ALF treatment was superior in the height (28 cm) and root length (14.7 cm) variables. For its part, CMJ recorded the highest leaf width (2.8 cm) and length (20.5 cm) values. However, ALF had higher yield (36.80 kg m^2), dry matter (4.89 kg m^2), protein content (29.88%), crude fiber (39.28%), and mineral content (4.95% N, 4.95% P, 5.95% K, and 1.97 kg of dry matter).
Study Limitations/Implications: Native corn from two different regions are proposed as an alternative HGF.
Findings/Conclusions: Native ALF corn with irrigation and without nutrient solution recorded better results as an alternative HGF in the following agronomic variables: yield, protein content, crude fiber, and mineral content in biomass.

Keywords: native, protein, yield, crude fiber, and minerals.

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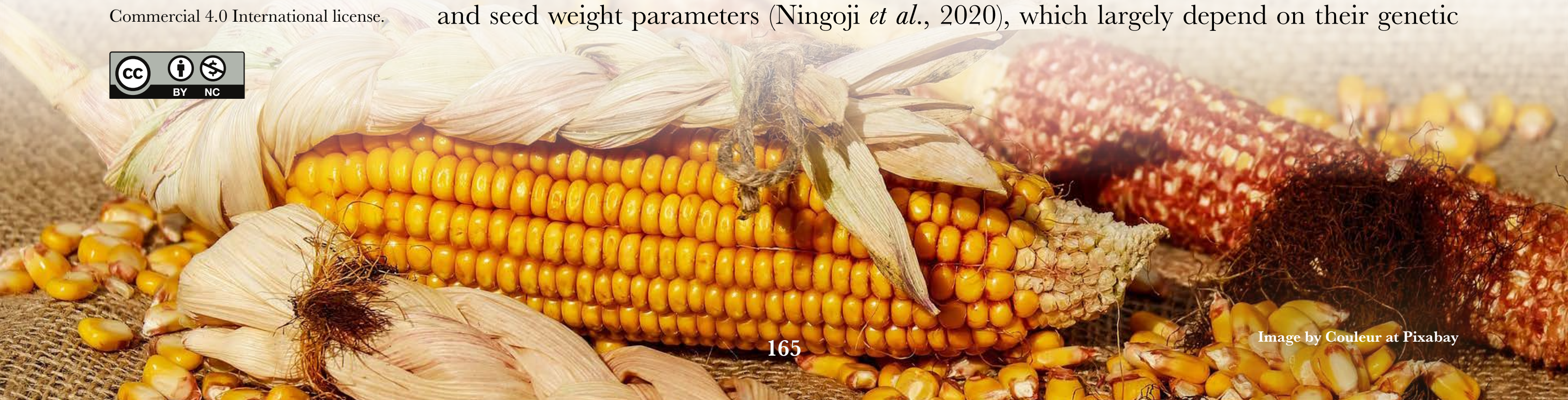
INTRODUCTION

Growing time, fertilizer requirement, rainy season, water scarcity, climate change-related natural disasters, and high input costs are the main limitations on green forage production, which in turn has a negative impact on the production and reproduction of livestock (Ramírez de la Ribera *et al.*, 2017).

In this sense, hydroponic systems used to produce forage have more efficient germination, water use, and yield (Bamikole *et al.*, 2020). In the case of corn, there are differences between yellow and white varieties, which record 6.92 and 6.74 kg·m^2 yields, respectively (Lamnganbi and Surve, 2017). These differences are attributed to shoot, root, and seed weight parameters (Ningoji *et al.*, 2020), which largely depend on their genetic



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characteristics and edaphoclimatic conditions. Yellow corn has been selected to produce Hydroponic Green Forage (HGF), given its 66.67% and 33.33% total yield in roots and shoots, respectively (Jemimah *et al.*, 2020); however, white corn is not far behind, considering that some varieties, such as "Morocho Blanco", record yields of 10.34 kg·m^2 (González *et al.*, 2015). In addition, these forages can contain on average 20.01% protein, 18.95% crude fiber, 4.5% ash, 7.44% ethereal extract, and 88.6% dry matter digestibility (Soto-Bravo and Ramírez-Víquez, 2018), which are parameters that indicate high nutritional quality in animal feeding. Therefore, the objective of this research was to evaluate native corn from two different soil-climatic regions, with the potential to produce hydroponic green forage without a nutrient solution and to study the hypothesis that some of the native corns from different edaphoclimatic conditions have high yield and quality values under a HGF system without nutrient solution.

MATERIALS AND METHODS

Plant material from the study areas

Table 1 describes the characteristics of the materials used. Additionally, an open-pollination hybrid material from the Universidad Autónoma de Chapingo was used as a control. This hybrid has high potential and optimal performance under moderate drought conditions, which allows it to adapt to different environments (Bonilla, 2018).

Study area

The experiment was established in a greenhouse at the Facultad de Ciencias Agrícolas-Xalapa of the Universidad Veracruzana. Average temperatures from 23 to 30 °C and relative humidity from 60 to 80% were recorded. Five-level racks with the following characteristics were used for the production of HGF: 1.06 m width, 1.30 m length, and 1.70 m height, and capacity for fifty trays with a 25 cm width, 53 cm length, and 2.5 cm height. Irrigation was carried out through micro-sprinklers.

Experimental design

A completely randomized experimental design with five treatments was used: T1 hybrid (HR), T2 Almolonga (ALF), T3 Coyutla (CPC), T4 Coyutla (CFJ), and T5 Coyutla (CMJ). One kg of seeds was placed per tray for each treatment, with three repetitions.

Seed selection and counting

The ears of each treatment were threshed and the damaged seeds were subsequently removed by hand. One kg of seeds from each sample was weighed and the number of seeds

Table 1. Edaphoclimatic characteristics of Coyutla and the town of Almolonga, municipality of Naolinco, Veracruz.

Provenances	Altitude (msnm)	Maximum temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Soil type	Slope (%)
Coyutla, Coyutla	160	45	5	2, 985.3	Luvisoles	25-40
Almolonga, Naolinco	724	23	10	768	Arcillosos y pedregosos	12-18

in each repetition was counted. The seeds were washed and disinfected with a 1% NaClO solution for 30 minutes, followed by 2 to 3 rinses with clean water to remove residues. For the pre-germination procedure, a CaO solution was prepared at a concentration of 50 $g \cdot L^{-1}$ of water. The solution was added to the seeds in plastic bags for 24 h, before they were rinsed again with water and aired on trays for 24 h. Finally, the seeds were placed in 780 cm^2 trays, forming a uniform 1.5 cm thick layer, and put into the HGF rack inside the greenhouse. To promote germination, the trays were covered with a 60% black shade cloth. The quality analysis of the water used for irrigation purposes had the following characteristics: 0.63 $mg \cdot L^{-1}$ of nitrates, 1.60 $mg \cdot L^{-1}$ of phosphates, 0 $mg \cdot L^{-1}$ of SO_4, 0.1025 $mL \cdot L^{-1}$ of K, 0.1 $mL \cdot L^{-1}$ of Ca, and 0.3 $mL \cdot L^{-1}$ of Mg. A Steren timer was programmed to activate the micro sprinklers for 60s every 5 h, starting at 8:00 h and ending at 20:00 h, to avoid water oversaturation and seed removal. The shade cloth was removed after germination and the specimens were irrigated for 60 s every 3 h, during the 12 days of the experiment, with a daily water consumption per tray of 1,564 mL.

Variables evaluated

Total forage height, leaf length and width, root length, fresh weight yield ($kg \cdot m^2$), and dry matter content were evaluated at 12 days after sowing (DAS). The dehydration method was used to evaluate the dry matter, applying the following formula:

$$dry\ matter = 100 - \left(pi - pf \ / \ pi \times 100 \right)$$

where: *pi* is the initial weight and *pf* is the final weight.

Likewise, the N, P, and K content was determined according to the official methods of the AOAC (1990). The crude protein percentage was obtained with the micro-Kjeldahl method, multiplying the total N percentage by a factor of 5.83. The AOAC (2000) methodology was used to determine crude fiber. The P, K, and Ca content was determined with a Perkin Palmer® 2380 atomic absorption spectrophotometer (AAS) (Perkin-Elmer, 1996).

Statistical analysis

Statistical analysis was performed using Statistics Software version 12.0, verifying the assumptions of normality and homoscedasticity. Likewise, the ANOVA and Tukey's mean comparison tests at 5% ($\alpha = 0.05$) were developed.

RESULTS AND DISCUSSION

Agronomic variables

Livestock production currently requires higher quality food in less time and consequently nutritional solutions are used to increase the production of HGF systems (Girma and Gebremariam, 2018). However, the production of forage without a nutrient solution, chemical fertilizers, pesticides, or fungicides, using only water, results in inputs savings for producers (Abdula, 2022). In this sense, the statistical analysis carried out in this work showed significant differences between the agronomic variables ($P \leq 0.05$). The ALF treatment reported better results (28 cm total height and 13 cm root length) than Zagal-Tranquilino *et al.*, (2016), who recorded a 22.2 cm height after 13 days. In the case of leaf length (20.5 cm) and width (2.8 cm), CMJ was a better treatment than HR, which reached a leaf length of 19 cm and a leaf width of 2.7 cm (Table 2). Height is important for producers, because greater height results in greater availability of green matter to meet the nutritional requirements of the animals. Unlike other studies no nutrient solution was applied during the 12 day harvest time, clearly demonstrating that the use of a solution is not always necessary and consequently reduces costs to the producer (Suma *et al.*, 2020).

Yield and dry matter

HGF systems increase the yield of forage production. The best treatment was ALF with 36.80 kg·m^2, followed by CPC (32.06 kg·m^2) and HR (28.33 kg·m^2) (Figure 1a). All these treatments showed higher yields than those reported by Zeferino-Hernández *et al.* (2021): an average of 21.5 kg m^2 in native corn from Southern Veracruz, irrigated with nutrient solution and harvested after 10 days. Additionally, the yield and quality of the forages are affected by the management of the system considering several elements, including labor, weight and quality of seeds, water quality, irrigation frequency, temperature, humidity, light intensity, and harvest time (Dogrusoz, 2022). Regarding total dry matter, the ALF treatment stood out with a weight of 4.89 kg m^2 (Figure 1b). Better yield results are also obtained with this treatment, perhaps due to the larger seeds used and even more so to the climatic conditions of the ALF origin, which were similar in the greenhouse (23-30 °C).

Protein content in HGF

In the case of protein, the statistical analysis detected significant differences ($P \leq 0.05$) (Figure 1c). ALF (29.88%) had a higher percentage than HR (15.96%). These values are higher than the 19% and 26.19% percentages in native corn reported by Bedolla-Torres *et al.* (2015) and by Zeferino-Hernández *et al.* (2021), respectively. No specific protein concentration exists, since it varies depending on the HGF production conditions and the genetic material used.

Table 2. Agronomic variables of native corn.

Treatments	Total height of HGF (cm)	Leaf length (cm)	Leaf width (cm)	Root length (cm)
HR	1.49±20 c	1.35±19 b	0.48±2.7 b	5.10±12.3 c
ALF	3.8±28 a	2.12±18 c	0.17±2 d	4.16±14.7 a
CPC	1.68±20 c	1.26±19 b	0.45±2.7 b	0.76±10 d
CFJ	2.55±18 d	1.81±12 d	0.26±2.5 c	1±10 d
CMJ	1.63±22 b	2.17±20.5 a	1.28±2.8 a	1±13 b
$P \leq 0.05$				

Values with equal letters within columns are statistically equal (Tukey, $P \leq 0.05$) and ± Standard deviation.

Crude Fiber Content

ALF was the best treatment for crude fiber with 39.28%, followed by CPC with 11.26%, HR with 10.48%, CMJ with 10.22%, and CFJ with 9.58% (Figure 1d). Zeferino-Hernández *et al.* (2021) reported less crude fiber (38.68%) in the aerial matter of native corn from southern Veracruz than the values reported in this work. Furthermore, previous reports state that the use of organo-mineral nutrient solutions can reduce crude protein content (Adeyemi *et al.*, 2020). In contrast, this study recorded positive results without the addition of minerals.

Mineral content

The ALF treatment recorded highest mineral content in dry matter (DM) for N (4.95%), P, K, and Ca (4.95, 5.95, and 1.97 kg DM). This content may be related to root development, which allowed better absorption of nutrients intended for tissue formation (Table 3). Noteworthily, the mineral content in DM did not obtain minimum parameters compared to the HGF systems produced with nutrient solution, which recorded values of up to 0.6230 mg kg^{-1} Ca (Zainab *et al.*, 2019). These nutritional requirements vary according to the metabolic rate and the tissue formation and reconversion, since each plant is different, even if they belong to the same genus, variety, or species (Mejía and Orellana,

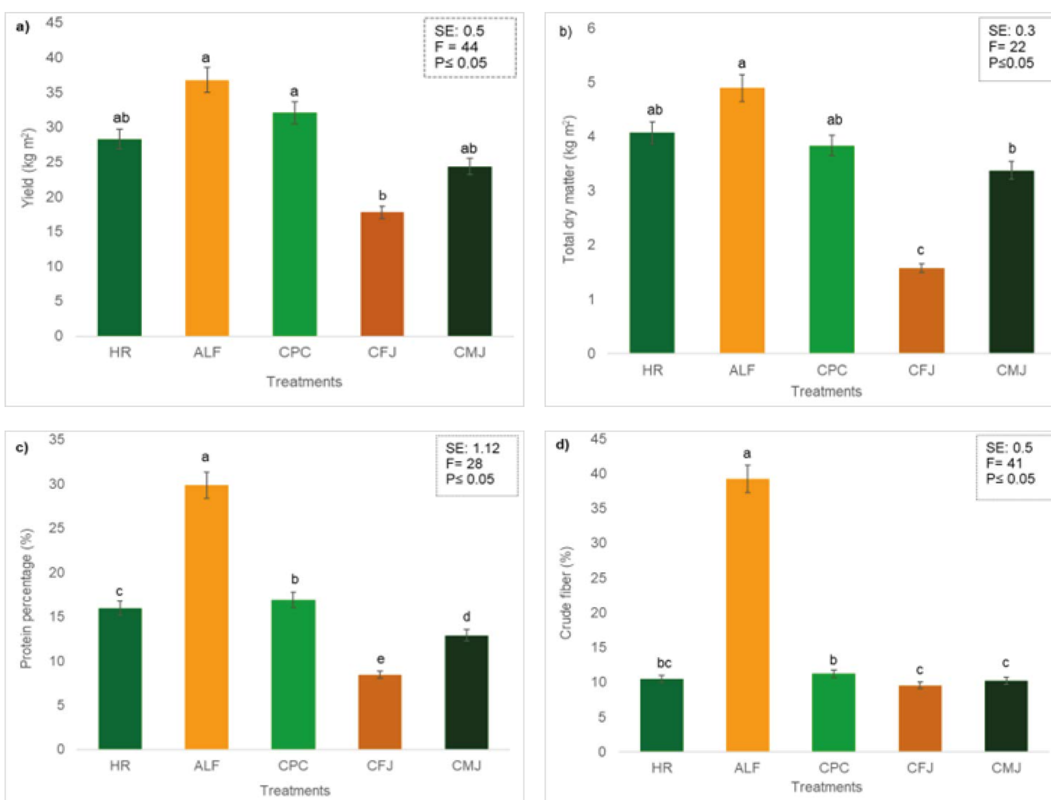

Figure 1. a) Yield of corns in HGF (kg·m^2), b) dry matter (kg·m^2), c) protein content (%), and d) crude fiber (%). Columns with the same letter are statistically equal (Tukey, $P \leq 0.05$). The vertical lines on the bars represent the standard error (±).

Table 3. Mineral content of green forage made from native corn.

Treatments	N (%)	P (Kg DM)	K (kg DM)	Ca (kg DM)
HR	0.01±4.09b	0.03±4.03b	0.03±4.66b	0.02±0.57b
ALF	0.05±4.95a	0.05±4.95a	0.05±5.95a	0.015±1.97a
CPC	0.11±3.84c	0.02±3.46c	0.22±3.80c	0.005±0.58b
CFJ	0.01±2.02e	0.01±1.56e	0.015±1.56e	0.025±0.23d
CMJ	0.015±3.02d	0.015±2.97d	0.19±2.77d	0.03±0.36c
P≤	0.05			

Note: DM (dry matter) ± Standard deviation. Same letters in the same column represent Tukey's statistical equality (P≤0.05).

2019). Finally, based on the results, the hypothesis was accepted. Regarding the use of native corn, the use of these materials from other regions with different edaphoclimatic conditions should be expanded and their performance without nutrient solution in HGF systems should be verified. This measure would simultaneously generate a genotypic conservation and reduce the input costs of producers in the state of Veracruz.

CONCLUSIONS

In the case of HGF, AL was the best native corn from two different edaphoclimatic regions, due to its higher forage yield (dry matter), protein percentage, and crude fiber. Additionally, it recorded high N, P, K, and Ca content, without using a nutrient solution. In conclusion, it is an alternative for the producers of Almolonga, municipality of Naolinco, Veracruz.

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