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Creole corn seed promotes increase in production and nutritional aspects in hydroponic forage

Semente de milho crioula promove incremento nos aspectos produtivos e nutricionais da forragem hidropônica

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ABSTRACT

The aimed of this study to assess the productivity and nutritional characteristics of hydroponic corn forage derived from bico de ouro creole seeds and AL-Bandeirante. Two treatments (T), each representing a corn seed variety, were randomly allocated to beds filled with a wood sawdust substrate: T1 (n=5) - bico de ouro creole seed variety, and T2 (n=5) - AL-Bandeirante hybrid seed variety. On the 13th day, forage was collected to assess seedling biometry, green and dry mass production, and bromatological analyses. The data were subjected to statistical analysis, with a 5% significance level. The creole seed variety yielded higher seedling height (17.53 cm), root length (10.19 cm), stem (5.37 cm), leaf (12.17 cm), and greater production of green mass (7.22 kg/m²) and dry matter (2.05kg/m²) ($P<0.05$). The AL-Bandeirante corn forage had higher dry matter content (39.18%), mineral matter (2.33%), non-fiber carbohydrate (31.88%), and estimated total digestible nutrients (68.14%) ($P<0.05$), while the creole corn forage had higher organic matter content (99.45%), ethereal extract (19.53%), neutral detergent fiber (45.56%), and cellulose (15.46%) ($P<0.05$). Crude protein, acid detergent fiber, and lignin were similar between the treatments ($P>0.05$). Despite the AL-Bandeirante variety yielding a higher concentration of certain nutrients, its forage productivity was significantly low.

Therefore, under the conditions of this study, the use of the creole seed variety is recommended.
Keywords: corn fodder, hydroponics, *Zea mays* L

RESUMO

O objetivo com este estudo foi avaliar a produtividade e as características nutricionais da forragem hidropônica de milho derivada de sementes de crioulo bico de ouro e AL-Bandeirante. Dois tratamentos (T), cada um representando uma variedade de semente de milho, foram distribuídos aleatoriamente em canteiros preenchidos com substrato de serragem de madeira: T1 (n=5) - variedade de semente crioula bico de ouro e T2 (n=5) - AL-Bandeirante variedade de semente híbrida. No 13º dia foi coletada forragem para avaliação da biometria das plântulas, produção de massa verde e seca e análises bromatológicas. Os dados foram submetidos à análise estatística, com nível de significância de 5%. A variedade de semente crioula proporcionou maior altura de plântula (17,53 cm), comprimento de raiz (10,19 cm), caule (5,37 cm), folha (12,17 cm) e maior produção de massa verde (7,22 kg/m²) e matéria seca (2,05kg /m²) ($P<0,05$). A forragem de milho AL-Bandeirante apresentou maior teor de matéria seca (39,18%), matéria mineral (2,33%), carboidrato não fibroso (31,88%) e nutrientes digestíveis totais estimados (68,14%) ($P<0,05$), enquanto a forragem de milho crioulo apresentou maior teor de matéria orgânica (99,45%), extrato etéreo (19,53%), fibra em detergente neutro (45,56%) e celulose (15,46%) ($P<0,05$). Proteína bruta, fibra em detergente ácido e lignina foram semelhantes entre os tratamentos ($P>0,05$). Apesar da variedade AL-Bandeirante apresentar maior concentração de alguns nutrientes, a produtividade de forragem foi significativamente baixa. Portanto, nas condições deste estudo, recomenda-se o uso da variedade crioula de sementes.
Palavras-chave: forragem de milho, hidroponia, *Zea mays* L

INTRODUÇÃO

Hydroponic forage is a technology that involves cultivating plants either with or without substrates (Bezerra Neto & Barreto, 2012). It is utilized as an addition to animal diets (Rocha et al., 2014) and in circumstances where traditional forage cannot be grown (Naik et al., 2017). This technique is notable for its rapid production cycle, high productivity, minimal water and agricultural input usage, reduced labor requirements, and low production costs.

Corn (*Zea mays* L.) is a prominent plant species cultivated in hydroponic systems (Fraga et al., 2009). Its popularity stems from its widespread availability, low seed cost, adaptability to tropical climates, high productivity, and short growth cycle (Crevelari, 2013). The appealing appearance, flavor, color, and texture of corn contribute to its good palatability and digestibility (Rocha et al., 2014).

The type of seed utilized significantly influences hydroponic forage production, as germination percentage and uniformity substantially affect forage productivity and quality. Among corn varieties, the Creole and AL-Bandeirante are noteworthy. Creole seeds are varieties that farmers have developed, produced, or adapted through selection, providing a wide genetic constitution and adaptability to low-tech environments. These seeds are predominantly used by small-scale producers. Consequently, the cost of these seeds is relatively minimal compared to genetically enhanced seeds. The AL-Bandeirante seed, a hybrid variety, exhibits moderate tolerance to diseases and possesses a semi-early cycle. Costa et al. (2013) identified AL-Bandeirante as a seed variety recommended by Embrapa for the semi-arid northeastern region. In a study conducted by Felipe et al. (2010), the grain yield of various corn varieties was evaluated, revealing that the AL-Bandeirante variety consistently demonstrated a superior genotype across nearly all locations.

The literature highlights the benefits of hydroponic corn forage (Silva, 2021; Almeida et al., 2021; Bombana & Gai, 2019), yet there is a lack of studies on production using creole seeds. It is hypothesized that the creole variety, bico de ouro, may enhance the productivity and nutritional quality of the forage due to its adaptability and resilience. This study aims to assess the productivity and nutritional characteristics of hydroponic corn forage cultivated with bico de ouro creole seeds and the AL-Bandeirante hybrid.

MATERIAL E METHODS

The experiment was conducted in the Vegetable Sector at the Experimental Farm, part of the Center for Agricultural, Environmental, and Biological Sciences at the Federal University of Recôncavo da Bahia. This facility is located in the city of Cruz das Almas, with geographical coordinates of 12º40'19" south latitude and 39º06'23" west longitude of Greenwich, at an average altitude of 220 m.

The experiment was executed using a completely randomized design with two treatments (T). These treatments consisted of two varieties of corn seeds (*Zea mays*, L) cultivated in a wood sawdust substrate: T1 - the Creole seed variety bico de ouro, and T2 - the hybrid seed variety AL-Bandeirante. Each treatment was assigned five repetitions (beds), with each bed representing the experimental unit.

The wood sawdust used as substrate was obtained trade from the Cruz das Almas. The sawdust predominantly consisted of 2.5 mm particles. It contained 93.47% dry matter, 2.16% mineral matter, and 97.84% organic matter. The crude protein content was 1.35 %, while the ether extract was 9.70%. The sawdust also contained 82.41% neutral detergent fiber, 58.21% acid detergent fiber, 35.72% cellulose, and 21.14% lignin.

The bico de ouro variety seed, boasting a germination rate of 94%, was procured from a rural producer. The AL-Bandeirante variety seed, with a germination rate of 98 %, was obtained from a trader in Santo Antônio de Jesus-BA. Before sowing, the corn seeds underwent disinfection with a 2% sodium hypochlorite solution. Subsequently, they were immersed in water for a 24-hour period to stimulate pre-germination.

Beds were constructed in a greenhouse using double-sided canvas, each covering a level ground area of 0.45 m² and separated by a distance of 0.5 m. Wood sawdust was uniformly distributed on the tarpaulins, forming layers 0.03 m high. The first layer of substrate was moistened with 1 L of water/m², after which sowing was performed manually in a uniform manner, maintaining a density of 2.2 kg/m². Following the sowing, an additional layer of wood sawdust, 0.02 m high, was added to the beds and similarly moistened with 1 L of water/m².

The field experiment spanned 13 days. Daily watering of the beds, at a volume of 3L/m², was conducted from the second to the twelfth day post-sowing.

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This volume was split into two portions, facilitated by a conventional watering can. Watering was omitted on rainy days, as the substrate retained the moisture from the previous watering, owing to minimal water evaporation.

The biometric measurements of corn seedlings, including seedling height, leaf length, and stem and root lengths were evaluated. The production of both green and dry biomass was also assessed. Additionally, the nutritional composition of the forage is analyzed, focusing on elements such as dry matter, mineral matter, organic matter, crude protein, ether extract, neutral detergent fiber, acid detergent fiber, cellulose, lignin, non-fiber carbohydrate, and estimated total digestible nutrients.

Thirteen days post-sowing, biometric evaluation was conducted on 10 randomly selected seedlings from each bed. Measurements of seedling height, leaf length, and stem and root dimensions were taken using a caliper. Following seedling collection, a 0.09 m^2 sample of forage was extracted from each plot to assess biomass production and analyze nutritional composition.

To calculate the fresh biomass, any excess substrate was eliminated through friction, and the sample was then weighed using a digital scale. This weight was documented and utilized to convert production per square meter. The production of dry biomass (PDB) was derived from the production of green biomass (PGB) and the dry matter content (DM) using the formula: $PDB/m^2 = (PGB \times DM)/100$.

The individual samples, once weighed, were placed in kraft paper bags and pre-dried in a forced ventilation oven at 55 ºC for a duration of 72 hours. Following this, they were weighed again and ground using a Wylle-type mill with a 1 mm sieve. Analyses were conducted for dry matter (DM), mineral matter (MM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL), and lignin (LIG) (Silva & Queiroz, 2002).

The content of organic matter (OM) was determined using the formula: OM = 100 – MM. The total digestible nutrients (TDN) were estimated using the equation: TDN= 83.79 – (0.4171*NDF), as suggested by Cappelle et al. (2001). The non-fiber carbohydrate (NFC) was computed using the formula: NFC = 100 – MM – EE – CP – NDF, with all variables expressed as a percentage of dry matter, as recommended by Detmann et al. (2012).

The Shapiro-Wilk test was employed to assess data normality. All variables demonstrated a normal distribution, thus the data were subjected to an analysis of variance (ANOVA) to examine the impact of seeds on the variables under study. A significance level of 5% was adopted for all evaluations.

RESULTS E DISCUSSION

The creole seed yielded higher seedling height, leaf length, stem and root system length, as well as increased production of green and dry biomass compared to the AL-Bandeirante variety ($P<0.05$) (Table 1). The observed results can be attributed to the adaptability and resilience of the Creole variety, particularly when considering its origin, the edaphoclimatic characteristics of the region where it was acquired, and the genetic selection process it underwent. The Creole seed likely demonstrated superior adversity tolerance compared to the AL-Bandeirante seed, leading to enhanced seedling development.

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Table 1. Seedling biometry and corn forage biomass produced in a hydroponic system with two seed varieties

Variables	Creole seed Bico de Ouro	Hybrid seed AL-Bandeirante	P value
Sheet length(cm)	12,17 ± 4,21[a]	9,67± 2,27[b]	0,001
Stem length (cm)	5,37 ± 1,71[a]	3,68 ± 0,95[b]	0,000
Root length (cm)	10,19 ± 4,61[a]	6,72 ± 2,99[b]	0,000
Seedling height (cm)	17,53 ± 5,64 [a]	13,36 ± 2,63[b]	0,000
Green biomass (kg/m²)	7,22 ± 2,57[a]	0,82 ± 0,66[b]	0,003
Dry biomass (kg/m² DM)	2,050 ± 0,73[a]	0,323 ± 0,259[b]	0,004

Variables had a normal distribution, therefore, data refer to the mean ± standard deviation; Different letters on the same line indicate difference between treatments by analysis of variance at the 5% significance level.

Costa et al. (2013) reported a faster emergence speed for landraces varieties, which exhibited greater seed vigor compared to AL-Bandeirante. This suggests that landraces seeds possess a heightened capacity to produce more competitive seedlings during the early crop stages. Furthermore, Silveira et al. (2015) noted that native varieties can match the yield potential of certain hybrids under low-technology conditions.

The development of seedlings directly influences the production of both green and dry biomass in forage. It can thus be inferred that the superior production observed in forage cultivated with creole seeds is linked to the inherent resistance and hardiness of these seeds. This characteristic ensures an advantage in seedling development, leading to increased biomass production. Almeida et al. (2021) noted a dry mass production of 2.64 kg/m², with a seed density of 2.0 kg/m², 15 days post-sowing.

The forage produced with the AL-Bandeirante variety seed exhibited higher DM and MM content, with an increase of 10.79% and 1.78% respectively. Conversely, the forage produced with native seed demonstrated higher OM and EE content ($P<0.05$). The CP content remained similar across both treatments ($P>0.05$) (Table 2).

Table 2. Nutritional composition of corn forage produced in a hydroponic system with two seed varieties

Variables	Creole seed Bico de Ouro	Hybrid seed AL-Bandeirante	P value
Dry matter (%)	28,39 ± 4,56[b]	39,18 ± 3,09[a]	0,000
Mineral matter (% DM)	0,55 ± 0,31[b]	2,33 ± 0,33[a]	0,000
Organic matter (% DM)	99,45 ± 0,31[a]	97,66 ± 0,33[b]	0,000
Crude protein (% DM)	11,33 ± 1,03	11,48 ± 0,69	0,735
Ethereal extract (% DM)	19,53 ± 0,51[a]	16,77 ± 1,19[b]	0,000

Variables had a normal distribution, therefore, data refer to the mean ± standard deviation; Different letters on the same line indicate difference between treatments by analysis of variance at the 5% significance level.

The observed results for DM can be attributed to the development of forage. The bico de ouro variety of corn seedlings, due to their superior growth,

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logically yield a higher moisture content compared to the forage produced with the AL-Bandeirante variety, resulting in a lower DM content. This discovery aligns with the findings of Rocha et al. (2014), who investigated varying corn sowing densities. They reported a decrease in DM content as the density increased, a phenomenon they attributed to the rise in natural matter production. These researchers achieved a DM content of 25.02% with a sowing density of 2 kg/m².

The concentration of organic matter in creole corn forage is highest when aligned with the content of mineral matter. These constituents have a complementary relationship; a decrease in mineral matter concentration in a sample corresponds to an increase in organic matter content, and vice versa, as demonstrated in this study. The mineral matter content found in the AL-Bandeirante maize seed mirrors the findings of Ndaru et al. (2020), who reported a 2.37% ash content in hydroponic corn forage at 12 days.

The concentration of OM correlates with the quantity of green mass in the sample. This correlation underscores the superiority of the creole seed, as it yielded a higher forage production. The OM derived from the AL-Bandeirante seed in this study was comparable to the results obtained by Ndaru et al. (2020) (97.63%) for hydroponic corn forage.

The CP concentration exceeded the levels reported in literature for hydroponic corn forage production without the application of fertilization or fertirrigation. Bombana & Gai (2019) assessed nutrient solution inclusion levels and reported a 9.32% CP for treatments devoid of fertilization. Similarly, Holland et al. (2021) examined the impact of nitrogen fertilization and found no significant difference in the protein content of hydroponic forage, with an average value of 6.7% CP in forage grown in rice husks. These findings suggest that the production of hydroponic corn forage without the necessity of fertirrigation is feasible, given that a substrate is incorporated into the process.

The EE concentration identified in this study was significant. Fraga et al. (2009) reported EE values of 3.52 % for the AL-Bandeirantes seed grown in rice straw. Conversely, Holanda et al. (2021) reported lower results of 1.4%. It is crucial to note that the elevated EE content in this study could be attributed to the presence of fungi (*Aspergillus* spp., *Rhizopus* spp., and *Fusarium* spp.) in the beds. These fungi began to develop six days post-sowing and persisted until the experiment’s conclusion. As per Murphy et al. (2005), microorganisms such as microalgae, protozoa, and fungi can accumulate approximately 30 to 80% of lipids in their biomass. Moura et al. (2015) isolated and characterized several genera of oleaginous fungi. Among the five isolates with the highest lipid content in their biomass, were fungi from the *Rhizopus* spp. and *Aspergillus* spp genera.

The forage produced with the AL-Bandeirante corn variety seed exhibited an 8.04% and 3.07% increase in NDF and cellulose content, respectively ($P<0.05$). Conversely, the forage produced with Creole corn seed showed an 8.86% increase in CNF content ($P<0.05$). There was no significant difference in lignin content and ADF between the treatments ($P>0.05$) (Table 3).

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Table 3. Fiber content and non-fiber carbohydrate concentration of hydroponic maize forage produced with two seed varieties

Variables (% DM)	Creole seed bico de ouro	Hybrid seed AL-Bandeirante	P value
Neutral Detergent Fiber	45,56 ± 8,11[a]	37,52 ± 4,11[b]	0,025
Acid Detergent Fiber	21,05 ± 4,89	17,19 ± 2,85	0,075
Cellulose	15,46 ± 3,37[a]	12,39 ± 1,61[b]	0,036
Lignina	5,12 ± 1,57	4,30 ± 1,17	0,257
Non-Fiber Carbohydrate	23,02 ± 7,66[b]	31,88 ± 2,72[a]	0,008

Variables had a normal distribution, therefore, data refer to the mean ± standard deviation; Different letters on the same line indicate difference between treatments by analysis of variance at the 5% significance level.

The elevated NDF content in creole maize forage is likely attributable to the extended stem, leaf, and root length of the seedlings. Bombana & Gai (2019) conducted experiments with various nutrient solutions in hydroponic corn forage, using a sowing density of 2.5 kg/m². They discovered NDF values ranging between 33.70% and 43.35%, which are comparable to the results obtained in this study.

The concentrations of ADF and lignin were found to be lower than those reported by several researchers. Holland et al. (2021) reported 47.4% ADF and 11.5% lignin, while Almeida et al. (2021) noted an increase in ADF concentration with harvest age, reporting 22.91% at 15 days and 36.49% at 25 days. Rocha et al. (2014) reported 59.85% ADF and 11.56% lignin. The higher values reported by these authors could be attributed to the more mature stage of the forage harvest (15 days after sowing), as the plant's maturation stage significantly influences its fiber content.

The AL-Bandeirante corn forage exhibits the highest concentration of NFC, which aligns with the concentration of other nutrients. This is due to the lower NDF and EE contents found in this treatment, while the CP levels remained consistent across all treatments. The NFC concentration is derived from a formula that incorporates the values of MM, NDF, EE, and CP. Therefore, a decrease in these constituents' levels results in an increased NFC concentration within a sample.

The levels of NFC in plants correlate directly with their maturity stage. Consequently, the grasses constituting the pastures exhibit an excess of insoluble portions, with the physiological age serving as a determinant for the forage's nutritional value. As the age progresses, there is an increase in the percentages of cellulose, hemicellulose, and lignin, which in turn reduces the proportion of soluble carbohydrates and proteins (Paciullo et al., 2001).

The estimated total digestible nutrients were 3.35% higher in the forage produced with the AL-Bandeirante variety corn seed ($P<0.05$) (Figure 1).

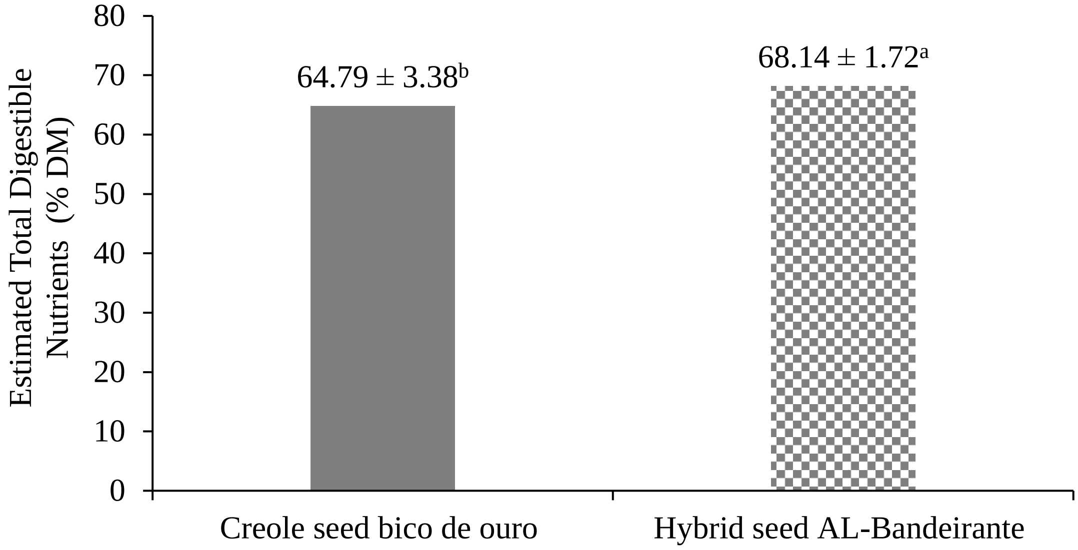

Figure 1. Estimated total digestible nutrient concentration, based on dry matter, of corn forage cultivated in a hydroponic system from two seed varieties

Data refer to mean ± standard deviation. Different letters indicate difference between treatments by analysis of variance at the 5% significance level.

The results align with the observed NDF content, as the estimate is predicated on the sample's NDF content. Consequently, as the NDF content decreases, the estimated TDN tends to rise. Despite the AL-Bandeirante seed's superiority, both seeds yielded a higher TDN content than the 58.55% obtained by Chaves et al. (2020) for corn forage on a sugarcane bagasse substrate, using a sowing density of 2.0 kg/m². These variations are consistent with Shit (2019), who posits that the bromatological composition of hydroponically produced material is subject to change.

CONCLUSION

The Creole variety of corn demonstrated superior seedling development and forage productivity. Despite the AL-Bandeirante variety promoting a higher concentration of certain nutrients, its forage productivity was low. Therefore, under the conditions of this study, the use of the Creole variety is recommended.

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