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Performance of maize cultivars for the production of sweet corn, baby corn, and fodder

Desempenho de cultivares de milho para produção de milho verde, minimilho e forragem

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ABSTRACT

Maize has multiple functions and can be used for human consumption, animal feed, or in industrial processes. Grain production has made Brazil a world reference. However, few cultivars are available despite the relevance of sweet corn, especially for family farmers. This is similar to baby corn, in which sweet corn or popcorn is used for its production. In the Brazilian semi-arid region, plant and animal production are limited by water deficit in the dry season. Therefore, the production of sweet and baby corn generates income from the commercialization of the ears and roughage production with the whole-plant harvest. This research has aimed to assess the agronomic performance of five cultivars for sweet corn, baby corn, and fodder production in Agreste Meridional, a semi-arid region of Pernambuco, Brazil. Two experiments were carried out in a randomized block design with five treatments (AG 1051, Alagoano, Branquinha, São Luiz, and PV2 Viçosense) and four blocks. The 1st experiment assessed the performance of the cultivars for sweet corn and fodder yield, in which the cultivars AG 1051 and Branquinha had higher yields for ears (21.9 and 20.3 Mg ha^{-1}) and fodder (10.7 and 10.9 Mg DM ha^{-1}), respectively. The 2nd experiment assessed the performance of the cultivars for baby corn and fodder yield, in which the cultivars AG 1051 and PV2 Viçosense obtained the highest yield for ears (3.1 and 2.9 Mg ha^{-1}, respectively); Branquinha had a higher yield for fodder (8.9 Mg DM ha^{-1}). Therefore, these cultivars have desirable characteristics and can be used in intensive or extensive production.

KEYWORDS: *Zea mays* L.; family farming; roughage; semi-arid region.

RESUMO

O milho apresenta múltiplas funções, podendo ser utilizado no consumo humano, alimentação animal ou em processos industriais. A produção de grãos tornou o Brasil uma referência mundial. Porém, apesar da relevância do milho verde, principalmente para agricultores familiares, são poucos os cultivares disponíveis. Do mesmo modo, para o minimilho, em que são utilizados milho doce ou pipoca para sua obtenção. Na região semiárida, as produções vegetal e animal são limitadas pelo déficit hídrico na época seca. Portanto, com a produção de milho verde e minimilho é possível obter renda com a comercialização das espigas e produzir volumoso com a colheita da planta inteira. O objetivo dessa pesquisa foi avaliar o desempenho agronômico de cinco cultivares para produção de milho verde e minimilho e produção de forragem no Agreste Meridional, região semiárida de Pernambuco. Foram realizados dois experimentos no delineamento em blocos casualizados, com cinco tratamentos (AG 1051, Alagoano, Branquinha, São Luiz e PV2 Viçosense) e quatro blocos. No primeiro experimento avaliou-se o desempenho dos cultivares para produção de milho verde e forragem, em que os cultivares AG 1051 e Branquinha tiveram, respectivamente, maiores produtividades de espigas comerciais (21,9 e 20,3 Mg ha^{-1}) e de forragem (10,7 e 10,9 Mg MS ha^{-1}). No segundo experimento, avaliou-se o desempenho dos cultivares para a produção de minimilho e forragem, em que os cultivares AG 1051 e PV2 Viçosense obtiveram a maior produtividade de espiguetas comerciais (3,1 e 2,9 Mg ha^{-1}, respetivamente); Branquinha, maior produtividade de forragem (8,9 Mg MS ha^{-1}). Portanto, esses cultivares reúnem características desejáveis, podendo ser utilizados em sistemas intensivos ou extensivos de produção.

PALAVRAS-CHAVE: *Zea mays* L.; agricultura familiar; volumoso; região semiárida.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereals cultivated and consumed in the world, being it adapted to different soil and climatic conditions and with cultivars developed for human consumption, animal feed, and the industry (PRESTES et al. 2019). Grown in all regions of the country, the Brazilian maize production is consolidated with 112.3 million tons of grains (CONAB 2022a) and 39.3 million tons of corn fodder (IBGE 2020a). As a commodity, in 2021 Brazil exported 20.8 million tons of grains (CONAB 2022b).

The production of sweet corn is one of the most important activities in Brazil (CÂNDIDO et al. 2020), which has a production of 348,900 tons of ears, of which 44.7% come from family-based establishments (IBGE 2020b). On the other hand, the baby corn market is still expanding, and it could become an opportunity that can diversify production by offering a product with greater added value and increase the income of family farmers in urban and peri-urban areas, especially within sustainable agricultural production systems (COSTA et al. 2020a).

Sweet corn is harvested in the R3 stage, which is characterized by milky grains and dry stigmas, and it occurs approximately twenty days after flowering depending on the cultivar and the place of cultivation (GUDIM et al. 2019). After harvesting the ears, the remaining biomass can be used as roughage in ruminant feed, as silage, or crushed and supplied in the trough (OLIVEIRA et al. 2020). According to SANTOS et al. (2018), the production of plant biomass without the ear can be commercialized, in this way becoming another source of income for the producer.

Baby corn is obtained from the harvest of young corn (R1 stage), still in development and unfertilized, with style and stigma between 2.0 and 3.0 cm (RAUPP et al. 2008). Considering the proximate concentrations of water (89.1 g), calories (42.2 kcal), protein (1.9 g), carbohydrates (8.2 g), and fiber (0.38 g), baby corn resembles vegetables such as cauliflower, cucumber, tomato, and eggplant, and it can be consumed fresh, processed by the food industry in the form of preserves, or as homemade pickles (CRUZ et al. 2011). After harvest, ARCANJO JÚNIOR et al. (2016) have observed that the mean biomass yield of the plant without the ear showed dry matter (20.9%), crude protein (6.6%), and digestibility (23.7%) contents that were favorable for animal feed.

Grains are an important commodity on the world stage, and the Brazilian corn seed market is focused on grain-producing cultivars with a reduced number of cultivars on the market for the production of sweet corn, in which the double hybrid AG 1051® can be highlighted (NASCIMENTO et al. 2017). Similarly, the sweet corn and popcorn cultivars have been used for the production of baby corn (TARGANSKI & TSUTSUMI 2017). COSTA et al. (2020b) have tested, in Piranhas (State of Alagoas, Brazil), different maize genotypes (creole variety, free pollination, and double hybrids) and all produced baby corn with commercial standards.

The Brazilian northeastern semi-arid region presents seasonality in plant production because of the water deficit in the dry season. In Pernambuco, 84.8% of the agricultural establishments are concentrated in the semi-arid region, and 82.7% of them are characterized as family members (IBGE 2020c), who face difficulties that often lead to the abandonment of the agricultural activity and rural exodus, especially young farmers (LIZARAZO & THOMÁS JÚNIOR 2016).

In the Brazilian Northeast region, the cultivation of sweet corn is a tradition, mainly by family farmers, and this demands the use of cultivars that can associate ear yield with that of roughage for animal feed. If baby corn production is integrated, it can increase the producers' income and quality of life. Therefore, the object of this research has been to assess the agronomic performance of maize cultivars for the production of sweet corn, baby corn, and fodder in the Agreste Meridional of Pernambuco, Brazil.

MATERIAL AND METHODS

Characterization of the experimental area

The research was conducted in the experimental area of the Federal University of Agreste de Pernambuco, Academic Unit of Garanhuns, under the coordinates 8º 54' 13" S and 36º 29' 38" W, at 847 m of altitude. The region has an "AS" climate, which represents a tropical climate with a dry season, according to the Köppen climate classification (CLIMATE-DATA 2022). The total rainfall is 870.4 mm, and the rainy season is concentrated between May and July (autumn-winter), a period that concentrates 70% of the total annual rainfall. The minimum average temperature is 16.9 ºC and the maximum average temperature is 25.5 ºC, with a relative humidity of 75% (INMET 2022). The soil has been classified as dystrophic Yellow Argisol.

Experimental design and treatments

Two experiments were established in a randomized block design with five treatments and four blocks.

This study assessed the double hybrid AG 1051® (semi-early, indicated for the production of sweet corn) and four open-pollinated cultivars (Alagoana, Branquinha, São Luiz, and PV2 Viçosense), developed by the Federal University of Alagoas. Each plot consisted of six rows of 6.0 m, and the four central rows were considered as the useful area of the plot.

Carrying out the experiments

The conventional soil tillage system had two plows and a harrow (0.20 m). Then, mechanized planting was carried out using a three-row pantographic seeder manufactured by the company Baldan® (SP light H-2500), one seed per planting hole at a depth of 5.0 cm. The spacing adopted was 0.80 x 0.20 m, in which the initial population of plants was 62,500 plants ha^{-1}.

For each experiment, a composite sample formed by fifteen simple soil samples in the 0 - 20 cm layer, collected randomly in the area, were collected for chemical analysis, and the results are presented in Table 1.

Table 1. Result of the chemical analysis of the soil.

Experiments	pH	P^1	K^1	$H^2 + Al^3$	$Ca^3 + Mg^3$	SOM
	H_2O	mg dm^{-3}	----------	$cmol_c$ dm^{-3}	----------	%
Sweet corn	5.22	35.00	0.08	5.10	7.71	3.5
Baby corn	6.24	8.45	0.11	3.60	2.40	3.1

[1]Mehlich; [2]Calcium acetate (pH 7.0); [3]N KCl.

Following the recommendations of CAVALCANTI (2008), at the time of planting of the experiment with sweet corn, a base fertilization was applied using 30 kg N ha^{-1} (ammonium sulfate), 10 kg P_2O_5 ha^{-1} (triple superphosphate), and 30 kg K_2O ha^{-1} (potassium chloride). Topdressing fertilization took place 40 days after planting with the application of 40 kg N ha^{-1}, in which the fertilizer was distributed alongside the plants, along the sowing line. In the second experiment (baby corn), 30 kg N ha^{-1} (ammonium sulfate), 30 kg P_2O_5 ha^{-1} (triple superphosphate), and 30 kg K_2O ha^{-1} (potassium chloride) were applied as base fertilization. Topdressing fertilization occurred at 40 days after planting, with the application of 40 kg N ha^{-1}.

Weed control was carried out by biweekly hand weeding. Interestingly, there was no need for irrigation because of the rains. As a result, there was no control of pests and diseases.

Variables analyzed

At 80 days after planting, in the reproductive R3 stage, the stand (plants ha^{-1}), the total number of ears per area (units ha^{-1}), and the total weight of ears (Mg ha^{-1}; with the aid of a digital scale) were assessed in all plants of the useful area of the plot. The number (units ha^{-1}) and the weight of marketable unhusked ears (Mg ha^{-1}; with the aid of a digital scale) and the number (units ha^{-1}) and the weight of marketable husked ears (Mg ha^{-1}; hand husked with the aid of a digital scale) were assessed in 2.0 linear m of the useful area of the plot. Marketable unhusked ears were considered to be those with adequate health and grading for commercialization and with a length equal to or greater than 23 cm (SILVA et al. 2003).

Baby corn was assessed at 56 days after planting. The harvest stage occurred when the style and stigma were 3.0 cm long (TARGANSKI & TSUTSUMI 2017). On this occasion, the number of baby corn per $plant^{-1}$ and per area (units ha^{-1}), the spikelet length (cm; using a graduated ruler), diameter (cm; with the aid of a caliper), and weight (g; with the aid of a digital scale), with and without husk, and the yield (Mg ha^{-1}) were assessed daily for ten days in all plants in the useful area of the plot. Marketable husked ears were considered to be those with adequate health and grading for commercialization and with a length between 8.0 and 12 cm (ALMEIDA et al. 2005).

The 4.0 m linear plants were cut close to the ground, weighed (with the aid of a digital scale), crushed in a fodder machine, sub-sampled (500 g), placed in Kraft paper bags, and dried in an forced circulation oven at 65 ºC until constant mass to obtain the dry biomass without the cob for the two experiments (Mg DM ha^{-1}).

Statistical analyses

Data from each experiment were tested for homoscedasticity (Bartlett's test), normality of residuals (Shapiro-Wilk test), independence of residuals (Durbin-Watson test), and model additivity (Tukey test), all of which were non-significant ($p>0.05$). Then, the analysis of variance was performed and the means were grouped by the Scott-Knott test ($p<0.05$) using the ExpDes package, version 1.2.2 (FERREIRA et al. 2014) of the R software (R CORE TEAM 2022).

RESULTS AND DISCUSSION

Agronomic performance of maize cultivars for sweet corn production

There was a significant difference ($p<0.05$) between cultivars for all variables except for the total weight of ears, which ranged from 21.4 to 23.4 Mg ha^{-1} (Table 2). These values were higher than those obtained by PEREIRA JÚNIOR et al. (2012), in which the study of the Puerto Rico creole variety presented a mean of 17.2 Mg ha^{-1}; this is probably due to its genetic constitution, since the double hybrid AG 1051 cultivated in Lavras/MG/Brazil by ALBUQUERQUE et al. (2008) obtained a mean of 22.1 Mg ha^{-1}, which is similar to this research.

Table 2. Evaluation of five cultivars for sweet corn production.

Treatments	Stand plants ha^{-1}	TNE un. ha^{-1}	TWE Mg ha^{-1}	NME un. ha^{-1}	WME Mg ha^{-1}	NMHE un. ha^{-1}	WMHE Mg ha^{-1}
AG 1051	59,777 a	71,777 c	23.4 a	59,777 a	21.9 a	59,344 a	13.4 a
Alagoano	61,110 a	86,110 a	23.1 a	63,888 a	17.1 b	44,444 b	5.1 d
Branquinha	56,110 b	74,221 c	22.2 a	63,888 a	20.3 a	49,999 b	9.1 b
São Luiz	58,333 a	88,762 a	21.4 a	55,510 b	14.4 c	37,888 c	6.1 d
Viçosense	59,777 a	80,555 b	21.4 a	47,222 c	15.6 c	39,878 c	7.6 c
CV (%)	5.92	11.22	10.61	6.44	12.87	17.63	20.27
$F_{Treatment}$	0.01**	0.01**	0.75ns	0.01**	0.01**	0.04*	0.01**

TNE: total number of ears; TWE: total weight of ears; NME: number of marketable ears; WME: weight of marketable ears; NMHE: number of marketable husked ears; WMHE: weight of marketable husked ears. Means followed by a different letter in the column belong to the same group by the Scott-Knott test ($p>0.05$). **, *, and ns: significant at 1 and 5% and non-significant at 5%, respectively. CV: coefficient of variation.

The decrease in stand of 10.2% (6,390 plants ha^{-1}) was significant ($p<0.05$) for the cultivar 'Branquinha'; the other cultivars had no significant decrease ($p>0.05$) with a loss of 4.4% of the plants (Table 2). Considering that there was no pest control, it is possible that the incidence of *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae) was the main causative agent that, according to OTA et al. (2011), act in the vegetative stage and cause leaf damage (reducing photosynthetic capacity) and even the death of the seedling.

The total number of ears was higher ($p<0.05$) for the cultivars Alagoano and São Luiz, as they are prolific types, in which more than one ear plant^{-1} is produced. However, the differences observed did not influence the total weight of ears, as there was no statistical difference between the cultivars, which indicates that, despite being prolific, they produce light ears. It is possible that the increase in fertilization can improve the weight of the ears, as observed by PINTO et al. (2017), who had a 32% increase in large ears, in this way increasing gross revenue by 340%.

Cultivars AG 1051, Alagoano, and Branquinha presented the highest ($p<0.05$) number of commercial ears ha^{-1}. Therefore, a mean decrease of 19.2% (14,852 ears; mean of the three cultivars) in the number of ears was observed, as the ears did not meet the commercial standard (small, light, and malformed ears), and this was higher ($p<0.05$) for the cultivar PV2 Viçosense with a decrease of 41.2%. The commercial standard is the main characteristic considered by the consumer when buying fresh corn (PINTO et al. 2017). The weight of marketable ears was higher for cultivars 'AG 1051' and Branquinha with a mean of 21.1 Mg ha^{-1}. On the other hand, the cultivars São Luiz and PV2 Viçosense presented the lowest yields.

When husked, damage could be observed in the ears caused by *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), and this damage was less expressive for AG 1051, which reflects the higher yield of this hybrid. Regardless of the cultivar assessed in this research, yield was higher than those obtained by MORAES et al. (2010), in São Paulo/SP/Brazil, whose mean was 4.8 Mg ha^{-1}. On the other hand, in Lavras/MG/Brazil, ALBUQUERQUE et al. (2008) have obtained similar yield with a mean of 13.1 Mg ha^{-1}; FAVARATO et al. (2016) had a mean of 10.8 Mg ha^{-1}, in Domingos Martins/ES/Brazil. The variation of results reinforces the need to assess cultivars in different production agroecosystems.

Agronomic performance of maize cultivars for baby corn production

Significant differences ($p<0.05$) were observed between cultivars for the variables number of ears per plant^{-1} and per area and yield of ears, and cultivars 'AG 1051' and 'PV2 Viçosense' had higher means (Table 3). These variables correlate with each other (CARGNELUTTI FILHO et al. 2021); plants that present a greater number of ears per plant^{-1} and per area will tend to present greater yield.

Table 3. Evaluation of five cultivars for baby corn production and roughage yield.

Treatments	NEP Un. pla.$^{-1}$	NEA Un. ha^{-1}	LEWH cm	LEWOH cm	DEWH cm	DEWOH cm	WEWH g	WEWOH g	EY Mg ha^{-1}
AG 1051	2.47 b	151,189 a	24.49 a	10.52 a	2.93 a	1.91 a	90.34 a	19.72 a	3.1 a
Alagoano	1.28 c	78,174 c	24.75 a	9.77 a	2.78 a	1.72 a	78.29 a	14.85 a	1.2 b
Branquinha	1.48 b	75,793 c	24.51 a	9.87 a	2.97 a	1.70 a	95.05 a	15.29 a	1.2 b
São Luiz	1.43 b	83,333 b	25.59 a	10.83 a	2.96 a	1.91 a	89.66 a	19.98 a	1.6 b
Viçosense	2.67 a	164,681 a	25.07 a	10.38 a	2.85 a	1.84 a	84.70 a	18.75 a	2.9 a
CV (%)	14.61	18.95	8.23	13.76	5.73	8.70	17.85	20.73	18.23
$F_{Treatment}$	0.01**	0.01**	0.09 ns	0.87 ns	0.61 ns	0.38 ns	0.74 ns	0.31 ns	0.01**

NEP: number of ears per plant^{-1}; NEA: number of ears per area^{-1}; LEWH: length of ear with husk; LEWOH: length of ear without husk; DEWH: diameter of ear with husk; DEWOH: diameter of ear without husk; WEWH: weight of ear with husk; WEWOH: weight of ear without husk; EY: ear yield. Means followed by a different letter in the column belong to the same group by the Scott-Knott test (p>0.05). **, *, and ns: significant at 1 and 5% and non-significant at 5%, respectively. CV: coefficient of variation.

The number of ears ha^{-1} was lower than the results obtained by TARGANSKI & TSUTSUMI (2017), who have evaluated maize cultivars for baby corn production in Marechal Cândido Rondon/PR/Brazil, and who have obtained means ranging from 144,048 to 266,667 ears ha^{-1} for the cultivars AL 34 and Pioneer 30S40, respectively. These authors, in addition to increasing the density of plants per ha^{-1}, carried out 24 harvests, which justify the superior results.

The lengths, diameters, and weight of the ear, with and without husk, showed no significant difference (p>0.05) among the cultivars and considering that the ears were previously selected based on commercial standards (ALMEIDA et al. 2005). The cultivars AG 1051 and PV2 Viçosense presented the highest yields, with 3.1 and 2.9 Mg ha^{-1}, respectively. COSTA et al. (2020b), in Piranhas, a semi-arid region of Alagoas, Brazil, have compared the performance of different cultivars and they have obtained similar means for lengths (20.1 and 9.97 cm) and diameters (2.36 and 1.37 cm), with and without husk, and lower values for the weight of the ear without husk (46.7g) and higher values for yield (9.97 Mg ha^{-1}), considering 21 harvests and an initial stand of 180,000 plants ha^{-1}. These authors consider baby corn as a new alternative for agricultural diversification with employment and income generation in the region.

The economic evaluation of baby corn has been evaluated by RAM et al. (2021), in Haryana/India, and the authors have observed the high profitability in the exploration of this product when considering the production costs of 111,480 rupees ha^{-1} and return of 142,451 rupees ha^{-1}. This information reinforces the economic viability of baby corn exploration, which may be a viable alternative for small family producers mainly because of the early harvest and decrease in the use of raw materials when compared to crops for grain production (SANTOS et al. 2014).

Based on the results presented, the hybrid AG 1051 presented the best agronomic performance followed by the cultivar PV2 Viçosense, and they can be used in intensive or extensive production systems. It is possible that the decrease in spacing (increase of the stand), doses of fertilizers (synthetic and/or organic), irrigation depths, and control of pests and diseases can increase the number of harvests and, consequently, the yield of ears.

Fodder production

The semi-arid region presents seasonality of plant production because of the water deficit, and the annual food planning of the ruminant herd becomes necessary. After harvesting the ears for commercialization of sweet corn, it was observed that the cultivars AG 1051 and Branquinha, with 10.7 and 10.9 Mg DM ha^{-1} respectively, had the highest whole-plant dry matter yields (Figure 1). On the other hand, when the objective was baby corn production, residual biomass was higher for cultivars AG 1051 and Branquinha, with 8.8 and 8.9 Mg DM ha^{-1}, respectively. Baby corn biomass is harvested from younger plants when compared to sweet corn, which have higher moisture content. Therefore, this lower productivity is justified.

When tested in Rio Largo/AL/Brazil, CARVALHO et al. (2018) have observed superior results for the cultivars Alagoano and PV2 Viçosense with yield of 15.0 and 17.1 Mg DM ha^{-1}, respectively, and silage yield of 8.7 and 9.1 Mg ha^{-1}. The observed differences can be explained by the climatic conditions ("Am" climate, humid tropical, according to Köppen), which evidence the effect of the genotype x environment interaction on the cultivars.

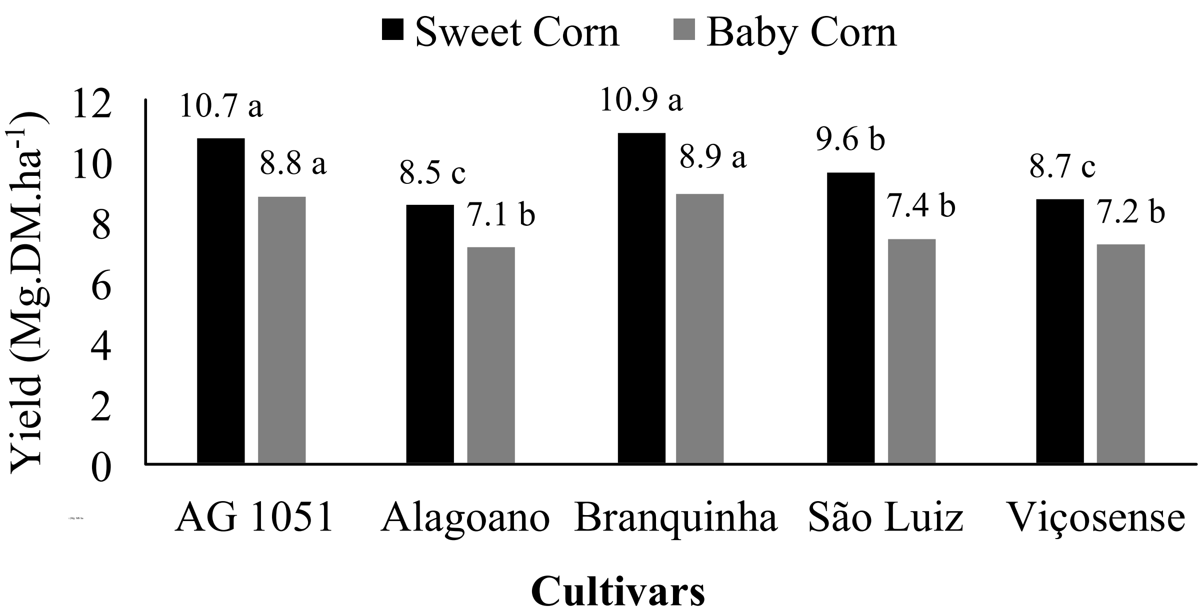

Figure 1. Roughage yield (Mg DM ha^{-1}) of maize cultivars after the harvest of sweet corn and baby corn.

According to the decrease in the number of marketable ears (Tables 1 and 2), as they do not present a commercial standard and, therefore, do not have economic importance, the use of whole-plant biomass for animal feed becomes relevant, as this will improve the nutritional value of the roughage (CARVALHO et al. 2018). In addition to this aspect, the green mass, as it contains approximately 65% of moisture (CARVALHO et al. 2018), will assist in the hydration of animals, especially in the semi-arid region (ARAÚJO 2015).

The maize cultivars showed different performance in the edaphoclimatic conditions of the Brazilian Agreste Meridional, a semi-arid region of Pernambuco, where the double hybrid AG 1051 presented high yield for sweet corn and baby corn, as well as higher yield for roughage. Thus, it can integrate high-tech production systems with intensive use of technologies (fertilization, irrigation, pest and disease control, mechanization). Among the open-pollinated cultivars, Branquinha stood out with higher yields of sweet corn and roughage, and PV2 Viçosense had high baby corn yield, being them recommended for use in medium/low technological systems such as family farming. With this, the producer will be able to sell the ears and fodder, produce silage, or crush the plant and supply it to animals.

CONCLUSION

When used for the production of sweet corn, the cultivars AG 1051 and Branquinha present the best agronomic performances by combining a high yield of marketable ears and fodder production. For baby corn production, cultivars AG 1051 and PV2 Viçosense present high spikelet yield, and Branquinha had high fodder yield.

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