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Cultivars of corn recommended for silage in the Agreste Meridional of Pernambuco

Cultivares de milho recomendadas para silagem no Agreste Meridional de Pernambuco

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ABSTRACT

The semiarid region of Pernambuco produces 99.5% of the forage corn, considering that 93.8% of the ruminant herd is produced in this region of the Brazilian Northeast. The Agreste Meridional is located in this region, which presents seasonality in production due to water deficit. Silage is one of the adopted roughage conservation strategies, with corn being the forage that presents the best indicators when fed to animals. Agronomic aspects are often neglected, considering that the performance of cultivars may vary with the growing environment. The objective of this research was the introduction and evaluation of corn cultivars for the production for whole-plant silage in the Agreste Meridional of Pernambuco, Brazil. The experiment was carried out in a randomized block design, with seven treatments, of which five non transgenic cultivars ('Alagoano', 'Nordestino', 'São Luís', 'PV2 Viçosense' and 'PV1 Branca') and two transgenic hybrids ('LG 6030 VT PRO2' and 'AS 1573 YG'). It was observed that all genotypes showed susceptibility to *Spodoptera frugiperda* and *Helicoverpa zea*, except for the 'AS 1573 YG' hybrid, due to the *Bt* technology. The biometric characters of the genotypes were influenced by the environment. However, with yield of 10,537 and 10,666 kg ha^{-1} (dry matter), the genotypes 'Alagoano' and 'AS 1573 YG', respectively, were selected for cultivation in the Agreste Meridional region for the production of silage, which can be used in intensive production systems or family farming.

KEYWORDS: *Zea mays; Spodoptera frugiperda; Helicoverpa zea;* transgenics; semiarid region.

RESUMO

A região semiárida de Pernambuco produz 99,5% do milho forrageiro, considerando que 93,8% do rebanho de ruminantes é produzido nesta região do Nordeste brasileiro. O Agreste Meridional está inserido nesta região, que apresenta sazonalidade na produção devido ao déficit hídrico. A silagem é uma das estratégias de conservação de volumoso adotado, sendo o milho a forrageira que apresenta os melhores indicadores quando fornecida aos animais. Aspectos agronômicos, muitas vezes, são negligenciados, considerando que o desempenho dos cultivares poderão variar com o ambiente de cultivo. O objetivo dessa pesquisa foi a introdução e avaliação de cultivares de milho para produção de silagem de planta inteira no Agreste Meridional de Pernambuco, Brasil. O experimento foi instalado no delineamento em blocos casualizados, com sete tratamentos, dos quais, cinco cultivares não transgênicas (Alagoano, Nordestino, São Luís, PV2 Viçosense, PV1 Branca) e dois híbridos transgênicos ('LG 6030 VT PRO2' e 'AS 1573 YG'). Observou-se que todos os genótipos apresentaram suscetibilidade às pragas *Spodoptera frugiperda* e *Helicoverpa zea*, exceto o híbrido 'AS 1573 YG', devido à tecnologia *Bt*. Os caracteres biométricos dos cultivares foram influenciados pelo ambiente. Porém, com produtividade de 10.537 e 10.666 kg ha^{-1} (matéria seca), os genótipos Alagoano e 'AS 1573 YG', respectivamente, foram selecionados para cultivo na região do Agreste Meridional para produção de silagem, podendo ser utilizados em sistemas intensivos de produção ou agricultura familiar.

PALAVRAS-CHAVE: *Zea mays; Spodoptera frugiperda; Helicoverpa zea;* transgênicos; região semiárida.

INTRODUCTION

Corn (*Zea mays* L.) is one of the most important cereals cultivated and consumed in the world, due to the nutritional value and productive potential of different cultivars, adapted to different edaphoclimatic conditions, with aptitudes for human consumption, animal feed and for industrial (FANCELLI 2011). In Brazil, it has been cultivated in all states, with Mato Grosso, Paraná and Goiás being the largest grain producers, with 28.6, 14.1 and 10.5 million tons, respectively. The states of Minas Gerais, Rio Grande do Sul and Santa Catarina, with 12.4, 8.1 and 6.5 million tons, respectively, are the largest producers of forage corn (IBGE 2020a).

Corn silage has been shown to be an important alternative in the conservation of forage within a livestock production system, especially in semiarid regions, in which there is seasonality of production, due to the water deficit in the dry season, making plant production impossible under rainfed conditions. In Pernambuco, the semiarid region is responsible for the production of 99.5% (22.5 thousand tons) of forage corn, used for feed of the ruminant herd (3.7 million heads), mainly goats (1.4 million), cattle (1.1 million) and sheep (1.1 million), according to IBGE (2020b).

When cultivars with aptitude for silage are used, it generates forage with nutritional and qualitative value considered a world reference (FERRARETTO et al. 2018). According to VALADARES FILHO et al. (2018), corn silage has average values, for the Pernambuco State, of 29.2% dry matter, 6.2% crude protein, 7.0% minerals, 49.3% neutral detergent fiber (NDF), 30.3% non-fibrous carbohydrates and 4.1% lignin. According to MACEDO JÚNIOR et al. (2018), the average digestibility was 56.1%, with dry matter consumption by sheep (37 kg LW) of 0.59 kg day^{-1}. In heifers (100 kg LW), consumption was 9.5 kg day^{-1}, with 70.8% of digestibility (NEUMANN et al. 2018).

There are multiple factors that will determine the final quality of the silage, such as those related to the production process (silo structure, particle size, compacting, humidity, silage time), maintenance of anaerobiosis and control of the oxidation of organic matter after silo opening (FERRARETTO et al. 2018). However, agronomic aspects of forage plants, such as management (cultivation, spacing, fertilization, irrigation, pest and disease control) are often neglected. According to KLEIN et al. (2018), soil and climate conditions influence the biometric characters of plants, directly influencing the quality of the ensiled material, justifying this research.

The breeding programs developed specific cultivars for silage production, combining yield, nutritional value (chemical composition and digestibility) and animal performance (consumption). The introduction and evaluation of cultivars is an important practice that aims to select superior genotypes, which preserve their characteristics, enabling quality forage, in addition to reducing dependence on external inputs to the property. Therefore, this research aimed at the introduction and evaluation of corn cultivars for whole-plant silage in Agreste Meridional, semiarid region of Pernambuco.

MATERIAL AND METHODS

The research was conducted on a commercial property located in the municipality of Terezinha, Agreste Meridional of Pernambuco, Brazil, under the coordinates 09º 03' 22" S and 36º 37' 22" W, with 751 m above sea level. The region has an 'Aw' climate, which represents a tropical climate with a dry winters, according to the Köppen classification, with total pluvial precipitation of 660 mm, a rainy season concentrated between May/July (autumn-winter), in which precipitation equivalent to 70% of the annual total (CLIMATE-DATA 2023). The minimum average temperature is 16.9 ºC and the maximum is 25.5 ºC, with a relative humidity of 75% (INMET 2023). The soil was classified as dystrophic Yellow Argisol.

The experiment was installed in a randomized block design with seven treatments (cultivars) and four blocks. The 'Alagoano', 'Nordestino', 'São Luís', 'PV2 Viçosense' and 'PV1 Branca' non transgenic cultivars were developed by the Federal University of Alagoas, indicated for silage production (SILVA JÚNIOR et al. 2017). The genetically modified hybrids 'LG 6030 VT PRO2' (LG Sementes S/A) and 'AS 1573 YG' (Agroeste S/A), developed for silage, present an early cycle and are demanding in a high technological level. The planting of hybrids was carried out in accordance with Normative Resolution No. 4 and Technical Opinion No. 1,100/2007 of the National Technical Commission on Biosafety (CTNBio, Brazil). Each plot consisted of six rows of 6.0 m, being considered the working area the four central rows.

The result of the chemical analysis of the soil (0 to 20 cm) presented the following characteristics: pH (H_2O): 5.5; organic matter: 2.9 mg dm^{-3}; P (Mehlich): 6.2 mg dm^{-3}; H^+ (calcium acetate, pH 7.0) + Al^{3+} (1N KCl), K^+ (Mehlich), Ca^{2+} + Mg^{2+} (1N KCl) showed, respectively, 0.33, 0.17 and 2.5 $cmol_c$ dm^{-3}. The sand, silt

and clay fractions were 58, 15 and 27%, respectively, and the texture was classified as sandy-clay loam. Following the recommendations of CAVALCANTI (2008), 20 kg N ha^{-1} as ammonium sulfate, 60 kg P_2O_5 ha^{-1} as triple superphosphate and 20 kg K_2O ha^{-1} as potassium chloride were applied at planting. At 40 days after planting, 40 kg N ha^{-1} were applied (ammonium sulfate).

The experiment was carried out in a conventional tillage system, with two harrowing harrows and one leveling harrow (0.20 m). Then, mechanized planting was carried out, using a fertilizer seeder of three-row pantographic manufactured by Baldan® Company (SP light H-2500), one seed per hole at 5.0 cm depth. The spacing adopted was 0.80 x 0.20 m, in which the plant population was 62,500 plants ha^{-1}. Weed control was carried out by hand weeding. There was no need for irrigation due to the rains. There was no control of pests and diseases, aiming to evaluate the inscience and damage to plants.

In the V8 phenological phase, the leaf damage caused by the *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae), in thirty plants $plot^{-1}$, was evaluated, obtaining the percentage of damage of the stand (%). Visual assessment of damage intensity (0 to 5) followed the scale proposed by DAVIS & WILLIAMS (1989), in which: 0 - no visible damage; 1 - pinholes and small circular lesions present on whorl leaves; 2 - several small to mid-sized 1.3 to 2.5 cm in length elongated lesions present on a few whorl and furl leaves; 3 - several large elongated lesions present on several whorl and furl leaves and/or several large uniform to irregular shaped holes eaten from furl and whorl leaves; 4 - many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular shaped holes eaten from the whorl and furl leaves; 5 - whorl and furl leaves almost totally destroyed.

In phase R4 (dough, inside the kernels are a “doughy” consistency), damage caused by the *Helicoverpa* zea (Boddie) (Lepidoptera: Noctuidae) in 2.0 m linear of plants was evaluated, obtaining the percentage of damage of the ear (%). Visual assessment of damage intensity (0 to 5) followed the scale proposed by CARVALHO (1980), being: 0 - no damages; 1 - damages of up to 1.0 cm as from the ear tip; 2 - between 1.1 and 2.0 cm; 3 - between 2.1 and 3.0 cm; 4 - between 3.1 and 4.0 cm; and 5 - damages extending over 4 cm. Before the evaluations, three evaluators were trained.

Corn growth stages R4, in six $plot^{-1}$, evaluations of plant heights (cm) were carried out, using a graduated ruler (from the ground to the insertion of the flag sheet), and the stem diameter (mm), using a graduated caliper (measured at 10 cm above the ground level). The determination of the stand (plants ha^{-1}) was carried out by counting all the plants in the working area of each plot. Plants measuring at 4.0 m linear were cut close to the ground, weighed (with the aid of a digital scale), sub-sampled (500 g), placed in kraf paper bags and dried in oven with forced air circulation at 65°C until mass constant to obtain the shoot dry biomass yield (kg SDB ha^{-1}).

In the data from of percentage and note scale, descriptive statistics was adopted, because they do not meet the assumptions for the analysis of variance (Anova). The others were tested for homoscedasticity (Bartlett 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, Anova was performed and the means grouped by the Scott-Knott test ($p < 0.05$), using the *ExpDes* package (FERREIRA et al. 2014) of the R software (R CORE TEAM 2022).

RESULTS AND DISCUSSION

It was observed that the damage caused to the plants by the *S. frugiperda* was more expressive in the cultivars (Table 1), ranging from 93.8 (‘PV1 Branca’) to 98.4% (‘Nordestina’), in which the plants presented note mean of 4.2 (many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular shaped holes eaten from the whorl and furl leaves). On the other hand, the ‘AS 1573 YG’ hybrid showed damage in 1.5% of the plants, with damages of up to 1.0 cm as from the ear tip scraped leaves (Table 1). This hybrid, transgenic (*Bt*), is tolerant to the *S. frugiperda*, by synthesizing the *Cry* and *Vip* insecticidal proteins, which act by break through the intestinal epithelial cells, leading to septicemia of the insect (SHOBIYA et al. 2021). MORAES et al. (2015), in Campinas/SP, also observed that the damage caused by *S. frugiperda* was greater in conventional hybrids when compared to transgenics, due to *Bt* technology.

Even though the hybrid ‘LG 6030 VT PRO2’ also had insecticidal proteins, the damage caused by the caterpillars was of high magnitude (Table 1), with damage to the leaves and cartridge (several large elongated lesions present on several whorl and furl leaves and/or several large uniform to irregular shaped holes eaten from furl and whorl leaves). SIMIONATO et al. (2020) also observed damage to hybrids that had

the 'VT PRO2®' technology. Despite ethical discussions about transgenics, the use of this technology reduces the use of insecticides. SILVA JÚNIOR et al. (2017), in Rio Largo/AL performed five fortnightly sprays of Decis® (pyrethroid) in corn cultivation. According to TEIXEIRA et al. (2022), this active principles has caused insect resistance and mortality of natural enemies, toxic effects on humans and environmental contamination.

Table 1. Damage to plants and ear corn attacked by *Spodoptera frugiperda* e *Helicoverpa zea*.

Cultivars	Damage to plants		Damage to ear	
	Stand (%)	Note scale (0 - 5)	Stand (%)	Note scale (0 - 5)
Alagoano	97.0	4.4	28.0	4.7
Nordestino	98.4	4.5	51.3	4.8
São Luiz	96.6	3.8	62.6	4.5
PV2 Viçosense	95.6	4.3	68.5	4.4
PV1 Branca	93.8	4.1	25.0	4.3
LG 6030	88.7	3.3	27.3	4.6
AS 1573 YG	1.5	0.5	3.3	1.2
CV (%)	12.9	8.0	23.1	10.1

CV: coefficient of variation.

The damage caused to the ears by *H. zea* was more expressive for the 'São Luiz' and 'PV2 Viçosense' cultivars (Table 1). However, ear damage (up to 4.0 cm, note 4) was similar between cultivars and the hybrid 'LG 6030 VT PRO2'. SIMIONATO et al. (2020) observed that the damage caused to hybrids with the 'VT PRO2®' technology showed no statistical difference ($p > 0.05$) between the non-transgenic cultivar. Likewise, SUEKANE et al. (2018) obtained the similar responses, in which the non-transgenic cultivar was more affected by the pest. On the other hand, the hybrid 'AS 1573 YG' showed damage of up to 1.0 cm from the apex (note 1.2; Table 1), due to the *Bt* technology.

The 'Alagoano' cultivar presented superior ($p < 0.05$) plant height to the other evaluated genotypes; the hybrid 'LG 6030 VT PRO2' presented the lowest values (Table 2), lower than that indicated by the manufacturer. On the other hand, the hybrid 'AS 1573 YG', with height of 2.03 m, had intermediate means, similar to the results obtained by GUADAGNIN et al. (2011). According to OLIVEIRA et al. (2020), the hybrid 'AS 1555 YG' showed adaptability to unfavorable environments. Therefore, it is possible that the semiarid conditions of the region had a negative effect on the LG hybrid.

Table 2. Evaluation of biometric characters and yield of different corn cultivars.

Cultivars	Plant height (m)	Stem diameter (mm)	Stand (plants ha^{-1})	Ear number (ear ha^{-1})	Yield (kg SDM ha^{-1})
Alagoano	2.22 a	23.1 b	57,913 a	78,913 a	10,537 a
Nordestino	2.04 c	23.3 b	53,831 b	72,688 a	9,695 b
São Luiz	2.12 b	21.9 c	58,881 a	75,125 a	8,101 c
PV2 Viçosense	1.96 c	22.2 c	53,546 b	74,188 a	8,797 c
PV1 Branca	2.12 b	27.4 a	39,998 c	61,036 b	7,129 d
LG 6030	1.74 d	25.2 b	53,130 b	53,130 c	9,363 b
AS 1573 YG	2.03 c	24.9 b	58,109 a	58,109 c	10,666 a
CV (%)	4.07	5.53	8.96	10.21	13.56
$F_{Treatment}$	<0.001**	<0.001**	<0.001**	0.006**	0.004*

Means followed by different letters 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, respectively. CV: coefficient of variation.

The stem diameter is an important variable that is related to plant lodging. Among the genotypes evaluated, the cultivar 'PV1 Branca' had the largest diameter, probably due to their genetic makeup (Table 2) which, associated with the low stand, allowed greater development of the plants. A similar mean was obtained by SILVA JÚNIOR et al. (2017), 21.2 mm, in Rio Largo/AL. These authors also highlighted that there is a positive correlation between the stem diameter and the soluble solids content, which is favorable for ear production and, consequently, for silage.

There was no significant difference (p > 0.05) between the 'Alagoano' cultivar and the 'AS 1573 YG' hybrid for the stand and yield shoot dry biomass (Table 2), with mean values of 58,011 plants ha^{-1} and 10,601.5 kg SDM ha^{-1}, respectively. The 'PV1 Branca' cultivar showed the lowest stand due to the incidence of *S. frugiperda* (Table 1), reflecting on yield. With damage to plant of 4.4 (Table 1), the stand of the "Alagoano" cultivar was not harmed (Table 2), probably due to the ADF content, reaching 422.3 g kg DM, according to ARCANJO JÚNIOR et al. (2016).

All cultivars were prolific, presenting more than one ear $plant^{-1}$, unlike the transgenic hybrids that presented one ear. The results observed were higher than the state yield (6,744.9 kg ha^{-1}; IBGE 2020b) and lower than those of KLEIN et al. (2018), in Santa Maria/RS, who evaluated transgenic hybrids for silage, with yields ranging from 14,843.3 to 16,421.6 kg SDM ha^{-1} for the hybrids 'AS 1656 PRO3' and 'AS 1596 PROX', respectively. Considering that the hybrids used in this research are of a high technological level, it is possible that the N fertilization used (40 kg N ha^{-1}) did not meet the nutritional requirements, reducing their yield. SOUZA et al. (2020), in Canindé do São Francisco/SE, observed that the Feroz, transgenic hybrid (*Bt*), showed a linear increase (up to 12.4 t SDM ha^{-1}) with the maximum dose (240 kg ha^{-1}). Besides the yield, high doses of N increased the *Cry* insecticidal proteins (MARQUARDT et al. 2014), in addition to the protein and NDF contents of the silage (UZUN et al. 2020).

The introductions carried out in the Agreste Meridional, semiarid region of Pernambuco, showed that the cultivars are susceptible to the *S. frugiperda* and *H. zea* pests, unlike the hybrid 'AS 1573 YG' (due to *Bt* technology) which, together with the 'Alagoano' cultivar, had similar yield. Therefore, both, intensive production systems and family farmers, will be able to cultivate these genotypes for silage production, favoring animal production with the forage allowance of quality.

CONCLUSION

The 'Alagoano' cultivar and the 'AS 1573 YG' transgenic hybrid are indicated for cultivation in the Agreste Meridional of Pernambuco, aiming at the production of whole plant silage.

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