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ORIGINAL ARTICLE

Phytotechnical performance and resistance to leaf-footed bugs of green maize intercropped with Poaceae in the Amazon savannah

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ABSTRACT

Green maize has great economic value, and the consumer market increasingly demands the production of ears for fresh consumption that are free from damage by pest attacks. The aim of this study was to evaluate the performance of varieties of AG1051 green maize and Roraima maize (ethnovariety Milhão) intercropped with dwarf grain sorghum, forage sorghum and millet in an environment of the Amazon savannah. We evaluated phytotechnical characteristics of the maize and damage from the leaf-footed bug (*Leptoglossus zonatus*). The experiment was set up in a 2 x 4 factorial randomised block design with four replications, where the two maize varieties corresponded to the first factor and four intercropping systems to the second factor. Regarding vegetative and reproductive components, Milhão had a longer cycle, greater plant growth and smaller stem diameter than AG1051, causing plant lodging. The intercropping systems had no influence on the production or quality of maize ears for any of the cultivars under study. Milhão did not differ from the AG1051 hybrid in any ear quality variable (ear length, number of grains per ear, cob diameter, ear weight and total number of ears). The AG1051 cultivar was preferred by *L. zonatus*, but had the highest yield of commercial ears. The intercropping systems had no influence on the damage caused by the leaf-footed bug.

KEYWORDS: *Leptoglossus zonatus*; *Pennisetum glaucum*; *Sorghum bicolor*; trap plants; *Zea mays*

Desempenho fitotécnico e resistência ao percevejo pé-de-folha do milho verde consorciado com Poaceae na Savana Amazônica

RESUMO

O milho verde possui grande valor econômico, e o mercado consumidor exige cada vez mais a produção de espigas para consumo *in natura* livres de danos por ataques de pragas. O objetivo deste trabalho foi avaliar o desempenho de variedades de milho verde AG1051 e milho Roraima (etnovariedade Milhão) consorciadas com sorgo granífero anão, sorgo forrageiro e milheto em ambiente da savana Amazônica. Avaliamos as características fitotécnicas do milho e os danos causados pelo percevejo pé-de-folha (*Leptoglossus zonatus*). O experimento foi instalado em um delineamento fatorial 2 x 4 de blocos casualizados com quatro repetições, onde as duas variedades de milho corresponderam ao primeiro fator e quatro sistemas de consórcio ao segundo fator. Com referência aos componentes vegetativos e reprodutivos, o Milhão apresentou ciclo mais longo, maior crescimento de plantas e menor diâmetro do colmo que o AG1051, causando acamamento de plantas. Os sistemas de consórcio não influenciaram a produção ou qualidade de espigas de milho de nenhuma das cultivares em estudo. O Milhão não diferiu do híbrido AG1051 em nenhuma variável de qualidade da espiga (comprimento da espiga, número de grãos por espiga, diâmetro da espiga, massa da espiga e número total de espigas). A cultivar AG1051 foi a preferida pelo *L. zonatus*, mas apresentou maior produtividade de espigas comerciais. Os sistemas de consórcio não influenciaram os danos causados pelo percevejo pé-de-folha.

PALAVRAS-CHAVE: *Leptoglossus zonatus*; *Pennisetum glaucum*; *Sorghum bicolor;* plantas armadilha; *Zea mays*

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INTRODUCTION

Maize (*Zea mays* L.) is one of the most important commodities in the world. In Brazil, cropping systems employing hybrid cultivars and criole varieties are used with a view to higher yields, better use of the area, and controlling pests and diseases (Carpentieri-Pípolo *et al.* 2010).

Creole ethnovarieties of maize are adapted to local conditions. Cultivated by small producers and indigenous communities, they have lower production costs, can be used for successive crops, and have high potential for cultivation with genetic variability, making the maize plant tolerant or resistant to undesirable factors such as pests, diseases and adverse soil and climate conditions (Carpentieri-Pípolo *et al.* 2010; Catão *et al.* 2010; Gonzalez-Muñoz *et al.* 2013).

Leptoglossus zonatus (Dallas, 1852), commonly known as the leaf-footed bug, is geographically distributed from North to South America. It is a polyphagous species, with up to three generations per year, feeding and ovipositing on several crop plants from various botanical families, such as maize, sorghum, tomato, passion fruit, and citrus (Barreto and Silva 2016; Daane *et al.* 2019; Joyce *et al.* 2019), attracted by volatiles produced by the host plants (Inoue *et al.* 2019). Although *L. zonatus* is polyphagous, it has a preference for maize and is especially important in maize cultivation due to the commercial value of the crop (Foresti *et al.* 2017). In maize, damage is related to the nymphs and adult bugs that suck the grain, causing wilt and rot (Moreira and Aragão 2009). The damage to ear production can reach up to 17% (Marega and Almeida Marques 2021). The period of greatest damage to the crop coincides with the developmental stages of the grain, although the bugs also attack during more-advanced stages of development (Foresti 2017).

Intercropping is one of the advantageous low-cost alternatives that can be used in pest management. It increases plant diversity, reduces the insect-pest population and increases the population of their natural enemies (Khan *et al.* 2016). Plants produce compounds that can attract or repel insects, such as semiochemicals, which are natural compounds used to emit signals that manipulate insect behaviour (Blassioli-Moraes *et al.* 2016; Khan *et al.* 2016).

The use of productive cultivars, such as AG1051 hybrid maize, which is highly susceptible to *L. zonatus* compared to creole varieties when intercropped with trap plants, is a management alternative for the production and quality of maize ears, with a view to pest control. In this context, the aim of this study was to evaluate the performance of AG1051 green maize and a northern Amazonian creole, Roraima maize (ethnovariety Milhão), intercropped with sorghum and millet, in terms of phytotechnical characteristics and damage from the leaf-footed bug in a region of Amazon savannah.

MATERIAL AND METHODS

The experiment was carried out from August to November 2020 in the experimental area of the Centre for Agrarian Sciences, on the Cauamé Campus of Universidade Federal de Roraima – CCA/UFRR (2º52'20.83"N, 60º42'44.99"W), in an area of the Amazon savannah in Boa Vista, Roraima state, Brazil. The Amazon savannah area has a predominatly flat to gently undulating relief with vegetation parkland savannah and grassy-woody savannah. The predominant tree species are caimbé (*Curatella americana* L.), murici (*Byrsonima crassifolia* (L.) H.B.K.), paricarana (*Bowdichia virgilioides* Kunth), sucuba (*Himatanthus articulathus* (Vahl) Wood) and Buriti (*Mauritia flexuosa* L.) (Benedetti *et al.* 2011). The climate in the region is of type Aw, according to the Köppen classification, with a rainy season from April to September, and a dry season from October to March. The average annual precipitation is 1,657 mm (Couto-Santos *et al.* 2014). Information on rainfall and maximum and minimum temperatures are shown in Figure 1. The data were obtained manually from an on-site weather station.

The soil in the experimental area is classified as a Latossolo Amarelo Distrófico (Embrapa 2018). The results for the chemical characteristics of the soil are shown in Table 1. The study was conducted under a rainfed regime with complementary irrigation using conventional sprinklers (Fabrimar ECO A320), an irrigation depth of approximately 8 mm and a daily watering regime on days with no rainfall. The experimental area was inserted into the production conventional tillage system in 2009. The planting and fertilisation history of the area is shown in Table S1.

We used a 2 x 4 factorial design in randomised blocks with four replications, resulting in 32 experimental units. The first factor corresponded to two maize cultivars and the second to four cropping systems including intercropping with dwarf grain sorghum (*Sorghum bicolor* (L.) Moench), forage sorghum (*S. bicolor*) and millet (*Pennisetum glaucum* (L.) R.Br.). We used the AG1051 double hybrid green maize

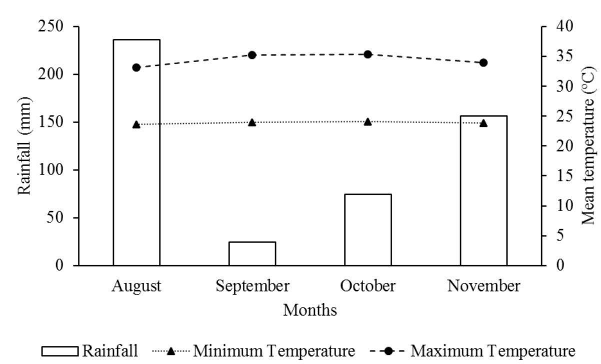

Figure 1. Total rainfall (mm) and mean daily maximum and minimum temperature (°C) in each month of the study period (August to November 2020) in the experimental area of the Centre for Agricultural Sciences, Cauamé Campus of Universidade Federal de Roraima, Brazil.

Table 1. Chemical characteristics of the soil at a depth of 0 – 0.20 m before setting up the experiment in an area of Amazon savannah in Roraima state (Brazil). Ca = exchangeable calcium; Mg = exchangeable magnesium; S = sulphur; Al = exchangeable aluminium; H+Al = potential acidity; CEC = cation exchange capacity; V = base saturation; m = aluminium saturation; P = available phosphorus; K = exchangeable potassium.

Depth (cm)	pH		Sorption complex					
	Water	KCl	Ca	Mg	S	Al	H+Al	CEC
			-------------------$cmol_c$ dm^{-3}-------------------					
0-20	5.8	4.73	1.35	0.48	0.05	-	1.1	3.07
	V	m	P	K		Clay	Silt	Sand
	-------%-------		--mg dm^{-3}--			--------------dag kg^{-1}--------------		
	64.2	-	20.2	55		26	2	72

pH in water and KCl – ratio 1:2.5; Ca – Mg – Al: extractor – KCl 1 mol L^{-1}; CEC: cation exchange capacity at pH 7; S: extractor – monocalcium phosphate in acetic acid; P – K: extractor – Mehlich 1; H+Al: extractor – SMP; Clay – Silt – Sand: pipette method.

cultivar, which has a semi-precocious cycle, tall size, yellow-toothed grains and a well developed root system, and is suitable for the production of green maize and silage, with a mean plant height and ear insertion height of 2.60 m and 1.60 m, respectively (Cruz *et al*. 2014). The second variety of maize used was a northern Brazilian regional ethnovariety, known as "Milhão", from a producer in the district of Iracema, Roraima state. The cultivar has a late cycle and is tall in size.

The combination of the two factors resulted in the following eight treatments:

1- Monocropped AG1051 maize (50,000 plants ha^{-1});

2 - Monocropped Milhão maize (50,000 plants ha^{-1});

3 - AG1051 maize (50,000 plants ha^{-1}) intercropped with dwarf grain sorghum 'BRS 330' (50,000 plants ha^{-1});

4 - AG1051 maize (50,000 plants ha^{-1}) intercropped with the FORMOSO + S cultivar of forage sorghum (50,000 plants ha^{-1});

5 - Milhão (50,000 plants ha^{-1}) intercropped with 'BRS 330' dwarf grain sorghum (50,000 plants ha^{-1});

6 - Milhão maize (50,000 plants ha^{-1}) intercropped with FORMOSO + S forage sorghum (50,000 plants ha^{-1});

7 - AG1051 maize (50,000 plants ha^{-1}) intercropped with ADR 300 millet (50,000 plants ha^{-1});

8 - Milhão maize (50,000 plants ha^{-1}) intercropped with ADR 300 millet (50,000 plants ha^{-1}).

Each experimental unit consisted of seven single rows of maize, spaced 0.80 m apart, 5 m in length, with a width of 5.6 m. For each intercropping treatment, six single rows of sorghum or millet were set up between the rows of maize, 5 m in length and 5.6 m in width, at a spacing of 0.40 m between each maize plant. The working area (9.6 m^2) of each experimental unit comprised the three central rows of maize, and the two central rows of sorghum or millet when intercropping, ignoring 0.5 m of the front borders and two rows of side borders. A space of 1.0 m was left between each block for better circulation and identifying the treatments.

The BRS 330 single hybrid of dwarf grain sorghum has high grain yield, good adaptability to different environments and its phenotypic characteristics are 1.25-m heigh plants, reddish grain as end use, 61-day flowering, a 130-day cycle, semi-open panicles, absence of tannin and lodging-tolerant. The cultivar also has a well-developed root system, and is resistant to toxic aluminium and a reducer of the nematode *Pratylenchus brachyurus* (Embrapa 2009).

The forage sorghum FORMOSO + S hybrid is recommended for silage, due to its high palatability, and its phenotypic characteristics are 2.3 to 2.8-high plants semi-compact panicles and light brown grain, silage and straw end use with a fresh-matter yield of 36 to 63 t ha^{-1} and dry-matter yield of 12 to 21 t ha^{-1}, 63-73-day flowering ready for silage in 95 to 105 days, presence of tannin and lodging–resistant (Priorizi 2022).

The ADR 300 millet cultivar is recommended for grain production, ground cover, no-tillage systems, pasture and silage production throughout Brazil, in addition to being a good reducer of the nematodes *Pratylenchus brachyurus* and *Rotylenchulus reniformis*. Its phenotypic characteristics are 1.89 to 2.30-m high plants, 45 to 5 days flowering, 92-day cycle, 25-cm long, compact candle-shaped panicles, good quality grain, average tillering capacity, grain yield of 2,300 kg ha^{-1}, mean weight of 1000 grains = 8.4 g (Pereira Filho *et al*. 2003).

The management system used in the study was conventional tillage, including ploughing and harrowing, incorporating the straw from the crop residue of the previous maize crop intercropped with black velvet beans (*Mucuna pruriens* L.) and spontaneous plants found in the area. At the time of planting, liming was carried out at a dose of 100 kg ha^{-1} limestone (46% CaO and 8% MgO) providing 2.17 $cmol_c$ dm^{-3} of Ca^{2+} and 0.68 $cmol_c$ dm^{-3} of Mg^{2+} in order to increase the Ca:Mg ratio to 3:1, as recommended for maize cultivation. In addition, 45 kg ha^{-1} urea was applied to provide 20 kg ha^{-1} of nitrogen, 156 kg ha^{-1} triple superphosphate to provide 70 kg ha^{-1} of P_2O_5, and 58 kg ha^{-1} potassium chloride (KCl) to provide 35 kg ha^{-1} of K_2O. For the first topdressing, 167 kg ha^{-1} ammonium sulphate was applied to supply 35 kg ha^{-1} of nitrogen and 38 kg ha^{-1} of sulphur, with 58 kg ha^{-1} KCl to supply 35 kg ha^{-1} of K_2O. For the second, third and fourth applications, 78 kg ha^{-1} urea was applied to provide 35 kg ha^{-1} of nitrogen.

Maize, sorghum and millet were planted on the same day by hand, with the seeds distributed in open furrows. In the plots of monocropped maize, six seeds were sown per metre in each row. In the intercropped plots, six seeds of maize were sown per linear metre, with six seeds of sorghum or millet sown between the rows of maize, depending on the treatment. Thinning was carried out 12 days after planting (DAP), leaving four monocropped maize plants per linear metre, and four maize plants and four sorghum or millet plants per metre, according to the treatment. Weed control was carried out by manual weeding, and armyworms (*Spodoptera frugiperda*) were controlled by applications of the insecticide Lannate BR (active ingredient: Methomil) until stage V5 in the maize. During the reproductive phase of the maize, no chemical products were applied.

At 70 DAP, while harvesting the maize ears, the following variables of the vegetative components were evaluated in six plants per experimental unit: total plant height (measured from ground level at the base of the plant to the final height of the tassel - expressed in cm); height of the flag leaf (measured from ground level at the base of the plant to the height of the visible flag leaf collar – expressed in cm); height of the first ear insertion (measured from ground level at the base of the plant to the height of the first ear insertion – expressed in cm); number of green leaves before and after the ear insertion (count of the number of green leaves above and below the ear insertion, respectively – expressed in units); stalk diameter (measured 10 cm above ground level – expressed in cm).

At 70 DAP for the AG1051 maize, and 100 DAP for the Milhão maize, at the R2/R3 stage of the maize, i.e. transition from milky to pasty grain, five ears were harvested (one ear from each of five plants) from the working area and husked to evaluate the following variables: ear length (expressed in cm); ear diameter (expressed in cm); number of grains per ear (estimated by counting the number of rows per grain and multiplying by the number of grains per row – expressed in units); cob diameter (measured with the ear half open and the cob exposed – expressed in mm); ear weight (measured as the product of the mean weight of the five ears); number of grains sucked by *L. zonatus* (estimated by counting the number of grains sucked by *L. zonatus* on the ear – expressed in units).

All the ears from the working area of each experimantal unit were collected to evaluate the following variables: number of commercial ears ha^{-1} (measured by counting the total number of commercial ears from the working area and extrapolating to hectares); total number of ears ha^{-1} (evaluated in the same way as the previous variable, but considering all the ears, i.e. both commercial and non-commercial).

The data were submitted to the Shapiro-Wilk normality test, without need for data transformation to attend the requeriments of parametric analysis. After verifying the normal distribution, all variables were submitted to analysis of variance by F-test at 5% probability considering the factorial design with two factors (two maize cultivars and four cropping systems), and the means, when significant, were compared with Tukey's test at 5% probability. We used the "ExpDes.pt" version 3.5.2 package (Ferreira *et al*. 2014) in the RStudio development environment (RStudio Team 2022).

RESULTS

For the vegetative variables under evaluation, there was no interaction between the maize varieties or intercropping systems. Most vegetative variables (total plant height, flag leaf height, ear insertion height, number of green leaves above the ear) were significantly higher in Milhão, while only stem diameter was significantly thicker in AG1051 (Table 2).

There was no interaction between the maize varieties and intercropping systems for the reproductive components of the maize: ear length, ear diameter, number of grains per ear, cob diameter and ear weight, number of commercial ears, total number of ears and the number of grains sucked by *L. zonatus*.

Most reproductive variables did not vary significantly between the maize cultivars, except ear diameter and number of commercial ears, which were significantly higher in AG1051 (Table 3). The number of grains sucked by *L. zonatus* was significantly lower in Milhão, while there was no significant difference among intercropping systems for any of these variables (Table 3).

DISCUSSION

The AG1051 maize has a greater requirement of water, light and nutrients to express than the Milhão maize, that is adapted to local conditions (Carpentieri-Pípolo *et al.* 2010; Catão *et al.* 2010; Edwards 2016). Milhão plants were able to develop more and reach a greater total and ear insertion height. However, stalk diameter was thicker in AG1051 maize. This is an important variable for the support and structure of the plant, as narrower stalks increase the risk of the plant lodging and toppling (Kamran *et al*. 2018), as we observed in some of our Milhão plants, with approximately 1.6% toppling.

In a study evaluating the effect of soil cover under organic cultivation in the southeastern state of Espirito Santo (Favarato *et al*. 2016), AG1051 maize showed slightly higher values for plant height, ear insertion height and stem diameter than in this study. Our lower values may be owed to that the study was carried out in the period from the end of the rainy season to the start of irrigation, and to the use of conventional tillage, possibly raising the soil temperature due to the absence of soil cover, affecting the phytotechnical components of the crop. In the second year of cultivation comparing conventional and organic cultivation in the southeastern state of São Paulo, Santos *et al*. (2015) obtained values similar to ours for total and ear insertion height in AG1051, which was explained by the effect of temperature delaying the cycle. Lower values for total plant height and ear insertion height in AG1051 were obtained in a study testing the effect of different planting densities on maize cultivars in the northeastern state of Piauí (Rocha *et al*. 2011), and when cultivating the hybrid as a monocrop and intercropped with cowpea in the Amazonian state of Pará (Silva *et al*. 2020). Regarding the Milhão variety, we obtained higher plants than those obtained by Barbosa *et al*. (2016) for two other maize criole in the southern state of Paraná.

Table 2. Vegetative characteristics of two maize cultivars (AG1051 hybrid green maize and Milhão criole maize) cultivated as monocrops or intercropped with sorghum or millet in the Amazon savannah in Roraima state, Brazil, in 2020. Values are the mean of four replicates ± standard deviation. TPH = total plant height; LFH = flag leaf height; EIH = ear insertion height; NLBE = number of green leaves below the ear; NLAE = number of green leaves above the ear; SD = stem diameter.

Variable	Maize cultivar	Intercropping system					CV (%)
		No intercrop	Dwarf sorghum	Forrage sorghum	Millet	Mean	
TPH (cm)	AG1051	228.7 ± 13.2	229.6 ± 20.1	234.6 ± 17.6	224.0 ± 26.3	**229.2 ± 18.2 b**	5.8
	Milhão	314.8 ± 9.0	314.9 ± 7.2	311.6 ± 15.2	308.6 ± 5.8	**312.5 ± 9.3 a**	
	Mean	**271.8 ± 47.2 A**	**272.2 ± 47.7 A**	**273.1 ± 43.9 A**	**266.3 ± 48.6 A**		
LFH (cm)	AG1051	196.2 ± 14.8	191.4 ± 15.6	204.1 ± 6.4	195.6 ± 12.9	**196.8 ± 12.5 b**	6.0
	Milhão	283.8 ± 12.3	289.3 ± 7.0	293.0 ± 29.6	285.9 ± 5.9	**288.0 ± 15.3 a**	
	Mean	**240.0 ± 48.5 A**	**240.4 ± 53.5 A**	**248.6 ± 51.5 A**	**240.8 ± 49.2 A**		
EIH (cm)	AG1051	126.7 ± 2.4	118.6 ± 8.0	129.6 ± 5.8	116.7 ± 9.9	**122.9 ± 8.4 b**	5.8
	Milhão	194.1 ± 3.2	182.3 ± 12.1	196.4 ± 11.3	184.8 ± 10.3	**189.4 ± 10.8 a**	
	Mean	**160.4 ± 47.7 A**	**150.5 ± 45.0 A**	**163.0 ± 47.2 A**	**150.7 ± 48.1 A**		
NLBE (unit)	AG1051	7 ± 0.5	6 ± 0.4	7 ± 0.7	7 ± 0.6	**6.8 ± 0.6 a**	9.1
	Milhão	7 ± 0.5	7 ± 0.7	7 ± 1.4	6 ± 0.6	**6.6 ± 0.8 a**	
	Mean	**7 ± 0.6 A**	**6.5 ± 0.6 A**	**7 ± 1.0 A**	**6.5 ± 0.6 A**		
NLAE (unit)	AG1051	5 ± 0.2	5 ± 0.3	5 ± 0.4	5 ± 0.2	**5 ± 0.3 b**	6.4
	Milhão	7 ± 0.2	7 ± 0.3	7 ± 0.6	7 ± 0.7	**7 ± 0.5 a**	
	Mean	**6 ± 0.7 A**	**6 ± 1.0 A**	**6 ± 0.9 A**	**6 ± 1.2 A**		
SD (cm)	AG1051	2.4 ± 0.2	2.1 ± 0.2	2.5 ± 0.2	2.0 ± 0.3	**2.3 ± 0.3 a**	12.0
	Milhão	2.1 ± 0.3	2.0 ± 0.1	2.0 ± 0.3	1.9 ± 0.1	**2.0 ± 0.2 b**	
	Mean	**2.3 ± 0.3 A**	**2.0 ± 0.2 A**	**2.2 ± 0.4 A**	**2.0 ± 0.2 A**		

For each variable, means followed by the same lowercase letter in a column and by the same uppercase letter in a row do not differ statistically at 5% probability according to a F-test for maize and Tukey's test for intercropping systems, respectively.

Ear length in the AG1051 cultivar in our study was similar to that obtained by Rocha *et al*. (2011) at the same cultivation density in Piauí state. However, our total number of ears for AG1051 was 40% lower than Rocha *et al*. (2011) and 70% lower than in Santos *et al*. (2015) in São Paulo State, which was likely due to the smaller plant spacing used in our study (0.4 m) relative to that used by Santos *et al*. (2015) (1.0 m) and by Rocha *et al*. (2011) (0.6 m). Better adjustment may therefore also improve productivity. In this context, although AG1051 maize has been genetically improved to achieve high levels of ear quality and yield (Edwards 2016), under the conditions of our experiment, Milhão achieved similar characteristics to the hybrid in ear length, number of grains per ear, cob diameter, ear weight and total number of ears.

The maximization of total and commercial ear yield is a desirable trait in green maize, as its ears are sold as whole product (Santos *et al*. 2015). Our mean yields for total ear production of 17,430 kg ha^{-1} for the AG1051 cultivar and 15,600 kg ha^{-1} for the Milhão cultivar were both superior to that obtained for the DBK 615 green maize hybrid in monocrop (14,026 kg ha^{-1}) and intercropped with *Brachiaria* sp (13,285 kg ha^{-1}) (Sousa *et al*. 2015).

Ear diameter was greater in the AG1051 maize than in the Milhão maize, probably owed to targeted genetic improvement of the hybrid. However, an enlarged ear may also be the reason for the feeding preference of pests for the hybrid, as indicated by the higher number of grains sucked by the leaf-footed bug in our study. Another characteristic that may explain this difference is that the ears of Milhão had fuller husks than those of the hybrid (personal observation, data not shown), which can make the insect attack more difficult.

We observed that some of the ears of the Milhão maize were uneven in terms of size and grain production, due to genetic variability (Catão *et al.* 2010), which was indicated by the lower number of commercial ears than AG1051 maize. This compromises the marketing of the green maize on a large scale due to the market standard for ear uniformity (Catão *et al.* 2010). Due to this characteristic and to its above-ground height around 3 m, Milhão is more recommended for forage production. Further studies on the Milhão cultivar should aim at obtaining a better green ear quality, by reducing plant density relative to what was used here.

In another study evaluating maize varieties, criole cultivars achieved superior phytotechnical characteristics, as well as low infestations by *L. zonatus*, compared to transgenic and conventional cultivars (Marega and Almeida Marques 2021). Greater attention is required in managing the pest, especially knowledge of its behaviour and its preference for maize, as well as in the search for cultivars that are more resistant to attack by the bug, since there are no records of any pesticides for its control (Brasil 2022).

Table 3. Reproductive characteristics of two maize cultivars (AG1051 hybdrid green maize and Milhão criole maize) cultivated as monocrops or intercropped with sorghum or millet and susceptibility to attack by leaf-footed bug (*Leptoglossus zonatus*) in the Amazon savannah in Roraima state, Brazil, in 2020. Values are the mean of four replicates ± standard deviation. EL = ear length; ED = ear diameter; NGE = number of grains per ear; CD = cob diameter, EW = ear weight; NCE = number of commercial ears; TNE = total number of ears and NGS = number of grains sucked by the leaf-footed bug.

Variable	Maize cultivar	Intercropping system					CV(%)
		No intercrop	Dwarf sorghum	Forrage sorghum	Millet	Mean	
EL (cm)	AG1051	19.4 ± 1.3	19.1 ± 1.3	19.3 ± 0.8	19.2 ± 1.8	**19.2 ± 1.2 a**	8.1
	Milhão	20.7 ± 1.6	19.7 ± 0.8	18.3 ± 2.6	20.9 ± 0.9	**19.9 ± 1.8 a**	
	Mean	**20.0 ± 1.5 A**	**19.4 ± 1.0 A**	**18.8 ± 1.8 A**	**20.0 ± 1.6 A**		
ED (cm)	AG1051	4.4 ± 0.1	4.3 ± 0.2	4.3 ± 0.1	4.3 ± 0.3	**4.3 ± 0.2 a**	4.9
	Milhão	4.1 ± 0.1	4.1 ± 0.2	3.9 ± 0.3	4.1 ± 0.1	**4.0 ± 0.2 b**	
	Mean	**4.2 ± 0.2 A**	**4.2 ± 0.2 A**	**4.1 ± 0.3 A**	**4.2 ± 0.2 A**		
NGE (unit)	AG1051	560.5 ± 44.8	548.2 ± 40.5	528.8 ± 38.7	553.1 ± 65.3	**547.7 ± 45.1 a**	14.1
	Milhão	524.8 ± 49.2	515.5 ± 35.5	466.8 ± 166.9	523.7 ± 57.1	**507.7 ± 87.0 a**	
	Mean	**542.7 ± 47.6 A**	**531.9 ± 39.3 A**	**497.8 ± 117.0 A**	**538.4 ± 58.9 A**		
CD (cm)	AG1051	1.0 ± 0.2	0.9 ± 0.2	0.9 ± 0.3	0.8 ± 0.3	**0.9 ± 0.2 a**	19.9
	Milhão	0.9 ± 0.1	0.9 ± 0.1	1.0 ± 0.2	0.9 ± 0.1	**0.9 ± 0.1 a**	
	Mean	**0.9 ± 0.2 A**	**0.9 ± 0.1 A**	**0.9 ± 0.2 A**	**0.9 ± 0.2 A**		
EW (g)	AG1051	223.0 ± 17.5	219.1 ± 27.5	207.9 ± 16.7	220.0 ± 39.6	**217.5 ± 24.8 a**	14.3
	Milhão	213.5 ± 9.9	203.5 ± 18.2	180.6 ± 51.6	223.1 ± 20.4	**205.2 ± 31.1 a**	
	Mean	**218.2 ± 14.1 A**	**211.3 ± 23.1 A**	**194.3 ± 38.4 A**	**221.5 ± 29.2 A**		
NCE (thousand ha^{-1})	AG1051	12.3 ± 2.6	12.6 ± 1.8	10.6 ± 2.2	12.1 ± 6.9	**11.9 ± 3.6 a**	37.1
	Milhão	6.5 ± 1.4	5.2 ± 0.8	3.5 ± 3.0	6.9 ± 1.5	**5.5 ± 2.1 b**	
	Mean	**9.4 ± 3.6 A**	**8.8 ± 4.1 A**	**7.0 ± 4.5 A**	**9.5 ± 5.3 A**		
TNE (thousand ha^{-1})	AG1051	17.7 ± 3.2	18.8 ± 1.5	16.2 ± 1.6	17.1 ± 6.6	**17.4 ± 3.5 a**	26.6
	Milhão	18.2 ± 1.9	15.0 ± 4.2	12.9 ± 7.0	16.3 ± 3.3	**15.6 ± 4.5 a**	
	Mean	**17.9 ± 2.4 A**	**16.9 ± 3.5 A**	**14.5 ± 5.0 A**	**16.7 ± 4.8 A**		
NGS (unit)	AG1051	21.4 ± 10.5	24.3 ± 23.7	40.4 ± 18.6	28.5 ± 21.3	**28.6 ± 18.7 a**	66.3
	Milhão	14.8 ± 13.0	10.4 ± 4.5	9.7 ± 6.0	12.4 ± 7.6	**11.8 ± 7.8 b**	
	Mean	**18.1 ± 11.5 A**	**17.3 ± 17.5 A**	**25.0 ± 20.8 A**	**20.4 ± 17.1 A**		

For each variable, means followed by the same lowercase letter in a column and by the same uppercase letter in a row do not differ statistically at 5% probability according to a F-test for maize and Tukey's test for intercropping systems, respectively.

CONCLUSIONS

The northern Amazonian maize ethnovariety Milhão had a longer cycle, higher plants and narrower stem diameter that caused plant lodging compared to the AG1051 hybrid green maize cultivar. The use of intercropping systems with dwarf sorghum, forage sorghum and millet had no effect on the phytotechnical performance, nor on the susceptibility to attack by the leaf-footed bug of either cultivar in an experimental plantation in the Amazon savannah. Milhão does not differ from AG1051 in ear quality, ear length, number of grains per ear, cob diameter, ear weight or total number of ears, but had both lower yield of commercial ears and lower infestation by the leaf-footed bug. Due to its greater height and uneven ear quality, Milhão cultivation is recommended for production as a forage species.

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SUPPLEMENTARY MATERIAL (only available in the electronic version)

Hermógenes *et al*. Phytotechnical performance and resistance to leaf-footed bugs of green maize intercropped with Poaceae in the Amazon savannah

Table S1. History of cultivation and fertilisation in the experimental area in the Amazon savannah in Roraima state (Brazil) prior to the experiment set up for this study.

Period	Crop	Fertiliser
Jun 2009 - Sep 2010	Cassava	–
Oct 2010 - Aug 2011	Cassava	• Dolomitic limestone (TRNP corrected to 100%): 1500 kg ha^{-1}; • Ammonium Sulphate: 30 kg ha^{-1} N + 33 kg ha^{-1} S; • Triple superphosphate: 60 kg ha^{-1} P_2O_5; • Single superphosphate: 20 kg ha^{-1} P_2O_5; • Potassium chloride: 70 kg ha^{-1} K_2O; • FTE-BR12: 50 kg ha^{-1}
Oct 2011 - Apr 2013	Cassava	–
May - Jul 2013	Cowpea	• Dolomitic limestone (TRNP corrected to 100%): 1000 kg ha^{-1}; • Potassium chloride: 90 kg ha^{-1} K_2O; • Single superphosphate: 90 kg ha^{-1} P_2O_5; • FTE-BR12: 50 kg ha^{-1}
Aug 2013 - Apr 2014	Cassava	–
May - Jul 2014	Maize	–
Aug - Sep 2014	Fallow	–
Oct 2014 - Oct 2015	Cassava	• Dolomitic limestone (TRNP corrected to 100%): 380 kg ha^{-1}; • Urea: 50 kg ha^{-1} N; • Potassium chloride: 70.3 kg ha^{-1} K_2O; • Single superphosphate: 180 kg ha^{-1} P_2O_5; • FTE-BR12: 28.38 kg ha^{-1}
Nov 2015 - Apr 2016	Fallow	–
May - Jul 2016	Cowpea	• Dolomitic limestone (TRNP corrected to 100%): 1000 kg ha^{-1}; • Potassium chloride: 60 kg ha^{-1} K_2O; • Triple superphosphate: 70 kg ha^{-1} P_2O_5; • FTE-BR12: 30 kg ha^{-1}
Aug - Oct 2016	Maize	• Formula 4 - 14 - 8: 600 kg ha^{-1} NPK; • Ammonium sulphate: 100 kg ha^{-1} N and 120 kg ha^{-1} S; • Urea: 100 kg ha^{-1} N; • Potassium Chloride: 200 kg ha^{-1} K_2O; • FTE-BR12: 50 kg ha^{-1}
Nov 2016 - Jul 2017	Fallow	–
Aug 2017 - Jan 2018	Soya	• Dolomitic limestone (TRNP corrected to 100%): 140 kg ha^{-1} • Agricultural gypsum: 3,000 kg ha^{-1}; • Triple superphosphate: 102 kg ha^{-1} P_2O_5; • Potassium Chloride: 102 kg ha^{-1} K_2O; • FTE-BR12: 50 kg ha^{-1}
Feb – Jul 2018	Fallow	–
Aug – Nov 2018	Maize and sorghum	• Dolomitic limestone (TRNP corrected to 100%): 600 kg ha^{-1}; • Urea: 90 kg ha^{-1} N; • Ammonia Sulphate: 30 kg ha^{-1} N and 33 kg ha^{-1} S; • Potassium Chloride: 90 kg ha^{-1} K2O; • Single superphosphate: 200 kg ha^{-1} P2O5; • Triple superphosphate: 60 kg ha^{-1} P2O5; • FTE-BR12: 50 kg ha^{-1}
Dec 2018 – Jul 2019	Fallow	–
Aug – Nov 2019	Maize and velvel bean	• Dolomitic limestone (PRNT corrected to 100%): 1400 kg ha^{-1}; • Urea: 140 kg ha^{-1} N; • Ammonia Sulphate: 60 kg ha^{-1} N and 66 kg ha^{-1} S; • Potassium Chloride: 200 kg ha^{-1} K2O; • Triple superphosphate: 120 kg ha^{-1} P2O5; FTE-BR12: 50 kg ha^{-1}
Dec 2019 – Jul 2020	Fallow	–