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Performance of corn hybrids in two locations in the northern Goiás

Luciana Borges e Silva[1], Wilian Henrique Diniz Buso[1]

[1] Instituto Federal Goiano, Campus Ceres, Ceres, Goiás, Brazil. E-mail: luciana.silva@ifgoiano.edu.br, wilian.buso@ifgoiano.edu.br

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ABSTRACT

The research aimed to evaluate the agronomic and yield traits of corn hybrids in two locations. The randomized blocks design arranged in an 11x2 factorial scheme (11 hybrids and two locations) with four replications was used. Each plot consisted of four rows of five meters. The evaluations took place in the two central rows leaving 0.50 m as a border at the ends. The variables analyzed were plant height, first ear insertion height, ear diameter, ear length, number of grain rows per ear, number of grains per row, 1000-grain weight, and grain yield. The corn hybrids adapted better in Santa Isabel. Regarding grain yield, in Santa Isabel, the hybrids were more adapted, and in Campinorte, the hybrid MG 711 PWU was the one that obtained the best performance. The MG 580 PWU hybrid presented the worst result in both locations.

Keywords: *Zea mays,* Genotype by environment interaction, Yield.

Desempenho de híbridos de milho em dois municípios do norte Goiano

RESUMO

Objetivou-se com a pesquisa avaliar os caracteres agronômicos e produtivos de híbridos de milho em dois locais. O delineamento experimental utilizado foi de blocos casualizados em esquema fatorial 11x2 (11 híbridos e dois locais) com quatro repetições. Cada parcela foi constituída por quatro linhas de cinco metros. As avaliações ocorreram nas duas linhas deixando 0,50 m de bordadura nas extremidades. As variáveis analisadas foram: altura de planta, altura da primeira espiga, diâmetro da espiga, número de fileira de grãos, número de grãos por fileira, comprimento da espiga, massa de mil grãos e produtividade. Os híbridos de milho se adaptaram melhor no município de Santa Isabel. Em relação a produtividade, no município de Santa Isabel os híbridos apresentaram mais adaptados e em Campinorte o híbrido MG 711 PWU foi que obteve melhor desempenho. O hibrido MG 580 PWU apesentou o pior resultado para os dois locais.

Palavras-chave: *Zea mays,* Genótipo x Ambiente, Produtividade.

1. Introduction

Corn (*Zea mays* L.) is a crop of great importance in Brazilian agribusiness. The cereal is present in various sectors of agriculture and livestock in the country due to its high nutritional value and wide use in products such as fuels, beverages, polymers, etc. (Miranda, 2018). Its grain yield has been important in Brazilian agribusiness, influencing the national and international economy. According to Conab (2021), corn grain yield in 2020/2021 harvest was 4,365 kg ha^{-1}, about 21% lower than that observed in the previous harvest. The drop in the estimate of corn yield is due to the delay in planting soybeans due to uneven rainfall at the beginning of the first harvest and the rainfall that slowed down the soybean harvest period, reflecting the delay in planting corn areas.

Due to its genetic diversity, corn has numerous cultivars adapted to different soil and climate regions and cultivated throughout the national territory (Abreu et al., 2019). According to Souza (2018), approximately 90% of corn planted areas in Brazil are mainly derived from hybrid seeds, especially single and triple hybrids, since they present higher yields and uniformity. Identifying hybrids adapted to the soil and climate conditions of each growing region helps the farmer obtain high grain yields and, therefore, greater economic returns (Silva et al., 2015). Thus, periodic monitoring of hybrids in the growing region is advised to support the farmer in decision-making.

Thus, the analysis between genotypes and environments is necessary to evaluate the interaction, which consists of the disparity in the performance of materials promoted by environmental changes (Oliveira et al., 2019). Considering the interaction between genotypes and environments, there is difficulty in safely establishing the materials (Pacheco et al., 2017). Thus, studies allow the recommendation of cultivars for exact regions and growing conditions (Uate et al., 2019). To achieve high yields, the producer must use hybrids adapted to the soil and climate conditions of each growing region. Therefore, the present research aimed to evaluate the agronomic and yield traits of corn hybrids in two locations in Northern Goiás.

2. Material and Methods

The experiments were carried out during the summer season, in two locations in the Northern region of the state of Goiás, namely Campinorte, at Farm Três Irmãos (14º29'70.03” S, 49º.08'11.07” W, and elevation of 537 m) and Santa Isabel, at Fazenda Jenipapo (15º29’05.10” S, 49º41’93.46” W, and elevation of 641 m). The average temperature and precipitation in the two locations are shown in Figures 1 and 2. The soil management followed the conventional system, with one plowing and two harrowings. Sowing in Campinorte and Santa Isabel was carried out manually on 11/09/2020 and 11/10/2020, respectively. In both locations, sowing fertilization was carried out with 16 kg ha^{-1} of N, 120 kg ha^{-1} of P_2O_5, and 40 kg ha^{-1} of K_2O, using the NPK formulation 04-30-10. The seeds of all hybrids received treatment in the industry.

Weed control was carried out with glyphosate application at a dose of 3 L ha^{-1} 30 days after sowing. For the control of leafhopper (*Dalbulus maidis*), the insecticide acetamiprid + bifenthrin was used at a dose of 300 g ha^{-1}, for gray leaf spot (*Cercospora zeae*-maydis) and phaeosphaeria leaf spot (*Phaeosphaeria maydis*), azoxystrobin + cyproconazole were used as a preventive method, at a dose of 300 mL ha^{-1}. In all sprayings, the spray volume of 150 L ha^{-1} was used. In both locations, topdressing fertilization was carried out 30 days after sowing, with 250 kg ha^{-1} of N (urea).

The randomized block design arranged in an 11x2 factorial scheme with four replications was used. Eleven hybrids (MG 607PWU, MG 711PWU, MG 545PWU, MG 593PWU, CNB 16C130PWU, DKB 363PRO3, MG 580PWU, AG 7098PRO2, MG 408PWU, MG 515P, and MG 515P) were evaluated in two locations (Campinorte and Santa Isabel). Each plot consisted of four rows of five meters with a spacing of 0.50 m between rows and three plants per meter. The evaluations were carried out in three random plants, collected in the two central rows of each experimental unit, leaving 0.50 m as the border at the ends, and measured similarly to that described by Carvalho et al. (2014).

The variables analyzed were plant height (PH): determined by measuring the distance from the soil surface to the apex of the plant with the aid of a tape measure; first ear eight (EH): measuring the distance from the soil surface to the ear insertion node with the aid of a tape measure; ear diameter (ED): measured in the middle third of the ear with the aid of a digital caliper; number of grain row per ear (GRN): count of the number of rows of grains on the ear, number of grains per row (NGR): count of the number of grains per row on the ear, from the base to the tip of the ear, ear length (EL): measured from the basal end to the apex of the ear, with the aid of a graduated ruler; 1000-grain weight (1000W): trait determined through the sampling of 400 grains counted and weighed, where later, the calculation was carried out to obtain the 1000-grain weight and grain yield (kg ha^{-1}).

The harvest was carried out on 04/09/2021 in Campinorte and on 04/10/2021 in Santa Isabel. All ears of the two central rows were harvested, disregarding 0.50 m at each end. The material was threshed with a manual thresher and then weighed to determine grain yield on a precision scale.

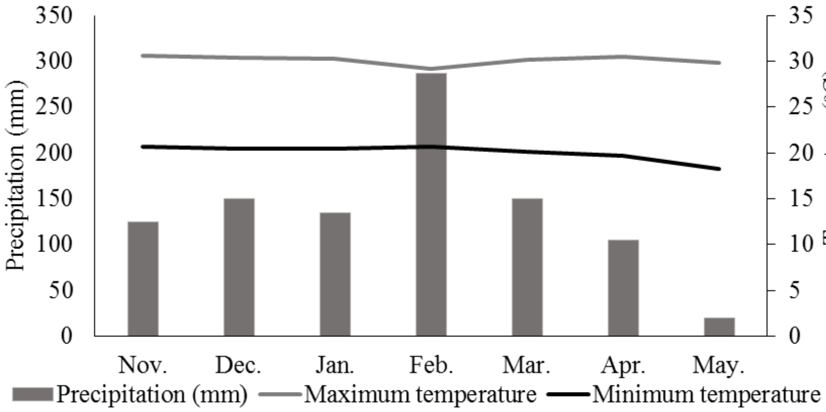

Figure 1. Weather data in Campinorte during the experimental period (Nov/20 to May/21). Source: Agritempo (2021)

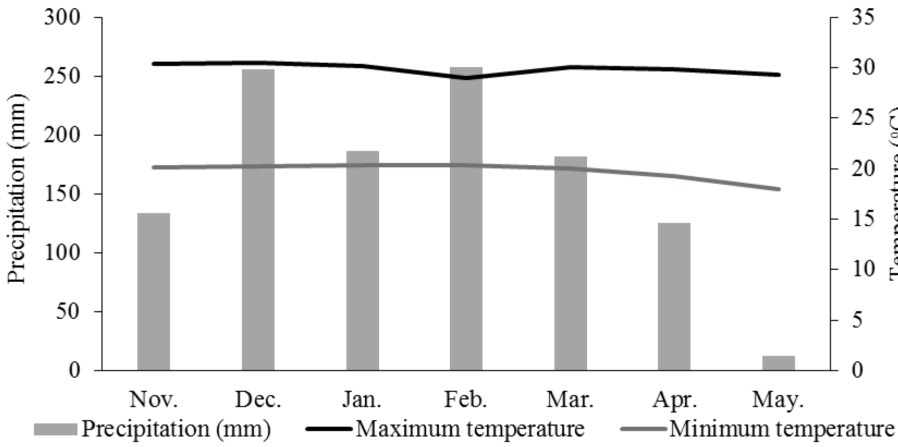

Figure 2. Weather data in Santa Isabel during the experimental period (Nov/20 to May/21). Source: Agritempo (2021).

Data were submitted for the analysis of variance. The means from hybrids were grouped using the Scott Knott test at a 5% significance level. For the comparison between locations, a multivariate analysis was performed for grain yield. The analyzes were performed using the R software (R Development Core Team, 2014) with the easyanova package (Arnhold, 2013).

3. Results and Discussion

The ANOVA summary (Table 1) shows significant interactions between locations and hybrids for the first ear height, ear length, and the number of grains per row. For plant height, the number of grain rows, and grain yield differed for the locations. Ear diameter and 1000-grain weight were different for the hybrids. Significant differences were observed between locations for the variable plant height (PH) (Tables 1 and 2). It observed higher PH (2.55 m) in Santa Isabel compared to Campinorte (2.15 m). This difference can be explained by the climatic data (Figures 1 and 2) since in Santa Isabel occurred higher precipitation due to the 13-day drought in the Campinorte region between 01/20/2021 to 02/01/2021. According to Silva et al. (2021), the water deficit in the plant from the tasseling stage causes poor ear formation, low yield, and reduced leaf area, thus limiting the development and grain yield of the crop.

Another factor that possibly influenced the difference in this variable was the altitude since Santa Isabel (641 m) is located at a higher altitude than Campinorte (537 m). According to Bergamaschi and Matzenauer (2014), altitude directly affects temperature day and night, affecting photosynthesis and spiration. For Brazilian conditions, corn planted at higher altitudes has a greater number of days to reach the tasseling stage, increasing the cycle and presenting greater grain yield, considering that temperature, water availability, soil fertility, solar radiation, and photoperiod influence the development and growth of plants. Thus, it is possible to explain which aspects were responsible for the change in the development of the corn crop.

There was no difference between the locations for ear diameter; however, for the hybrids, higher averages were observed for MG 711PWU, MG 580PWU, and MG 607PWU, whose values were 5.06; 5.20, and 5.07 cm, respectively (Table 2).

Table 1. Mean squares of plant height (PH), first ear height (HE), ear diameter (ED), ear length (EL), number of grain rows per ear (GRN), number of grains per row (NGR), 1000-grain weight (1000W), and grain yield (YLD) of corn hybrids in two locations in the Northern Goiás.

Variables	Mean square			
	Local	Hybrid	H x L	Error
PH	2.6400 *	0.0081 ns	0.0124 ns	0.0087
HE	0.7424 *	0.0411*	0.0199 *	0.0081
ED	0.3361 ns	13.2561*	1.6443 ns	2.8220
EL	1,906.2438 *	446.0057 *	232.7178 *	92.0979
GRN	67.2458 *	4.7543 ns	4.1002 ns	3.1465
NGR	3.2607 ns	13.4202 ns	12.3959 *	4.4121
1000W	30.9350 ns	3,629.0499 *	110.6122 ns	348.9278
YLD	28383811.0 *	1881680.0 ns	902153.0 ns	1150479.5
DF[2]	1	10	10	42

[1]ns = not significant, *significant at 5%. [2] DF = degrees of freedom

Table 2. Mean values of plant height (PH), ear diameter (ED), number of rows of grains per ear (GRN), 1000-grain weight (1000W), and grain yield (YLD) of corn hybrids in two locations in the Northern Goiás.

Locations	PH (m)	ED (cm)	GRN (un)	1000W (g)	YLD (kg ha^{-1})
Campinorte	2.15 b	4.90 a	14.44 b	356.74 a	7,670 b
Santa Isabel	2.55 a	4.92 a	16.46 a	355.37 a	8,982 a
Hybrid	PH (m)	ED (cm)	GRN (cm)	1000W (g)	YLD (kg ha^{-1})
DKB 363PRO3	2.33 a	4.77 b	15.89 a	379.36 a	8,911 a
AG 7098PRO2	2.37 a	4.80 b	15.44 a	359.33 b	7,839 b
MG 593PWU	2.32 a	4.91 b	14.50 a	360.85 b	7,973 b
MG 711PWU	2.35 a	5.06 a	14.83 a	327.04 c	8,710 a
MG 545PWU	2.35 a	4.94 b	15.89 a	395.26 a	8,799 a
CNB 16130PWU	2.31 a	4.88 b	15.22 a	334.82 c	8,777 a
MG 580PWU	2.30 a	5.20 a	16.56 a	364.23 b	8,821 a
MG 408PWU	2.39 a	4.72 b	15.00 a	379.96 a	7,504 b
MG 515PWU	2.43 a	4.90 b	17.33 a	312.74 c	7,883 b
MG 607PWU	2.35 a	5.07 a	14.67 a	357.97 b	8,777 a
JM 2M91PRO3	2.35 a	4.78 b	14.67 a	344.97 c	7,593 b
CV (%)	3.96	3.42	11.48	5.25	12.88

Means followed by the same uppercase letter in the line and lowercase in the column belongs to the same group by the Scott Knott test at 5% probability.

This variable (Table 2), can increase the number of grain rows and/or greater grain depth in the ear, resulting in grain yield increases. He et al. (2014) argue that ear diameter and height are significant traits for obtaining genotypes with higher grain yield. The ear diameter causes an increase in the number of grain rows per ear and consequently increases the number of grains per ear, resulting in higher grain yield (Homayoun, 2011). According to Edwiges et al. (2017), the presentation of specificities for each hybrid analyzed occurs because they are commercial hybrids that have traits defined in the plant breeding program of each company.

Comparing the locations in the expression of the number of grain rows (GRN), it is observed that there were differences between the locations, as shown in Table 2, considering that in Campinorte, this variable was lower (14.44) compared to the result obtained in Santa Isabel (16.46). The increments in the size of the ears (length and diameter) are due to the observed increases in the number of rows and of grains/rows. Such increases can be attributed to better vegetative development (height and diameter of the plant). However, lower GRN can result in ears with smaller diameters, which can be detrimental to the hybrid's yield potential (Guerra et al., 2017).

The mass of one thousand grains (1000W) was the same in the locations and different for the hybrids (Table 2) with emphasis on DKB 363PRO3, MG 545PWU, and MG 408PWU, whose values were 379.36; 395.26, and 379.96 g, respectively. 1000M is an essential factor of production, as it contributes to productivity increases, and many hybrids with a high value of 1000M also tend to be very productive.. According to Kvitschal et al. (2010), the occurrence of differences in the 1000-grain weight is related to the texture of the grains, and hybrids with semi-hard and hard grains have higher mass.

As for grain yield, there was a difference between the locations, as shown in Figure 3. In Campinorte, the hybrid MG 711 PWU showed the best adaptability. In Santa Isabel, the hybrids showed better adaptation. The MG 580 PW hybrid was worse in both locations than in the negative quadrant of Figure 3. According to Buso and Arnhold (2016), factors such as water deficit and genetic differences of the hybrids contribute to the adaptation in the regions resulting in different responses to the locations.

For the hybrids, those with the highest productivity were DKB 363PRO3, MG 711PWU, MG 545PWU, CNB 16130PWU, MG 580PWU, and MG 607PWU, with an average of 8,799.16 kg ha^{-1} of grains. However, it is important to emphasize that the general productivity average was higher than the average of the last crop in the state of Goiás, with 8,280 kg ha^{-1} of grains produced (CONAB, 2021). It should be noted that the use of hibrids that best adapt to growing conditions can achieve higher grain yields (Silva et al., 2015). In work by Buso et al. (2019), when evaluating 11 hybrids in three regions of Goiás (Itapaci, Campinorte, and Itaberaí), reported that grain yield is a trait that is not significantly heritable and sensitive to climatic conditions, mainly when they occur in the period of the definition of grain yield potential and the flowering phase and grain filling.

A significant interaction was observed between the locations and the hybrids concerning the height of the first ear (Table 3) since the highest heights occurred in Santa Isabel in the hybrids DKB 363PRO3 (1.27 m); AG 7098PRO2 (1.59 m); MG 711PWU (1.46 m); CNB 16130PWU (1.38 m); MG 515PWU (1.55 m); MG 607PWU (1.51 m). Among the hybrids evaluated in Campinorte, except DKB 363PRO3 (0.96 m), which was lower, there were no significant differences for this variable for the other hybrids (Table 3). Regarding Santa Isabel, the hybrids AG 7098PRO2 (1.59 m), MG 711PWU (1.46 m), MG 515PWU (1.55 m), and MG 607PWU (1.51 m) reached an average of 1.53 m, being superior to the others. It is correct to say that plant height positively correlates with ear insertion height.

According to Cabral et al. (2016), this is part of the plant's physiological structure, as the taller the plant, the greater the height of insertion of the ear into the stem, which allows for the mechanization of the crop. Therefore, taller plants with a higher first ear insertion height also have advantages in mechanized harvesting. Campos et al. (2010), when evaluating 49 corn cultivars during the off-season in five municipalities in Goiás, observed differences in plant height according to the location of the experiment, concluding that the humidity and temperature of each location interfere with plant height and ear insertion.

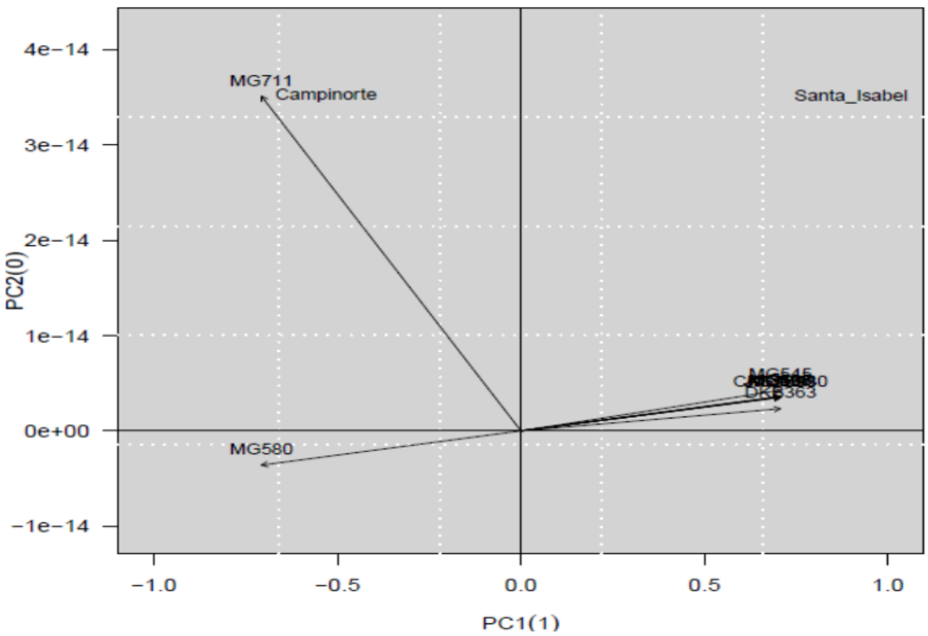

Figure 3. Multivariate analysis of corn hybrids in two locations in Northern Goiás (Santa Isabel and Campinorte).

Table 3. Interaction between hybrids and locations for first ear insertion height (m).

Hybrids	Locations	
	Campinorte	Santa Isabel
DKB 363PRO3	0.96 Bb	1.27 Ab
AG 7098PRO2	1.21 Ba	1.59 Aa
MG 593PWU	1.23 Aa	1.34 Ab
MG 711PWU	1.18 Ba	1.46 Aa
MG 545PWU	1.29 Aa	1.31 Ab
CNB 16130PWU	1.17 Ba	1.38 Ab
MG 580PWU	1.18 Aa	1.33 Ab
MG 408PWU	1.17 Aa	1.29 Ab
MG 515PWU	1.27 Ba	1.55 Aa
MG 607PWU	1.16 Ba	1.51 Aa
JM 2M91PRO3	1.19 Aa	1.32 Ab
CV (%)	6.97	

Means followed by the same uppercase letter in the line and lowercase in the column belongs to the same group by the Scott Knott test at 5% probability.

Table 4. Interaction between hybrids and locations for the ear length (cm).

Hybrids	Locations	
	Campinorte	Santa Isabel
DKB 363PRO3	17.10 Aa	16.91 Aa
AG 7098PRO2	15.18 Ab	16.27 Aa
MG 593PWU	13.97 Ab	13.92 Ab
MG 711PWU	14.43 Ab	15.26 Ab
MG 545PWU	15.78 Ba	17.67 Aa
CNB 16130PWU	13.99 Bb	16.78 Aa
MG 580PWU	16.10 Aa	14.85 Ab
MG 408PWU	15.54 Aa	16.44 Aa
MG 515PWU	14.94 Ab	16.54 Aa
MG 607PWU	14.30 Ab	15.71 Ab
JM 2M91PRO3	14.81 Bb	17.86 Aa
CV (%)	6.08	

Means followed by the same uppercase letter in the line and lowercase in the column belongs to the same group by the Scott Knott test at 5% probability.

The interaction between locations and corn hybrids significantly influenced ear length (EL) (Table 4). For this variable, the hybrids MG 545PWU (15.78 and 17.67 cm), CNB 16130PWU (13.99 and 16.78 cm), and JM 2M91PRO3 (14.81 and 17.86) showed lower EL in Campinorte than in Santa Isabel, respectively, according to Table 4. EL can directly interfere with the number of grains per row and, consequently, with corn grain yield. Therefore, the choice of cultivars with greater ear length is indicated for higher crop yields (Pizolato Neto et al., 2016), as observed in the hybrid CNB 16130PWU, which presented values higher than the variables: ear length (Table 4), number of grains per row (Table 5) and yield (Table 2) in the municipality of Santa Isabel. However, the results presented here (Table 4) differ from the statements by Silva et al. (2019), in which they state that the selection of taller plants can result in larger and heavier ears; thus, the length of the ear can directly interfere in the number of grains per row and, consequently, in corn grain yield. Buso et al. (2019) observed that EL was the variable that most correlated with productivity, whose correlation coefficient was 0.61.

The interaction between locations and hybrids influenced the number of grains per row (NGR). The hybrids CNB 16130PWU (39.89), MG 580PWU (31.33), and MG 408PWU (31.44) showed the highest NGR in Santa Isabel when compared to Campinorte, as shown in Table 5; the others were statistically equal in both locations. In Campinorte, the hybrids did not show statistical differences for NGR. In Santa Isabel, the hybrid CNB 16130PWU presented the highest NGR, whose value was 39.89 grains. The hybrids DKB 363PRO3 and MG 607PWU were statistically inferior, with averages of 36.00 and 36.78 grains per row, respectively. This variable is important because it can directly influence hybrid grain yield; thus, as the number of grains per row increases, there are more grains per ear, resulting in higher grain yield (Gomes et al., 2019). In studies carried out by Vilela et al. (2012), the authors found a difference in this production component among six hybrids evaluated and supported that NGR is related to the average ear length.

Table 5. Interaction between hybrids and locations for the number of grains per row (NGR)

Hybrids	Locations	
	Campinorte	Santa Isabel
DKB 363PRO3	35.45 Aa	36.00 Ab
AG 7098PRO2	35.44 Aa	32.22 Ac
MG 593PWU	35.22 Aa	32.22 Ac
MG 711PWU	37.44 Aa	34.78 Ac
MG 545PWU	33.22 Aa	34.00 Ac
CNB 16130PWU	35.45 Ba	39.89 Aa
MG 580PWU	35.11 Ba	31.33 Ac
MG 408PWU	35.00 Ba	31.44 Ac
MG 515PWU	32.67 Aa	34.55 Ac
MG 607PWU	34.44 Aa	36.78 Ab
JM 2M91PRO3	32.77 Aa	34.11 Ac
CV (%)	5.25	

Means followed by the same uppercase letter in the line and lowercase in the column belongs to the same group by the Scott Knott test at 5% probability

4. Conclusions

The hybrid MG 580 PWU had the worst adaptation in both locations. In Campinorte, the hybrid that best adapted was the MG 711 PWU. The hybrids studied are well adapted in Santa Isabel. Among the hybrids analyzed, the hybrids MG 711PWU, MG 545PWU, CNB 16130PWU, MG 580PWU, and MG 607PWU are the ones with the best performance.

Authors' Contribution

Luciana Borges e Silva contributed to the experiment setup, evaluations, data collection, tabulation, and manuscript writing. Wilian Henrique Diniz Buso assisted in the experiment setup, data reviewing, manuscript writing, data analysis, elaboration of graphs, and guided the first author.

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