

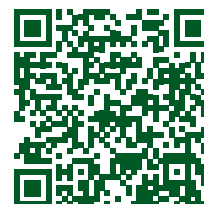
Adaptability and yield stability of cowpea genotypes in Mato Grosso do Sul

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Abstract: *The objective of this study was to identify cowpea genotypes that fulfill the criteria of high grain yield, adaptability, and stability in the Mato Grosso do Sul (MS) region. Yield data from Value for Cultivation and Use (VCU) trials conducted in the municipalities of Dourados and Aquidauana/MS from March to August 2017 and 2018 were used, totaling four environments. A randomized block design with 14 treatments and four repetitions was adopted. Yield was evaluated by weighing the grains from the usable plot and converting the values to kilogram per hectare. After the analysis of variance, the interaction between genotypes and environments was evaluated by the methodologies of adaptability-stability analysis of Eberhart and Russell, Lin and Binns modified by Carneiro and GGE-Biplot. The genotypes Pingo-de-ouro 1-5-7, Pingo-de-ouro 1-5-5 and Bico-de-ouro 1-5-24 are stable, adaptable and productive for the state according to the complementary use of the methods.*

Keywords: *Eberhart and Russell, GGE Biplot, Genotypes-by-environments interaction, Lin and Binns, Vigna unguiculata*




INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is a legume of African origin that can be grown in tropical and subtropical regions throughout the year (Ottoni et al. 2021). In Brazil, its production is concentrated in the North and Northeast regions. However, in recent years, its production has expanded to the Midwest and Southeast regions of Brazil (Freire Filho et al. 2017).

Expansion in the Midwest region was a result of the development of cultivars possessing compelling characteristics for mechanized cultivation (Freire Filho et al. 2017). However, it is crucial to consider the implications of genetic and environmental factors when evaluating a range of environments, growing seasons, regions, or line selections in multi-environment trials carried out in breeding programs. In multi-environmental trials, there is an effect known as genotypes by environments (GxE) interaction, which arises from the interaction between genetic and environmental factors (Angelini et al. 2019).

Due to the presence of genotype-by-environment interaction, no cultivar performs better compared to other genotypes deployed in all environments. Therefore, to deal with GxE, the growing areas of a crop should be divided into sub-regions, i.e., mega-environments (Yan 2019). In addition, to identify

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materials with predictable behavior that are responsive to environmental variations under both broad and specific conditions, adaptability and stability analyses are used.

The main methods developed to study the adaptability and stability of genotypes can be parametric or nonparametric. Among the parametric methods, one of the most widely used is that of Eberhart and Russell (1966), which is based on simple linear regression of genotypes as a function of environmental indices. Another method is that of Lin and Binns (1988), which is based on nonparametric analyses, where the parameter P_i is estimated from the mean square of the distance between the mean of the genotype and the maximum mean response obtained in the environment. Carneiro decomposed the P_i estimator into favorable and unfavorable environments.

In addition, the GGE biplot method based on multivariate analysis proposed by Yan et al. (2000) has been used in several studies on cowpea. The analysis groups the additive effects of genotypes with the multiplicative interaction effects and subjects them to principal component analysis. The which-won-where biplot is efficient in showing the performance of the best genotypes in their respective environments and can form target mega-environments for the crop (Araújo et al. 2022).

According to Rezende et al. (2021), some methods have a high probability of being used together in works with more than one method. In this context, the objective of this study was to select cowpea genotypes that meet the requirements of high grain yield, adaptability and stability for environments of the State of Mato Grosso do Sul using the Eberhart and Russell, Lin and Binns modified by Carneiro and GGE Biplot methods.

MATERIAL AND METHODS

This study used yield data from Value for Cultivation and Use (VCU) trials of cowpea genotypes from the Cowpea Breeding Program of Embrapa Meio-Norte. The trials were conducted from March to August 2017 and 2018 in the State of Mato Grosso do Sul, in the municipalities of Dourados and Aquidauana, totaling four environments. The combinations between municipalities and years constituted the environments.

The trials were set up according to the minimum requirements established for bean VCU trials, in accordance with Normative Instruction N°. 25, dated May 23, 2006, of the Ministry of Agriculture, Livestock and Food Supply (MAPA). The experimental design adopted was a randomized block design with 14 treatments and four repetitions. The genotypes were arranged in four 5.0-m-long rows. The plants were spaced at 0.50 m × 0.1 m, with a usable area of 5 m² formed by the two central rows, which were used to measure yield.

The trial material consisted of 14 cowpea genotypes, 12 lineages selected in the preliminary yield trial from Embrapa Meio-Norte and two commercial cultivars, BRS Tumucumaque and BRS Imponente (Table 1).

The trials in Dourados were carried out in the trial field of Embrapa Agropecuária Oeste (lat 22° 14' 00" S, long 54° 49' 00" W, alt 400 m asl). According to Köppen's classification, the climate of the region humid mesothermal - Cwa, with an average annual rainfall of 1,448 mm and an average annual temperature of 22.7 °C. In the year 2017, the average temperature during the trial was 21.26 °C and the precipitation was 506.66 mm. In 2018 the values were 21.42 °C and 304.80 mm, respectively. According to Santos et al. (2013), the soil in the area in Dourados was classified as Oxisol (*Latossolo Vermelho Distrófico* - LVdf), with a very clayey texture.

In Aquidauana, the trials were conducted at the State University of Mato Grosso do Sul - UEMS (lat 22° 13' 16" S, long 55° 48' 00" W, alt 207 m asl). The climate of the region is classified, according to Köppen, as Tropical Hot and Subhumid - AW, with an average annual rainfall of 1,282.7 mm (Kraeski et al. 2021) and an average annual temperature of 24.0 °C. In the year 2017, the mean temperature during the trial was 25.07 °C and the precipitation was 575.08 mm. In 2018, the values were 23.16 °C and 345.60 mm, respectively. The soil of Aquidauana was classified by Schiavo et al. (2010) as Ultisol (*Argissolo Vermelho-Amarelo Distrófico*) of sandy texture.

In the municipality of Dourados, the no-till system was adopted in March, using a plot seeder with four lines and no chemical fertilizers. In Aquidauana, the conventional system was used in April, with two heavy harrowing operations, one leveling operation and the demarcation of the sowing areas. This sowing plan aimed to homogenize the climatic conditions, taking into account the particularities of each municipality. Weed control was carried out mechanically by

Table 1. List of commercial lineages and cultivars destined for the VCU trial of cowpea in the municipalities of Dourados/MS and Aquidauana/MS in the years 2017 and 2018

Code	Genotype	Parents/ Origin	Cultivar/ Lineage	Commercial Subclass*
G1	Bico-de-ouro 1-5-11		Lineage	SV
G2	Bico-de-ouro 1-5-15	Selection of individual plants with progeny test from plants collected in the state of Mato Grosso	Lineage	SV
G3	Bico-de-ouro 1-5-19		Lineage	SV
G4	Bico-de-ouro 1-5-24		Lineage	ML
G5	Pingo-de-ouro 1-5-26		Lineage	ML
G6	Pingo-de-ouro 1-5-4		Lineage	ML
G7	Pingo-de-ouro 1-5-5		Lineage	ML
G8	Pingo-de-ouro 1-5-7	Selection of individual plants with progeny test from plants collected in the semi-arid region of Piauí	Lineage	ML
G9	Pingo-de-ouro 1-5-8		Lineage	ML
G10	Pingo-de-ouro 1-5-10		Lineage	ML
G11	Pingo-de-ouro 1-5-11		Lineage	ML
G12	Pingo-de-ouro 1-5-14		Lineage	ML
G13	BRS Tumucumaque	TE96-282-22G x IT87D-611-3	Cultivar	BR
G14	BRS Imponente	MNC00-553D-81-2-3xMNC01626F-11-1	Cultivar	BC

* BR: branco; BC: brancão; ML: mulato; SV: sempre-verde.

weeding and manual pulling. Pest control was carried out, when necessary, by applying insecticides Deltamethrin at a dose of 60 mL ha⁻¹ of the commercial product and Methamidophos at a dose of 1 L ha⁻¹ of the commercial product containing 600 grams of active ingredient/L.

At the end of the crop cycle, in July in Dourados and in August in Aquidauana, the crop was harvested. Yield was evaluated by weighing the grains of the usable plot on analytical scales and converting the values to kilograms per hectare.

The yield data were subjected to individual analysis of variance for each environment and, later, joint analysis of variance. The joint analysis of variance was performed in randomized blocks and with triple interaction, Genotypes (G) x Locations (L) x Years (Y), according to the statistical model $Y_{ijk} = m + (B/L)/Y_{jkm} + G_i + Y_j + L_k + GY_{ij} + GL_{jk} + YL_{jk} + GYL_{ijk} + E_{ijk}$, where: Y_{ijk} is the observation of the i -th genotype in block j and in repetition k ; m is the overall mean; $(B/L)/Y_{jkm}$ is the effect of the m -th block within the k -th location within the j -th year; G_i is the effect of the i -th genotype (fixed); Y_j is the j -th year effect (random); L_k is the effect of the k -th location (fixed); GY_{ij} is the effect of the interaction between the i -th genotype and the j -th year; GL_{jk} is the effect of the interaction between the i -th genotype and the k -th location; YL_{jk} is the effect of the interaction between the j -th year and k -th location; GYL_{ijk} is the effect of the interaction between the i -th genotype, j -th year and k -th location; and E_{ijk} is the random error.

Once the occurrence of the genotype-environment interaction was detected, the interaction was decomposed into complex parts according to Cruz and Castoldi (1991), using the expression $C = \sqrt[3]{(1-r)Q_1Q_2}$, where: Q_1 and Q_2 are the mean squares of the genotypes in locations 1 and 2, respectively; and r is the correlation between the means of genotypes in the two environments.

For the analysis of adaptability and stability, the combination of municipality and agricultural year was considered as the environment and the following methods were used: Eberhart and Russell (1966), Lin and Binns (1988) modified by Carneiro, using the GENES program (Cruz 2016), and GGE-Biplot with the help of the GGEBiplotGui package implemented in the R software (Frutos et al. 2014).

The regression model proposed by Eberhart and Russell (1966) is $Y_{ij} = \beta_0 + \beta_{1ij} + d_{ij} + E_{ij}$, where: Y_{ij} is grain yield, corresponding to the mean of genotype i in environment j ; β_0 is the overall mean of genotype i ; β_1 is the linear regression coefficient, which measures the response of the i -th genotype to environmental variation; lj is the coded environmental index; d_{ij} is the regression variance; and E_{ij} is the mean experimental error.

The genotypes recommended by the method of Eberhart and Russell were those that obtained regression deviations (α_{di}^2) not significant and coefficient of determination above 90%, because all genotypes showed regression coefficient β_{1i} of general adaptation.

The Lin and Binns method modified by Carneiro makes the general recommendation based on the lowest estimates of the parameter P_i . The estimator was decomposed in P_i for the favorable (P_{if}) and unfavorable (P_{id}) environments, according to the equations: $P_{if} = \frac{\sum_{j=1}^f (Y_{ij} - M_j)^2}{2f}$ and $P_{id} = \frac{\sum_{j=1}^d (Y_{ij} - M_j)^2}{2d}$, where: f is the number of favorable environments; d is the number of unfavorable environments; Y_{ij} is the yield of the i -th genotype in the j -th environment; and M_j is the maximum response observed among all genotypes in the j -th environment.

The graphical GGE Biplot which-won-where model used was the following $Y_{ij} - y_j = y_1 \varepsilon_{i1} \varrho_{j1} \varrho_{j2} + y_2 \varepsilon_{i2} \varrho_{j2} + \varepsilon_{ij}$, where: Y_{ij} represents the average grain yield of the genotype i in the j environment; y_j is the total average of the genotypes in environment j ; $\varepsilon_{i1} \varrho_{j1} \varrho_{j2}$ is the first principal component (PC1); $y_2 \varepsilon_{i2} \varrho_{j2}$ is the second principal component (PC2); y_1 and y_2 are the eigenvalues associated with PC1 and PC2, respectively; ε_{i1} and ε_{i2} are PC1 and PC2 values, respectively, for genotype i ; ϱ_{j1} and ϱ_{j2} are PC1 and PC2, respectively, for environment j ; and ε_{ij} is the error associated with the model for the i -th genotype and j -th environment (Yan et al. 2000).

RESULTS AND DISCUSSION

In the combined analysis, there were no significant differences for locations (L) and for the genotype-location interaction (GxL) for grain yield, which showed similarity in the behavior of the genotypes in the evaluated locations. Therefore, according to Borém et al. (2017), it is recommended to use only one of the locations in order to reduce costs when conducting trials in a genetic improvement program. However, significant differences were observed between the genotypes (G), years (Y) and for the GxY, LxY and GxYxL interactions (Table 2).

The coefficient of variation (CV), which measures the experimental precision, was 25.38% (Table 2). Given the polygenic nature of grain yield, its value is deemed acceptable for the crop, as it is greatly influenced by the edaphoclimatic conditions of each evaluated environment (Sousa et al. 2019). Studies conducted on cowpea by Silva et al. (2016) and Araújo et al. (2022) have found similar results, with CV values for yield of 24.26% and 25.44%.

The significance of the GxY, YxL and GxYxL interactions indicated the need to study the phenotypic stability because it showed a difference in the response pattern of genotypes for the edaphoclimatic variations of years and locations. The locations varied in both their soil and their climate properties, while the two years showed differences in rainfall levels and temperature fluctuations throughout the trials. Therefore, the environment was the primary factor contributing to the variance with a substantial impact on the yield of the genotypes. Santos et al. (2019) identified significant genotype-environment interactions in cowpea genotypes cultivated in the Brazilian Cerrado.

The presence of significant GxY and LxY interaction is a complicating factor for selection, because the best genotype in a location in a given year does not show the same performance in another year. To analyze this interaction in detail, a study of genotype x environment interactions was performed using Cruz and Castoldi's (1991) complex component estimation method (Table 3).

The environments presented showed a complex interaction (Table 3), in which the ranking of the genotypes changed when they were grown in different environments.

Table 2. Summary of the analysis of variance for grain yield, in kg ha⁻¹, of 14 cowpea genotypes, evaluated in four environments in the state of Mato Grosso do Sul in the years 2017 and 2018

SV	df	MS
(Blocks/Locations)/Years	12	3,848,605,516,596
Genotypes (G)	13	2,072,900,106,109*
Years (Y)	1	7,738,072,938,516**
Locations (L)	1	1,688,801,821,779
G x Y	13	120,601,340,632**
G x L	13	97,887,027,862
Y x L	1	2,267,093,433,945*
G x Y x L	13	79,848,303,661*
Residual	156	38,679,521,178
Mean		774.89
CV		25.38

¹ SV: sources of variation; DF: degrees of freedom; MS: Mean squares; CV: Coefficient of variation; *, **: significant at 5 and 1% de probability of error by F test, respectively.

Table 3. Estimates of the complex interactions (%C), in four environments, for grain yield in 14 lineages of cowpea in the municipalities of Dourados and Aquidauana in the years 2017 and 2018

Environments	Complex interactions (% C)
Dourados 2017 x Dourados 2018	43.77
Dourados 2017 x Aquidauana 2017	53.45
Dourados 2017 x Aquidauana 2018	70.93
Dourados 2018 x Aquidauana 2017	68.67
Dourados 2018 x Aquidauana 2018	74.97
Aquidauana 2017 x Aquidauana 2018	95.99

These results support the predominance of the complex component of the GxY interaction in cowpea, as identified by Cruz et al. (2021) and Angelini et al. (2019).

The highest complex interaction was found in Aquidauana 2017 x Aquidauana 2018 with 95.99%; this percentage indicates that the variations in the classification of genotypes within the municipality were greater than the variations between the studied municipalities. In the municipality of Aquidauana, there were differences in accumulated precipitation and average temperature throughout the agricultural years. In 2017, the total precipitation was 575.08 mm and the average temperature was 25.07 °C. In 2018, total precipitation was only 345.60 mm and average temperature was 23.16 °C.

The complex interaction among genotypes suggests inconsistency in their superiority, making it challenging to provide a generalized recommendation without bias towards maximum yield (Cruz and Castoldi 1991). Therefore, adaptability and stability analyses are advisable.

According to the Eberhart & Russell method (Table 4), the ideal genotype should have a yield higher than the average mean, a statistically equivalent regression coefficient of 1 ($\beta_{1i} = 1$), a non-significant regression deviation (α_{di}^2), and coefficients of determination greater than 80% (Tavares et al. 2017). However, when analyzing the regression coefficient (β_{1i}), it is evident that all genotypes evaluated showed general adaptability, i.e., they did not show significant differences in relation to the unit.

Thus, the recommendation was made on the basis of the genotypes that showed a yield above the overall mean, non-significant regression deviations and coefficients of determination above 90%. Bico-de-ouro 1-5-15, Pingo-de-ouro 1-5-5 and Pingo-de-ouro 1-5-10 showed general adaptability, high performance predictability and yield above the overall mean. This indicates that these genotypes exploited the environmental effects to obtain high yields. These results are different from those found by Kindie et al. (2021), who reported differences among cowpea genotypes in terms of their responsiveness and stability for grain yield tested in different environments in Ethiopia.

Table 4 shows the indices of adaptability and stability of Lin and Binns (1988), modified by Carneiro. According to this method, to identify the genotypes that are close to the maximum in most environments, the parameter P_i is estimated; the lower the value of P_i , the more adapted the material is (Barroso et al. 2017).

From the performance of the genotypes for general and unfavorable environments, it is observed that the same ranking order was established. The cowpea lineages Pingo-de-ouro 1-5-7, Pingo-de-ouro 1-5-5, Pingo-de-ouro 1-5-14, Pingo-de-ouro 1-5-10 and Bico-de-ouro 1-5-15 showed the lowest P_i value associated with yield. Kavalco et al. (2018) point out that genotypes with superior performance in unfavorable environments have greater ability to maintain agronomic

Table 4. Adaptability and stability estimates obtained by the Eberhart and Russell method and Lin and Binns method modified by Carneiro for 14 cowpea genotypes, evaluated in four environments in the state of Mato Grosso do Sul

Genotype	β_0	β_{1i}	α_{di}^2	R^2	P_i general	P_i favorable	P_i unfavorable
					x10000		
Bico-de-ouro 1-5-11	751.46 e	0.88	2.71*	69.01	81.24	18.56	102.14
Bico-de-ouro 1-5-15	787.25 d	1.09	0.20	91.4	35.08	18.48	40.61
Bico-de-ouro 1-5-19	715.75 f	0.91	2.94*	69.1	94.01	22.88	117.71
Bico-de-ouro 1-5-24	844.94 b	1.04	0.58	88.14	46.79	2	61.73
Pingo-de-ouro 1-5-26	748.97 e	0.86	1.42	76.16	47.86	52	46.48
Pingo-de-ouro 1-5-4	900.18 a	0.83	1.56	74.28	12.87	19.53	10.65
Pingo-de-ouro 1-5-5	830.68 c	1.20	0.45	91.34	49.19	0.28	65.49
Pingo-de-ouro 1-5-7	948.37 a	1.39	7.23**	70.28	7.5	0	10
Pingo-de-ouro 1-5-8	688.03 g	0.89	-0.65	96.34	78.64	47.79	88.92
Pingo-de-ouro 1-5-10	843.08 b	1.06	-0.70	97.76	25.24	8.89	30.69
Pingo-de-ouro 1-5-11	685.26 g	0.89	1.88	74.33	96.51	36.62	116.47
Pingo-de-ouro 1-5-14	814.40 c	0.97	2.61*	73.23	24.8	31.32	22.63
BRS Tumucumaque	732.63 f	1.09	4.65**	68.69	50.13	43.5	52.34
BRS Imponente	557.41 h	0.90	6.83**	52.23	173.86	62.07	211.12

Means followed by the same letters do not differ by the Scott-Knott test at 5% probability of error. *: Significant at 5% probability of error, by the F test for the parameter α_{di}^2 and by the t-test for the parameter β_{1i} ; β_0 : overall mean; β_{1i} : regression coefficient; α_{di}^2 : regression deviations; R^2 : coefficient of determination.

potential under non-ideal conditions for cultivation. Thus, it results in greater stability in grain yield and greater confidence in the indication of cultivars.

For favorable environments, the lineages Bico-de-ouro 1-5-15, Bico-de-ouro 1-5-24, Pingo-de-ouro 1-5-5, Pingo-de-ouro 1-5-7, and Pingo-de-ouro 1-5-10 were the five most promising (Table 4). This is an indication of the responsiveness of the genotypes to improved environmental conditions.

Pingo-de-ouro 1-5-7 stands out as the most recommended, showing the lowest P_i value (7.50, 0 and 10, respectively), which indicates that this lineage is the closest to the hypothetical ideal genotype under all environmental conditions. Thus, it is suggested that this material can be recommended for all the environments of the study and environments with characteristics similar to those the environments of this study because, besides being the genotype with the highest yield, it shows a wide adaptability and high stability. These results are in agreement with the work of Kindie et al. (2021), who reported that the most stable cowpea genotypes had the lowest P_i value and high mean grain yield in their study.

In the GGE-Biplot methodology, it was found that the first two principal components (PC1 and PC2) expressed the respective values of 44.33% and 26.85%, which explained 71.18% of the total variance for grain yield (Figure 1). The present study is consistent with the results presented by Santos et al. (2019) and Melo et al. (2020), who, when using the GGE Biplot methodology to evaluate the grain yield of cowpea genotypes, obtained a variance of 67.21% and 72.17%, respectively, explained by the first two principal components.

The graphical GGE biplot model in Figure 1 is known as the “which-won-where”. It identifies the 14 genotypes from G1 to G14 and the four environments from A1 to A4. It shows the formation of a polygon to determine the best genotypes in each environment. This is due to the connection of the genotypes at the extreme points of the graph origin and their respective perpendicular lines, with the other genotypes included in the polygon.

The vectors in the center of the biplot (0;0) divided the graph into six sectors. The environments grouped within these sectors were divided into two mega-environments. Mega-environments are the sectors containing one or more environments. The first group was assigned to Dourados 2017 (A1) and Aquidauana 2017 (A3), where the environmental conditions of that year influenced the genotypes in a similar way, different from the second group, composed of Dourados 2018 (A2), Aquidauana 2018 (A4).

When analyzing the test environments, one can observe their environmental similarity, since the two municipalities were allocated to the same mega-environment based on the crop year. This is linked to the unpredictable climate factors that affect the crop output. Similar results were found by Goa et al. (2022) in a study conducted in southern Ethiopia on cowpea. The environments were categorized based on moisture terminal stress and compared across seasons in a year.

In the first group, genotypes G6 (Pingo-de-ouro 1-5-4), G8 (Pingo-de-ouro 1-5-7), and G10 (Pingo-de-ouro 1-5-10) were assigned. The second group consisted of G4 (Bico-de-ouro 1-5-24) and G7 (Pingo-de-ouro 1-5-15). These genotypes possess specific adaptations which require careful evaluation to obtain optimal recommendations. Thus, the top-performing genotypes were G8, G4, and G7. These genotypes are located on the vertices of the polygon of the first and second mega-environment and exhibit the highest average yield within these environments.

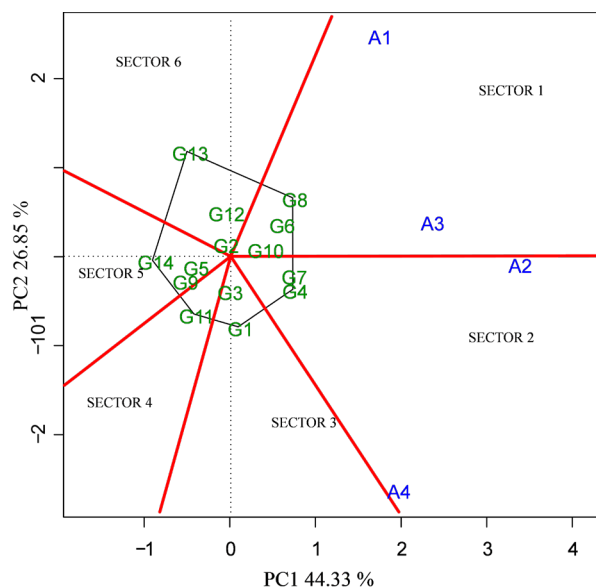


Figure 1. GGE biplot (“Which-won-where”) plot for analysis of best genotype performance in environment and mega-environment for cowpea yield (kg ha^{-1}). PC1: First principal component; PC2: Second principal component. A1: Dourados 2017; A2: Aquidauana 2017; A3: Dourados 2018; A4: Aquidauana 2018; See codes of genotypes (G1 to G14) in Table 1.

The genotypes that form the vertices of the polygon but are not part of any grouped environment, and the individuals within the sectors they define, are deemed unfavorable to the tested environments and have low yield, according to the recommendations of Abreu et al. (2019).

The Lin and Binns method, as revised by Carneiro, and the Eberhart and Russell method suggest similar genotypes, such as Pingo-de-ouro 1-5-5, Pingo-de-ouro 1-5-10, and Bico-de-ouro 1-5-15, for favorable conditions. However, the clustering indicated by the Lin and Binns method, modified by Carneiro and the GGE biplot, displays a greater similarity in categorizing Pingo-de-ouro 1-5-7, Pingo-de-ouro 1-5-5, and Bico-de-ouro 1-5-24. According to Tavares et al. (2017), employing multiple adaptability and stability methodologies leads to more accurate genotype recommendations.

The genotypes recommended for favorable environments, Pingo-de-ouro 1-5-5, Pingo-de-ouro 1-5-10 and Bico-de-ouro 1-5-15, are recommended for producers in the municipalities of Dourados and Aquidauana who use high technology, because they are responsive in improving production management. For producers in the region who cultivate on a smaller scale or adopt low-production technology, Pingo-de-ouro 1-5-14 is highly recommended because it has a greater ability to maintain its agronomic potential.

The evaluated genotypes demonstrated similar adaptability and productive stability in the municipalities of Aquidauana and Dourados. It is advised to select a single location to minimize expenses during the conduction of genetic improvement program trials in the state. Furthermore, conducting trials in other municipalities of the state is recommended.

CONCLUSIONS

The genotypes Pingo-de-ouro 1-5-7, Pingo-de-ouro 1-5-5, and Bico-de-ouro 1-5-24 showed grain yields above the overall mean of the environments, and sufficient stability for a recommendation for the state of Mato Grosso do Sul.

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