Yield of Corn Hybrids in Western Bahia and Southwest Goiania in the Agricultural Year 2017/2018

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Authors’ contributions
This work was carried out in collaboration among all authors. Author LLF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AIAP, CRSC and IRC managed the analyses of the study. Author IRC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT
The objective of this study was to evaluate the yield of corn hybrids in west Bahia and south-west Goias in the agricultural year of 2017/2018. The study was carried out in the municipalities of Luís Eduardo Magalhães in west Bahia - BA and Mineiros in south-west Goias – GO, Brasil. The experimental design was a randomized complete block design, the treatments being corn hybrids, 12 in west of Bahia and 23 in south-west of Goias. Each experimental unit was composed of 6 lines of 8 m in length spaced every 0.5 m and population of 70.000 ha⁻¹ plants in 4 replications. The

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applications of pesticides were carried out in the morning, and the control of weeds, insects and diseases were carried out whenever necessary respecting the good practices of integrated pest management. After the harvest the yield was determined, correcting the grain moisture to 14%. Statistical analyzes were carried out at the Rbio and R interface. The analysis of variance analysis revealed that corn hybrids in the regions of west Bahia and south-west Goias were significant. The cultivation of the DKB390, MG711, DKB290 and 30F53 corn hybrids is recommended for west Bahia and the P3707 hybrid that has obtained yields above \(170 \text{ sc ha}^{-1}\) in south-west Goias. For both regions it was evidenced that the UPGMA grouping method using the generalized distance of Mahalanobis was efficient.

Keywords: Zea mays; agricultural genetics; grains; competition test.

1. INTRODUCTION

Among the factors contributing to the increase in corn yield, the use of improved seeds is recommended, where the recommendation and the use of hybrids adapted to the edaphoclimatic conditions for each growing region is an essential factor for the producer to obtain high yields in the development of agricultural activity [1,2].

The breeding programs of corn seed companies are dynamic, making available annually great diversity of genotypes for farmers, in this context, the most used genetic base are hybrids from lineages and open pollination adapted to specific environmental conditions, due to the variability present in its constitution [2].

For [3], the increase in the availability of hybrids for the off-season crop, potentiates the uncertainties of the producer regarding the choice of genotypes, since the use of hybrids that better adapt to the growing conditions can provide higher yields of grains and consequently, higher economic return. Thus, the economic analysis of the financial return should be a preponderant factor for the decision-making of the choice of the hybrid to be cultivated in the off-season.

Work has sought to demonstrate the productive adaptability of corn hybrids in several locations such as [2] in a tropical climate under high technology conditions. [3], observing the behavior of corn hybrids in the off-season under closed conditions. Or [1], evaluating the agronomic performance of different maize hybrids, under the edaphoclimatic conditions of the Alto Vale do Itajaí.

Annually, several public and private institutions have developed and recommended corn hybrids that associate good adaptation to desirable agronomic attributes [4], in order to meet this demand. The corn genetic improvement programs in Brazil allow to obtain new hybrids adapted to several regions of the country [3].

Corn (Zea mays L.) is considered to be one of the main cereals grown around the world, supplying products widely used both for food, feed and raw materials for industry, mainly due to the quantity and quality of accumulated reserves in the grains [5].

Brazil is among the world's largest corn producers, with a total production estimate of 95 million tons in the 2018/19 crop, with more than 18 million hectares planted. The State of Goiás is one of the largest national cereal producers [6].

The conditions of corn cultivation in Brazil are diversified, ranging from very technified crops to crops for subsistence, the latter being one of the justifications for the low average yields found in the country. For, in order to have an increase in yield of grains of corn depends largely on the interactions between genetic, environmental factors and adequate pest management [7]. Being the seed the main input of a crop, the proper choice of it must deserve the full attention of the producer to be successful in its planting and good yield [8].

Plant growth is the result of interactions between the genetic potential of plants and environmental factors. That is, the difference in average yield obtained in crops and those that are verified under conditions of adequate management can be attributed to several causes, such as the use of hybrids with low potential of grain production and/or not adapted to the region of cultivation, and the use of low doses of fertilizers, inappropriate sowing season, inadequate plant arrangement, and failure to manage weeds, pests and diseases [9].
In Brazil, the 2017/2018 harvest survey was related to 298 corn hybrids, including corn, silage, popcorn and common green corn. Of the total of 298 hybrids, 195 are transgenic, with one or more events, and the remaining 103 are conventional, which means that 65.43% of the corn hybrids on the market are transgenic and only 34.56% are conventional [8]. Therefore, the objective of this research was to evaluate the yield of corn hybrids in west Bahia and south-west Goias in the agricultural year 2017/2018.

2. MATERIALS AND METHODS

2.1 Climatic Factors and Chemical and Physical Soil Attributes

Table 1. Average of climatic factors during the execution of the experiments and the chemical and physical attributes of the experimental areas before the installation of the experiments. UNIFIMES, Brazil, 2020

<table>
<thead>
<tr>
<th>Site</th>
<th>Temperature</th>
<th>Relative humidity</th>
<th>Dew point</th>
<th>Atmospheric pressure</th>
<th>Wind velocity</th>
<th>Radiation</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Bahia</td>
<td>23.5</td>
<td>81.1</td>
<td>19.6</td>
<td>927.3</td>
<td>1.8</td>
<td>886.7</td>
<td>199.6</td>
</tr>
<tr>
<td>South-west Goias</td>
<td>24.2</td>
<td>81.0</td>
<td>19.0</td>
<td>934.1</td>
<td>1.0</td>
<td>901.4</td>
<td>605.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>Ca cmol c dm⁻³</th>
<th>Mg cmol c dm⁻³</th>
<th>H⁺Al cmol c dm⁻³</th>
<th>K cmol c dm⁻³</th>
<th>P mg dm⁻³</th>
<th>Clay %</th>
<th>Silt %</th>
<th>Sand %</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Bahia</td>
<td>6.1</td>
<td>1.8</td>
<td>0.9</td>
<td>1.2</td>
<td>95.2</td>
<td>27.7</td>
<td>13.0</td>
<td>7.0</td>
<td>86.3</td>
</tr>
<tr>
<td>South-west Goias</td>
<td>4.1</td>
<td>0.5</td>
<td>0.3</td>
<td>2.9</td>
<td>23.4</td>
<td>3.0</td>
<td>8.0</td>
<td>3.0</td>
<td>89.0</td>
</tr>
</tbody>
</table>

Source: INMET, 2019. *Analysis in the 0-20 layer performed at the UNIFIMES Soil Chemistry and Fertility Laboratory, according to the methodology of (EMBRAPA, 2009)*

2.2 Geographical Localization and Experimental Design

2.2.1 West Bahia

The study was carried out at the Fam Research & Development Experimental Station, located in the municipality of Luís Eduardo Magalhães in West Baiano-BA. The local coordinates are latitude S 12°07'133" and longitude W 45°57'200", with average altitude of 792 m. The experimental area is classified as subhumid and humid climate, characterized by a rainy season and a dry season. The soil of the experimental area was classified as Yellow Latosol, with sandy-loam texture, flat topography and high drainage [10].

The experimental design was in a randomized block, with 12 corn hybrids (DKB345, DKB390, DKB290, DKB310, STATUS, SUPREMO, M8934, 30F53, MG711, MG545, RB9006 and RB9606).

2.2.2 South-west Goias

The experiment was carried out at Fazenda Passinatto, located in the municipality of Mineiros in south-west Goias - GO, with a geographical location latitude 17° 52'57.0"S, longitude 53° 00'00.6"O, and altitude of 930 meters. The experimental area is classified according to Köppen as type Aw climate (hot to dry). The soil of the experimental area was classified as Quartzarenic Neosol, with low texture, smoothly wavy topography and limited drainage [10].

The experimental design was a randomized block design with 23 treatments corresponding to corn hybrids (P3707, AG1581, MG388, MG711, JMN3M51, KWS9100, DOW2A401, DKB335, MG545, P3456, P3646, AG8700P3, P30F53, KWS9110, AG8070P3, DOW2B640, KWS9606, DKB290, KWS9105, DKB310, P3630 and BOLIVIAN).

2.3 Cultivar Treatment Applied

The sowing was done with one-line planter coupled to micro tractor and fertilization according to [11]. Each experimental unit was composed of 6 lines of 8 meters in length spaced every 0.5 m and density of 3.5 seeds per linear meter, relating a population of 70,000 ha⁻¹ plants in 4 replicates. In the applications of pesticides, a
Jacto model Condor 600 spray was used, with a 12 m bar and cone spout spaced 0.5 m apart, producing a volume of 150 L ha\(^{-1}\) syrup. All applications were performed in the morning, with an average ambient temperature of 24°C, relative air humidity above 75% and winds below 5 km h\(^{-1}\). The cultural practices pertinent to the control of weeds and pests were carried out whenever necessary, using good practices of integrated pest management [12].

2.4 Data Collection and Statistical Analysis

After the harvest the yield was determined [13], correcting the moisture of the grain to 14%. The data obtained was submitted to the assumptions of the statistical model, verifying the normality and homogeneity of the residual variances, as well as the additivity of the model. Afterwards, the analysis of variance was performed in order to identify the significance and grouping of means by Scott-Knott, at 5% probability. After genetic dissimilarity was established by the Mahalanobis algorithm where the residue matrix was weighted, after the distance dendrogram was constructed through the UPGMA cluster. The analyzes were performed at the Rbio and R interface [14].

3. RESULTS AND DISCUSSION

The analysis of variance analysis revealed that corn hybrids in the regions of west Bahia and south-west Goias were significant (p <0.01) (Table 1). Corroborating with [4,15,16,17,18]. The mean values among the hybrids were similar with 150.44 and 149.85 sc ha\(^{-1}\), respectively, for West Baiano and Sudoeste Goiano, respectively (Table 2).

3.1 Yield in West Bahia

The DKB390 hybrid was the most productive under experimental conditions with a mean of 192.72 sc ha\(^{-1}\), followed by MG711 (183.57 sc ha\(^{-1}\)), DKB290 (176.97 sc ha\(^{-1}\)) and 30F53 (171.58 sc ha\(^{-1}\)), the others were well to whom, where the least productive was the KWSRB9606 yielding a yield of 145.82 sc ha\(^{-1}\) (Fig. 1). When comparing the results obtained in this study with the national average that is 84.33 sc ha\(^{-1}\), with the average of the northeast region that is 47.85 sc ha\(^{-1}\) and with the state of Bahia with 36.90 sc ha\(^{-1}\) [19], we observed the potential of the hybrids worked.

Carvalho et al. [4] also found variations in corn hybrids when submitted to different environmental conditions in the brazilian northeast, with average yield ranging from 134.63 to 174.96 sc ha\(^{-1}\). [15] observed differences between hybrids and between sites, being it possible to find hybrids with yield above 133.33 sc ha\(^{-1}\), when the environmental and genetic variables were maximized. [16] evaluating the productive behavior of corn hybrids in different environments of the northeast region found the highest grain yields between 152.45 and 129.60 sc ha\(^{-1}\).

Variations can occur due to responses to the natural fertility of the soils, or even, the practices of liming and fertilization, the latter being even foliar. Variations can also be explained by the degree of pest incidence, and the environmental adaptability of these in west Bahia. For Taiz et al. (Soil moisture and availability), carbon dioxide, oxygen, content and availability of soil nutrients, temperature and toxins (inert ingredients, heavy metals and salinity) can affect the growth and development of the plant.

Carvalho et al. [16] points out that the indication and use of hybrids not adapted to certain regions brings serious economic, social and environmental problems, since ill-adapted hybrids result in low levels of yield, indiscriminate use of agrochemicals and over-treatment cultural activities.

<table>
<thead>
<tr>
<th>FV</th>
<th>West Bahia</th>
<th>South-west Goias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid</td>
<td>788.98</td>
<td>565.67</td>
</tr>
<tr>
<td>Block</td>
<td>0.01(^{ns})</td>
<td>0.03(^{ns})</td>
</tr>
<tr>
<td>C.V (%)</td>
<td>8.56</td>
<td>11.23</td>
</tr>
<tr>
<td>Average (sc ha(^{-1}))</td>
<td>150.44</td>
<td>149.85</td>
</tr>
</tbody>
</table>

**Table 2. Summary of analysis of variance (Q.M, CV and average) for yield of corn hybrids in west Bahia and south-west Goias. UNIFIMES, Brazil, 2020**

**Note:** significant at 1% probability by F test; ns not significant at 5% probability by the F test.
Fig. 1. Means for yield of corn hybrids in western Bahia conditions. UNIFIMES, Brazil, 2020
Means followed by the same lowercase vertical letter do not differ by Scott-Knott test at 5% probability

Fig. 2. Dendrogram representative of the dissimilarity among corn hybrids, obtained by the UPGMA grouping method, using the generalized Mahalanobis distance. The co-behavioral correlation coefficient (r) was 0.80. UNIFIMES, Brazil, 2020
Group I (RB9006, RB9606 and M8934), Group II (DKB345, DKB310, STATUS, SUPREMO, 30F53 and MG545) and Group III (DKB390) were used for the mean Euclidean distance and the UPGMA grouping method. DKB290 and MG711) (Fig. 2). The coefficient of correlation coefficient, which estimates the representativity of the dendrogram dissimilarity matrix data, revealed a magnitude of r: 0.80, indicating that the matrix data presented a satisfactory adjustment in the graphical representation presented by the dendrogram, according tom [20,5].

Nardino et al. [21] testing genetic dissimilarity among 25 corn genotypes in five growing environments in southern Brazil, observed the formation of 9 different clusters. The results of cluster analysis using UPGMA methods may serve as a basis for future work involving the study of genetic diversity for corn [20].

3.2 Yield in South-West Goias

Fig. 3 shows the yield of the 23 corn hybrids in the 2017/18 harvest in Mineiros - GO, where the hybrids differed statistically (p≥0.05). The hybrid P3707 obtained the highest yield, with 172.46 sc ha⁻¹, standing out over the others. According to [17], the same hybrid in the north/west of the state of São Paulo, in the 2016/17 harvest, obtained 147 sc ha⁻¹, with a lower yield of 16 sc ha⁻¹. Yield levels were followed by AG1581 with 166.56 sc ha⁻¹, P3898 with 164.07 sc ha⁻¹ and MG580 with 163.84 sc ha⁻¹.

![Fig. 3. Averages for yield of corn hybrids in south-west Goias conditions. UNIFIMES, Brazil, 2020](image)

*Means followed by the same lowercase vertical letter do not differ by Scott-Knott test at 5% probability*
According to the IBGE in the agricultural year of 2017 the off-season presented average yield in the order of 93.02, 99.92 and 96.27 sc ha\(^{-1}\), for Brazil, central-west and Goiás, respectively, with reductions in the agricultural year of 2018 at 12.27, 10.42 and 1.28 sc ha\(^{-1}\), in this order [22].

Backes et al. [18], with an experiment in Santo Cristo - RS obtained a yield of 124.68 sc ha\(^{-1}\) in the 2016/17 harvest. Despite being in another region of Brazil, the average is well below the average obtained in the experiment. In another experiment, in the city of Santa Helena - GO in the 2012/13 crop, it obtained 143.28 sc ha\(^{-1}\) [23], 15 sc ha\(^{-1}\) less than that obtained in Mineiros - GO. According to [17] for the 2016/17 crop, presented a median yield of 134 sc ha\(^{-1}\), lower than the yield of Mineiros-GO.

The hybrid BOLIVIANO showed the lowest average grain yield with only 123.74 sc ha\(^{-1}\), implying that this hybrid is not recommended for the South-west Goias conditions. In spite of the low yield, the dispersion of the values shows that there is great genetic variability among these genotypes, being something positive, since, this variability allows to establish which hybrids are better suited to regions with greater water deficit or managements that intend to invest in smaller proportions [24].

As in West Bahia, south-west Goias also presented the formation of 3 distinct clusters. Group I (DOW2A401, DKB335, MG545, P3456, P3646, AG8700P3, P30F53, KWS9110, AG8070P3, DOW2B640, KWS9606, DKB290, KWS9105, DKB310 and P3630), and Group II (P3707, JMEM3M51, KWS9100, AG1581 MG711 P3898 and MG580) and Group III (BOLIVIAN) (Fig. 4). The coefficient of correlation coefficient was significant with a magnitude of r: 0.80, which evidences consistency of the clustering pattern according to [20,21,5]. [20] estimating the genetic divergence between half-sibling progenies through hierarchical methods observed the formation of 11 clusters, as well as. [5], which counted the formation of 4 clusters, from studies with genetic divergence among corn genotypes.

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![Dendrogram](image-url)  

**Fig. 4.** Dendrogram representative of the dissimilarity among corn hybrids, obtained by the UPGMA grouping method, using the generalized Mahalanobis distance. The co-behavioral correlation coefficient \(r\) was 0.75

*UNIFIMES, Brazil, 2020*
The differences between the hybrids can be pointed out as a consequence of their genotype and adaptation to the growing environments. This fact indicates that, even in favorable or adverse conditions, there are well-adapted hybrids with high productive potential, where farmers should seek information on the best material for use in their production systems, grain yield being a variable representative for the choice of the best hybrid.

4. CONCLUSION

According to the experimental conditions and desiring to obtain high yields (> 170 sc ha⁻¹), it is recommended for the West of Bahia the cultivation of hybrids of corn DKB390, MG711, DKB290 and 30F53. In this way the work presents a satisfactory answer, since the yields reached were higher than the current averages of the state of Bahia. However, it is necessary that more competition studies of hybrids are performed.

The numbers of 23 hybrids are not of Goias-state type with the yield of 170 sc ha⁻¹, but profits with yield> 150 sc ha⁻¹ are also excellent when high yields.

For both regions it was evidenced that the UPGMA grouping method, using the generalized distance of Mahalanobis, was considered efficient in the grouping of maize hybrids.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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