ISSN 1984-431X
Revista Eletrônica Interdisciplinar
Barra do Garças – MT, Brasil
Ano: 2025 Volume: 17 Número: 1

# PRODUCTION PERFORMANCE OF MAIZE GENETIC BASES SUBJECTED TO TRANSVERSE CUTS OF PLANTS AT VEGETATIVE DEVELOPMENT STAGES

Murilo Vieira Loro[1]
Alberto Cargnelutti Filho[2]
Mikael Brum dos Reis[3]
João Augusto Andretta[4]

## ABSTRACT

The objective of this study was to evaluate the production performance of maize genetic bases subjected to transverse cuts of plants at vegetative development stages. An experiment was conducted with three maize genetic bases, on two sowing dates in the 2021/2022 harvest in a completely randomized design. For each sowing date and genetic base, transverse cuts of plants were carried out at development stages V1, V2, V3, V4 and V5, in addition to a treatment without cutting. Number of ears (NE) and grain yield (GY, Mg ha$^{-1}$) were evaluated. Boxplot graphs were constructed and principal component analysis was performed. Analysis of variance, F test and Scott-Knott means clustering analysis were performed at 5% significance level. The number of ears and grain yield of maize decreased in the following order: double hybrid, triple hybrid and single hybrid. Cutting plants at advanced stages reduces the number of ears and grain yield in all maize genetic bases. Single and triple hybrids show a smaller reduction in the number of ears and grain yield when cut at more advanced stages compared to the double hybrid, which shows a greater reduction.

**Keywords:** *Zea mays*. Abiotic stress. Sowing dates.

## 1. INTRODUCTION

The evolution of management techniques and the development of resource-efficient maize genotypes have maximized the expression of grain yield and tolerance to biotic and abiotic stresses (LIMA; BORÉM, 2018). Although great efforts are dedicated to maize breeding, production environments are exposed to severe abiotic stress that reduces the production performance of the crop.

Physiological changes that occur when plants are under unfavorable conditions, which prevent the expression of their genetic potential, are considered a definition of stress (GASPAR et al., 2002). The occurrence of abiotic stress such as frost, hail and strong winds cause severe damage, especially reducing leaf area and, in small plants, breaking them close to the soil surface. Leaves are the main vegetative organs responsible for photosynthesis (TAIZ et al.,

[1]Discente do curso de Doutorado em Agronomia, UFSM, Santa Maria, RS, Brasil, muriloloro@gmail.com; https://orcid.org/0000-0003-0241-4226
[2]Docente do Departamento de Fitotecnia, UFSM, Santa Maria, RS, Brasil, alberto.cargnelutti.filho@gmail.com; https://orcid.org/0000-0002-8608-9960
[3]Discente do curso de Mestrado em Agronomia, UFSM, Santa Maria, RS, Brasil, mikareis1999@gmail.com; https://orcid.org/0000-0003-4226-690X
[4]Discente do curso de Agronomia, UFSM, Santa Maria, RS, Brasil, aundregusto@gmail.com; https://orcid.org/0000-0003-0633-1102

ISSN 1984-431X

2017) and their maintenance is important, as the ability to compensate for leaf losses in maize is limited due to the low capacity to occupy spaces.

Studies aimed at understanding the responses of maize plants to physical stresses, which simulate abiotic stresses, have been conducted by Echarte et al. (2006), Karam et al. (2010), Rezende et al. (2015), Battaglia et al. (2019) and Blanco et al. (2022). Cuts above the second leaf and maceration of maize plants at the V2 and V4 stages reduce grain yield (KARAM et al., 2010). A 14.05% reduction in maize grain yield was reported by Rezende et al. (2015), when total defoliation was applied at the vegetative stage V4. However, studies have reported that there was no reduction in maize yield with 33 and 66% defoliation at V1-V2 and V3-V4 (BLANCO et al., 2022), with 50% and 100% defoliation at V4 (GAIAS et al., 2017) and with severe defoliation at V7 (BATTAGLIA et al., 2018).

Total defoliation at early vegetative stages may have minimal effects on maize grain yield, as long as the growing point is not affected (BATTAGLIA et al., 2019). In addition, authors report an increase in maize grain yield after defoliation, when it is carried out in environments with water stress conditions (ZENGH et al., 2021). It was also observed that the response of plants to physical stress varies among the genotypes evaluated (ECHARTE et al., 2006).

Research indicates that there are variations in the results obtained in relation to the performance of maize under defoliation. This indicates that genetic bases, environment, and defoliation methods can influence grain yield results in maize. Therefore, understanding the responses of maize genetic bases to abiotic stress, such as cutting of plants, allows making inferences about their tolerance and plasticity, supporting decisions during crop management. In this context, the objective of this study was to evaluate the production performance of maize genetic bases subjected to transverse cuts at vegetative development stages.

## 2. MATERIAL AND METHODS

Experiments were carried out with two sowing dates (November 08, 2021 and January 07, 2022) in the area of the Plant Science Department of the Federal University of Santa Maria, located at 29°42’S, 53°49’W and 95 m altitude. According to Köppen’s classification (ALVARES et al., 2013), the climate of the region is classified as humid subtropical - *Cfa*, with hot summers and no defined dry season. The soil of the region is classified as *Argissolo vermelho distrófico arênico* (Ultisol) (SANTOS et al., 2018).

For the two sowing dates, three maize genetic bases were evaluated: single hybrid (DKB 240 PRO3), triple hybrid (NTX 303 PRO3) and double hybrid (Feroz Viptera3). Preparation and fertilization of the area were previously carried out with 415 kg $ha^{-1}$ of chemical fertilizer with the 05-20-20 formula (NPK). For each sowing date, maize genotypes were sown in plots consisting of two 3-m-long rows at spacing of 0.80 m between rows and 0.20 m between plants in the row, totaling 8 $m^2$. Sowing was carried out on November 8, 2021 and January 7, 2022 with two seeds per hole. After seedling emergence, the density was adjusted by thinning to 62,500 plants $ha^{-1}$ (50 plants per plot). Nitrogen fertilization was carried out with 400 kg $ha^{-1}$ of urea (N - 46%). The other cultural management practices, such as weed, pest and disease control, were carried out according to the technical indications for the maize crop, and uniformly in all genotypes (FANCELLI; DOURADO NETO, 2009).

For the two sowing dates, a completely randomized design with four replicates was used to evaluate three genetic bases and five transverse cuts in the plants. The levels of the cutting treatments were: transverse cut of plants at the development stage V1, transverse cut of plants at the development stage V2, transverse cut of plants at development stage V3, transverse cut of plants at development stage V4, transverse cut of plants at development stage V5, and a treatment without transverse cut of plants. The transverse cuts were performed manually at the insertion of the first leaf, using pruning shears.

At full physiological maturity of the plants, harvest was performed and the number of ears per plot was counted to estimate the number of ears per hectare (NE, in thousand ears $ha^{-1}$). Grain yield (GY, in Mg $ha^{-1}$) was evaluated using all plants in the plot, after correction to 13% moisture. The meteorological variables were obtained from a station of the National Institute of Meteorology (INMET) located 100 meters away from the experimental area. Rainfall, in mm, and the maximum daily temperature (Tmax) for the period between sowing and physiological maturity of the genotypes were obtained for each sowing date.

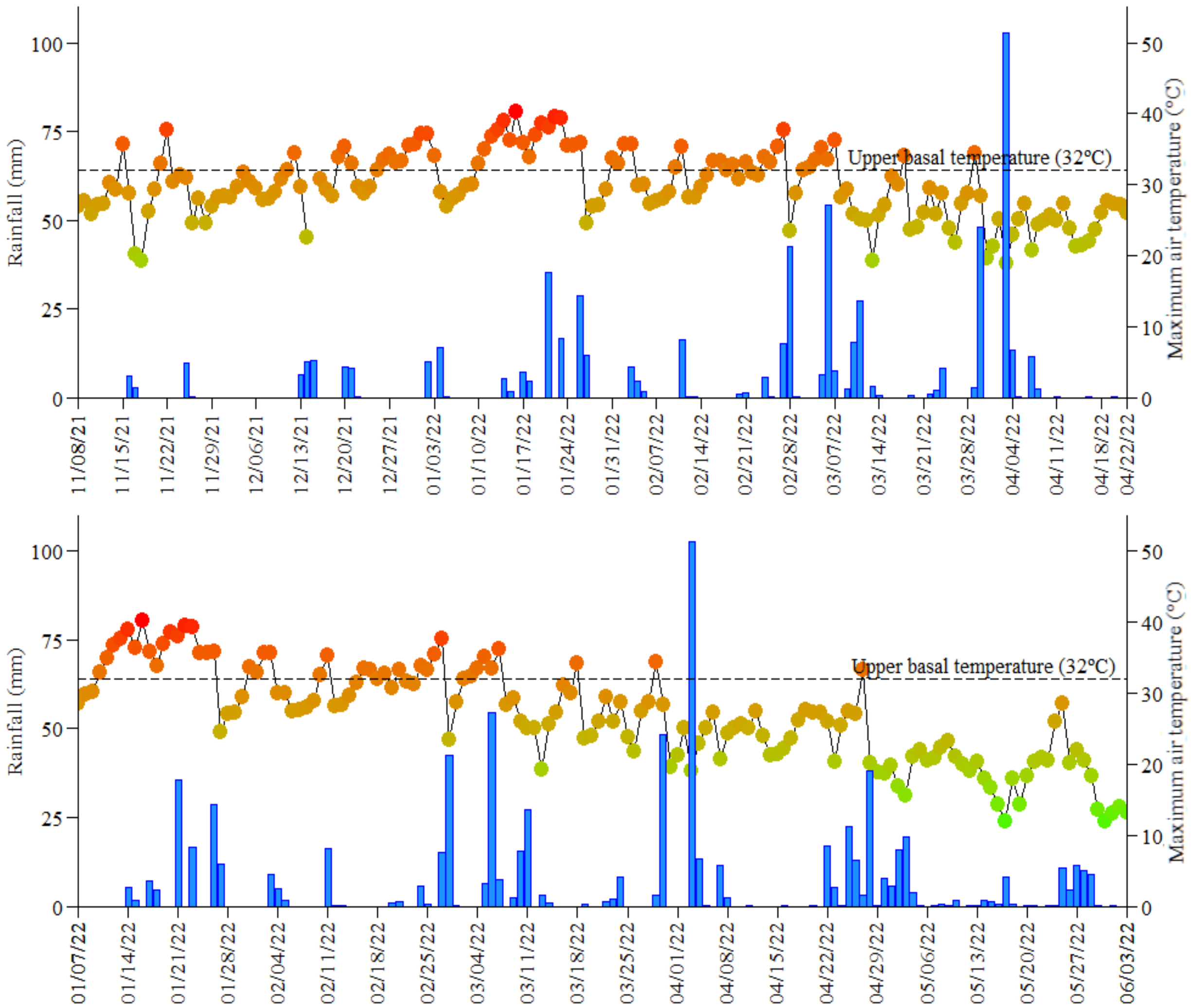
For each sowing date, Boxplot graphs were constructed to represent the distribution of the number of ears and grain yield of the maize genetic bases subjected to the levels of plant transverse cuts. Principal component analysis was applied considering each sowing date in order to check possible group formations between the genetic bases and levels of plant transverse cuts. Analysis of variance and F test at 5% significance level were performed for the number of ears and grain yield considering each sowing date. Means of the genetic bases for each cutting stage and the cutting stages for each genetic base were grouped by the Scott-Knott test at 5% significance level. The analyses were carried out using the Microsoft Office Excel® application and R software (R CORE TEAM, 2024), using the *ggplot2* package (WICKHAM, 2016).

## 3. RESULTS AND DISCUSSION

Revista Eletrônica Interdisciplinar
Barra do Garças – MT, Brasil
Ano: 2025 Volume: 17 Número: 1
ISSN 1984-431X

During the maize development period, meteorological conditions varied between sowing dates (Figure 1). For the sowing on November 8, 2021, a lower frequency of rainfall was observed during the initial stage of plant development, while the maximum air temperature had an increase followed by a decrease during the maize growing cycle. For the sowing on January 7, 2022, there was a higher occurrence of rainfall in the early stages of development, and the maximum air temperature showed a gradual reduction throughout the cycle. Therefore, it is possible to infer that, for the first sowing date, there was a lower frequency of rainfall during the stages at which the plants were cut (V1 to V5).

**Figure 1.** Rainfall and maximum daily air temperature during the development of the maize genetic bases with the two sowing dates (November 08, 2021 and January 07, 2022).



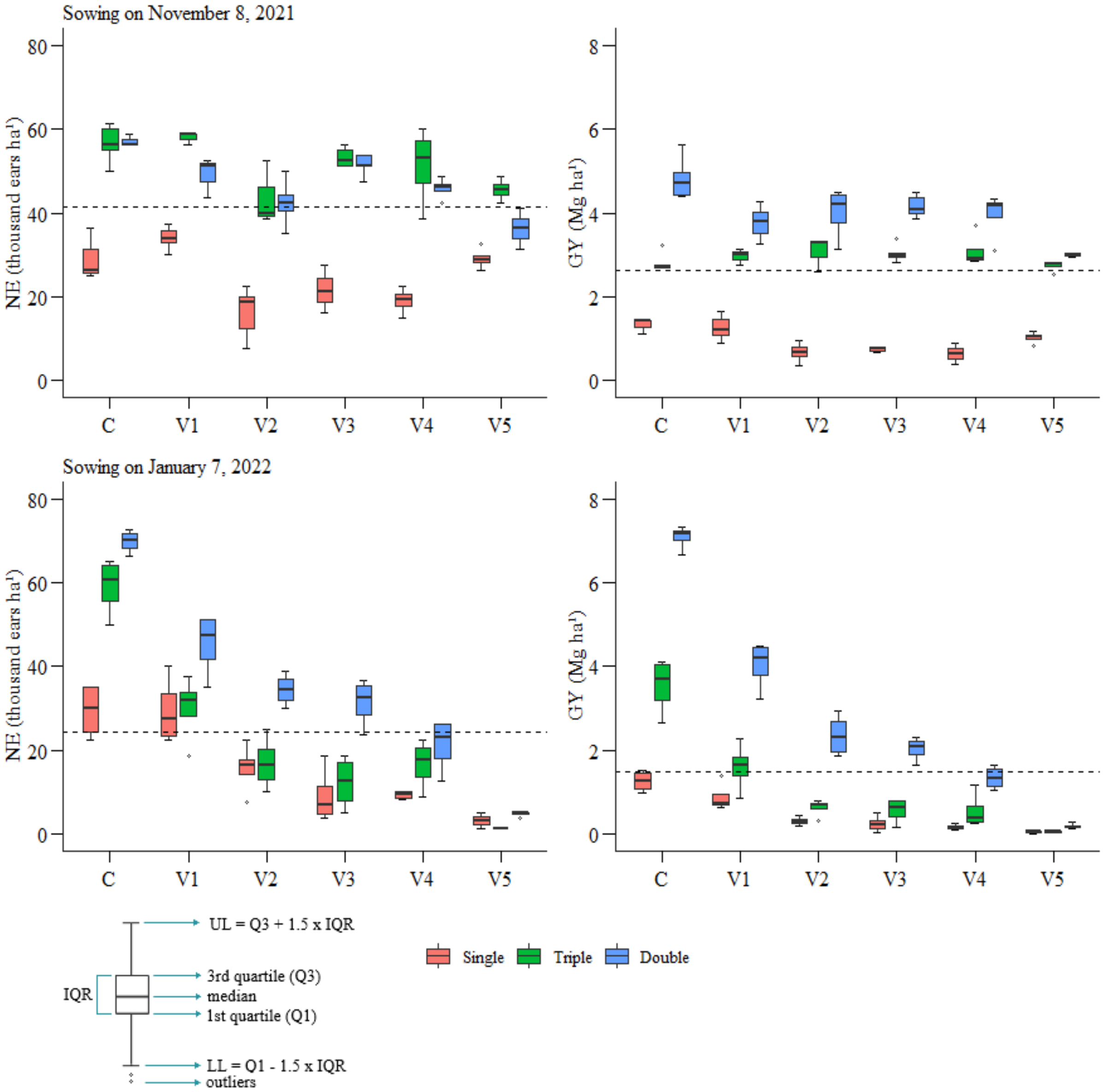
On average, the highest number of ears (NE) and the highest grain yield (GY) were observed for the first sowing date (Figure 2). For this date, there was greater stability in the response of the genetic bases in relation to the plant cutting stages. The triple and double hybrids had the highest means of NE and GY, regardless of the cutting stage, while the single hybrid had the lowest means for both traits. This indicates that the response of the plants to the cuts varied between the sowing dates and the genetic bases. Variations of responses to defoliation between genotypes have also been reported by Echarte et al. (2006) and Battaglia et al. (2018).

For the sowing on January 7, 2022, the double hybrid showed the highest average performance for NE and GY. In all genetic bases, the means of these traits gradually decreased with the cuts carried out at advanced stages. The double hybrid was the most sensitive to the cut, showing the greatest reduction in NE and GY. For this date, the effects of the cuts were more evident, with a marked reduction in the performance of the three genetic bases.

The first two principal components explained 100% of the total variability of the data for the two sowing dates (Figure 3), which is explained by the fact that there are only two traits (NE and GY). The observations related to each sowing date were colored distinctly for each genetic base and cutting stage. For the sowing on November 8, 2021, three distinct groups were formed, identified mainly by genetic bases. The highest NE and GY were observed in the triple and double hybrids, and it was not possible to observe the formation of groups in relation to the cutting stages. This indicates that, for this sowing date, the maize genetic bases showed greater effects on the evaluated traits. With sowing on January 7, 2022, the triple and double hybrids also showed the highest production performance, while there was a reduction in NE and GY as the cuts were carried out in advanced stages. Therefore, it can be observed that, with sowing on this date, there was a greater manifestation of the effects of the cuts on the expression of the production traits of the genetic bases.

ISSN 1984-431X

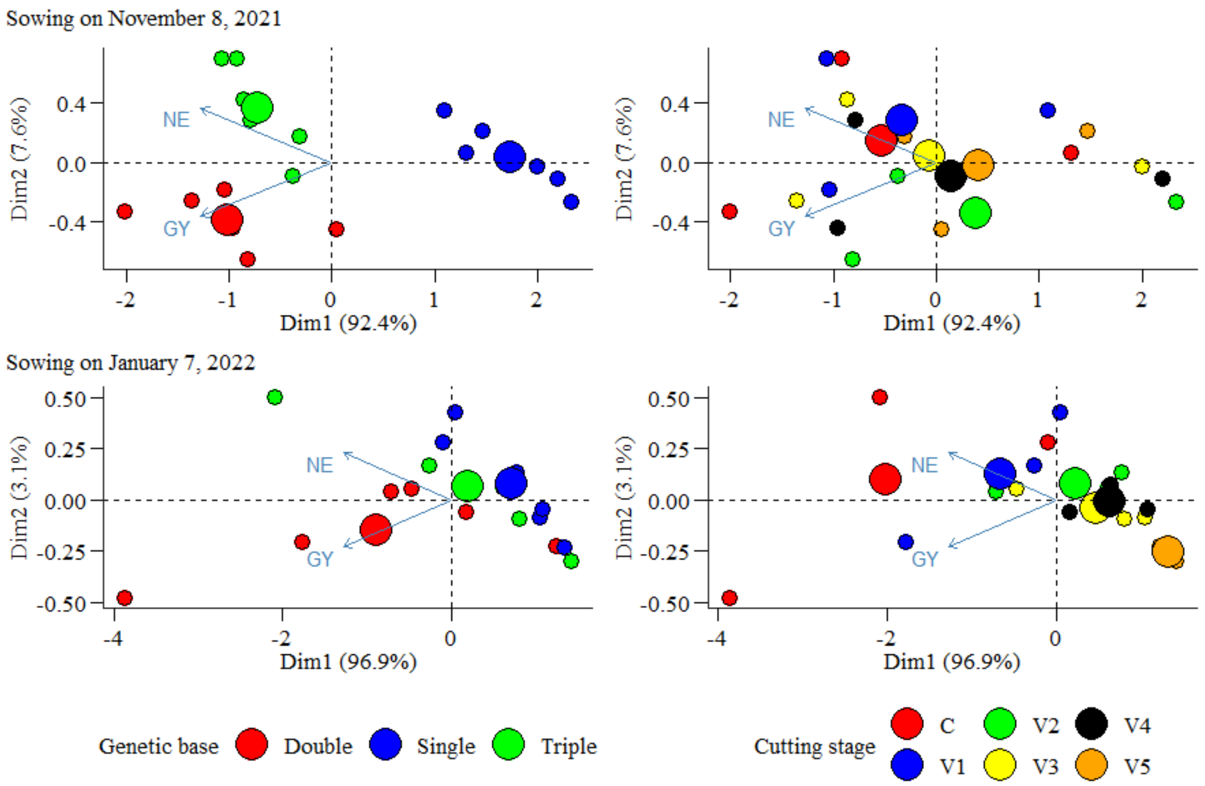
**Figure 2.** Boxplot of the distribution of the number of ears (NE, in thousand ears ha$^{-1}$) and grain yield (GY, in Mg ha$^{-1}$) of three maize genetic bases subjected to transverse cuts of plants at vegetative development stages.




C: absence of transverse cut of plants; V1: transverse cut of plants at the development stage V1; V2: transverse cut of plants at the development stage V2; V3: transverse cut of plants at the development stage V3; V4: transverse cut of plants at the development stage V4; and V5: transverse cut of plants at the development stage V5. UL: upper limit; LL: lower limit; and IQR: interquartile range. Dotted line represents the overall mean of each trait.

Revista Eletrônica Interdisciplinar
Barra do Garças – MT, Brasil
Ano: 2025 Volume: 17 Número: 1

**Figure 3.** Representation of the variability in the number of ears (NE, in thousand ears ha$^{-1}$) and grain yield (GY, in Mg ha$^{-1}$) of three maize genetic bases subjected to transverse cuts of plants at vegetative development stages.




C: absence of transverse cut of plants; V1: transverse cut of plants at the development stage V1; V2: transverse cut of plants at the development stage V2; V3: transverse cut of plants at the development stage V3; V4: transverse cut of plants at the development stage V4; and V5: transverse cut of plants at the development stage V5.

For both sowing dates, the F test of the analysis of variance revealed that the genetic base *vs* cutting stage interaction was significant for NE and GY (Table 1). This indicates that the genetic bases showed different responses according to the stages at which the cuts were carried out. The experimental precision, evaluated by the coefficient of variation, was medium (11.04 and 12.92%) for the sowing on November 8, 2021, and low (23.44 and 23.74%) for the sowing on January 7, 2022.

ISSN 1984-431X

**Table 1.** Calculated F values of the analysis of variance for the number of ears (NE, in thousand ears ha$^{-1}$) and grain yield (GY, in Mg ha$^{-1}$) of three maize genetic bases subjected to transverse cuts of plants at vegetative development stages.

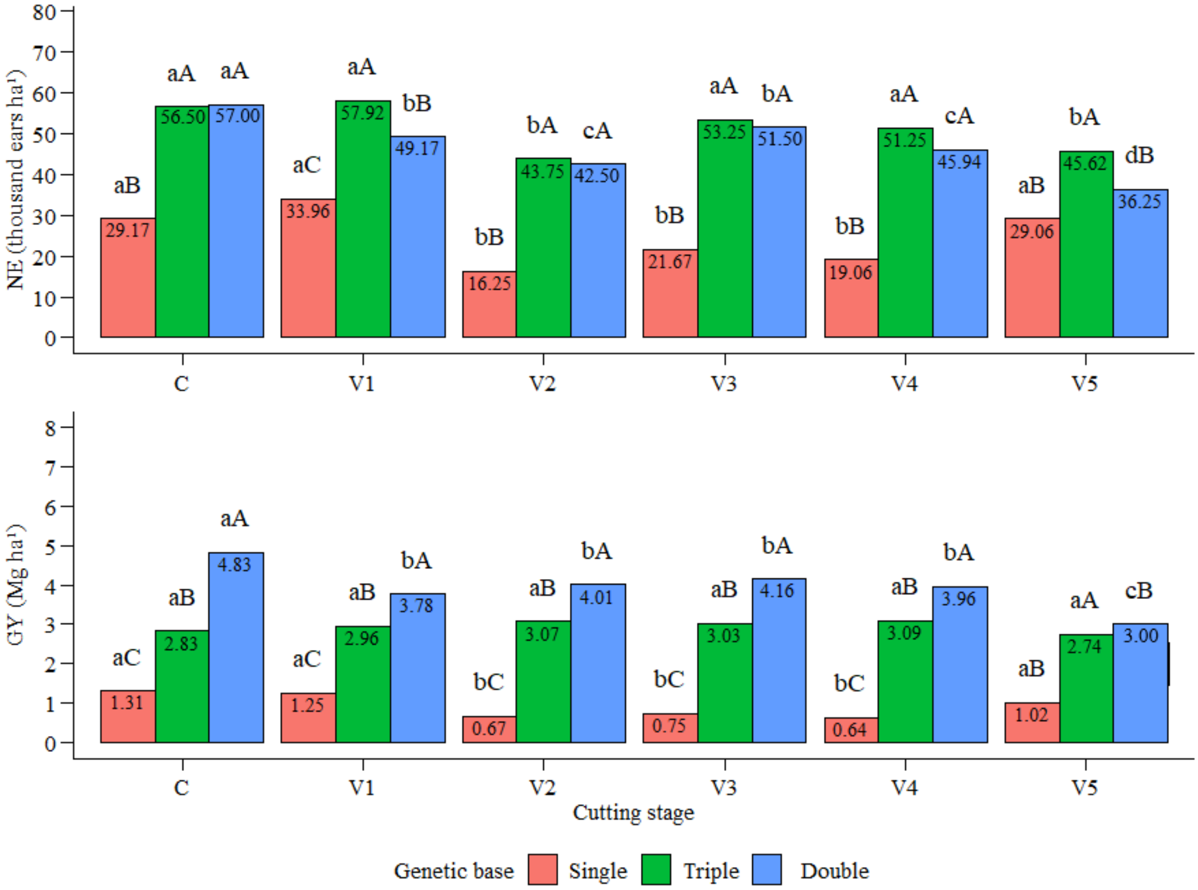
| SV | DF | NE | GY |
|---|---|---|---|
| | | Calculated F for sowing on November 8, 2021 | |
| Bases | 2 | 245.24* | 535.19* |
| Cuts | 5 | 17.84* | 4.31* |
| Bases × Cuts | 10 | 3.55* | 4.67* |
| Residual | 54 | - | - |
| CV (%) | - | 11.04 | 12.92 |
| | | Calculated F for sowing on January 7, 2022 | |
| Bases | 2 | 64.47* | 283.03* |
| Cuts | 5 | 110.15* | 185.14* |
| Bases × Cuts | 10 | 7.07* | 32.19* |
| Residual | 54 | - | - |
| CV (%) | - | 23.44 | 23.74 |

*Significant by the F-test at 5%. SV: source of variation; DF: degrees of freedom; CV: coefficient of variation.

NE and GY means for the first sowing date ranged from 16.25 to 57.92 thousand ears per hectare and 0.64 to 4.83 Mg ha$^{-1}$, respectively (Figure 4). For the second sowing date, NE and GY means ranged from 1.25 to 69.69 thousand ears and 0.04 to 7.08 Mg ha$^{-1}$, respectively (Figure 5). There was greater variation in the means of the traits for the second sowing date. The contrasting weather conditions between the two dates may contribute to the variations observed in the traits (Figure 1). Karam et al. (2010) observed grain yield variations from 1.8 to 3.10 Mg ha$^{-1}$ in a study with transverse cuts in maize plants.

ISSN 1984-431X

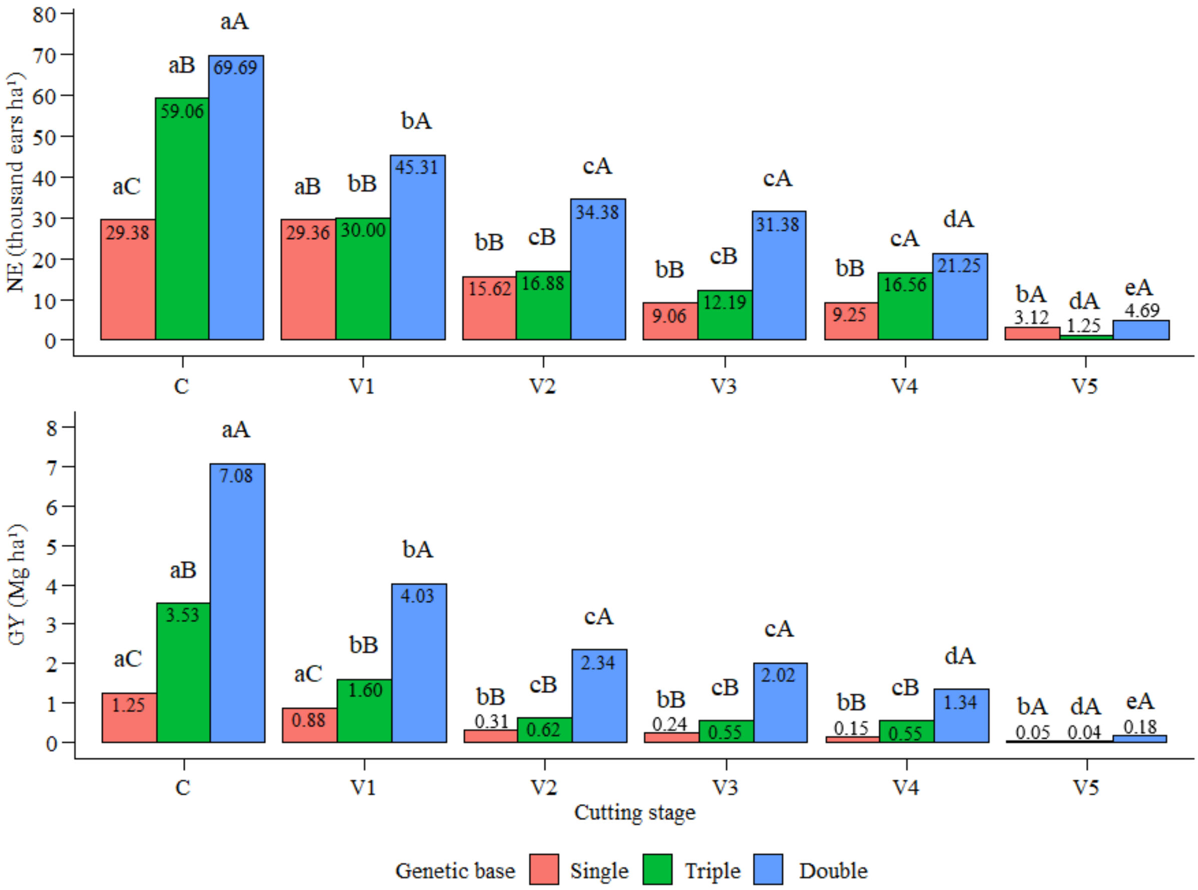
**Figure 4.** Scott-Knott means clustering test for the number of ears (NE, in thousand ears ha$^{-1}$) and grain yield (GY, Mg ha$^{-1}$) of three maize genetic bases subjected to transverse cuts of plants at vegetative development stages with sowing date of November 08, 2021.




C: absence of transverse cut of plants; V1: transverse cut of plants at the development stage V1; V2: transverse cut of plants at the development stage V2; V3: transverse cut of plants at the development stage V3; V4: transverse cut of plants at the development stage V4; and V5: transverse cut of plants at the development stage V5. Means followed by the same lowercase letter of a genetic base within the cutting stages do not differ from each other at 5% probability level by the Scott-Knott test. Means followed by the same uppercase letter of a cutting stage within the genetic bases do not differ from each other at 5% probability level by the Scott-Knott test.

ISSN 1984-431X

**Figure 5.** Scott-Knott means clustering test for the number of ears (NE, in thousand ears ha$^{-1}$) and grain yield (GY, Mg ha$^{-1}$) of three maize genetic bases subjected to transverse cuts of plants at vegetative development stages with the sowing date of January 07, 2022.




C: absence of transverse cut of plants; V1: transverse cut of plants at the development stage V1; V2: transverse cut of plants at the development stage V2; V3: transverse cut of plants at the development stage V3; V4: transverse cut of plants at the development stage V4; and V5: transverse cut of plants at the development stage V5. Means followed by the same lowercase letter of a genetic base within the cutting stages do not differ from each other at 5% probability level by the Scott-Knott test. Means followed by the same uppercase letter of a cutting stage within the genetic bases do not differ from each other at 5% probability level by the Scott-Knott test.

For the first sowing date, when comparing the means of NE and GY of the genetic bases considering each cutting stage, the Scott-Knott test separated the genetic bases into two to three groups (Figure 4). The triple and double hybrids exhibited superior NE in all cutting stages, with higher performance of the triple hybrid in the cuts at V1 and V5. The double hybrid had the highest mean of GY in all cutting stages. In the comparisons of NE and GY means of the cutting stages for each genetic base, one to four groups were formed. The treatment without plant cutting was grouped into the groups of higher NE and GY for the three genetic bases, indicating the potential for superiority of the genetic bases under ideal conditions, without stress caused by the cuts.

The single and triple hybrids showed little variation in NE when subjected to the cuts at the five stages, forming only two groups of means. The double hybrid showed the greatest variation in NE, with the formation of four groups of means. For GY, the single and triple hybrids also showed little variation with cuts at the five stages, with the single hybrid forming two groups of means and the triple hybrid showing no significant differences between the cutting stages. Three groups of GY means were formed for the double hybrid, which indicates the greatest variability of response to the cuts.

Studies have revealed absence of influence of defoliation on maize performance (GAIAS et al., 2017; BATTAGLIA et al., 2019; BATTAGLIA et al., 2018, BLANCO et al., 2022). Total defoliation at early vegetative stages may have minimal effects on maize grain yield, as long as the growing point is not affected (BATTAGLIA et al., 2019). Absence of reduction in grain yield was also reported by Battaglia et al. (2018), when 100% defoliation was performed at the V7 stage. Blanco et al. (2022) applied defoliation levels of 33 and 66% at V1-V2 and V3-V4, describing absence of reduction in maize yield. Gaias et al. (2017) performed 50% and total defoliation at the V4 stage and obtained yield reductions of 0.05% and 1.34%, respectively, although there was no significant difference. These results are similar to the response observed in the triple hybrid, indicating that the production performance under defoliation conditions is influenced by the genetic bases and environmental conditions of cultivation. Therefore, this result indicates that young maize plants can compensate for drastic defoliation without reducing their yield potential.

For the first sowing date, a lower frequency of rainfall was observed in the initial stages of plant development and higher air temperature (Figure 1). This may explain the maintenance of NE and GY, especially in the single and triple hybrids with cuts in advanced stages. According to Zengh et al. (2021), there may be an increase in the agronomic performance of maize after defoliation, when it is carried out in environments with low rainfall frequency conditions. Bataglia et al. (2018) also revealed that there was no significant interaction between maize hybrids and defoliation levels in a dry and hot year, while under conditions of higher humidity and lower temperature the interaction was significant. Therefore, under conditions of lower rainfall frequency and high temperature, there was less variation of NE and GY, with the triple hybrid showing the highest stability, regardless of the stage at which the plants were cut.

For the sowing on January 7, 2022, the double hybrid showed the highest means of NE and GY at all cutting stages. In the three genetic bases, the treatment without cutting was grouped

Revista Eletrônica Interdisciplinar
Barra do Garças – MT, Brasil
Ano: 2025 Volume: 17 Número: 1
ISSN 1984-431X

in the group with the highest NE and GY. There was a gradual reduction of NE and GY as the cuts were carried out at more advanced stages, indicating the negative impact of late cuts on the production capacity of the maize genetic bases. A similar result was reported by Rezende et al. (2015), who observed that the cutting of maize plants at the V4 stage led to the greatest reduction in grain yield (14.05%), compared to the removal of plant parts. Karam et al. (2010) also revealed that cuts above the second leaf and maceration of maize plants at the V2 and V4 stages reduced grain yield. The response of the genetic bases to the cuts was more pronounced when they were sown on January 7, 2022, with sharper reductions in NE and GY as the cuts were carried out at more advanced stages. This suggests that the stress caused by the cuts is more severe in plants that develop under conditions of higher rainfall and lower air temperature.

Under the environmental conditions associated with the second sowing date, the single hybrid exhibited the highest stability of agronomic performance at the different cutting stages, although it had the lowest NE and GY compared to the triple and double hybrids. This stability can be observed by the smaller number of groups of means formed in this genetic base (two groups for each variable and sowing date). The double hybrid showed the greatest reduction in production performance as the cuts were carried out at advanced stages of plant development, indicated by the formation of the largest number of groups of means (3 to 5 groups). Therefore, according to the specific conditions of the environment and management practices, such as cutting the plants, the choice between single, double or triple hybrids can significantly impact agronomic performance. The occurrence of physical stress, especially at more advanced stages, significantly reduces the production performance of the hybrids, especially under adequate rainfall conditions.

The results indicate that, although there was a long period for the plant to recover after the cut, such recovery did not occur effectively, as reported by Karam et al. (2010) and Rezende et al. (2015). Reduction of leaf area at the early stages of development significantly affects yield, especially in crops with adequate rainfall. Thus, the production performance of maize plants subjected to cutting is determined by the genetic base, cutting stage and environmental conditions.

## 4. FINAL CONSIDERATIONS

The number of ears and grain yield of maize decreased in the following order: double hybrid, triple hybrid and single hybrid.

Cutting plants at advanced stages reduces the number of ears and grain yield in all maize genetic bases.

Single and triple hybrids show a smaller reduction in the number of ears and grain yield under cuts at more advanced stages compared to the double hybrid, which shows a greater reduction.

## 5. BIBLIOGRAPHIC REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, v. 22, n. 6, p. 711-728. 2013. Doi: https://doi.org/10.1127/0941-2948/2013/0507

BATTAGLIA, M. L.; LEE, C.; THOMASON, W. Corn yield components and yield responses to defoliation at different row widths. **Agronomy Journal**, v. 110, n. 1, p. 210-225, 2018. Doi: https://doi.org/10.2134/agronj2017.06.0322

BATTAGLIA, M. L.; LEE, C.; THOMASON, W.; FIKE, J.; SADEGHPOUR, M A. Hail damage impacts on corn productivity: A review. **Crop Science**, v. 59, p. 1-14, 2019. Doi: https://doi.org/10.2135/cropsci2018.04.0285

BLANCO, C. A.; CONOVER, K.; HERNANDEZ, G.; VALENTINI, G.; PORTILLA, M.; ABEL, C. A.; WILLIAMS, P.; NAVA-CAMBEROS, U.; HUTCHISON, W. D.; DIVELY, G. P. Grain yield is not impacted by early defoliation of maize: Implications for fall armyworm action thresholds. **Southwestern Entomologist**, v. 47, n. 2, p. 335-344. 2022. Doi: https://doi.org/10.3958/059.047.0209

ECHARTE, L.; ANDRADE, F.H.; SADRAS, V.O.; ABBATE, P. Kernel weight and its response to source manipulations during grain filling in Argentinean maize hybrids released in different decades. **Field Crops Research**, v. 96, p. 307-312, 2006. Doi: https://doi.org/10.1016/j.fcr.2005.07.013

FANCELLI, A. L.; DOURADO NETO, D. **Milho: manejo e produtividade**. Piracicaba: ESALQ/USP, 2009, 181p.

GASPAR, T.; FRANCK, T.; BISBIS, B.; KEVERS, C.; JOUVE, L.; HAUSMAN, J. F.; DOMMES, J. Concepts in plant stress physiology. Application to plant tissue cultures. **Plant Growth Regulation**, v. 37, p. 263-285, 2002. Doi: https://doi.org/10.1023/A:1020835304842

GAIAS, W. L.; GIBBERT, E. R.; CHIDICHIMA, L. P. D. S.; HENDGES, C.; MULLER, A. L. Corn crop performance in different levels of defoliation. **Journal of Agricultural Science**, v. 10, n. 1, p. 354, 2017. Doi: https://doi.org/10.5539/jas.v10n1p354

KARAM, D.; PEREIRA FILHO, I. A.; MAGALHÃES, P. C.; PAES, M. C. D.; SILVA, J. A. A.; GAMA, J. C. M. Respostas de plantas de milho à simulação de danos mecânicos. **Revista Brasileira de Milho e Sorgo**, v. 9, n. 2, p. 2001-2011, 2010. Doi: https://doi.org/10.18512/1980-6477/rbms.v9n2p201-211

LIMA, R. O.; BORÉM, A. **Melhoramento de milho**. Editora: UFV, 2018, 396p.

R CORE TEAM. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. 2024. https://www.R-project.org

REZENDE, W. S.; BRITO, C. H.; BRANDÃO, A. M.; FRANCO, C. J. F.; FERREIRA, M. V.; FERREIRA, A. S. Desenvolvimento e produtividade de grãos de milho submetido a níveis de desfolha. **Pesquisa Agropecuária Brasileira**, v. 50, n. 3, p. 203-209, 2015. Doi: https://doi.org/10.1590/S0100-204X2015000300003

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAÚJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F. **Sistema Brasileiro de Classificação de Solos**, 5ª ed., Brasília: Embrapa, 2018.

ISSN 1984-431X

TAIZ, L.; ZEIGER, E.; MOLLER, I.M. **Fisiologia e desenvolvimento vegetal**. Porto Alegre: Artmed Editora, 2017. 858p.

WICKHAM, H. **ggplot2: elegant graphics for data analysis**. Springer-Verlag New York, 2016.

ZENGH, Z.; POWEL, J. J.; YE, X.; XUEQIANG, L.; YUAN, Z.; LIU, C. Overcompensation can be an ideal breeding target. **Agronomy**, v. 11, n. 7, p. 1376, 2021. Doi: https://doi.org/10.3390/agronomy11071376