

Intercropping of maize with *Megathyrsus maximus* cv. BRS Quênia managed with tembotrione¹

Consórcio de milho com *Megathyrsus maximus* cv. BRS Quênia manejado com tembotrione

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HIGHLIGHTS:

Megathyrsus maximus, cultivar BRS Quênia, can assist in weed control.

The forage *M. maximus*, cultivar BRS Quênia, does not reduce the performance of maize.

Increasing tembotrione doses reduces the density and dry mass of weeds.

ABSTRACT: The application of herbicides is the primary technique used to limit the growth and development of *Megathyrsus maximus* intercropped with maize, thus mitigating competition among the species. Therefore, this study aimed to verify the effect of tembotrione doses on the management of *M. maximus*, cultivar BRS Quênia, intercropped with maize, and its effect on weed control and corn yield. This experiment was conducted under field conditions in a randomized block design. The treatments included applying six tembotrione doses (0, 3.78, 7.56, 18.9, 37.8, and 75.6 g a.i. ha⁻¹) and one treatment with maize without forage crop (*M. maximus*). None of the doses used were able to maintain the forage at an adequate height for intercropping. The presence of the forage exerted crop control on weeds and did not influence maize yield. *Digitaria horizontalis*, *Commelina benghalensis*, and *Alternanthera tenell* were the main species of the weed community. Increasing tembotrione doses reduced the weed density and its dry mass at 38 days after application.

Key words: weeds, chemical management, competition, *Zea mays*, *Panicum maximum*

RESUMO: Na busca de limitar o crescimento e o desenvolvimento de *Megathyrsus maximus* consorciado com o milho, a principal técnica utilizada é a aplicação de herbicidas, sendo assim possível atenuar a competição entre as culturas. Portanto, o objetivo deste estudo foi verificar o efeito de doses de tembotrione no manejo de *M. maximus* cv. BRS Quênia consorciado com milho e seu efeito no controle de plantas daninhas e produtividade do milho. O trabalho foi conduzido no campo, em delineamento experimental de blocos casualizados. Os tratamentos foram constituídos pela aplicação de seis doses de tembotrione (0; 3,78; 7,56; 18,9; 37,8 e 75,6 g i.a. ha⁻¹) e um tratamento com milho sem a forrageira *M. maximus*. Nenhuma das doses utilizadas foi capaz manter a forrageira em altura adequada para o consórcio. A presença da forrageira exerceu controle cultural nas plantas daninhas e não interferiu no rendimento do milho. As principais espécies de plantas daninhas na comunidade infestante foram, *Digitaria horizontalis*, *Commelina benghalensis* e *Alternanthera tenella*. As crescentes doses de tembotrione reduziram a densidade e a massa seca das plantas daninhas aos 38 dias após a aplicação.

Palavras-chave: plantas daninhas, manejo químico, competição, *Zea mays*, *Panicum maximum*

INTRODUCTION

With the intensification of agricultural production, there is a search for a balance between increased yield and reduced cultivated areas. In this context, the integrated agricultural production system aims to achieve synergism between different crops in the same area, which over the years can lead to greater profitability for the producer, as well as environmental benefits and reduced production vulnerability (Carvalho et al., 2018; Silva et al., 2021).

The intercropping of forage grasses with annual crops is a sustainable cultivation alternative that can increase soil cover for no-till systems and reduce weed occurrence, which can cause yield losses (Gazziero et al., 2019). In recent years, institutions have contributed to developing improved forage cultivars of the genus *Megathyrsus*, emphasizing their potential for use in intercropping. However, it is necessary to manage these grasses to avoid competition with grain crops (Adegas et al., 2011; Dias et al., 2020; Cruvinel et al., 2021; Pereira et al., 2021).

In this sense, applying herbicide in adequate doses is a management technique that can limit the initial growth of forage grasses (Martins et al., 2019). Among the herbicides available for the intercropping between *Megathyrsus* and maize (*Zea mays* L.), tembotrione is a viable alternative due to its selectivity. Used in post-emergence in the maize crop, it inhibits carotenoid biosynthesis and has a broad spectrum of action against weeds (Sivamurugan et al., 2022).

Therefore, this study aimed to verify the effect of tembotrione doses on the management of *Megathyrsus maximus*, cultivar BRS Quênia, intercropped with maize, and its effect on weed control and corn yield.

MATERIAL AND METHODS

The experiment was conducted during the 2020/2021 harvest, between December 2020 to May 2021, under field conditions at the Instituto Federal Goiano, Campus Rio Verde (17° 48' 67" S, 50° 54' 18" W, and altitude of 754 m). The climate of the region is classified as Aw-type, tropical

humid, with rainfall in the summer and dry conditions in the winter, according to the Köppen classification. Precipitation, temperature, and relative humidity data are presented in Figure 1 and were obtained from the Instituto Nacional de Meteorologia (INMET, 2022).

The soil in the area is classified as Oxisol, corresponding to Typic Hapludox, according to the USDA Soil Taxonomy (Soil Survey Staff, 2014). Soil fertility was assessed in the 0-20 cm layer. The results were: pH (CaCl₂), 4.5, phosphorus, 11.94 mg dm⁻³, potassium, 0.36 cmol_c dm⁻³, calcium, 0.95 cmol_c dm⁻³, magnesium, 0.69 cmol_c dm⁻³; aluminum, 0.15 cmol_c dm⁻³, base saturation, 34.5%, and organic matter, 39.1 g dm⁻³. The particle size analysis results indicated 51.0 dag kg⁻¹ sand, 4.0 dag kg⁻¹, and 45.0 dag kg⁻¹ clay (clayey texture).

Before sowing, the experimental area was desiccated with glyphosate (Shadow[®]) at 1,680 g a.e. ha⁻¹, followed by soil preparation with plowing and leveling harrowing. The maize cultivar used was B2360PW with Roundup Ready[®] (RR) technology, allowing glyphosate application. The sowing fertilization was 300 kg ha⁻¹ of the 5-25-15 NPK formulation, composed of urea, single superphosphate, and potassium chloride. Maize was sown on 19/12/2020 at a depth of 4 cm using a four-row seed drill, with 0.45 m of row spacing, aiming for a final population of 60,000 plants ha⁻¹. Simultaneously, forage (*M. maximus* BRS Quênia) was broadcast sown using 10 kg ha⁻¹ of coated seeds, with a 79% cultural value (VC).

At 20 days after maize emergence (DAE), at the V4 - V5 phenological stage, a topdressing with nitrogen at 150 kg ha⁻¹ was conducted, using urea as the source.

The experimental design was randomized blocks with four replications. Treatments included applying six tembotrione doses (0, 3.78, 7.56, 18.9, 37.8, 75.6 g a.i. ha⁻¹) and one treatment of maize without forage. The treatments were applied to the maize intercropped with the forage crop, and the doses used were determined based on the herbicide label dose; therefore, the maximum dose was divided into sub-doses. In the treatment of maize without the presence of forage, a post-emergence application of 960 g of acid equivalent of glyphosate was made. All treatments included

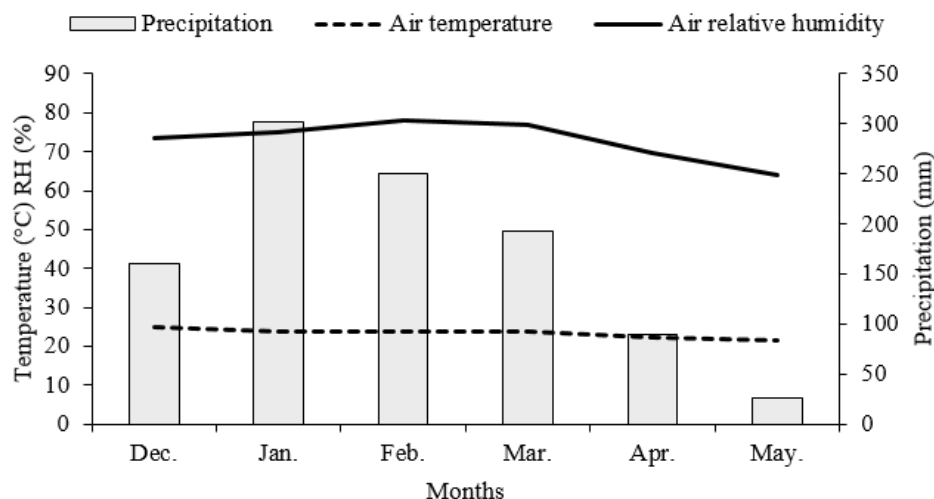


Figure 1. Precipitation, average air temperature, and relative humidity of air (RH) during the experimental period (December 12, 2020 to May 20, 2021)

the addition of atrazine (1500 g a.i. ha⁻¹) to the spray solution for broadleaf weed control. Experimental units consisted of nine maize rows, each 5 m long, with the effective area of each plot corresponding to the central four rows.

Treatments were applied at 20 DAE of maize, when the forage had two to three tillers. A pressurized CO₂ backpack sprayer was used at a constant pressure of 2.3 bar. A dual fan spray nozzle (110.02) was used, with a spray volume of 200 L ha⁻¹. During application, the temperature was 28 °C, wind speed was 2.2 km h⁻¹, and air humidity was 45.7%, monitored punctually with a thermo-hygro-anemometer.

At 60 DAE, in the flowering phase, maize plants were evaluated for plant height, ear insertion height, and stem diameter. Five plants were taken at random within the effective area of each plot for measurements. Ear insertion height was determined by measuring the distance from the ground to the upper ear insertion point. Plant height was measured from the ground to the flag leaf insertion. Stem diameter was measured using a digital caliper in the first internode above the ground.

Weed control evaluations were conducted 38 and 112 days after treatment using a 0.25 m² area. Weeds were collected from four random samples, totaling 1 m² per plot. Samples were separated by species, dried in an oven at 65 °C to constant weight, and then weighed to determine density and dry weight. The relative importance (RI) of each species was calculated as a weighted percentage of frequency, density, and dry mass, as described by Pitelli (2000).

At maize harvest, at 128 DAE, yield components were evaluated, including the number of rows per ear, number of grains per row, ear length, and 1000-grain weight. Five ears were used per plot in the effective area. Grain yield was obtained by threshing ears harvested from the plot's effective area (four rows, three meters long), followed by grain weighing. Values were converted to kg ha⁻¹ and adjusted to 13% moisture (Mello et al., 2023).

During maize harvest, forage height was measured using a graduated ruler in centimeters. Plants were harvested with a knife in a 2 m² area of each plot, approximately 30 cm above the ground. Forage yield was determined by weighing the collected material taking a 0.5 kg sample. The samples were separated into leaves and stems and dried in a forced-air oven at 65 °C until they obtained constant weight. Leaf/stem ratio and forage dry matter yield were evaluated (Mello et al., 2023).

Data were subjected to analysis of variance, and when significant effects were detected, regression analysis was applied using SISVAR 5.6 software (Ferreira, 2011). Models were adjusted based on simplicity, biological significance, and coefficient of determination.

RESULTS AND DISCUSSION

For the evaluations related to the forage (*M. maximus*) BRS Quênia (Table 1), the different tembotrione doses did not influence the analyzed variables: forage height (FHE), forage yield (FYD), and leaf/stem ratio (L/S).

For the forage height, after herbicide application, all treatments showed values very close to those found in the treatment where tembotrione was not applied, indicating the inefficacy of the doses used to limit forage growth in intercropping with maize.

The cultivar BRS Quênia typically reaches around 1.40 m in height under free cultivation with tussock growth (Dias et al., 2020). These traits and good water availability during the experimental period may have favored forage growth. Additionally, being intercropped with maize could have contributed. The reduced light incidence due to maize shading not only promotes greater stem elongation but also causes the forage to relocate its leaves to higher strata in search of light, resulting in increased height (Paciullo et al., 2017; Januskiewicz et al., 2021).

Regarding leaf/stem ratio, all treatments showed low values close to 1, which is considered critical for this variable (Santos et al., 2017). Similar to findings for forage height, these results can be attributed to maize shading, which caused the forage to elongate its stems in search of light. Another influencing factor could be the developmental stage of the forage at harvest, as it was in flowering, during which plants halt leaf production and promote stem elongation, progressively reducing the leaf/stem ratio (Almeida et al., 2017; Tesk et al., 2018).

For forage yield (FYD), it was observed that none of the doses used were sufficient to limit this variable, as the values obtained with the highest dose were similar to those observed for untreated forage, with values of 9.21 and 9.19 t ha⁻¹, respectively. These results demonstrate that maize did not exert a competitive effect on forage, emphasizing the need for an effective herbicide dose to make intercropping viable.

Considering the phenological stage (three to four tillers) at which the tembotrione application was made, adequate rainfall distribution during the experimental period, and no nutritional restriction for forage development, these results suggest tembotrione and atrazine selectivity at the doses tested for BRS Quênia. A study by Cruvinel et al. (2021), focusing on managing different forage grasses, showed that BRS Quênia was the least sensitive to herbicide application, requiring 84 g ha⁻¹ of tembotrione to limit forage growth and development.

Regarding the weed community (Table 2), 11 species from seven distinct botanical families were recorded at 38 and 112 DAA (days after application). The species identified in the crop were abbreviated following the EPPO Code Database (2024).

Table 1. Forage height (FHE), forage yield (FYD), and leaf/stem ratio (L/S) of *Megathyrsus maximus* cv. BRS Quênia intercropped with maize according to different tembotrione doses

Variable	Doses (g a.i. ha ⁻¹)						Regression	CV (%)
	0	3.78	7.56	18.9	37.8	75.6		
FHE (m)	1.77	1.79	1.77	1.74	1.78	1.76	$\hat{Y} = \bar{Y} = 1.77^{ns}$	3.44
FYD (t ha ⁻¹)	9.19	9.22	9.14	9.16	9.15	9.21	$\hat{Y} = \bar{Y} = 9.17^{ns}$	7.61
L/S	0.98	1.2	1.1	0.96	0.98	0.97	$\hat{Y} = \bar{Y} = 1.04^{ns}$	1.14

ns - Not significant by F-test

Table 2. Relative importance (RI in %) of the weed species evaluated at 38 and 112 days after application (DAA) according to different tembotrione doses

Species	Tembotrione doses (g a.i. ha ⁻¹)							
	MM	0	3.78	7.56	18.9	37.8	75.6	Average (%)
38 DAA								
ALTTE	14.57	0.00	9.21	8.60	0.00	3.80	16.13	7.47
COMBE	20.85	11.73	8.45	0.00	0.00	18.20	11.39	10.09
BIDPI	8.64	0.00	0.00	0.00	0.00	0.00	0.00	1.23
ELEIN	13.14	0.00	0.00	4.70	0.00	9.03	21.71	6.94
RICCO	13.61	0.00	0.00	13.70	5.95	0.00	0.00	4.75
EUPHE	12.39	0.00	0.00	0.00	0.00	0.00	0.00	1.77
DIGHO	16.80	88.27	82.34	73.03	94.05	68.96	50.77	67.75
112 DAA								
ALTTE	29.17	40.52	31.94	78.26	33.11	37.93	38.30	41.32
COMBE	10.74	59.48	47.69	21.74	54.93	19.01	30.68	34.89
ELEIN	11.59	0.00	0.00	0.00	0.00	4.76	13.93	4.33
RICCO	2.06	0.00	0.00	0.00	0.00	0.00	0.00	0.29
RICBR	3.28	0.00	20.37	0.00	0.00	0.00	0.00	3.38
AGECO	7.52	0.00	0.00	0.00	11.96	10.22	5.89	5.09
DIGHO	2.68	0.00	0.00	0.00	0.00	10.31	0.00	1.86
SIDRH	2.05	0.00	0.00	0.00	0.00	0.00	0.00	0.29
CNDSS	30.90	0.00	0.00	0.00	0.00	17.76	11.19	8.55

MM - Maize monoculture; ALTTE - *Alternanthera tenella*; COMBE - *Commelina benghalensis*; BIDPI - *Bidens pilosa*; ELEIN - *Eleusine indica*; RICCO - *Ricinus communis*; EUPHE - *Euphorbia heterophylla*; RICBR - *Richardia brasiliensis*; DIGHO - *Digitaria horizontalis*; AGECO - *Ageratum conyzoides*; SIDRH - *Sida rhombifolia*; CNDSS - *Conyza bonariensis*.

These included *Bidens pilosa* (BIDPI), *Conyza bonariensis* (CNDSS), and *Ageratum conyzoides* (AGECO), all from the Asteraceae family. *Eleusine indica* (ELEIN) and *Digitaria horizontalis* (DIGHO) belonged to the Poaceae family. *Euphorbia heterophylla* (EUPHE) and *Ricinus communis* (RICCO), from the Euphorbiaceae family. Lastly, *Alternanthera tenella* (ALTTE), *Commelina benghalensis* (COMBE), *Richardia brasiliensis* (RICBR), and *Sida rhombifolia* (SIDRH) were classified under the Amaranthaceae, Commelinaceae, Rubiaceae, and Malvaceae families, respectively.

The RI value demonstrates the relative importance of each species, being a weighted percentage measure of frequency, density, and dry biomass accumulation (Pitelli, 2000). In this context, at 38 DAA, on average, the species DIGHO and COMBE were predominant in the area, jointly representing 77.84% of the weed community. By 112 DAA, the most relevant species were ALTTE and COMBE, with RI values of 41.32 and 34.89%, respectively. The other weed species showed low RI values in both evaluation periods.

The high relative importance observed for DIGHO, ALTTE, and COMBE can be attributed to their highly competitive potential, as they are considered some of the most aggressive in crops, with high seed production, easy dispersal, and adaptation, characterized as weeds that are difficult to control (Silva et al., 2018). A similar result was observed by Martins et al. (2018), who, working with tembotrione doses in maize intercropped with *Urochloa brizantha*, found that ALTTE and COMBE had the highest RI values within the weed community at 109 DAA.

Considering that none of the tembotrione doses used were able to limit the growth and development of the forage species (Table 1), it is worth noting that in both evaluation periods (38 and 122 DAA), the treatment with maize monoculture presented the highest variety of weed species due to the absence of ground cover. The intercropped forage contributes to the cultural control of weeds, potentially reducing their regrowth and development (Schuster et al., 2019).

A significant effect was observed for weed density and dry biomass (Figures 2A and B) at 38 days after the application of tembotrione. There was a linear decrease for both variables, as for each 1 g a.i. ha⁻¹ of herbicide applied, the reduction was 0.0287 plants m⁻² and 0.06 g m⁻² for density and dry biomass, respectively, indicating that increasing herbicide doses can reduce both the quantity and size of weeds. However, by 112 DAA, no differences were observed among the treatments for these two variables.

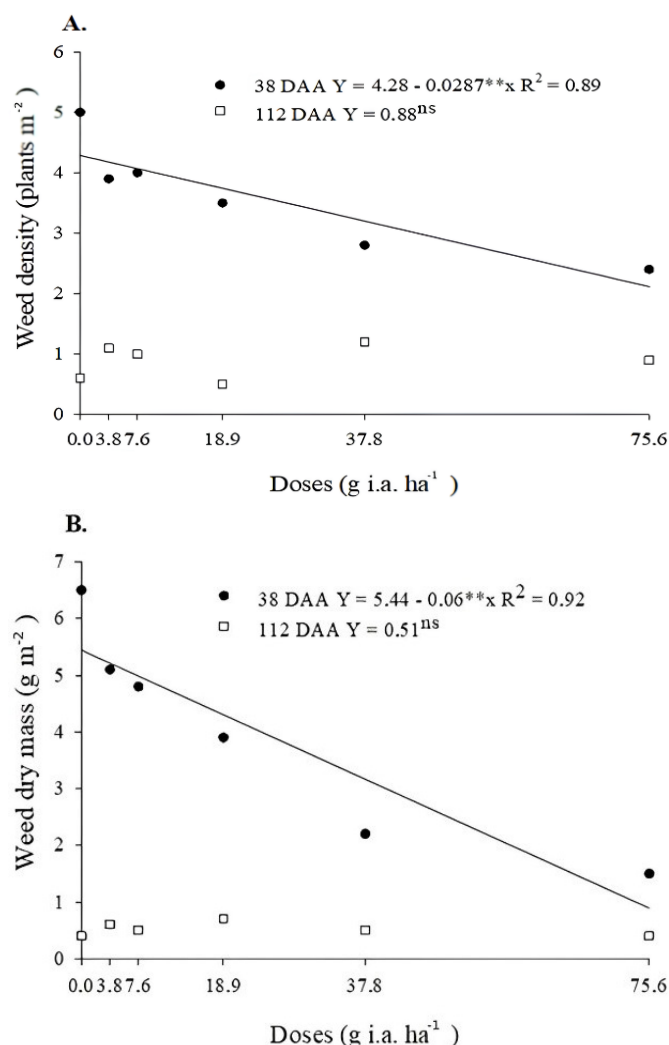
For maize monoculture, the highest weed density and dry biomass values were recorded in both evaluation periods. This demonstrates that the presence of intercropped forage has the potential to promote cultural control over the weed community. Competition for space, water, light, and nutrients is crucial for the suppressive effect of forage (Martins et al., 2018).

Ferreira et al. (2018) found that the presence of *U. brizantha* and *M. maximus* resulted in total control of various weed species, such as *A. tenella*, *C. benghalensis*, and *D. horizontalis*, which were also observed in this study as having the highest relative importance (Table 2).

Intercropped forage can reduce both the density and dry biomass of the weed community (Mello et al., 2023). Furthermore, the use of cultural practices of integrated weed management, such as intercropping, can reduce and ultimately eliminate the need for herbicide application in successive crops. The mulch provided by the forage after grain crop harvest protects the soil and prevents light penetration, thus hindering weed germination (Ryan et al., 2018; Dominschek et al., 2021).

Regarding maize (Table 3), it is observed that the application of different herbicide doses did not influence the measured traits, as no significant effects were found in any of the evaluations.

Considering that tembotrione is selective for maize, the results demonstrate that there was no influence of the forage on the components of maize and adequate water availability



** - Significant at $p \leq 0.01$ by F-test; ^{ns} - non-significant at $p > 0.05$ by F-test Weed density and weed dry mass in maize monoculture at 38 and 112 DAA was 61 and 73 plants m⁻² and 47.2 and 103.11 g m⁻², respectively.

Figure 2. Weed density (A) and weed dry mass (B) according to different tembotrione doses at 38 and 112 days after application (DAA) of treatments in intercropping between maize and *Megathyrsus maximus* (cultivar BRS Quênia)

during the experimental period (Figure 1) may have contributed to this outcome.

Furthermore, the herbicide application was conducted within the critical period of weed interference prevention (CPWIP) for maize, which may have favored the proper development of the grain crop. This demonstrates that maize

grain yield was not compromised even with excessive forage growth in the intercropping system. However, it is important to emphasize that forage height is a relevant factor in intercropping with grain crops, as exceeding the ear insertion height may hinder the mechanized grain harvesting process.

Martins et al. (2018), working with the tembotrione application in maize intercropped with *U. brizantha*, did not observe differences in grain yield. Similar results were found by Silva et al. (2023), who aimed to manage *M. maximus* in intercropping with maize and found that yield was not influenced.

However, it is important to note that for intercropping to be successful, it is crucial to control the forage. Even though maize yield was not significantly influenced in this study, excessive growth of the forage can cause problems in the mechanized harvesting of grains and increase the number of lodged maize plants (Mello et al., 2023).

CONCLUSIONS

1. The highest tembotrione dose (75.6 g a.i. ha⁻¹) was insufficient to limit the growth and development of the forage grass (*Megathyrsus maximus*, cultivar BRS Quênia).
2. The maize grain yield was not harmed by the forage grass (*M. maximus*, cultivar BRS Quênia) in intercropping.
3. The forage grass (*M. maximus*, cultivar BRS Quênia) exerted cultural control over the weed community.

Contribution of authors: Carlos E. L. Mello: Work execution, manuscript writing, analyses, administration, and data collection. Adriano Jakelaitis: Supervision, administration, and research conception. Carlos H. de L. e Silva: Work execution, data collection, and analyses. Jaqueline O. da Silva: Work execution and data collection. Felipe P. Cunha: Work execution and data collection. Elias J. da Silva: Work execution and data collection.

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Table 3. Number of rows per ear (NRE), number of grains per row (NGR), ear diameter (ED), ear length (EL), ear height (EH), plant height (PH), stem diameter (SD), 1000-grain weight (1000W), and grain yield (GY) of maize intercropped with *Megathyrsus maximus* (cultivar BRS Quênia) according to the application of different tembotrione doses

Variables	Doses (g a.i. ha ⁻¹)						Regression	MM	CV (%)
	0	3.78	7.56	18.9	37.8	75.6			
NRE	16.50	16.00	16.00	17.05	17.00	16.50	$\hat{Y} = \bar{Y} = 16.5^{ns}$	17.00	1.62
NGR	31.00	29.75	30.15	31.75	29.00	29.50	$\hat{Y} = \bar{Y} = 30.19^{ns}$	30.5	9.34
ED (cm)	42.45	44.54	42.78	45.15	42.07	44.16	$\hat{Y} = \bar{Y} = 43.52^{ns}$	43.07	5.12
EL (cm)	15.65	14.94	15.25	15.95	15.16	15.04	$\hat{Y} = \bar{Y} = 15.33^{ns}$	16.02	5.19
EH (m)	1.15	1.12	1.14	1.15	1.09	1.12	$\hat{Y} = \bar{Y} = 1.12^{ns}$	1.10	2.50
PH (m)	1.93	1.82	1.87	1.83	1.78	1.87	$\hat{Y} = \bar{Y} = 1.85^{ns}$	1.88	3.25
SD (cm)	25.91	24.13	25.73	25.02	25.84	25.15	$\hat{Y} = \bar{Y} = 25.29^{ns}$	24.68	1.76
1000W (g)	206.15	222.5	215.2	233.56	211.15	230.95	$\hat{Y} = \bar{Y} = 219.91^{ns}$	229.25	8.12
GY (t ha ⁻¹)	6.39	6.21	6.58	6.23	6.37	6.74	$\hat{Y} = \bar{Y} = 6.42^{ns}$	6.82	3.6

ns - Not significant by F-test; MM - Monocrop maize; CV - Coefficient of variation

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