ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 13, Issue, 01, pp. 61234-61238, January, 2023
https://doi.org/10.37118/ijdr.26018.01.2023

RESEARCH ARTICLE OPEN ACCESS

CONTRASTING TIMES IN THE PRODUCTION OF GREEN MAIZE UNDER DEFOLIATION AND ROW SPACING

Eliene Wellita Vieira Barcelos Ramos[1], Lucas Silva Mendes[2], Milena Costa dos Santos[3], Laidson Alves Leão Júnior[4] and Wilian Henrique Diniz Buso*[5]

[1]Agronomist, Master in Cerrado Irrigation, Instituto Federal Goiano Campus Ceres, Ceres-Go, Brasil; [2,3,4] Agronomist, Instituto Federal Goiano Campus Ceres, Ceres-Go, Brasil; [5]Agronomist, Doctor, Teacher of Agronomic Course, Instituto Federal Goiano Campus Ceres, Ceres-Go, Brasil

ARTICLE INFO

Article History:

Received 14th November, 2022
Received in revised form
23rd November, 2022
Accepted 16th December, 2022
Published online 24th January, 2023

Key Words:

Zea mays L.,
Spatial Arrangement,
Yield, Temperature.

****Corresponding author:***
Wilian Henrique Diniz Buso

ABSTRACT

Consumed fresh or processed, green maize is present in several regions of Brazil and the world. The scarcity of specific technical cultivation information for the Cerrado region and other regions of the country, besides the data on the correct sowing time, makes it impossible to obtain high yields. Therefore, the objective of this work was to evaluate the agronomic performance of the maize cultivar AG 1051, submitted to different spacing, defoliation, and sowing times. The experimental design was randomized blocks arranged in a 3x4x4 factorial scheme with four repetitions. Three sowing times(time I: 06/09/2017, time II: 08/12/2017, and time III: 12/17/2017), four row spacings (0.60; 0.70; 0.80; and 0.90 m), and four types of defoliation (removal of all leaves above the ear (AE), removal of all leaves below the ear (BE), removal of two leaves below and two leaves above the ear (ME) and the control without defoliation (CONTROL)) done in the VT stage were evaluated. The variables analyzed were the length of the ears without husk (ELH), the yield of the ear with and without husk (YWH) (YWHK) (kg ha^{-1}), and dry matter content (DM) (%). The spacing of 0.60 m provides a greater yield of ears with and without husk (15,530.21 and 8,571.6 kg ha^{-1}). Sowing time II provides greater YWH andYWHK. Defoliation AE reduces ELH in the sowing time III, andYWHK in times II and III.

Citation: ***Eliene Wellita Vieira Barcelos Ramos, Lucas Silva Mendes, Milena Costa dos Santos, Laidson Alves Leão Júnior and Wilian Henrique Diniz Buso. 2023.*** "Contrasting times in the production of green maize under defoliation and row spacing", *International Journal of Development Research*, 13, (01), 61234-61238.

INTRODUCTION

Green Maize (*Zea mays*) is a crop of great importance for the economy. Grown practically all over Brazil in 16,608.1 million hectares, it showed a 5.6% reduction in the 2017/2018 harvest compared to the 2016/2017 harvest. In the Midwest Region, cultivation covers an area of 7,697.9 million hectares (CONAB, 2018). Green maize is understood when the ear is harvested with about 70 to 80% moisture and with soft grains and before all the sugar is converted into starch (Courter *et al*. 1988). Cultivation stands out mainly in family farming on small farms; however, it is also cultivated in medium and large areas with high technological levels (Mattoso& Melo Filho 2010). The improvement of maize crop management practices, besides the use of cultivars with high yields, allowed flexibility in spacing reducing between rows and in increasing plant density (Argenta *et al*. 2001). As a result, the use of reduced spacing and different population densities is increasingly addressed in research. Sowing in colder times makes the plant need more time to reach the thermal sum necessary for flowering, and this does not depend on the cultivar used (Simão *et al*., 2018). Another essential factor to be observed is luminosity. Maize plants subjected to a 30 - 40% decrease in light intensity have an elongated cycle (Fancelli& Dourado Neto 1997). Studies on leaf area and defoliation in the plant can help understand the source-sink relationship and provide information on grain yields (Silva 2001, Sangoi *et al*. 2014, Rezende *et al*. 2015). Therefore, the objective of this study was to evaluate the agronomic performance of irrigated and rainfed green maize submitted to different spacing and defoliation cultivated in threesowingtimes.

MATERIAL AND METHODS

The experiments were conducted at the Goiano Federal Institute - Campus Ceres, in Ceres-GO, in an irrigated and rainfed area. In the area irrigated by sprinkling via center pivot (15º18'30" S, 49º35'54" W, and 571 meters of altitude), sowing was carried out on 06/09/2017 (time I) and 08/12/2017 (time II). The soil of this area is characterized as ArgissoloVermelho, with a dry and mild winter climate and hot and rainy summer. The sowing of 12/17/2017 (time III) was in a rainfed area (15°20'52.00" S, 49°36'16.42" W, and altitude of 570 m). The experimental design was randomized blocks arranged in a 3x4x4 factorial scheme, with four replications. Three sowing times (time I, time II, and time III), four row spacings (0.60; 0.70; 0.80; and 0.90 m), and four types of defoliation: removal of all leaves above the ear (AE), removal of all leaves below the ear (BE), removal of two leaves below and two leaves above the ear (ME) and finally the control that is without leaf removal (CONTROL) were evaluated. The leaves were removed manually, keeping the sheath at the plant at the VT stage. The treatment of seeds with fungicides and insecticides and the application of herbicides were carried out according to the technical recommendations for the crop. In the sowing, 16 kg ha^{-1} of N, 120 kg ha^{-1} of P_2O_5, and 40 kg ha^{-1} of K_2O were applied. As topdressing fertilization, at the V5 stage, 180 kg ha^{-1} of nitrogen (urea) was applied**.** The plots were composed of four five-meter rows, and the evaluations consisted of the two central rows, excluding 0.50 m from the ends. Irrigation via center pivot was managed through the evaporation pan. The ears were harvested at the R3 stage. The harvests took place on 09/23/2017, 11/11/2017, and 03/03/2018 (sowing times I, II, and III, respectively). The length of the ears without husk (ELH), the yield of ears with husk (YWH) and without husk (YWHK) (kg ha^{-1}), and the dry matter content (DM) (%) were evaluated. All data were subjected to analysis of variance by the F test. The Tukey test compared the means of sowing times and types of defoliation at the 5% probability, and the means of spacing were subjected to regression analysis. All analyzes were performed using Software R.

RESULTS AND DISCUSSION

The maximum and minimum temperatures ranged during the period in which the experiments were in the field, as well as the precipitation (Figure 1).

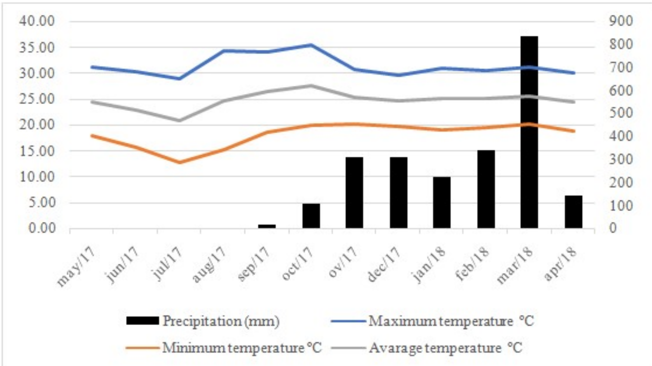

Figure 1. Precipitation and temperatures in the experimental period from Jun/2017 to Mar./2018

The accumulated daily thermal sum in the sowing time III was higher, causing the plant cycle to be reduced, reaching the required number of degree days (DD) to the plant cycle in less time. The lower temperatures at the sowing time I caused the plant to decrease its metabolism, staying well below the ideal temperature (Figure 1), for plant growth and development, with little development of leaf area. Factors such as solar radiation and air temperature influence the growth, development, and phenology of maize plants (Piana *et al.* 2008). Low air temperatures cause the cycle to increase, while sowing in times with high temperatures reduces it (Couto *et al.* 1984). Maize plants are considered sensitive to large temperature fluctuations and can be anticipated or prolonged (Shioga & Gerage 2010). The ideal temperature ranges from 30 to 40ºC (Stewart *et al.* 1998). The average monthly temperatures in the sowing time II were the highest and ranged between 21.33 and 28.12ºC. The thermal sum considers the maximum temperature, minimum temperature, and basal temperature (Leme 2007). For the length of the ear without husk (ELH), there was no significant interaction. There was a difference between the sowing times and the defoliation performed. When assessing the length of the ear without husk (ELH), it was noted that those of greater length was from plants sown in the time III (18.02 cm). This may be related to the greater number of grains per grain row. The more grains, the longer the ear. There was no difference between the sowing times I and II (Table 1).

Table 1. Length of the ear without husk (ELH) of green maize plants grown under irrigated and rainfed conditions according to the sowing time and types of defoliation

Defoliation		Sowing times	
CONTROL	17.70 a	I	16.68 b
AE	16.54 c	II	16.82 b
BE	17.03 bc	III	18.02 a
ME	17.44 ab	-	-

Means followed by the same lowercase letters in the columns are statistically equal by the Tukey test at the 5% probability. I (sowing time I); II (sowing time II); III (sowing time III). CONTROL (without defoliation); AE (defoliation of all leaves above the ear); BE (defoliation of all leaves below the ear); ME (defoliation of two leaves above and two below the ear).

Caron *et al*. (2017) evaluated two maize hybrids submitted to different sowing dates. They found that the later the sowing, the smaller the diameters. Favarato *et al*. (2016) worked with the cultivar AG 1051 and found that the plants produced ears with a length of 20.76 cm and a diameter of 47.8 mm when they were sown in October. The longest ears were from plants that did not have their leaves removed (CONTROL), producing ears of 17.70 cm. The defoliation AE, BE, and ME reduced the length of the ears, and the defoliation AE promoted the shortest length (Table 1). Trogello *et al*. (2017) found different results. There was no significant difference in the ear length in any of the defoliations. The control presented 17.84 cm; defoliation of all leaves above the ear 16.94 cm; defoliation of all leaves below the ear 16.33 cm and the defoliation of two leaves above and two leaves below, 16.6 cm long. Kuhn *et al*. (2018) evaluated the hybrid LG 6033 VT PRO 2, which was subjected to different defoliation in the VT stage: defoliation of all leaves, defoliation leaving only the lower third leaves; defoliation leaving only the middle third leaves, and defoliation preserving only the upper third leaves, besides the control, which was without the removal of leaves. They found that the different defoliations reduced the ear length; however, the number of grains per row did not differ. The removal of the leaves reduced the photosynthetic area of the plant and, consequently, the accumulation of photoassimilates. Thus, the ears had a reduced length, regardless of the type of defoliation performed. About 50% of the carbohydrates accumulated in the grains come from the upper third leaves. The middle third leaves account for about 30% of these carbohydrates and the other 20% for the basal leaves (Fornasieri Filho 2007). As seen, larger leaf areas may be more efficient in photosynthesis due to the larger photosynthetic area and the efficiency of the incidence of solar radiation (Ferreira Junior *et al*., 2014). In this way, defoliation in plants causes loss of leaf area and interferes with metabolism, carbohydrate production, which influences many plant production characteristics. There was an influence of double interaction on the variables YWH, YWHK, and DM. YWH and YWHK had a significant interaction between sowing times and defoliation, and it was also significant for row spacing. The dry matter content was influenced by the interaction between the sowing time and the type of defoliation. YWH, without defoliation (CONTROL), was higher in the sowing time II. Sowing times I and III were also lower (Table 2).

Caron *et al*. (2017) evaluated the caron ear yield at different sowing times and found that sowing in December reduced the crop yield.Favarato *et al*. (2016) evaluated the performance of the cultivar AG 1051 sown in August, and they found that the yield of ears with husk was 16,877 kg ha^{-1}, lower than that obtained in the present study (18,195.93 kg ha^{-1}). Higher temperatures during the day favor photosynthesis, with the accumulation of photoassimilates, which, combined with milder temperatures at night, promote an increase in the vegetative growth phase of the plant, making better use of the incident solar radiation. Thus, the accumulation of reserves is greater, and the loss of photoassimilates caused by the respiration process is reduced (Andrade 1992).

Table 2. Yield of the ear with husk (YWH) (kg ha^{-1}) of green maize plants grown under irrigated and rainfed conditions according to the sowing time and types of defoliation

Sowing times	Types of defoliation			
	CONTROL	AE	BE	ME
I	13,260.83 bA	13,061.31 bA	12,898.85 bA	13,109.97 aA
II	18,195.93 aA	16,540.33 aA	16,912.98 aA	15,629.65 aA
III	14,470.85 bA	9,681.96 cC	11,210.90 bBC	12,973.16 aAB

Means followed by the same lowercase letters in the columns and uppercase letters in the lines are statistically equal by the Tukey test at the 5% probability. I (sowing time I); II (sowing time II); III (sowing time III). CONTROL (without defoliation); AE (defoliation of all leaves above the ear); BE (defoliation of all leaves below the ear); ME (defoliation of two leaves above and two below the ear).

The ideal time for sowing maize should be when the plant reaches the tassel emergence with the largest possible leaf area (Piana *et al*. 2008). The taller plants, which accumulate in the leaves and stalk a greater amount of photoassimilates, promote the filling of grains in a more satisfactory way, resulting in heavier ears, which is the case of the sowing time II compared to sowing times I and III. The defoliation AE, which occurred in the sowing time II, caused fewer losses in YWH, followed by the sowing time I (13,061.31 kg ha^{-1}) and, finally, sowing time III which had the lowest yield (9,681.96 kg ha^{-1}). Plants that were sown in the time II accumulated a greater amount of photoassimilates than times I and III, making it even superior in terms of YWH under defoliation. When submitting the plants to the removal of the upper leaves in the reproductive stage, Alvim *et al*. (2011) confirmed the hypothesis that, despite the importance of the entire leaf area, the leaves of the upper third are the ones that contribute with the greatest amount of photoassimilates, which are subsequently translocated to the grains, producing heavier and more spiky ears, attractive for commercialization. Plants that were sown in time II submitted to BE defoliation also showed higher yield than the other sowing times (16,912.98 kg ha^{-1}) (Table 2). When the plants were submitted to ME defoliation, it was observed that there was no significant difference in the yield of eras with husk, regardless of the sowing time (Table 2).

When individually evaluating sowing time I, it was observed that the removal of leaves (AE, BE, and ME) did not reduce the yield of ears with husk compared to those whose leaves were not removed (CONTROL), being all statistically equal (Table 2). In sowing time II, the yield of ears with husk was also statistically equal for all, regardless of the type of defoliation of the green maize plants. However, in sowing time III, it was observed that the highest yield of ears with husk was that of plants without defoliation (CONTROL), with 14,470.85 kg ha^{-1}. The removal of leaves affected yield, regardless of defoliation, highlighting the one in which all leaves from the upper third (AE) were removed, with a yield of ears with husk of 9,681.96 kg ha^{-1}. This may be related to the shortest cycle of crop presented at the sowing time III. With a shorter cycle, the plant has fewer leaves and, consequently, fewer reserves, caused by the short term for filling the grains and increased yield, which, together with the defoliation factor, made the photosynthetic area even more compromised. The yield of maize plants is totally dependent on the photosynthetic area provided by the leaves and their permanence for a longer period during cultivation (Fancelli& Dourado Neto 2008). Abut the row spacing, the YWH adjusted to the linear regression $y = -9823.6x + 21363$, with the spacing of 0.60 m providing the highest yield (15,530.21 kg ha^{-1}). It can be observed that the spacing of 0.90 m showed the lowest yield of ears with husk (12,493.49 kg ha^{-1}) concerning all other row spacings (0.60; 0.70; 0.80 m) and, as the row spacing increased, the yield of ears with husk decreased (Figure 2). This is due to the greater competition of plants in the sowing row. The cultivar AG 1051 is characterized as large, which, in sowing with reduced row spacing, tends to be even higher due to the competition for light. Even with this characteristic, the row spacing of 0.60 m was more effective in the yield of ears with husk and reducing the incidence of weeds by reducing the solar radiation on the soil. Silva *et al*. (2015) evaluated the cultivar AG 1051 and found that the plants sown with a row spacing of 0.80 m have a yield of ears with husk of 8,843.75 kg ha^{-1}. Nascimento *et al*. (2017) sowed the cultivar AG 1051 in the row spacing of 0.80 m and found a yield of ears with husk of approximately 10,000 kg ha^{-1}, both with yields much lower than that of the present study (13,622.54 kg ha^{-1}).

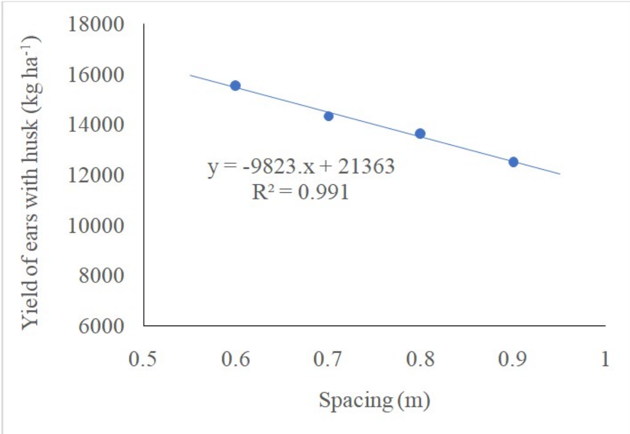

Figure 2. Yield of ears with husk (kg ha^{-1}) of green maize plants under irrigated and rainfed conditions according to the row spacing

Table 3. Yield of ears without husk (kg ha^{-1}) of green maize plants under irrigated and rainfed conditions according to the sowing time and types of defoliation

Sowing times	Types of defoliation			
	CONTROL	AE	BE	ME
I	7,438.15 bA	6,954.20 bA	7,123.40 bA	7,710.72 aA
II	10,669.70 aA	8,884.55 aB	9,023.28 aB	8,668.93 aB
III	8,068.06 bA	4,910.71 cB	6,802.28 bA	7,648.45 aA

Means followed by the same lowercase letters in the columns and uppercase letters in the lines are statistically equal by the Tukey test at the 5% probability. I (sowing time I); II (sowing time II); III (sowing time III). CONTROL (without defoliation); AE (defoliation of all leaves above the ear); BE (defoliation of all leaves below the ear); ME (defoliation of two leaves above and two below the ear).

These differences of yield are related to the climate of each region, which influences the thermal sum of the crop and, consequently, in its cycle, causing the amount of accumulated photoassimilates to be different in each situation, resulting in discordant yield. The amount of solar radiation in each region ranges and depends on several factors, including season and time of year, besides the latitude and angle of exposure to which the site is subjected (Barni & Bergamaschi 1981). About the yield of ears without husk, it was found that plants without defoliation (CONTROL) in sowing time II showed higher yield (10,669.70 kg ha^{-1}) compared to times I (7,438.15 kg ha^{-1}) and III (8,068.06 kg ha^{-1}), statistically equal (Table 3). Comparing the YWHK data obtained in this research (10,669.70 kg ha^{-1}) with the data by Favarato *et al*. (2016) (10,946 kg ha^{-1}), it is noted that they presented similar values. When the plants were subjected to defoliation AE, sowing time II also stood out from the others, with 8,884.55 kg ha^{-1} of ears without husk. Note that sowing time III showed a lower yield (Table 3). The BE defoliation, in turn, caused times I and III to obtain the lowest yields. Sowing time II submitted to this defoliation was statistically superior (Table 3). There was no significant difference in the productivity of ears without husk at different sowing times when submitted to ME defoliation. The superiority of sowing time II in plants without defoliation (CONTROL) and defoliation AE and BE shows that the supply of ears was more effective. The photosynthetic area at that time provided greater accumulation of dry matter, as it contained more reserves in its leaves and stem, which were translocated to the ears. As a result, the ears became heavier, resulting in high yield. Alvim *et al*. (2011) evaluated the defoliation of all leaves above the ear and the defoliation of all leaves below the ear of the hybrid NB 7376. They concluded that the entire leaf area of the plant is essential in the production of photoassimilates, which are later converted to drains. They also found that the leaves above the ear are the main ones responsible for efficiency in the yield. When evaluating the types of defoliations in the sowing time I, it can be seen in Table 3 that there was no significant difference between treatments. In sowing time II, the plants that did not have their leaves removed (CONTROL) showed a yield of ears without husk statistically higher than the others (10,669.70 kg ha^{-1}); that is, the leaf removal promotes the reduction of yield of ears without husk. At sowing time III, it was found that the defoliation AE was the only one that promoted a yield decrease. The amount of photoassimilates accumulated at this sowing time was small and, together with removing the leaves that most contribute to the accumulation of dry matter in the ear, showed a lower yieldthan other sowing times (Table 3). The lower third leaves (defoliation BE) and the intermediates removed (ME) at that sowing time did not cause a reduction in the yield compared to the control. This shows that defoliation resulting from the attack of caterpillars, hail, or winds that possibly damage the leaves of this region of the plant will not cause losses to the producer. Row spacing had a significant effect on the production of ears without husk. The YWHK adjusted to the linear regression y = -4657.6x + 11318, with the spacing of 0.60 m providing the highest yield of ears without husk, 8,571.60kg ha^{-1} (Figure 3). As row spacing increased, yield decreased, with row spacings of 0.80 and 0.90 m having the lowest yield, 7,696.68 kg ha^{-1} and 7,098.27 kg ha^{-1}, respectively (Figure 3).

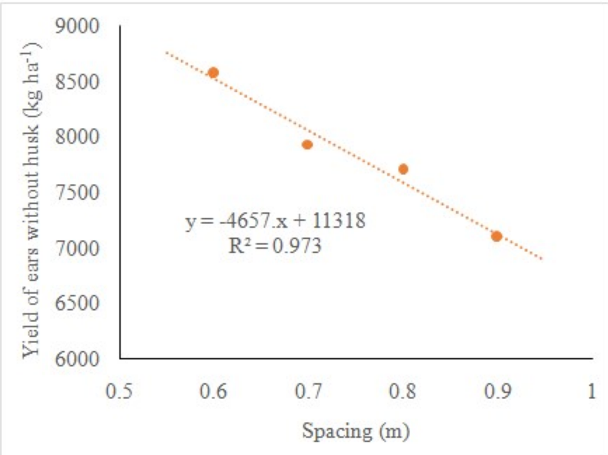

Figure 3. Yield of ears without husk (kg ha^{-1}) of green maize plants under irrigated and rainfed conditions according to the row spacing

Table 4. Dry matter content (DM) (%) of green maize plants under irrigated and rainfed conditions according to the sowing time and types of defoliation

Sowing time	Types of defoliation			
	CONTROL	AE	BE	ME
I	22.35 bA	21.58 bA	22.77 bA	23.72 bA
II	31.46 aB	35.67 aA	33.16 aB	32.78 aB
III	18.26 cA	18.47 cA	19.24 cA	17.74 cA

Means followed by the same lowercase letters in the columns and uppercase letters in the lines are statistically equal by the Tukey test at the 5% probability. I (sowing time I); II (sowing time II); III (sowing time III). CONTROL (without defoliation); AE (defoliation of all leaves above the ear); BE (defoliation of all leaves below the ear); ME (defoliation of two leaves above and two below the ear).

Carvalho *et al*. (2020) evaluated the row spacing of 0.5 m and 1.0 m and different sowing densities. They concluded that the closer row spacing of 0.5 m and the sowing density of 72,000 plants ha^{-1} provided grain yield higher than the other treatments. According to the results of the research carried out by Silva *et al*. (2015), plants that were sown with a row spacing of 0.80 m showed a yield of ears without husk of 5,406.25 kg ha^{-1}. The same behavior was verified by Nascimento *et al*. (2017), who evaluated the yield of ears without husk in the row spacing of 0.80 m of the cultivar AG 1051, which produced just over 6,000 kg ha $^{-1}$, lower than the values obtained in this study (Figure 3). Besides supporting the leaves and tassel, the taller stem acts as a plant reserve and, by accumulating sucrose, serves as a source for translocating these compounds to the ear. This storage is initiated before filling the grains since all the carbohydrate assimilated before this phase is directed towards the emission of new leaves, roots, reproductive organs, and the growth of stem (Fornasiere Filho 2007). The DM content in plants of sowing time II without defoliation (CONTROL) was higher than the other sowing times (31.46%). Sowing time I showed 22.35% DM, and time III, 18.26% (Table 4). The greatest fluctuations in the daytime and nighttime temperatures (Figure 1) may have contributed to the greater accumulation of DM in the grains of sowing time II. In the treatment in which all the leaves above the ear (AE) were removed, there was a highlight for the sowing time II, with a DM content of 35.67%, and time I had a content of 21.58% and time III, 18.47% (Table 4). The BE defoliation showed higher DM levels in the sowing time II (33.16%), being statistically superior to sowing times I and III, 22.77%, and 19.24%, respectively. Sowing time III, regardless of defoliation type, was the one that had the dry matter content reduced by defoliation. The reduction of the cycle decreased the number of leaves. The use of reserves by the drain was in excess of the capacity of the sources (Fornasiere Filho 2007). Sowing time I, in turn, in this parameter, presented higher means than sowing time III (Table 4). In the CONTROL, AE, BE, and ME treatments, the dry matter content was higher in sowing time II, which stood out from the other sowing times, with 32.78% of dry matter (Table 4). When evaluating the influence of the defoliation types on the dry matter content in the sowing time I, it was found that there was no significant difference. In sowing time II, the dry matter contents for the CONTROL, BE, and ME were lower than the contents of the TA. In sowing time III, there was no significant difference in dry matter content among the different types of defoliation that the plants were subjected (Table 4).

CONCLUSION

- The 0.60 m row spacing provides a greater yield of ears with and without husk.
- The defoliation of all the leaves above the ear (AE) is the one that most affects the yield characteristics of maize, such as reduced length of ears without husk, reduced yield of ears with husk in sowing time III, and yield of ears without husk in sowing times II and III.
- The sowing time II provides a greater yield of ears with husk (YWH) and without husk (YWHK).

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