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Can Biostimulant Work as a Water Stress Attenuator in Corn Crop?

GABRIEL LUIZ PIATI[1]
Universidade Federal da Grande Dourados, Faculdade de Ciências Agrárias
Rodovia Dourados-Itahum, Dourados, MS, Brazil
SEBASTIÃO FERREIRA DE LIMA[2]
Universidade Federal de Mato Grosso do Sul, Campus de Chapadão do Sul
Programa de Pós-Graduação em Agronomia, Chapadão do Sul, MS, Brazil
GUSTAVO RIBEIRO BARZOTTO[3]
Universidade Estadual Paulista, Faculdade de Ciências Agronômica
Programa de Pós-Graduação em Agronomia, Botucatu, SP, Brazil
MARCELA PACOLA OLIVEIRA[4]
Universidade Estadual Paulista, Faculdade de Ciências Agronômicas
Botucatu, SP, Brazil
OSVALDIR FELICIANO DOS SANTOS[5]
Universidade Estadual Paulista, Faculdade de Ciências Agronômica
Programa de Pós-Graduação em Agronomia, Botucatu, SP, Brazil
IRINEU EDUARDO KÜHN[6]
Universidade Estadual Paulista, Faculdade de Ciências Agronômica
Programa de Pós-Graduação em Agronomia, Botucatu, SP, Brazil

Abstract

Adequate positioning of technologies that aim to minimize losses caused by abiotic stress has great applicability in crop management. The objective of this work was to evaluate the effect of

[1] Gabriel Luiz Piati is a Agronomy PhD student (crop production), with articles published on the following topics: grain production system, soil physics, cover crops, use of biostimulants in agriculture and nitrogen fertilization. The last article published in co-authorship is entitled: Nitrogen and mepiquat chloride can affect fiber quality and cotton yield. https://doi.org/10.1590/1807-1929/agriambi.v24n4p238-243 **E-mail: gabrielpiati@hotmail.com**

[2] Professor at the UFMS in Agronomy and Forest Engineering. Publication of articles in grain production system, cover crops, use of biostimulants in agriculture, nitrogen fertilization, silviculture, weed and horticulture. Sample article: Management of nitrogen fertilization on agronomic and nutritional characteristics in second crop corn. https://doi.org/10.14393/BJ-v36n2a2020-45166 **E-mail: sebatiao.lima@ufms.br**

[3] Gustavo Ribeiro Barzotto is master in Agronomy, develops works with emphasis on Phytotechnics, mainly related to Physiology and Nutrition of plants. The researcher investigates the agronomic application of growth-promoting bacteria, biostimulants and nutrition with silicon. There are published works showing that the use of *Azospirillum brasilense* and silicon in annual cultures is positive. **E-mail: grbarzotto@gmail.com**

[4] Has a master's degree in Agronomy (crop production), working mainly on the following themes: no-till, compaction, agro-ecosystem, cover crops and soil conditioners. The last article published as an author is entitled: Cover crops and residual effect of lime and plaster on physical attributes of the soil subsoil. http://dx.doi.org/10.33448/rsd-v9i6.3490. E-mail: marcelapacola@gmail.com

[5] With experience in the field of Agronomy, with emphasis on Irrigation, Phytotechnics and Biochemistry, acting mainly on the following themes: Irrigation systems and management, water stress in plants and use of biostimulants in agricultural crops. The last article published in co-authorship is entitled: https://doi.org/10.1016/j.agwat.2019.105762. **E-mail: osvaldir.feliciano@gmail.com**

[6] Has experience in agronomy, currently working with biochemical and physiological analysis on plants, evaluating the effects of stress, depending on the use of biostimulants. Has published works on: Biostimulants, Irrigation, Soy, Corn, Beans, Barley, Oilseeds. Last work published as co-author: Water availability for high yield of soybean cultivars. http://dx.doi.org/10.33448/rsd-v9i6.3373 **E-mail: irineuk@live.com.**

applying biostimulant on the production components and the yield of corn grain sown within and outside the recommended period for the second harvest. AG 8061 VT PRO YieldGard® simple corn hybrid seeds were sown in a randomized complete block design implementing a 4x5x2 factorial scheme with four replications. The treatments were formed by combining four corn sowing times, divided into two agricultural crops in February and March of 2016 and 2017, employing five doses of biostimulant in the seed treatments (0, 6.25, 12.50, 18.75; 25.00 mL kg^{-1}) with or without foliar biostimulant application (500 mL ha^{-1}) in the V4 stage of the corn crop. Biostimulant application provided an increase in the production yields and corn kernel yield at all evaluated sowing times. Smaller biostimulant doses on the seeds are effective in reaching the highest component yield values and corn kernel yield when foliar biostimulant application is carried out in the crop. Combining biostimulant application on the seeds with foliar application provides greater corn kernel yield. The use of biostimulant reduces the effect of water stress on the corn crop.

Key words: yield components, phytohormones, Stimulate®, second harvest, sowing time.

INTRODUCTION

The importance of corn (*Zea mays* L.) crops in agribusiness is characterized by its varied uses ranging from animal feed to high technology industry. The year 2012 was the first year in which Brazilian corn production was higher in the second harvest compared to the first, with 38.7 and 33.9 million tons respectively (Duarte 2014). Since then, corn production has increased to 54 million tons in the second crop of 2018, which is 2 times higher than the corn yield in the first harvest of the same year (Conab 2018).

In order to ensure that the second corn crop reaches satisfactory yields (around 6,000 kg ha^{-1}) in the northeast region of Mato Grosso do Sul state, it is recommended to plant the second crop by mid-February (Anselmo, De Paula, and Andrade 2013). Even with the sowing season for corn in the second harvest being defined due to operational issues, most of the rural producers of this region have been sowing part of the area after the first fortnight of February. Sowing the crop in unfavorable times to the crop's development due to adverse climatic conditions, mainly due to water deficit, stands out among the causes of reduced yield in the second harvest for corn kernels.

Technologies aiming to improve and adapt the corn crop to the second harvest production system have contributed to raise crop yields for this season, and biostimulant management can minimize the damage caused by corn cultivation in environments with restricted water. This is one of the management options that can be used when the second corn harvest sowing occurs outside the recommended season and there is a high probability that crop performance will be affected by low rainfall rates.

Castro (2006) defines a bioregulator as an organic, non-nutrient compound that can inhibit or modify the plant's morphological and physiological processes at low concentrations in plants. Auxins, gibberellins and cytokinins fall into this definition, which are the main plant hormones for exogenous use (Castro 2006; Taiz et al. 2017), in addition to being part of the composition of the Stimulate® biostimulant.

Even with the large volume of literature on the positive effects resulting from biostimulant application on diverse agricultural crops such as soybean (Albrecht et al. 2011; Ávila et al. 2008; Vieira and Castro 2001), cotton (Albrecht et al. 2009) and bean (Abrantes et al. 2011; Lana et al. 2009), the interaction between doses and application forms of these products is still little known regarding the responses for corn cultivation.

For corn, important studies reporting the benefits of using biostimulant have been conducted (Dourado Neto et al. 2004; Dourado Neto et al. 2014); however, even though they define the ideal doses to be applied, the application forms to the crop (via seeds, sowing grooves and foliar) have only been investigated individually.

Therefore, the objective of this work was to evaluate the effect of biostimulant application on the production components and kernel yield for corn sown within and outside the recommended season for the second harvest.

MATERIAL AND METHODS

The experiment was conducted during the second harvest of 2016 and 2017, at two times each year, within the period indicated for second harvest (sowing in February) and outside this period (sowing in March), in the experimental area of the Federal University of Mato Grosso do Sul, Chapadão do Sul Campus, with a latitude of 18º 47 '39 "S, longitude 52º 37' 22" W and an altitude of 820 m.

According to Cunha, Magalhães, and Castro (2013), the climate of the region is classified as tropical humid with dry winter and rainy summer. The water balance was carried out via meteorological data, where the crop Evapotranspiration (ETc) was obtained by the product of the Reference crop Evapotranspiration (ETo) and the crop Coefficient (Kc). The ETo estimates were obtained by the Penman-Monteith-FAO method according to Allen et al. (1998), using data from an automatic meteorological station (Code A730) of the National Meteorological Institute (INMET).

For corn sown in February 2016 (2016/1), a mean temperature of 22.6°C was observed during the 136 days of the crop cycle, where it remained under water deficit for 66 days. In the 2016/2 sowing season (March 2016), the water deficit period was 105 days accumulating -47.2 mm at the end of the crop cycle (140 days) with a mean temperature of 21.9°C. For sowing in February 2017 (2017/1), the average temperature during the course of the experiment reached 22.3°C where 101 of the 137 days of the crop cycle were under water deficit conditions with a final water balance of -267.7 mm; while for corn sown in March 2017 (2017/2), the average temperature was 21.8°C with 114 of the 140 days of the cycle under water deficit reaching the accumulated amount of -319.4 mm (Figure 1).

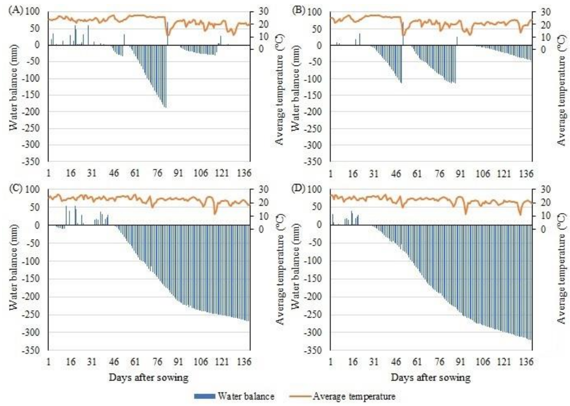

Figure 1: Water balance and average temperature in the corn crop sown in February (A) and March (B) in 2016, and in February (C) and in March (D) in 2017, Chapadão do Sul, MS.

The soil of the experimental area is classified as dystrophic Red Oxisol with a clayey texture, according to the Brazilian soil classification system (Santos et al. 2018), presenting a density of 1.2108 g dm^{-3} and water content equivalent to field capacity and plant permanent wilting point of 0.26652 and 0.1858 dm^3 per dm^{-3}, respectively. The soil chemical analysis at the experimental sites was conducted during the two years of experiment, where the chemical properties found in the 0-20 cm layer in 2016 were: 9.0 mg dm^{-3} of P (melich); 33.5 g dm^{-3} of O.M.; 4.9 pH ($CaCl_2$); K^+, Ca^{2+}, Mg^{+2} and H+Al = 0.07; 2.40; 0.9 and 2.9 $cmol_c$ dm^{-3}, respectively, and 53.7% saturation per base; and for the year 2017 were: 8.8 mg dm^{-3} of P (melich); 28.0 g dm^{-3} of O.M.; 4.9 pH ($CaCl_2$); K +, Ca^{2+}, Mg^{+2} and H+Al = 0.24; 2.10; 0.90 and 3.8 $cmol_c$ dm^{-3}, respectively, and 46.37% base saturation.

The experimental design was a randomized complete block design in a 4x5x2 factorial scheme, corresponding to: four corn sowing times divided into two agricultural years: in 2016, the first sowing season occurred on February 5th (2016/1), and the second season on March 8th (2016/2); and in the year 2017, sowing was done on February 15th (2017/1) and March 9th (2017/2); five doses of biostimulant for seed treatment (0, 6.25, 12.50, 18.75, 25.00 mL kg^{-1}); with and without foliar biostimulant application (500 mL ha^{-1}) in the V4 stage of the corn crop, with four replications. The biostimulant used was Stimulate® which has three phytoregulators in its composition: 0.009% kinetin (cytokinin), 0.005% gibberellic acid (gibberiline) and 0.005% indolebutyric acid (auxin). The experimental plots were 5 m long and 2.25 m wide, resulting in a total area of 11.25 m^2 and a useful area of 4.05 m^2.

The experimental corn cultivations were carried out in a no-tillage system in 2016 and 2017, with soybeans being cultivated in the first crops of the 2015/16 and 2016/17 agricultural years. AG 8061 VT PRO YieldGard® simple hybrid corn seeds from the Agroceres company were used, with characteristics such as: early cycle; adaptation to the first and second harvests; suitability for producing kernels and silage; orange and semi-humid kernel; high resistance to lodging and high level of technology.

In order to control pest and disease in the corn crop, the seeds were pre-treated with Pyraclostrobin (0.005 kg a.i. 100 kg^{-1}), Methyldopa thiophanate (0.045 kg a.i. 100 kg^{-1}) and Fipronil (0.05 kg a.i. 100 kg^{-1}). The biostimulant dose applications to the seeds were carried out one day after the phytosanitary treatment and moments before sowing using a graduated pipette to dose the product applied directly to the seeds and conditioned in transparent plastic bags with a capacity of 2.0 kg. The contents were vigorously shaken manually for two minutes in order to standardize the treatment on the seed mass.

About one week before sowing, the experimental area was desiccated in each season using Diquate herbicide (0.5 kg a.i. ha^{-1}) and mineral oil (0.321 kg a.i. ha^{-1}). The grooves were opened with a five-row tractor spaced at 0.45 m on the corresponding days of each sowing, whereupon 610 kg ha^{-1} of the 4-14-8 formulation was applied. The corn was subsequently sown manually with three seeds per meter corresponding to a density of 66,666.66 seeds ha^{-1}.

Coverage fertilizations were applied to supply 60 kg ha^{-1} of K using potassium chloride in V3, and 120 kg ha^{-1} of N divided into V3 and V6 phenological phases, using urea as the N source. Phytosanitary management during the course of the experiment in both seasons consisted of: an application of Atrazine (2.5 kg a.i. ha^{-1}) and Tembotrione (0.1008 kg a.i. ha^{-1}) herbicides to control weeds post-emergence; (0.129 kg a.i. ha^{-1}) and Thiamethoxam + Lambda-cyhalothrin (0.03525 + 0.0265 kg a.i. ha^{-1}) for controlling lepidopteran and spittlebug larvae; and a preventive application of Azoxystrobin +

Ciproconazole (0.06 + 0.024 kg a.i. ha^{-1}) fungicide, while always adding mineral oil (0.321 kg a.i. ha^{-1}) to the application mix.

The foliar application of Stimulate® occurred at the V4 phenological stage of the corn crop (0.5 L ha^{-1}), respecting the ideal environmental conditions for maximum absorption of the product by the plants (temperature of 20 to 25°C, 70% of relative air humidity and wind speed below 10 km h^{-1}) and with spray flow of 150 L ha^{-1}.

When the corn crop reached the R6 phenological stage, manual harvesting of the ears present in each plot was performed to evaluate the production components and kernel yield, namely: number of kernel rows per ear (NRE), number of kernels per row (NKR) and number of kernels per ear (NKE). The mean for these three variables was obtained by evaluating eight ears per plot; weight of 100 kernels (HKW): average of eight samples of 100 kernels and kernel yield (KY), obtained by weighing the harvested kernels and correcting the moisture values to 13%.

The data were submitted to joint variance analysis to verify the existence of interaction between biostimulant application and sowing times. Therefore, the two sowing times in each year of the experiment conduction were included among the variation sources in the analysis of variance. The Stimulate® doses in the seed treatments were evaluated by the polynomial regression test and the means of the data obtained from the foliar Stimulate® doses and the sowing times were compared by the Tukey test at 5% probability.

RESULTS AND DISCUSSION

There was a significant interaction among all the factors for the number of kernels per row, number of kernels per ear and corn kernel yield. The number of rows per ear only presented significance for the interaction of sowing x biostimulant via seeds and the weight of 100 corn kernels was only not significant for the combination of foliar biostimulant x biostimulant via seeds (Table 1).

Table 1: Analysis of variance for number of rows per ear (NRE), number of kernels per row (NKR), number of kernels per ear (NKE), weight of 100 kernels (HKW) and corn kernel yield (KY), Chapadão do Sul, MS, 2016 and 2017.

FV	GL	Mean square				
		NRE	NKR	NKE	HKW	KY
Block	3	0.62	0.41	522.94	0.35	7600.76
Sowing time (T)	3	10.64**	113.27**	65859.02**	232.28**	43126271.1**
Foliar Biostimulant (F)	1	6.63**	14.36**	17228.46**	0.21	9658762.52**
Biostimulant in seeds (S)	4	2.83**	35.98**	19665.71**	6.33**	2197082.53**
T x F	1	0.5	28.75**	6561.71**	5.33**	3388766.17**
T x S	4	1.05**	5.73**	4071.29**	3.34**	592905.53**
F x S	4	0.05	13.71**	4287.73**	0.95	567458.01**
Error	61	0.22	1.31	607.7	0.79	46636.76
CV (%)		2.89	4.2	5.55	3.35	3.22
Average		16.26	27.22	443.82	26.44	6716.23

** significant at 1% probability by the F-test.

Foliar biostimulant application yielded an increase in the weight of 100 kernels only for corn sown in February 2016 (2016/1), but this increase did not interfere in kernel yield. Positive effects were observed for the variable KY in the three subsequent seasons (2016/2, 2017/1 and 2017/2) via foliar biostimulant application, where there was also an increase in number of kernels per row and number of kernels per ear when corn sowing was carried out in March 2016 (Table 2).

Table 2: Average number of kernels per row (NKR), number of kernels per ear (NKE), weight of 100 kernels (HKW) and kernel yield (KY) of corn according to the presence or absence of foliar biostimulant application and sowing time of corn grown in Chapadão do Sul, MS, 2016 and 2017.

Variable	Biostimulant	Sowing time			
		2016/1	2016/2	2017/1	2017/2
NKR	With foliar	28.99 a A	27.56 a B	28.15 a AB	25.40 a C
	Without foliar	28.69 a A	24.49 b C	28.83 a A	25.69 a B
NKE	With foliar	494.93 a A	447.57 a C	470.61 a B	403.67 a D
	Without foliar	483.69 a A	388.77 b C	460.67 a B	400.61 a C
HKW	With foliar	29.48 a A	24.80 a C	27.78 a B	23.87 a D
	Without foliar	28.35 b A	25.03 a B	28.31 a A	23.95 a C
KY	With foliar	7902.78 a A	6646.85 a C	7417.06 a B	5881.01 a D
	Without foliar	7842.39 a A	5298.22 b C	7189.60 b B	5551.91 b D

Averages followed by uppercase letters in the row and lowercase in the column do not differ statistically from each other by the Tukey test at 5%.

In general, the best results were obtained when sowing was carried out in February in both years (2016 and 2017), because this was in a more favorable environment for corn development (Table 2). These results are in agreement with the recommendation of Anselmo, De

Paula, and Andrade (2013), where there are significant productive losses in late sowings (after the first half of February), mainly due to water deficit, which was observed in this study (Figure 1).

At all evaluated sowing times, water deficit was recorded at the beginning of the crop's reproductive phase, however there were variations regarding the stress intensity, significantly impacting on the production components and corn kernel yield. According to Silva et al. (2012), flowering is the most sensitive phase to water deficit in corn, and the plant needs a greater amount of water in the soil to realize its productive potential.

The corn tassels began in February 2016 at 58 days after sowing (DAS), of which the crop was submitted to water deficiency for 14 days, resulting in negative 10.8 mm on the water balance. When the sowing was carried out in March 2016, a water balance of 38.6 mm was registered in the same phase, and there was a water deficit in 36 of the 62 days after sowing for the crop (Figure 1). For the year 2017 when sowing was done in February (58 DAS), the crop's water balance at the beginning of flowering was negative 65.5 mm with 24 days submitted to water deficiency, while for the subsequent sowing (2017/2) the beginning of flowering (62 DAS) was marked by a negative water balance of 128.4 mm with 36 days of water deficit in the soil.

In severe water deficient conditions, corn crops are unable to realize their productive potential (Heinemann et al. 2009), such environmental conditions described in the present study are reflected in the obtained results and demonstrated that there was a decrease in the production components and corn yield in sowing that is considered late for the second crop, independent of the foliar biostimulant application (Table 2).

It was observed that the duration of the sowing-tasseling sub-period was lower when sowing was performed in February (58 to 59 days) compared to sowing in March (62 days). This behavior may be related to the thermal sum required for beginning the corn reproductive phase, with higher average temperatures in anticipated crops with 24.2 and 24°C for sowing in February and 23.6 and 23°C when sowing was carried out in March 2016 and 2017, respectively. Renato et al. (2013) state that plant development at each phenological phase or in the crop cycle is controlled by the thermal sum needed according to the plant species, which also justifies the greater cycle of the corn crops sown in March, presenting three to four days difference in relation to sowing in the month of February.

On average, the water requirement of the corn crop during its cycle for adequate development is 600 mm, with three main critical periods: floral initiation, pollination and kernel filling (Magalhães and Durães 2008). The best results for the variables NRE, NKR, NKE, HKW and KY obtained in the sowing performed in February 2016 and 2017 (Figure 2) may be related to the distinct water availability for the different seasons, in addition to the shorter period in which the crop was under a negative water balance condition. The lowest deficit intensity was observed for the February sowing in comparison with the sowing in March in the two years of the experiment, especially in the crop's critical periods, as was previously observed for the beginning of flowering.

According to Taiz et al. (2017), water deficit also causes a decrease in the photosynthetic rate in addition to inhibiting vegetative growth, which is associated with photoassimilate production, so it is known that there is a strong relation of these factors with the production components and corn kernel yield.

In the majority of the observed results, there was a quadratic adjustment of the variables as a function of the biostimulant doses, with some reservations for which the response to the product application to the seeds provided a linear adjustment as to the number of kernel rows per ear for sowing in February 2016, with an increase of about 7% in this variable via application of the highest tested dose (25 mL kg^{-1} of seed). there was an increase in the values of this variable at later sowing times up to the biostimulant doses of 14.69; 11.08; and 12.30 mL kg^{-1} resulting in 16.39; 16.78; 16.06 rows for the 2016/2, 2017/1 and 2017/2 seasons, respectively (Figure 2A).

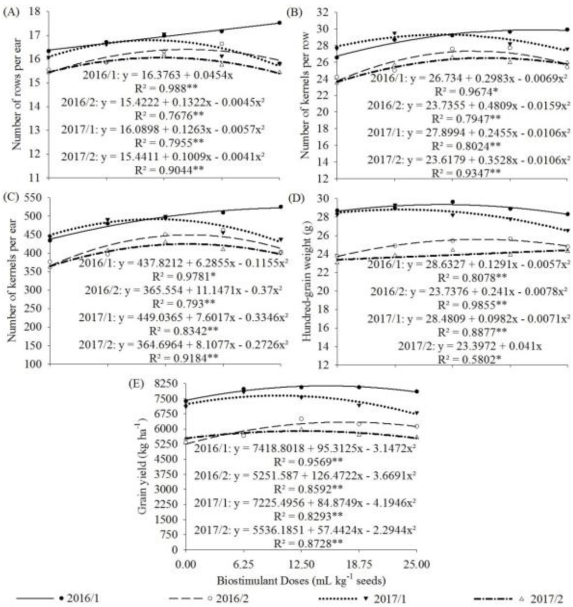

Figure 2: Number of rows per ear (A), number of kernels per row (B), number of kernels per ear (C), weight of 100 kernels (D) and kernel yield (E) of corn submitted to biostimulant doses to seeds at different sowing times, Chapadão do Sul, MS, 2016 and 2017.

According to Magalhães and Durães (2008), the definition of the number of kernel rows in the ears occurs during the V8 stage of the corn crop. The plants sown in February only presented water deficit in this phase in 2017 (-27.2 mm), while for the same phenological crop stage but with sowing in March the water balance reached negative 105.1 and 89.9 mm for 2016 and 2017, respectively (Figure 1). This water deficit occurring when sowing was performed later negatively affected the NRE variable (Figure 2A).

All the variables showed similar behavior from biostimulant application because of their strong inter-relationship, and (just as for the variable discussed above) the number of kernels per row expressed the best response with a high biostimulant dose to the seeds of the first sowing season of 2016, where 21.62 ml of the product provided 29.96 grains per row of corn ear, representing a 10.76% increase compared to without the biostimulant. The increase of this variable in relation to the control was more significant in the March sowing for both cultivation years, representing 13.28% in 2016 at the dose of 15.12 ml, and 11.06% in 2017 with 16.64 mL of biostimulant application to the seeds. However, with the corn sowing in February 2017, application of the highest tested biostimulant dose (25 mL kg^{-1} of seed) caused greater losses in the number of kernels per row than in the absence of the same product, being 6.51% lower than the biostimulant dose of 11.58 mL kg^{-1} of seed (Figure 2B).

According to Ritchie, Hanway, and Benson (2003), the definition of the number of kernels per row in corn crops occurs in the pre-flowering phase. The most vigorous corn development in the present work was observed at this stage, when sowing was performed in February in relation to March in both years of the experiment.

For the number of kernels per ear (Figure 2C), the maximum dose tested in the experiment was responsible for the best result when sowing was performed in February 2016. Such behavior may vary at similar times, where sowing performed later in 2017 but in the same month (15/02) showed better results for the NKE variable, with lower biostimulant doses in the seeds, as the dose of 11.36 mL kg^{-1} of seed provided 492.21 kernels per corn ears. In the 2017/1 season, the dose of 25 mL kg^{-1} of seed was more damaging than the control, with a decrease of 12.65% in the values of this variable.

When sowing was carried out in March in both years, approximately 15 mL of biostimulant kg^{-1} of seed was the dose that provided the best results, with 449.51 and 424.98 kernels per ear, representing gains of 19 and 14% compared to the absence of biostimulant for 2016 and 2017, respectively. There was a 5.5% decrease in this variable in 2017 compared to the same period of the previous year, with the main reason being the greater intensity and duration of the water deficit to the corn crop. The same occurred in February sowing, with a 5.8% decrease in this variable in 2017, affecting kernel yield (Figures 2C and E).

Results for the weight of 100 kernels had lower variation with biostimulant application to the seeds in comparison with the other variables. March sowing presented the highest increases in the HKW variable with biostimulant application to the seeds with a quadratic response in 2016, where the dose of 15.45 mL kg^{-1} of seed provided a 7.3% linear increase in 2017, with an increase of 4.2% with the highest dose applied (Figure 2D).

The other seasons (2016/1 and 2017/1) showed larger drops in the weight of 100 kernels with high biostimulant doses when compared to without treatment application to the seeds, with an estimated decrease of 3.6 and 8.1% with application of the highest dose in relation to the biostimulant doses of 11.32 and 6.92 mL kg^{-1} of seed in the seasons of February 2016 and 2017, respectively, being the doses that provided higher values for the weight of 100 kernels (Figure 2D).

Variations in the biostimulant doses that provided the best results in corn kernel yield were verified according to the sowing season due to different climatic conditions affecting different phenological crop stages, according to the sowing season utilized. In general, the second corn crop allows higher biostimulant doses in treating seeds at later plantings (March), and this variation in dosage corresponds to approximately 2 mL of biostimulant kg^{-1} of seed between the February and March sowings.

When corn sowing was performed in February 2016, seed treatment with 15.14 mL of biostimulant kg^{-1} resulted in an 8.86% increase in kernel yield, which reached 8140.43 kg ha^{-1}; however, 17.23 mL of biostimulant kg^{-1} of seeds were required the following month for maximum yield of 6341.45 kg ha^{-1}, which represented an increase of 17.19% over the control (Figure 2E).

On average, the increase in yield provided by biostimulant seed treatment was lower in 2017 than in 2016, mainly due to the greater rainfall irregularity during the crop cycle in both sowing seasons. For the most stressful season in 2017 (sowing in March), higher biostimulant doses were adequate to minimize these negative effects. Thus, application of 12.52 mL of biostimulant kg^{-1} of seed in March allowed a 6.10% increase in kernel yield reaching 5895.72 kg ha^{-1}; and the seed dose of 10.12 mL kg^{-1} was the most adequate for February sowing and corresponded to 7654.84 kg of corn kernels ha^{-1}, being 5.61% and 12.14% higher than the absence and 25 mL dose of biostimulant kg^{-1} of seed, respectively (Fig. 2E).

Therefore, these results demonstrate that it is necessary to apply higher doses of phytohormones to create an adequate hormonal balance in the plants at times which are less favorable to the corn crop's development, since March sowing was submitted to a greater period of drought compared to February. Vieira and Castro (2001) report that there must be a balance in the addition of hormone analogues for an increase in seedling performance; this is generally reflected in a more vigorous crop during its cycle, and consequently able to obtain higher productive yield.

The stress-relieving effect on plants provided by the biostimulant in this work at both sowing times is clear. Other studies have already demonstrated the attenuating effects of abiotic stress on plants using biostimulants in both seed treatment and in foliar applications (Albrecht et al. 2009; Albrecht et al. 2011; Castro, 2006).

Studies indicate that biostimulant application results in increased levels of endogenous antioxidant activity in plants subjected to drought, as there is a strong relationship of this behavior with stress tolerance in corn (Malan, Greyling, and Gressel 1990; Zhang and Shimidt 1999). The results obtained in the present study with biostimulant application to the seeds and the sowing inside and outside the recommended period for the second harvest indicate that correct management of phytohormones helps in reducing the negative impact caused by the water deficit on the corn crop.

As previously mentioned, the restriction of water availability has a negative impact on plant photosynthetic efficiency (Taiz et al. 2017); on the other hand, Richardson et al. (2004) report a significant increase in plants' photochemical efficiency with biostimulant application. Therefore, the increase of the photosynthetic efficiency in the crop together with the greater tolerance to water deficiency through the biostimulant application observed in the present study can justify the positive results of using these substances on the production components and corn kernel yield.

In addition to the biostimulant doses affecting the production components and the corn kernel yield at different sowing times, they also had an effect according to the presence or absence of the biostimulant application in the V4 stage of corn (Figure 3).

Regarding kernel per row (Figure 3A), it is observed that the dose responsible for the best result in the absence of foliar phytohormone was 19.43 mL kg^{-1} of biostimulant in the seeds, which resulted in 28.08 kernels per row. When the same product was applied in V4, the dose that provided the highest NKR was 13 mL kg^{-1}, reaching 28.53 kernels per row; values 12.23 and 7.63% higher compared to the absence of seed biostimulant, for factors without foliar biostimulant application (WOF) and with foliar application (WF), respectively.

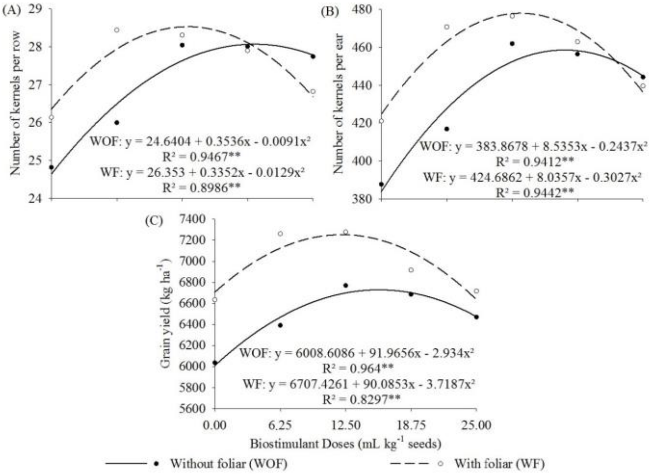

Figure 3: Number of kernels per row (A), number of kernels per ear (B) and kernel yield (C) submitted to biostimulant doses in the seeds with or without foliar application of the same product in V4, Chapadão do Sul, MS.

The number of kernels per ear follows the same trend; when there is no foliar application, the dose with the highest NKE value was 17.51 mL kg^{-1} of biostimulant, providing 458.60 kernels, which is 16.30% higher than that obtained without the biostimulant. With foliar phytohormone application, the dose of 13.27 mL kg^{-1} of the product provided 478.02 kernels per ear, representing an 11.16% increment for the NKE variable (Figure 3B).

In spite of the significant increase that the biostimulant application to the seeds provided for the number of kernels per row and kernels per corn ear, it is noticeable that the same dose that results in higher values is lower when the phytohormone is applied to the corn crop's husk. In studying the application of different isolated biostimulant forms and doses in corn, Dourado Neto et al. (2014) demonstrated that the best results for the components number of kernels per row and kernels per ear were obtained by applying the product to the seeds, regardless of the dose used, because (according to the authors) the plants had a longer period in contact with the hormones in the respective treatments.

Application of biostimulant products via seeds generally allows dormancy breakage, uniformity in growth and morphological and physiological modifications of the seedlings, thereby avoiding possible phytotoxicity of these products when via foliar application (Castro, Gonçalves, and Demétrio, 1985), therefore, even if a combination of biostimulant foliar and seed applications results in an increase in kernel yield, it is necessary to pay attention to the amount applied to the seeds, because (according to the present study) a smaller amount of the product is recommended for treating seeds when there is foliar application in the crop, in addition to the fact that excessive doses increases the production costs.

The seed dose most responsive to productivity in treatments receiving foliar biostimulant application was 12.11 mL kg^{-1} which resulted in 7253 kg ha^{-1} of corn kernels, an increase of 7.52 and 8.52% in relation to without biostimulant and 25 mL kg^{-1} of biostimulant, respectively. In working with a biostimulant composed of auxin and cytokinin, Lana et al. (2009) found that the combination of the product applied to the seeds and husks yielded higher kernel yield compared to the isolated application, meaning only via seed or husk.

Without the foliar biostimulant application, the dose in the seeds of 15.67 mL kg^{-1} of the same product provided the maximum productivity between treatments, resulting in 6729.27 kg ha^{-1} corn kernels, being 3.76 and 10.71% greater than the maximum dose applied (25 mL kg^{-1} of biostimulant) and without biostimulant, respectively (Figure 3C).

Albrecht et al. (2011) obtained a significant productive increase in the simultaneous seed and foliar application of Stimulate® in the soybean crop, but only at low doses of the product (125 mL ha^{-1}) applied in the R3 stage. Determining the greatest response point provided by biostimulant application to crops is of paramount importance to establish scientifically based recommendations on the handling of these products.

CONCLUSIONS

Biostimulant application provides an increase in the production components and corn kernel yield at all evaluated sowing times. When foliar biostimulant application is performed on the crop, smaller doses to the seeds are necessary to achieve the highest values in the production components and corn kernel yield. The combination of foliar and seed biostimulant application provides greater corn kernel yield. Biostimulant use/application reduces the effect of water stress on corn.

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