Non-nutritional biostimulant improves maize cultivation economic parameters

Bioestimulante não nutricional melhora os parâmetros econômicos do cultivo de milho

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ABSTRACT

Maize cultivation in the second season has a significant risk of reducing economic profitability due to the common water scarcity for this period in the Brazilian Cerrado. It was considered the...
hypothesis that the application of biostimulant can act positively on the financial return obtained with the production of second period maize. Therefore, the objective was to obtain the economic indicators related to the crop under application of biostimulant. The experiment was conducted in a randomized block design with four replications, being 2x5x2: Two sowing periods for second-season maize in two years (February-March); five doses of biostimulant in the treatment of seeds (0, 6.25, 12.50, 18.75, 25.00 ml kg⁻¹); presence and absence of foliar application of biostimulant (500 ml ha⁻¹). Seed treatments with 6.25 ml kg⁻¹ and 12.50 ml kg⁻¹ resulted in better economic results for the sowing of February and March, respectively, when combined with foliar application. The highest profitability indexes were obtained when maize was cultivated in February. However, despite the lower monetary return, maize grown in the second season results in positive economic returns.

**Keywords:** Zea mays L., Adverse conditions, Second season cultivation, Hydric deficit, Grain production, Plant protection.

**RESUMO**

O cultivo de milho na segunda safra tem um risco significativo de reduzir a rentabilidade econômica devido à escassez de água comum neste período no cerrado brasileiro. Considerou-se a hipótese de que a aplicação do bioestimulante possa atuar positivamente no retorno financeiro obtido com a produção de milho na segunda safra. Portanto, o objetivo foi obter os indicadores econômicos relacionados à cultura com a aplicação de bioestimulante. O experimento foi conduzido em delineamento de blocos ao acaso, com quatro repetições, sendo 2x5x2: dois períodos de semeadura para o milho na segunda safras em dois anos (fevereiro a março); cinco doses de bioestimulante no tratamento de sementes (0, 6,25, 12,50, 18,75, 25,00 ml kg⁻¹); presença e ausência de aplicação foliar de bioestimulante (500 ml ha⁻¹). Os tratamentos com 6,25 ml kg⁻¹ e 12,50 ml kg⁻¹ resultaram em melhores resultados econômicos para a semeadura de fevereiro e março respectivamente, quando combinados com a aplicação foliar. Os maiores índices de rentabilidade foram obtidos quando o milho foi cultivado em fevereiro. No entanto, apesar do menor retorno monetário, o milho cultivado no segundo período resulta em retornos econômicos positivos.

**Palavras-chave:** Zea mays L., Condições adversas, Cultivo de segunda safra, Déficit hídrico, Produção de grãos, Proteção de plantas.

**1. INTRODUCTION**

The use of methodologies that point to the viability of a certain technology use is essential, since the results are used, among other factors, as a basis for the decision-making of the producers (Mwangi and Kariuki 2015). This applies not only to technologies already employed, as fertilizers, for example, which are a significant part of the composition of productive costs (Kappes et al. 2015), but also to emerging technologies, among which are biostimulating products (Jesus et al. 2016; Vendruscolo et al. 2018).

It is observed that the demand for products that favor the plants development, maintenance, or even increase of productivity, has been growing considerably (Tejada et al. 2018). This may be a reflection of the oscillations caused by abrupt changes in the climate, which potentiate the productive losses of the main species cultivated worldwide, including maize (Meng et al. 2016).

Economically, the losses suffered by the agricultural sector come from different sources, varying for each producing region due to its unique characteristics (Nelson et al. 2014). These losses
are accentuated in regions where the climate is prone to the occurrence of water deficit, as in the case of some African regions (Omoyo et al. 2015; Rurinda et al. 2015) and in South America, especially in the Brazilian savannah. In this last place, despite the occurrence of an period marked by abundance of rainfall, the dry season occurs (Cunha et al. 2013) which, in part, includes the second season maize cultivation.

Although maize cultivation in second season provides high productivity when carried out under irrigation conditions, resulting in adequate financial return to the producer (Souza et al. 2012), this is not the reality of most properties. In these cases, the production is dependent on the rains that occur during the vegetative plants development (Simão et al. 2017). Thus, in years with water shortage, maize plants develop in an irregular way, with decrease of photosynthetic activities and, consequently, productive losses (Melo et al. 2018; Tůmová et al. 2018).

Given the impossibility of obtaining constant climatic conditions and the high cost of implementing irrigated systems, the products with biostimulating action have been a possibility of technology to be exploited by the farmers, having as one of the main characteristics the low participation in the costs of production. The low cost, combined with the increase in productivity, proportional to the improvement of economic parameters (Jesus et al. 2016; Vendruscolo et al. 2018). The effects of biostimulant products are mainly related to their ability to improve physiological, nutritional and protective conditions, even when the culture is exposed to stressful conditions (Van Oosten et al. 2017).

In this way, considering the hypothesis that the biostimulant acts positively on the financial return obtained with the production of second-season maize, the study aimed at obtaining the economic indicators related to the crop under application of biostimulant.

2. MATERIAL AND METHODS

The experiment was carried out in the experimental area of the Mato Grosso do Sul Federal University, Chapadão do Sul Campus (18° 47' 39" S, 52° 37' 22" W, 820 m altitude) during the second-season of 2016 and 2017.

According to Cunha et al. (2013) The region climate is classified as tropical humid, with dry winter and rainy summer. The climatic data presented in Figure 1 were obtained from an automatic meteorological station of the National Meteorological Institute (INMET) located in the municipality of Chapadão do Sul near the experiment site.
Figure 1  Daily values of rainfall (mm), relative humidity (RH) and mean temperature (°C) during the experimental period in 2016 (A) and 2017 (B), Chapadão do Sul, MS.

In both of the experimental years, sowing and cultivation of maize was proceeded in two periods. For sowing performed in February 2016 during the 136 days of the crop cycle the accumulated rainfall was 692 mm and the average temperature recorded of 22.6 °C and 421 mm of rainfall and 21.7 °C of average temperature were recorded at the sowing in March 2016 (Figure 1A). When sowing was carried out in February 2017, rainfall during the crop cycle (137 days) totaled 525 mm with an average temperature of 22.4 °C. When the experiment was implemented in March of the same year, there was a reduction of 204 mm in the accumulated precipitation (321 mm) and average temperature of 21.5 °C during a period of 140 days of the maize crop cycle (Figure 1B).

The soil of the experimental area is classified as a LATOSSOLO VERMELHO distrófico with a clayey texture, according to the Brazilian soil classification system (Santos et al. 2013). The soil chemical analysis was performed in the 0-20 cm layer in the two years. In 2016 the chemical
The properties were: 9.0 mg dm$^{-3}$ of P (Melich); 33.5 g dm$^{-3}$ of Organic matter; pH (CaCl$_2$) 4.9; K$^+$, Ca$^{2+}$, Mg$^{2+}$ and H+Al = 0.07; 2.40; 0.9 and 2.9 cmol, dm$^{-3}$, respectively; 53.7% of base saturation and in 2017: 8.8 mg dm$^{-3}$ of P (Melich); 28.0 g dm$^{-3}$ of Organic matter; pH (CaCl$_2$) 4.9; K$^+$, Ca$_{2+}$, Mg$_{2+}$ and H+Al = 0.24; 2.10; 0.90 and 3.8 cmol, dm$^{-3}$, respectively and 46.37% base saturation.

The experiment was conducted in a randomized block design in a 2x5x2 factorial scheme, corresponding to: two sowing periods in two years, in 2016 sowing was performed on February 5 and March 8, 2017 on February 15 and March 9; five doses of biostimulant in the treatment of seeds (0, 6.25, 12.50, 18.75, 25.00 mL kg$^{-1}$); presence and absence of foliar application of biostimulant (500 mL ha$^{-1}$) in the V4 stage of the maize plants, with four replicates. The experimental plots were composed of five lines of five meters in length spaced at 0.45 m, considering a useful area to the three central lines eliminating one meter of each side.

The biostimulant used was Stimulate® which has three plant regulators in its formulation: 0.009% kinetin (cytokinin), 0.005% gibberellic acid (gibbereline) and 0.005% indolebutyric acid (auxin).

In 2016 and 2017 the experimental cultivation of maize was conducted in a no-tillage system, with soybean cultivated in the first season in 2015/16 and 2016/17. The AG 8061 VT PRO YieldGard® maize simple hybrid from the company Agroceres was used, with have characteristics such as early cycle, adaptation to the first and second cultivation seasons, high resistance to lodging and high level of technology.

For both experiment years it was applied the same treatments of phytosanitary management and fertilization for the maize crop. In order to control pests and diseases, the seeds were pre-treated with Pyraclostrobin (0.005 kg a.i. 100 kg$^{-1}$), Methyl Thiophanate (0.045 kg a.i. 100 kg$^{-1}$) and Fipronil (0.05 kg a.i. 100 kg$^{-1}$). The biostimulant application on seeds was made one day after the phytosanitary treatment and moments before sown, using a graduated pipette to dose the product directly applied to the seeds that were conditioned in transparent plastic bags and vigorously stirred.

One week before sowing in each season, the experimental area was desiccated using the herbicide Diquate (0.5 kg i.a. ha$^{-1}$) and mineral oil (0.321 kg i.a. ha$^{-1}$). On the corresponding days of each sowing, the furrows were opened with a five-row seed drill spaced at 0.45 m, applying 610 kg ha$^{-1}$ of 4-14-8 formulation. Subsequently, the maize was sown manually, with three seeds per meter corresponding to a density of 66,666.66 ha$^{-1}$ seeds.

Cover fertilization was performed at the V3 stage by applying 60 kg ha$^{-1}$ of KCl (60% K$_2$O) and 120 kg ha$^{-1}$ of urea (45% N). Phytosanitary management was: application of herbicides Atrazine (2.5 kg i.a. ha$^{-1}$) and Tembotrione (0.1008 kg i.a. ha$^{-1}$) for post-emergence weed control. Two applications of insecticides Methomyl (0.129 kg a.i. ha$^{-1}$) and Thiamethoxam + Lambda-cyhalothrin...
(0.03525 + 0.0265 kg a.i. ha^{-1}) were used for the control of lepidopteran larvae, bedbugs and leafhoppers and a preventive application of fungicide Azoxystrobin + Ciproconazole (0.06 + 0.024 kg a.i. ha^{-1}). Mineral oil (0.321 kg ia ha^{-1}) was applied to all the applications.

Stimulate® was applied at the phenological stage V4 of the maize plants (0.5 L ha^{-1}), in the plots corresponding to the treatment with the product as foliar application. It was respected the ideal environmental conditions for the maximum product absorption by the plants (temperature between 20 and 25 °C, 70% of relative humidity, wind speed below 10 km h^{-1} and with a spray flow rate of 150 L ha^{-1}).

The grain yield was obtained by manual perioding of all the ears present in the useful area of each plot at the end of the crop cycle (R6), where the grain mass was measured on a precision digital scale and humidity determined by a portable grain moisture meter (AL-102 ECO) for correction of the values to 13%.

In order to proceed the calculations regarding the production costs of a maize cultivation cycle, the total operational cost (TOC) methodology was used (Matsunaga et al. 1976; Montes et al. 2006). This is made up of the sum of the direct charges arising from operations carried out, purchased inputs and contracted manpower, which compose the effective operating cost (EOC), together with depreciation, social and financial charges, considered as 5% of EOC. The sum of all the factors of burden results in the TOC that, for calculation purposes, was obtained for an area equivalent to 1 ha.

Individually, treatments were considered as commercial treatments and the variation within each treatment was given by the amounts paid according to the volume of biostimulant used. At the same time, the data collected from the Institute of Agricultural Economics (IEA) website, Economic Research Center of the Luiz de Queiroz College of Agriculture (CEPEA) and the values in the region. The value of the 60 kg maize bag was US$ 10.17 bag^{-1} (June to October 2018) and the value of labor force was US$ 21.05 man^{-1} day^{-1}.

3. RESULTS AND DISCUSSION

It was verified that the main factor of burden was the acquisition of fertilizers, representing half of the investments applied to maize grain production. The main factors contributing to the composition of the production cost were mechanized operations, seed acquisition, agrochemicals acquisition, manual operations and other expenses, respectively (Table 1).
The significant participation of fertilizers is related to their high market value and also to the fertilization needs of cerrado soils, mainly with phosphorus. The high degree of weathering of the Brazilian Cerrado soils and the low availability of natural phosphorus in the superficial layers can be one of the main obstacles for the agricultural production, being that in these conditions high doses of this nutrient are also required in order to overcome the adsorption of this element (Bastos et al. 2010).

After insertion of the required values for the seed treatment or foliar application on maize plants with the biostimulant, it was observed that the highest TOC was obtained with the treatment
composed by the seed treatment with 25.00 ml kg\(^{-1}\) combined with the foliar application at 0.5 ml ha\(^{-1}\) (Table 2). This result is due to the increase in the quantity of product used for the treatment application and the monetary expenditure applied to their purchase.

In general, when compared to their equivalent doses, the treatments composed by the foliar application resulted in an increase of 1.50% on the TOC. It was also found that among the treatments with lower and higher TOC, there was an increase of around 3.00%, corresponding to the amount of US$ 21.05. This suggests that the biostimulant application, even in the treatments with greater volume employed, participates as little importance factor in the productive process.

Table 2: Total operational cost (TOC) obtained with maize crop due to forms and doses of biostimulant application, in two sowing periods

| Stimulate | Total volume (l ha\(^{-1}\)) | Aditional cost (US$ ha\(^{-1}\)) | TOC (US$ ha\(^{-1}\)) |
|-----------|-----------------------------|----------------------------------|------------------------|
| Seed (ml kg\(^{-1}\)) | Foliar (l ha\(^{-1}\)) | 0.00 | 0.00 | 0.00 | 704.54 |
| 6.25 | 0.00 | 0.13 | 2.63 | 707.17 |
| 12.50 | 0.00 | 0.25 | 5.26 | 709.80 |
| 18.75 | 0.00 | 0.38 | 7.89 | 712.43 |
| 25.00 | 0.00 | 0.50 | 10.53 | 715.06 |
| 0.00 | 0.50 | 0.50 | 10.53 | 715.06 |
| 6.25 | 0.50 | 0.63 | 13.16 | 717.70 |
| 12.50 | 0.50 | 0.75 | 15.79 | 720.33 |
| 18.75 | 0.50 | 0.88 | 18.42 | 722.96 |
| 25.00 | 0.50 | 1.00 | 21.05 | 725.59 |

Maize cultivation, as well as other grass species, is highly influenced by cultural practices, mainly by the application of fertilizers, which culminates in higher production costs (Souza et al. 2012; Kappes et al. 2015). In this context, the value applied to the purchase of the biostimulant is not significant, corroborating with the results obtained for the sweet maize crop, in which the application of 28.00 ml kg\(^{-1}\) of seeds resulted in an increase of 1.50% on the TOC (Jesus et al. 2016).

The highest gross revenue obtained at each sowing season coincided with the highest yields, and in the first season the treatment composed by the application of 6.25 ml kg\(^{-1}\) of seeds and foliar application was highlighted, while for the second season treatment of seeds with 12.50 ml kg\(^{-1}\) of seeds combined with leaf application resulted in higher productivity (Table 3). In relation to the control treatment, there was an increase of about 14.51% and 39.57% with the best treatments obtained in the first and second season, respectively.

Among sowing times, it was observed superiority of the cultivations carried out in the first period. The lower volume of water from the rains during the second period resulted in an average decrease of 22.98% in productivity and 29.20% in gross revenue from maize sales.
The positive effects of the biostimulant may be related to its ability to increase the root system development (Bontempo et al. 2016). Higher root volumes increase the soil exploration capacity, increasing the contact area between root and soil, consequently increasing nutrient and water absorption capacity. This higher development root system is due to the action of the hormones that compose the biostimulant product, which act on cell division and expansion (Taiz et al. 2017).

After discounting the TOC values in each treatment, it was obtained that the treatments that resulted in higher operating profit and, consequently, higher profitability index were those mentioned above as the ones with higher productivity (Table 4). In addition, the first sowing period was highlighted, which resulted in increments of 107.13% in the operating profit and 56.15% in profitability index, in relation to the second period.

The lowest values observed for the second planting period for all variables, except for the equilibrium price, are due to the water stress at which the plants were exposed. The lack of water...
supply causes the inhibition of vegetative growth, besides negatively influencing the photosynthetic process, culminating in a decrease in the productivity and production components due to its high relation with the availability of photoassimilates (Taiz et al. 2017).

For all treatments, productivities above the equilibrium productivity required for discharge during the productive cycle were obtained (Table 5). On average, productivity was 79.93% and 38.58% above equilibrium productivity in the first and second sowing periods, respectively.

Also the equilibrium price was below that used for the bags commercialization. The value obtained with the treatments average in the first and second periods, respectively, was 44.34% and 27.31% lower than the value practiced for the bags commercialization (US$ 10.17 bag\(^{-1}\)).

Table 5  Equilibrium productivity and equilibrium price obtained with maize crop due to forms, doses and times of application of biostimulant, in two sowing periods

| Stimulate | Equilibrium productivity (bag ha\(^{-1}\)) | Equilibrium price (US$ bag\(^{-1}\)) |
|-----------|-------------------------------------------|-------------------------------------|
| Seed      | 1\(^{st}\) period | 2\(^{nd}\) period | 1\(^{st}\) period | 2\(^{nd}\) period |
| 0.00      | 69.25 | 69.51 | 5.83 | 8.76 |
| 6.25      | 0.00 | 69.77 | 5.45 | 7.43 |
| 12.50     | 0.00 | 70.03 | 5.57 | 7.50 |
| 18.75     | 0.00 | 70.29 | 5.85 | 7.65 |
| 25.00     | 0.00 | 70.29 | 5.92 | 7.12 |
| 0.00      | 0.50 | 70.54 | 5.19 | 6.92 |
| 6.25      | 0.50 | 70.80 | 5.52 | 6.42 |
| 12.50     | 0.50 | 71.06 | 5.72 | 6.94 |
| 18.75     | 0.50 | 71.32 | 5.93 | 7.15 |
| Average   | 70.29 | 7.40 |

Regardless of the sowing period used, second-season maize provides a positive economic return and the biostimulant can be used to obtain higher yields, also constituting a low cost technology. It should also be noted that in the case of late sowing the biostimulant has greater effectiveness on production and economic indices.

5. CONCLUSIONS

Among the combinations between doses and forms of biostimulant application, the seed treatment with 6.25 ml kg\(^{-1}\) and 12.50 ml kg\(^{-1}\), culminate in better economic results for the first and second sowing periods, respectively, when combined to foliar application.

The highest profitability indexes were obtained with the cultivation in the first period. However, despite the lower monetary return, maize grown in the second period results in positive economic results.
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