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Article

# Residual Activity of [imazapic+imazapyr] Applied to Imidazolinones Resistant Soybean on Cotton in Succession

*Atividade Residual de [imazapic+imazapyr] Aplicado em Soja Resistente a Imidazolinonas sobre o Algodoeiro em Sucessão*

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ABSTRACT - In the current scenario of resistance of weeds to glyphosate in grain and fiber production systems, imidazolinone-resistant soybean is shown as an option in the rotation of biotechnology events and herbicide action mechanisms through the application of [imazapic+imazapyr]. However, due to its persistence in the soil, the herbicide may harm the subsequent crop. The objective of this work was to evaluate the residual activity of the herbicide [imazapic+imazapyr] applied in pre-emergence in soybean cultivation on cotton in succession. The experimental design was a randomized block design with five replicates, using seven concentrations (0; 6.25; 12.5; 25; 50; 100 and 200%) of the recommended dosage of the herbicide [imazapic+imazapyr] ([78,75+26,25] g $ha^{-1}$). The cotton was sown 112 days after application of the herbicide with accumulated rainfall of 637 mm during the soybean cycle, totalizing 1,043 mm until the cotton harvest. There was no significant difference for the analyzed variables. It is concluded that the BRS 8482cv soybean cultivar is resistant to double of the recommended dosage ([157.5+52.5] g $ha^{-1}$) of [imazapic+imazapyr], and its residual soil activity does not affect cotton cv. TMG 42 WS, in the 112 day interval between pre-emergence herbicide application in soybean cultivation and sowing of cotton.

**Keywords:** *Glycine max*, *Gossypium hirsutum*, carryover, herbicide, resistance.

*RESUMO - No cenário atual de resistência de plantas daninhas ao glyphosate nos sistemas de produção de grãos e fibras, a soja resistente a imidazolinonas mostra-se como opção na rotação de eventos de biotecnologia e mecanismos de ação de herbicidas, por meio da aplicação da mistura formulada [imazapic+imazapyr]. Entretanto, devido à sua persistência no solo, esses herbicidas podem prejudicar a cultura subsequente. Objetivou-se com este trabalho avaliar a atividade residual da mistura formulada [imazapic+imazapyr] aplicada em pré-emergência na cultura da soja sobre o algodoeiro em sucessão. O delineamento experimental foi o de blocos ao acaso com cinco repetições, sendo utilizadas sete concentrações (0; 6,25; 12,5; 25; 50; 100; e 200%) da dosagem recomendada da mistura formulada [imazapic+imazapyr] ([78,75+26,25] g $ha^{-1}$). O algodoeiro foi semeado 112 dias após a aplicação dos herbicidas, com precipitação pluvial acumulada de 637 mm durante o ciclo da soja, sendo totalizados 1.043 mm até a colheita do algodoeiro. Foram avaliadas variáveis relacionadas a características fotossintéticas, fitointoxicação, estabelecimento, desenvolvimento e produtividade em ambas as culturas. Não houve diferença significativa para as variáveis analisadas. Conclui-se que o cultivar de soja BRS 8482cv é resistente ao dobro da dosagem recomendada da mistura formulada [imazapic+imazapyr] ([52,5+157,5] g $ha^{-1}$)*

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*e sua atividade residual no solo não afeta o algodoeiro cultivar TMG 42 WS, semeado 112 dias após a aplicação em pré-emergência na cultura da soja.*

**Palavras chave:** *Glycine max*, *Gossypium hirsutum*, *carryover*, herbicida, resistência.

## INTRODUCTION

The State of Mato Grosso is the largest national producer of oilseeds and fibers, accountable for 27% of the soybean production and 65% of the cotton production in Brazil (Conab, 2016), and the succession of these crops in the State is common, mainly in the Mid-North region. However, both crops may show significant losses of production under the interference of weeds, due to the competition with the crop for the resources of the agroecosystem (sunlight, water, nutrients, $CO_2$ and space), production of harmful allelopathic compounds to the development of the plants, in addition to compromising mechanical operations and the quality of the end product, whether grains or fibers (Scholten et al., 2011). To ensure that the crop of economic interest is able to express its full production potential, it is necessary to control the weeds.

Among the weed control methods, the chemical control is the most widely employed, with the use of herbicides, due to its operational capacity, cost and efficiency. However, the characteristics of the herbicides and the production system may favor the selection of resistant weed biotypes (López Ovejero et al., 2014).

Over the last years, due to the problem of weed resistance to glyphosate, new technologies involving genetically modified organisms (GMOs) are being used. The main purpose is to confer resistance to non-selective and wide-spectrum herbicides to previously sensitive crops. Among these GMO technologies is the imidazolinone-resistant soybean, a rotation option of action mechanisms of herbicides, assisting in the management of the resistance of several weeds and hard to control species (Embrapa, 2016).

The resistance of soybeans to imidazolinones was developed by introducing the csr1-2 gene of *Arabidopsis thaliana* in the soybean genome, coding of the acetohydroxyacid synthase (AHAS) enzyme, allowing the use of ALS inhibiting herbicides, such as [imazapic+imazapyr], pre and/or post-emergence, usually not selective to conventional soybean due to a mutation that results in the substitution of the serine amino acid with asparagine on position 653 (Ser653Asn) (López Ovejero et al., 2014).

The formulated mix [imazapic+imazapyr] is recommended to control grassy weeds and broadleaves, such as purple nutsedge (*Cyperus rotundus*), ivyleaf morningglory (*Ipomoea grandifolia*), fireplant (*Euphorbia heterophylla*), among other hard-to-control species. The characteristics of imazapyr are the following: water solubility: 11,272 $mg\ L^{-1}$ (pH 7.0 and 25 °C); density: 0.38 $g\ mL^{-1}$; vapor pressure: < 1.3 x $10^{-5}$ Pa (60 °C); Kow: 1.3; ionization coefficient ($pKa_1$) of 1.9 and $pKa_2$ of 3.6; and estimated half-life in soil of 90 days. The characteristics of imazapic are the following: water solubility: 2,200 $mg\ L^{-1}$ (25 °C); density: 0.34 $g\ mL^{-1}$; vapor pressure: < 1.3 x $10^{-5}$ Pa (45 °C); Kow: 2.47; pKa of 3.9; and estimated half-life in soil of 120 days (Shaner and O'Connor, 1991; Senseman, 2007).

In general, the application of herbicides from the imidazolinone group allows the control of the first emergency flows, ensuring the initial development of the crop, free from the interference of weeds. More persistent herbicides offer the advantage of prolonged efficiency, however, they may promote, in crops in succession, a phenomenon known as residual activity or carryover, depending basically on the soil, the environmental conditions and the physical-chemical properties of the herbicide (Bedmar and Gianelli, 2014). This phenomenon may occur in different crops (Grey et al., 2012; Walperes et al., 2015), with reports of herbicides from the imidazolinone group applied to soybeans in crops in succession (Ulbrich et al., 2005; Dan et al., 2011; Felix et al., 2012; Fraga et al., 2014), including cotton (York et al., 2000; Matocha et al., 2003).

Since this system has been recently developed, little is known about the potential effects of the residual activity of herbicides derived from imidazolinones in cotton in succession. Thus, the objective of this research was to evaluate the residual activity of [imazapic+imazapyr] applied in pre-emergence in soybean cultivation cv. BRS 8482cv on cotton cv. TMG 42 WS in succession, under the climate and soil conditions of the mid-north region of Mato Grosso.

## MATERIAL AND METHODS

The experiment was conducted in the experimental area of the Center for Technology Training and Dissemination of the Cotton Institute of Mato Grosso (IMAmt), located in the municipality of Sorriso-MT (12º45'47" S and 55º50'14" W), from November 2015 to July 2016. The rainfalls and average temperature during the entire study are shown on Figure 1. A total of 637 mm of accumulated rainfall was recorded for the period between the application day and cotton sowing, with a total of 1,043 mm until the harvest.

The experiment was conducted in typical dystrophic Red-Yellow Latosol (LVAd). On August 15, 2015, a subsoiling operation was conducted and, then, the soil was corrected, with the application of 2,000 kg $ha^{-1}$ of dolomitic limestone and incorporation at 0.2 m with a disc plow. The base fertilization of the area was conducted on September 15, 2015, using the broadcast application of 1,000 kg $ha^{-1}$ of simple superphosphate, with posterior incorporation using a leveling disc plow. The soil of the 0.0 to 0.2 m layer on the experimental units had the following characteristics: pH in $CaCl_2$: 4.9; $Ca^{+2}$: 2.6 $cmol_c$ $dm^{-3}$; $Mg^{+2}$: 1.0 $cmol_c$ $dm^{-3}$; $Al^{+3}$: 0.0 $cmol_c$ $dm^{-3}$; $H^{+}$+$Al^{+3}$: 5,2 $cmol_c$ $dm^{-3}$; $K^{+}$: 52.0 mg $dm^{-3}$; P: 14.6 mg $dm^{-3}$; CTC: 8,8 $cmol_c$ $dm^{-3}$; MO: 3.7% and clay texture (sand: 140 g $kg^{-1}$; silt: 180 g $kg^{-1}$; clay: 680 g $kg^{-1}$). Seven days before the experiment was installed, due to the prevalence of grass weeds in initial state, the clethodim herbicide (100 g $ha^{-1}$) was applied in the entire area.

The soybean cultivar used was BRS 8482cv, resistant to herbicides from the imidazolinone group, with determined growth and cycle of 111 days. The sowing was mechanically made on November 6, 2015, with row spacing of 0.45 m, adjusting the planter to obtain a final population of 260 thousand plants $ha^{-1}$. The seeds were treated with the insecticide thiamethoxam at a dose of 100 g 100 $kg^{-1}$ of seeds and with the fungicide [carboxin + thiram] (60 + 60 g 100 $kg^{-1}$ of seeds). In addition to the seed treatment, the inoculation was conducted with nitrogen-fixing bacteria (*Bradyrhizobium* $5x10^9$ UFC $mL^{-1}$) in liquid formulation, at a dose of 100 mL 50 $kg^{-1}$ of seeds. The topdressing was conducted 30 days after the soybean sowing, with broadcast application of 150 kg $ha^{-1}$ of the fertilizer potassium chloride.

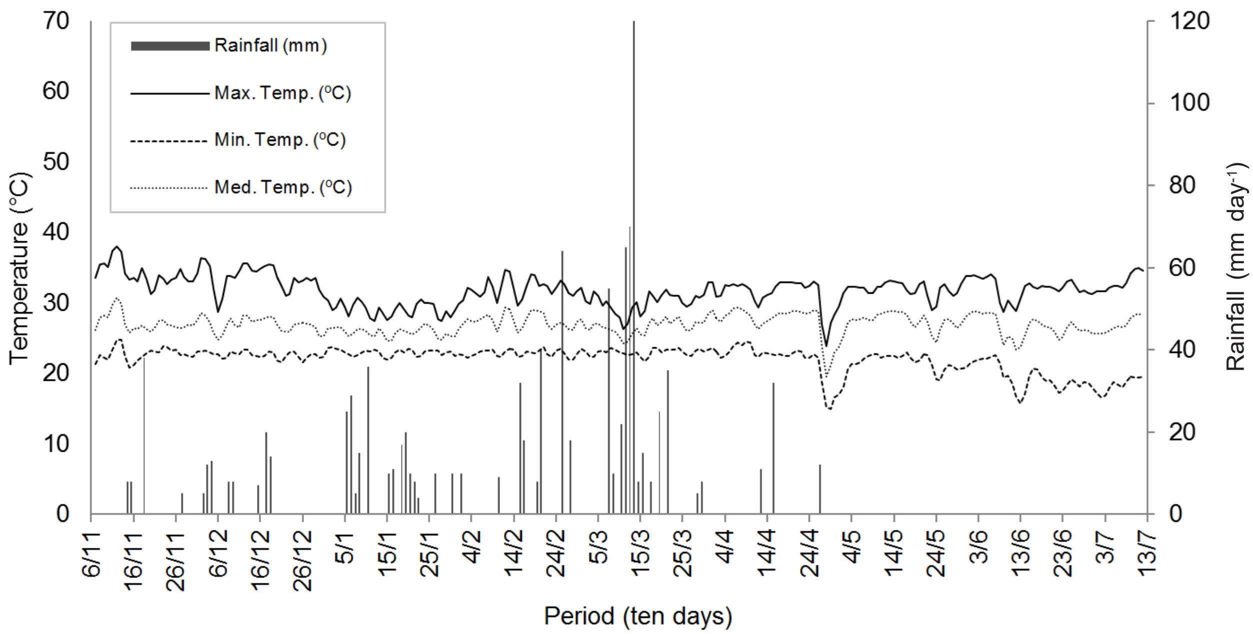


***Figure 1*** - Climate conditions recorded at the weather station of the Cotton Institute of Mato Grosso (IMAmt) during the period in which the experiment was conducted, including the soybean-cotton succession. Sorriso-MT, 2016.

The experimental design used was the random block design with five replicates, at seven concentrations (0; 6,25; 12,5; 25; 50; 100; and 200%) of the recommended dose of the formulated mix [imazapic+imazapyr] ([78.75+26.25]g $ha^{-1}$). The plots were constituted by eight soybean sowing lines with 6 m in length. Then, after the soybean harvest, four rows of cotton were sown on the same plots with row spacing of 0.90 m. The useful plot had 10.8 $m^2$, constituted by four central lines on the soybean crop and by the two central lines in cotton in succession.

The herbicide treatments were applied in pre-emergence right after the soybean sowing, with the assistance of a $CO_2$ pressurized backpack sprayer, equipped with a bar containing six fan-type spraying nozzles XR 110.02, with nozzle spacing of 0.5 m, positioned at 0.5 m of the soil surface, under pressure of 2.11 kgf $cm^2$, offering an application volume equivalent to 200 L $ha^{-1}$. The plots were maintained without the presence of weeds for the entire experimental period, through manual hoeing.

Seven days after the application of the treatments (DAA), the initial soybean stand evaluation was conducted, by counting the number of emerged plants by linear meter on the useful area of the plot. At 19, 27 and 34 DAA, the variables related to photosynthesis were evaluated: internal $CO_2$ concentration in the substomatal chamber ($C_i$), photosynthetic rate ($A$), stomatal conductance ($g_s$) and transpiration rate ($E$), with the assistance of an infrared gas analyzer (IRGA) (ADC BioScientific, model LC-pro SD) coupled to a foliar chamber of 6.25 $cm^2$, with a lighting and refrigeration system, under artificial saturating light (1,500 µmol photons $m^{-2}$ $s^{-1}$) and environmental $CO_2$ concentration. The readings with IRGA (gas exchanges) were made from 8 a.m. to 10 a.m., choosing the plant with the most representative vegetative stage for the plot, taking the measurements on the youngest completely expanded trifoliate leaf.

The phytotoxicity evaluations on soybean were visually made, using the 0-100% scale, where 0 (zero) represented the lack of injuries and 100 (one hundred), the death of the plants (Frans and Crowley, 1986), on the same date as the evaluations related to photosynthetic characteristics.

At 104 DAA, the soybean pre-harvest evaluations were made, involving: height of the plants (soil level until the insertion of the last pod) and insertion height of the first pod, evaluating ten plants by experimental unit. The final stand of the plants (number of plants by meter) was also evaluated on the referred date. At the occasion, ten plants were collected by plot, for later evaluation of the number of pods by plant and number of grains by pod. Also, at 104 DAA, the soybean was desiccated, with the application of 400 g $ha^{-1}$ of diquat in the entire area.

The harvest was conducted at 112 DAA. The mass of 100 grains and the productivity were measured with the assistance of an analytical precision scale, adjusting the humidity to 13%. In succession to soy, cotton was sown, keeping the same experimental design previously used.

The cotton cultivar used was TMG 42 WS, with a medium-early cycle, commonly used as second crop in the mid-north region of Mato Grosso. The sowing was conducted on February 26, 2016. The base fertilization was conducted on the sowing grooves, applying 250 kg $ha^{-1}$ of monoammonium phosphate (MAP). The topdressing was conducted 30 days after sowing, with the broadcast application of 150 kg $ha^{-1}$ of the potassium chloride fertilizer.

After the cotton emergence, the initial stand was determined, seven days after sowing (DAS), corresponding to 119 DAA. At 14, 20 and 27 DAS for the cotton, the variables related to the photosynthesis were evaluated, with the assistance of IRGA. The intoxication caused by the herbicide was also evaluated using a percentage scale, similarly to the evaluation conducted for the soybean crop.

At 132 DAS, the pre-harvest evaluations were made, obtaining the height of the plants, measured from the soil up to the top of the plant, and the height of the first productive branch, measured from the soil up to its insertion, taking samples from ten plants to represent the plot. On the occasion, the number of bolls by plant was obtained, taking samples from ten plants by plot, as well as the average mass of bolls, collecting ten bolls by plot, randomly.

The defoliation was performed by applying the formulated mix containing 60 g $ha^{-1}$ of thidiazuron + 30 g $ha^{-1}$ of diuron pre-harvest, at 132 DAS, when over 80% of the apples were open. Seven days after applying the defoliant, the cotton was manually harvested, in the useful area of the plot; after harvesting, the lint was stored in bags and identified, to obtain the cotton seed productivity. At the time of the harvest, ten lint samples were collected from each plot and sent to the laboratory of UNICOTTON, located in Primavera do Leste (MT), in order to evaluate the main characteristics in terms of quality of the fiber (impurity area, average length of the fibers, uniformity index, index of short fibers, rupture resistance, stretching, fiber thickness, reflectance unit, yellowing degree, index of thread spinning and maturity).

The soil of the experimental units after cotton harvesting, in August 2016, had the following characteristic on the 0.0 to 0.2 m layer: pH at $CaCl_2$: 5.4; $Ca^{+2}$: 3.3 $cmol_c\ dm^{-3}$; $Mg^{+2}$: 2.0 $cmol_c\ dm^{-3}$; $Al^{+3}$: 0.0 $cmol_c\ dm^{-3}$; $H^{+}$+$Al^{+3}$: 4.2 $cmol_c\ dm^{-3}$; $K^{+}$: 65.0 mg $dm^{-3}$; P: 18.0 mg $dm^{-3}$; CTC: 9.6 $cmol_c\ dm^{-3}$; MO: 4.1%; and clay texture (sand: 140 g $kg^{-1}$; silt: 180 g $kg^{-1}$; clay: 680 g $kg^{-1}$).

The data obtained were subjected to the analysis of variance by the F test, with the assistance of the statistical program SAS/STAT v. 9.1 ($p<0.05$) (SAS, 2004).

## RESULTS AND DISCUSSION

The [imazapic+imazapyr] applied pre-emergence did not significantly affect ($p<0.05$) any of the characteristics evaluated for the soybean crop cv. 8482cv up to the dose of [157.5+52.5] g $ha^{-1}$, double of the recommended dose for this crop (Tables 1 and 2).

The formulated mix applied pre-emergence did not injure the soybean plants on none of the evaluation dates, even when double the recommended dose for the crop was applied. The application of [73.5+24.5] g $ha^{-1}$ of the formulated mix [imazapic+imazapyr] resulted in 17% of soybean intoxication when applied post-emergence, when the soybean plants were in the vegetative stage (V2), at 9 DAA (Fraga et al., 2014). This difference may be assigned to different

***Table 1*** - Summary of the analysis of variance regarding the characteristics related to photosynthesis ($C_i$: internal concentration of $CO_2$ in the substomatal chamber; *E*: transpiration rate; $g_s$: stomatal conductance; *A*: photosynthetic rate), evaluated for the soybean crop cv. 8482cv subject to the application of the formulated mix [imazapic+imazapyr] in pre-emergence. Sorriso-MT, 2016

| Photosynthetic characteristics | 19 DAA | | | 27 DAA | | | 34 DAA | | |
|---|---|---|---|---|---|---|---|---|---|
| | General Average | CV (%) | Pr > F | General Average | CV (%) | Pr > F | General Average | CV (%) | Pr > F |
| $C_i$ (µmol $mol^{-1}$) | 321.34 | 7.22 | $0.20^{ns}$ | 234.88 | 7.58 | $0.22^{ns}$ | 277.62 | 7.03 | $0.42^{ns}$ |
| *E* (mmol $H_2O\ m^{-2}\ s^{-1}$) | 3.27 | 9.64 | $0.06^{ns}$ | 4.89 | 13.59 | $0.08^{ns}$ | 5.07 | 7.68 | $0.09^{ns}$ |
| $g_s$ (mol $m^{-2}\ s^{-1}$) | 1.65 | 19.55 | $0.07^{ns}$ | 0.41 | 12.96 | $0.06^{ns}$ | 0.95 | 18.18 | $0.06^{ns}$ |
| *A* (µmol $CO_2\ m^{-2}\ s^{-1}$) | 19.31 | 14.06 | $0.07^{ns}$ | 20.79 | 14.51 | $0.06^{ns}$ | 21.23 | 13.42 | $0.48^{ns}$ |

DAA: days after application; ns: non-significant according to the F test ($p<0.05$).

***Table 2*** - Summary of the analysis of variance regarding the development characteristics (EI: initial stand; EF: final stand; AP: height of the plants; AI: insertion height for the 1st pod), production components (NV: number of pods by plant; NGV: number of grains by pod; M100: mass of 100 grains) and productivity (P), evaluated for the soybean crop cv. 8482cv subject to the application of the formulated mix [imazapic+imazapyr] in pre-emergence. Sorriso-MT, 2016

| Development characteristics | General average | CV (%) | Pr > F |
|---|---|---|---|
| EI (plants $m^{-1}$) - 7 DAA | 9.70 | 6.04 | $0.38^{ns}$ |
| EF (plants $m^{-1}$) - 104 DAA | 9.95 | 4.77 | $0.18^{ns}$ |
| AP (cm) - 104 DAA | 67.75 | 4.51 | $0.11^{ns}$ |
| AI (cm) - 104 DAA | 21.86 | 10.52 | $0.24^{ns}$ |
| Production and productivity components | - | - | - |
| NV (pod per plant) | 35.65 | 15.10 | $0.37^{ns}$ |
| NGV (grain $pod^{-1}$) | 2.54 | 5.32 | $0.79^{ns}$ |
| M100 (g) | 18.58 | 3.18 | $0.11^{ns}$ |
| P (kg $ha^{-1}$) | 2710.04 | 10.64 | $0.85^{ns}$ |

DAA: days after application; ns: non-significant according to the F test ($p<0.05$).

factors, such as: different concentrations of imazapyr and imazapic for the herbicide formulation, time of application, climate and soil conditions and cultivars.

Results of evaluations regarding the photosynthetic characteristics for soybean cultivars resistant to herbicides from the imidazolinone group were not found in the literature. The photosynthetic activity of the soybean was possibly not affected due to the coding gene of the *AHAS* enzyme, which allowed the use of the herbicides belonging to the chemical group of imidazolinones, with no damages to the synthesis of the amino acids, interrupting the cell division and, consequently, interrupting growth, as happens for susceptible plants (Kissmann, 2016).

No reduction on the analyzed variables for the soybean crop was observed, confirming the resistance of the soybean cultivar BRS 8482cv to the herbicide within the evaluated dosage interval and the local climate and soil conditions. These results corroborate other research using crops resistant to imidazolinones, for which the development and productivity of the crop suffered no reductions (Marchesan et al., 2011; Francischini et al., 2012).

In relation to cotton, the application of [imazapic+imazapyr] in pre-emergence for the soybean crop did not affect any of the evaluated characteristics (Tables 3, 4 and 5) when performed 112 days before cotton sowing.

***Table 3*** - Summary of the analysis of variance regarding the characteristics related to photosynthesis ($C_i$: internal concentration of $CO_2$ in the substomatal chamber; *E*: transpiration rate; $g_s$: stomatal conductance; *A*: photosynthetic rate), evaluated for cotton cv. TMG 42 WS planted in succession to soybean cv. 8482cv subject to the application of the formulated mix [imazapic+imazapyr] in pre-emergence. Sorriso-MT, 2016

| Photosynthetic characteristics | 14 DAA | | | 20 DAA | | | 27 DAA | | |
|---|---|---|---|---|---|---|---|---|---|
| | General Average | CV (%) | Pr > F | General Average | CV (%) | Pr > F | General Average | CV (%) | Pr > F |
| $C_i$ (μmol mol$^{-1}$) | 237.35 | 7.45 | 0.26$^{ns}$ | 236.62 | 7.14 | 0.38$^{ns}$ | 257.22 | 7.20 | 0.14$^{ns}$ |
| *E* (mmol $H_2O$ m$^{-2}$ s$^{-1}$) | 5.22 | 12.39 | 0.29$^{ns}$ | 6.95 | 10.19 | 0.76$^{ns}$ | 5.05 | 11.24 | 0.47$^{ns}$ |
| $g_s$ (mol m$^{-2}$ s$^{-1}$) | 0.45 | 19.14 | 0.71$^{ns}$ | 0.63 | 21.82 | 0.49$^{ns}$ | 0.88 | 20.98 | 0.41$^{ns}$ |
| *A* (μmol $CO_2$ m$^{-2}$ s$^{-1}$) | 21.09 | 14.03 | 0.07$^{ns}$ | 23.85 | 4.89 | 0.08$^{ns}$ | 21.74 | 11.98 | 0.21$^{ns}$ |

DAA: days after the application; $^{ns}$: non-significant according to the F test ($p<0.05$).

***Table 4*** - Summary of the analysis of variance regarding the development characteristics (EI: initial stand; EF: final stand; AP 80 DAS: height of the plants; MSA 80 DAS: shoot dry matter; AP 132 DAS: height of the plants; ARP 132 DAS: insertion height of the 1st productive branch), production and productivity components (NC: number of bolls by plant; MMC: average boll mass; RP: lint yield; PC: cotton seed productivity), evaluated for cotton cv. TMG 42 WS planted in succession to soybean cv. 8482cv subject to the application of the formulated mix [imazapic+imazapyr] in pre-emergence. Sorriso-MT, 2016

| Development characteristics | General average | CV (%) | Pr > F |
|---|---|---|---|
| EI (plants m$^{-1}$) - 7 DAS | 7.78 | 5.57 | 0.13$^{ns}$ |
| EF (plants m$^{-1}$) - 132 DAS | 8.79 | 8.69 | 0.06$^{ns}$ |
| AP (cm) - 80 DAS | 52.83 | 16.19 | 0.99$^{ns}$ |
| MSA (g) - 80 DAS | 48.76 | 18.14 | 0.09$^{ns}$ |
| AP (cm) - 132 DAS | 52.33 | 16.16 | 0.25$^{ns}$ |
| ARP (cm) - 132 DAS | 23.28 | 29.14 | 0.11$^{ns}$ |
| Production and productivity components | - | - | - |
| NC | 6.02 | 8.30 | 0.10$^{ns}$ |
| MMC (g) | 3.23 | 7.37 | 0.44$^{ns}$ |
| RP (%) | 42.94 | 1.46 | 0.70$^{ns}$ |
| PC (kg ha$^{-1}$) | 1329.08 | 9.91 | 0.12$^{ns}$ |

DAA: days after the application; $^{ns}$: non-significant according to the F test ($p<0.05$).

***Table 5*** - Summary of the analysis of variance regarding the fiber quality characteristics (TR: leaves; A: impurity area; UHM: average fiber length; UI: uniformity index; SFC: short fiber index; STR: rupture resistance; ELONG: stretching; MIC: fiber thinness; RD: reflectance unit; +B: yellowing degree; SCI: amount of pounds-force to break an 120 yd long hank with 1.5 yd of circumference; MAT: maturity), evaluated for cotton cv. TMG 42 WS planted in succession to soybean cv. 8482cv subject to the application of the formulated mix [imazapic+imazapyr] in pre-emergence. Sorriso-MT, 2016

| Fiber quality characteristics | General average | CV (%) | Pr > F |
|---|---|---|---|
| TR | 3.28 | 18.98 | 0.62$^{ns}$ |
| A (%) | 0.43 | 15.52 | 0.53$^{ns}$ |
| UHM (in) | 1.14 | 2.06 | 0.26$^{ns}$ |
| UI (%) | 82.73 | 1.41 | 0.55$^{ns}$ |
| SFC (%) | 9.37 | 5.38 | 0.09$^{ns}$ |
| STR (gf tex$^{-1}$) | 29.00 | 4.17 | 0.11$^{ns}$ |
| ELONG (%) | 6.31 | 6.01 | 0.31$^{ns}$ |
| MIC (μg in$^{-1}$) | 3.95 | 3.19 | 0.85$^{ns}$ |
| RD (%) | 83.47 | 1.32 | 0.47$^{ns}$ |
| +B | 8.01 | 3.89 | 0.11$^{ns}$ |
| SCI (lbf) | 137.45 | 6.13 | 0.37$^{ns}$ |
| MAT (%) | 85.20 | 0.52 | 0.44$^{ns}$ |

DAA: days after the application; $^{ns}$: non-significant according to the F ($p<0,05$).

The formulated mix had no effect on any of the physiological processes evaluated for cotton for the dosages and climate and soil conditions of the experiment. It is assumed that the intoxication potential of cotton in the face of the residual of the formulated mix dosages applied in pre-emergence is considerably low. It is suggested that a higher degradation and leaching of herbicides imazapic and imazapyr occurred in the soil during the soybean crop, due to the fact that the herbicides are characterized as weak acids, and the pH of the soil is higher than the pKa of both molecules, and they are immediately dissociated and the sorption capacity in the soil is reduced, thus, showing lower residual activity.

Both the initial and the final stand of the plants was close to the recommended for cultivar TMG 42 WS, from 8 to 10 plants m$^{-1}$, for the row spacing used. York et al. (2000) observed a reduction of the stand of cotton plants when a dose of 140 g ha$^{-1}$ of imazapic was applied in a clay-loam soil with low organic matter content (1.1%) for a peanut crop, in the year before the cotton crop. Similarly, no reduction was observed for the cotton stand when doses of up to 210 g ha$^{-1}$ of imazapic were applied in the year before the crop. These results were obtained for clay-texture soils in different years and locations in the state of Georgia, USA (Matocha et al., 2003; Grey et al., 2012). The authors observed that the dose of 70 g ha$^{-1}$ of imazapic did not affect the cotton shown in the subsequent year, for the cultivars and local climate and soil conditions.

The residual activity of imazapic applied to the peanut crop on cotton in succession, even at a dose of 210 g ha$^{-1}$, caused no reduction to the production components and the cotton productivity (York et al., 2000; Matocha et al., 2003). It is highlighted that the highest dose of imazapic studied by the authors is almost three times the recommended dose for the herbicide [imazapic+imazapyr] for imidazolinone-resistant soybeans ([78.75+26.25]g ha$^{-1}$). No reduction occurred on the amount of fibers as a response to the residual activity of the herbicides. It is noteworthy that the commercialization value of the cotton lint depends on its quality, and it must meet preestablished indexes. York et al. (2000) showed on their study that the application imazapic (140 g ha$^{-1}$) to the peanut crop did not affect the lint yield and the quality parameters of the fiber on the cotton crop sown over the subsequent year.

The clay and organic matter content of the soil favors the sorption of the formulated mix [imazapic+imazapyr] in the soil, however, the pH of the soil is the most important interference factor to the sorption potential (Ahmad and Rahman, 2009). The herbicides from the imidazolinone group used are characterized as a weak acid, both with $pKa_1$ and $pKa_2$ lower than the pH found on the experimental conditions, from the implantation (pH $CaCl_2$: 4.9) up to the end of the experiment (pH $CaCl_2$: 5.4). Under those conditions, imazapyr and imazapic had little sorption and, therefore, were more available in the soil solution, more vulnerable to microbial degradation

(Kraemer et al., 2009) and/or percolation to deeper layers, thus, reducing the residual effect on cotton. The rise in the pH, through liming, increases the leaching of herbicides imazapyr and imazapic (Monquero et al., 2010; Refatti et al., 2014). Furthermore, the climate conditions during the soybean cultivation period (Figure 1), with frequent rainfalls, favored the degradation processed and the mobility of the herbicide in the soil.

It is concluded that the soybean cultivar BRS 8482cv is resistant to the formulated mix [imazapic+imazapyr] applied in pre-emergence up to double the recommended dose and that its residual activity did not affect the photosynthetic characteristics, development, productivity and quality of the fibers of cotton cultivar TMG 42 WS sown 112 days after the application.

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