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Glyphosate and cotton growth regulator sub-doses systems application[1]

Sistemas de aplicação de subdoses de glyphosate e de regulador de crescimento em algodoeiro

Gabriela Helena Pinê Américo[2]; Enes Furlani Junior[3]; Danilo Marcelo Aires Santos[4]; Juliana Heloisa Pinê Américo[5]; Carolina Cipriano Pinto[6]

Abstract - In order to increase productivity levels, reduce costs and improve efficiency in mechanical harvesting, new technologies are being incorporated such as governor use of growth and application of sub-dose of glyphosate with promising hormetic effect on cotton plants. To do this, this study aims to evaluate the effect of the application of sub-dose of glyphosate and growth regulator system on cotton agronomic characteristics. The experimental design was randomized blocks in a factorial 6 x 2 + 1, with four replications, the first factor was frequency of application of glyphosate, using the same dose (78 g a.e. ha^{-1}) in one single time 40 days after emergency (DAE), split in 2 times (at 40 and 50 DAE), in 3 times (40, 50 and 60 DAE), in 4 times (40, 50, 60 and 70 DAE) and 5 times (40, 50, 60, 70 and 80 DAE) , and the second factor was with and without the application of mepiquat chloride in the dose 1 L ha^{-1}, with split spraying in 5 times, at 45, 55, 65, 75, 85 DAE, besides the control without application of products. It has been found that the use of mepiquat chloride reduced the plant height and the number of nodes of the stem. The split application of sub-dose of the herbicide in 3 times led to increased cotton yield compared to treatments without application.
Keywords: hormesis; mepiquat chloride; herbicide

Resumo - Com o intuito de aumentar os índices de produtividade, reduzir os custos de produção e melhorar a eficiência na colheita mecanizada, novas tecnologias vêm sendo incorporadas como o uso regulador de crescimento e aplicação de subdose de glyphosate com promissor efeito hormético nas plantas de algodão. Para tal, objetivou-se com o trabalho avaliar o efeito do sistema de aplicação de subdose de glyphosate e de regulador de crescimento nas características agronômicas do algodoeiro. O delineamento experimental foi de blocos ao acaso em um esquema fatorial 6 x 2 + 1, com 4 repetições, sendo o primeiro fator frequência de aplicação do glyphosate, utilizando-se a mesma dose (78 g e.a. ha^{-1}) em 1 única vez aos 40 dias após emergência (DAE), parcelada em 2 vezes (aos 40 e 50 DAE), em 3 vezes (40, 50 e 60 DAE), em 4 vezes (40, 50, 60 e 70 DAE) e 5 vezes (40, 50, 60, 70 e 80 DAE) , e o segundo fator foi com e sem aplicação de cloreto de mepiquat na dose 1 L ha^{-1}, com pulverização parcelada em 5 vezes, aos 45, 55, 65, 75,

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[2] Mestranda em Agronomia, Faculdade de Engenharia de Ilha Solteira (FEIS-UNESP), Departamento de Fitotecnia, Tecnologia de Alimentos e Sócio Economia. Rua Monção, 226. Zona Norte, CEP: 1535-000, Ilha Solteira - SP. *E-mail: americo.gabi@gmail.com.
[3] Professor Doutor, Faculdade de Engenharia de Ilha Solteira (FEIS-UNESP), Departamento de Fitotecnia, Tecnologia de Alimentos e Sócio Economia, Ilha Solteira – SP, Brasil.
[4] Doutor em Agronomia, Engenheiro agrônomo na Nutriplant Indústria e Comércio S.A. Barueri - SP, Brasil.
[5] Doutoranda em Aquicultura, Centro de Aquicultura da UNESP, Jaboticabal - SP. Brasil
[6] Doutoranda em Agronomia, Faculdade de Agronomia Eliseu Maciela (FAEM – UFPEL), Pelotas - RS, Brasil.

85 DAE, além da testemunha sem aplicação dos produtos. Verificou-se que o uso do cloreto de mepiquat diminuiu a altura da planta e número de nós do caule. A aplicação parcelada da subdose do herbicida em 3 vezes propiciou aumento da produtividade do algodão em relação aos tratamentos que não receberam aplicação.
Palavras-chaves: hormese; cloreto de mepiquat; herbicida

Introduction

Cotton is a natural fiber, with extensive use by the domestic textile industry, and to be competitive in the globalized economy it requires advanced technology demand, in order to obtain high productivity, quality of fiber and lower production costs. According to Conab (2014) the 2013/14 season records an area to be planted with cotton in the country in 1,074.2 thousand hectares, 20.1% higher than the 894.3 thousand hectares in the 2012/13 crop, this result represents an increase of 179.9 thousand hectares compared to last season. The seed cotton production is expected to reach 4,141.5 thousand tons, a 24.4% increase compared to the previous harvest.

Cotton is a perennial plant with indeterminate growth habit, making it difficult to crop management. The use of growth regulators is a strategy to balance the vegetative and reproductive growth of cotton, the adequacy of their plant for mechanical harvesting and maximize production per plant (Cothren and Oosterhuis, 2010).

The cotton industry has advanced technology demand for obtaining high productivity, in this context the use of substances that, by definition, are considered toxic to plants and in smaller doses can stimulate plant development causing the effect known as "hormesis" which emerged as a great alternative capable of increasing productivity in cotton production systems (Calabrese and Baldwin, 2002).

In this context glyphosate is a great choice for this type of use, due to the responses obtained in Godoy (2007) experiments that reported an increase of results on phosphorus uptake in cultivating conventional soybean in 2.67 times with 18 g of a.i. ha^{-1} of glyphosate and increased dry matter accumulation (48%) and Furlani Junior et al. (2009) studying the effect of varying sub-doses of glyphosate 0 to 72 g a.e. ha^{-1} in cotton concluded that there was an increase in cotton seed yield until the dose of 23 g a.e. ha^{-1}. In this same study, they found that there was an increase in the number of bolls to the dose 10 g a.e. ha^{-1}, highlighting the hormetic effect on cotton.

Due to the concept of hormesis and the requirement of the cotton plant growth regulator, this study aimed to evaluate the effect of sub-dose of glyphosate application system and the split of mepiquat chloride on the agronomic characteristics of cotton.

Material and Methods

The experiment was conducted in the experimental area of the Teaching Farm and Research (FEPE) of Universidade Estadual Paulista "Julio de Mesquita Filho", campus Ilha Solteira, located in Selvíria-MS in the agricultural year 2011/12. The corresponding geographic coordinates are: 20º20'45"S Latitude and 51º24'11"W Longitude and average altitude of 344 m.

The soil of the area was classified as Oxisol, as Brazilian soil classification (Embrapa, 2013). Soil sampling was carried out to characterize the chemical properties in accordance with the analysis method described by Raij and Quaggio (1983) in 2011 (Table 1).

The climate is classified by Köppen as Aw, defined as tropical humid with rainy season in summer and dry in winter. It has average annual temperature of 24.5 °C, average annual rainfall of 1,232 mm and an average annual relative humidity of 64.8% (Hernandez et al., 1995).

During the trial implementation period data on monthly average temperature and monthly average rainfall for the town of Selvíria-MS were collected (Figure 1).

Table 1. Initial chemical characteristics of the soil of the field in depth from 0.00 to 0.20 m. Selvíria-MS, 2011.

$P_{(Resin)}$	M.O.	pH	K	Ca	Mg	H+Al	Al	CTC	V
(mg/dm^3)	g/dm^3	($CaCl_2$)			($mmol_c/dm^3$)				(%)
29	21	5.3	3.5	38	22	29	0	92.5	69

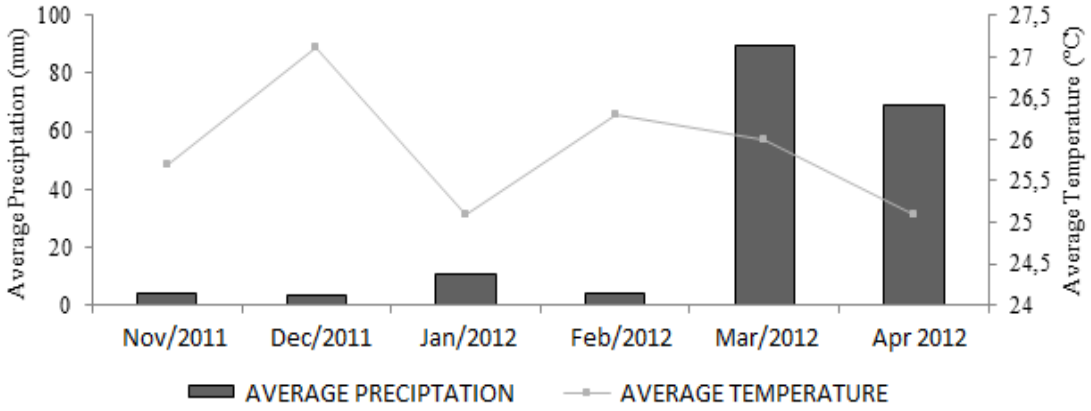

Figure 1. Rainfall and average temperature during the period of conduction of the experiment. Selvíria-MS, 2011/2012.

The experimental design was the randomized blocks (Gomes, 2000) in a factorial 6 x 2 + 1, with four replications, the first factor was frequency of application of glyphosate, using the same dose (78 g a.e. ha^{-1}) in 1 only time at 40 days after emergence (DAE), split in 2 times (at 40 and 50 DAE), in 3 times (40, 50, and 60 DAE), in 4 times (40, 50, 60, and 70 DAE) and 5 times (40, 50, 60, 70, and 80 DAE), and the second factor was with and without the application of mepiquat chloride in the dose 1 L ha^{-1}, with split spraying in 5 times, at 45, 55, 65, 75, and 85 DAE, besides the control without application of products.

The applications of the products were with costal sprayer at constant pressure on the basis of CO_2 fitted with spray nozzles model XR11002 calibrated at 3 bar pressure and volume of applied syrup of 160 liters per hectare in the morning with the intention of avoiding high temperatures occurred during of the day. Each plot consisted of four rows of cultivation, with five meters long, with a floor area consisting of the two central rows of the plot.

In the agricultural Season 2009/2010 the area used for this experiment presented the cotton crop in conventional tillage. In September 2010 interventions were carried out which enabled the implementation of tillage. The preparation of the soil happened through plowing and disking to a depth of 0.30 m. In the agricultural year 2011/2012 tillage operations were not made, in order to proceed with the installation in tillage in this way.

The installation of the project was on November 21, 2011 with mechanized planting using the cotton cultivar FMT 701. Based on the soil analysis 350 kg ha^{-1} of fertilizer on formulation 04-30-10 for sowing and two application coverage at 30 and 45 DAE of 50 kg ha^{-1} of urea as a nitrogen source were used.

After plant emergence and establishment, they were thinned, resulting in eight plants per meter in all treatments with a

combined population of approximately 88,900 plants per hectare.

The management of pests and diseases was conducted by spraying with pesticides registered for cotton growing, seeking the good development of the cotton plants, so it does not interfere in the treatments under study. The main pests found and subsidiaries were: stainer bug (*Dysdercus ruficollis*), spotted spider mite (*Tetranychus urticae*), leafworm (*Alabama argilacea*), weevil (*Anthonomus grandis*) and tobacco budworm (*Heliothis virescens*). The diseases found during the development of the cotton crop were ramulosis (*Coletotrichum gossypii* pv. *cephalosporioides*) and spot alternaria (*Alternaria* spp.).

The harvest occurred at 160 days after emergence of the cotton plant, when the withdrawal of all bolls of the two centerlines was held manually for later weighing. The agronomic characteristics were analyzed in five randomly selected plants in the central rows of each plot, and these evaluations were conducted every two weeks from 45 DAE of the plant until the end of the cycle, with the purpose of acquiring data during the development of cotton.

The following agronomic characteristics were evaluated: plant height, stem diameter, number of nodes on the stem and number of bolls per plant. Plant height was obtained by the aid of a scale, with the neck being measured until the last branch of the apical meristem of the plant. The stem diameter was obtained by caliper aid in height of 2 centimeters from the ground. The number of nodes on the stem was acquired by counting.

The seed cotton productivity was obtained from the manual harvest of the two central lines, leaving a border line on each side and the mass of 20 bolls through bolls randomly picked in the middle third of the plants and scaled with the aid of digital scale.

The data obtained in this study were subjected to the comparison test averages (Tukey test) at the 5% significance level using the methodology described by Gomes (2000). The statistic software used was SISVAR 5.1.

Results and Discussion

Prior to the application of sub-doses of glyphosate and plant growth regulator, an evaluation was performed to verify the homogeneity of plants to prevent them to interfere with interpretation of results. Glyphosate application systems had no statistical significance of the plant height agronomic characteristic in any of the reviews, but the treatments that used growth regulator application had significant difference (Table 2).

The plant height was not influenced by the use of suboptimal dose of glyphosate, this result differs from reports of Neves et al. (2011) that evaluated the effect of application of sub-doses of glyphosate varying the dose from 0 to 72 grams of acid equivalent (a.e.) ha^{-1} in cotton cultivars FMT 701 in Selvíria-MS and BRS Cedro in Costa Rica-MS, concluding that the application of glyphosate increased the plant height in FMT 701 cultivating in 7% at dose of 16.2 grams a.e. ha^{-1} and at BRS Cedro this increment reached 15% at dose 27.4 g a.e. ha^{-1}.

The treatments with the application of growth regulators showed significant differences in the assessments at 60, 75, 90, 105, and 120 DAE of the plant, the first evaluation (45 DAE) was not significant, this fact can be explained because regulator applications started the same day of this assessment. In the other assessments reduction in the growth of the plant for treatment in which was governor applied occurred, because mepiquat chloride reduces the concentration of gibberellic acid plant by inhibiting its synthesis, this fact can be explained because the gibberellic acid is an hormone responsible for cell division and growth (Taiz and Zeiger, 2002), blocking or decreasing their synthesis causes a reduction in plant height (Bogiani and Rosolem, 2009).

The results are consistent with studies by Athayde and Lamas (1999) who analyzed several times and growth regulator doses, they

found height differences of up to 34.56 cm between plants with or without the application of mepiquat chloride. These results are also similar to those reported by Laca-Buendia (1989) and Carvalho et al. (2004).

Table 2. Height of cotton plants at 45, 60, 75, 90, 105, and 120 days after emergence (DAE), in sub-doses of glyphosate and growth regulator function. Selvíria-MS, 2011/2012.

Plant height (cm)						
Treatments	45 DAE	60 DAE	75 DAE	90 DAE	105 DAE	120 DAE
Timing of glyphosate application						
Without application	89.20	110.91	122.12	113.40	117.37	120.16
One application	90.31	109.20	115.00	113.62	112.79	115.54
Split 2x	88.64	96.88	116.04	116.58	116.00	118.00
Split 3x	89.67	110.45	117.62	115.70	116.29	118.50
Split 4x	88.50	110.83	116.91	114.08	113.49	115.79
Split 5x	91.72	111.00	117.20	117.45	114.12	118.04
D.M.S.	6.10	28.24	17.24	15.64	14.85	15.97
Growth regulator (mepiquat chloride)						
Without application	89.71	114.00a	127.43a	127.26a	126.59a	135.49a
With application	89.65	102.89b	103.83b	105.13b	104.36b	106.84b
D.M.S.	2.37	10.98	6.71	6.09	5.78	6.21

* Significant at the 5% level, distinct letters differ by Tukey test

The height difference of the plant obtained by growth regulator is of great importance to cotton production, as it allows better matching cotton for mechanical harvesting and spraying the plant (control of pests and diseases) besides favoring the precocity of cotton. According to Embrapa (2003), the ideal plant height for the good performance of the harvester should range between 1.00 to 1.30 m.

The stem diameter was not changed by the herbicide application modalities and growth regulator use, regardless of the evaluated period (Table 3). These results are similar to experiments conducted by Souza et al. (2005) who found no difference in the diameter of the plants with regulatory enforcement in installments, as well as the results of this work, however they differ from the experiment carried out by Azevedo et al. (2004) they found smaller stem diameter when using two regulatory application, compared to control in two regions, one in Paraíba and one in Rio Grande do Norte.

The number of nodes on the stem was not altered by the application of glyphosate (Table 4). This fact can be explained by the fact that the number of nodes is a more stable characteristic in relation to environmental conditions and management that culture gets along its cycle.

Growth regulator applications reduced the number of nodes in the cotton stem from the second evaluation (60 DAE). The reduction of cell elongation after application of mepiquat chloride can result in reduced numbers of nodes on stem and vegetative branches. Often, the photosynthetic rate is reduced in the treatments submitted to mepiquat chloride, as there is a reduction in the activity of ribulose 1,5 bisphosphate carboxylase. The relationship between the use of mepiquat chloride and carboxylases accumulation in leaves of cotton plants is complex (Reddy and Hodges, 1996).

Similar results were obtained by Neves et al. (2011) with BRS Cedro in Costa Rica-MS, which found no significant difference for application of glyphosate sub-doses at the number of nodes on the stem. However, to cultivate FMT 701 in Selvíria-MS, there were statistical differences in number of nodes, an increase of 6.8% at dose 16 g a.e. ha^{-1} compared to control.

Table 3. Stem diameter of cotton plants at 45, 60, 75, 90, 105, and 120 days after emergence (DAE) in sub-doses of glyphosate and growth regulator. Selvíria-MS, 2011/2012.

Stem diameter (cm)						
Treatments	45 DAE	60 DAE	75 DAE	90 DAE	105 DAE	120 DAE
Timing of glyphosate application						
Without application	0.85	0.97	0.94	1.54	1.55	1.39
One application	0.90	0.99	0.95	1.52	1.52	1.32
Split 2x	0.81	0.95	0.94	1.52	1.21	1.32
Split 3x	0.86	0.98	0.92	1.53	1.51	1.34
Split 4x	0.90	1.01	0.92	1.54	1.47	1.33
Split 5x	0.90	1.05	1.02	1.62	1.59	1.46
D.M.S.	0.16	0.19	0.22	0.20	0.20	0.20
Growth Regulator (mepiquat chloride)						
Without application	0.85	0.99	0.94	1.56	1.52	1.37
With application	0.89	0.99	0.96	1.53	1.52	1.36
D.M.S.	0.06	0.07	0.08	0.08	0.08	0.79

* Significant at the 5% level, distinct letters differ by Tukey test.

Treatments with growth regulator use had significant difference, noting that the use of mepiquat chloride in addition to reducing the height (Table 2) also reduces the number of nodes on the stem, checking the growth regulator action efficiency in reducing the size of the plant.

Surveys with similar results were found by Bogiani and Rosolem (2009) and Ferrari et al. (2008), which splits not treated with growth regulator had on average larger number of nodes on the stem compared to no treatment with regulator.

Table 4. Number of nodes on the stem in sub-doses of glyphosate and growth regulator. Selvíria-MS, 2011/2012.

Number of nodes on the stem						
Treatments	45 DAE	60 DAE	75 DAE	90 DAE	105 DAE	120 DAE
Timing of glyphosate application						
Without application	13.00	15.37	15.62	15.37	16.12	18.25
One application	13.12	15.12	15.75	15.12	16.50	17.75
Split 2x	13.25	16.25	15.62	16.25	17.75	18.12
Split 3x	13.50	16.12	14.87	16.12	16.75	17.87
Split 4x	14.12	15.75	15.25	15.75	17.62	17.62
Split 5x	14.00	16.50	15.12	16.50	17.75	17.87
D.M.S.	2.53	2.24	3.56	2.33	2.72	2.24
Growth Regulator (mepiquat chloride)						
Without application	13.52	16.60a	16.30a	16.62a	17.54a	19.08a
With application	13.48	15.16b	14.52b	15.08b	16.78b	16.75b
D.M.S.	0.97	0.86	1.37	0.90	1.05	0.87

* Significant at the 5% level, distinct letters differ by Tukey test

According to the number of bolls per plant of cotton (Table 5) glyphosate application system caused no effects on cotton in any of the evaluation periods. This result is similar to that reported by Neves et al. (2011) who found no differences in reproductive structures of cultivar FMT 701 in Selvíria-MS.

On the split application of mepiquat chloride it was noted that there was also no difference on this assessment (Table 5). Similar results were found by Ferrari et al. (2008) who found no difference between the number of bolls per plant for use regulator with single dose and split and Neves et al. (2011) also found no

differences in the reproductive structures of cultivar FMT 701 in Selvíria-MS. On the other hand, Athayde and Lamas (1999), found no satisfactory results when using different doses, and growth regulator application times (mepiquat chloride).

Table 5. Number of bolls per plant of cotton at 45, 60, 75, 90, 105 and 120 days after emergence (DAE) in sub-doses of glyphosate and growth regulator. Selvíria-MS, 2011/2012.

Number of bolls per plant						
Treatments	45 DAE	60 DAE	75 DAE	90 DAE	105 DAE	120 DAE
Timing of glyphosate application						
Without application	14.45	20.45	18.16	9.29	10.87	14.12
One application	13.21	24.83	21.37	10.91	13.70	14.70
Split 2x	14.70	21.50	22.37	10.16	13.78	15.70
Split 3x	14.41	25.04	24.08	11.29	14.95	14.91
Split 4x	15.62	24.08	25.00	11.04	14.25	15.35
Split 5x	16.02	26.37	24.66	12.58	15.95	15.75
D.M.S.	3.89	7.60	9.74	3.86	5.77	2.70
Growth Regulator (mepiquat chloride)						
Without application	14.79	22.56	22.33	11.44	13.82	15.86
With application	14.68	24.77	22.86	10.36	14.01	14.82
D.M.S.	1.51	2.95	3.79	1.50	2.24	1.05

* Significant at the 5% level, distinct letters differ by Tukey test.

Through the analysis of Table 6 it was observed that the mass of 20 bolls, showed no difference when submitted in split application of growth regulator, such results corroborate the reports of Furlani Junior et al. (2003) and Zanqueta et al. (2004) who found no differences between the treatments with split application of plant growth regulator with control.

Table 6. Mass of 20 bolls and cotton yields in seeds in sub-doses of glyphosate and growth regulator. Selvíria-MS, 2011/2012.

	Treatments	Mass of 20 bolls (g)	Productivity (kg ha^{-1})
p > F	Glyphosate (G)	0.45	0.02*
	Regulator (R)	0.33	0.11
	G*R	0.39	0.04*
	CV(%)	118.33	18.78
	Timing of glyphosate application		
	Without application	103.12	1968 b
	One application	100.12	2570 ab
	Split 2 x	98.62	2438 ab
	Split 3 x	113.12	2802 a
	Split 4 x	95.87	2377 ab
	Split 5 x	99.37	2347 ab
	D.M.S.	207.62	686.48
	Growth Regulator (mepiquat chloride)		
	Without application	96.66	2306
	With application	135.41	2520
	D.M.S.	80.64	266.86

* Significant at the 5% level, distinct letters differ by Tukey test.

On the productivity of cotton seed (Table 6), it was found that there was no significant difference in the growth regulator, but differ from the results obtained by Carvalho et al. (2004), who studied the behavior of Delta Opal, IAC 23 and COODETEC 401, found no

difference between the use or not of plant growth regulator. On the other hand, these results agree with those of Soares (1999), who claims to have found no difference for seed cotton productivity with the application or not of regulator.

For glyphosate application system there was difference, and the largest cotton productivity in seed when split times this herbicide in three was verified in relation to treatments that did not receive the application of glyphosate, but to the other treatments, there was no significant difference between them (Table 6). The results are similar to Furlani Junior et al. (2003), studying the effect of glyphosate sub-doses ranging from 0-72 grams a.e. ha^{-1} in cotton concluded that there was increase in productivity until the dose of 23 g a.e. ha^{-1} evidencing the hormético effect on cotton plants.

The increased seed cotton yield from this assay is probably due to the increase in the mass of 20 bolls (Table 6), which, although not significant, it was observed an increase in this variable in the same sub-doses ranges that increased cottonseed yield. The results are similar to those found by Neves et al. (2011) who observed that an increase of 13% in cottonseed production in the application of glyphosate with subdose 29 g a.e. ha^{-1} to cultivar FMT 701 compared to control. Besides confirming the positive effect of glyphosate application, difference in the interaction of glyphosate application and the growth regulator were observed (Table 7).

In the deployment of glyphosate interact x growth regulator for seed cotton yield variable (Table 7), it was found that the application of mepiquat chloride interfere positively on cottonseed yield in treatments with glyphosate application split at three times (40, 50, and 60 DAE) and without application. There was also no significant difference in cottonseed productivity (kg ha^{-1}) when we applied growth regulator at different levels of glyphosate application system, but in the absence of application of growth regulator we noted that the lowest yield was obtained when glyphosate was not applied, being minor in relation to the other application rates of glyphosate.

Table 7. Deployment of glyphosate interaction x growth regulator for cottonseed productivity variable. Selvíria-MS, 2011/2012.

Cotton seed productivity (kg ha^{-1})						
Timing of glyphosate application						
Growth regulator	Without application	One Application	Split 2x	Split 3x	Split 4x	Split 5x
With	2327 aA	2470 aA	2633 aA	3169 aA	2273 aA	2296 aA
Without	1371 bB	2670 aA	2244 aA	2436 bA	2482 aA	2398 aA
D.M.S.			997.44			

* Means followed by the same lower case letter in columns and capitals in lines, they do not differ statistically by Tukey test 5% probability.

Conclusions

The sequential use of the growth regulator is effective in the development of cotton in relation to plant height.

The application of sub-dose of glyphosate split up to three times provides higher yields of cottonseed compared to the control, allowing establishing the occurrence of hormetic effect.

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