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Vegetative growth response of cotton plants due to growth regulator supply via seeds

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ABSTRACT. The global cotton industry is distinguished by its numerous industrial uses of the plume as well as by high production costs. Excessive vegetative growth can interfere negatively with productivity, and thus, applying growth regulators is essential for the development of the cotton culture. The objective of this study was to evaluate the development and yield of the cotton cultivar FMT 701 with the application of mepiquat chloride to seeds and leaves. The experimental design used a randomized block design with four replications, arranged in bands. The treatments consisted of mepiquat chloride rates (MC) (0, 4, 6, 8 and 10 g a.i. kg^{-1} of seeds) applied directly to the cotton seeds and MC management by foliar spray using a 250 mL ha^{-1} rates that was administered under the following conditions: divided into four applications (35, 45, 55 and 65 days after emergence); as a single application at 70 days; and without the application of the product. The mepiquat chloride applied to cotton seeds controls the initial plant height and stem diameter, while foliar application reduces the height of the plants. After application to seed, foliar spraying MC promotes increase mass of 20 bolls, however no direct influence amount bolls per plant and yield of cotton seed. Higher cotton seed yield was obtained with a rate of 3.4 g a.i. MC kg^{-1} seeds.

Keywords: mepiquat chloride, growth, yield components.

Resposta do crescimento vegetativo do algodoeiro em relação à aplicação de regulador de crescimento via sementes

RESUMO. A indústria mundial do algodão distingui-se por suas numerosas utilizações industriais da pluma, bem como pelos elevados custos de produção. Crescimento vegetativo excessivo pode interferir negativamente na produtividade e, por conseguinte, a aplicação de reguladores de crescimento é essencial para o desenvolvimento da cultura do algodão. O objetivo deste estudo foi avaliar o desenvolvimento e a produtividade do algodoeiro cultivar FMT 701 em função de aplicação de cloreto de mepiquat via sementes e folhas. O delineamento experimental utilizado foi de blocos ao acaso com quatro repetições, dispostos em faixas. Os tratamentos consistiram de doses de cloreto de mepiquat (CM) (0, 4, 6, 8 e 10 g ia kg^{-1} de sementes) aplicadas diretamente nas sementes de algodão e do manejo de CM via pulverização foliar na dose de 250 mL ha^{-1} da seguinte forma: divididos em quatro aplicações (35, 45, 55 e 65 dias após a emergência), como uma única aplicação, aos 70 dias, e sem a aplicação do produto. O cloreto de mepiquat aplicado via sementes de algodão controla a altura inicial das plantas e o diâmetro do caule, enquanto que a aplicação foliar reduz a altura das plantas. Após aplicação nas sementes, pulverização foliar de CM promoveu aumento da massa de 20 capulhos, no entanto não promoveu influência na quantidade de capulhos por planta e na produtividade de algodão em caroço. Maior rendimento de algodão em caroço foi obtido com dose de 3,4 g ia de CM kg^{-1} de sementes.

Palavras-chave: cloreto de mepiquat, crescimento, componentes de produção.

Introduction

When cultivated under conditions with unrestricted availability of moisture, light and nutrients, especially nitrogen, the cotton plant exhibits excessive vegetative growth, which negatively interferes with productivity. Thus, applying a growth regulator is vital for the development of the cotton culture (FERRARI et al., 2008).

Additionally, under these conditions, the adequate development of the culture may not be obtained with the application of growth regulators to the leaves, primarily due to the application time or due to rainfall after the application. According to

Mateus et al. (2004), the activity of mepiquat chloride via foliar application to the cotton plants requires a minimum of 16 hours for the full effect of the product, and if there is rain during this period, an additional new application is then required.

Studies indicate that growth regulators can alternatively be applied to the seeds, with the advantages of an easier practical application and the reduction of the cotton plants' initial development after emergence (FERRARI et al., 2010; NAGASHIMA et al., 2005), without affecting root system development (ALMEIDA; ROSOLEM, 2012). Another favorable aspect is protection against adverse conditions during the first application of the growth regulator, which can prevent the product from producing the desired results (MATEUS et al., 2004).

Acquiring good productivity results is more dependent on the proper management of the culture than increasing the amount of the input. Thus, it is necessary to evaluate the physiological behaviors of the plant, especially with regard to the photosynthetic process and the partitioning of photoassimilates, which are two extremely important factors in crop yield outcome, and to compare these behaviors to those obtained using the new widely adopted techniques in the cotton culture.

Therefore, this study aimed to evaluate the growth and yield of the cotton plant cv. FMT 701 following the application of mepiquat chloride to seeds and leaves. Let there be that the management with growth regulator is extremely important for providing control of vegetative growth. Thus studies that indicate the viability of different forms to application of growth regulators it seems necessary as they may assist in search a rational cotton crop management.

Material and methods

The study was carried out in the 2008/09 and 2009/10 crop years at geographical coordinates 51°24'W, 20°20'S and an altitude of approximately 335 m in Selvíria, Mato Grosso do Sul State, Brazil. The soil in the experimental area was classified as a Latosol (Dark Red, Clayey Dystrophic Latosol) (EMBRAPA, 2006), with average annual rainfall of 1232 mm and temperature of 24.5°C.

In June 2008, the 0-0.20 m soil layer was sampled and chemically analyzed, and the results are shown in Table 1. In July 2008, 1000 kg of dolomitic limestone was applied, with 80% efficiency. After the application, the soil was prepared using a moldboard plow and grading. This area has been planted with cotton crops in conventional tillage since 2007.

The experimental design used a randomized block design with four replicates, arranged in bands. The treatments consisted of mepiquat chloride rates (0, 4, 6, 8 and 10 g a.i. kg^{-1} of seeds) applied directly to the cotton seeds and MC management through foliar applications using a 250 mL ha^{-1} rate that was administered under the following conditions: divided into four applications (35, 45, 55 and 65 days after emergence (d.a.e.)); single application at 70 d.a.e; and without application of product.

The experiment began in September 2008 and in September 2009, with millet sown as a preceding crop to obtain straw in the area; this condition was chosen because of its desirable dry matter production (GUIDELI et al., 2000) and because of its wide use as a seeding system in the large cotton producing regions of Brazil's Central-West region.

Cotton seeds were treated with carboxin+tiram (100 g a.i. per 100 kg seeds) and thiamethoxam (210 g a.i. per 100 kg seeds). After drying for 4 hours, the seeds were divided into plastic bags, and these seeds either received the application of MC (250 g a.i. L^{-1}) according to the defined rates or were not further treated. They were then agitated for 3 minutes and left to dry for 5 hours. On the same day, the dried seeds were sowed. Each experimental plot consisted of four rows that were five meters long, spaced 0.90 m apart, with two central rows in the useful area of each plot.

The cotton sowing was performed on November 17 in the first agricultural year and on the November 23 in the second year, with emergence on November 23 and 27 of the respective years. In 2008 and 2009, a tractor-drawn seeder-fertilizer applicator was used, with 200 kg ha^{-1} of NPK at a 8-28-16 proportion in the sowing furrow. The strain used was FMT 701 due to its superior performance in tests carried out in the locality. The seeding rate was 11 seeds m^{-1} with 0.90 m spacing between rows.

Table 1. Chemical analysis soil results at a depth of 0-0.20 m. Selvíria, Mato Grosso do Sul State, Brazil, 2008.

P_{resin} mg dm^{-3}	M.O. g dm^{-3}	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	CTC	V (%)
			mmol$_c$ dm^{-3}						
12	22	4.8	4.6	19	11	22	0	58	58

Looping was performed after the emergence and set up (14 d.a.e.), with 8 m^{-1} plants remaining. The fertilizer coverage comprised 60 kg ha^{-1} of nitrogen divided into two applications: one at 35 d.a.e. using urea (45% of N) as the source and the second at 55 d.a.e. using ammonium sulfate (21% of N and 24% of S).

The application of growth regulator to the leaves was performed according to the treatments described above. The applications were performed in the morning to avoid high temperatures during the application.

Plant heights were measured using a measuring tape to measure from the ground to the top of the plant. Calipers were used to measure the stem diameter at 2 cm above the ground.

The number of reproductive branches and bolls per plants were counted at the time of harvest, in addition to 20 bolls that were randomly harvested at the middle third of the plants. The measurements were randomly obtained on five plants in the useful area of the plots. In April 2008 and April 2009, at 150 and 152 days, respectively, harvesting was manually performed in the two central rows of each plot to quantify the cotton seed production per hectare, which was weighed using a digital scale.

The data obtained in this study underwent analysis of variance using an F-test and a means comparison test (Tukey) as well as by polynomial regression at the 5% significance level using the methodology described by Banzatto and Kronka (2006). Correlation and regression analyses were performed using SISVAR software (FERREIRA, 2011). Regression equations were fitted to the significant features, and the best-fitting model was selected by the coefficient of determination.

Results and discussion

Tables 2 and 3 show the results of the plant height evaluation during the development of the cotton plants. In the assessments carried out in the early stages of development of the cotton plants (10 to 60 days in Tables 2 and 3) and in both agricultural years under study (2008/09 and 2009/10), the growth regulator rates was observed to have a significant linear effect on the reduction of plant height. These results indicate that using the product for seed treatment effectively controls initial cotton plant development, thereby facilitating the management of the cotton culture. The first months after sowing typically exhibit high rainfall, which can undermine the growth regulator applications, exceeding the time or too late for the first growth regulator application. Treating the seeds instead of the leaves also affords savings in the quantity of spraying in the production areas, resulting in reduced production costs. Similar results were found by Almeida and Rosolem (2012) in a greenhouse study evaluating the development of roots and shoots of the cotton cultivar cv. FM 993 from seeds treated with MC. They concluded that this promotes a reduction of plant height and leaf area without affecting the dry matter production of the shoots. Similarly, Nagashima et al. (2011) observed a reduction in the initial development of cotton plants after spraying MC on the seeds.

At 60 days (Table 3), the growth regulator applied to the seeds loses its residual effect and does not control the development of height of the cotton plants, therefore, the application of growth regulator via foliar spray is required. This growth regulator management was studied and was shown to be efficient because there was a reduction in plant height by using the product divided into parts, beginning at 60 days.

Similarly, a single application of the growth regulator was also efficient in reducing plant height, resulting in significant differences at 90 and 125 days in comparison with the control, with average reductions of 25.22 cm in the two years under evaluation (Table 3). The main purpose of using the growth regulator is to disrupt the biosynthesis of gibberellic acid, thus influencing dry matter production, which is related to the transport of carbohydrates because the development of the cotton plant is related to favorable weather conditions, water and also nutrient availability (ELKOCA; KANTAR, 2006; HAQUE et al., 2007; TAIZ; ZEIGER, 2013). Height control of cotton plant can be efficiently performed with the use of MC, as it inhibits cell growth (LAMAS, 2001). The use of growth regulator under Cerrado conditions is required because it can help control plant height, thereby facilitating crop management, which is especially important for mechanical harvesting.

Similarly, Ferrari et al. (2008) found that over several seasons and growth regulator rates, height differences of up to 34.56 cm between plants were observed with and without application of the product.

Table 2. Evaluation (days) of cotton plant heights (cm) in two crop years, according to the rates and application methods of the growth regulator.

p > F		10		20		30		40	
		Days after emergence							
		2008/09	2009/10	2008/09	2009/10	2008/09	2009/10	2008/09	2009/10
Application (a)		0.713	0.940	0.123	0.684	0.711	0.783	0.978	0.933
Rates (r)		0.001**	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**
a*r		0.850	0.998	0.980	0.992	0.929	0.932	0.961	0.991
	Without	6.05	7.30	10.94	11.05	30.40	32.37	54.58	54.92
Application Methods	Single	5.98	7.52	11.77	11.51	30.12	31.16	54.37	55.02
	Split	5.94	7.41	11.07	11.97	29.75	31.68	54.62	54.51
	0	9.30(1)	10.70(2)	16.00(3)	16.35(4)	37.67(5)	40.46(6)	62.75	66.23
	4	5.79	8.12	11.97	12.15	29.08	32.53	52.78	57.05
Rates	6	4.98	7.11	11.00	11.19	30.08	31.24	55.75	52.44
	8	5.24	6.16	9.39	9.51	29.81	30.32	57.53	53.62
	10	4.62	4.98	7.94	8.33	24.95	24.12	43.81	44.75
C.V.%		7.00	26.70	11.85	28.83	8.26	17.18	7.49	8.34
D.M.S.		0.32	1.52	1.03	2.55	1.91	4.19	3.14	3.51

Polynomial Equations

(1) $Y= 9.231 - 1.057x + 0.062x^2$ $R^2=0.97^{**}$ (2) $Y= 10.567 - 0.564x$ $R^2=0.98^{**}$

(3) $Y=15.693-0.7916x$ $R^2=0.98^{**}$ (4) $Y=15.960-0.795x$ $R^2=0.98^{**}$

(5) $Y= 36.631 - 1.168x$ $R^2=0.82^{**}$ (6) $Y= 39.987 - 1.473x$ $R^2=0.94^{**}$

**Significant at 1% level by Test F. Means followed by same letter vertically do not differ, by Tukey test at 5% of probability.

Table 3. Evaluation (days) of cotton plant heights (cm) in two crop years, according to the rates and application methods of the growth regulator.

p > F		60		90		125	
		Days after emergence					
		2008/09	2009/10	2008/09	2009/10	2008/09	2009/10
Application (a)		0.001**	0.001**	0.001**	0.001**	0.001**	0.001**
Rates (r)		0.001**	0.004**	0.846	0.173	0.186	0.308
a*r		0.682	0.999	0.781	0.993	0.727	0.999
	Without	83.02 a	92.68 a	111.62 a	119.68a	150.60a	146.57 a
Application Methods	Single	82.10 a	91.70 a	100.75 b	103.28 b	122.82 b	123.92 b
	Split	74.40 b	79.94 b	95.00 b	95.58 c	119.23 b	115.79 b
	0	88.08(1)	93.88(2)	101.45	110.13	132.20	133.47
	4	77.72	88.73	101.56	108.50	127.42	128.50
Rates	6	80.22	90.71	104.72	106.95	131.03	127.23
	8	83.89	87.27	102.19	103.51	134.31	130.43
	10	69.28	79.94	102.36	101.80	129.47	124.19
C.V.%		5.76	9.62	7.65	8.72	5.45	8.38
D.M.S.		3.54	6.51	6.02	7.11	5.48	8.29

Polynomial Equations

(1) $Y=87.348-1.341x$ $R^2=0.53^{**}$ (2) $Y=94.746-1.186x$ $R^2=0.77^{**}$

**Significant at 1% level by Test F. Means followed by same letter vertically do not differ, by Tukey test at 5% of probability.

The results presented in Table 4 show that the application of increased rates of growth regulator to cotton seeds reduced the stem diameter of the plants in assessments performed at 30 days. There were significant effects in the two evaluation years, with linear and quadratic fitting averages, respectively, for 2008/2009 and 2009/10. This reduction is due to the action of the product from the early stages of vegetative growth of the cotton plant, thus restricting plant development in both diameter and in height (Tables 2 and 3).

However, analyzing stem diameter averages at 80 days, it was observed that the plant growth regulator applied to seeds stopped acting to inhibit plant growth, resulting in similar values for the treatments in the two study years. However, in the 2008/09 crop year, there was a stem diameter increase for the plants that received divided MC foliar applications. One possible explanation is that product applied to the cotton leaf at different times decrease height development (Table 3, assessment at 90 days), with accumulated reserves supporting stem development instead.

In the evaluation performed at 125 days (Table 4), in the two years evaluated, no significant differences were found in the stem diameter of the cotton plant due to the application of growth regulators to the seeds and stems. Similar results were found by Cordao Sobrinho et al. (2007) that found no effect of the growth regulator in reducing the stem diameter. Thus, in contrast to plant height, stem diameter resumes its normal development after the effect of the growth regulator is complete, with no significant difference between the averages. Most likely, such dynamic stem development is necessary for the cotton plants to become resistant to growth and to withstand the weight of branches and bolls during the development progress.

An analysis of the number of reproductive branches of cotton plants indicated no changes based on the growth regulator application to the seeds or leaves (Table 4) in the two years under study. With this result, it can be observed that the growth regulator has no function in changing the number of fruiting branches per plant and that this characteristic is strongly influenced by genotype. On the other hand Bogiani and Rosolem (2009) and Rosolem et al. (2013) using rates at growth regulator in cotton plants, concluded that rates up to 22.5 and 30 g ha^{-1} (respectively) of active ingredient MC further reduction in the number of reproductive branches.

The data in Table 5 show no significant difference for the mass of 20 bolls with the treatments under study. For the growth regulator applied to the leaves and with the application methods described above, 20 bolls revealed a greater mass for the treatment in which the product was applied at different times in the assessment conducted in the 2009/10 crop year. Similarly, Teixeira et al. (2008) and Ferrari et al. (2008) observed a greater mass of 20 bolls on the cotton plants (cv. FMX 986 and Delta Opal respectively) that had received growth regulator applications at different times. For the MC rates via seeds, there was a quadratic fitting of the averages in the two years of evaluations, in which rates of 4, 6 and 8 g a.i. kg^{-1} seeds promoted the highest values. Tables 2, 3 and 4 show the interference in vegetative growth of the cotton plants, indicating a significant vegetative growth or strong initial control of the plants observed by the development of bolls.

The application of growth regulator to leaves did not interfere significantly with the average number of bolls per plant for both years under study (Table 5). Thus, the use of MC to control the growth of cotton plants did not change the number of bolls per plant. Similar results were reported by Ferrari et al. (2008), who found no significant difference for this variable.

Table 5 shows that there was a significant effect of quadratic fitting for the MC rates applied to seeds on cotton kernel yield. Where there was no treatment with phytoregulators via seeds, productivity was lower, thus verifying that as these plants had higher vegetative growth, they produced less.

Table 5 shows that the rates above 4 g a.i. kg^{-1} seeds showed a decrease in productivity, indicating excessive control of plant size. A detailed analysis showed that, in both years under study, the MC rate that provided the highest cotton yield was approximately 3.4 g a.i. kg^{-1} seeds. It was also observed that the highest rate used (10 g a.i. kg^{-1} seeds) caused a decrease in cotton kernel productivity of 17% (543 kg ha^{-1}) and 19% (594 kg ha^{-1}), respectively, for the agricultural years 2008/09 and 2009/10. Similarly, Yeats et al. (2005) observed lower yields in cotton plants that underwent soaking of the seeds with rates greater than 4 g a.i. MC kg^{-1} seeds.

Table 4. Evaluation (days) of stem diameter (cm) and number of reproductive branches of cotton plants, in two crop years, according to the rates and application methods of growth regulator.

Treatments		30		80		125		Reproductive branches (nº)	
		Days after emergence							
		2008/09	2009/10	2008/09	2009/10	2008/09	2009/10	2008/09	2009/10
Application (a)		0.042	0.956	0.008**	0.928	0.176	0.653	0.637	0.793
Rates (r)		0.001**	0.001**	0.211	0.857	0.192	0.872	0.507	0.870
a*r		0.854	0.637	0.071	0.998	0.948	0.999	0.276	0.995
	Without	7.18	8.69	17.55b	18.72	21.54	21.69	16.91	16.57
Application Methods	Single	7.15	8.81	17.71 b	18.80	22.63	22.87	17.41	17.62
	Split	6.97	8.78	19.00 a	18.30	22.86	22.90	17.18	17.51
	0	7.86(1)	9.57(2)	18.52	19.59	21.90	21.49	16.83	17.47
	4	7.08	8.79	17.65	19.07	22.14	22.54	17.33	18.29
Rates	6	7.08	9.11	18.53	18.27	23.81	22.84	17.30	17.50
	8	7.42	9.38	17.67	18.39	21.62	23.47	17.74	16.92
	10	6.06	6.96	18.07	17.71	22.24	22.08	16.62	15.98
C.V. %		8.03	14.46	6.72	23.82	10.48	20.83	9.72	30.34
D.M.S.		0.44	0.97	0.93	3.41	1.80	3.60	1.28	4.09

Polynomial Equations

(1) $Y=7.864-0.136x$ $R^2=0.62^{**}$ (2) $Y= 9.372+0.162x-0.035x^2$ $R^2=0.98^{**}$

** Significant at 1% level by Test F. Means followed by same letter vertically do not differ. by Tukey test at 5% of probability.

Table 5. Evaluation of 20 bolls, number of bolls per plant and cotton plant yield, cv. Delta Opal, in two crop years, according to rates and application methods of growth regulator.

Treatments		Mass 20 bolls(g)		Bolls/plant (nº)		Yield (kg ha^{-1})	
		2008/09	2009/10	2008/09	2009/10	2008/09	2009/10
Application (a)		0.186	0.044*	0.595	0.591	0.755	0.960
Rates (r)		0.048*	0.012*	0.016*	0.344	0.002**	0.010*
a*r		0.574	0.957	0.994	0.991	0.987	0.992
	Without	111.04	103.57* b	15.96	15.78	3122.29	2917.05
Application Methods	Single	110.07	108.31 ab	16.39	16.13	3112.15	2940.87
	Split	117.44	111.73 a	16.79	16.55	3192.83	2954.36
	0	112.44(1)	106.91(2)	16.53(3)	16.05	3232.08(4)	3034.56(5)
	4	116.35	111.22	16.93	17.00	3283.27	3148.47
Rates	6	113.77	113.21	16.73	16.51	3227.23	3079.29
	8	118.33	109.01	17.65	16.21	3129.43	2870.45
	10	103.36	99.00	14.05	15.03	2740.11	2554.36
C.V. %		12.01	9.26	15.63	14.54	11.77	14.40
D.M.S.		10.42	7.68	1.97	1.80	284.27	325.17

Polynomial Equations

(1) $Y=111.801+2.799x-0.339x^2$ $R^2=0.63^*$ (2) $Y=106.404+3.317x-0.395x^2$ $R^2=0.92$ **(3) $Y=16.332+0.580x-0.074x^2$ $R^2=0.60^*$

(4) $Y=3212.515+92.651x-13.633x^2$ $R^2=0.94^{**}$ (5) $Y=3031.518+86.075x-13.358x^2$ $R^2=0.99^*$

**,*Significant at 1% and 5% levels respectively by Test F analysis of variance. Means followed by same letter vertically do not differ, by Tukey test at 5% of probability.

It was not possible to verify significant differences between the growth regulator application modes via leaf. Azevedo et al. (2004) found no difference regarding whether or not MC foliar application methods were performed.

Conclusion

The mepiquat chloride applied to cotton seeds controls the initial plant height and stem diameter, while foliar application reduces the height of the plants.

After application to seed, foliar spraying MC promotes increase mass of 20 bolls, however no direct influence amount bolls per plant and yield of cotton seed.

Higher cotton seed yields are obtained with a rate of 3.4 g a.i. MC kg^{-1} seeds.

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