DOI: 10.1590/S0100-83582015000300011

Effect of Trinexapac-Ethyl on Growth and Yield of Sugarcane[1]

Efeito do Trinexapac-Ethyl no Crescimento e na Produção da Cana-de-Açúcar

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ABSTRACT - Growth regulators can be used to further retard or inhibit vegetative growth. In this sense, the objective of this study was to determine the effects of age and number of trinexapac-ethyl applications on the growth and yield of sugarcane. The experiment was in a randomized complete block design with four replications. The treatments were in a 3 x 2 + 2 factorial arrangement, where factor A corresponded to the application times of the plant growth regulator (120, 200 and 240 days after bud burst (DAB) of sugarcane) and factor B to the number of applications (one or two applications). In addition, two controls (one with three applications and another application without the regulator) were added. The application of trinexapac-ethyl decreased the number and the distance between buds, height, root volume and sugarcane yield. The sequential application (2 or 3 times) induced an increase in stem diameter and three applications of the product increased the number of plant tillers. The use of growth regulators applied at 240 DAB has reduced plant height, however without changing the number of buds. It can be concluded that trinexapac-ethyl changes sugarcane growth and yield, regardless of season and number of applications.

Keywords: growth regulator, application timing, number of applications.

RESUMO - Os reguladores vegetais podem ser utilizados para promover, retardar ou inibir o crescimento vegetativo. Neste sentido, o objetivo deste trabalho foi determinar os efeitos de épocas e número de aplicações do trinexapac-ethyl sobre o crescimento e a produtividade da cana-de-açúcar. O experimento foi delineado em blocos casualizados com quatro repetições. Os tratamentos foram arranjados em esquema fatorial (3 x 2 + 2); o fator A correspondeu às épocas de aplicação do regulador vegetal (120, 200 e 240 dias após a brotação das gemas (DAB) da cana-de-açúcar), e o fator B, ao número de aplicações (uma ou duas). Além disso, foram adicionadas duas testemunhas (uma com três aplicações e outra sem aplicação do regulador). A aplicação do trinexapac-ethyl reduziu o número e a distância entre gemas, a altura, o volume radicular e a produtividade da cana-de-açúcar. A aplicação sequencial (duas ou três vezes) promoveu incremento no diâmetro do caule, e três aplicações do produto aumentaram o número de perfilhos das plantas. O uso do regulador vegetal aplicado aos 240 DAB reduziu a altura das plantas, porém sem alterar o número de gemas. Conclui-se que o trinexapac-ethyl altera o crescimento e a produção da cana-de-açúcar, independentemente da época e do número de aplicações.

Palavras-chave: regulador vegetal, época de aplicação, número de aplicações.

INTRODUCTION

Increased global interest in renewable fuels has led to a significant expansion of this sector in Brazil. Currently, the area cultivated with sugarcane in the country exceeds 8 million hectares, with an average productivity of 69 t ha^{-1} (Conab, 2013). It is consumed fresh as fodder, feed, or raw material for the production of brown sugar, molasses,

[1] Recebido para publicação em 8.12.2014 e aprovado em 2.6.2015.
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(distilled spirit) cachaça, sugar and alcohol (Caputo et al., 2008). In recent years, various agricultural techniques have been adopted to improve the technological quality of raw materials for industry, including the application of plant growth regulators (Leite et al., 2011; van Heerden, 2014).

Plant growth regulators are synthetic compounds applied to plants to obtain different effects, such as promoting, delaying or inhibiting vegetative growth without lowering productivity (Rademacher, 2000). The use of plant growth regulators on sugarcane crops has been frequent, especially in the large sugar or alcohol sugarcane processing facilities in Brazil, due to the need for early harvest and to optimize crop planning (Faria et al., 2014).

Trinexapac-ethyl is a growth regulator which inhibits the 3β-hydroxylase enzyme, reduces the active gibberellic acid (GA_1) and increases its immediate biosynthetic precursor GA_{20} (Heckman et al., 2005), which causes the stoppage of cell elongation of the plants during the vegetative stage (Davies, 1987). Trinexapac-ethyl operates on sugarcane physiology and metabolism, reduces gibberellic acid production, affects and extends the cell walls, thereby facilitating further accumulation of sugar (Resende et al., 2000; Faria et al., 2014).

In sugarcane, trinexapac-ethyl is used to promote increases in sucrose content of internodes, early ripening, and increasing sugar production, being used in the final harvest. The use of regulators during the crop cycle can be an interesting strategy, particularly in sugarcane seedling production nurseries, because with their application throughout the cycle it is expected to reduce the plant height, reduce internodes length, and minimize lodging problem in the crop (Castro, 1999).

It is expected that the use of trinexapac-ethyl on sugarcane shall enable gains in the crop economic yield. In this sense, the aim of this study was to assess the effects of trinexapac-ethyl applications in different ways on sugarcane growth and production.

MATERIALS AND METHODS

The experiment was conducted in an open environment, with the units consisting of polyethylene boxes containing 150 dm^3 of substrate (soil + fertilizers). As a substrate, a red-yellow latosol was used, previously limed and fertilized according to soil properties: pH in water of 4.3; MO = 2.5 dag kg^{-1}; P = 1.5 mg dm^{-3}; K = 40 mg dm^{-3}; Al^{3+} = 0.5 $cmol_c$ dm^{-3}; Ca^{2+} = 1.3 $cmol_c$ dm^{-3}; Mg^{2+} = 0.2 $cmol_c$ dm^{-3}; CTC(t) = 2.1 $cmol_c$ dm^{-3}; CTC(T) = 6.39 $cmol_c$ dm^{-3}; H+Al = 4.79 $cmol_c$ dm^{-3}; SB = 1.6 $cmol_c$ dm^{-3}; V = 25%; and clay = 38%.

The treatments were outlined in randomized blocks arranged in a 3 x 2 + 2 factorial arrangement with four replications. Factor A corresponded to the application times of the plant growth regulator (120, 200 and 240 DAB) and factor B to the number of applications (1 and 2). In addition, two controls were added (one with three applications and the other without application of the regulator). The single applications were done at 120, 200 and 240 DAB of the crop, and the sequential applications at 120 and 200 DAB, 200 and 240 DAB, and 120 and 240 DAB (Table 1).

Table 1 - Times of trinexapac-ethyl applications days after bud burst (DAB) in sugarcane plants of cultivar RB867515

Treatment	Times of A = application of trinexapac-ethyl		
Single application 1	120 DAB[1/]	-------	-------
Single application 2	-------	200 DAB	-------
Single application 3	-------	-------	240 DAB
Sequential application 1	120 DAB	200 DAB	-------
Sequential application 2	-------	200 DAB	240 DAB
Sequential application 3	120 DAB	-------	240 DAB
Control 1	120 DAB	200 DAB	240 DAB
Control 2	-------	-------	-------

[1/] DAB – days after bud burst of sugarcane buds.

The sugarcane variety used was RB 867515, and four buds per pot were planted. At 15 DAB thinning was conducted, leaving three shoots (plants) per experimental unit. The growth regulator application (trinexapac-ethyl at a dose of 1.0 L h^{-1} of the commercial product Moddus®) was done with a backpack pressurized sprayer by carbon dioxide, equipped with a bar containing a spray tip of series TTI 110.02, calibrated to spray 150 L ha^{-1} of spray solution. The spray tip was held at 50 cm from the target.

At 360 DAB of the crop, the following characteristics were assessed: plant height (HEI –cm), which was determined from the ground surface to the atrial area of the leaf +1; number of buds per plant (NBU); number of tillers (NTL); stem diameter (DIA (mm)); average distance between buds (DBB), calculated from the height of the plants/ number of buds per plant; the root system volume (RSV – dm^3); and productivity (PROD – kg) of each plot.

The data were submitted to analysis of variance by F-test, and, where necessary, the means of treatments were compared by Tukey test at 5% probability.

RESULTS AND DISCUSSION

Trinexapac-ethyl has reduced sugarcane NBU in single or sequential applications, except for treatment in one application at 240 DAB of the crop (Table 2). When applied three times during the crop cycle, the product reduced NBU by 22%. There was no difference in NBU between application times of trinexapac-ethyl (single or sequential).

DGE has been reduced for all assessed application times, except for the single application done at 120 DAB (Table 3). At the first time it was found that two applications of the product (120 and 200 DAE (days after emergence)) reduced GIP compared to a single application at 120 DAE. As for the other times, there was no difference between the numbers of applications. The reduction in number of buds and the shortest distance between the buds are explained by the mechanism of action of trinexapac-ethyl, which inhibits the synthesis metabolism of gibberellin and hence reduces cell elongation in treated plants (Ervin & Koski, 2001a), as observed in wheat cultivars treated with trinexapac-ethyl, which had a substantial reduction in plant height, by decreasing the length of the internodes, without, however, affecting the stem diameter and the mass of the dried plants (Zagonel et al., 2002).

HEI was reduced with the application of trinexapac-ethyl at all times, especially at 200 DAE (Table 4). This effect was intensified where three applications of the regulator were held. When assessing the HEI of plants that received twice the product, a negative effect of the product for all times was also seen. In relation to the number of applications within each season, there was a difference only when the product was applied at 120 DAE, and HEI values for application were superior to that found for two applications (Table 4). The use of plant growth regulators to reduce

Table 2 - Number of buds (NBU) of sugarcane plants in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times in single or sequential applications

Single application		Sequential application	
DAB[1/]	NBU	DAB	NBU
120	13.75 b A[2/]	120 and 200	14.14 b A
200	14.09 b A	200 and 240	13.76 b A
240	15.18 abA	120 and 240	14.26 b A
Three applications	11.64 b		
No application	15.75 a		
CV (%)	17.56		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

Table 3 **-** Distance between buds (DBB (cm)) of sugarcane plants in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times in single or sequential applications

Single application		Sequential application	
DAB[1/]	DBB (cm)	DAB	DBB (cm)
120	14.53 a A[2/]	120 and 200	9.26 b B
200	7.71 b A	200 and 240	8.04 b A
240	10.14 b A	120 and 240	9.76 b A
Three applications	5.77 c		
No application	13.06 a		
CV (%)	10.42		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

Table 4 **-** Plant height (HEI (cm)) of sugarcane plant in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times, in single or sequential applications

Single application		Sequential application	
DAB[1/]	HEI (cm)	DAB	HEI (cm)
120	249.08 b A[2/]	120 and 200	198.08 b B
200	182.08 c A	200 and 240	183.00 b A
240	209.58 bcA	120 and 240	195.59 b A
Three applications	113.25 d		
No application	274.25 a		
CV (%)	21.87		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

plant growth is a practice often employed in agriculture. Tatnell (1995) and Teixeira & Rodrigues (2003) have obtained reductions in the height of barley plants with the use of trinexapac-ethyl. For rice, Alvarez et al. (2007) have found that plant growth regulator at a dose of 200 g ha^{-1} of a.i. has reduced plant height in 0.34 m. In the sugarcane crop, reduction in height decreases the risk of lodging, which makes the plant more compact and provides better utilization of photoassimilates, since 60% of these are used in the upper internodes elongation, and the remaining is directed to the growth of young leaves and panicles (Murata & Matsushima, 1978).

The application, sequential or in three times, of trinexapac-ethyl increased the diameter of the sugarcane stem (Table 5). There was no difference in the number of applications in the times assessed. For low-sized wheat plants, this was not observed: the product promoted substantial reduction in plant height, without affecting stem diameter and mass of dried plants (Zagonel et al., 2002). This increase in diameter may have been due to the thickening of the sclerenchyma tissue, resulting in increased stem diameter, which was observed for two wheat cultivars treated with trinexapac-ethyl (Lozano & leaden, 2001).

RSV was reduced by the application of the plant growth regulator, regardless of the type of application (Table 6). For the first time of application, it was observed that two product applications (120 and 200 DAE) reduced RSV, and for the other times no difference was found between the number of applications (Table 7). For NTL, when sugarcane plants received one and two product applications, it was found that the control subjected three times to the application of the product showed higher tillering compared to treatments with one application and control without application of the product. No difference in the number of applications within each assessment period was found (Table 8). The application of

Table 5 **-** Stem diameter (DIA (mm)) of sugarcane plants in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times in single or sequential applications

Single application		Sequential application	
DAB[1/]	DIA (mm)	DAB	DIA (mm)
120	31.71 b A[2/]	120 and 200	34.00 a A
200	31.79 b A	200 and 240	33.03 a A
240	32.01 b A	120 and 240	34.25 a A
Three applications	34.70 a		
No application	31.33 b		
CV (%)	7.45		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

Table 6 **-** Root volume (RSV – dm^3) of sugarcane plants in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times in single or sequential applications

Single application		Sequential application	
DAB[1/]	RSV (dm^3)	DAB	RSV (dm^3)
120	2.76 b A[2/]	120 and 200	2.00 c B
200	2.74 b A	200 and 240	2.55 bc A
240	2.77 b A	120 and 240	2.64 b A
Three applications	2.20 c		
No application	3.75 a		
CV (%)	22.01		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

Table 7 **-** Number of tillers (NTL) of sugarcane plants in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times in single or sequential applications

Single application		Sequential application	
DAB[1/]	NTL	DAB	NTL
120	12.25 b A[2/]	120 and 200	12.00 b A
200	14.00 ab A	200 and 240	15.00 a A
240	14.25 ab A	120 and 240	11.75 b A
Three applications	16.75 a		
No application	12.50 b		
CV (%)	22.66		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

Table 8 **-** Productivity (PROD – kg) per plot of sugarcane plants in cultivar RB86 7515 subject to the application of trinexapac-ethyl at three times in single or sequential applications

Single application		Sequential application	
DAB[1/]	PROD (kg per plot)	DAB	PROD (kg per plot)
120	60.51 b A[2/]	120 and 200	42.71 c B
200	43.49 c A	200 and 240	41.99 c A
240	64.09 b A	120 and 240	50.95 b A
Three applications	33.20 c		
No application	78.02 a		
CV (%)	25.95		

[1/] Days after bud burst. [2/] Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 5% probability.

trinexapac-ethyl reduced by about 30% the length and root surface area at the base of *Poa pratensis* tillers (Beasley et al., 2005). As for low light conditions, trinexapac-ethyl reduced the production of roots per tiller of *Agrostis stolonifera* cv. Penncross in a period of seven weeks (Goss et al., 2002). Conversely, Ervin & Koski (2001b) and Fagerness & Yelverton (2001) have found no influence of trinexapac-ethyl in the production of roots of *P. pratensis* and *A. stolonfera*, as well as McCarty et al. (2004) have found a 45% increase for *Cynodon dactylon*, unlike growth regulators paclobutrazol and flurprimidol, which reduced the roots production.

The single application of trinexapac-ethyl growth regulator promoted decrease in PROD of sugarcane for all times assessed in relation to the control, and the PROD was reduced to a greater extent with the application at the second time (200 DAE) and three product applications. Similar behavior was observed when two applications of the product were done, with all times assessed presenting lower yield than the one observed for the control without applying the regulator. When assessing the number of product applications within each time, it was found that, at 120 DAE, PROD was reduced with two sequential applications of trinexapac-ethyl; for the other times, there was no difference in the product application number (Table 2). Lozano & Leaden (2001), assessing trinexapac-ethyl on two wheat cultivars, have found opposite results, noting significant productivity gains (27%). Whereas sugarcane yield is measured by stem mass, an organ directly affected by the growth regulator, trinexapac-ethyl main effect is to reduce the distance between the nodes, and consequently the size of the plants.

Taking into account the logistics of planting sugarcane, the application of trinexapac-ethyl at 240 DAB could be viable, since a reduction in plant height was observed, without reducing the number of buds; in that, for a same volume of stems, there would have been a greater number of buds, thereby reducing the expenses with transportation for planting. Another important fact is that sugarcane plants with the most buds have a higher number of shoots (Christofoletti Jr., 2012).

It can be concluded that trinexapac-ethyl reduces height, root volume, the number and distance of buds and productivity of sugarcane. Sequential application (two or three times) increases the plants stem diameter, and three product applications also increase the number of tillers. Plant growth regulator applied at 240 DAB reduces plant height, but without changing the number of buds, showing potential for use in planting sugarcane.

ACKNOWLEDGMENT

To Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG; Research Support Foundation of the Brazilian State of Minas Gerais) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES; Coordination of Improvement of Higher Education), for the financial support and the scholarships awarded.

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