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Sub-doses of 2-chloroethylphosphonic acid in vegetative stages of corn cultivation[1]

Subdoses do ácido 2-cloroetilfosfônico em estádios vegetativos da cultura do milho

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Abstract - The use of ripeners has been common practice in sugarcane cultivation. The application of these products is often performed through aerial spraying, which increases the chances of molecules from the ripener drifting into other crops, such as corn. With the aim of studying possible phytointoxication in corn caused by ethephon drift, a field experiment was conducted in order to evaluate the effect of ripener sub-dosing when applied in the V4 and V8 development stages of corn cultivation. The experiment was set up in a randomized block design, with four replications. Treatments were arranged in a 2 x 5 factorial scheme, with first factor corresponding to the corn growth stages in which the ripener was applied (V4 and V8), and the second factor referred to the ethephon sub-doses (0; 14.26; 28.51; 42.77, and 57.02 g ha^{-1} a.i.). Visual phytotoxicity effects were not perceptible when sub-doses were applied in the V4 and V8 corn growth stages. Similarly, agronomic characteristics and grain yield were not altered by ethephon sub-doses of up to 57.02 g ha^{-1} a.i.
Keywords: simulated drift; ethephon; phytotoxicity; *Zea mays*

Resumo - O uso de maturadores tem sido prática comum na cultura da cana-de-açúcar. A aplicação destes produtos ocorre muitas vezes por meio de pulverização aérea, o que aumenta as chances de ocorrer deriva das moléculas do maturador em outras culturas, como o milho. Visando estudar possíveis fitointoxicações no milho ocasionadas por deriva de ethephon, foi realizado um experimento em campo com o objetivo de avaliar o efeito de subdoses do maturador quando aplicado nos estádios de desenvolvimento V4 e V8 da cultura do milho. O experimento foi instalado no delineamento com blocos casualizados, com quatro repetições. Os tratamentos foram arranjados em esquema fatorial 2 x 5, com primeiro fator correspondente aos estádios de desenvolvimento do milho em que foi aplicado o maturador (V4 e V8) e o segundo fator foi referente às subdoses de ethephon (0; 14,26; 28,51; 42,77 e 57,02 g ha^{-1} i.a.). Efeitos de fitotoxicidade visual não foram perceptíveis quando se aplicou as subdoses nos estádios V4 e V8 de desenvolvimento da cultura do milho. Da mesma forma, as características agronômicas e a

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produtividade de grãos não foram alterados por subdoses de até 57,02 g ha^{-1} i.a. de ethephon.
Palavras-chaves: deriva simulada; ethephon; fitotoxicidade; *Zea mays*

Introduction

The Brazilian Cerrado region is conducive to the cultivation of sugarcane (Silva et al., 2011a). From the industrial perspective, this environment entails some implications, such as the low accumulation of sucrose in periods of higher rainfall. In this sense, while the plants do not encounter growth limiting factors, such as water restriction, nutrients or cold, they do not boast a significant accumulation of sucrose. Therefore, chemical ripeners must be used to initiate the ripening process, in order to ensure a constant supply flow throughout the year (Caputo et al., 2008).

Ethephon, chloroethylphosphonic acid, is a growth regulator from the ethylene group and has been used to accelerate the ripening of sugarcane in order to enable proper handling at harvest (Agrofit, 2015). Sprayed in an aqueous solution, the ethephon is rapidly absorbed and transported inside the plant, slowly releasing the ethylene by means of a chemical reaction, enabling the hormone to exert its effects. An important characteristic of ethylene is its promotion of autocatalysis, a reaction triggered by the hormone itself, which results in the conversion of the 1-aminocycloproprane-1-carboxylic acid (ACC) to ethylene. The precursor of the ACC is the amino acid, methionine, and the ACC acts as an intermediary in the conversion of methionine into ethylene (Taiz and Zeiger, 2013).

Plants that received ethephon showed a decrease in the water and chlorophyll content of their leaves and a drop in respiratory rate, in addition to the inhibition of enzyme activity such as NADP-malic, invertase acid, nitrate reductase and amylase. However, peroxidase, polyphenol oxidase, neutral invertase and acid phosphatase showed greater activity (Li, 2004).

In certain cases, products such as ethephon are applied when the sugarcane is already established which prevents the use of land machinery and makes it necessary to spray these products through crop-dusters. Consequently, the use of ripeners in sugarcane has represented a risk to sensitive crops located in surrounding areas.

There have been several studies on ethephon, as ripener (Almeida et al., 2005; Meschede et al, 2009), flowering inhibitor (Araldi et al, 2010), in relation to sugarcane ratoon resprout and yield (Silva et al., 2010), the development and yield of sugarcane stalks (Leite et al., 2011), tillering and yield of ratoon cane (Silva et al., 2007), fruit ripening (Braz et al. , 2008; Silva et al, 2011b) and growth regulator (Zhang et al, 2014). However, studies on the effect caused by sub-doses of ethephon in corn crops and the description of phytotoxicity symptoms in the field have not yet been performed.

Phytotoxicity in corn cultivation, resulting from the application of sugarcane ripeners in adjacent plantations, has been reported empirically based on the observations of producers. In light of this, and the possibility of corn crop sensitivity to ethephon culture, our goal was to evaluate the effect of sub-doses of ethephon on corn cultivation when applied in the V4 and V8 growth stages.

Material and Methods

The experiment was set up and conducted at the farm of the Universidade Federal de Goiás (UFG) – Regional Jataí, located in the municipality of Jataí, GO. The geographical coordinates of the area are 17º 55' 37,3''S, 51º 43' 4,7''W, with altitude of 663 m. According to Köppen (1931) the climate is classified as Awa, tropical savanna, mesothermal, and well defined seasons, with rainy summers and dry winters, which allows for two annual high yield harvests in a soybean-corn rotation scheme.

According to INMET (2014), the region's mean maximum and minimum temperature, in the period from January to June 2014 was 23.4ºC and 21.8ºC, respectively, with total rainfall of approximately 796 mm (Figure 1).

The soil of the experimental area was classified as distropheric Red Latosol with a clayey texture. A sample of the soil was sent for chemical analysis of fertility in order to determine soil correction and fertilizer requirements (Table 1).

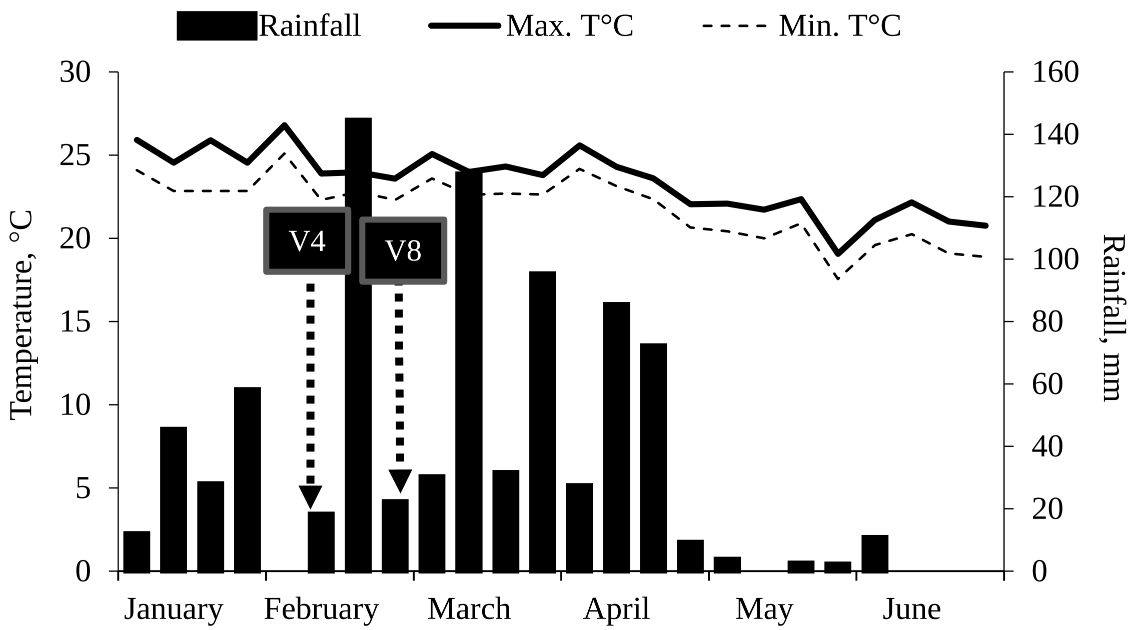

Figure 1. Climate data and V4 and V8 phenological stages of corn crops that received sub-doses of ethephon, from January to June 2014. Jataí (GO), 2014.

Table 1. Chemical analysis result for 0 to 20 cm surface soil sample from the experimental area. Jataí (GO), 2014.

pH	M.O.	P	H + Al	K	Ca	Mg	SB	CTC	V	$S\text{-}SO_4^{2-}$
	g dm^{-3}	mg dm^{-3}			$cmol_c$ dm^{-3}				%	mg dm^{-3}
4.7	40	4.82	4.54	0.12	1.75	0.31	2.18	6.72	32.4	8.6

pH in $CaCl_2$; P, K - Mehlich-1; Ca, Mg – KCl.

The experiment consisted of 10 treatments established in randomized block design with a 2 x 5 factorial arrangement, and four replications. The first factor corresponded to the application in the V4 and V8 corn growth stages and the second factor at ethephon doses of 0; 14.26; 28.51; 42.77; and 57.02 g ha^{-1} a.i., which corresponds to 0, 3, 6, 9 and 12% of the recommended ethephon dose as sugarcane ripener (475.2 g ha^{-1} a.i.).

Sowing of the corn was carried out on January 22, 2014 with fertilization of 500 kg ha^{-1} 08-20-18 + 0.3% Zn. Each experimental unit had 10 rows of the SYN 7G17 corn hybrid at length of 9 meters. Each experimental unit had 10 rows of the SYN 7G17 corn hybrid at length of 9 meters. The row spacing used was 0.45 m with an estimated population of 66,667 plants ha^{-1}. Nine days after sowing (DAS) the herbicides, atrazine and tembotrione, were applied to the total area by way of weed control. The topdressing was carried out at 24 DAS with 250 kg ha^{-1} of urea.

At 20 and 36 DAS when the corn plants had 4 (V4) and 8 (V8) fully expanded leaves, ethephon sub-doses were applied to 6 central rows of the plot leaving two rows on each side without application in order to serve as lateral reference for visual assessments. Products were applied using a CO_2 pressurized backpack sprayer equipped with 6 point bar DG 11002 flat jet plane, 0.50 m spacing, constant 2.8 bar pressure and spray volume equivalent to 200 L ha^{-1}. A plastic tarp was positioned alongside the spray area to avoid excess drift. At the 20 DAS application (11h08min to 12h00min), mean climate conditions were 32.5°C, 46% relative air humidity and 7.5 km h^{-1} wind speed. At the 36 DAS application, (09h26min to 10h35min) mean climate conditions were 35.5°C, 33.1% relative air humidity and 3.35 km h^{-1} wind speed.

Visual assessments were made of phytotoxicity effects based on the EWRC plant intoxication score (1964), which ranges from 1 to 9, whereby the lower value represents the absence of phytotoxicity and the highest value, the most extreme case, that is, plant death. Visual percentage scores (0 to 100%) were also attributed for delay in plant growth at 7, 14, 21, 28 and 42 days after application (DAA) with the lateral reference serving as visual assessment.

In growth stage R1 (flowering), we determined stalk diameter (SD), insertion height of first ear (EIH) and corn plant height (PH). SD was measured in millimeters using a digital pachymeter at the second internode from the soil surface. PH and EIH were measured with a topographic ruler, considering the distance between the soil surface and the insertion point of the corn plant and insertion of the first ear, respectively. All assessments were carried out randomly on 10 plants from each experimental unit.

In each experimental unit, three central rows of corn were collected at four meters length (useful area), totaling 5.4 m^2 of harvested area. Ten ears were separated randomly to determine the number of kernel rows per corn ear (NKR), number of kernels per row (KR) and ear length (EL). NKR and KR were obtained from a simple count. EL was determined using a tape to measure from the base of the ear as far as the kernel stretched. A digital pachymeter was used to measure ear diameter (ED) and cob diameter (CD) in the central region of the ear in millimeters and from the subtraction of the value between the ED and CD and the division of the sum by two, we arrived at the kernel size (KS).

Grain yield was obtained from the kernel mass, contained in the useful area of each experimental unit through weighing (expressed in kg ha^{-1}) and adjusted to 13% water content. To determine the mass of 1000 kernels, random counts of eight 100 kernel repetitions were performed (Brasil, 2009), whose masses were determined and adjusted to 13% water content, enabling the estimation of the 1000 kernel mass through the mean.

The data obtained was subjected to variance analysis through the F test and the quantitative data (ethephon sub-doses) submitted to regression analysis, both at 5% significance.

Results and Discussion

The development of the corn plants that received sub-doses of ethephon in the V4 and V8 stages of growth was not affected and there was no visual delay in plants 7, 14, 21, 28 and 42 days after application (DAA) and EWRC phytotoxicity scores were equal to 1 (without visual damage) for all evaluations.

Of the agronomic characteristics assessed, there was no statistical difference noted for ethephon application at the V4 and V8 stages of corn growth for EL, KS, NKR, KR, SD, EIH, PH, M1000 and GY (Table 2). Ethephon did not alter the agronomic characteristics or corn yield, regardless of the sub-dose used (Table 3).

Table 2. Means for ear length (EL), kernel size (KS), number of kernel rows per corn ear (NKR), number of kernels per row (KR), stalk diameter (SD), insertion height of first ear (EIH), plant height (PH), mass of 1000 kernels (M1000), and grain yield (GY), analyzed in relation to the application of ethephon doses in corn growth stages V4 and V8. Jataí (GO), 2014.

Stage	EL	KS	NKR	KR	SD	EIH	PH	M1000	GY
	cm	mm	-- units --		mm	----- m -----		g	kg ha^{-1}
V4	15.64	10.27	15.88	31.33	26.22	1.40	2.35	286.23	8033.71
V8	15.33	10.10	15.89	30.69	25.80	1.35	2.33	280.07	8043.06
F	3.69^{ns}	0.87^{ns}	0.00^{ns}	3.30^{ns}	0.77^{ns}	4.03^{ns}	0.59^{ns}	2.80^{ns}	0.00^{ns}
CV (%)	3.25	5.72	4.08	3.59	5.80	4.99	3.42	4.12	8.77

^{ns} Not significant by F Test with p<0.05; CV, Coefficient of variation.

Table 3. Means for ear length (EL), kernel size (KS), number of kernel rows per corn ear (NKR), number of kernels per row (KR), stalk diameter (SD), insertion height of first ear (EIH), plant height (PH), mass of 1000 kernels (M1000), and grain yield (GY), analyzed in relation to ethephon sub-doses. Jataí (GO), 2014.

Sub-doses	EL	KS	NKR	KR	SD	EIH	PH	M1000	GY
	cm	mm	-- units --		mm	----- m -----		g	kg ha^{-1}
0.00	15.77	10.77	15.98	31.05	26.14	1.43	2.37	285.50	7884.09
14.26	15.42	10.17	15.74	30.81	25.49	1.39	2.38	289.57	8223.84
28.51	15.39	9.97	15.78	31.08	25.74	1.35	2.34	285.32	8089.32
42.77	15.17	10.09	15.95	30.35	26.50	1.35	2.33	280.78	8077.40
57.02	15.68	9.94	15.98	31.76	26.18	1.35	2.29	274.58	7917.27
F	1.85^{ns}	2.68^{ns}	0.26^{ns}	1.70^{ns}	0.55^{ns}	1.93^{ns}	1.34^{ns}	1.92^{ns}	0.31^{ns}
CV (%)	3.25	5.72	4.08	3.59	5.80	4.99	3.42	4.12	8.77

^{ns} Not significant by F Test with p<0.05; CV, Coefficient of variation.

The corn plants subjected to ethephon sub-doses of up to 57.02 g ha^{-1} a.i. did not demonstrate differences in the evaluated parameters. It is possible that as ethephon is a phytoregulator that releases ethylene on entering into contact with plant tissue, sub-doses of this ripener are metabolized. Similar results were described by Pires et al. (2013) in eucalyptus plants subjected to ethephon drift simulation.

Almeida et al. (2005) assessed the effect of ethephon on sugarcane cultivation and did not note any significant differences in this ripener when compared to those witnessed for Pol%, fiber content and brix. The same authors, as well as Hida et al. (2009), attribute the main cause of a lack of response to the existence of conditions that promote the natural ripening of sugarcane, besides the time of year and application conditions. The fact that the corn crop had been in second harvest and the low rainfall (Figure 1) during the period of both applications may be mitigated the possible effects of ethephon sub-doses on the corn plants, since under drier conditions the effect some ripeners are minimized (Almeida et al. 2005).

Unlike the findings of this study, in which plant height and cob insertion height were not altered, Khosravi and Anderson (1991) attributed the application of ethephon to a reduction in these parameters, which improves the resistance of corn plants to lodging. On the other hand, the same authors report that this ripener can reduce grain mass and yield, especially in high dose applications.

Results found in work done on plant regulators for soybean and bean crops (Ngatia et al., 2003; Campos et al., 2009) show that the height of plants that received ethephon was similar or lower than the control treatment and did not render any benefit in the production of said plants. According to Shekoofa and Emam (2008), the application of ethephon in corn plants has better effects in enhancing the crop performance in conditions of water deficiency, although they emphasize that further studies need to be carried out.

In this study, we verified whether at the loss limit due to drift of up to 12% of the ethephon dose used as sugarcane ripener, the application of this product represented a risk to corn crop cultivation. However, little is known about drift potential via aerial spraying whereby product deposits may occur in doses above those studied which could result in damage to the affected crop.

Conclusions

The use of ethephon at sub-doses of up to 57.02 g ha^{-1} a.i. does not alter the growth and yield of corn when applied at the V4 and V8 crop development stages.

References

AGROFIT. Sistema de Agrotóxicos Fitossanitários. **Ethephon**. Disponível em: <http://extranet.agricultura.gov.br/agrofit_cons /principal_agrofit_cons>. Acesso em: 30 mar. 2015.

Almeida, J.C.V.; Leite, C.R.F.; Souza, J.R.P. Efeitos de maturadores nas características tecnológicas da cana-de-açúcar. **Semina: Ciências Agrárias**, v.26, n.4, p.441-448, 2005.

Araldi, R.; Silva, F.M.L.; Ono, E.O.; Rodrigues, J.D. Florescimento em cana-de-açúcar. **Ciência Rural**, v.40, n.3, p.694-702, 2010.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Regras para análise de sementes**. Brasília: MAPA/ACS, 2009. 399p.

Braz, V.B.; Nunes, E.S.; Vieira, G.; Ribeiro Júnior, J.I.; Bertini, L.A.; Couto, F.A.D. Indução do amadurecimento de mangas cv. Tommy Atkins e cv. Ubá pela aplicação de ethephon pós-colheita. **Bragantia**, v.67, n.1, p.225-232, 2008.

Campos, M.F.; Ono, E.O.; Rodrigues, J.D. Desenvolvimento da parte aérea de plantas de soja em função de reguladores vegetais. **Revista Ceres**, v.56, n.1, p.74-79, 2009.

Caputo, M.M.; Beauclair, E.G.F.; Silva, M.A.; Piedade, S.M.S. Resposta de genótipos de cana-de-açúcar à aplicação de indutores de maturação. **Bragantia**, v.67, n.1, p.15-23, 2008.

EUROPEAN WEED RESEARCH COUNCIL (EWRC). Methods in weeds research. **Weed Research**, Oxford, v.4, n.1, p.88, 1964.

Hida, J.N.T.; Silveira, J.C.F.; Segato, S.V. Efeito dos maturadores químicos na cultura da canade-açúcar (*Saccharum* spp). **Nucleus**, v.6, n.2, p.149-166, 2009.

INMET. Instituto Nacional de Meteorologia. **Dados Climatológicos**. Disponível em: <http://www.inmet.gov.br/>. Acesso em: 20 jun. 2014.

Khosravi, G.R.; Anderson, I.C. Growth, yield, and yield componentes of ethephon-treated corn. **Plant Growth Regulation**, v.10, n.1, p.27-36, 1991.

Köppen, W. **Climatologia con un studio de los climas de la Tierra**. Buenos Aires, 1931. 320p.

Leite, G.H.P.; Crusciol, C.A.C.; Silva, M.A. Desenvolvimento e produtividade da cana-de-açúcar após aplicação de reguladores vegetais em meio de safra. **Semina: Ciências Agrárias**, v.32, n.1, p.129-138, 2011.

Li, Y. Beneficial effect of ethephon application on sugarcane under sub-tropical climate in China. **Sugar Tech**, v.6, n.4, p.235-240, 2004.

Meschede, D.K.; Carbonari, C.A.; Velini, E.D. Ação de diferentes maturadores na produtividade e qualidade tecnológica da cana-de-açúcar. **Revista Brasileira de Herbicidas**, v.8, n.2, p.62-67, 2009.

Ngatia, T.M.; Shibairo, S.I.; Emongor, V.E.; Kimenju, J.W. Effects of ethefon on the growth, yield and yield components of beans (*Phaseolus vulgaris* L.). **Journal of Agricultural Science and Technology**, v.5, n.1, p.22-38. 2003.

Pires, R.N; Pereira, F.C.M.; Nepomuceno, M.P.; Alves, P.L.C.A. Effects of the simulated drift of ripeners on *Eucalyptus urograndis*. **Journal of Agricultural Science**, v.5, n.12, p.78-86, 2013.

Shekoofa, A.; Emam, Y. Plant growth regulator (ethephon) alters maize (*Zea mays* L.), water use and grain yield under water stress. **Journal of Agronomy**, v.7, n.1, p.41-48, 2008.

Silva, E.G.; Takata, W.H.S.; Almeida, G.V.B.; Evangelista, R.M.; Ono, E.O.; Rodrigues, J.D. Qualidade de frutos de pimentão em função de concentrações de ethephon durante o amadurecimento. **Revista Iberoamericana de Tecnologia Postcosecha**, v.12, n.2, p.199-205, 2011b.

Silva, M.A.; Cato, S.C.; Costa, A.G.F. Produtividade e qualidade tecnológica da soqueira de cana-de-açúcar submetida à aplicação de biorregulador e fertilizantes líquidos. **Ciência Rural**, v.40, n.4, p.774-780, 2010.

Silva, M.A.; Gava, G.J.C.; Caputo, M.M.; Pincelli, R.P. Jerônimo, E.M. Cruz, J.C.S. Uso de reguladores de crescimento como potencializadores do perfilhamento e da produtividade em cana soca. **Bragantia**, v.66, n.4, p.545-552, 2007.

Silva, S.D.; Pietrafesa, J.P.; Santos, A.E.A.F. O Cerrado e a produção sucroalcooleira: expansão e transferência histórico-geográfica da produção de etanol em Goiás. In: Pietrafesa, J.P.; Silva, S.D. (Orgs.). **Transformação do Cerrado**: progresso, consumo e natureza. Goiânia: Editora da PUC Goiás, 2011a, p.21-46.

Taiz, L.; Zeiger, E. **Fisiologia vegetal**. 5ed. Porto Alegre: Artmed, 2013. 918p.

Zhang, Q.; Zhang, L.; Evers, J.; Werf, W.V.; Zhang, W. Duan, L. Maize yield plant and quality in response to plant density and application of a novel plant growth regulator. **Field Crops Research**, v.164, n.4, p.82-89, 2014.