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Article

Selectivity of Metribuzin in Postemergence of Culture of Carrot

Seletividade do Metribuzin em Pós-Emergência para Cultura da Cenoura

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ABSTRACT - The initial slow growth and short stature of carrot can allow that weeds settle in crop areas, requiring the management of these plants for productivity not to decrease. Nevertheless, weeds control has been difficult because there are few herbicides available for weeds control in postemergence of carrots. Two experiments in the field were carried out to evaluate selectivity of metribuzin applied in postemergence of carrots. A experimental randomized block design was utilized with four repetitions. Treatments consisted of metribuzin doses (0, 144, 288, 432, 576, 720, 960 and 1,200 g ha^{-1}), applied in postemergence of carrots of the Nantes variety. Roots productivity was evaluated and percentage of commercial roots and no-commercial roots was calculated. Metribuzin has not caused visual symptoms of intoxication in carrots. Doses lower than 432 g ha^{-1} of metribuzin do not reduce the total productivity of roots, independent of the application period. Any doses of metribuzin changed the percentage of commercial and noncommercial roots. It is concluded that metribuzin is selective for carrots of the Nantes variety in postemergence applications at doses of 432 g ha^{-1}.

Keywords: *Daucus carota*, chemical control, herbicide.

RESUMO - O lento crescimento inicial da cenoura favorece o estabelecimento de plantas daninhas nas áreas de cultivo, sendo necessário o manejo dessas plantas para que não ocorra redução da produtividade. Todavia, o controle tem sido dificultado por existirem poucas opções de herbicidas para o controle de plantas daninhas em pós-emergência da cultura. Dois experimentos de campo foram realizados para avaliar a seletividade do metribuzin aplicado em pós-emergência da cenoura, em dois diferentes períodos de cultivo (inverno e inverno-verão). O delineamento experimental foi o de blocos casualizados com quatro repetições. Os tratamentos corresponderam à aplicação de 0, 144, 288, 432, 576, 720, 960 e 1.200 g ha^{-1} do metribuzin na cultura da cenoura, cultivar Nantes. Foram avaliadas a produtividade total de raízes e a porcentagem de raízes comerciais e não comerciais. A produtividade total de raízes de cenoura não foi alterada pela aplicação de metribuzin até a dose de 432 g ha^{-1}, independentemente da época de cultivo. A porcentagem de cenouras comercializáveis e descartáveis não foi alterada pelas doses do herbicida. Conclui-se que o metribuzin é seletivo para aplicação em pós-emergência da cenoura, cultivar Nantes, até a dose de 432 g ha^{-1}.

Palavras-chave: *Daucus carota*, controle químico, herbicida.

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INTRODUCTION

Carrots (*Daucus carota*) production systems encompass high fertilization, intensive soil preparation and constant water supply. This system favors the establishment of weeds, which, when incorrectly handled, can reduce root productivity and quality, since carrots present slow initial growth and low competitive capacity in relation to these plants (Teófilo et al., 2009; Sasnauskas et al., 2012).

The most widely used method for weed control in large-scale carrot crops has been the application of herbicides (Konieczka et al., 2009; Sasnauskas et al., 2012) and linuron is the main product recommended (Jensen et al., 2004). However, this herbicide has not shown good control of some weed species, which has encouraged producers to seek new alternatives, such as metribuzin, which has a broader range of action.

Metribuzin belongs to the chemical group of triazinones and has as mechanism of action the inhibition of photosystemII (PPDB, 2015). Although not registered in Brazil for carrot culture, metribuzin is widely used in other countries, such as the United States and Portugal. In the United States it is recommended in the dose of 250 g a.i. ha^{-1} in the stage of five to six carrot leaves (USDA, 2015) and in Portugal of 150 g a.i. ha^{-1} in the stage of three leaves (BAYER, 2016).

Metribuzin doses must vary according to the soil type and pH (Oukali-Haouchine et al., 2015), as well as the temperature, which increases the degradation of this molecule (Zhang et al., 2014) and the cultivars tolerance (Jensen et al., 2004). In addition, the time of application of the herbicide may vary according to the stage of the plant. These two variables (dose and time of application) are crucial for the presence or absence of intoxication (Jensen et al., 2004, 2006; Golian et al., 2014). Poisoning caused by metribuzin has been reported mainly when applied in postemergence of the crop and in stages of less than five leaves (Jensen et al., 2004). However, little is known about metribuzin selectivity in carrot grown in tropical environments.

Selectivity is understood as the ability of a herbicidal molecule to kill or slow plant growth of one or more species and, at the same time, not to harm other plants of commercial interest (Azania and Azania, 2014). Selectivity should not be determined solely by observing the presence or absence of intoxication symptoms as there are examples of herbicides that may reduce the species productivity even without causing detectable intoxication through visual analysis (Silva, 2003).

Information on carrot postemergence metribuzin selectivity may contribute to greater weed control efficiency in crops. Thus, metribuzin selectivity was evaluated in two seasons (winter and winter-summer) when applied in postemergence of carrot cultivation.

MATERIALS AND METHODS

The experiments were carried out from May to September (Brazilian winter) and from July to October 2015 (Brazilian winter-summer transition) at the Experimental Station of COOPADAP [Cooperativa Agropecuária do Alto Paranaíba (Agriculture and Livestock Cooperative of the Alto Paranaíba)] in the Brazilian city of Rio Paranaíba, MG. The experimental area soil was classified as Distroferric Red Latosol of clayey texture with: pH (water) of 6.0; organic matter content of 2.4 dag kg^{-1}; P of 13.90; K of 1 (mg dm^{-3}); Ca of 3,6; Mg of 1.0; Al of 0.0; H + Al of 3.5; and $CTC_{effective}$ of 8.4 ($cmol_c$ dm^{-3}). Sowing fertilization consisted of 80, 600 and 200 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. At 25 and 55 days after emergence the area was fertilized with 80, 80 and 467 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Climate data collected in the experimental area during the research are presented in Figure 1.

The carrot cultivar was Nantes, conducted in the final population of 550,000 ha^{-1} after thinning at 20 days after emergence. The experimental plots consisted of four double rows of carrots, totaling 5 m^2.

The experimental design used was in randomized blocks with eight treatments (0, 144, 288, 432, 576, 720, 960 and 1,200 g ha^{-1} of metribuzin) and four replications. Treatments were applied when carrot plants were in the stage of three fully expanded leaves. The application was carried out with a knapsack sprayer pressurized with CO_2 at 28 lbf pol^{-2}, equipped with 110.02 “fan-” type spraying nozzles tips and a spray mix volume equivalent to 200 L ha^{-1}.

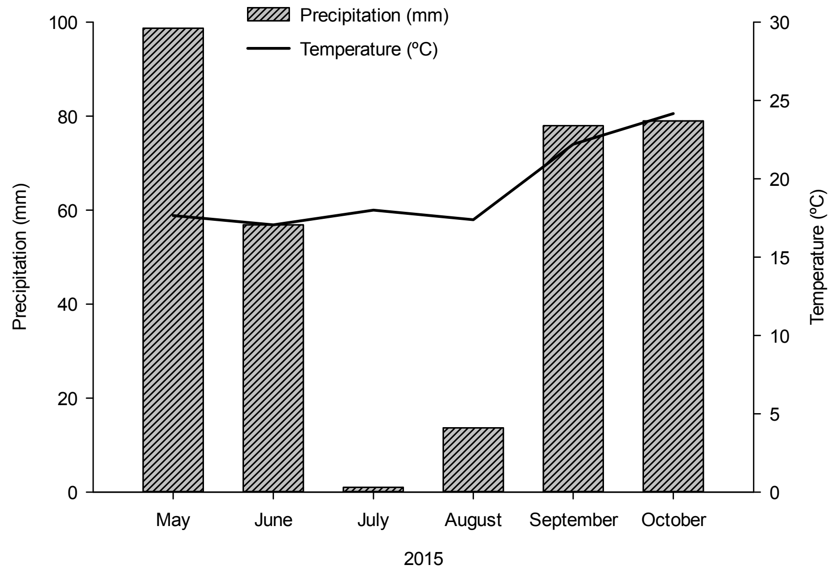


Figure 1 **-** Rainfall and average monthly temperatures during the period when the experiments were carried out.

In the whole experimental area 675 g ha^{-1} of linuron were applied in preemergence and, when necessary, manual weeding was performed in order to maintain a weed-free area. Thus, the effects found in this study came only from the effects of metribuzin doses on carrot plants, since there was no competition with weeds.

Visual assessments of intoxication were carried out throughout the cycle but symptoms were not observed. At 120 days after sowing, carrot roots contained in the floor area were collected (3 m^2 central) to obtain yield of commercial carrot roots (22-14 cm of length) and noncommercial (< 10 cm and/or with the presence of defects) (CEAGESP, 2016) and total productivity, which corresponded to the sum of the previous ones.

The data were submitted to the Cochran's and Bartlett's and Shapiro-Wilk tests to test homoscedasticity and normality. Subsequently, they were submitted to analysis of variance by the F test ($p < 0.05$). The choice was for the use of the standard error to compare the means of treatments within each experiment.

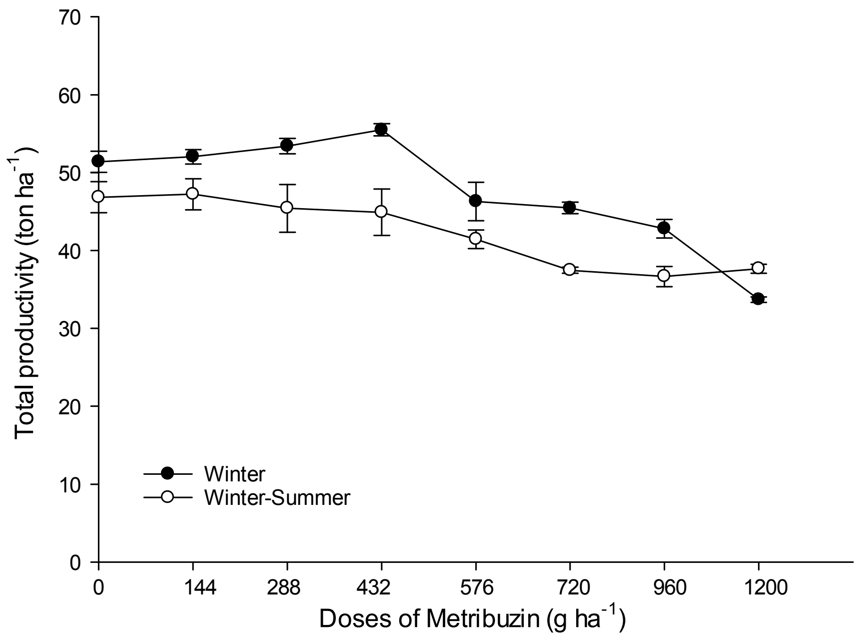
RESULTS AND DISCUSSION

The use of metribuzin up to the dose of 1,200 g ha^{-1} has not caused visual symptoms of carrot poisoning, regardless of the growing season. Studies have shown that tolerance to metribuzin may vary with genotypes cultivated and with edaphoclimatic conditions (Bellinder et al., 1997; Jensen et al., 2004). Possibly, cultivar Nantes is tolerant to the tested doses of the herbicide.

Carrot roots total yield was not altered by the application of metribuzin up to the dose of 432 g ha^{-1} regardless of the time at which the experiment was performed (Figure 2). In the other doses, carrot total productivity was reduced. In the winter experiment, the greatest reduction occurred with the highest dose (1,200 g a.i. ha^{-1}) while in the winter-summer transition experiment the lowest yields were observed in the doses of 720, 960 and 1,200 g a.i. ha^{-1}.

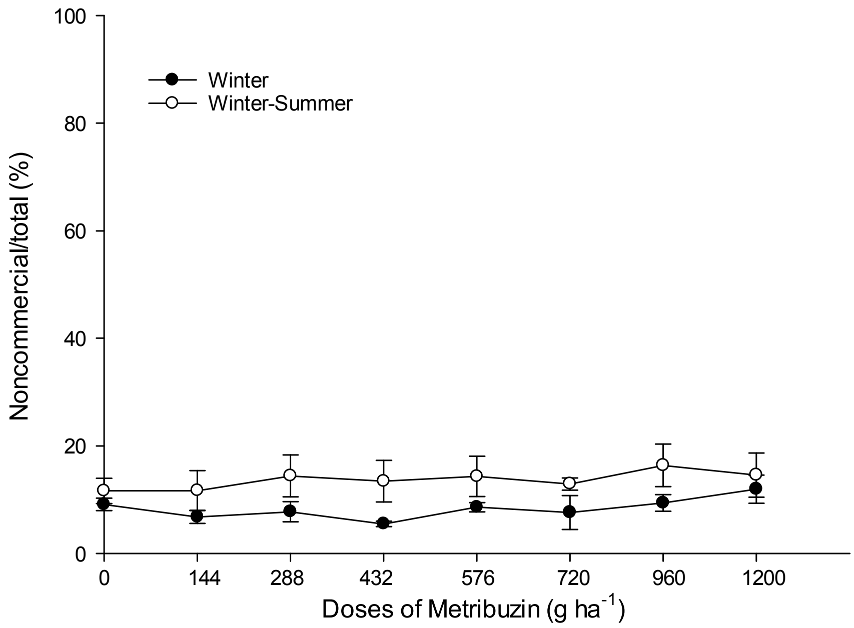
Tolerance observed up to the dose of 432 g ha^{-1} may be due to the metribuzin detoxification mechanism by â-D-(N-glycoside) during the seedlings initial stages (Smith et al., 1989). In turn, there is a conjugation of the herbicidal molecule with UDP-glucose through the enzyme glycosyl transferase or with GHS by the enzyme glutathione S-transferases (GSTs) (Anzalone, 2010), which are substrates for conversion into non-phytotoxic peptide conjugates (Owen, 1991). Possibly increased doses of the herbicide have caused greater absorption of metribuzin by carrots, which may have exceeded the plant inherent capacity to metabolize the herbicide.

Carrot producers in the region of Brazilian river Paranaíba suspected that the use of metribuzin increased the amount of disposable (noncommercial) carrots. However, in this study the percentage of disposable roots in relation to total productivity was not altered, regardless of the metribuzin dose and the planting season (Figure 3).



The vertical bar at each point represents the standard error of the mean.

Figure 2 **-** Total yield of carrot roots according to the application of doses of metribuzin (0, 144, 288, 432, 576, 720, 960, and 1,200 g ha^{-1}) in two harvests in the Brazilian city of Rio Paranaíba, MG, 2015.

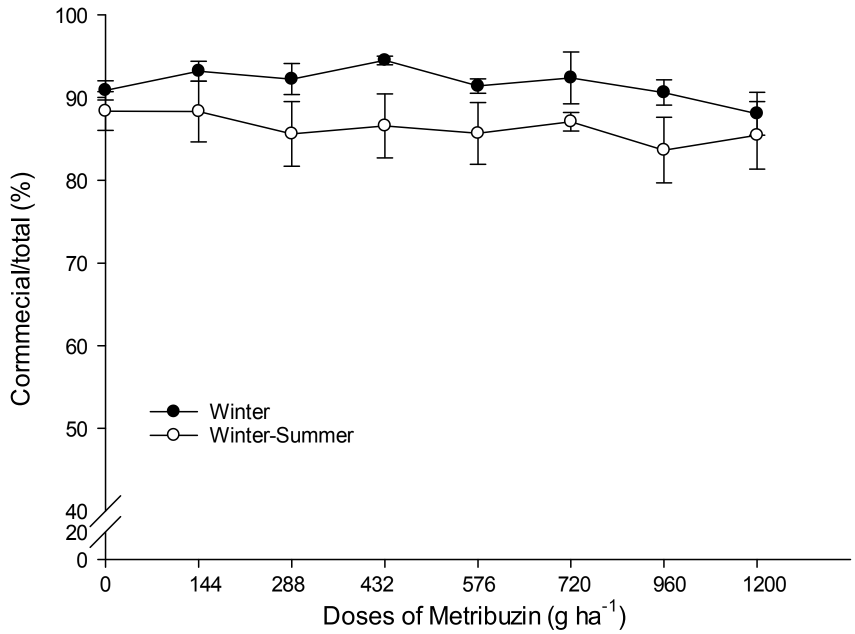


The vertical bar at each point represents the standard error of the mean.

Figure 3 **-** Percentage of nonmarketable carrots in relation to total productivity according to the application of doses of metribuzin (0, 144, 288, 432, 576, 720, 960, and 1,200 g ha^{-1}) in two harvests in the Brazilian city of Rio Paranaíba, MG, 2015.

Although there was no variation in the percentage of nonmarketable roots among treatments, there was a higher percentage of disposable carrots in the experiment conducted in the winter-summer transition compared to the winter. Cultivar Nantes, used in this study, is more demanding in mild temperatures, of less than 25 °C, presenting in this condition greater number of marketable roots, which are cylindrical, with excellent color quality, texture and shape (Finger et al., 2005). As planting progresses to the summer, total and commercial productivity decreases, being very low in the summer (Luz et al., 2009), demonstrating the lower adaptation of this cultivar to this growing season (Carvalho et al., 2003; Luz et al., 2009).

The percentage of marketable carrots did not change with the use of metribuzin, regardless of the dose and planting time (Figure 4). Average values of marketable carrots were 91.67% and 86.35% in the winter experiment and winter-spring transition, respectively. These values are within those observed by other authors in studies with carrots, such as that by Luz et al. (2009) with cultivar Nantes planted in autumn-winter, which presented total productivity of 30.70 ton ha^{-1} and marketable carrots yield of 74%.



The vertical bar at each point represents the standard error of the mean.

Figure 4 **-** Percentage of marketable carrots in relation to total productivity according to the application of doses of metribuzin (0, 144, 288, 432, 576, 720, 960, and 1,200 g ha^{-1}) in two harvests in the Brazilian city of Rio Paranaíba, MG, 2015.

According to Kempen (1989) and Bellinder et al. (1997), the greater carrot development may alter its tolerance to metribuzin and tolerance tends to increase in more advanced stages. This information corroborates the recommended doses of metribuzin in Portugal (150 g ha^{-1}) for applications in the stage of two to three leaves (BAYER, 2016) and in the United States (280 g ha^{-1}) with five to six leaves (USDA, 2016). In the present study, metribuzin was applied at the vegetative stage of three fully expanded leaves and selectivity, based on total productivity, was verified up to the dose of 432 g ha^{-1}.

In Brazil, in high altitude regions, carrots can be grown during all seasons, which causes changes in mean temperature, air humidity, precipitation intensity and cultivars used. These aspects may change carrot tolerance to metribuzin. Milder temperatures may increase tolerance to metribuzin in carrot crops, bearing higher doses than recommended (Phatak and Stephenson, 1973; Al-Khatib etal., 1997). As for selectivity, it is variable with the cultivars (Jensen et al., 2004).

Metribuzin is selective up to the dose of 432 g ha^{-1} when applied in postemergence of the Nantes carrot cultivar, regardless of the planting time. Higher doses reduce the crop commercial yield but without changing the percentage of commercial and noncommercial roots.

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