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Use of metribuzin, associated with different foliar fertilizers, on carrot crops

Uso de la metribuzina, asociado con diferentes fertilizantes foliares, en cultivos de zanahoria

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Forked carrots by herbicide intoxication.

Photo: G. Soares da Silva

ABSTRACT

This study aimed to evaluate the use of different foliar fertilizers, associated or not associated with metribuzin, in terms of carrot yield. The experiments were carried out over two crop years with treatments in a 2×4 factorial scheme. The first factor was the absence or presence of metribuzin (0 and 288 g ha^{-1} a.i.) and the second factor was the foliar fertilizers: FertiG, FertiB, sucrose and no application. In crop year 1, the commercial yield increased with FertiG with metribuzin, and the forked/total discard ratio decreased when the foliar fertilizers were applied together with metribuzin. The isolated metribuzin decreased the total yield and the commercial/total yield ratio in crop year 1; however, the stress was attenuated when FertiG was applied. In crop year 2, the metribuzin, isolated or associated with FertiG, increased the commercial yield. The FertiB decreased the forked/total discard ratio. The metribuzin, isolated or associated with FertiG, and FertiB obtained similar results for the commercial/total yield ratio in crop year 2. FertiG satisfactorily attenuated the stress caused by metribuzin in the carrot plants, with a positive effect on the commercial yield of the carrot crop.

Additional key words: *Daucus carota*, herbicide, commercial yield, safener.

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RESUMEN

El objetivo del estudio evaluó el uso de diferentes fertilizantes foliares asociados, y no asociados con metribuzina, sobre la productividad de zanahoria. Los experimentos se realizaron en dos ciclos de cultivo con un arreglo factorial 2×4 de los tratamientos. El primer factor fue la ausencia y presencia de la metribuzina (0 y 288 g ha^{-1} i.a.) y el segundo factor fueron los fertilizantes foliares: FertiG, FertiB, sacarosa y sin aplicación. En el primer ciclo de producción, la productividad comercial aumentó en la asociación de FertiG y metribuzina, la relación bifurcación/descarte total disminuyó cuando se aplica los fertilizantes foliares junto con la metribuzina. La metribuzina sola disminuyó la productividad total y la relación producción comercial/rendimiento total en el primer ciclo, sin embargo el estrés se mitigó cuando se aplicó FertiG. En el segundo ciclo, la metribuzina sola o asociada a FertiG aumentó la productividad comercial. El FertiB disminuyó la relación bifurcación/descarte total. La metribuzina sola o asociada con FertiG y FertiB obtuvieron resultados similares en la relación producción comercial/rendimiento total en el ciclo 2. FertiG atenúa satisfactoriamente el estrés causado por la metribuzina a las plantas de zanahoria con un impacto positivo en la productividad comercial del cultivo de zanahoria.

Palabras clave adicionales: *Daucus carota*, herbicida, productividad comercial, protector.

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INTRODUCTION

Carrot is one of the principal plants cultivated in Brazil and its cultivation is characterized by high soil disturbance, high nutritional demand and constant supply of water. These factors contribute to the high incidence of weeds, which, when mismanaged, can cause quantitative and qualitative losses of the product (Coelho *et al*., 2009) and become one of the limiting factors for yield (Reis *et al*., 2016). Therefore, it is necessary to adopt strategies for weed control.

The use of herbicides is the most used weed control method in carrot crops since it is has a lower cost and greater efficiency (Silva *et al*., 2012). Currently, there are seven herbicides used for the cultivation of carrots in Brazil, with linuron being the most selective product used to control for dicotyledonous (Agrofit, 2017). Because of the reduced number of herbicides used in carrot cultivation and the low residual effect of linuron in soil, metribuzin may be an alternative, exerting greater control over weeds.

Metribuzin belongs to the chemical group of triazinones and uses an action mechanism that inhibits the electron flow in photosystem II (Silva *et al*., 2007; Vidal *et al*., 2014). This herbicide is registered for the control of mocot and dicot weeds in many crops such as potato, tomato, wheat, coffee and sugarcane (Agrofit, 2017). Even without registration in carrot crops, metribuzin has shown a potential for use in commercial crops because of a greater spectrum of action of the product in relation to linuron. However, it is believed that this herbicide can cause toxicity carrot plants, especially when applied in post-emergence.

Some products used as plant growth stimulators, known as biostimulants, may also act to reduce herbicide toxicity in plants, including foliar fertilizers containing amino acids and organic acids - fulvic and humic. The response of the cultivated species to these products is influenced by the genetic material cultivated, composition of the product, application time and dose, abiotic stresses - application of herbicides, as well as by edaphoclimatic characteristics (Silva, 2015). However, information on the carrot response to these products is scarce, which has hindered their use in this crop.

The use of foliar fertilizers may be an alternative for the reduction of the toxicity of pesticides in cultivated species such as carrots. The aim of this study was to evaluate the use of different foliar fertilizers, associated or not associated with the herbicide metribuzin, in terms of carrot yield.

MATERIALS AND METHODS

The experiments were carried out in an experimental area located in the city of Rio Paranaíba, Minas Gerais at 19°14'59.6" S and 46°13'14.4" W. The first experiment occurred during the months of August to December, 2014 (crop 1), and the second experiment was conducted from October, 2014 to February, 2015 (crop 2). The temperature and rainfall averages for the first and second crop were 22.72 and 23.36°C, 157.6 and 244.6 mm, respectively (Fig. 1).

The soil of the experimental area is classified as red-yellow Latosol, with a clayey texture. Based on the results of the soil chemical and physical analysis (Tab. 1), the fertilizer application was done with 80 kg ha^{-1} of N, 600 kg ha^{-1} of P_2O_5 and 200 kg ha^{-1} of K_2O. The cover fertilization was done in two applications: the first one used 28.5 kg ha^{-1} of N, 6 kg ha^{-1} of P_2O_5 and 28.5 kg ha^{-1} of K_2O, and the second experiment used the same composition, but was increased by 78 kg ha^{-1} of K_2O. The carrot cultivars included Nayarit (crop 1), from the Nantes group, adapted to mild temperatures, and Verano (crop 2), from the Alvorada group, adapted to higher temperatures.

The two experiments used a randomized block experiment design with four replications. The treatments were arranged in a 2×4 factorial scheme; the first factor corresponding to the absence or presence of the herbicide metribuzin (0 and 288 g ha^{-1} a.i.) and the second factor to the foliar fertilizers in their respective doses: FertiG (1 L ha^{-1}), FertiB (1 L ha^{-1}), sucrose (1% vol/vol) and no application.

The commercial foliar fertilizers used were Fertiactyl® GZ (13% N, 5% K_2O and 5% total organic carbon) and Liqui-Plex Bonder (1% N, 2% P_2O5, 1% K_2O, 8.25% organic carbon and 8% amino acid additives), referred to as FertiG and FertiB, respectively.

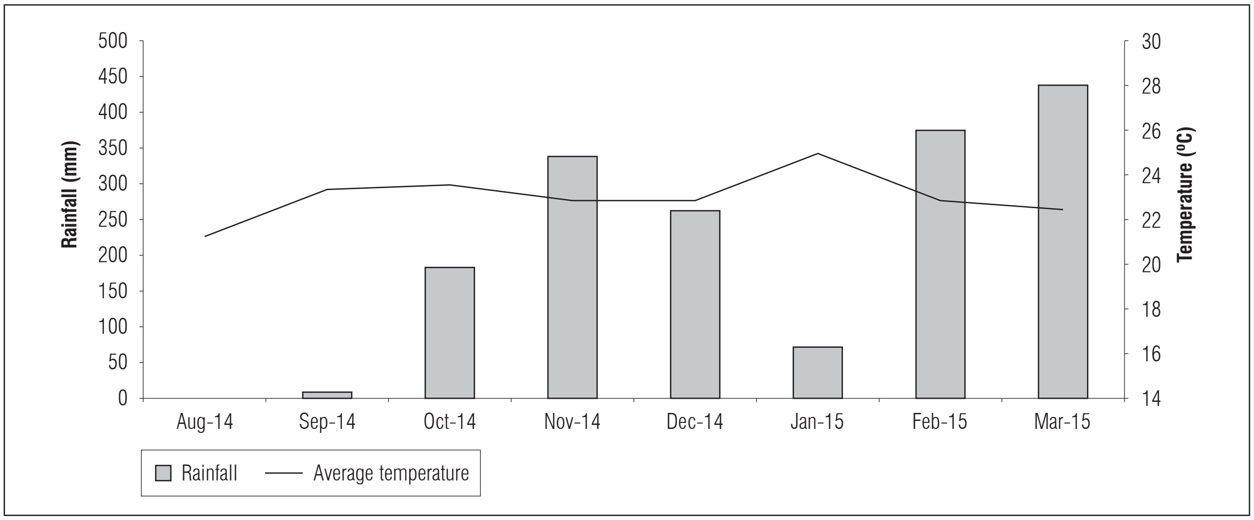

Figure 1. Rainfall and average temperature from August, 2014 to March, 2015.

Table 1. Physical and chemical attributes of the soil of the experimental area.

pH	P	K	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	t	T	MO	P-rem
	mg dm^{-3}		cmol$_c$ dm^{-3}						dag kg^{-1}	mg L^{-1}
6.30	8.20	58.00	4.70	1.00	0.00	2.60	5.85	8.45	2.40	15.60
Sand				Silt			Clay			
%										
21				17			62			

Extractors: pH - H_2O; P and K - Mehlich 1; Ca, Mg, Al - KCl 1 mol L^{-1}; H+Al - $Ca(OAc)_2$ 0,5 mol L^{-1}; t – CTC effective; T – CTC to pH 7.0; MO – organic matter.

The experimental plots corresponded to four double rows of carrots, 5 m in length, with each double row spaced 0.20 m from each other and 0.07 m between each constituent line of the double line, totaling 5 m^2. The useful area consisted of the two central double lines, excluding 1 m at each edge of the plot, for 3 m^2. The plant population per hectare was 550,000, obtained after manual thinning that was done 20 days after emergence of the crop. In order to maintain the weed-free area at the beginning of the crop growth, 675 g ha^{-1} a.i. of linuron was applied at pre-emergence, and manual weeding was done when necessary.

The treatments were applied when the carrot plants had three completely expanded leaves. When the treatment consisted of the association of the foliar fertilizer with the herbicide, a tank mixture was made. The application was carried out with a CO_2 pressurized sprayer with 200 kPa, equipped with a bar with two nozzles 11002 spaced at 50 cm, at a height of approximately 50 cm with respect to the plant.

At 110 d after planting (DAP), the plants contained in the useful area of each plot were harvested and root classification was performed (Ceagesp, 2015). The roots were classified by commercial class (between 10 to 26 cm in length): forked, discard and total discard (forked + discard). The sum of all classes was subsequently calculated, resulting in total yield. The commercial/total yield ratio was calculated by dividing the commercial class value by the total yield, multiplied by 100 ([commercial/total yield] × 100), and the forked/total discard ratio was calculated by dividing the value of the forked class by the total discard, multiplied by 100 ([forked/total discard] × 100).

The data of each harvest were submitted to analysis of variance by the F test ($P \leq 0.05$) and the means were compared by the Tukey test ($P \leq 0.05$). The statistical software Sisvar 5.6 was used.

RESULTS AND DISCUSSION

The foliar fertilizers did not increase the commercial yield of the carrots when isolated in crop 1, indicating that, when metribuzin is absent, they are not necessary. In the presence of metribuzin, the commercial yield of the carrots in crop 1 was 24% higher when associated with FertiG, as compared to the treatment without an application of foliar fertilizers. The application of FertiG with metribuzin increased the yield of the commercial carrots by 20.5%, as compared to the isolated fertilizer. Conversely, the herbicide application caused a reduction in the commercial yield when associated with FertiB and without a fertilizer (Tab. 2). Although visual symptoms of plant toxicity were not observed in the field, there was a reduction in the commercial yield in these cases, not affecting the aerial part, but damaging the root system.

In crop 2, only FertiG increased the commercial yield isolated, providing similar results when associated with metribuzin (Tab. 2). Bezerra *et al*. (2007), when evaluating lettuce development under the effect of two commercial leaf fertilizers (Fertiactyl GZ® and Ruter AA), observed an increase in root length by 26.2%. Blat *et al*. (2010) did not verify the yield response of potato tubers with Stimulate® applications under different application modes.

Table 2. Commercial yield of carrot roots (t ha^{-1}) after applications of different foliar fertilizers, associated or not associated with metribuzin, in crops from August to December, 2014 (crop 1) and from October, 2014 to February, 2015 (crop 2).

Foliar fertilizer	Metribuzin (g ha^{-1})			
	Crop 1		Crop 2	
	0	288	0	288
FertiB[2]	33.0 Aa[1]	28.4 Bb	17.9 Ac	20.8 Ab
FertiG[3]	31.9 Ba	40.1 Aa	29.3 Aa	30.1 Aa
Sucrose[4]	32.2 Aa	31.5 Ab	12.9 Ad	9.2 Bc
No application	34.9 Aa	30.5 Bb	24.5 Bb	28.6 Aa
CV (%)	5.44		9.24	

[1] Means followed by the same capital letter in a row within each crop are conclusive according to the F test and averages followed by the same lowercase letter in a column within each crop do not differ according to the Tukey test ($P \leq 0.05$); [2] FertiB - 1.0% N, 2.0% P_2O_5, 1.0% K_2O, 8.25% organic carbon and 8.0% amino acid additives; [3] FertiG - 13.0% N, 5.0% K_2O and 5.0% organic carbon total; [4] Sucrose - 1% (vol/vol).

The Isolated leaf fertilizers did not increase the commercial/total yield ratio. When FertiB was applied with metribuzin, the commercial/total yield ratio decreased; however, it increased when FertiG was applied with the herbicide in crop 1. The increase was 15.44% for the FertiG and metribuzin association, as compared to the non-application of the herbicide, 9.79% higher than the non-application of the leaf fertilizer (Tab. 3).

In contrast, in the second crop, FertiB with the herbicide increased the commercial/total yield ratio. The use of metribuzin at the dose of 288 g ha^{-1}, associated with sucrose, decreased this ratio by 26.3%. In the commercial/total yield ratio, the presence of metribuzin applied alone did not influence crop 1 as it did crop 2. However, with the presence of the FertiG foliar fertilizer, there were increases in crop 1 (Tab. 3).

The use of foliar fertilizers in association with the herbicide, FertiB in crop 1 and sucrose in crop 2, reduced or even did not change the yield in some cases (Tabs. 2 and 3). In a study using a sucrose solution in order to minimize the effects of metribuzin on carrot crops, Carneiro (2016) also observed that there was no increase in the yield of commercial carrots when sucrose was used. The use of these substances in combination with metribuzin may favor incompatibility, interfering with the efficacy. Other cases of problems with tank mixing herbicides and foliar fertilizers have been reported; their use is effective, but precautions should be taken (Gazziero, 2015).

The application of FertiG and sucrose together with metribuzin in crop 1 reduced the forked/total discard ratio (Tab. 4). A higher ratio of carrots in forked/total discard was observed when only metribuzin was

Table 3. Commercial/total yield ratio (%) after applications of different foliar fertilizers, associated or not associated with metribuzin, in crops from August to December, 2014 (crop 1) and from October, 2014 to February, 2015 (crop 2).

Treatment	Metribuzin (g ha^{-1})			
	Crop 1		Crop 2	
	0	288	0	288
FertiB[2]	59.5 Ab[1]	55.1 Bc	41.4 Bb	47.8 Aa
FertiG[3]	58.9 Bb	74.3 Aa	60.9 Aa	55.2 Aa
Sucrose[4]	61.2 Aab	63.0 Ab	34.9 Ab	24.5 Bb
No application	64.9 Aa	64.6 Ab	52.5 Aa	50.8 Aa
CV (%)	3.42		13.15	

[1] Means followed by the same capital letter in a row within each crop are conclusive according to the F test and averages followed by the same lowercase letter in a column within each crop do not differ according to the Tukey test ($P \leq 0.05$); [2] FertiB - 1.0 % N, 2.0% P_2O_5, 1.0% K_2O, 8.25% organic carbon and 8.0% amino acid additives; [3] FertiG - 13.0% N, 5.0% K_2O and 5.0% organic carbon total; [4] Sucrose - 1% (vol/vol).

Table 4. Forked/total discard ratio (%) after application of different foliar fertilizers, associated or not associated with metribuzin, in crops from August to December, 2014 (crop 1) and from October, 2014 to February, 2015 (crop 2).

Treatment	Metribuzin (g ha^{-1})			
	Crop 1		Crop 2	
	0	288	0	288
FertiB[2]	6.1 Bc[1]	14.8 Ab	24.5 Ab	22.0 Ab
FertiG[3]	18.9 Aa	11.6 Bc	30.1 Bb	49.6 Aa
Sucrose[4]	12.6 Ab	7.5 Bd	48.5 Aa	49.3 Aa
No application	7.8 Bc	18.4 Aa	36.4 Aab	43.8 Aa
CV (%)	9.32		16.24	

[1] Means followed by the same capital letter in a row within each crop are conclusive according to the F test and averages followed by the same lowercase letter in a column within each crop do not differ according to the Tukey test ($P \leq 0.05$); [2] FertiB - 1.0 % N, 2.0% P_2O_5, 1.0% K_2O, 8.25% organic carbon and 8.0% amino acid additives; [3] FertiG - 13.0% N, 5.0% K_2O and 5.0% organic carbon total; [4] Sucrose - 1% (vol/vol).

applied. This result confirms the suspicion of carrot farmers from Alto Paranaíba in the Minas Gerais region, who attributed a fork increase in carrots to the use of metribuzin.

In crop 2, the treatment with FertiG increased the forked/total discard ratio in the presence of metribuzin, as compared to the absence of metribuzin (Tab. 4). When metribuzin was applied, FertiB minimized the percentage of forked carrots, reducing the forked/total discard ratio by 21.8% in relation to the other treatments.

Metribuzin reduced the commercial yield (Tab. 2) and increased the forked/total discard ratio (Tab. 4) of the carrots in crop 1 when there was no application of the foliar fertilizers; however, it did not affect the development of the crop in the second harvest. Thus, it can be inferred that metribuzin may be more toxic to carrots in crops with low temperatures according to the genotype.

However, differential tolerance to metribuzin may occur according to cultivated genotypes and edaphoclimatic conditions (Jensen *et al*., 2004). In situations with higher air temperatures and light incidence, plant metabolism is more active and, consequently, there is greater photosynthetic activity in the plants. Similarly, in mild temperatures, the metabolism of plants is slower, with greater difficulty detoxifying herbicidal molecules. However, at high temperatures, there is a greater input of metabolites, such as sucrose (Bita and Gerats, 2013; Li *et al*., 2012), and plants recover more quickly from stress caused by metribuzin, which is inactivated by conjugation with sucrose, which is involved in the elimination of reactive oxygen species (Sugio *et al*., 2009; Lang-Mladek *et al*., 2010) through the oxidative pathway pentose-phosphate (Couée *et al*., 2006).

In addition, it was observed that the associated use of the foliar fertilizer FertiB or FertiG with the herbicide provided gains in yield (Tab. 2), indicating that the use of foliar fertilizers could possibly attenuate the stress caused by metribuzin. It is known that temperature influences plant metabolism, and different climatic conditions can modify the reaction of carrot plants to the application of biostimulants (Grabowska *et al*., 2012).

Climatic factors should be taken into account for the interpretation of results, according to the gentotypes used. The use of fertilizers, such as FertiG, had an action on the carrot plants at mild temperatures, where the stress caused by the herbicide was attenuated. The same did not occur in crop 2 because of the higher temperatures with thermal stress in January (Fig. 1); the foliar fertilizers did not act in the metribuzin detoxification, where the plant metabolic capacity was more active. In studies on tomato, Sousa (2016) observed that the application of micronutrients, alone or in combination with plant regulators, acted as a protector against stress in tomatoes, as they showed higher activities of antioxidant enzymes at the end of the cycle and improved the yield and the quality of the fruits produced.

The applied foliar fertilizers are used directly by plants in the synthesis of proteins, with a consequent accumulation of metabolic energy used to cope with adverse situations during plant development. A number of studies have shown that the nutritional status of plants affects the ability to adapt to adverse environmental conditions (Waraich *et al*., 2012), meaning nutrients also act to attenuate abiotic stresses (Tahir *et al*., 2011) in the strutural integrity of plants and are the key to physiological processes such as photosynthesis, osmotic regulation and enzyme activation (Waraich *et al*., 2011).

Through their defense system, plants signal stress situations where the enzymes act to minimize the negative effects, perhaps as a result of herbicide toxicity or temperature variation. In the case of photosystem II inhibitor herbicides, such as metribuzin, this stress is caused by the accumulation of reactive oxygen species (Vidal *et al*., 2014), which is a secondary physiological effect of temperature increases (Taiz and Zeiger, 2013). In these cases, catalase is the effective enzyme, mainly in relatively high concentrations of H_2O_2, considered indispensable for the detoxification of reactive oxygen species (Dubey, 2010).

In order to potentiate the enzymes of plant defense mechanisms, foliar fertilizers and biostimulants activate or retard specific physiological processes, especially in the growth zones (root, leaf apices and buds), according to the energy demands or the point activation of metabolic processes of the plant. On the other hand, the aim is to strengthen natural defense systems against biotic and abiotic stresses using hormone-based substances or applying essential nutrients to the plant. These substances have the function of stimulating root development, resistance to diseases, stimulating development and increasing productive performance. In studies on the treatment of soybean seeds with and subsequent application of organomineral foliar fertilizers, Soares (2013) reported that the use of amino acids or hormones associated with foliar treatments reduces the stress level of plants during the initial period of growth and increases the total dry mass.

Thus, the use of foliar fertilizers helps to attenuate the toxic effects caused by herbicides; it should be taken into account that the response of plants to treatments is a product of the cultivated genotype, the edaphoclimatic conditions and the suitability of the foliar fertilizer to the type of toxicity caused by the herbicide.

CONCLUSION

The foliar fertilizer FertiG attenuates the toxicity caused in carrot plants by metribuzin, mitigating the negative effects on crop yield.

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