Interaction between timing of foliar fertilizer application and different Metribuzin doses in carrot

Interacción entre la época de aplicación de un fertilizante foliar y diferentes dosis de Metribuzin en zanahoria

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ABSTRACT

The objective of this research was to evaluate the potential of the foliar fertilizer FertiG as an attenuator of Metribuzin toxicity in the carrot crop. Experiments were carried out in the 2014 and 2015 crops cycles. The treatments were arranged in a 4 x 3 factorial scheme, four times of foliar fertilizer application and three doses of Metribuzin (0, 288 and 576 g ha^{-1}). In crop 1, the foliar fertilizer with the herbicide (288 g ha^{-1}) increased the commercial yield 5 d before the Metribuzin application. The use of FertiG associated to Metribuzin reduced the production of forked carrots 5 d before application and without the foliar fertilizer. The tank mixture decreased the total discard as well as the total yield (576 g ha^{-1}). In crop 2, the commercial yield increased 5 d before (576 g ha^{-1}) and 5 d after (288 g ha^{-1}) the application of Metribuzin when the leaf fertilizer was associated with the herbicide. The yield of the forked carrots decreased 5 d after the application of Metribuzin (288 g ha^{-1}), as well as the total discard. Thus, when associated with Metribuzin (288 g ha^{-1}), FertiG has the potential to attenuate the herbicide toxicity in carrots.

Key words: forked carrots, *Daucus carota*, herbicide, phytotoxicity, commercial yield.

RESUMEN

El objetivo fue evaluar el potencial del fertilizante foliar FertiG como atenuador de la toxicidad de Metribuzin en el cultivo de zanahoria. Se realizaron experimentos en las cosechas 2014 y 2015. Los tratamientos fueron arreglados en un esquema factorial 4 x 3, realizando cuatro aplicaciones del fertilizante foliar en diferentes épocas y tres dosis de Metribuzin (0, 288 y 576 g ha^{-1}). En la cosecha 1, el fertilizante foliar con el herbicida (288 g ha^{-1}) aumentó la productividad comercial cinco d antes de la aplicación del Metribuzin. El uso de FertiG asociado al Metribuzin redujo la producción de zanahorias bifurcadas cinco d antes de la aplicación y sin el fertilizante foliar. La mezcla en tanque disminuyó el descarte total, así como la productividad total (576 g ha^{-1}). En la cosecha 2, la productividad comercial aumentó cinco d antes (576 g ha^{-1}) y cinco d después (288 g ha^{-1}) de la aplicación del Metribuzin cuando se asoció el fertilizante foliar al herbicida. Las zanahorias bifurcadas disminuyeron cinco d después de la aplicación del Metribuzin (288 g ha^{-1}), así como el descarte total. Así, FertiG tiene potencial para atenuar la intoxicación en zanahoria bifurcada (288 g ha^{-1}) cuando se asocia al Metribuzin.

Palabras clave: zanahoria bifurcada, *Daucus carota*, herbicida, fitotoxicidad, productividad comercial.

Introduction

Carrot *(Daucus carota* L.) is native to the Mediterranean Sea region in the area where Afghanistan is located nowadays and transported to South America in the 16th century. It is a crop of great relevance in the Brazilian horticultural sector, occupying the fifth position among the vegetables with the largest participation in the production of the country (Carvalho *et al*., 2013). Known as the largest producer of vegetables in Brazil, the Alto Paranaiba region at Minas Gerais state, accounts for approximately 50% of the national carrot production (Anuário Brasileiro de Hortaliças, 2016), which is notorious for the city of São Gotardo. The carrot is a species of the family Apiaceae with presence of tuberous axial roots. It has a high content of beta-carotene and requires typical crop labors to avoid planting intolerance, control high water rate and to allow the proper soils conditions for the good development of the root.

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Weed interference has been one of the main biotic factors causing reduced yield and increased carrot production costs. The application of herbicides has been the most used method for weed control because it is the most efficient and the least labor demanding (Mascarenhas, 1984; Silva *et al.*, 2017). The herbicides Clethodim, Linuron, Fenoxaprop, Fluazifop and Trifluralin (Agrofit, 2018) are registered for use in carrot cultivation. This low number of registered herbicides has hindered weed management by farmers, who often use herbicides recommended for other crops.

Metribuzin is an herbicide of the chemical group of triazinones, which acts as an inhibitor of photosystem II (Rodrigues and Almeida, 2011), and although it is not registered for the carrot crop in the country, it has already been used in post emergence by producers in the Alto Paranaiba. However, some research indicate that the use of Metribuzin may cause plant toxicity, which is usually observed due to the damage to the shoot organs of the plant (Bellinder *et al.*, 1997; Jensen *et al.*, 2004). These damages can cause a reduction of the green area of the leaves and consequently the decrease in the photosynthetic rate, the conversion of photoassimilates and the development of the plant, reducing the production and causing the marketable fraction to lose market value (Zobiole *et al.*, 2010).

Substances known as safeners, which can be foliar fertilizers, plant growth regulators, amino acids, among others, can avoid problems caused by herbicides. These compounds have the ability to regulate adaptive responses of the plant to detoxify superoxide anions, which modifies the plant metabolism (Ananievaa *et al.*, 2004). It has been observed that in some crops biostimulants are effective in minimizing the toxic effects of herbicides (Zobiole *et al.*, 2011). Metribuzin has, as detoxification mechanism in the plant, the conjugation of the herbicidal molecule with the UDP-glucose through the enzyme glycosyl transferase (GT), or with the GSH by the enzyme glutathione S-transferase (GST) (Anzalone, 2010).

The safeners on the market are mainly applied to grain crops. These crops are cultivated and highly consumed around the world, thus high yields are constantly required (Galon *et al.*, 2011). Due to the economic importance of these crops, researches have been focused on understanding the relationship between herbicides and grain crops systems, so information of this nature in the vegetables area is scarce.

Vegetable growers have used selective herbicides applied in post emergence, because they control weeds with morphological features similar to those plants that infest. However, these crops are not a target for the development and registration of specific products; thus, biostimulants associated with herbicides are used in post emergence in order to reduce phytotoxicity. In this research, the foliar fertilizer was used in order to assist the defense systems of the plant to metabolize the toxic compounds and protecting the plant from the effects of the herbicide. The main objective of this research was to evaluate the potential use of a foliar fertilizer (FertiG) associated with Metribuzin as attenuator of phytotoxicity in the carrot crop.

Materials and methods

The experiments were carried out in an experimental area located in the city of Rio Paranaiba, Minas Gerais (MG) state (19º14'59.6" S and 46º13'14.4" W), with elevation of 1,073 m a.s.l. The first experiment was performed during the months of August to December 2014 (crop 1) and the second experiment from October 2014 to February 2015 (crop 2). The temperature averages for the first and second crop were 22.72ºC and 23.36ºC and rainfall of 157.6 mm and 244.6 mm, respectively (Fig. 1). Irrigations were performed during the two crop seasons (crop 1 and 2), with a total irrigation volume of 400 mm, divided into approximately 4 mm per day.

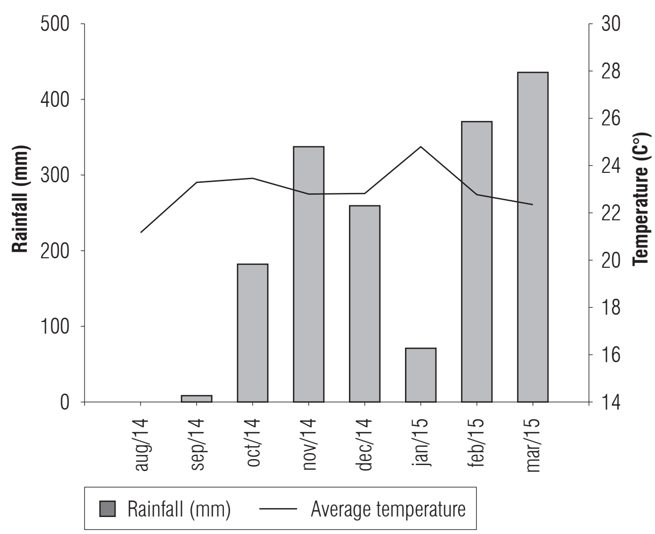

FIGURE 1. Rainfall (mm) and average temperature (ºC) from August 2014 to March 2015. Rio Paranaiba – MG.

The soil of the experimental area was classified as a red-yellow Latosol, of clay texture. Based on the chemical and physical analysis of the soil (Tab. 1), fertilization was carried out with 80 kg N ha^{-1}, 600 kg P_2O_5 ha^{-1} and 200 kg K_2O ha^{-1}. The cover fertilization was divided in two applications; on the first one 28.5 kg N ha^{-1}, 6 kg P_2O_5 ha^{-1} and

TABLE 1. Physical and chemical characteristics of the soil of the experimental area. Rio Paranaiba – MG.

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; P-rem – Remaining soil phosphorus content.

28.5 kg K_2O ha^{-1} were applied, the second event consisted on same composition of the first plus 78 kg K_2O ha^{-1}. The carrot cultivars used were Nayarit (crop 1), which belongs to the Nantes group and is adapted to mild temperatures, and Verano (crop 2), from the Alvorada group, adapted to higher temperatures.

The two experiments were carried out in a randomized complete block design, with four replicates. The treatments were arranged in a 4×3 factorial scheme, the first factor corresponding to the modalities of application of the foliar fertilizer (application 5 d before the herbicide (5 DBA), mixing in the tank with the herbicide (0), application 5 d after the use of the herbicide (5 DAA) and no FertiG application). The second factor was the herbicide Metribuzin doses (0, 288 and 576 g ha^{-1}). The fertilizer used was Fertiactyl® GZ (Timac AGRO, Spain), denominated in this research as FertiG, which has a composition of 13.0% N, 5.0% K_2O and 5.0% organic carbon.

The experimental plots were settled as four crop lines (5 m length) arranged in a double stand each. Plants were spaced at 0.20 m between lines and 0.07 m between double stands. Total research area was equal to 5 m^2; and the evaluation working area only covered 3 m^2. The plant population was 550,000 plants per ha, obtained after manual thinning performed at 20 d after crop emergence. In the total area, 675 g ha^{-1} of Linuron were applied in pre-emergence, avoiding any weed competition area during the crop cycle; manual weeding was performed when needed.

The treatments were applied when the carrot plants had three completely expanded leaves. The application of FertiG at a dose of 1 L ha^{-1} and of the herbicide (associated or not), was performed with a CO_2 pressurized sprayer at 200 kPa. Two spray nozzles 11002 spaced 50 cm apart were used, and the treatments were applied at approximately 50 cm to the target. The volume of application was equivalent to 200 L ha^{-1}.

At 30 and 60 d after application of the herbicide, 10 plants were randomly collected in each experimental plot to determine the shoot dry matter. The samples were conditioned in paper bags and dried in a forced air circulation oven at an average temperature of 72°C until reaching a constant mass, and then weighed in an analytical balance.

At 110 d after planting, the plants contained in the useful area of each plot were harvested and root classification was performed (Ceagesp, 2015). The roots were classified into commercial class (between 10 and 26 cm), forked and total discard (forked + discard). The sum of all classes was subsequently calculated, resulting in total yield.

The data were submitted to analysis of variance by the F test and the average results were compared by the Tukey's test ($P \leq 0.05$).

Results and discussion

Crop 1

Assessing the dry matter of the carrot, the associated use of FertiG and Metribuzin did not provide increments at 30 d. The dry matter of the carrot under the application of Metribuzin increased at 30 d in the absence of FertiG (Tab. 2). At 5 DBA, the use of FertiG associated with Metribuzin (288 and 576 g ha^{-1}) decreased the shoot dry matter of the carrot, and the isolated FertiG did not change. At the other times, the isolated application of FertiG or along with Metribuzin did not change the shoot dry matter.

FertiG increased the shoot dry matter of the carrot 5 DBA and 5 DAA in the absence of the herbicide at 60 d. The use of Metribuzin at a dose of 288 g ha^{-1} associated with FertiG increased dry matter by 23.5% at 60 d, compared to treatment without FertiG application, regardless of the application time at 60 d. The association of the herbicide (576 g ha^{-1}) with FertiG at the time of application (time 0) showed an increase in dry matter in relation to the other treatments (Tab. 2). In the present research, it was observed that the response to FertiG is closely related to the time of application and dose of the herbicide. At 60 d, in the presence of FertiG, the plant recovered the shoot dry matter

TABLE 2. Shoot dry matter of carrot (g) collected at 30 and 60 d after the application of different doses of herbicide Metribuzin associated or not with FertiG* at three different times – Crop 1. Rio Paranaiba – MG.

	Metribuzin (g ha^{-1})			CV (%)
	0	288	576	
		30 d		
5 DBA[1]	1.305 Aa[3]	0.905 Bb	1.004 Bb	14.17
0	1.214 Aab	1.035 Ab	0.962 Ab	
5 DAA[2]	0.931 Ab	0.846 Ab	0.902 Ab	
No application	1.255 Aa	1.482 Aa	1.479 Aa	
		60 d		
5 DBA	5.850 Aa	6.024 Aa	5.294 Bb	5.35
0	4.820 Bb	5.846 Aab	5.991 Aa	
5 DAA	5.842 Aa	5.365 ABb	5.336 Bb	
No application	4.536 Bb	4.392 Bc	5.161 Ab	

[1] DBA: days before application; [2]DAA: days after application; [3]Averages followed by the same capital letter in the row and averages followed by the same lowercase letter in the column do not differ according to the Tukey's test ($P \leq 0.05$); *FertiG - 13.0% N, 5.0% K_2O and 5.0% organic carbon.

due to the effect of FertiG, especially the dose of 288 g ha^{-1}. When evaluating the effect of biostimulant doses on sweet potatoes (*Ipomoea batatas*), Rós *et al*. (2015) also observed significant differences at 28, 37 and 46 d after planting, obtaining satisfactory results at 46 d; it was stated that the increase of the biostimulant dose caused an increase of shoot dry matter.

The use of FertiG as a single solution (dose 0) increased the commercial yield of carrots at 5 DBA, while FertiG associated with Metribuzin (288 g ha^{-1}) also increased commercial yield. However, at the dose 576 g ha^{-1} the yield rate was higher in the absence of FertiG (Tab. 3). In a study by Reghin *et al*. (2000), 10 mL L^{-1}, doses of the growth regulator Stimulate Mo® were tested in Peruvian carrot (*Arracacia xanthorrhiza*) further verifying that the number of roots per plant presented a linear trend response, directly correlated to the increase in the dose of the growth regulator. Dobrei *et al*. (2010) reported that Fertiactyl GZ® presented higher yield and higher sugar content after evaluating five grape fertilizers in grape cultivars for wine production characteristics.

The application of FertiG in the absence of Metribuzin decreased the yield of forked carrots, except at 5 DBA (Tab. 3). FertiG associated with Metribuzin increased the incidence of forked roots at doses 288 g ha^{-1} and 576 g ha^{-1} (time 0

TABLE 3. Commercial and forked carrot root yield (t ha^{-1}) in different application times of FertiG* associated and not associated with Metribuzin – Crop 1. Rio Paranaiba – MG.

	Commercial			Forked		
	Metribuzin (g ha^{-1})			Metribuzin (g ha^{-1})		
Time	0	288	576	0	288	576
5 DBA[1]	43.9 Aa[3]	44.3 Aa	30.3 Bb	4.2 Aa	1.6 Bc	1.5 Bc
0	31.9 Bb	40.1 Ab	29.0 Bb	2.8 Ad	3.6 Ab	2.8 Ba
5 DAA[2]	32.2 ABb	33.5 Ac	29.4 Bb	3.5 Bb	3.8 Aa	2.4 Cb
No application	34.9 Bb	33.6 Bc	39.6 Aa	3.4 Ac	2.6 Bc	2.0 Bc
CV (%)		4.66			5.10	

[1] DBA: days before application; [2]DAA: days after application; [3]Averages followed by the same capital letter in the row and averages followed by the same lowercase letter in the column do not differ according to the Tukey's test ($P \leq 0.05$); *FertiG– 13.0% N, 5.0% K_2O and 5.0% organic carbon.

TABLE 4. Total yield and total discard (forked + discard) of carrot roots (t ha^{-1}) in different application times of FertiG* associated or not with Metribuzin – Crop 1. Rio Paranaiba – MG.

	Total discard			Total yield		
	Metribuzin (g ha^{-1})			Metribuzin (g ha^{-1})		
Time	0	288	576	0	288	576
5 DBA[1]	15.7 Bc[3]	20.1 Aa	21.1 Aa	59.6 Ba	64.4 Aa	51.4 Cb
0	22.3 Aa	13.9 Bb	15.5 Bc	54.2 Ab	54.0 Ab	44.5 Bc
5 DAA[2]	18.2 Abc	18.2 Aa	17.9 Abc	50.4 ABb	51.7 Ab	47.2 Bbc
No application	18.9 Ab	20.0 Aa	19.2 Aab	53.8 Bb	53.5 Bb	58.8 Aa
CV (%)		8.59			4.66	

[1] DBA: days before application; [2]DAA: days after application; [3]Averages followed by the same capital letter in the row and averages followed by the same lowercase letter in the column do not differ according to the Tukey's test ($P \leq 0.05$); *FertiG – 13.0% N, 5.0% K_2O and 5.0% organic carbon.

and 5 DAA). Thus, the absence of FertiG as well as its application before the herbicide had the most representative effect (Tab. 3). At a dose of 576 g ha^{-1}, there was a constant reduction of forked carrots due to FertiG application. In general, the application of Metribuzin did not affect and even decrease the yield of forked carrots, contrary to the suspicions and the reports of producers regarding the action of the herbicide on the formation of carrots of this class.

At dose 0, FertiG isolated decreased the yield of discard carrots, except at time 0 (Tab. 4). In contrast, when the herbicide (288 g ha^{-1} and 576 g ha^{-1}) is associated with FertiG at the time of application, there is a decrease in total discard. The use of FertiG decreases the total discard only in the tank mix (time 0) (Tab. 4).

The application of FertiG in the absence of the herbicide (dose 0) and the association of Metribuzin with the leaf fertilizer (288 g ha^{-1}) increased the total yield by 11% and 17%, respectively, exclusively to the treatment 5 DBA. These results were corroborated with commercial yield data. At the dose 576 g ha^{-1}, a higher total yield was verified in the absence of FertiG application. Metribuzin provided an increase in total yield at doses of 288 g ha^{-1} 5 DBA and 576 g ha^{-1} without FertiG application.

When FertiG was applied along with the herbicide (576 g ha^{-1}) at the time of application, there was a decrease in the carrot classes, except in the commercial class. The tank mix may have an antagonism effect, causing the product formulation to interfere with its efficiency. Therefore, the safener should be applied separately when it causes damage to the crop; antagonism or competition scenarios may occur when the same site of action is shared with the herbicide (Roman and Pinto, 2003). Across all the experiment, when the dose of Metribuzin is increased, at a dose of 576 g ha^{-1} there was a yield decrease in all crop classes except for the total discard. This shows a possible phytotoxicity

TABLE 5. Shoot dry matter of carrot (g) collected at 30 and 60 d after application of different doses of FertiG* associated or not with the herbicide Metribuzin at different times – Crop 2. Rio Paranaiba – MG.

	Metribuzin (g ha^{-1})			CV (%)
	0	288	576	
		30 d		
5 DBA[1]	3.347 Bb[3]	3.273 Bb	4.346 Aa	13.10
0	3.412 Bb	4.315 Aa	4.303 ABa	
5 DAA[2]	3.600 Aab	3.765 Aab	3.720 Aa	
No application	4.536 Aa	4.388 Aa	4.466 Aa	
		60 d		
5 DBA	6.660 Aa	7.242 Aab	5.942 Ab	13.98
0	7.550 Aa	7.652 Aa	6.147 Ab	
5 DAA	6.122 Aa	5.707 Ab	6.102 Ab	
No application	7.320 Ba	3.070 Cc	10.850 Aa	

[1]DBA: days before application; [2]DAA: days after application; [3]Averages followed by the same capital letter in the row and averages followed by the same lowercase letter in the column do not differ according to the Tukey's test ($P \leq 0.05$); *FertiG – 13.0% N, 5.0% K_2O and 5.0% organic carbon.

TABLE 6. Commercial and forked carrot root yield (t ha^{-1}) at different application times of FertiG* associated or not with Metribuzin– Crop 2. Rio Paranaiba – MG.

	Commercial			Forked		
	Metribuzin (g ha^{-1})			Metribuzin (g ha^{-1})		
Time	**0**	**288**	**576**	**0**	**288**	**576**
5 DBA[1]	29.0 Ba[3]	25.8 Bb	34.7 Aa	5.2 Ba	6.2 Bb	11.1 Aa
0	29.3 Aa	30.1 Aa	25.6 Bb	5.0 Ba	10.5 Aa	6.7 Bb
5 DAA[2]	26.7 Bab	30.6 Aa	23.8 Bb	5.2 Aa	4.5 Ab	6.1 Ab
No application	24.5 Bb	28.6 Aab	26.1 ABb	8.1 Ba	11.6 Aa	9.1 ABab
CV (%)		7.20			25.33	

[1]DBA: days before application; [2]DAA: days after application; [3]Averages followed by the same capital letter in the row and averages followed by the same lowercase letter in the column do not differ according to the Tukey's test ($P \leq 0.05$); *FertiG – 13.0% N, 5.0% K_2O and 5.0% organic carbon.

TABLE 7. Total yield and total discard (forked + discard) of carrot roots (t ha^{-1}) at different application times of FertiG* associated or not with Metribuzin – Crop 2. Rio Paranaiba – MG.

	Total discard			Total yield		
	Dose (g ha^{-1})			Dose (g ha^{-1})		
Time	**0**	**288**	**576**	**0**	**288**	**576**
5 DBA[1]	20.2 Ba[3]	21.0 Bbc	25.4 Aa	49.2 Ba	46.9 Bb	60.1 Aa
0	18.2 Ba	24.4 Aab	19.3 Bb	48.2 Bab	54.4 Aa	44.8 Cc
5 DAA[2]	18.9 Aa	17.3 Ac	19.5 Ab	45.5 ABb	47.9 Ab	43.3 Bc
No application	22.2 Ba	27.7 Aa	23.1 Bab	46.7 Bab	56.3 Aa	49.2 Bb
CV (%)		10.57			3.54	

[1]DBA: days before application; [2]DAA: days after application; [3]Averages followed by the same capital letter in the row and averages followed by the same lowercase letter in the column do not differ according to the Tukey's test ($P \leq 0.05$); *FertiG – 13.0% N, 5.0% K_2O and 5.0% organic carbon.

at higher doses even in the presence of FertiG, and the use of the correct dose of the herbicide provides yield gains.

The interaction between a safener and a herbicide is designed to create a synergism towards the weed control (Hatzios and Burgos, 2004). In crop 1, the effect of FertiG use was desirable as long as the application of FertiG before the herbicide (288 g ha^{-1}) caused a preventive effect. Thus, FertiG possibly acted improving the plant's defense system, so that the herbicide was applied at a dose that the plant was able to metabolize, maintaining a greater total and commercial yield and also decreasing the yield of forked carrots.

Crop 2

FertiG applied in association with Metribuzin (576 g ha^{-1}) 5 DBA increased the shoot dry matter of the carrot in 23.8%, compared to the other doses at 30 d (Tab. 5). At 60 d, the application of FertiG associated with Metribuzin (288 g ha^{-1}) increased the dry matter more than 55%, regardless the time of application. However, at 576 g ha^{-1} there was a constant reduction correlated to the absence of FertiG (no application) (Tab. 5). In Canada, Jensen *et al.* (2004) reported that at the third to fifth leaf stages, carrot culture was tolerant to 280 g Metribuzin ha^{-1}. Bellinder *et al.* (1997) reported that the application of up to 280 g Metribuzin ha^{-1}caused mild injury to carrot plants (<18%); the authors further stated that tolerance to Metribuzin in carrot increased along with the leaf development stage.

The FertiG at 5 DBA (576 g ha^{-1}) increased the commercial carrot yield by 27.5% (Tab. 6). The commercial yield increased with the use of FertiG at 5 DAA (288 g ha^{-1}); at a dose of 576 g ha^{-1} the previous herbicide application strategy was considered as the most accurate FertiG application. When evaluating the development of lettuce under the effect of two foliar fertilizers (Fertiactyl GZ® and Ruter AA®), Bezerra *et al.* (2007) observed that with increasing the concentration, there was an increment of 26.2% in root length with Fertiactyl GZ®. For the same biostimulants, Costa *et al.* (2008) reported higher root length in watermelon seedlings.

The combined use of FertiG with the herbicide (288 g ha^{-1}) reduced forked carrots at 5 DBA and 5 DAA. In the presence of Metribuzin at a dose of 288 g ha^{-1}, FertiG in tank mix is considered as the most accurate application. When the dose increased to 576 g ha^{-1}, the best application time is at 5 DBA (Tab. 6). The application of FertiG before and after the herbicide (288 g ha^{-1}) decreased the total discard compared to the control. When FertiG was applied along with Metribuzin at the initial time 0 (576 g ha^{-1}) and 5 DAA (288 g ha^{-1} and 576 g ha^{-1}), it reduced total discard (Tab. 7).

The total yield at a dose of 288 g ha^{-1} increased whether the Metribuzin was applied along with FertiG and alone. At a dose of 576 g ha^{-1}, the previous herbicide application increased the yield compared to the other application events (Tab. 7). The results of the two crops show that the Metribuzin was not toxic to the carrot crop, with total yield being raised at a dose of 576 g ha^{-1} in crop 1 and 288 g ha^{-1} in crop 2, without increasing the total discard rate.

In the climatic conditions of Brazil in high altitude regions, carrots can be cultivated throughout the year according to the average temperature, precipitation and adapted cultivars (Pessoa Carneiro *et al.*, 2017). In this study, each carrot genotype (Nayarit and Verano) was selected for the most appropriate planting season. Jensen *et al.* (2004) reported that there was no reduction in carrot yield when treated with 560 g ha^{-1} of Metribuzin, and differential tolerance to Metribuzin could occur on each of the genotypes grown according to the edaphoclimatic conditions.

Conclusions

Applications of only Metribuzin in the carrot crop did not cause phytotoxicity. However, when Metribuzin was applied at a dose of 288 g ha^{-1} associated with FertiG before or after the application of the herbicide, there was an increase in commercial and total root yields in crop 1 and a reduction of forked carrots in crop 2. Therefore, when FertiG is associated with Metribuzin has the potential to mitigate the phytotoxicity caused to the carrots.

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