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Residual effect of metribuzin in the soil on the growth of garlic, onion and beans[1]

Residual de metribuzin no solo sobre o crescimento do alho, cebola e feijão

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Abstract - Metribuzin is an herbicide widely used in the control of weeds in crops such as soybean, potato and tomato. However, there is suspicion of intoxication in crops cultivated in succession due to the residual effect of the product in the soil. As such, our goal was to evaluate the residual effect of metribuzin in the soil on the growth of garlic, onion and beans plants. Three experiments were conducted in a greenhouse, in a randomized block design, with four replications. Each experiment corresponded to the evaluated crop: garlic, onion or beans. The treatments consisted of different metribuzin concentrations in the soil (0; 6; 12; 24; 48; 96; 144; 192; 240 and 480 ppb). Visual intoxication was evaluated at 7, 14, 21 and 28 days after emergence (DAE) of the crops and dry matter at 28 DAE. Intoxication was identified in the garlic and bean plants at metribuzin concentration of 96 ppb, with maximum impact of 55 and 63%, respectively, at 28 DAE. In the onion crop, symptoms of intoxication arose at 40 ppb, and from 14 DAE onwards, plant death was noted at herbicide concentrations from 240 to 480 ppb. The dry matter of the bean and onion plants was reduced by the presence of herbicide in the soil, while garlic plant growth was not affected. Residues of metribuzin in the soil can hinder successive planting of garlic, onion or bean crops. It was concluded that garlic, onion and bean plants are sensitive to the residual effect of metribuzin in the soil.
Keywords: *Allium sativum*; *Allium cepa*; *Phaseolus vulgaris*; carryover

Resumo - O metribuzin é um herbicida amplamente utilizado para o controle de plantas daninhas em culturas como a soja, a batata e o tomate. No entanto, há suspeitas de intoxicações de culturas cultivadas em sucessão devido a resíduos desse produto no solo. Assim, objetivou-se avaliar o efeito de resíduos de metribuzin no solo sobre o crescimento de plantas de alho, cebola e feijão. Foram realizados três experimentos em casa de vegetação, no delineamento de blocos casualizados,

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com quatro repetições. Cada experimento correspondeu à cultura avaliada: alho, cebola ou feijão. Os tratamentos constituíram de diferentes concentrações de metribuzin no solo (0; 6; 12; 24; 48; 96; 144; 192; 240 e 480 ppb). Avaliou-se a intoxicação visual aos 7, 14, 21 e 28 dias após a emergência (DAE) das culturas e matéria seca aos 28 DAE. Constatou-se intoxicação das plantas de alho e feijão a partir da concentração de 96 ppb do metribuzin, com máxima injúria de 55 e 63%, respectivamente, aos 28 DAE. Na cultura da cebola os sintomas de intoxicação surgiram a partir de 40 ppb, sendo que a partir de 14 DAE foi observada morte das plantas nas concentrações de 240 a 480 ppb do herbicida. A massa da matéria seca do feijoeiro e da cebola foi reduzida pela presença do herbicida no solo, enquanto o crescimento do alho não foi afetado. Resíduos de metribuzin no solo podem inviabilizar a sucessão de culturas com alho, cebola ou feijão. Conclui-se que as plantas de alho, cebola e feijão são sensíveis aos resíduos de metribuzin no solo.
Palavras-chaves: *Allium sativum*; *Allium cepa*; *Phaseolus vulgaris*; *carryover*

Introduction

The use of herbicides has been the weed control method most widely used in agriculture, especially the more technified types, mainly because they provide greater efficiency and, in many cases, cost reduction of weed control. Some of these herbicides have a residual effect on the soil, that is, they remain active in the soil enabling weed control for a longer time period (Melo et al., 2010). However, the residue from herbicides in the soil can increase the risk of contamination in surface and underground water (Marchesan et al., 2010; Otto et al., 2012; Santos et al., 2015), besides causing intoxication of the crops cultivated in succession (Artuzi e Contiero, 2006; Dan et al., 2010; Mancuso et al., 2011).

Herbicides with greater soil persistence can intoxicate sensitive crops sown in succession, a phenomenon called *carryover* (Mancuso et al., 2011). This intoxication may not be visible but can result in the reduction of crop growth and production, even in situations of low herbicide concentrations in the soil (Robinson et al., 2008).

Metribuzin is a herbicide from the triazine chemical group, a photosystem II inhibitor. It is widely used in the control of monocotyledonous and dicotyledonous weeds in crops such as soybean, potato and tomato. However, due to the short cycle of these crops, there is the risk of toxic damage to crops planted in succession, seeing as their half-life could be up to two months and persistence could exceed cultivation time, depending on soil texture and climatic conditions. (Rodrigues e Almeida, 2011).

The method most used in behavior studies of herbicides in the soil has been bioassay, which consists in using plants sensitive to the herbicide tested, so that residues can be gauged through the alteration in the morphophysiological characteristics of the bioindicator plants. It is a low cost method that produces accurate results. (El-Nahhal, 2003; Melo et al., 2010).

Frequently, crops such as garlic, onion and beans are cultivated in succession to tomato and potato. The constant application of metribuzin in potato or tomato crops can make the cultivation of other crops unfeasible due to the intoxication produced by this herbicide. The goal of this research was to evaluate the sensitivity of garlic, onion and bean plants to different concentrations of metribuzin in the soil.

Material and Methods

The experiment was carried out in a greenhouse located in the Federal University of Viçosa, Campus Rio Paranaíba (UTM = 19º12’29”S and 46º07’57”W). Three experiments were performed in a protected environment. Each experiment was represented by one evaluated crop: garlic (*Allium sativum*), onion (*Allium cepa*) and beans (*Phaseolus* *vulgaris*). We used a red clayey distropheric latosol, collected at a depth of 0-10 cm which, after air drying, was strained (five mm mesh). The chemical and granulometric characteristics of the soil are described in Table 1.

Table 1. Physical-chemical characteristics of the red clayey distropheric latosol used in the experiment. Rio Paranaíba (MG), 2014

pH		Al^{3+}	$H^{+}+Al^{3+}$	Mg^{2+}	Ca^{2+}	K^{+}
(H_2O)		(cmol$_c$ dm^{-3})				
6.00		0.00	3.50	1.00	3.60	1.00
M.O.	P	CTC	V	Sand	Silt	Clay
(dag dm^{-3})	(mg dm^{-3})	(cmol$_c$ dm^{-3})	(%)	(dag kg^{-1})		
2.40	13.90	8.37	58.00	32.90	11.70	55.40

The three experiments were conducted in randomized block design with four replications. Treatments were composed of the metribuzin concentrations in the soil (0; 6; 12; 24; 48; 96; 144; 192; 240 and 480 ppb) equivalent to doses of 0, 6; 12; 24; 48; 96; 144; 192; 240, and 480 g ha^{-1} active ingredient (a.i.), respectively, considering depth at 0-10 cm of one hectare and soil density of 1.0 g dm^{-3}.

Vases with 5.0 dm^3 capacity were filled with the soild matter and the herbicide, and six seeds from the test crop (onion, beans and garlic) were deposited. Five days after emergence of the seedlings, thinning was carried out leaving four plants per vase. Each vase was considered one experimental unit. One single balanced nutrient solution was applied 10 days after emergence (DAE), containing 4% N, 14% P_2O_5 and 8% K_2O, with primary macronutrients and micronutrients.

Visual intoxication evaluations of the crops were carried out at 7, 14, 21 and 28 DAE. A scale from 0 to 100% was used, in which zero corresponds to no impact and 100 signifies plant death (SBCPD, 1995). At 28 DAE, the aerial part of the plant was collected and placed in paper bags for drying in forced ventilation stove at 72 ºC, until constant mass was achieved, before being weighed to determine the dry matter.

Data were subjected to variance and regression analysis. Regression equations were adjusted ($p < 0.05$) using the SigmaPlot 10.0 program. Intoxication curves were adjusted in the sigmoidal model:

$$\hat{y} = \frac{a}{1+e^{-\frac{X-X_0}{b}}}$$

Where: ŷ is the response variable of interest (visual intoxication); X is the metribuzin concentration in ppb; “a” is the asymptote corresponding to the maximum value of the variable in question; “b” is the slope of the response variable and X0 is the curve inflection point and corresponds to the concentration necessary for the occurrence of 50% response, also called I_{50}.

Results and Discussion

Garlic (*Allium sativum*)

Visual intoxication of garlic plants, at seven days after emergence (DAE), was more pronounced starting at 144 ppb of metribuzin in the soil, while at larger doses (>280 ppb) maximum intoxication was 31.32% (Figure 1 A). This same behavior remained in the other evaluations, with maximum intoxication of 74.69 and 69.92% at 14 and 21 DAE, respectively (Figure 1B and 1C).

At 28 DAE (Figure 1D), garlic recovery was noted, with reduction in intoxication to a maximum of 55.70%. The increase in intoxication throughout the cultivation period is related to the growth of the plant’s root system, which starts to exploit a greater volume of soil, also increasing contact with the metribuzin residues.

According to the I_{50}, the metribuzin concentrations in the soil needed to cause 50% intoxication in the garlic plants were 163.11; 171.77 and 165.07 ppb respectively at 14, 21 and 28 DAE.

Garlic plant intoxication caused by metribuzin was also reported by Mehmood et al. (2007) for applications in crop pre-emergence at the dose of 450 g ha^{-1} a.i. These authors noted leaf drying followed by plant death. The incorporation of the herbicide to the soil, caused by the machine mixture, probably led to greater metribuzin dilution in the soil when compared to the pre-emergence application, resulting in the intoxication of the garlic, but short of plant death. It is worth stressing that in the preparation of the area for garlic cultivation, the soil undergoes intense tilling and if the metribuzin has been applied to a prior plantation, the herbicide will be mixed into the soil.

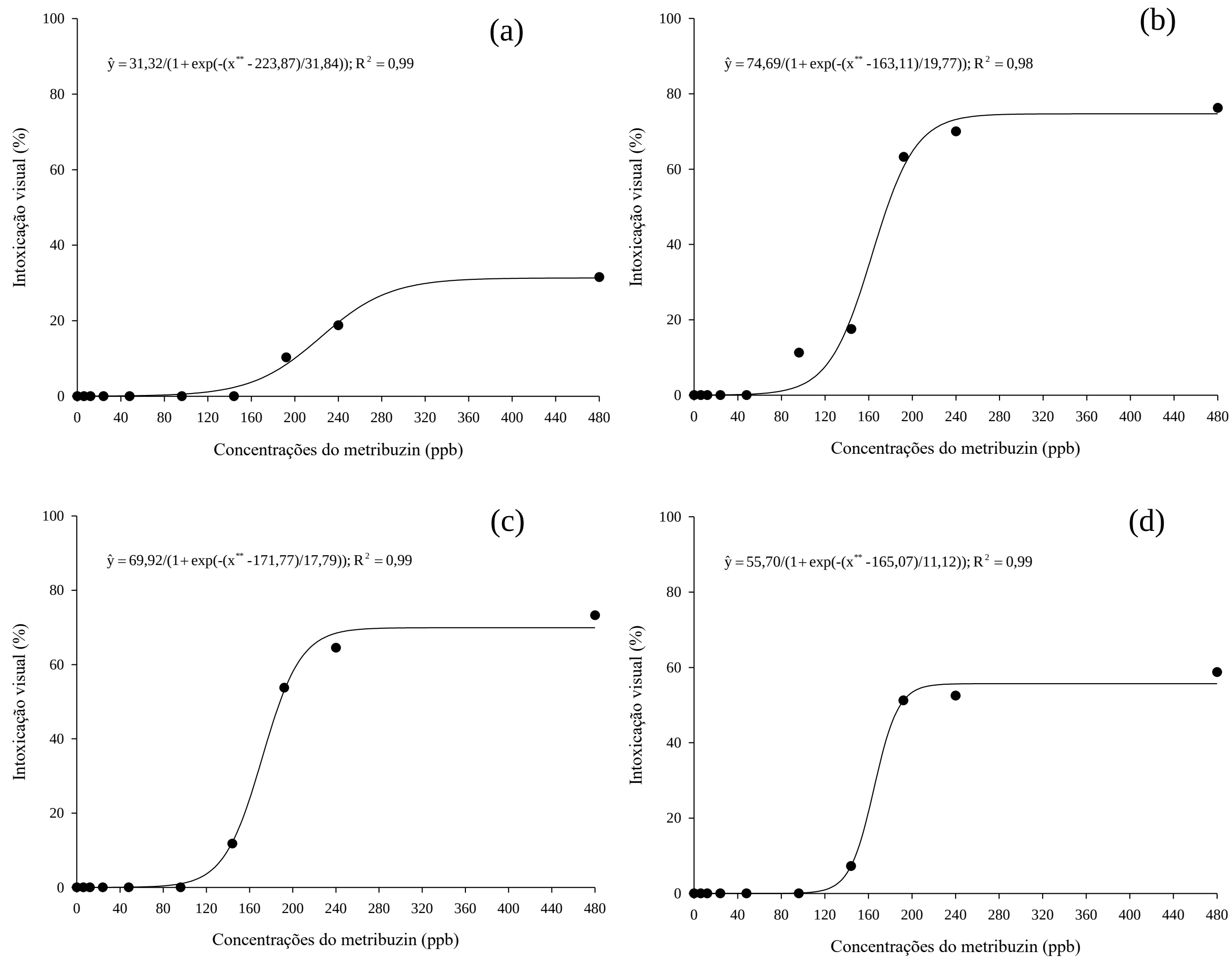

Figure 1. Percentage of visual intoxication of the garlic crop for metribuzin concentrations of 0 to 480 ppb in the soil, at 7 (a), 14 (b), 21 (c) and 28 (d) days after crop emergence. Rio Paranaíba (MG), 2014.

Despite symptoms of intoxication (Figure 1), the dry matter from the aerial part of the garlic was not influenced by metribuzin concentrations in the soil (Figure 2A). This fact is related to the characteristics of the intoxication caused to the garlic by metribuzin. Even after dry, the symptomatic leaves of the garlic continue adhered to plant collection, not changing the values of the variable even at greater doses. The effects of the herbicide on growth could be more evident in more advanced stages of crop growth, as evaluated by Qasem (1996) who verified that the application of metribuzin at the dose of 420 g ha^{-1} a.i. resulted in a reduction of crop growth and yield.

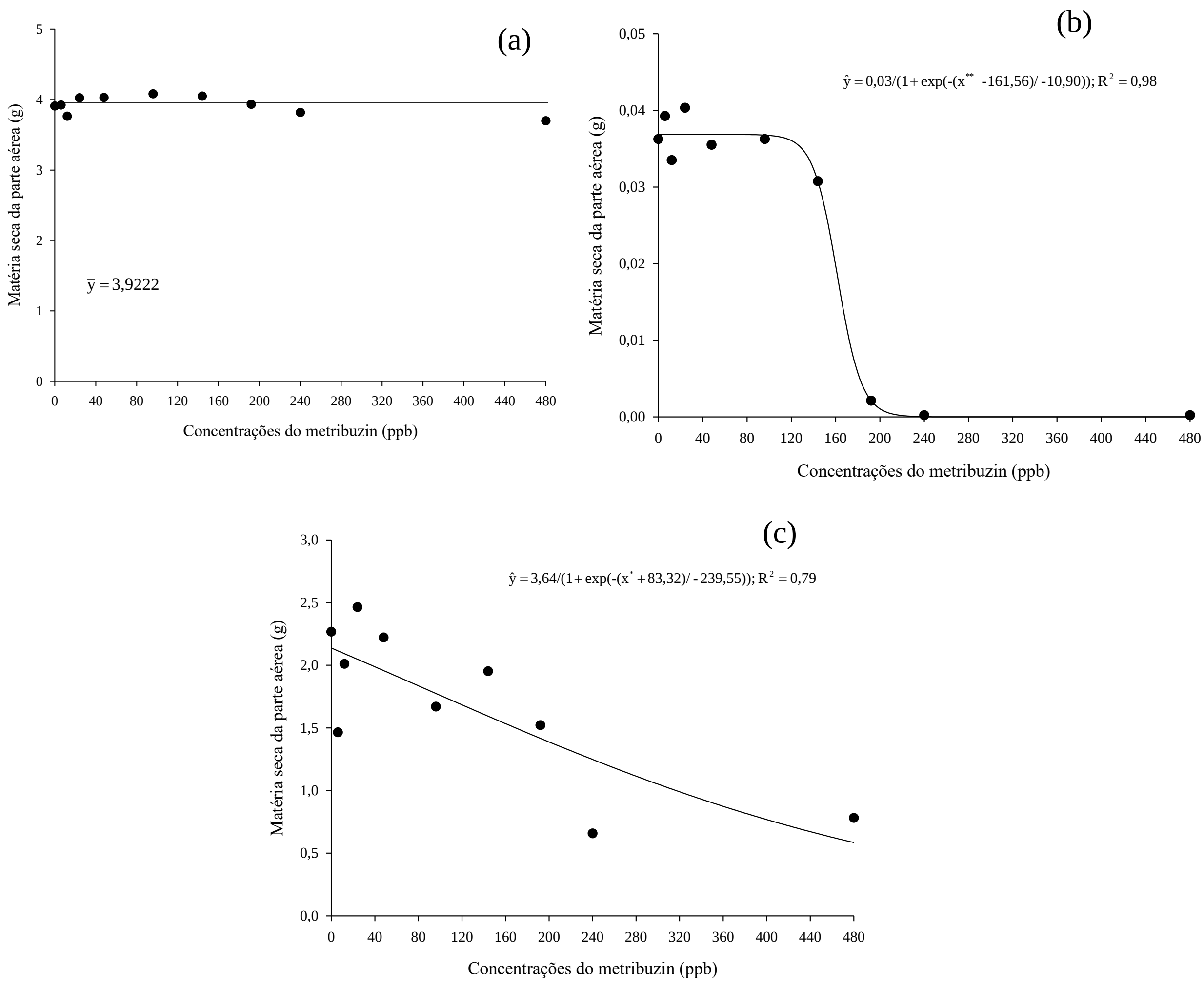

Figure 2. Dry matter from the aerial part (g) of the garlic (a), onion (b) and beans (c) crops for metribuzin concentrations of 0 to 480 ppb in the soil, at 28 days after crop emergence. Rio Paranaíba (MG), 2014.

Onion (*Allium cepa*)

A low level of visual intoxication was noted for onion at metribuzin concentrations less than 120 ppb, regardless of the evaluation period (Figure 3). However, at concentrations from 240 to 480 ppb plant death was noted in the second evaluation (14 DAA) (Figure 3B), while at 28 DAE the death of the cultivated plants was observed at 192 ppb of the herbicide in the soil (Figure 3C). These results demonstrate that the onion's tolerance of the herbicide is closely linked to the residue concentration in the soil.

The lower values for the "b" coefficient noted in the evaluation periods 14, 21 and 28

DAE demonstrate the high slope of the straight line and the greater tendency towards curve stabilization, unlike the behavior verified at 7 DAE. The maximum intoxication caused by the presence of the herbicide in the soil was 84.17% at 7 DAE and 100% for the other periods.

The dry matter from the aerial part of the onion was not influenced by the metribuzin until approximately 140 ppb, when there was an accumulation of 35 mg in dry matter from the aerial part. However, death resulted for plants cultivated in soil with metribuzin concentrations above 192 ppb (Figure 2B). Metribuzin concentration of 161.63 ppb in the soil was responsible for the 50% reduction in the accumulation of this variable by the onion plants.

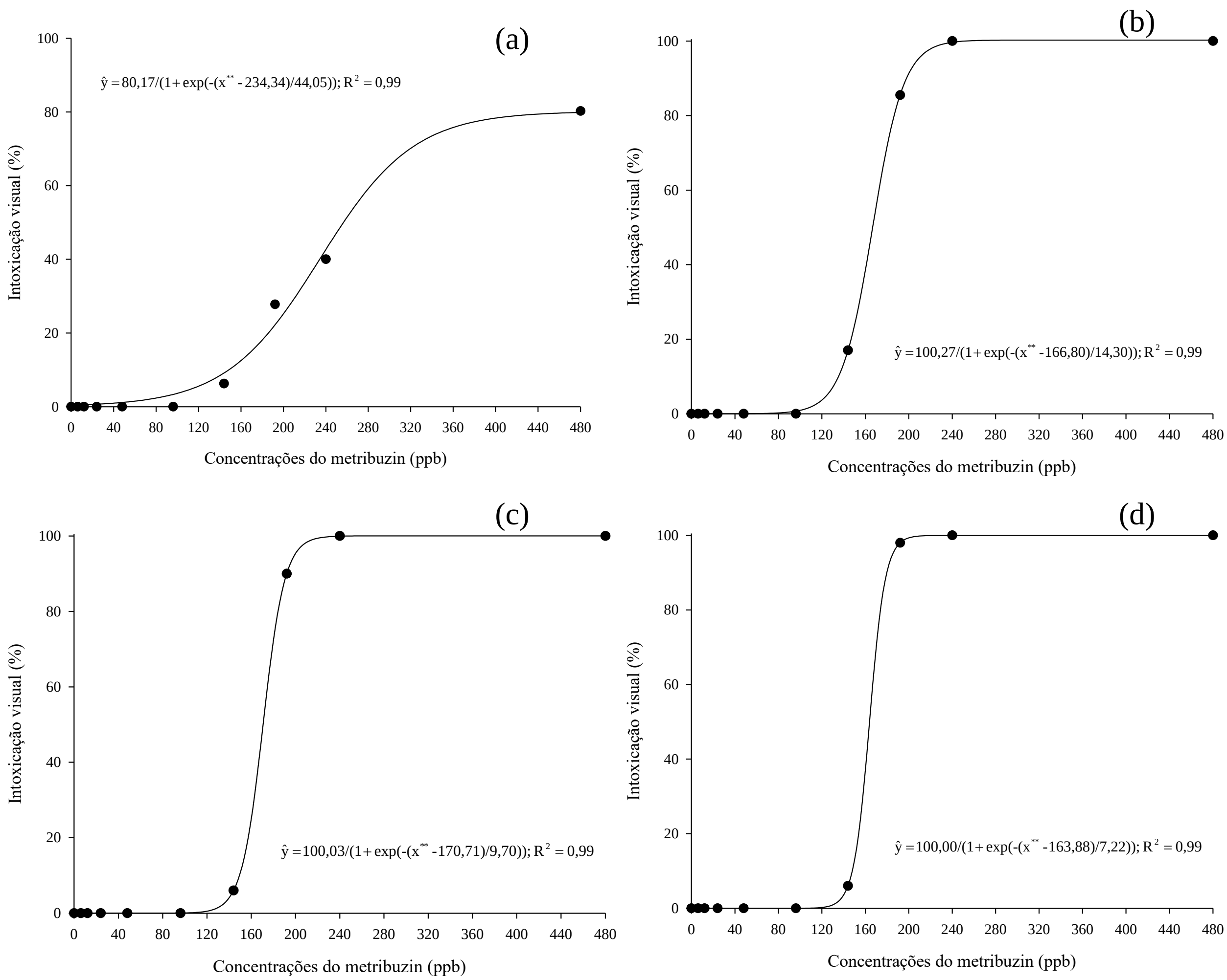

Figure 3. Percentage of visual intoxication of the onion crop for metribuzin concentrations of 0 to 480 ppb in the soil, at 7 (a), 14 (b), 21 (c) and 28 (d) days after crop emergence. Rio Paranaíba (MG), 2014.

The intoxication of the onion caused by the metribuzin was also reported by Qasem (2006) who verified metribuzin toxicity in onion planted via seeds or seedlings. Meanwhile, Sanjeev et al. (2003) found contrary results, in which metribuzin at the dose of 700 g ha^{-1} a.i. in mixture with oxyfluorfen and pendimethalin reduced weed population and increased onion yield. In studies by Ghosheh (2004), the application of metribuzin at the dose of 350 g ha^{-1} a.i. caused intoxication of 20% in onion, without affecting crop growth and yield.

Beans (*Phaseolus vulgaris*)

The intoxication of the bean plant caused by the application of metribuzin was greater at higher concentrations of the herbicide and in the first two evaluations, at 7 and 14 DAE, with maximum intoxication of 66.69 and 79.56%, respectively (Figure 4A and 4B). At 14 DAE symptoms in the bean leaves were more evident, which can be proven by the lower value of “b” in the equation, reaching maximum intoxication (“a”) in lower concentrations of metribuzin in the soil, compared to other periods. On the other hand, at 21 and 28 DAE there was a reduction of symptoms at greater concentrations of the herbicide, with a smaller curve slope and greater values of “b”. In the last evaluation, phytointoxication values were less than 20% up to concentrations of 240 ppb, which indicates that the bean plants recovered as new leaves free of the symptoms emerged. (Figures 4C and 4D).

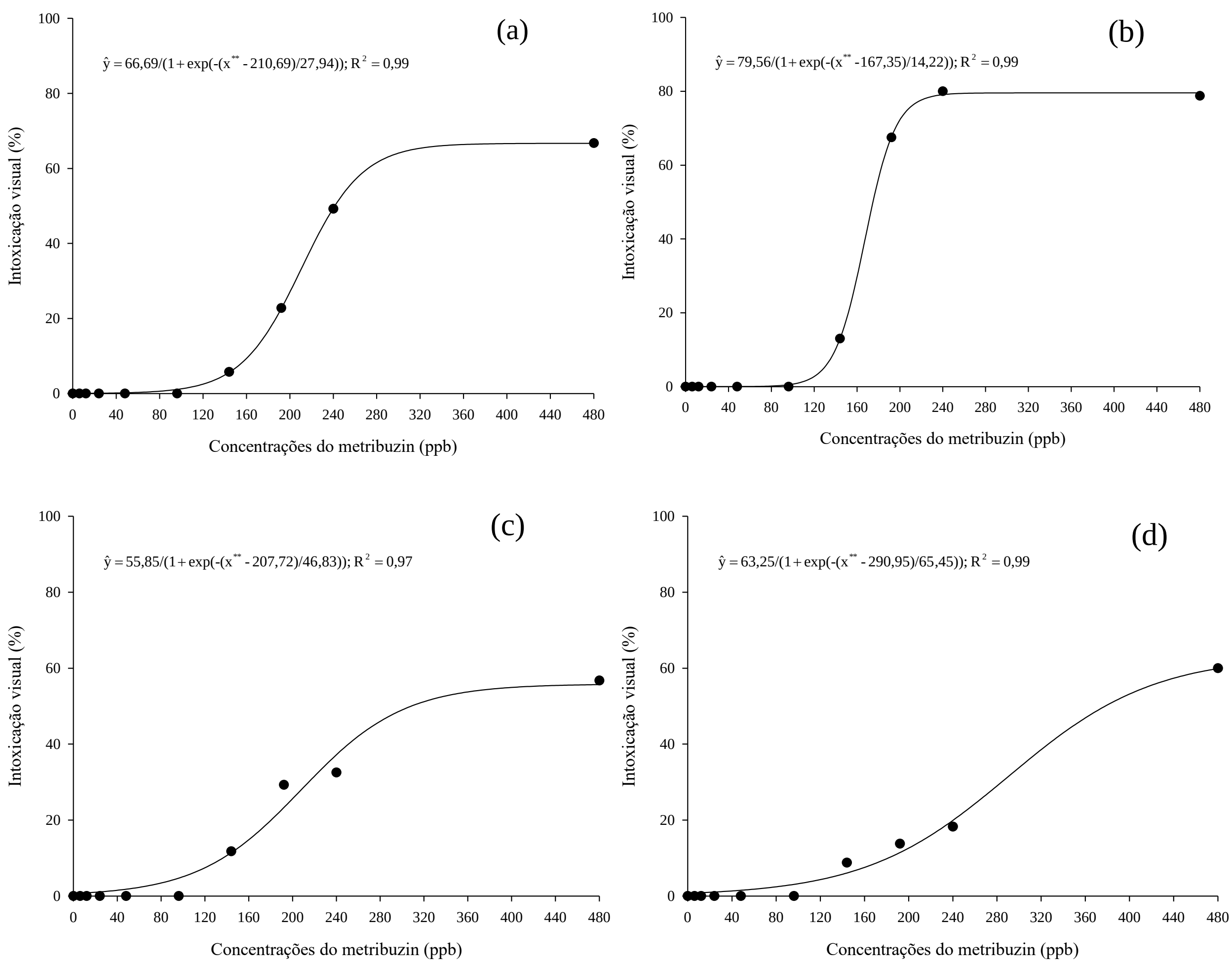

Figure 4. Percentage of visual intoxication of the bean crop for metribuzin concentrations of 0 to 480 ppb in the soil, at 7 (a), 14 (b), 21 (c) and 28 (d) days after crop emergence. Rio Paranaíba (MG), 2014.

For the bean plant’s dry matter, an inversely proportional relation was noted, that is, as the concentration of the metribuzin herbicide in the soil increased, there was a linear reduction in the aerial part of the bean plant (Figure 2C). Freitas et al. (2009) reported that metribuzin at the dose of 1.0 L ha^{-1} applied in pre-emergence resulted in the death of the caupi-bean plants, since this herbicide is selective for the soybean crop and non-selective for the common kidney bean (Rodrigues e Almeida, 2011). Fernandes et al. (2012) observed that where metribuzin was applied in pre-emergence at the dose of 1,440 g ha^{-1}, intoxication levels were so high that 7 days after herbicide application, not one bean plant was found alive or even emerged.

Differential sensitivity was verified for crops tested at the herbicide concentrations in the soil. This behavior may be related to the distinct capacity of the plants to tolerate the herbicide through the mechanisms of detoxification and metabolization of the herbicide molecule. According to Cataneo e Carvalho (2008) metribuzin detoxification in the plant is associated with glucose conjugation through glycosyltransferases. In this study, the onion plants showed the greatest sensitivity to metribuzin, possibly because of lesser efficiency in the performance of these mechanisms.

The intoxication caused to the aerial part, as well as the reduction in the accumulation of plant dry matter can, when not rendering the area unfit for cultivation, reflect in significant decreases in yield. Results obtained in these studies reinforce the importance of know the behavior of herbicides in the soil, as well as the sensitivity of the species that will be cultivated in succession in the areas that will receive these products. Therefore, any recommendation for the planting of garlic, onion and beans in soil with residual metribuzin resulting from previous cultivations must be closely analyzed to avoid carryover problems.

Conclusions

Garlic, beans and onion plants are sensitive to the residual effect of metribuzin in the soil, in an ascending order of crop sensitivity to the herbicide.

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