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Persistence of 2,4-D and glyphosate in a *Cerrado* soil, Brazil

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The state of Mato Grosso is the main grain producer in Brazil, and weeds occurrence remains the major obstacle in the production of these grains, also increasing herbicide consumption. The aim of this study was to assess 2, 4-dichlorophenoxyacetic acid and Glyphosate (N-phosphonomethyl-glycine) herbicides mixture persistence in soybeans of Ultisol in the Brazilian *Cerrado*. The study was conducted in a greenhouse with randomized blocks experimental design consisting of 6x5 factorial, six application periods (0, 3, 5, 7, 10 and 14 days before sowing), five herbicide doses (0, 750 , 1500, 2250 and 3000 g ia. ha^{-1}) and four repetitions. Herbicides were sprayed with a knapsack sprayer. Residual effect was assessed through emergence speed index (ESI), plant height, visual phytotoxicity and dry biomass of shoot and root. Results showed that, according to the decrease in the interval between herbicide application and soybean seeding, the residual effect of products was higher. As the dose increased, higher was the plant phytointoxication, influencing in the reduction of emergence speed, shoot dry matter, root dry matter and plant height, and negatively acting on crop development.

Key words: Pesticides, residual effect, sowing, soybean.

INTRODUCTION

Grain production in Brazil was 209 million tons, of which the Brazilian Midwest region accounted for 42% of production. According to Conab (2015), it is the main agricultural region in the country. Weeds occurrence remain a major obstacle in the production of these grains. Among weed management possibilities, the chemical method is still the most popular. According to the National Health Surveillance Agency (Anvisa, 2013), the Brazilian market of pesticides expanded in 190% in the last decade, more than twice the global market (93%).

Growth has primarily been accompanied by herbicides use (Peres, 2009) due to the influence of important crops, such as soybean. Soybean is the main crop responsible for agricultural chain and livestock commercial viability in

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Table 1. Chemical and particle size characterization of an Ultisol sample in the 0-0.20 m depth layer.

pH	P	K	Ca	Mg	H	Al	SB	CTC	V	O.M	sand	silt	clay
$CaCl_2$	mg dm^{-3}		----------$Cmol_c$ dm^{-3}---------						%	g dm^{-3}	--------g kg^{-1}-------		
4.1	2.4	28	0.3	0.2	4.2	1.1	0.6	5.9	9.8	22.7	549	84	367

the Midwest, as it also serves as raw material for the production of animal feed for cattle, swine and poultry (Aprosoja, 2013). The state of Mato Grosso is the largest national producer of grains, and this growth has also been associated with pesticides intensive use, both for weed control and pre-planting desiccation (Mapa, 2010; Conab 2015).

Indiscriminate use of herbicides favors the increase of tolerant individuals in the area and resistant species selection, diminishing efficiency and causing environmental pollution, aspects that demand optimization in pesticides use and distribution (Chiras, 1995; White, 1997; Cunha et al., 2005; Weed Science, 2014; Pacheco, 2012). Glyphosate and 2,4-dichlorophenoxyacetic acid (2,4-D) are officially the most sold in the whole national territory (Ibama, 2009). 2,4-D was the first selective herbicide and is widely used for weeds pre or post-emergence application in various crops (Ibama, 2009).

Glyphosate is a post-emergent herbicide belonging to the substituted glycine chemical group. It is toxic to aquatic organisms and slightly toxic to soil organisms, birds and bees, besides being little bioaccumulative (Rebelo et al., 2010). 2,4-D is a growth regulator which has a similar effect to auxin hormone (Ashton and Crafts, 1973). It belongs to the phenolic compounds family, being salts or esters of high molecular weight and low volatility derived from phenoxyacetic acid (Saad, 1978). Flaws in the control of certain weed species by Glyphosate use has led farmers to use other herbicides, such as 2,4-D, one of the most used in this association, especially in pre-planting desiccation application (Takano et al., 2013). The objective of the present study was to assess 2,4-D and Glyphosate herbicides persistence in an Ultisol of the *Cerrado,* and also to assess their effects on soybeans.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse (temperature between 19-50o C) located at 16°28' South latitude, 50°34' West longitude and altitude of 284 m. The experimental design was of randomized block, consisting of a 6X5 factorial, six application periods before sowing (0, 3, 5, 7, 10 and 14 days before sowing), five 2,4-D doses (0 , 750, 1500, 2250 and 3000 g ia. ha^{-1}) and a constant dose of glyphosate (4000 ia. ha^{-1}), with four repetitions.

Each experimental unit consisted of pots with 5 dm^3 soil capacity and eight TMG 132 cv. (seeded at 5 cm depth) soybean plants. The soil used was an Ultisol (EMBRAPA, 2013) collected in the region of Rondonópolis, MT state, in the depth of 0 to 0.20 m, being subsequently sieved in a 4 mm mesh for insertion in the experimental units. The soil was characterized by chemical and size analysis, according to the methodology of Embrapa (1997) (Table 1). The soil was maintained at 80% field capacity moisture, for the gravimetric method, according to the methodology of Bonfim-Silva et al. (2011).

Herbicide spraying was carried in pre emergency, out with a knapsack sprayer equipped with XR 11002 and syrup consumption corresponding to 200 L ha^{-1}. The persistence of these herbicides in the soil was assessed through emergence speed index (ESI), soybean visual phytotoxicity, with scores ranging from 1 to 5 (where 1 corresponds to no injury and 5 to plant death) (SBCPD 1995), plant height (cm), shoot biomass dry matter - BDM (g) and root biomass dry matter - BDM (g) at 26 days after sowing, at the end of the study. Statistical analysis was conducted in accordance with the polynomial regression model.

RESULTS AND DISCUSSION

Emergence speed index (ESI) was influenced in all assessed dosages, being statistically different (Figure 1). The only emergence speed index which was unaffected by dose was 0, due to herbicides absence (Figure 1a). Increasing doses along the periods showed that the period of 0 days before sowing was the one which reduced emergence the most in all applied doses, being more severe as the dose was increased (Figure 1b).

Similar results were observed by Nascimento and Yamashita (2009), in which species sensitive to auxinic herbicides showed linear decrease in plant emergence as doses were increased. In the periods of 7 and 10 days before sowing (Figure 1a), the interval between spraying and seeding gave higher emergence speed to the maximum dose of 3000, and the dose of 2250 g e. a. ha^{-1} obtained the lowest plant emergence mean. This result may be related to 2,4-D mechanism of action, as it is a herbicide characterized for being similar to auxin. According to Mortensen et al. (2012), 2,4-D acts as a herbicide for dicotyledonous weed species control. However, it also has hormonal action, acting as a synthetic auxin that can be used as plant growth regulator.

The highest herbicide doses (3000 and 2250 g e. a. ha^{-1}) were the most harmful to crop initial development in periods closer to spraying. These results were also found by Silva et al. (2011), where the shorter period between application and sowing (0 days before sowing) showed lower plant emergence. Phytotoxicity visual symptoms found (leaves shriveling and petioles epinasty) were observed in all treatments.

Plant injury effect (Figure 2) over the periods was higher at 0 days before sowing, and intensified as there was an increase of doses (Figure 2a), even in the lowest

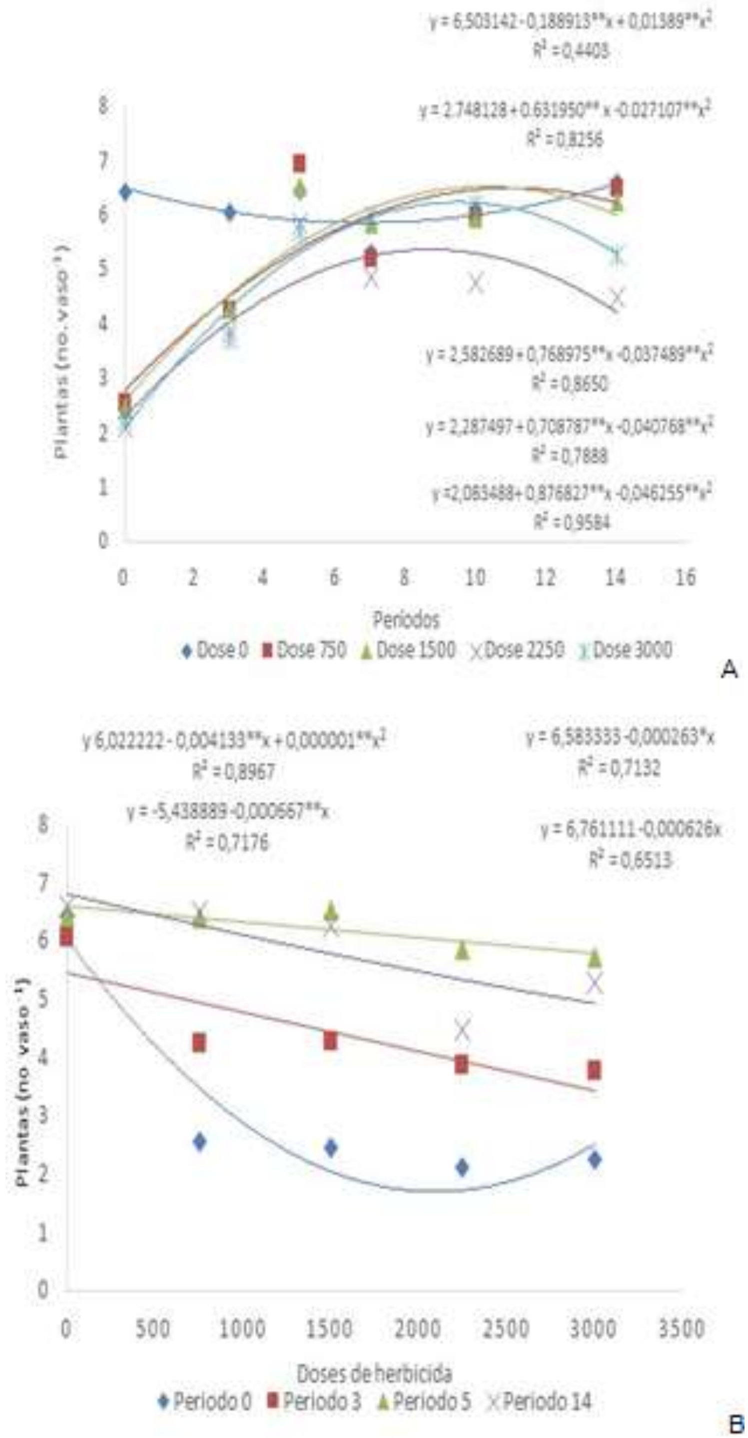

Figure 1. Emergence speed index. Treatments interaction with doses over the periods (a) and treatments interaction in the periods between sowing and spraying, according with the increasing doses (b). ***, **, *: significant a 01, 1 e 5% respectively.

dose used. The effect had a decrease as spraying was distanced from seeding, and at 14 days before sowing, the 3000 g e. a. ha^{-1} dose still was the most harmful to the crop. Phytotoxicity may be related to higher plant exposure from the germination stage. This result corroborates with those found by Silva et al. (2011), in

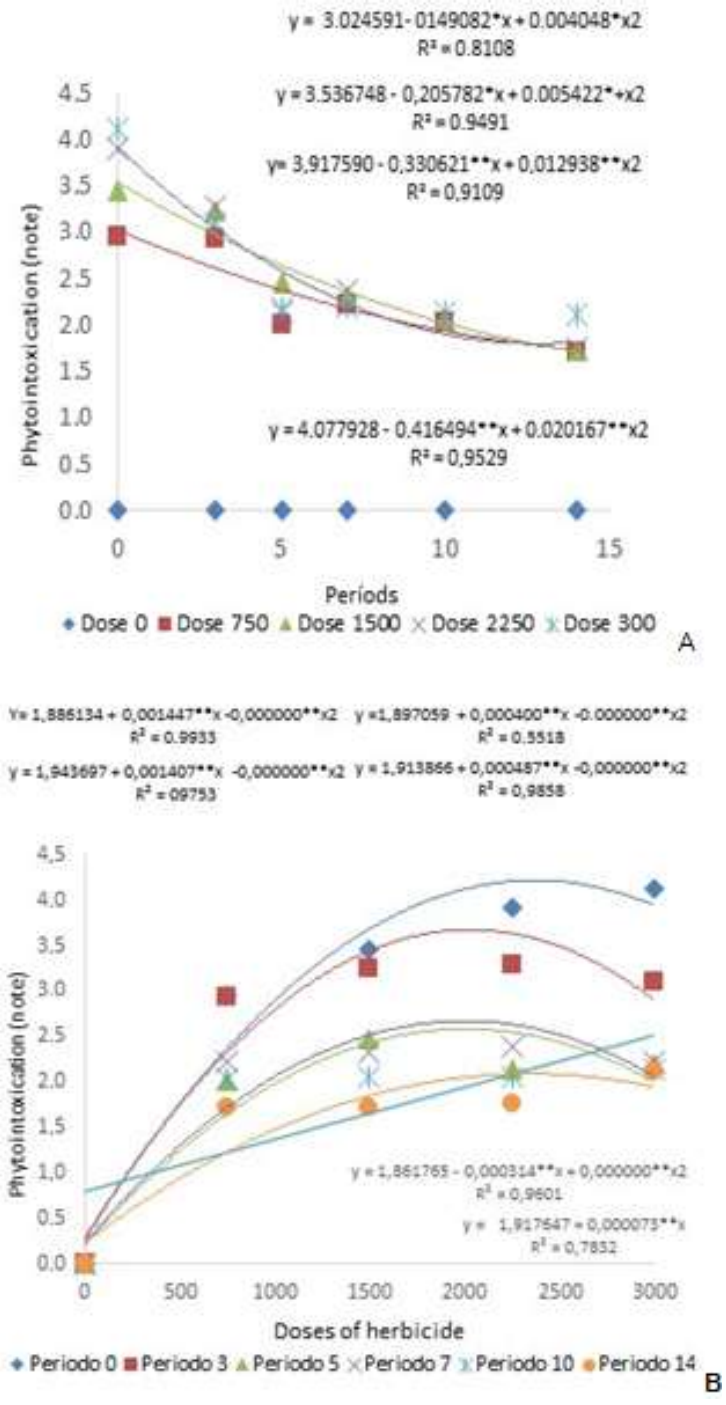

Figure 2. Phytointoxication. Treatments interaction with doses over the periods (a) and treatments interaction in the periods between sowing and spraying, according with the increasing doses (b). ***, **, *: significant a 01, 1 e 5% respectively.

which it was observed that the highest phytotoxicity values were during periods closer to soybean seeding, leading to phytotoxic effects to the crop as a result of residues of this herbicide in the medium texture soil.

Regarding periods, according to each dose, the effect was similar for 0 days before sowing, regardless of the dose used. That is, the shorter the period between spraying and sowing, higher was the appearance of symptoms, as shown in Figure 2b. Injuries increased according with the dose increases at 0 days before

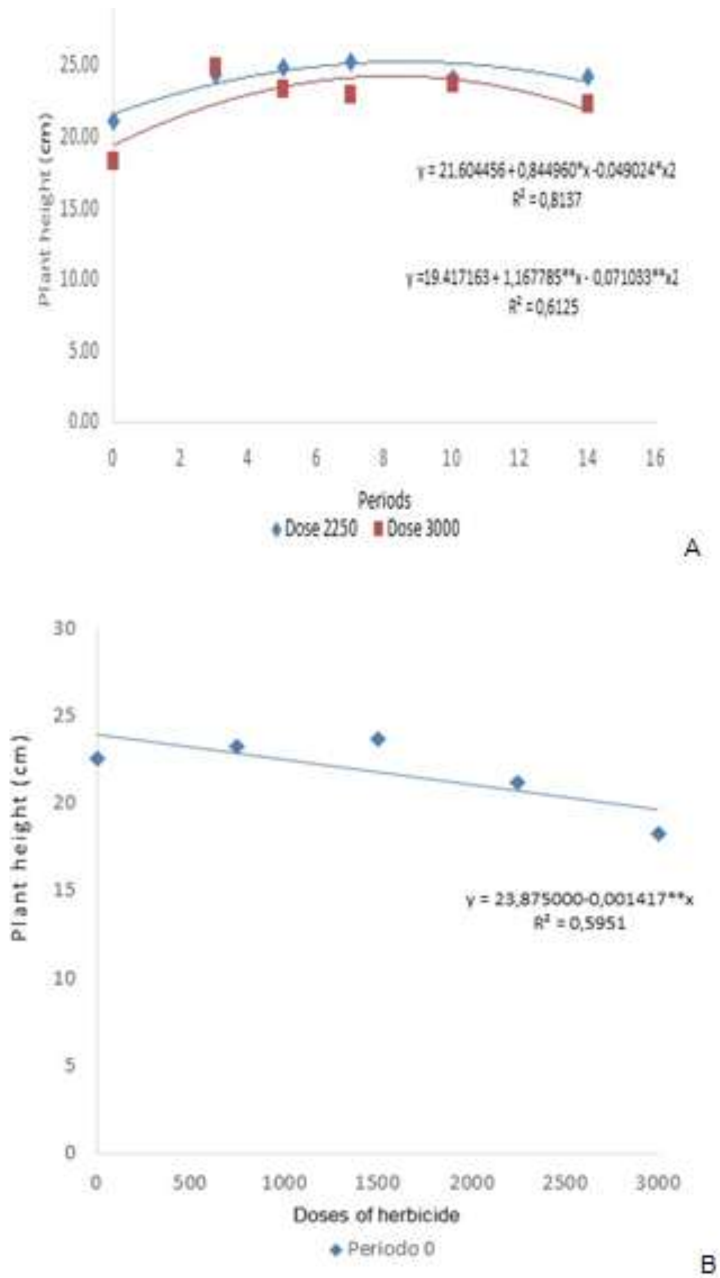

Figure 3. Plant height: Treatments interaction with doses over the periods (a) and treatments interaction in the periods between sowing and spraying, according with the increasing doses (b). ***, **, *: significant a 01, 1 e 5% respectively.

sowing, and as the dose was increased, higher were the symptoms. Similar behavior was observed at 5, 7, 10 and 14 days before sowing. Some studies have reported 2,4-D phytotoxicity in several cultures, alone or mixed with other herbicides, as observed by Nascimento and Yamashita (2009). The authors observed phytotoxicity of species that were sown in a substrate with the mixture of 2,4-D and other herbicides. Similar results were observed in 2,4-D pre-emergence application by Reis (2010), in which there was higher phytotoxicity as the doses increased, causing negative effects on plants.

In the plant height parameter (Figure 3), the only statistically significant treatments were the highest doses (2250 and 3000 e. a. ha^{-1}), and the only application

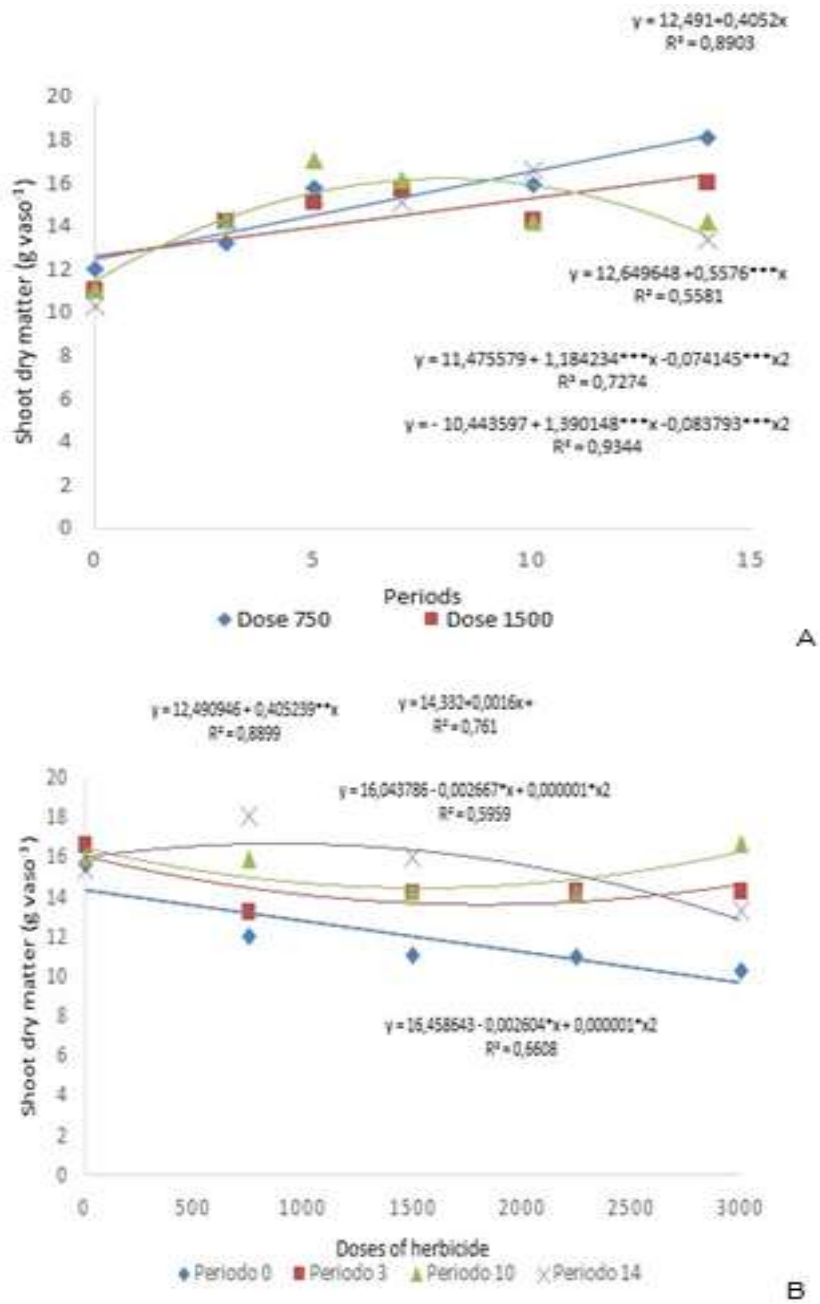

Figure 4. Shoot dry matter. Treatments interaction with doses over the periods (a) and treatments interaction in the periods between sowing and spraying, according with the increasing doses (b). ***, **, *: significant a 01, 1 e 5% respectively.

interval that had lower plant height was at 0 days before sowing. From the following periods (3, 5, 7, 10 and 14 days before sowing), the herbicide mixture did not cause harm to plant height (Figure 3a). Santos et al. (2013) observed plant height decrease in plants that are sensitive to auxinic herbicides, with this variable being inversely proportional to the increase in the dose of the 2,4-D herbicide, in a short interval between product application and seeding. 2,4-D herbicide is of short persistence in the soil, allowing the sowing of crops that are susceptible to it two weeks after application (Rodrigues and Almeida, 2011).

In the study of Silva et al. (2011), all application periods showed reduced plant height. Shoot dry matter (Figure 4) achieved better increases in more distant periods between spraying and seeding (Figure 4a). The 0 dose,

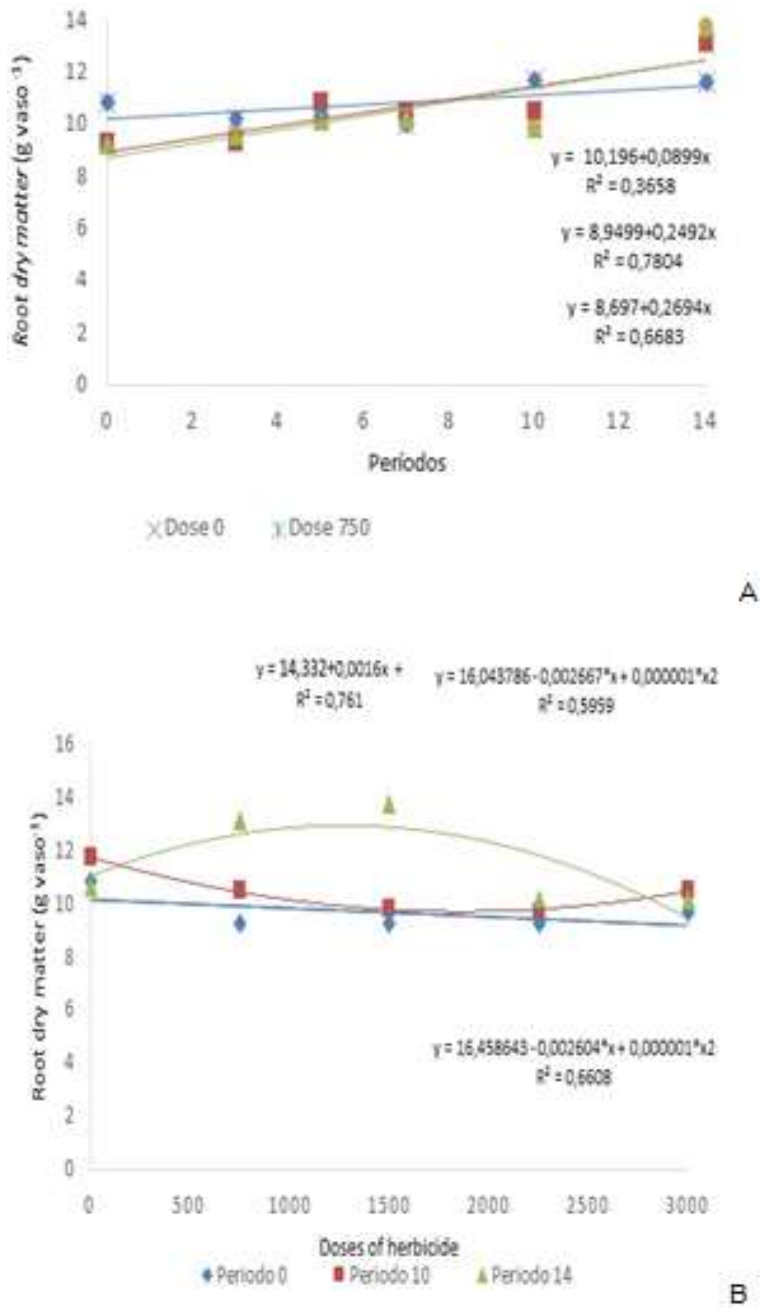

Figure 5. Root dry matter. Treatments interaction with doses over the periods (a) and treatments interaction in the periods between sowing and spraying, according with the increasing doses (b). ***, **, *: significant a 01, 1 e 5% respectively.

without herbicides mixture, performed better, followed by the lowest dose (0.750 g e. a. ha^{-1}). Mixture highest doses (2250 and 3000 g e. a. ha^{-1}) showed better development in the periods of 5 and 10 days before seeding, respectively.

The assessment of doses applied over the days (Figure 4b) showed that the lowest dry matter index occurred at 0 days before sowing. That is, the closer spraying and seeding are, the lower the crop development. The highest shoot dry matter increase occurred at 14 days before sowing. Similar results were obtained by Reis (2010), who observed that 2,4-D doses increase gradually reduced shoot green and dry matter development in corn crops. In the root dry matter parameter (Figure 5), days between each applied dose (Figure 5a) showed that root dry matter was influenced by the distance between seeding and herbicides spraying in both applied doses. The highest number of days between spraying and seeding provided better root development, which is reflected on their weight. Thus, the root system has undergone lower development at shorter herbicide application intervals and increased root growth at 14 days before sowing.

2,4-D and Glyphosate herbicides have deleterious effect on soyben as bioindicator plants, influencing in the reduction of plant dry biomass, height and germination percentage due to their persistence in the soil. Similar results were found by Silva et al. (2011), where dry matter biomass was reduced in all treatments, with the lowest values being observed at 0 days before sowing. There was no statistical difference for 2250 and 3000 doses regarding application periods.

In the doses applied throughout the days (Figure 5b), there was no statistical difference to the doses at 3, 5 and 7 days before sowing. With respect to 0 days before sowing, the lowest herbicide dose could cause low root development. In the interval of 14 days before sowing, there was product dose increase in periods that were more distant from application.

Conclusion

Glyphosate and 2,4-D residual effect is more evident in soybean plants, as the interval between application and sowing decreases. Increased doses act negatively on crop development, providing higher phytotoxic effect and influencing all other parameters. Desiccation with 2,4-D and Glyphosate close to soybean sowing causes phytotoxic effects to the crop and dry biomass reduction due to the residue of this herbicide in the soil

Conflicts of interest

The authors have not declared any conflict of interest.

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