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Dicamba residues in sprayers: Phytotoxicity on non-dicamba tolerant soybean¹

Resíduos de dicamba em pulverizadores: Fitotoxicidade em soja não tolerante ao dicamba

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HIGHLIGHTS:

The triple rinsing was effective in removing dicamba residue in fiberglass and polyethylene tank sprayers.

The sprayer with fiberglass tank accumulated more dicamba residue in the first rinse.

Visual injury, yield loss and plant height reduction were avoided when at least two full tank volume rinses were performed.

ABSTRACT: This study aimed to evaluate the dicamba residue after cleanout procedures in sprayers with different tank materials (fiberglass and polyethylene) and its effects on the symptomatology of non-dicamba tolerant (DT) soybean. The experiment consisted of spraying rinsates collected during a cleanout of boom sprayers on non-DT soybean at the V3 stage. Once the dicamba solution was mixed in the sprayer tank and sprayed, four rinses were made, and for each rinse, a sample was collected. The dicamba residue analyses in each rinse solution were conducted in a completely randomized design with three replicates in a 2 × 4 factorial scheme, corresponding to two sprayer tank materials (fiberglass and polyethylene) and four rinses, using High-Performance Liquid Chromatograph (HPLC). The evaluation of the potential risk of injury on non-DT soybean caused by dicamba residue was conducted in a randomized block design with four replicates and a 2 × 4 + 1 factorial scheme, corresponding to two types of sprayer tank material (fiberglass and polyethylene), four rinses, and control (without application). The dicamba was effectively removed using at least three rinses regardless of spray tank material. Fiberglass tank sprayer retained more residue in the first rinsate, but similar to polyethylene tank sprayer in the following rinses. Plant height was reduced by spraying rinsates collected from the first rinse regardless of tank material. In contrast, visual estimation of injury and reduced yield were observed due to the rinsate application collected from the first and second rinses.

Key words: tank contamination, tank residue, fiberglass tank, polyethylene tank, non-dicamba resistant soybean

RESUMO: O objetivo deste estudo foi avaliar o resíduo de dicamba após a limpeza de pulverizadores com tanques de diferentes materiais (fibra de vidro e polietileno), e os efeitos desse resíduo na sintomatologia de soja não-tolerante ao dicamba. O experimento consistiu na pulverização de água coletada nos enxágues durante a limpeza dos pulverizadores em soja não-resistente ao dicamba no estágio V3. Depois que a solução com dicamba foi misturada no tanque do pulverizador e pulverizada, quatro enxágues foram feitos e, para cada enxágue, uma amostra foi coletada. As análises do resíduo de dicamba nos enxágues foram realizadas em delineamento inteiramente casualizado, com três repetições no esquema fatorial 2 × 4, correspondendo a dois tipos de material do tanque (fibra de vidro e polietileno) e quatro enxágues, utilizando Cromatografia Líquida de Alta Eficiência (CLAE). A avaliação do risco potencial de injúria em soja por resíduo de dicamba foi realizada em um delineamento em blocos casualizados, com quatro repetições, no esquema fatorial 2 × 4 + 1, correspondendo a dois tipos de material do tanque (fibra de vidro e polietileno), quatro enxágues e controle (sem aplicação). O dicamba foi removido efetivamente com a realização de pelo menos três enxágues, independentemente do material do tanque. O pulverizador com tanque de fibra de vidro reteve mais resíduos no primeiro enxágue, mas foi similar ao pulverizador com tanque de polietileno nos enxágues seguintes. A altura das plantas foi reduzida pela aplicação do primeiro enxágue, independentemente do material do tanque, enquanto a estimativa visual de injúria e a redução da produtividade foram observadas pela aplicação do primeiro e segundo enxágues.

Palavras-chave: contaminação de tanque, resíduo do tanque, tanque de fibra de vidro, tanque de polietileno, soja não-resistente ao dicamba

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INTRODUCTION

Dicamba-tolerant (DT) soybean cultivars were developed as an additional tool to control glyphosate-resistant weeds (Behrens et al., 2007; Green, 2014). Dicamba is a synthetic auxin used to control dicotyledonous weed species, especially in cereal crops (Grossmann, 2010). However, the adoption of this technology may cause symptomology in susceptible crops, including non-DT soybean plants (Mortensen et al., 2012; Egan et al., 2014).

Dicamba exposure may occur due to spray particle drift, vapor drift, and tank contamination (Al Heidary et al., 2014; Werle et al., 2018; Jones et al., 2019). Several sprayer parts have the potential to accumulate residues that can cause symptomology in susceptible crops in the following applications (Werle et al., 2018). The retention capacity of these parts depends on material composition. Rough and porous materials are more likely to accumulate residues than smooth and nonporous materials (Cundiff et al., 2017).

Tank cleanout recommendations for dicamba follow a triple rinse procedure in the entire system, generally adding an ammonium-based tank cleaner in the second rinse (BASF, 2019). Many factors affect cleanout effectiveness, such as the amount of water, agitation time, sprayer cleaning system, and tank material, which make difficult a general recommendation for cleanout. Besides that, little information is available in the literature showing the effectiveness of tank cleanout procedures after dicamba applications.

Therefore, this study aimed to evaluate dicamba residue persistency in different sprayer tank materials during the cleanout procedure and the effect of dicamba residue in sprayer tanks on the symptomology of non-DT soybean plants.

MATERIAL AND METHODS

The experiment was conducted during the 2019/2020 harvest at the Capim Branco Experimental Farm of the Universidade Federal de Uberlândia, in Uberlândia, Minas Gerais, Brazil. The geographic coordinates of the area are 18°53'13.7" S, 48°20'37.3" W, located at 842 m above sea level with Aw-type climate classification, tropical wet and dry season during winter (Alvares et al., 2013; Beck et al., 2018).

The research was split into three steps: the first step was related to tank contamination and cleanout procedures, including the collection of samples during the rinses (rinsates); the second step corresponded to the quantification of dicamba in the rinsate samples; the third step related to rinsate applications on non-DT soybean plants to determine the effect of dicamba residue on crop symptomology.

Two types of boom sprayers were used: TLP 400 (Montana, São José dos Pinhais, PR, Brazil; manufacturing year: 2007), with polyethylene tank, MPP 22 pump, and 10 m boom length with two sections; JB 80-400 BR 12 (FMCopling, Araraquara, SP, Brazil; manufacturing year: 2007, average usage: 50 hours per year), with fiberglass tank, KPL 80 pump, and 12 m boom length with four sections. Both sprayers had 400 L tank capacities, pumps that provided 80 L min⁻¹ flow rate, and

hydraulic agitation through return flow. The same cleanout procedures were made for both sprayers.

Although the sprayers were not used to make any dicamba applications, sprayer parts were previously clean to avoid potential interferences from other pesticide residues. Sprayer tank and main, section, and nozzle strainers were cleaned following a triple rinse procedure using dodecylbenzenesulfonic acid (Cleaner TIS[®], Forquímica, Cambira, PR, Brazil) at 0.2% v/v of the commercial product. This product is commonly used for sprayer cleanout procedures. The product was used in the second rinse, and each rinse was made using 300 L of water. The rinsates were sprayed through the boom. Once cleaned, TTI 11002 nozzles and 100 mesh strainers (Teejet Technologies Spraying Systems Co., Glendale Heights, IL, USA) were set in the spray booms.

Diglycolamine salt of dicamba (Atectra[®], BASF São Paulo, SP, Brazil) was tank-mixed with water at 480 g of acid equivalent (a.e.) ha⁻¹ simulating an application at 150 L ha⁻¹ carrier volume. The total volume of spray solution mixed was 300 L, corresponding to a theoretical dicamba concentration of 3.2 g a.e. L⁻¹. Clean water was used for the mixing process, which followed the label recommendations. The herbicide was added to the solution when the tank had 240 L of water, and the sprayer agitation system was working. At 15 min after the mixing was completed, applications were made in a non-planted area using slow travel speed (3 km h⁻¹), boom height close to the ground (0.5 m above ground), and 200 kPa pressure to avoid the spray drift. According to the nozzle manufacturer, ultra-coarse droplet classification is produced at this pressure. At 5, 10, and 15 min after applications were commenced, samples of spray solution (rinsates) were collected from the nozzles. These samples were combined to represent a more accurate dicamba concentration in the spray solution to minimize the collection point and time interference.

After the application was completed and no solution was left in the tank, the sprayer tank was completely filled with water. The dicamba (Atectra[®]) label does not mention the tank material, in special fiberglass, in the cleaning process. Therefore, this process was made with the whole tank volume aiming a better tank cleaning. Moreover, the cleaning systems of the evaluated sprayers were not capable of washing the tank with a smaller volume. However, this volume is an important point that can interfere in the process.

After the agitation system worked for 10 min with sections closed, rinsates were collected from the nozzles at three different points across the spray boom (right, center, and left) at 5, 10, and 15 min after the sections were open and the solution started circulating through the nozzles at 200 kPa. These samples were collected into 2 L plastic bottles previously identified to represent the amount of residues more accurately. The composite sample was analyzed as a single rinse but with three replications in the chromatography technique. Once the tank was run out of solution, the main and section filters were taken out, put in a bucket with clean water, agitated during 15 s, and manually cleaned so possible dicamba residues could be detached.

The procedure aforementioned were repeated three more times, corresponding to second, third, and fourth rinses.

A portion (600 mL) of the rinsate samples was placed into plastic containers and sent to the laboratory for dicamba quantification. The other portion was kept in 2 L plastic bottles in the dark (20-25 °C) until applications were made on non-DT soybean plants.

Study 1 - Quantification of dicamba residue in rinsates

This study was conducted in a completely randomized design (CRD) with three replications in a 2 x 4 factorial scheme, corresponding to two sprayer tank materials (fiberglass and polyethylene) and four rinses. The quantification analysis was performed at the Customer Support and Development Laboratory of the Bayer Crop Science in São José dos Campos, SP, Brazil. The rinsate samples were analyzed using High-Performance Liquid Chromatograph (HPLC) technique. Known aliquots were diluted in water and injected into the chromatograph. The methodology was previously validated, and the chromatograph was calibrated using known standard dicamba concentrations. The quantification of dicamba in the rinsate samples were made using the estimative concentration technique (mg a.e. L⁻¹) based on values obtained with an analytical standard set-in chromatograph.

Study 2 - Soybean response to dicamba residue in rinsates

The potential damage caused by dicamba residue in rinsates was measured by spraying the rinsates on glyphosate-tolerant and non-DT soybean (NS 6906 IPRO, Nidera, São Paulo state, Brazil) in experimental plots, planted at 350,000 seeds ha⁻¹ (3 cm depth and 0.5 m row spacing). Plot dimensions were 5 m in length by 2 m wide (10 m² plot⁻¹). An N-P-K formulation (02-25-10) was used while planting at 320 kg ha⁻¹, and 250 kg ha⁻¹ of KCl was applied 54 days after planting when soybean was at the R2 growth stage. Control of insects, diseases, and weeds was made by spraying pesticides as needed.

This study was conducted in a randomized block design (RBD) with four repetitions in a 2x4+1 factorial scheme. The factors corresponded to two types of sprayer tank material

(fiberglass and polyethylene), four rinses, and control (without application). The rinsate from the first rinse represents an application without previous cleanout procedures. Simultaneously, the rinsate from the fourth rinse (also known as “follow-up”) represents an application after the triple rinse. Applications were made when soybean was at the V3 growth stage (timing when dicamba would be more likely to be sprayed in the field) using a CO₂ backpack sprayer (Herbicat, Catanduva, SP, Brazil) with a four-nozzle boom (0.5 m nozzle spacing), TTI 110015 nozzles (Teejet Technologies Spraying Systems Co., Glendale Heights, IL, USA), 200 kPa pressure, and 3.8 km h⁻¹ walk speed to deliver 150 L ha⁻¹ carrier volume. Meteorological conditions were recorded during applications using a thermo-hygro-anemometer (Kestrel, Boothwyn, PA, USA). The temperature ranged from 23.1 to 24.0 °C, air relative humidity was between 70.0 and 76.8%, and wind speed ranged from 0.2 to 5.1 km h⁻¹.

Visual estimations of soybean injury were recorded at 7, 14, 21, and 28 days after application (DAA), rated on a 0 to 100% scale (Table 1), with 0% representing no crop injury and 100% representing complete plant death (Robinson et al., 2013).

Plant heights were recorded using tape measures when soybean reached the maturity growth stage (R8) by randomly choosing three plants in each plot. For yield evaluation, plants in the two middle rows of the plots were manually harvested and mechanically threshed. Plants within a border of 1 m on each side of the plot were not harvested. Impurities in samples were separated, and then soybean grain weight was recorded. Grain weight was adjusted to 13% moisture and converted into yield (kg ha⁻¹).

Data were analyzed using R Software (R Core Team, 2019). The normality of residuals was tested using the Shapiro-Wilk test. The homogeneity of variance was tested using the Bartlett and O'Neil & Mathews tests for the studies conducted in CRD and RBD, respectively. Interactions between blocks and treatments were tested using the Tukey test for additivity. When assumptions were not reached at $p \leq 0.01$, data was transformed

Table 1. Rating scale for visual estimation of soybean injury (Robinson et al., 2013)

Rating	Description
0	No injury; plant growth is normal.
10	Slight reduction in height or canopy volume, cupped or bubbled leaves on less than or equal to the upper 10% of the plant, bent petioles, and chlorosis or necrosis.
20	Moderately crinkled leaflets (in less than or equal to 20% of the plant), curled petioles, reduced height and canopy volume, cupped terminal leaflets.
30	From moderate to a high reduction of height and canopy; compacted internodes and plants begin to have an abnormal appearance; malformation with drawstring, fiddleneck, or cupped effects on less than or equal to the upper 30% of the plant; many petioles curled, and main stems may be bent.
40	Highly stunted plants (less than or equal to 40% of the plant), petioles curled, and main stems bent or starting to curl, upper leaves exhibit severe malformation and expansion of new leaves suppressed, the plant may have patches of necrotic tissue.
50	Very high reduction of plant height (less than or equal to 50% of the plant) with little likelihood of recovery from the apical meristem, new growth suppressed, formation of pods reduced or malformed, some leaf and stem tissue becomes necrotic, petioles and stems show severe twisting.
60	Severe height and canopy reduction, including any new growth from axillary buds; leaves severely cupped or fiddle necked on less than or equal to 60% of the plant; petioles and stems twisted, swollen, and splitting; more extensive die-back of tissue.
70	Severe to very severe reduction of plants, new growth callused and inhibited, most leaves severely deformed and mostly necrotic, extensive petiole bending.
80	Very severe soybean injury, less than or equal to 80% of the plants mainly prostrate, petioles twisted with leaves drooping, leaves chlorotic or necrotic, stems severely twisted, swollen, and split.
90	Plant dying, less than or equal to 90% of the plants mainly prostrate, leaves and stems mostly chlorotic or necrotic, all petioles severely twisted, swollen, or split.
100	All plants dead.

and subjected to another round of assumptions analysis. Once assumptions were reached at $p > 0.01$, data were subjected to analysis of variance, and mean comparisons were made using the Tukey test. Comparisons between the treatments and untreated control were made using the Dunnett test ($p \leq 0.05$).

RESULTS AND DISCUSSION

A significant interaction ($p \leq 0.05$) between tank material and the number of rinses was observed for dicamba residue and visual estimation of injury on soybean plants at 14, 21, and 28 days after application (DAA) (Table 2). Only the number of rinses was significant for visual estimation of injury at 7 DAA, plant height, and grain yield.

The amount of dicamba residue in rinsate samples was affected by the tank material and the number of rinses during the cleanout procedure (Table 3). The first rinsate sample collected from the fiberglass tank sprayer had a 2.2-fold greater dicamba concentration than the rinsate collected in the polyethylene tank sprayer. However, dicamba concentration in rinsates collected from both tanks was similar at second, third, and fourth rinses.

Fiberglass and polyethylene are common materials used in sprayer tanks. Both materials are mechanically resistant, although the polyethylene tanks have a smooth internal surface that facilitates cleanout processes (Minguela & Cunha, 2010). Rough surfaces have a greater potential of retaining pesticides and make cleanout processes more difficult (Cundiff et al., 2017). Thus, fiberglass tanks may retain more residues than other types of tank materials (Eberlein et al., 1997). More residues were retained in the fiberglass tank sprayer during the spray solution before the cleaning process in the present study.

When dicamba concentration is compared across rinses, most residues were removed from the tanks during the first rinse, reaching 97.0 and 93.3% of the total residue detected from four rinses of fiberglass and polyethylene tanks sprayer, respectively. The dicamba concentration detected from the first rinsate corresponded to 2.14% of the initial concentration for the fiberglass tank sprayer and 0.95% for the polyethylene tank sprayer. In the following rinses, the dicamba concentrations were lower than 1.2 mg L^{-1} . The dicamba concentration detected from the second, third, and fourth rinsates was similar between both tank materials, representing on average 0.037, 0.019, and 0.016% of initial concentration, respectively.

Luke (2017) observed that at least 79.8% of dicamba residue was removed from the tank sprayer at the first rinse, reaching a maximum value of 93.3%. The number of rinses was crucial in reducing herbicide concentration, whereas the cleanout effectiveness was variable when cleaning products were used.

Table 3. Dicamba concentration in rinsates collected before and during cleanout procedure (four rinses) of two sprayer tank materials

Rinse	Dicamba concentration (mg L^{-1})	
	Sprayer tank material	
	Fiberglass	Polyethylene
First ¹	68.37 aA	30.50 bA
Second	1.13 aB	1.11 aB
Third	0.54 aC	0.60 aC
Fourth ²	0.48 aC	0.49 aD
Spray solution ³	3008.55	3042.67

Means followed by the same lowercase letters in the lines and uppercase letters in the column do not differ by the Tukey test ($p \leq 0.05$); ¹The first rinse represents an application without previous cleanout procedures; ²The fourth rinse represents an application after the triple rinse; ³The spray solution represents the concentration of dicamba collected from the nozzles during the sprayer tank contamination procedures

According to this author, water itself resulted in greater performance than cleaning products on removing dicamba in the first year of study. In contrast, the opposite was observed in the second year of study.

However, Inman (2019) did not observe differences in dicamba concentration due to the cleaning agent (water, tank cleaning product, and ammonia), along with the rinses. There was also no difference between the dicamba concentrations between the third rinse and the subsequent rinse. Similarly, Browne (2020) found that the triple rinse procedure with water achieves similar results using ammonia and tank cleaning product in rinses. Thus, the use of some products in the cleaning process may not bring additional benefits for removing dicamba concerning the triple rinse with water due to the high water solubility of this herbicide.

Osborne et al. (2015) evaluated the effectiveness of cleanout procedures made by applicators in the US and found that dicamba concentration retained in the sprayer tank was exponentially reduced as the number of rinses increased, and the first rinse was responsible for removing up to 95% of residue in most of the sprayers. Despite the reduction of dicamba residue throughout rinses, additional factors may affect the cleanout effectiveness and risk of damage to susceptible crops, such as (1) internal cleaning system which may provide better contact between tank cleaner and tank internal surface, and (2) amount of water, because higher volumes of water used in each rinse diminish the herbicide concentration.

Carpenter (2019) evaluated the dicamba concentrations along the rinses using 10, 20, 40, and 60% of the total tank capacity. It was observed that higher volumes of water resulted in lower concentrations of dicamba in the first three rinses, and no difference was observed in the fourth rinse.

Considering that the first rinse removed most dicamba residue in the tank, it was expected that this treatment would produce a greater soybean visual estimation of injury. At 7 DAA,

Table 2. Summary of analysis of variance

SV	DF	Sprayer residue ¹	Visual estimation of injury				Plant height	Grain yield
			7 DAA	14 DAA	21 DAA	28 DAA		
			F-values					
Sprayer tank (ST)	1	412.7*	1.642	9.013*	17.408*	7.705*	0.0019	0.072
Rinse (R)	3	31591.2*	192.831*	543.672*	1132.460*	568.252*	33.678*	5.019*
ST × R	3	457.2*	0.669	5.168*	11.724*	6.007*	0.656	0.966
CV (%)		1.68	38.2	20.51	14.24	22.72	5.26	8.71

* - Significant at $p \leq 0.05$ by the F-test; CV - Coefficient of variation; SV - Source of variation; DF - Degrees of freedom; ¹Original data was transformed using $\log(x + 1)$; DAA - Days after application

soybean visual estimation of injury was only affected by the number of rinses, and the first rinse resulted in 20.0 to 22.5% injury regardless of sprayer tank material (Table 4).

At 14, 21, and 28 DAA, soybean visual estimation of injury depended on the interaction between sprayer tank material and the number of rinses. By making comparisons within rinse, rinsates collected from the fiberglass tank sprayer resulted in greater crop injury than polyethylene tank sprayer in the first rinse; however, no differences were observed between both tanks in the following rinses.

Lower soybean visual estimation of injury levels was observed at 7 DAA, whereas the greatest levels were observed at 14 and 21 DAA. At 28 DAA, the visual ratings were lower because of soybean development and recovery. At 7 DAA, the crop visual estimation of injury caused by rinsates collected from the first rinse of both tank materials was greater than the untreated control, similarly as observed at 14, 21, and 28 DAA, for the rinsates collected from the first and second rinses. Similar findings were observed by Luke (2017), who evaluated sprayer cleanout processes in two locations and two years. The author observed that the first rinse had the potential to cause greater crop injury, and the second and third rinses produced intermediate and low injury levels, respectively.

Kniss (2018) conducted a meta-analysis to evaluate dicamba dose-response using non-linear models and found that a 5% soybean visual injury is estimated to be caused by 0.038, 0.048, and 0.038 g ae ha⁻¹ at V1-V3, V4-V7, and R1-R2 growth stages, respectively. However, it is difficult to obtain the exact dicamba amount to which plants were exposed, meaning that yield loss prediction due to visual estimation of injury is not adequate, especially when the exposure occurs during vegetative stages (Egan et al., 2014).

It has been reported that exposure of susceptible plants to dicamba can affect their heights due to reduced apical meristem, petioles, and leaves (Soltani et al., 2016; Osipitan et al., 2019). In this study, plant reduction was only observed when soybeans were exposed to the rinsates collected from the first tank rinse, reaching an average of 22% shorter plants than the untreated control (Table 5). No differences were observed between the other rinses (second, third, and fourth) and untreated control. Similar plant heights were observed when soybeans were exposed to the rinsates collected from the second, third, and fourth rinses regardless of tank material.

The application of rinsates collected from the first and second rinses resulted in 17 and 7% yield losses, respectively,

Table 4. Visual estimation of injury on soybean produced by applications of dicamba rinsates collected during cleanout procedure (four rinses) of two sprayer tank materials

Rinse	Visual estimation of injury (%)								
	7 DAA ¹		14 DAA		21 DAA		28 DAA		
	Sprayer tank material								
	FG	P	Mean	FG	P	FG	P	FG	P
First	*22.5	*20.0	21.3 A	*42.5 aA	*35.0 bA	*41.3 aA	*33.8 bA	*33.8 aA	*27.6 bA
Second	3.1	1.9	2.5 B	*10.6 aB	*8.8 aB	*9.4 aB	*8.1 aB	*4.4 aB	*3.8 aB
Third	0.6	0.6	0.6 B	0.6 aC	0.6 aC	0.6 aC	0.6 aC	0.0 aC	0.0 aC
Fourth	0.0	0.0	0.0 B	0.0 aC	0.0 aC	0.0 aC	0.0 aC	0.0 aC	0.0 aC
Mean	6.6	5.6							
Control		0.0		0.0		0.0		0.0	

Means followed by the same lowercase letters in the lines and uppercase letters in the column do not differ by the Tukey test ($p \leq 0.05$); * - Means different from untreated control by the Dunnett test ($p \leq 0.05$); FG - Fiberglass tank material; P - Polyethylene tank material; DAA - Days after application; ¹The interaction was not significant at 7 DAA

Table 5. Soybean plant height at the R8 stage and grain yield affected by applications of dicamba rinsates collected during cleanout procedure (four rinses) of two sprayer tank materials

	Plant height (m)	Grain yield (kg ha ⁻¹)
	Rinse	
First	0.65 b	2758 b
Second	0.82 a	3073 ab
Third	0.81 a	3222 a
Fourth	0.82 a	3197 a
Sprayer tank material		
FG	0.77	3050
P	0.77	3076
Control	0.83	3308

Means followed by the same letters do not differ by the Tukey test ($p \leq 0.05$); FG - Fiberglass tank material; P - Polyethylene tank material

concerning the untreated control (Table 5). The tank material did not affect plant height and crop yield, whereas two or more rinses reduced dicamba symptomology on soybean. By making one tank rinse, representing an application without previous cleanout procedures, approximately 400 kg ha⁻¹ soybean yield loss was observed compared to four tank rinses, representing an application after the triple rinse. This result emphasizes that sprayers used to apply dicamba must be rigorously clean before any application on non-DT soybean or susceptible crops.

Carpenter (2019) observed that when the cleaning procedure was performed with a water volume of 10% of the total capacity of the tank, the triple rinse was not enough to prevent injury, reduced plant height, and crop yield of the non-DT soybean plants. However, when the rinses were performed with volumes of 40 and 60% of the tank capacity, less impact was observed on the non-DT soybean for the same characteristics evaluated.

As non-DT soybeans are extremely susceptible to dicamba, possible residues attached to the sprayer tank and other parts, even at extremely low amounts, have the potential to cause crop symptomology. However, visual estimation of injury does not always lead to yield loss, which depends on herbicide rate and growth stage during the exposure (Osipitan et al., 2019). Other factors may also affect soybean response to dicamba exposure, such as cultivar, physiological condition, crop plasticity, and meteorological conditions during the cropping development season (Auch & Arnold, 1978; McCown et al., 2018).

In summary, non-DT soybean can be affected by different sources of dicamba exposure, such as tank contamination. This study was conducted under experimental conditions, and results might vary according to other variables observed in the

field. Rate, carrier volume, and load mixing solution may affect the amount of residue attached to the tank and other parts of the sprayers. Considering that sprayers used only for dicamba applications are not a reality for most growers and applicators, sprayer cleanout procedures are extremely important to avoid symptomatology on susceptible plants. In short, it was verified that the number of rinses is a crucial factor in sprayer tank cleanout.

CONCLUSIONS

1. The tank cleanout procedure with three full tank volume rinses was efficient in removing dicamba residue, regardless of sprayer tank material (fiberglass or polyethylene).

2. Fiberglass tank sprayer retained a higher amount of dicamba at the first rinse; however, no difference in dicamba concentration was observed than the polyethylene tank sprayer after the first rinse.

3. Applications of rinsates collected from the first and second rinses caused visual injury and yield loss on non-DT soybean. Plant height was not reduced when two or more rinses were made, although the manufacturer's recommendation is at least three rinses.

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