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Article

News Techniques for the Application of Herbicides on Soybean Crops

Novas Técnicas para a Aplicação de Herbicidas na Cultura da Soja

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ABSTRACT - There is a need for an increase nin efficiency and a reduction in the risk of environmental contamination in controlling weeds; this can be obtained with the development of the new techniques for the application of herbicides. The objective was to verify the efficiency of different herbicide application techniques on soybean crops (*Glycine max* (L.) Merrill). The experiment was conducted in a commercial area in the municipality of Sinop, Mato Grosso state. The design was a randomized block, with four replications and six treatments, namely: herbicide application with a manual backpack sprayer; application with an acrylic wool roll with 9 mm long hairs; sheep's wool roller with 9 mm long hairs; high density polyester foam roller; weeding with a hoe and free growth (no control). The used cultivar was TMG 132. The herbicide spray used in the treatments was: glyphosate 960 g ha^{-1}, 80 g ha^{-1} haloxyfop-p-methyl 600 mL ha^{-1} and oil, diluted in water and applied 14 and 27 days after emergence (DAE). The weed population, vegetative growth, chlorophyll content and soybean yield were evaluated. The use of the sprayer and the application with the sheep's wool roller showed greater efficiency in weed control, but the mixture of herbicides resulted in culture phytotoxicity when applied via foliar spraying.

Keywords: spray, rollers, application technology.

*RESUMO - Há necessidade de aumento na eficiência e redução no risco de contaminação ambiental no controle de plantas daninhas, o que pode ser obtido com o desenvolvimento de novas técnicas de aplicação de herbicidas. Objetivou-se neste estudo verificar a eficiência de diferentes técnicas de aplicação de herbicidas na cultura da soja (**Glycine max** (L) Merrill). O experimento foi instalado numa área de lavoura comercial de cultura da soja no município de Sinop-MT. O delineamento utilizado foi em blocos ao acaso com quatro repetições e seis tratamentos: aplicação de herbicida com auxílio de pulverizador costal manual; aplicação com auxílio de rolo de lã acrílica com fios de 9 mm de comprimento; rolo de lã de carneiro com fios de 9 mm de comprimento; rolo de espuma de poliéster de alta densidade; capina com enxada; e livre crescimento (testemunha; sem controle). O cultivar utilizado foi o TMG 132. A calda com herbicida usada nos tratamentos foi: glifosato 960 g ha^{-1}, 80 g ha^{-1} de haloxifop-p-metílico e 600 mL ha^{-1} de óleo, diluídos em água e aplicados aos 14 e 27 dias após a emergência (DAE). Avaliou-se a de população de plantas daninhas e, na soja, o crescimento vegetativo, os teores de clorofila e a produtividade. O uso de pulverizador e a aplicação com rolo lã de carneiro apresentaram maior eficiência no controle de invasoras. A mistura de herbicidas resultou em fitotoxidade na cultura apenas quando aplicada via pulverização foliar.*

Palavras-chave: pulverização, rolos, tecnologia de aplicação.

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INTRODUCTION

The climate of Mato Grosso is favorable for soybean yield, but also contributes to the germination and growth of weeds, which act negatively on soybean growth and yield (Carvalho et al., 2002). Among the damages to the culture, Juan et al. (2003) verified that the reduction can reach 40% in the number of pods and 6.5% in the number of grains per pods.

There are several technologies for herbicide application, and the most common is the chemical application with foliar spraying, which stands out for the working efficiency, especially in large cultivation areas, for the price and easy handling. Currently, the dependence of spraying is great; manual weeding is incompatible with the technology used in the system (Carvalho et al., 2002).

The application of herbicides by foliar spraying is a well-established technology, but farmers are bound to environmental conditions and to a strict orientation in the choice and the way of using this equipment (Dornelles et al., 2009).

Problems in the use of sprayers include drifting, which is a deviation of the product from the target to be achieved; the product is dispersed in the air, moves and reaches a different location than the desired one (Gandolfo et al., 2013). In addition to drifting, even selective post-emergence herbicides, when they reach crops, especially under excessive doses and volume and wrong spraying calibration, promote crop damages, which reduce productivity (Beltrão et al., 2001).

Despite all the mentioned problems, the application of herbicides through foliar spraying is a technology that has not been replaced yet. The objective of this work was to evaluate and test the use of "paint" rollers with different materials, compared to backpack spraying, on weed control, in order to develop a new implement to help the application of chemical pesticides on soybean crops.

MATERIAL AND METHODS

The experiment was conducted between October 2014 and March 2015, in a commercial area, in a property located in the municipality of Sinop - Mato Grosso state, with the following coordinates: latitude 11°52'23" S, longitude 55°29'54" and altitude of 380 m. The climate is classified, according to Koppen-Geiger, as Am, having two well-defined seasons, a rainy one between October and April, and a dry one, from May to September. The annual thermal amplitude varies between 24 and 27 °C. The experimental design was in randomized blocks with four replications and six treatments.

Treatments were: application with an acrylic wool roller, 9 mm long; acrylic wool roller, 4 mm long; application with high density polyester foam roller; application of herbicides through a manual backpack sprayer with fan-type XR 11002VS nozzles; mechanical hoe control (7 and 27 DAE); and lack of control (free growth). Figure 1 shows the application mode via wool roller and the used types of roller, and Figure 2 shows the design of the equipment to be developed for weed control. The experimental plots consisted of five lines of five meters in length and a spacing of 0.5 m, totaling 12.5 m². The border consisted of two lateral lines of the plot and 0.5 m between the plots.

The soybean cultivar TMG 132 RR was used to seed 15 seeds per linear meter, reaching a mean population of 260,000 thousand ha^{-1} plants. Before sowing, seeds were inoculated with *Bradyrhizobium japonicum* and treated with Co and Mo micronutrients at the dose of 3 g ha^{-1} and 30 g ha^{-1}, respectively. In the basal fertilization, 100 kg ha^{-1} of P_2O_5 and 50 kg ha^{-1} of K_2O were used and, 30 days after emergence, the same dose of K_2O was applied in cover. The herbicide mixture used in the application technology treatments had the following composition: 960 g of glyphosate ha^{-1}, 80 g ha^{-1} of haloxyfop-p-methyl and 600 mL ha^{-1} of oil. Two applications of the herbicide mixture were performed during the critical period of crop competition at 7 and 27 DAE, always in the morning period. The spraying volume applied in the treatments was 100 L ha^{-1} in the application with a manual backpack sprayer and 20 L ha^{-1} in the treatments with different rollers. It is worth mentioning that weeding, from the mechanical weeding treatment with hoe, was made in the same time frame of herbicide applications.

(A)

(B)

Figure 1 - (A) Method of application via sheep's wool roll, (B) Three types of roller: application with 4 mm long acrylic wool roller, 9 mm long sheep's wool roller and high density polyester foam roller.

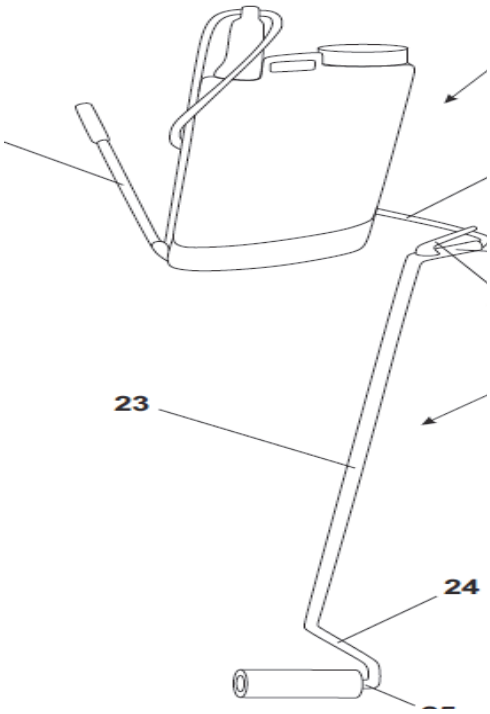

Figure 2 - Design of the equipment to be developed to control weeds, following the concept used in the control with "rollers".

A survey about species and quantification of weed individuals was performed 14, 21, 28 and 35 DAE. For this, a wood frame with 0.25 m^2 (0.50 x 0.50 m) was cast between the lines of the crop in each plot (Pereira et al., 2016). The specific composition of the weed community (identification of weed species) and the density of individuals (direct counting) were determined at the sampling site through the wood frame. The shoots of the weeds were collected, identified, stored in paper bags and taken to a forced air circulation oven at 60 °C, where they were dried until constant weight, obtaining the mass of the weed shoot, with the help of a precision scale.

In the soybean crop, the chlorophyll content was evaluated during full flowering, using a clorofiLOG chlorophyll meter (model CFL-1030). For this variable, three random plants per plot with three intact leaves were evaluated in the median region of plants.

The vegetative growth was also determined during full flowering, obtaining the height of plants, number of leaves, number of nodes, stem diameter and shoot dry matter. The height of plants was obtained with the help of

a measuring tape, measuring from the soil to the apical meristem of plants. The stem diameter was obtained at 5 cm from the soil, with the help of a digital caliper, and the number of nodes and leaves was obtained by counting the structures. After the measurements on the field, plants were cut close to the ground, placed in paper bags and taken for drying in a forced air circulation oven at 60 °C until constant weight, obtaining the shoot dry matter (Pereira et al., 2014).

Harvesting was done manually when grains had approximately 180 g kg^{-1} of water, and the trailing and threshing of soybean grains were done manually. After these steps, in order to perform production evaluations, soybean had its moisture corrected to 130 g kg^{-1} of water. The initial water content of grains was determined by the direct method, in a forced air circulation oven, at a temperature of 105 °C for 24 hours (Brasil, 2009).

After harvesting, 1,000 grain weight, number of pods and yield ha^{-1} were obtained. The 1,000 grain weight was obtained by the sum of the average weight of ten samples of one hundred grains from each plot. The number of pods was determined by adding the pods of all plants from the useful plot, and yield was quantified through grain production in the useful area of the plot, being transformed into kg ha^{-1}.

The obtained data were submitted to analysis of variance with the help of the SISVAR software (Ferreira, 2011). In case of significance by the F test ($p > 0.05$) of the analysis of variance, the means were compared by Tukey's test.

RESULTS AND DISCUSSION

The weed population was significantly altered by different technologies of herbicide application and control. The dominant species in the experiment area was the benghal dayflower (*Commelina benghalensis*).

It was verified that the herbicide application with a sheep's wool roller and foliar spraying were the most effective in controlling weeds (Tables 1 and 2). As for the foliar application, it is possible to verify that it had 100% efficiency. Souza et al. (2010) also reached 100% in the control of *Commelina benghalensis*, in two foliar applications with glyphosate.

The efficiency of the sheep's wool roller application can be explained by the intimate contact between the roller and the plants, by the absence of drifting and by the ability of the roller coating material (sheep's wool) to absorb and release liquids (herbicide mixture); this did not occur with the synthetic wool roller and the foam roller, which showed intermediate control (Tables 1 and 2). According to Gandolfo and Mosquini (2005), to be successful in an herbicide application, there must be an efficient and even coverage, target penetration (plant mass) and low drifting or evaporation.

The treatment with free growth (without control) was the most infested, reaching 135 individuals, or 18 g of dry matter $plot^{-1}$ at 35 DAE. In the treatment with hoe, the occurrence of weeds is due to the time between the weeding, which was 20 days. It is known that weed seeds have a germination period of six days (Correia and Durigan, 2004).

Table 1 - Mean number of weed individuals, 14, 21, 28 and 35 days after emergence (DAE) and application dates at 7 and 27 AA, after applications of weed control methods. Sinop – Mato Grosso state

Treatment	Number of individuals			
	1st application (7 DAA)		2nd application (27 DAA)	
	14 DAE	21 DAE	28 DAE	35 DAE
Free growth	59.00 b	103.00 b	97.00 c	135.00 c
Synthetic wool roller	0.00 a	14.50 a	41.50 b	13.75 b
Hoe	4.00 a	3.75 a	0.00 a	0.00 a
Foam roller	2.00 a	4.00 a	17.50 ab	14.00 ab
Sheep's wool roller	0.00 a	0.00 a	0.00 a	0.00 a
Sprayer	0.00 a	0.00 a	0.00 a	0.00 a

Averages followed by the same letters do not differ from each other at 5% probability.

Table 2 - Dry mass (g) of weeds at 7 and 14 DAA, after application of weed control methods. Sinop – MT

Treatment	Weed dry matter			
	1st Application		2nd Application	
	7 DAA	14 DAA	7 DAA	14 DAA
Free growth	16.40 b	18.25 b	7.97 a	18.00 b
Synthetic wool roller	0.00 a	4.20 ab	7.99 a	2.49 ab
Hoe	1.55 a	2.53 ab	0.00 a	0.00 a
Foam roller	0.00 a	0.00 a	3.11 a	2.00 a
Sheep's wool roller	0.00 a	0.00 a	0.00 a	0.00 a
Sprayer	0.00 a	0.00 a	0.00 a	0.00 a

Averages followed by the same letters do not differ from each other at 5% probability.

Among the vegetative characteristics, plant height, number of leaves and shoot dry matter were significantly altered by different technologies and herbicide applications (Table 3). The lowest plant height occurred with the foliar application of herbicides (70.75 cm). Treatments with synthetic wool rollers, hoe weed, foam roller and sheep's wool roller did not differ from each other at 5% probability. The greatest plant height occurred in the treatment with free growth (absence of control) (84.25 cm). Plants with the lowest number of leaves were observed in free growth treatments (13) and with the synthetic wool roller (17.5). The use of hoe had an intermediate behavior (18.5), and the treatments with a backpack sprayer (21.25), foam roller (19.5) and sheep's wool roller (20.5) did not differ from each other (Table 3). The highest shoot dry matter occurred in the treatment with the sheep's wool roller (8.90 t ha^{-1}), but not differing from the application with the foliar sprayer. In free growth, the lowest dry matter (4.93 t ha) and the other technologies showed intermediate behavior.

Weeds reflect a tone of light that is recognized by the crop, which responds growing in height even though it is not in competition. This adaptive mechanism of the crop is a way for plants to capture the maximum available light, generating shade on weeds (Taiz and Ziegler, 2013).

The stimulation of soybean growth in the presence of weeds generates plant dewatering, modifying physiological processes such as: cell division and hormone production, which reduces the absorption of nutrients and water and, consequently, the photosynthetic rates (Rajcan and Swanton, 2001).

Soybean vegetative growth (Table 3) was closely related to weed control levels (Tables 1 and 2). Fleck et al. (2007) correlated a lower dry matter and number of soybean leaves to the infestation intensity of *Bidens pilosa* (blackjack) and attributed this fact to the competition between crop and weeds for nutrients, CO_2, water and light.

Treatments did not significantly affect the stem diameter, chlorophyll index, number of branches and number of nodes (Table 4). Opposite results were found by Cabral et al. (2013) in sorghum, with a reduction in the stem diameter of sorghum coexisting with weeds. Fleck et al. (2007) verified that the coexistence of soybean plants and blackjack reduced the number of branches of the crop.

It should be emphasized that, probably, the absence of differences in this work can be attributed to weed populations, which may not have reached sufficient values to interfere with these variables, or to the weed species present in the area, to Benghal dayflower (*Commelina benghalensis*), which normally interferes in the physiological aspects of the cultures, such as photosynthesis and transpiration, influencing to a lesser extent their morphological aspects (Lemos et al., 2013).

The number of pods, grains per pod and the 1,000 grain weight were not significantly altered by the treatments, with the exception of productivity. The highest productivity occurred in the application of herbicide via sheep's wool roller, reaching 3,530.44 kg ha^{-1}, and the lowest occurred in the free-growth treatment, reaching 2,362.10 kg ha^{-1}, with a difference of 49.46% between these two treatments. Treatments with the backpack sprayer, hoe weeding, synthetic wool roller and foam roller had an intermediate productive behavior (Table 5).

Table 3 - Average plant height, number of leaves and shoot dry matter obtained in the flowering of soybean, after the application of weed control methods. Sinop – Mato Grosso state

Treatment	Analyzed variables		
	Height (cm)	N. of leaves	Shoot dry matter (t ha^{-1})
Free growth	84.25 a	13.00 b	4.93 b
Synthetic wool roller	76.00 ab	17.50 b	5.27 ab
Hoe	77.37 ab	18.50 ab	6.95 ab
Foam roller	81.50 ab	19.50 a	6.22 ab
Sheep's wool roller	81.50 ab	20.50 a	8.90 a
Sprayer	70.75b	21.25 a	7.45 a

Averages followed by the same letters do not differ from each other at 5% probability.

Table 4 - Means of diameter, chlorophyll index, number of branches and number of nodes, after the application of weed control methods. Sinop – Mato Grosso state

Treatment	Analyzed variables			N. of nodes
	Diameter (mm)	Chlorophyll index	N. of branches	
Free growth	7.16 a	52.63 a	4.00 a	8.00 a
Synthetic wool roller	7.43 a	54.64 a	5.00 a	8.25 a
Hoe	7.51 a	52.92 a	4.25 a	8.25 a
Foam roller	7.46 a	53.65 a	4.00 a	9.25 a
Sheep's wool roller	7.70 a	51.90 a	5.00 a	8.75 a
Sprayer	7.77 a	51.65 a	4.75 a	9.00 a

Averages followed by the same letters do not differ from each other at 5% probability.

Table 5 - Mean number of pods (NP), number of grains per pod (GGP), 1,000 grain weight (W1000) and productivity, after the application of weed control methods. Sinop – Mato Grosso state

Treatment	Analyzed variables			Productivity (kg ha^{-1})
	NP	GGP	W 1000 (g)	
Free growth	71.25 a	1.46 a	131.86 a	2,362.10 b
Synthetic wool roller	66.50 a	1.90 a	136.45 a	2,855.93 ab
Hoe	63.50 a	1.85 a	138.51 a	2,820.99 ab
Foam roller	74.00 a	1.59 a	167.05 a	3,037.87 ab
Sheep's wool roller	77.75 a	1.93 a	163.14 a	3,276.63 ab
Sprayer	88.25 a	1.75 a	144.82 a	3,530.44 a

Averages followed by the same letters do not differ from each other at 5% probability.

It is possible to verify that plants in free growth had the maximum competition between weeds and culture, and in treatments with hoe, foam roller and synthetic wool roller the presence of some invaders in smaller amount was verified (Tables 1 and 2); this reduced the lowest vegetative growth of the plants in these treatments (Table 3), due to a greater competition for water, light, CO_2 and nutrients between them, which reached the final productivity (Oliveira Jr et al., 2006; Fleck et al., 2007).

However, the reduction in soybean yield should not be completely attributed at the presence of weeds only to the competition for space, nutrients, light, CO_2 or water; there is also the allelopathic effect that these plants have on agronomic crops (Melhorança Filho et al., 2011).

Although it did not suffer weed interference, the application with the backpack sprayer had a statistically equal productivity to treatments that presented infestation and below the ones with the sheep's wool roller (most productive treatment). This fact is due to phytotoxic effects that the herbicide mixture promotes in contact with the leaves of the crop. Neto et al. (2009) claim that the application of isolated or mixed herbicides can promote phytotoxic effects when

they come into direct contact with the crop. These effects can range from injuries with presence of lesions on the leaves, to changes in their phenological characteristics, or even imperceptible physiological effects, but which spontaneously affect productivity.

It is possible to conclude that herbicide application via leaf sprayer and sheep's wool roller provides greater weed control in soybean crops. The application of herbicide mixtures through leaves causes phytotoxicity, which in turn causes reductions in crop growth and yield.

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