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Efficiency of the Adapted Automatic Row Hoe for Weed Control in Organic Soybean

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of the present study was to evaluate the row hoe model CHOPSTAR®, the mechanical control of weeds in between the rows of soybean implanted in organic direct sowing system, associated with the camera-guided system. Two experiments were carried, being that in the first experiment an experimental design with sub-subdivided plots with four replicates. The plots corresponded to two soybean varieties ('Embrapa BRS 284' and 'Coodetec CD 216'), the subplots corresponded to the sowing densities of 329.2 and 574.6 thousand plants ha^{-1}; and the sub-subplots corresponded to four managements of weeds: one mechanized hoe (2 days after sowing – DAS), two mechanized hoes (22 and 47 DAS), one control manually hoed and other control without hoeing. In the second experiment a randomized block design in subdivided plots with three replicates was used. The plots corresponded to two soybean varieties ('BRS 284' and 'DF 2353'),

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the subplots constituted of different times when the hoes were made, being: one (14 DAS); two (7 and 21 DAS; two (14 and 28 DAS); three (7, 14 and 28 DAS); besides one control manually hoed up to 28 DAS. In the first experiment it was observed that the automatized hoe was efficient in controlling the weeds and it was necessary only one mechanized hoe (22 DAS) for the 'BRS 284' independent of the sowing density, while for the 'CD 216' the number of mechanized hoes depended on the sowing density. In the second experiment, it was necessary only one mechanized hoe (14 DAS) to avoid production losses in the varieties 'BRS 284' and 'DF 2353'. The automatized hoe is an alternative to control weeds in areas of organic soybean in direct sowing system, however, damages to the crop can occur depending on the sowing density, mainly in the late management of the mechanized hoe.

Keywords: Agricultural sustainability; Glycine max (L.) Merrill; alternative control; mechanized hoe.

1. INTRODUCTION

The control of weeds in agricultural organic systems has been mentioned by the farmers as one of the main barriers for the organic production and, the adoption of integrated weed management practices (IWMP) is still minimal [1-3].

The IWMP can be defined as a holistic approach for the weeds management that integrate different control methods to provide an advantage to the crop over the weeds [4], being that the IWMP has the potential to restrict the weeds to a controllable level, reduce the environmental impact of individual practices of control, increase the crop system sustainability and reduce the selection pressure to resistant biotypes to the conventional herbicides [5,6].

In organic systems, the main weed control practices are based on the usage of a cultural management and mechanic control. The cultural management of weeds can be intensified in the production of organic soybean under direct sowing system [7]. This system is based on the use of cover crops which are mechanically managed to form a cover over the soil which suppresses the germination and emergence of weeds, besides improving the biological, chemical and physical conditions of the soil [8-10]. For example, 10 t ha^{-1} of oats straw (*Avena strigosa*) reduced about 90% the density of the weed *Brachiaria plantaginea* in the soybean crop in direct sowing system [11].

Similarly, the use of tolerant varieties to weed competition and of seeding densities that favors the fast closing of the crop space between the rows also contributes to the IWMP [12-15]. The crop densification in the sowing row can impede the development of weeds, while the control between the rows can be complemented with the use of mechanized hoes.

Generally, the traditional equipment that is used in the mechanized hoes operations causes damages to the crops, however, the densification in the row can reduce the negative effect of these damages, once the higher number of plants keeps the minimal population for the obtainment of economically viable productions. As an auxiliary measure, the use of automatized hoes can avoid crop damages caused by the mechanical hoes [16].

The camera directing system allows the machines to recognize patterns in the crop rows and to control automatized devices which will kill the weeds in between the rows without reducing the crop density of plants or even touching the sowed row [17,18]. Still, these systems have the potential to significantly increase the precision and the working speed with the row hoes for the control of weeds [19].

In Europe these equipments, with the aim to control weeds between the rows and plants in the sowed rows, are commercially available being worth mentioning the Garford Farm Machinery – model Robocrop [20] and of the Einbock – model Row-guard [21], among others [22].

It is emphasized that these equipments were developed for the European crop situations where the soil is revolved, remaining uncovered and has low resistance (compaction) for the operation of weed control devices that, besides cutting the weeds, they also pile them in the crop rows to suffocate the weeds in the sowed row [23,14].

It can be stood out that in Brazil the mechanized hoes were widely used before the appearance of the direct sowing system, and that they were fixed to the tractor or manually directed by a person. However, although in most areas of organic cultivation the soil prepare consists in its revolving (conventional system) and then it can still be used, the Brazilian cultivation conditions, with intense rains in some periods of the year and also the area's declivity, makes the soils susceptible to the erosion that can cause great losses, affecting the sustainability of the production systems.

In this context, it is indispensable the development or improvement of automatized hoes for the weeds control in between the crop rows implanted in the organic direct sowing system, which must have mechanisms to cut the straw and mechanisms to cut the weeds in the subsurface, also, that are resistant to stand the soil resistance that is higher in direct sowing system, and also causing minimum soil revolvment, aiming to keep it covered with straw to suppress the seed bank and also to protect the soil [24]. Thus, it is possible the obtainment of a higher precision and still make the organic cultivation of soybean more and more sustainable practice in Brazil.

Therefore, in Brazil, modifications in the mechanized hoe CHOPSTAR® are being made coupling it to the directing system in between the rows ROWGUARD® (controlled by a video camera that detects the crop row), for the direct sowing conditions (personal communication).

The objective was to evaluate the automatized hoe CHOPSTAR coupled to the directing system in between the rows ROWGUARD® (controlled by a video camera that detects the crop row), adapted to control weeds in the soybean organic crop under direct sowing system.

2. MATERIALS AND METHODS

The experiments were made in an agroecological area of soybean (*Glycine max*) production, in the agricultural years of 2015/2016 and 2016/2017, in Entre Rios do Oeste – PR, Brazil, on the geographical coordinate's latitude 24º43' S, and longitude 54º14' W, with an altitude of 260 meters.

Two experiments were made, being a randomized block design in sub-subdivided plots with four replicates used in the first one. The plots corresponded to two soybean cultivars ('BRS 284' and 'CD 216'), the sub-plots corresponded of two sowing densities (329.2 and 574.6 thousand plants ha^{-1}); and the sub-subplots corresponded to four weed managements: one mechanized hoe 22 days after sowed (22 DAS); two mechanized hoes (22 and 47 DAS); control, which was mechanically hoed until 47 DAS and other control without hoeing.

Each subplot constituted of an area of 120 m² (10 m x 12 m) and the sub-subplots constituted of an area of 30 m² (5 m x 6 m). In July 2015 the black oats (*Avena strigosa*) were sown in the density of 250 seeds m^{-2}. The area was managed one-week prior the sowing (10/01/2015), using a crimper roller, and, posteriorly, the weeds were controlled with the equipment Eletroherb®, model EH 60kva, which kills the weeds in the total area of the electric shock. The oats straw production was about 2,995 kg ha^{-1} of dry matter.

The soybean varieties were sown in 10/08/2016, with a spacing of 0.50 meters between rows, being the sowed regulated to obtain populations of 329.2 and 574.6 thousand plants ha^{-1}. The fertilization was made based on the results from the soil analysis, using 372 kg ha^{-1} from the organic formulation 01-07-11 (N, P_2O_5 and K_2O).

Weeds were mechanical managed with the automatized hoe, composed by the mechanized hoe CHOPSTAR® coupled to the direction system in between the rows ROWGUARD® (controlled by video camera which detects the crop rows), adapted for the weed control in the organic soybean under direct sowing system. The adaptations in relation to the equipment commercialized in Europe, after various stages, consisted basically in replacing the frontal depth control wheels (Fig. 1A and B) for cutting discs with the lateral band for depth control and replacing the spring-type rods for the free-turning axes with horizontal flat discs and safety fuse to break in case of stones, stumps, etc. (Fig. 1C and D). The horizontal discs work depth is adjustable with a handle that changes the depth limiting disc in relation to the horizontal, being necessary the adjustment so the depth action of the horizontal disc is around 2 to 3 cm so it can cut the weeds and revolve the soil as minimum as possible to keep the straw on the surface and avoid the roots reestablishment of some weeds.

Fig. 1. Row hoe guided by video-camera adapted to be used in areas under direct sowing system. A: Automatized hoe in the bean crop; B: cut discs used to cut the straw; C: video-camera to detect the crop row; D: cut discs placed in the horizontal, with rotary axel, system used to cut the weeds

Before the mechanized hoes, the camera height from the directing system in between the rows ROWGUARD® was adjusted according to the crop spacing between rows (0.5 m), the plant height and the canopy width of soybean based on the manufacturer recommendations.

The treatments related to weed management consisted in: One mechanized hoe carried at 22 days after sowing (DAS) and two mechanized hoes carried at 22 and 47 DAS, besides two controls, one manually hoed up to 47 DAS and other without hoeing.

The population (plants ha^{-1}) of soybean cultivars was evaluated at 47 DAS, being counted the plants in the two central rows, in 4 linear meters of each sub-subplot.

Due to the harvest it was collected the weeds biomass in each sub-subplot, in an area of 0.25 m². In the sequence the plants were oven dried in an air forced circulation oven at 65ºC for a period of 72 h. After drying, it was determined the weed's aerial dry matter (kg ha^{-1}).

The soybean cultivars were harvested on 01/21/2016, by manually collecting the plants from each sub-subplot useful area (20 m²), which were threshed to determine grain yield (kg ha^{-1}) after correction of the grain mass to 13% moisture.

In the second experiment a randomized block design with an arrangement of subdivided plots, with three replicates, was used. The plots were composed of two soybean cultivars (BRS 284 and DF 2353), while the sub-plots constituted of different periods of mechanized hoes, being: one mechanized hoe (14 DAS); two mechanized hoes (7 and 21 DAS); two mechanized hoes (14 and 28 DAS); three mechanized hoes (7, 14 and 28 DAS); besides one control which was manually hoed until 28 DAS.

Oats (*A. strigosa*) were sown in May 2016 and the area was managed one week prior to the crop sowing (10/08/2016), using a roller crimper and, posteriorly, the weeds were controlled with the equipment Eletroherb®, model EH 60kva, which performs the desiccation of the vegetation in total area through electric shock. The oats straw production was of around 2,755 kg ha^{-1} of dry matter.

The soybean varieties were sowed in 10/08/2016, where for the 'BRS 284' a density of 14 seeds m^{-1} was used, while for the 'DF 2353' a density of 16 seeds m^{-1} was used. Both varieties were sown in a row spacing of 0.50 m. Fertilization was made using about 240 kg ha^{-1} of the fertilizer with organic formulation 01-07-10 (N, P_2O_5, K_2O).

The soybean populations of each cultivar (plants ha^{-1}) were determined by counting the plants in 4 linear meters after the last management date, that is, at 21 DAS.

Due to the harvest, the weed's biomass of each subplot was collected in an area of 0.25 m². In the sequence they were oven dried in an air forced circulation oven at 65ºC for a period of 72 h. After dried the weed's aerial dry matter was determined (kg ha^{-1}).

Soybean cultivars were harvested on 01/21/2016, by manually collecting the plants from the useful area of each sub-subplot (20 m²), which were threshed to determine grain yield (kg ha^{-1}).

The results obtained in the first and second experiments were submitted to variance analysis by the F test at 5% and when significant they were submitted to the Tukey test at 5% of significance.

3. RESULTS AND DISCUSSION

In the first experiment, the weeds managed at 22 and 47 DAS with the automatized hoe reduced the soybean populations from the varieties 'BRS 284' and 'CD 216' in both populations, in relation to the manually hoed controls (Table 1). It was verified that the soybean population was reduced in 31.5% for 'CD 216' in relation to 'BRS 284' when two mechanized hoes were used (22 and 47 days after sowing) in the highest sowing density of the varieties.

In general, the automatized hoe damaged the soybean population because it cuts the plants, mainly when the number of hoes and the plants population was increased.

Table 1. Average population of soybean (thousand plants ha^{-1}) varieties in different sowing densities and after the weeds were managed with the automatized hoe

Varieties	Density	Automatized hoe (Days after sowing)			
	(thousand plants ha^{-1})	22 DAS	22 and 47 DAS	Manual hoeing	Without hoeing
BRS 284	329.2	252.5 BCbα	200.0 Cbα	327.5 Abα	310.0 ABbα
	574.6	432.5 Baα	412.5 Baα	585.0 Aaα	560.0 Aaα
CD 216	329.2	282.5 BCbα	230.0 Cbα	335.0 ABbα	350.0 Abα
	574.6	455.0 Baα	282.5 Caβ	542.5 Aaα	475.0 Baβ

Variation source	Degrees of freedom	Square mean
Block	1	528125000.00^{ns}
Variety (V)	1	8.128^{ns}
Error (A)	1	1.015
Density (D)	1	1.062^{ns}
(D) x (V)	1	5.865^{ns}
Error (B)	1	5.865
Management (M)	3	1.789**
(M) x (V)	3	7.961*
(M) x (V) x (D)	3	9.636**
Error (C)	112	2.407
General Mean	377031.25	
CV% (A)	26.73	
CV% (B)	64.23	
CV% (C)	13.01	

*Means followed by the same Greek letters do not differ statistically between the varieties, within each level of soybean population and weed management. Means followed by the same uppercase letters in the row, lower case letters in the column do not statistically differ from each other within each variety. ^{ns}, *, ** Not significant, significant at 5% and 1% probability, respectively, by the test F. DAS = Days after sowing*

The weeds dry matter was mainly reduced in the plots with the ‘BRS 284’ in relation to ‘CD 216’ considering the same variety’s sowing density (Table 2). For the ‘BRS 284’ there was a 25.5% reduction in the weeds dry matter in relation to the obtained in the plots from the ‘CD 216’, when it was only used one mechanized hoe at 22 DAS for a smaller sowing density. However, this behavior became more evident when two mechanized hoes were made (22 and 47 DAS) for both the varieties sowing densities.

It is emphasized that the experimental area has a high weed infestation, due to its seed bank, which demands a higher number of mechanized hoes to avoid the weeds interference on the crop, however, the number of mechanized hoes may vary according to the variety’s competitive capacity.

Considering the sowing density effects for the ‘BRS 284’ a smaller weed dry matter was found in the smallest density when a mechanized hoe was made at 22 DAS, as well as in the manual hoed control. The ‘BRS 284’ sowing in high densities may have caused an intraspecific competition and favored the development of weeds.

In contrast, for the variety ‘CD 216’ no differences were verified in the weeds dry matter between the sowing densities and the times of mechanized hoeing. The use of two mechanized hoeing was more efficient in the control of weeds in the ‘BRS 284’ in higher density, being necessary to consider the best sowing density so the variety can maximize the control effect.

The use of high sowing densities resulted in the best weeds control in organic soybean when compared to soybean that had tillage management [25]. The authors mentioned that populations of 533 thousand plants ha^{-1} (in a spacing between rows of 19 cm) suppressed more the gramineous and broad leaf species than populations of 238 thousand plants ha^{-1} and 178 thousand plants ha^{-1} in the spacing between rows of 57 and 95 cm, respectively, even using pre and post-emergent herbicides. Similarly, some authors found reductions of 30.8%, 31.3% and of 23.8% in the weeds biomass in the soybean cultivated with a population of 445 thousand plants ha^{-1} in relation to the population of 124 thousand plants ha^{-1}, in the spacing between rows of 19, 38 and 76 cm, respectively [13].

In relation to the morphological characteristics from the varieties, the ‘BRS 284’ have an indeterminate growth habit, a maturation cycle of 110 days, plant average height of 100 cm and higher branching potential, and the variety ‘CD 216’ have an indeterminate growth habit, a maturation cycle of 112 days, plant average height of 83 cm and higher branching potential [26]. Thus, the varieties ‘BRS 284’ and ‘CD 216’ show morphological characteristics of high branching potential, which can be used as a tool in the weeds control due to the fast closing between rows that prevents the competition for light with the infesting community. However, the plant morphology can be changed in denser cultivations.

The increase in the sowing density may reduce the number of branches per plant, once they found a reduction of 32% in the branching of soybean plants cv. ‘BRS 295’ cultivated in the density if 562.5 thousand plants ha^{-1} in relation to the density of 375 thousand plants ha^{-1} [27]. This fact may favor the passage of light in between the rows and explain the higher accumulation in the weeds dry matter even in the highest density of soybean as it was verified in the cultivar ‘BRS 284’.

The soybean variety ‘BRAGG’ which have high branching, promoted a decrease in the weeds dry matter of 13%, caused by the solar radiation interception, in relation to the varieties ‘IAS 5’, ‘M-Soy 6101’, ‘Fundacep 38’, ‘Fepagro RS10’ and ‘FT 2000’ which have low branching [28].

The grain production from the variety ‘CD 216’ was 68.5% lower than the one from the ‘BRS 284’ in the manually hoed plots in the smallest sowing density (Table 3). However, it was found that the weeds management with the automatized hoe reduced the productivity of the variety ‘BRS 284’ in relation to the manually hoed control, in both population densities.

For the variety ‘CD 216’ a reduction of 24.1% in the production was observed when one mechanized hoe was made in the smallest sowing density, as well as a reduction of 32.4% when two mechanized hoes were made in the highest sowing density in comparison to the manually hoed control, respectively.

The yield results for both varieties corroborate with the data of plant population (Table 1). Another point to be considered refers to the mechanized hoe made at 47 DAS, which would not be adequate, especially for the ‘CD 216’ in high sowing density, once the soybean plants show an advanced development stage, closing the space between rows and, consequently, the precision of the automatized hoe may have been compromised.

The automatized hoe may lose its efficiency in recognizing the space between the soybean rows as the crop grows and, consequently, cause an involuntary thinning by the horizontal cutting discs. Another point to be considered would be the damages caused by the mechanized hoeing to the root system, being important the choosing of adequate sowing densities and varieties that are tolerant to the mechanized hoe [16].

In general, the automatized hoe was efficient in controlling weeds, however, the number of mechanized hoes depended on the variety, being necessary only one mechanized hoe for the 'BRS 284', independent of the sowing density, while for the 'CD 216' the number of mechanized hoes depended on the sowing density.

Different from the verified in the first experiment, it was found a varietal effect in the weeds dry matter reduction due to the crop harvest (Table 5). The presence of weeds in the variety 'BRS 284' was 34% superior to the 'DF 2353'.

The variety 'DF 2353' has an initial growth faster than the 'BRS 284' [29], being that this characteristic contributes to the management of weeds.

In general, there were no differences between the management periods for weeds dry matter due to the harvest of soybean varieties. Thus, only one mechanized hoe carried at 14 DAS would be enough to control the weeds in the crop critical period that ranges from 8 up to 38 days after the emergence [30-33].

The times in which the mechanized hoes were made did not reduce the yield of the varieties 'BRS 284' and 'DF 2353' (Table 6). However, the grain production of the variety 'BRS 284' was 23.9% higher than the one obtained for the 'DF 2353'.

The organic soybean farmers in the southeastern United States used the flail mower in the weed's control between three to five times during the crop cycle [14]. Even though this practice reduces the density of weeds, the authors mention that a reduction in the soybean yield can happen. On the contrary, other authors verified that the Robovator

Table 2. Average of weeds dry matter (kg ha^{-1}) due to the soybean harvest in different sowing densities and after the management with the automatized hoe

Varieties	Density (thousand plants ha^{-1})	Automatized hoe (Days after sowing)		
		22 DAS	22 and 47 DAS	Without hoeing
BRS 284	329.2	4,352.50 Bbβ	3,716.25 Baβ	5,681.25 Abα
	574.6	5,485.00 Baα	3,096.25 Caβ	7,832.50 Aaα
CD 216	329.2	5,847.50 Aaα	5,998.75 Aaα	6,353.75 Abα
	574.6	6,491.25 Aaα	6,840.00 Aaα	7,433.75 Aaα
Variation sources	**Degrees of freedom**		**Square mean**	
Block	1		5826276.04^{ns}	
Variety (V)	1		51641334.37^{ns}	
Error (A)	1		15464176.04	
Density (D)	1		18226551^{ns}	
(D) x (V)	1		6501.04^{ns}	
Error (B)	1		1648792.70	
Management (M)	2		30387916.66**	
(M) x (V)	2		16826212.50**	
(M) x (V) x (D)	2		3518454.16*	
Error (C)	80		1004207.81	
General Mean	5760.72			
CV% (A)	68.26			
CV% (B)	22.29			
CV% (C)	17.40			

*Means followed by the same Greek letters do not differ statistically between the varieties, within each level of soybean population and weed management. Means followed by the same uppercase letters in the row, lower case letters in the column do not statistically differ from each other within each variety. ^{ns}, *, ** Not significant, significant at 5% and 1% probability, respectively, by the test F. DAS = Days after sowing*

Table 3. Soybean grain average yield kg ha^{-1} in different sowing densities and after the management with the automatized hoe

Varieties	Density (thousand plants ha^{-1})	Automatized hoe (Days after sowing)			
		22 DAS	22 and 47 DAS	Manual hoeing	Without hoeing
BRS 284	329.2	2,134.87 Baα	2,202.62 Baα	4,687.75 Aaα	545.75 Caα
	574.6	2,852.37 Baα	2,717.62 Baα	4,168.62 Aaα	350.12 Caα
CD 216	329.2	1,947.5 Baα	2,439.12 ABaα	2,567.37 Aaβ	328.62 Caα
	574.6	2,907.62 Aaα	2,211.00 Baα	3,271.62 Aaα	730.37 Caα
Variation sources	**Degrees of freedom**			**Square mean**	
Block	1			1648020.13^{ns}	
Variety (V)	1			5302396.13^{ns}	
Error (A)	1			1348082.00	
Density (D)	1			2774779.03^{ns}	
(D) x (V)	1			871530.03^{ns}	
Error (B)	1			3758657.03	
Management (M)	3			55403342.45**	
(M) x (V)	3			4380258.75**	
(M) x (V) x (D)	3			1352559.94**	
Error (C)	112			170275.13	
General Mean	2253.93				
CV% (A)	51.51				
CV% (B)	86.02				
CV% (C)	18.31				

*Means followed by the same Greek letters do not differ statistically between the varieties, within each level of soybean population and weed management. Means followed by the same uppercase letters in the row, lower case letters in the column do not statistically differ from each other within each variety. ^{ns}, *, ** Not significant, significant at 5% and 1% probability, respectively, by the test F. DAS = Days after sowingIn the second experiment, the plant's population of the soybean varieties 'DF 2353' and 'BRS 284' was not reduced after different management times of the mechanized hoe (Table 4)*

Table 4. Soybean plants population average (thousand plants ha^{-1}) after the weed's management with the automatized hoe

Automatized hoe (Days after sowing)	DF 2353	BRS 284
14	239.33	209.33
7 - 14	237.00	262.66
14 - 28	235.33	236.67
7 - 14 - 28	252.67	231.00
Hoed control	239.33	222.00
Variation source	**Degrees of freedom**	**Square mean**
Block	2	561.03^{ns}
Hoeing (H)	4	588.78^{ns}
Error (A)	8	167.91
Variety (V)	1	512.53^{ns}
(H) x (V)	4	737.28^{ns}
Error (B)	10	434.13
General Mean	236.47	
CV (%) (A)	5.48	
CV (%) (B)	8.81	

*Averages followed by the same capital letter in the line do not differ from each other by the Tukey test at 5%. ^{ns}, *, ** Not significant, significant at 5% and 1% probability, respectively, by the test F*

(cultivator with camera detection system to detect plants) removed from 18% to 41% more weeds in moderate to high densities, respectively, and reduced the manual removing time of 20% to 45% in comparison to the regular cultivator (without the camera detection system) [34]. The authors mentioned that the Robovator did not reduce broccoli's (*Brassica oleracea* L. 'Marathon') harvest or marketable yield in comparison to the regular cultivator.

Table 5. Weeds dry matter average (kg ha^{-1}) due to harvest of the soybean varieties after the management with the automatized hoe

Automatized hoe (Days after sowing)	DF 2353	BRS 284
14	4,514.30	4,593.63
7 - 14	3,951.43	6,519.67
14 - 28	4,126.23	8,171.33
7 - 14 - 28	4,022.83	7,191.23
Hoed control	4,146.00	5,018.23
Averages	4,152.16 B	6,298.82 A
Variation source	**Degrees of freedom**	**Square mean**
Block	2	3349503.23^{ns}
Hoeing (H)	4	2794529.89^{ns}
Error (A)	8	4186548.03
Variety (V)	1	34561118.68*
(H) x (V)	4	4021407.75^{ns}
Error (B)	10	4035779.89
General Mean	5,225.49	
CV (%) (A)	39.16	
CV (%) (B)	38.44	

Averages followed by the same capital letter in the line do not differ from each other by the Tukey test at 5%.
*^{ns}, *, ** Not significant, significant at 5% and 1% probability, respectively, by the test F*

Table 6. Grain average yield (kg ha^{-1}) of soybean varieties after the management with the automatized hoe

Automatized hoe (Days after sowing)	DF 2353	BRS 284
14	2,321.64	2,678.36
7 - 14	2,237.43	2,725.15
14 - 28	2,257.31	3,450.29
7 - 14 - 28	2,087.72	3,163.74
Hoed Control	2,619.88	3,116.96
Averages	2,304.79 B	3,026.90 A
Variation sources	**Degrees of freedom**	**Square Mean**
Block	2	607580.70^{ns}
Hoeing (H)	4	209307.98^{ns}
Error (A)	8	196816.63
Variety (V)	1	3910778.06*
(H) x (V)	4	219775.70^{ns}
Error (B)	10	647343.48
General Mean	2,665.85	
CV (%) (A)	16.64	
CV (%) (B)	30.18	

Averages followed by the same capital letter in the line do not differ from each other by the Tukey test at 5%.
*^{ns}, *, ** Not significant, significant at 5% and 1% probability, respectively, by the test F*

For the manual control of weeds in tomatoes in 100 m² it was necessary, in average, 0.241 h $person^{-1}$, while with the 'co-robot' (automatized cultivator) adapted to control weeds in the row and in between the rows, with real time detection system and pneumatic response, based on an odometry technique, spent only 0.102 h to manage the same area. This represented a reduction of 57.5% in the labor requirements to control weeds and stands the potential of using the automatized mechanized control [35].

Overall, the adaptation of the automatized hoe to use in organic soybean in direct sowing system promoted a low soil revolvment and it allows the maintenance of the plant covers. This fact may help in the weed's control due to the physical effect of the straw on the weed's seed bank and the release of allelopathic compounds. However, the use of the automatized hoe when the crop is in an advanced development stage or when the crop had already closed the space between rows may harm the crop and, consequently, the production of a certain variety. Therefore, attention must be given when recommending the sowing density for each variety so the ideal number and the time of operations with the automatized hoe can be determined.

On the other hand, the use of the automatized hoe in the critical period of the soybean crop and without complete closure between rows, presented high efficiency in controlling weeds without harming the grain production.

4. CONCLUSION

The automatized hoe is an alternative to the mechanical control of weeds in agroecological areas of soybean under direct sowing system.

Varieties and sowing densities affected the results, making it necessary to choose the varieties with greatest competition potential with the weeds and establishing the strategies in terms of amounts of hoeing and when to make them.

The realization of more than one mechanized hoe must be well evaluated because the effects over the reduction in the weeds dry mass production was not significantly affected and a reduction in the soybean yield occurred when the mechanized hoe was carried out late at 47 DAS of the crop.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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