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Article

Performance of Crops Grown in Succession to Soybeans Treated with Different Residual Herbicides

Desempenho de Culturas Cultivadas em Sucessão à Soja Tratada com Diferentes Herbicidas Residuais

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ABSTRACT - Herbicides with residual effect applied in soybeans may affect the productivity of late harvest crops grown in succession. Thus, the objective of this research was to evaluate the agronomic performance of adzuki bean crops, crambe, millet and palisade grass pasture grown in succession to soybean crop treated with residual herbicides, as well as assess the contribution in weed management. Four trials were conducted in field conditions at the soybean crop in the harvest and then succeeded by adzuki bean crops, crambe, millet and palisade grass as late harvest. An experimental design was adopted in a randomized block arrangement with four replications and nine treatments represented by the application of residual herbicides: imazethapyr (1.0 and 1.5 L ha^{-1}), chlorimuron (60 and 90 g ha^{-1}), fomesafen (1.0 and 1.5 L ha^{-1}) and chloransulan methyl (74.6 and 71.4 g ha^{-1}) and without herbicide control, kept in manual weeding. The herbicides were efficient in weed control in soybeans, not affecting crop yield. However, there was no residual activity of herbicides contribution in reducing infestation in the late harvest crops. The herbicides did not promote phytotoxicity to crops of crambe, beans, millet and palisadegrass pasture when they were compared with the other treatments. The beans treated with methyl chloransulan, regardless of dose, showed a higher yield. The absence of phytotoxicity to crops can be associated with rainfall incident on soybens which contributed to the dissipation of herbicides.

Keywords: *carryover*, late harvest, weeds, commercial herbicides.

RESUMO - Herbicidas com efeito residual aplicados na cultura da soja podem afetar a produtividade de culturas de safrinha cultivadas em sucessão. Assim, objetivou-se nesta pesquisa avaliar o desempenho agronômico das culturas de feijão-azuki, crambe, milheto e pastagem de capim-xaraés cultivadas em sucessão à cultura da soja tratada com herbicidas residuais, bem como avaliar a contribuição no manejo de plantas daninhas. Quatro ensaios foram realizados em campo com a cultura da soja na safra, sendo em seguida sucedida pelos cultivos do feijão-azuki, crambe, milheto e pastagem de capim-xaraés como safrinha. Foi adotado o delineamento experimental em blocos ao acaso com quatro repetições e nove tratamentos, representados pela aplicação dos herbicidas residuais: imazethapyr (1,0 e 1,5 L ha^{-1}), chlorimuron (60 e 90 g ha^{-1}), fomesafen (1,0 e 1,5 L ha^{-1}) e chloransulan-methyl (74,6 e 71,4 g ha^{-1}) e a testemunha sem herbicida, mantida sob capina manual. Os herbicidas foram eficientes no controle de plantas daninhas na cultura da soja, não afetando a produtividade da cultura. Contudo, não houve contribuição da atividade residual dos herbicidas na redução da infestação nas culturas de safrinha. Os herbicidas não promoveram fitotoxicidade às culturas de

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crambe, feijão-azuki, milheto e pastagem de capim-xaraés, quando comparadas com a testemunha sem herbicida. O feijão-azuki tratado com chloransulan-methyl, independentemente da dose, apresentou maior rendimento de grãos. A ausência de fitotoxicidade nas culturas pode estar associada à precipitação pluviométrica incidente sobre a soja, que contribuiu na dissipação dos herbicidas.

Palavras-chave: *carryover*, safrinha, plantas daninhas, herbicidas comerciais.

INTRODUCTION

In the western region of Brazil it is common to have two agricultural crops in the same year due to the adequate environmental condition (Fietz and Rangel, 2008). Soybeans are usually sown as main crop because of their higher yield compared to maize. Most of the soybeans are harvested in late February or early March and the second crop is immediately sown. However, in recent years there have been some other crops with potential for cultivation in succession to soybeans.

Crambe (*Crambe abyssinica*) is a native species of the Mediterranean that has been cultivated in some tropical and subtropical regions due to the industrial interest in the oil extracted from its seeds, recently used for biodiesel production (Carneiro et al., 2009; Oliveira et al., 2013). However, with the advent of biodiesel production, this oilseed has become a very interesting option because it presents advantages such as precocity, drought and frost tolerance, low production costs and productivity between 1,000 and 1,500 kg ha^{-1} (Jasper et al., 2010).

Among crops grown in the Brazilian cerrado in succession, millet stands out because its cultivation has expanded because of its rusticity, accelerated growth, adaptation to low fertility soils and its own plant biomass production capacity (Silva et al., 2012). As another possibility, in addition to millet, there are forage species such as palisade grass [*Urochloa brizantha* (Syn. *Brachiaria brizantha* cv. Xaraés)]. The potential for forage production in intercropping in succession to soybeans varies among cultivars of Urochloa brizantha but palisade grass has advantages over other *Urochloa* due to the speed of regrowth and forage production, which ensures high support capacity and higher productivity per area (Flores et al., 2008; Machado and Valle, 2011).

Adzuki bean (*Vigna angularis*) is a species originating in China, where it has been cultivated for centuries. It has been gaining ground in Brazil, being cultivated mainly by *Japanese producers* (Vieira et al., 2000). It is a food rich in protein, with full acceptance in the most diverse eating habits, and its cultivation is widespread throughout the country (Resende, 2010).

The use of herbicides is the most used control method in the most technically advanced agriculture, mainly because it provides greater efficiency and in many cases cost reduction (Walperes et al., 2015).

Despite the increasing adoption of chemical weed control in crops, the current availability of herbicides registered in Brazil for application after the emergence of these crops is small. In addition, there is little information on the selectivity of preemergent or residual herbicides for the main common bean cultivars, being practically non-existent in the tropics for adzuki bean. Similarly, for crambe and millet crops, there are no recorded herbicides in Brazil, and weed control strategies need to be identified to make this crop viable (Dan et al., 2011).

Among the strategies to optimize the effectiveness of weed control, the use of herbicides that have residual soil activity is included. For example, the use of residual herbicides in bean plants can be very timely, reducing by up to 90% the infestation of these species (Soltani et al., 2010).

The practice of crops succession, associated with the use of herbicides, is used as a means to prevent infestations of some weed species and plays an important role in the control of those weeds adapted to a particular cropping system (Cobucci et al., 2006). Therefore, the choice of species to be used in the succession system should take into account complementary characteristics in the process of adaptation to the system proposed, so that a crop or herbicide used in the predecessor crop do not interfere in the successor crop development.

In this context, herbicides with residual effect applied in postemergence of soybean cultivation in the summer do not affect late harvest crops development and productivity. The objective of this study was to evaluate the agronomic performance of adzuki bean, crambe, millet and palisade grass cultivated in succession to soybeans treated with residual herbicides.

MATERIALS AND METHODS

The study was conducted in the experimental area of Brazilian Instituto Federal Goiano [Federal Institute of Brazilian State Goiás] – campus Rio Verde, GO, located in latitude 17º48'67" S and longitude 50º54'18" W, with an average altitude of 758 m and a smooth undulating relief (6% slope). The region climate has been classified according to the Köppen-Geiger climate classification system as Aw (tropical) with precipitation in the summer (October to April) and a well defined dry period in the winter months (May to September). The average annual temperature ranges from 20 to 35 ºC and rainfall fluctuates from annual 1,200 to 1,500 mm. The climatological data that occurred during the conduction of the experiment are shown in Figure 1.

Four experiments were carried out simultaneously under field conditions on Distroferric Red Latosol, whose physicochemical characteristics, in depth of 0 to 20 cm, were: pH ($CaCl_2$) of 5.2; P of 11 mg dm^{-3}; K of 246 mg dm^{-3}; Ca of 5.77 cmol$_c$ dm^{-3}; Mg of 1.63 cmol$_c$ dm^{-3}; Al of 0.03 cmolc dm^{-3}; V% of 64,6; and granulometry of 460, 100 and 440 g kg^{-1} of clay, silt and sand, respectively. Soybean cultivar Nidera Intacta RR2 PROTM (NS 7337 IPRO) was used for sowing in the harvest period. The experiments had as successor crops adzuki bean, crambe (FMS Brilhante), millet (cv. ADR 300) and palisade grass (*Urochloa brizantha* cv. Xaraés).

The experimental design adopted was in completely randomized blocks with four replicates and the following herbicides were tested: imazethapyr in doses of 106 and 159 g a.i. ha^{-1} of Zethapyr® (106 g L^{-1}), chlorimuron in doses of 15 and 22.5 g a.i. ha^{-1} of Classic® (250 g kg^{-1}), fomesafen in doses of 250 and 375 g a.i. ha^{-1} of Flex® (250 g L^{-1}) and chloransulan-methyl in doses of 40 and 60 g a.i. ha^{-1} of Pacto® (840 g kg^{-1}). A control without herbicide maintained under weeding was used.

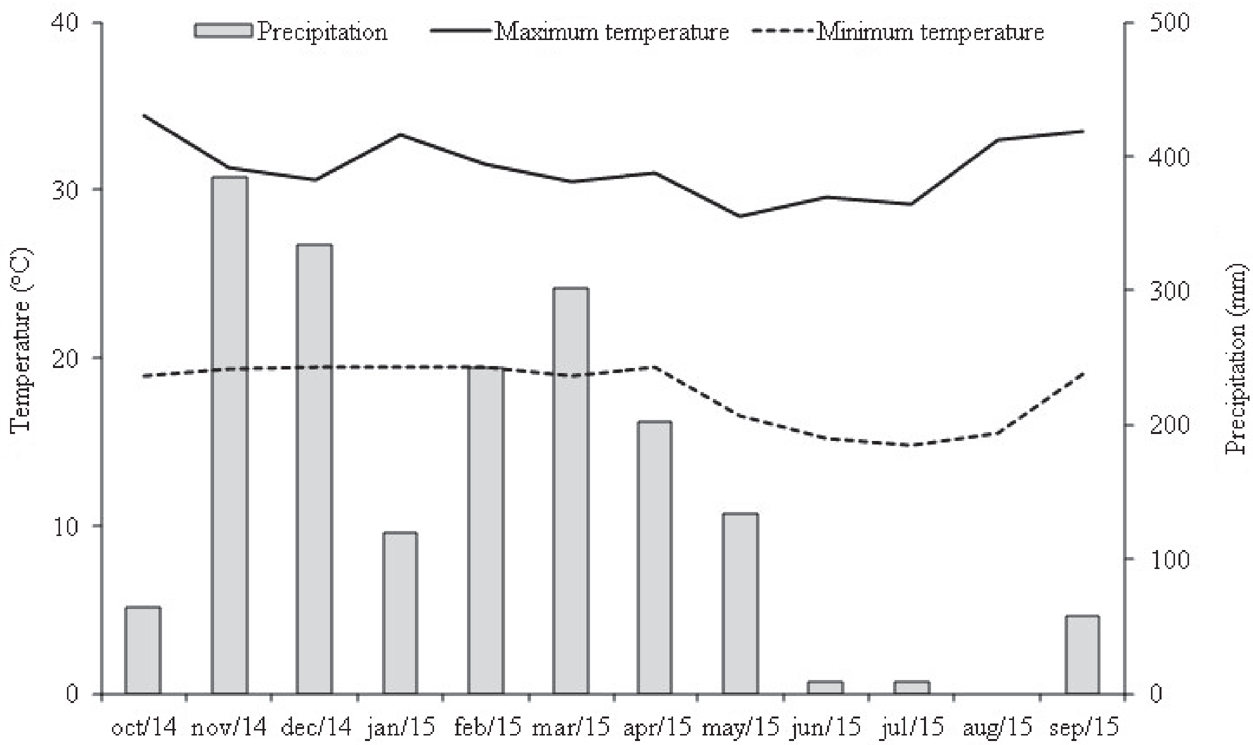

Figure 1 - Cumulative rainfall and average temperature in the period from October 2014 to September 2015, in Rio Verde, GO.

Weed control in the weeded control was done through (two) manual weeding until the closing of the crop canopy, a stage in which soybeans started to suppress their development through cultivation control. The applications of the products were carried out with a knapsack sprayer with constant pressure maintained by compressed CO2 equipped with a boom with four spray tips of the TT 110.02 series. One hundred and forty-five L ha^{-1} of spray solution at a constant pressure of 2.5 bar were applied. The climatic conditions at the beginning of the application were: air temperature of 23 °C, wind speed of 0.93 s^{-1} and relative humidity of 78%. The application of the herbicides was in postemergence in the period of 25 days after emergence (DAE) of soybeans.

The experimental plots consisted of eight rows of soybeans, spaced 0.45 m apart, with 5 m linear in length, totaling an area of 18 m^2. As a floor area for samplings and evaluations, the four central rows were considered, discarding the borders and also 0.50 m from each end.

Soil preparation was carried out by plowing and harrowing, with a harrowing of three days before soybean sowing. Soybean seeds were treated with Standak Top® (100 L/100 kg of seeds) and inoculated with Bradyrhizobium japonicum (300 mL/100 kg of seeds) and their sowing was carried out on 11/7/2014 with the use of a multiple sowing machine of five rows and a density of 18 seeds per linear meter at a depth of 3 cm. The base fertilization carried out in the sowing groove was of 350 kg ha^{-1} of the formulation 8-28-18 (N, P_2O_5, K_2O). As a phytosanitary treatment, the application of fungicide pyraclostrobin at a dose of 0.075 kg ha^{-1} was carried at 28 DAS.

Manual harvesting of soybeans was carried out on 3/13/2015, at which time grain yield was evaluated in the floor area of the plot (four rows of 2 m) and the specific mass of the seeds. Soybean plants were threshed by a plant thresher coupled to the tractor to separate the grains and the total weight of the floor area of each experimental unit was determined. Two hundred grains of each plot were randomly selected, weighed and placed in "crucibles" and kept in an oven at 105 °C for 24 hours to determine humidity.

After the soybean harvest on 3/16/2015, sowing adzuki bean, crambe, millet and palisade grass in the plots previously treated with residual herbicides was carried out. With the same five-row seeder used in soybean sowing, the rows of the four successor experiments were grooved or demarcated. The area was fertilized soon after with 200 kg ha^{-1} of formulation 8-28-18 (N, P_2O_5, K_2O) as a basic fertilization. Six central rows of both cultures were manually sown using 15 kg ha_{-1} of seeds for crambe, 20 kg ha^{-1} of seeds for millet, 5 kg ha^{-1} of viable pure seeds of cultivation value of 76% for palisade grass and density of 15 seeds per linear meter of groove for adzuki bean. After 25 days of sowing, topdressing with 60 kg ha^{-1} of N in the form of urea was performed.

The experimental plots of the successor crops consisted of six rows, spaced 0.45 m apart, with 5 m of linear length, totaling an area of 13.5 m^2. As a floor area for samplings and evaluations, the two central rows were considered, discarding the borders and also 0.50 m from each end.

Regarding weeds, two evaluations were performed, the first one being at 30 days after the application of herbicides on soybeans and the second one at 20 DAE of the subsequent crops. The cast iron inventory square method was applied, based on the use of a 0.5 x 0.5 m square arranged at random within the plots. Two samples were collected in each plot and the weeds present were identified, counted and placed in kraft paper bags for drying in a forced-air circulation oven for 72 hours at 75 °C and then weighed. After the weed evaluation (20 DAE), weeding was carried out in the control without herbicide. In the other treatments, the plots were kept weeded until the harvest of the late harvest crops. The two central rows, with an area of 4.45 m^2, were considered as floor area of the plot for the evaluations in the late harvest crops.

Adzuki bean harvest was carried out on 6/16/2015 and crambe harvest on 6/17/2015, all manually. In both crops, all the plants of the plot floor area were counted and five plants were collected at random in each plot of crambe and adzuki bean to determine the yield components. After harvesting, total grains per plot in the floor area (quantity), weight of the aliquot of the five plants and yield of the plot (total weight of the plot grains) were evaluated in both crops. Besides, in adzuki bean all pods of the plot floor area were counted, thus determining the number of grains per pod and the number of pods per plant. In crambe, the number of seeds per plant was obtained. In both cultures, the number of plants per linear meter and the grain yield expressed in kg ha^{-1} were measured.

The crambe and adzuki bean plants were threshed by a specific plant thresher of both crops provided by Brazilian foundation Fundação MS. One sample of crambe and one sample of adzuki bean of each plot were randomly selected, weighed and placed in "crucibles," which were kept in an oven at 105 °C for 24 hours to determine humidity.

Manual harvesting of millet was carried out on 6/19/2015. In the floor area, an aliquot of five plants was weighed, counting all panicles and randomly collecting five uniform panicles. The aliquots were placed in paper bags and then drying in a forced-air circulation oven for 72 h at 75 °C, thus obtaining the dry matter.

From the panicles collected, the crop yield components evaluations were carried out and the dry matter, the diameter and the height were determined. Soon afterwards, they were manually threshed and all the seeds were counted. The thousand grain weight, the dry and fresh matters of the aliquot and the plot and the grain yield in kg ha^{-1} were determined. As for the thousand grain weight, these were randomly selected, weighed and placed in "crucibles," which were kept in an oven at 105 °C for 24 hours for determination of humidity.

For the palisade grass, two uniformity cuts were made at 25 cm of the soil in the floor area of each plot, the first being on May 20, 2015 and the second on September 18, 2015. Before each cut, homogeneous tillers were removed to evaluate the leaf blade/stalk ratio. The average height of the forage was measured and the aerial part of the grass was removed to determine the forage yield. The height of the canopy was determined in five random points per plot, using a ruler graduated in centimeters. The readings were performed with the ruler positioned on the surface of the soil and adopting as a reference the horizon of the leaves around the ruler.

For the forage yield and the leaf/stalk ratio, the whole fresh grass and the ten tillers were weighed and an aliquot of approximately 700 g was removed and weighed. In order to evaluate the leaf/stalk ratio, the ten tillers collected per plot were manually separated into leaf blades, stalks (stalks + leaf sheaths) and dead material, packed in paper bags, weighed and then sent for drying in a forced-air circulation oven at 65 °C for 72 hours until reaching constant mass and again weighed. The leaf/stalk ratio was calculated as the quotient between the dry matter of leaf blades and the dry matter of stalks.

In the agronomic characteristics evaluations of palisade grass, after separation of the morphological components the aliquot was removed to determine the total dry matter and components leaf blade, stalk and dead material. These samples were also taken to the oven at 65 °C for 72 hours until reaching a constant mass and obtaining the dry matter. Productivity was determined from the area and the forage mass contained in the sampling floor area and converted to kg ha^{-1}.

All data were submitted to analysis of variance by the F test ($p \leq 0.05$). In cases of significance, means were compared by the Scott-Knott test ($p \leq 0.05$), using statistical software ASSISTAT® version 7.7.

RESULTS AND DISCUSSION

In soybean cultivation, which predated late harvest crops, grain yield and thousand grain weight variables did not show significant effects for herbicides with residual effect used to control weeds in soybean cultivation (Table 1). These non-significant effects are explained by the selectivity of the herbicides to soybeans. Nevertheless, authors like Artuzi and Contiero (2006), Melo et al. (2010) and Mancuso et al. (2011) have reported that herbicides may remain with a residual effect on the soil, i.e., remain active, allowing control of weeds for a longer period of time than recommended and cause poisoning of crops cultivated in succession.

The weed community present in the four experiments consisted of 20 species, represented by: *Ageratum conyzoides* (billygoat-weed, chick weed, goatweed, whiteweed), *Alternanthera tenella* (parrotleaf, Calicoplant), *Axonopus purpusii* (Purpus' Carpetgrass), *Bidens pilosa* (black-jack, beggar-ticks, cobbler's pegs, Spanish needle), *Cenchrus echinatus* (buffelgrasses, sandburs, sand spur), *Commelina benghalensis* (Benghal dayflower, tropical spiderwort, wandering Jew), *Desmodium tortuosom* (tick-trefoil, tick clover, hitch hikers, beggar lice), *Digitaria horizontalis* (crabgrass,

Table 1 - Grain yield and thousand grain weight of soybeans due to the herbicides applied in the postemergence period

Treatment	Grain yield (kg ha^{-1})				One hundred seed-weight (g)			
	I[(1)]	II	III	IV	I	II	III	IV
T1	3,502.01	3,354.61	3,845.70	3,442.60	90.2	143.1	95.6	123.2
T2	3,438.29	3,352.03	3,803.50	3,586.02	131.6	108.0	105.4	111.6
T3	3,490.87	3,228.36	3,656.30	3,663.55	121.7	76.1	103.9	108.2
T4	3,256.63	3,449.83	3,506.60	3,384.15	82.2	130.3	95.4	100.4
T5	3,251.45	3,069.40	3,103.64	3,698.44	102.3	77.0	93.2	89.8
T6	3,397.70	3,396.90	3,532.50	3,766.80	104.2	111.2	104.0	84.2
T7	3,571.83	3,686.85	3,284.64	3,582.19	96.1	97.8	123.3	106.6
T8	3,344.49	3,408.32	3,298.13	3,537.62	110.3	128.2	126.1	107.2
T9	3,384.00	3,042.88	3,373.44	3,531.00	90.8	109.0	91.3	84.1
F	0.37^{ns}	1.66^{ns}	1.49^{ns}	0.46^{ns}	2.05^{ns}	1.41^{ns}	0.64^{ns}	0.98^{ns}
VC (%)	10.50	9.21	11.69	9.99	27.96	35.46	30.33	33.42

T1 – imazethapyr (106 g ha^{-1}.); T2 – imazethapyr (159 g ha^{-1}); T3 – chlorimuron (15 ha^{-1}); T4 – chlorimuron (22.5 g ha^{-1}); T5 – fomesafen (250 g ha^{-1}); T6 – fomesafen (375 g ha^{-1}); T7 – chloransulan methyl (40 g ha^{-1}); T8 – chloransulan-methyl (60 g ha^{-1}); and T9 – control. ^{ns} Non-significant by the F-test. (1) I, II, III, and IV correspond, respectively, to the experiments with the crops of adzuki bean, crambe, millet and pasture that have succeeded soybeans.

finger-grass, fonio), *Eleusine indica* (Indian goosegrass, yard-grass, goosegrass, wiregrass, crowfootgrass), *Galinsoga parviflora* (gallant soldier), *Ipomoea purpurea* (common morning-glory, tall morning-glory, purple morning glory), *Nicandra physaloides* (apple-of-Peru, shoo-fly plant), *Panicum maximum* (Guinea grass, green panic grass), *Pennisetum setosum* (mission grass), *Phyllanthus tenellus* (gale of the wind, stonebreaker, seed-under-leaf), *Ricinus communis* (castorbean, castor-oil-plant), *Sida rhombifolia* (arrowleaf sida, rhombus-leaved sida, Paddy's lucerne, jelly leaf, and also somewhat confusingly as Cuban jute), *Solanum americanum* (American black nightshade,[3] small-flowered nightshade, glossy nightshade), *Tridax procumbens* (coatbuttons, tridax daisy) and *Urochloa plantaginea* (creeping signal grass).

After 30 days of application (DAA) of the herbicides, there were positive effects on weed community control, as evidenced by the residual activity of the products when compared to the control, which was weeded until the soybean crop was closed (Table 2). Although there were no significant effects between herbicides and doses, low density of individuals and dry matter accumulation of the weed community were observed in all four experiments at 30 DAA (Table 2). These effects persisted during the soybean cycle, represented by crop yields in all treatments and experiments (Table 1).

However, after harvesting soybeans up to 20 DAE of the crops grown in succession, it is noticed that there was no significant effect of the herbicides on the weed community in the four experiments but higher densities of individuals were noticed in relation to the evaluations carried out at 30 DAA (Table 2). Even though there was a low dry matter accumulation by the weed community at 20 DAE, a reduction in residual herbicide activity for weed control was observed when comparing their germination flow with the control and also the absence of significance among the treatments (Table 2).

The herbicide residual activity was sufficient to maintain weed control in the soybean crop but did not contribute to the limitation of weed germination in soybean succeeding crops (Table 2).

Table 3 shows the results of the agronomic performance of adzuki bean and crambe grown after soybeans. In the cultivation of adzuki bean, variables number of plants, number of pods, number of grains and thousand grain weight did not show significant effects. As for the grain yield variable, it showed a significant effect among the herbicides used in the control of weeds infesting soybeans (Table 3). It was also observed that herbicides imazethapyr, fomesafen and chlorimuron, in both doses tested (100 and 150% of the commercial dose) and applied on soybeans, they did not alter the grain yield of adzuki bean grown in succession because they did not differ from the weeded control (Table 2).

Table 2 - Density and dry matter of the weed community evaluated at 30 days after the application (DAA) of the herbicides applied in postemergence on soybeans and at 20 days after the emergence (DAE) of crops of millet, adzuki bean, crambe and pasture of *Urochloa brizantha* cv. Xaraés cultivated in succession to soybeans

Treatment	30 DAA of soybeans							
	Density (n m^{-2})				Dry matter (g m^{-2})			
	I[(1)]	II	III	IV	I	II	III	IV
T1	6.5	6.0	4.3*	12.0	0.37	0.66	0.46*	0.65
T2	2.5	4.0	7.0	9.0	0.06	0.22	0.12	0.27
T3	11.0	6.8	5.0	10.0	0.47	0.27	0.08	2.25
T4	3.8	7.3	9.3	11.0	0.16	0.28	0.25	0.77
T5	6.8	12.0	6.5	12.0	0.27	1.02	0.55	1.86
T6	9.5	5.8	5.8	5.0	0.33	0.34	0.12	5.20
T7	5.8	8.0	7.8	18.0	0.27	0.26	0.89	0.71
T8	9.0	6.5	5.3	11.0	0.28	0.39	0.95	2.25
T9	5.3	5.3	4.5	8.0	0.24	0.72	0.20	2.15
F	0.95^{ns}	2.03^{ns}	0.64^{ns}	0.80^{ns}	0.65^{ns}	2.33^{ns}	1.02^{ns}	1.45^{ns}
VC (%)	9.32	6.81	8.02	8.58	10.69	9.14	10.78	12.35
Treatment	20 DAE of plants cultivated in succession							
	Density (n m^{-2})				Dry matter (g m^{-2})			
	I[(1)]	II	III	IV	I	II	III	IV
T1	100.5	76.0	94.0*	15.0	23.54	9.32	8.54*	1.05
T2	87.5	55.5	114.0	11.0	17.95	4.52	12.92	0.73
T3	100.5	76.5	99.5	16.5	20.33	7.28	10.12	1.99
T4	98.0	75.0	104.0	24.0	20.31	10.17	14.45	1.96
T5	82.0	68.5	103.5	28.0	15.49	7.78	9.71	3.32
T6	79.5	83.5	141.0	24.0	10.83	8.05	11.46	3.07
T7	70.0	70.5	108.0	24.5	13.21	8.39	11.02	3.01
T8	73.0	62.0	105.0	38.5	13.62	8.34	9.11	2.06
T9	73.5	80.5	104.0	22.0	15.56	8.59	11.28	1.74
F	1.08^{ns}	0.40^{ns}	0.72^{ns}	1.03^{ns}	1.48^{ns}	0.51^{ns}	0.33^{ns}	1.23^{ns}
VC (%)	5.22	6.28	5.57	7.82	6.49	7.62	6.27	8.57

T1 – imazethapyr (106 g ha^{-1}.); T2 – imazethapyr (159 g ha^{-1}); T3 – chlorimuron (15 ha^{-1}); T4 – chlorimuron (22.5 g ha^{-1}); T5 – fomesafen (250 g ha^{-1}); T6 – fomesafen (375 g ha^{-1}); T7 – chloransulan methyl (40 g ha^{-1}); T8 – chloransulan-methyl (60 g ha^{-1}); and T9 – control. ^{ns} Non-significant by the F-test. * Data transformed into root (x) for analysis. [(1)] I, II, III and IV correspond, respectively, to the experiments with crops of adzuki bean, crambe, millet and pasture that have succeeded soybeans.

Table 3 - Number of plants per linear meter (NP), number of pods per plant (PP), number of grains per pod (GP), one hundred seed-weight (HSW) and grain yield (GY) de adzuki bean and number of plants per linear meter (NP1), number of seeds per plant (SP), thousand seed weight (TSW) and grain yield (GY1) of crambe cultivated in succession to soybeans due to the herbicides applied in postemergence on soybeans

Treatment	Adzuki bean					Crambe			
	NP	PP	GP	HSW (g)	GY (kg ha^{-1})	NP1	SP	TSW (g)	GY (kg ha^{-1})
T1	23.81	13.50	2.39	8.35	1,478.89 b	38.81	374.60	10.27	661.19
T2	23.88	17.35	2.75	7.16	1,419.51 b	42.81	414.50	10.48	568.11
T3	22.56	14.65	3.26	8.85	1,375.85 b	39.81	353.30	12.39	546.79
T4	22.25	15.55	3.53	7.26	1,647.95 b	38.25	401.50	11.06	648.57
T5	18.19	17.75	3.75	8.19	1,518.71 b	43.69	362.55	10.71	663.73
T6	22.00	14.70	3.97	8.48	1,659.41 b	37.56	365.65	10.00	595.26
T7	23.00	17.15	4.02	8.48	1,973.06 a	39.19	477.40	8.84	644.83
T8	25.50	16.10	3.74	8.43	1,992.58 a	34.75	373.95	12.67	588.10
T9	24.25	14.35	3.57	8.11	1,579.83 b	38.25	452.50	10.23	598.22
F	0.46^{ns}	0.34^{ns}	1.49^{ns}	0.53^{ns}	3.10*	0.7^{ns}	0.69^{ns}	1.17^{ns}	0.26^{ns}
VC (%)	26.63	32.72	26.33	19.17	15.25	16.23	26.2	20.41	27.34

T1 – imazethapyr (106 g ha^{-1}.); T2 – imazethapyr (159 g ha^{-1}); T3 – chlorimuron (15 ha^{-1}); T4 – chlorimuron (22.5 g ha^{-1}); T5 – fomesafen (250 g ha^{-1}); T6 – fomesafen (375 g ha^{-1}); T7 – chloransulan methyl (40 g ha^{-1}); T8 – chloransulan-methyl (60 g ha^{-1}); and T9 – control. ^{ns} Non-significant, * Significant at 1% by the F-test. Means followed by equal letters in the columns do not differ by the Scott-Knott test at 5% probability.

Higher grain yields were observed for chloransulan treatments at both doses. However, it was not possible to determine, within a statistical significance, the likely effects associated with these yields, since there were no statistical differences for weed density and dry matter evaluated at 20 DAE of the crop (Table 2) nor for the other yield components associated with bean plants (Table 3).

There are few studies reported in the literature on the effects or selectivity of herbicides on adzuki bean. In studies with adzuki bean selectivity with herbicides applied in postemergence in Ontario, Canada, Soltani et al. (2006) have concluded that the application of herbicides fomesafen, sethoxydim, quizalofop-p-ethyl and imazamox + fomesafen is safe for the crop. In embedded preplanting applications, Soltani et al. (2005) have concluded that imazethapyr was the only herbicide that presented a sufficient safety margin for use in weed control in this crop.

Also Sikkema et al. (2006a), evaluating the performance of herbicides dimethenamid, clomazone, S-metolachlor and imazethapyr in applications in preemergence of adzuki bean crops, have confirmed the safety margin for the use of imazetapyr at doses 75 and 150 g ha^{-1}. On the other hand, Sikkema et al. (2006b) have verified that the application of imazethapyr in preplanting in an area cultivated with other species of beans has reduced the plants height, the shoot dry matter and the grain yield in 8, 18 and 12% at the dose of 75 g ha^{-1} and 19, 38 and 27% at the dose of 150 g ha^{-1}, respectively. Thus, Soltani et al. (2005) recommend carrying out experiments in other locations with different climatic conditions and soil types, involving more bean cultivars in order to form a secure database for imazethapyr registration application for preplanting applications.

For common bean plants, working with the selectivity of herbicides chlorimuron, imazethapyr and chloransulam, applied in association with fomesafen in ten cultivars, have verified that these herbicides were phytotoxic but the most severe symptoms were observed in the treatment containing chlorimuron. The association of fomesafen with chlorimuron has caused reductions in plant height and in the accumulation of shoot dry matter, prolonging the maturation cycle of all cultivars.

These authors have also verified that fomesafen isolated has reduced the grain yield of cultivars BRS Timbó and BRS Vereda. And when added to imazethapyr it has reduced the productivity of cultivars BRS Supremo, Timbó and Vereda. The addition of chloransulam, besides reducing the yield of these three cultivars, has also reduced yield of cultivar BRS Requinte. Imazethapyr showed potential to be used in beans crops.

In growing crambe in succession to growing soybeans, variables number of plants, number of grains per plant, one hundred seed-weight and grain yield did not present a significant effect for the different herbicides used in controlling weeds in soybeans crops (Table 3). For Kalsing and Vidal (2013), several specific factors, such as environmental conditions, soil attributes and crop management, among others, may affect crops tolerance to herbicides in higher or lower levels.

Herbicides residual activity was not long enough to cause crop yield losses. Therefore, for Timossi et al. (2013), the crambe crop becomes another option to be cultivated in the second harvest for areas where the herbicide associations were used in the soybean crop. According to Oliveira Júnior (2002), crop rotation planning should be judicious in order to avoid herbicides residual effect.

Crambe grain yield is not yet well defined in the different regions with potential for its cultivation. However, according to Table 3, the values obtained were considered low when compared to the averages obtained by Pitol et al. (2010), from 500 to 1,500 kg ha^{-1}.

Regarding the variables evaluated for millet resulting from the treatments applied to soybeans, no significant effects were observed for fresh and dry matters, number of panicles per meter, panicle weight and length and grain yield (Table 4). Dan et al. (2011), working with residual activity of preemergent herbicides applied in soybean crops, have verified that herbicides imazethapyr and chlorimuron-ethyl have not affected crop yield when millet sowing was done from 80 days after application and fomesafen at 120 days, disagreeing with the results found in this research.

Table 4 - Total fresh weight (TFW), total dry matter (TDM), number of panicles (NP), mass of panicles (MP), panicle length (PL), thousand seed weight (TSW) and grain yield (GY) of millet cultivated in succession to soybeans due to the herbicides applied in postemergence on soybeans

Treatment	TFW	TDM	NP	MP	PL	TSW	GY
	(kg ha^{-1})			(g)	(cm)	(g)	(kg ha^{-1})
T1	15,887.0	5,039.3	17.38	22.52	20.95	10.85	1,690.68
T2	16,418.7	5,908.0	15.44	26.64	22.55	11.32	1,559.32
T3	16,812.3	5,599.7	16.38	24.43	22.43	11.41	1,848.48
T4	19,006.1	5,656.0	18.94	26.07	23.87	10.43	1,869.22
T5	14,268.6	4,207.6	14.63	21.61	23.51	10.22	1,444.67
T6	14,368.5	4,741.7	14.81	22.30	23.39	11.02	1,501.76
T7	18,118.4	5,940.6	14.44	23.82	22.46	10.56	1,455.29
T8	14,755.9	4,575.5	13.31	21.55	22.46	10.41	1,694.52
T9	16,943.5	4,922.1	14.81	23.76	23.38	10.72	1,622.59
F	0.66^{ns}	0.52^{ns}	1.16^{ns}	0.98^{ns}	0.70^{ns}	0.54^{ns}	0.68^{ns}
VC (%)	24.47	23.51	20.48	15.75	9.18	10.46	23.41

T1 – imazethapyr (106 g ha^{-1}.); T2 – imazethapyr (159 g ha^{-1}); T3 – chlorimuron (15 ha^{-1}); T4 – chlorimuron (22.5 g ha^{-1}); T5 – fomesafen (250 g ha^{-1}); T6 – fomesafen (375 g ha^{-1}); T7 – chloransulan methyl (40 g ha^{-1}); T8 – chloransulan-methyl (60 g ha^{-1}); and T9 – control. ^{ns} Non-significant by the F test.

Similar to what was observed for crambe, herbicides residual activity was not enough to show deleterious effects to the crop and affect its productive potential. The dry matter yield of the crop and grains is within the range considered suitable for the crop (Priesnitz et al., 2011; Queiroz et al., 2012).

Regarding the variables evaluated in forage *U. brizantha* cv. Xaraés established after soybean cultivation, it was found that the use of residual herbicides in the predecessor crop has not interfered with plant height, leaf/stalk ratio and dry matter yield of stalks, leaves, dead material and dry matter of the whole plant at the two times of cutting when comparing to the untreated control (Table 5). This shows that the succession of soybeans with forage is a promising alternative for cultivation since, in addition to soybean crops, it is still possible to obtain the use of the brachiaria for both animal feed and stover for the direct planting system (Timossi et al., 2007). In this way, the importance of evaluating the succession system of crops in an integrated way was verified in order to guarantee the sustainability in systems involving agriculture and livestock (Pariz et al., 2009).

In general, there was no effect of herbicides toxicity used in soybeans on the growth and production of crops grown in succession nor the absence of their contribution to weeds control in succeeding crops. For Inoue et al. (2011), the differences between herbicides can be attributed to the specific physical and chemical characteristics of each product, which allow them to persist in the soil for certain periods of time. These characteristics include in particular the values of water solubility and the octanol-water partition, which influence the dissipation processes of these compounds in the environment. In addition, other factors, such as environmental conditions, soil attributes and crop management, among others, affect the dynamics of herbicides in the soil. In particular, in this research, excess precipitation during the soybean cycle (Figure 1) may have contributed to the faster degradation or leaching of the herbicides below the effective depth of the root system of the late harvest crops.

Thus, herbicides at the doses tested were effective in weed control in soybean cultivation and did not affect its yield.

There was no contribution of herbicides applied to soybeans in controlling weeds in crops grown in succession to soybeans.

Herbicides residual activity did not affect the performance of adzuki bean, crambe, millet and palisade grass, except the use of chloransulan in adzuki bean. New research in different soil and climatic conditions is necessary to consolidate the results.

Table 5 - Plants height (PH), leaf/stalk ratio (LSR) and total dry matter of leaves, stalks and dead material of forage *Urochloa brizantha* cv. Xaraés, evaluated at 1st and 2nd cuts after cultivation of soybeans due to the herbicides applied in postemergence on soybeans

Treatment	1st cut					
	PH	LSR	Dry matter (kg ha^{-1})			
	(cm)		Total	Leaf	Stalk	Dead material
T1	84.85	1.26	3,618.95	1,943.09	1,583.73	92.13*
T2	87.55	1.15	3,811.89	1,953.71	1,707.01	151.17
T3	84.85	1.06	3,780.25	1,853.43	1,755.71	171.10
T4	77.65	1.17	3,945.03	1,993.45	1,781.03	170.55
T5	89.45	1.22	4,622.28	2,471.45	2,040.39	110.43
T6	84.70	1.14	3,989.45	2,030.97	1,792.54	165.93
T7	91.70	1.01	3,832.69	1,875.21	1,896.56	60.92
T8	87.50	1.14	4,352.52	2,229.96	1,969.11	153.45
T9	84.80	1.09	4,025.98	2,366.88	1,449.64	209.46
F	0.83^{ns}	0.89^{ns}	1.20^{ns}	1.58^{ns}	0.74^{ns}	0.41^{ns}
VC (%)	10.06	14.43	14.16	17.02	24.06	10.01
Treatment	2nd cut					
	PH	LSR	Dry matter (kg ha^{-1})			
	(cm)		Total	Leaf	Stalk	Dead material
T1	53.85	1.31	5,103.96	2,619.99	2,038.62	445.34
T2	48.90	1.32	4,519.69	2,374.94	1,780.30	364.45
T3	50.40	1.31	4,587.46	2,385.08	1,806.29	396.09
T4	50.40	1.33	4,324.54	2,046.75	1,632.65	645.13
T5	55.65	1.08	4,713.14	2,117.08	1,974.45	621.62
T6	55.15	1.24	4,262.17	1,979.41	1,653.64	629.13
T7	53.85	1.18	5,017.45	2,322.66	1,964.36	730.43
T8	56.05	1.12	4,794.74	2,174.57	2,163.58	456.59
T9	46.95	1.18	5,154.19	2,428.98	2,125.62	599.59
F	1.37^{ns}	0.37^{ns}	0.38^{ns}	0.51^{ns}	0.56^{ns}	0.83^{ns}
VC (%)	10.67	25.32	22.30	25.61	28.81	8.01

T1 – imazethapyr (106 g ha^{-1}.); T2 – imazethapyr (159 g ha^{-1}); T3 – chlorimuron (15 ha^{-1}); T4 – chlorimuron (22.5 g ha^{-1}); T5 – fomesafen (250 g ha^{-1}); T6 – fomesafen (375 g ha^{-1}); T7 – chloransulan methyl (40 g ha^{-1}); T8 – chloransulan-methyl (60 g ha^{-1}); and T9 – control. ^{ns} non-significant by the F-test. VC – variation coefficient.* Data transformed into root (x) for analysis.

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