Economic analysis of rice and common bean production in succession to green manure crops and mecahnical soil decompression in Brazilian Savannah [1]

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ABSTRACT

The previous cultivation of green manures and mechanical soil decompression are options to minimize compaction of the topsoil in no-tilage system (NTS) set in different production systems in the Brazilian Savannah. In addition, it is essential to relate these agricultural practices with the economic benefits generated through the production cycles. The objective of this study was to evaluate economically the effect of sporadic mechanical decompression of the soil and previous cultivation of green manure in the production and net gain margin of upland rice and "winter" common bean, under sprinkler irrigation, in NTS in lowland Brazilian savannah. This study was developed in the 2012/13 harvest and 2013 winter in Selvíria, state of Mato Grosso do Sul, in an clay texture Oxisol in the savanah in the state of Mato Grosso do Sul, in a randomized block design arranged in a 5 x 2 factorial arrangement with four replications. The treatments were a combination of five green manures (fallow (control), *Cajanus cajan*, *Crotalaria juncea*, *Pennisetum glaucum* and *Urochloa ruziziensis*) with and without mechanical soil scarification. The yields of upland rice and common bean grains were not influenced by the previous green manure cultivation; the upland rice grown in succession to *Cajanus cajan* in the presence of mechanical soil scarification provided greater increase in grain yield and higher gross margin profit. Beans cultivated in succession to *Crotalaria juncea* and *Pennisetum glaucum* in the presence of mechanical soil scarification, followed by rice cultivation, provided greater increases in grain yield and gross profit margins.

Key words: *Phaseolus vulgaris* L.; *Oryza sativa* L.; profit margin; cover crops; sprinkler irrigation; no-tilage system.

RESUMO

Análise econômica da produção de arroz e feijão em sucessão a cultivos de adubos verdes e descompactação mecânica no cerrado

O cultivo antecessor de adubos verdes e a descompactação mecânica do solo são opções para minimizar a compactação da camada superficial do solo em sistema plantio direto (SPD) implantado, em diversos sistemas de produção no cerrado. Além disso, é essencial relacionar estas praticas agrícolas com os benefícios econômicos gerados. Assim, este trabalho objetivou avaliar economicamente o efeito da descompactação mecânica esporádica do solo e cultivo antecessor de adubos verdes, na produtividade e margem liquida do ganho para o arroz de terras altas e feijão "de inverno", sob irrigação por aspersão, em SPD em área de cerrado de baixa altitude. Este estudo foi desenvolvido na safra 2012/13 e no inverno de 2013 em Selvíria, MS, em um Latossolo Vermelho distrófico de cerrado Sul Mato Grossense de textura argilosa, com delineamento em blocos casualizados disposto em esquema fatorial 5x2, com quatro repetições. Os tratamentos foram constituídos pela combinação de cinco adubos verdes (pousio (controle), *Cajanus cajan*, *Crotalaria*

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juncea, *Urochloa ruziziensis* e *Pennisetum glaucum*) com e sem escarificação mecânica do solo. A**s** produtividade**s** de grãos do arroz e feijão não foram influenciadas pelo cultivo antecessor de adubos verdes; o arroz de terras altas cultivado em sucessão a *Cajanus cajan*, na presença de escarificação mecânica do solo, proporcionou maior acréscimo de produtividade de grãos e maior margem de ganho bruta. O feijão cultivado em sucessão a *Crotalaria juncea* e *Pennisetum glaucum*, na presença de escarificação mecânica do solo, seguida de cultivo do arroz, proporcionaram maiores acréscimos na produtividade de grãos e nas margens de ganho brutas.

Palavras-chave: *Phaseolus vulgaris* L.; *Oryza sativa* L.; margem de ganho; plantas de cobertura; irrigação por aspersão; sistema plantio direto.

INTRODUCTION

Rice and beans have economic, social and nutriton importance due to the daily consumption habit. The per capita annual consumption of rice in Brazil is between 25 and 50 kg^{-1} inhabitant $^{-1}$ $year^{-1}$ (FAO, 2011), being an excellent source of carbohydrates, in its natural form, but it can also be an important source of proteins, mineral salts (mainly phosphorus, iron and calcium) and vitamins of B complex such as B_1 (thiamine), B_2 (riboflavin) and B_3 (niacin). However, in relation to beans, out of ten Brazilians, seven consume beans daily. Moreover, the grain, besides being typical of the Brazilian cuisine, is a source of vegetable protein, B vitamins, mineral salt, iron, calcium and phosphorus (Brazil, 2013). For the total Brazilian harvest of rice and beans in 2014/15, a total cultivated area of 2.4 and 3.2 million hectares was estimated, and the domestic production of 12.2 and 3.3 million tons of grains, and average yield of 5,182 and 1,044 ha^{-1}, respectively, according to Conab (2015).

In an established no-tillage system (NTS), because of the small mobilization in the soil, compactation issues have been occuring with greater intensity and extenion in in the surface layers. This occurs because of the compression process caused by machinary traffic in agricultural operations where the soil at moisture conditions above the ideal, especially in clay soils, and also due to no soil mobilization, combined with higher water retention in the soil, determining a short period of time with adequate moisture for mechanized operations (Araújo *et al*., 2001).

The sporadic mechanical scarification of established no-tillage soil can be a viable alternative to minimize the physical limitations in the surface layers of soil to plant growth. Some studies have shown significant increases in crop yields in soils under scarified non-tillage (Câmara & Klein, 2005; Vieira, 2006). This practice increases porosity and decreases soil density (Reichert *et al*., 2009) while the compacted layers are broken up to a depth of 0.30 m. As a result, scarification increases the rate of infiltration and water storage capacity. However, nothing prevents the decompressed soil to be used again in the no-tillage system since the decompression process is suitably performed with well regulated equipment (scarifiers and escarifying rods) with thin stems and narrow tip, so they revolve the soil as little as possible, trying to break the soil in its natural break up plan and keeping most of the plant debris on the soil surface (Salton *et al*., 1998).

The cultivation of green manures with root systems that exploit different volumes of soil provides nutrient cycling (Boer *et al*., 2007). Since the decomposition of vegetal debris of these plants release nutrients that contribute to increases in corn yields (Lara Cabezas *et al*., 2004) and soybean (Carvalho *et al*., 2004) or maintaining the productivity of these crops (Andrioli, 2004; Bertin *et al*., 2005). According to Tanaka *et al*. (1992), the use of velvet bean, lablab and crotolaria as green manure provided significant increases in yields of rice, beans and soybean in succession. So, there is a need to adjust the production system, taking into account the previous crops and sporadic mechanical descompactation of the soil to obtain the highest profit margin, as failure in rice and bean crop is often determined by compactation on the surface layer of soil in established non-tilage systems, altering the quality of the soil because it changes the flow of water and air and the dynamics of soil nutrients, promoting the reduction of productivity of crops in several production systems.

In studies with economic analysis in corn crop in no-tillage system after green manures in Red Latosol soil, Silva *et al*. (2007) found that corn crop in succesion to crotolaria provided greater physical and economic yield of grains, compared to corn in successsion to millet crop and fallow.

To use in a rational manner the production systems created from the established no-tillage system is needed the knowledege of various fields of study. Among them, financial management of the property stands out, which is important for assessing the profitability of practices used within the production systems, assisting in decision making of investments. Economic information of a crop is of fundamental importance to the farmer since it helps in the combination of the resources used in its production, in order to obtain better results (Crepaldi, 1998).

Thus, studies that contribute to an appropriate recommendation from not only the agronomic point of view but also from economic production system over its previous use of green manures and sporadic mechanical decompression of the soil, particularly with compaction problems on the superficial layer are needed. The objective of this study was to estimate the increase in productivity and net monetary margin with sporadic mechanical decompression of the soil and previous crop of green manure on the production of upland rice and winter beans under sprinkler irrigation in no tillage system implanted 12 years ago, in lowland Brazilian Savannah.

MATERIAL AND METHODS

This study was developed in the 2012/13 crop and 2013 winter in Selvíria, state of Mato Grosso do Sul, located at 51°22' W and 20°22' south, 335 m above seal level in a clay texture oxisol, epi-eutrophic alic, according to EMBRAPA (2013) classification. The average annual values of rainfall, temperature and relative humidity are 1,370 mm, 23.5 °C and 70-80%, respectively. According to Köppen, the climate type is Aw, characterized as humid tropical, with rainy season in Summer and dry season in Winter. The experimental area had been used for 12 years in no-tillage system, cultivated in 2009/10, 2010/11 and 2011/12 with corn (Summer) and beans (Winter) crops, except in the winter of 2011/12 when the area was maintained in fallow. In 2012/13, management was carried out with mechanical soil descompactation, cultivation of green manure in the spring (September to November) and rice (Summer) and "Winter" beans.

Before the experiment setting up, chemical and physical characterization of soil was carried out in June 14th, 2012 (Table 1). For soil analysis, a composite sample, originated from 20 simple soil deformed samples was removed from all experimental area at the stratified layers of 0.00-0.05, 0.05-0.10, 0.10-0.20 and 0.20-0.40 m. As for physical analysis, non-deformable soil samples were taken at 10 random sites in the experimental area, in the layers already cited, with 10^{-4} m^{-3} volumetric rings.

The experimental design was a randomized block arranged in a 5 x 2 factorial design, with four replications. The treatments were a combination of five green manures (fallow (control), *Cajanus cajan*, *Crotalaria juncea*, *Urochloa ruziziensis* and *Pennisetum glaucum*) with and without mechanical soil scarification. In fallow with and without soil scarification, growth of natural vegetation of weeds was allowed. Each plot consisted of 12 m in length and 7 m of width.

Thus, after the initial characterization on June 10th, 2012, 1,600 kg ha $^{-1}$ of dolomitic limestone was applied all over the experimental area, with 85% PRNT using equipment with broatcast distributer. Soil tillage was carried out using scarificator in some of the experimental area on August, 9th, 2012, before the sowing of green manure (GM), with seven-rod scarifier reaching the working depth of 0.30 m and width of cut range 2.1 m. In the scarified parts, an operation with levelling disk was carried out.

All green manures were hand sown on August, 14th, 2012 without fertilization, with spacing between rows of 0.45 m. Sowing densities used for *Cajanus cajan* were 60 kg ha^{-1}, *Crotalaria juncea* and *Pennisetum glaucum* of 30 kg ha^{-1} and for *Urochloa ruziziensis*, 12 kg ha^{-1}. All green manures were dessicated on day 68 after sowing (DAS) with glyphosate (1.440 g ha^{-1} a.i.) + 2,4-D (670 g ha^{-1} a.i.). After 10 days, all GM were mecanchally ground, with cutting height of 0.10 m. On June 6th, 2013, additional dessication was carried out with paraquat (1.314 g ha^{-1} a.i.).

Mechanical sowing of rice was held on November, 13th, 2012, conducted from November to March, under sprinkler irrigation, following the same experimental design and treatments. The basic fertilizer in planting furrows consisted of 250 kg ha^{-1} of 06-30-10, following the recommendation of Cantarella & Furlani (1996). Cultivar IAC 203, with the number of certified seed, needed for a

Table 1: Chemical and physical characteristics of the soil in the experimental area in the evaluated layers before experiment setting up

	Chemical characteristics							Physical characteristics				
	P	O.M.	pH	K	Ca	Mg	Al	V	Ma	Mi	TP	SD
Depth (m)	mg dm^{-3}	g dm^{-3}	$CaCl_2$	($mmol_c$ dm^{-3})				%	m^3 m^{-3}			Mg dm^{-3}
0.00-0.05	29	24	5.9	3.5	41	25	0	79	0.08	0.36	0.44	1.49
0.05-0.10	6	17	4.9	1.8	17	12	2	48	0.06	0.35	0.41	1.56
0.10-0.20	38	15	4.5	1.3	10	7	6	33	0.07	0.35	0.42	1.54
0.20-0.40	7	13	4.8	1.4	10	8	2	40	0.10	0.36	0.46	1.42

Depth: soil depth (metter); P: available phosphorus (resina); O.M.: organic matter; exchangeable K, Ca, Mg and Al; V(%): base saturation; Ma: Macroporosity, Mi: Microporosity; PT: Total porosity and SD: soil density.

stand of 180 plants m^{-2} was used. Topdressing nitrogen fertilization was performed 30 days after emergence (DAE) of seedlings at a dose of 60 kg ha^{-1} N, using ammonium sulfate. Other crops and phytosanitary treatments were those usually recommended to upland rice crop for the region. Harvest was carried out on March, 4th, 2013.

On March 4th, 2013, the herbicide glyphosate (1,440 g ha^{-1} a.i.) was applied. Following that, mechanical sowing of beans was performed on May, 3rd, 2013, and conducted from May to August, under sprinkler irrigation, following the same experimental design and treatment. The plots consisted of 14 lines of 12 m in length, considered as useful area, 12 rows in the center, leaving 0.5 m at both ends of each line. The spacing between rows was 0.45 m with seed distribution allowing to obtain 12 plants m^{-1}.

Basic fertilizer in planting furrows consisted of 250 kg ha^{-1} of 04-30-10 + 0.3% Zn, following recommendations of Ambrosano *et al*. (1997). Nitrogen fertilization was performed at 19 DAE of seedlings at a dose of 60 kg ha^{-1} N, using ammonium sulfate. Perola cultivar with type III plants and carioca type grain were used. Seeds were treated just prior sowing with carboxin + thiram (50 + 50 g a.i. per 100 kg of seed). At 12 DAE, post-emergence herbicide Bentazon (720 g a.i. ha^{-1}) was used. Other cultural and phytosanitary practices were those usually recommended for bean crop for the region. Harvest was carried out on August,15th, 2013.

The yield of rice grains was determined by weighing the grain from the useful area of the plot, correcting the moisture to 13% and converting it into kg ha^{-1}. As for evaluation of bean grain yield, plants were pulled out from the useful area of each plot and left to dry in unshaded area. After drying, they were submitted to mechanical track, the beans were weighed and the data trasnsformed into kg ha^{-1} (13% wet basis).

As for the economic analysis, the technique of partial budgeting, described in Noronha (1987) was used, and also in analysis of experiments carried out by Teixeira Filho *et al*. (2010), Binotti *et al*. (2010) and Sabundjian, *et al*. (2014). Partial budgeting is used to analyze decisions involving partial changes in the organization of a productive activity. The objective is to compare the increase in costs with the benefits of the decision. The best alternative is that offering greater net benefits or profit margins (Teixeira Filho *et al*., 2010). The average yields and costs were assessed. The costs of the seeds were obtained through pieces of information from supliers of the region, being from seeds of *Cajanus cajan* (R$ 10.06), *Crotalaria juncea* (R$ 13.50), *Urochloa ruziziensis* (R$ 13.29) and *Pennisetum glaucum* (R$ 1.73) per kg, during the harvest of 2013. The cost of scarification operation was R$ 60.00 and the sowing of green manure was R$ 100.00, based on Agrianual (2014). The values obtained with the costs for each treatment were divided by the rice (50%) and bean (50%) crops. Based on the average grain yield of each treatment, the increase in the yield was estimated provided by the use of green manure compared to the control (fallow with and without mechanical soil scarification).

The production value in each treatment was obtained by multiplying the additional yield by the average price received by producers of rice in husk and “Winter” beans of the study area. The profit margin was obtained by subtracting the production value by the cost obtained with mechanical soil scarification, the kilogram of seeds of GM and sowing of GM for each treatment. The price of rice and beans (60 kg bag) refers to the average price received by producers during the month of harvest in the growing crop, which was R$ 45.67 bag^{-1} for rice and R$ 147.49 bag^{-1} for beans, both in the crop years (IEA, 2015). Average prices were deflated by the General Price Index - Internal Availability (IGP-DI) - published by the Getulio Vargas Foundation.

RESULTS AND DISCUSSION

Costs with green manure, mechanical decomposition, quantities of green manure seeds, rice and bean grains yield, increases in grain yield, production value and costs of seeds and sowing operations of GM and mechanical soil scarification per hectare are shown in Table 2. It is found that upland rice cultivated in succession to *Cajanus cajan* with (6,074 kg ha^{-1}) and without (5,154 kg ha^{-1}) mechanical soil scarification, in addition to *Crotalaria juncea* with scarification (5,015 kg ha^{-1}) provided greater increases in the yield of rice grains in relation to other GMs (Table 2). These results evidence the potential of *Cajanus cajan*, regardless of scarification, in providing greater cycling and release of nutrients for rice grown in succession. Rice grain yields were higher than those found by Pacheco *et al*. (2013), who found that the previous crop of *Urochloa ruziziensis* (1,554 kg ha^{-1}) was the best option of green manure for rice, explaining that low productivity was due to the occurrence of water deficit (pre-flowering), different from the experiment in at matter since it had been irrigated. However, according to Pacheco *et al*. (2011) who obtained higher rice yields in no-tillage system on haystacks of *Pennisetum glaucum* and *Urochloa ruziziensis*.

Among the alternatives to minimize the effects of the thickening of soil particles, it is essential to use decompressor crops with abundant and vigorous root system, which provide the most efficient disruption of the compacted layer, providing improved stability of aggregates, thus increasing soil porosity and improving the production system, resulting in increased yield of crops in succession (Villamil *et al*., 2006). Among the decompressor species of plants, *Cajanus cajan* stands out for presenting deep root system, able to grow in soils with a tendency to form crusts on the surface (Brazaca *et al*., 1996), with good potential to absorb water and the possibility of cycling of nutrients from deeper layers (Alvarenga *et al*., 1995).

Regarding the productivity of "Winter" bean obtained in the treatments (Table 2), it was found that greater increases of bean grain yield occured in previos crops of *Crotalaria juncea* (2,381 kg ha^{-1}) and *Pennisetum glaucum* (2,158 kg ha^{-1}) with mechanical soil scarification, evidencing that the previous crop of *Crotalaria juncea* and *Pennisetum glaucum* associated with the operation of mechanical soil scarification interacted positively. Results contrary to that presented by Collares *et al*. (2008), when they found that the mechanical soil scarification did not promote the increase in bean yield, but showed to be effective in decreasing the effects of compaction on the soil surface layer, especially in the reduction of soil penetration resistance.

However, in an oxisol and in the same climate conditions, Almeida *et al*. (2008) found that a higher productivity of bean grains occured after the previous growth of *Crotalaria juncea* in relation to *Pennisetum glaucum*, possibly because *Crotalaria juncea* had generated more favorable enviroment to bean nodulations, providing the highest grain yield. Confirming the study by Oliveira *et al*. (2002), in which the authors found that the yield of common bean grains in the no-tillage system is influenced by different hays of green manures, in general, the bean crop in winter proved to be good alternative of crop succession and could add value, according to Silveira *et al*. (2001). In addition, the crop keeps the soil covered in the off season and uses nutrients from the previous biomass.

It was found that the previous cultivation of *Cajanus cajan* with and without mechanical soil scarification (Table 2), provided higher increases in grain yield (950 and 277 kg ha^{-1}) and production values (R$ 723.11 and 210.84 ha^{-1}) for rice crop. No increases in grain yield and production value were found in the other treatments in relation to fallow.

Table 2: Green manure (GM), mechanical decompactation (MD), quantities of seeds of green manure, yields (Y), increses in rice and beans yields, producitio value and costs with seeds + seeder + scarifier, per hectare

Costs for upland rice crop - 2012/13 harvest						
Green manure	**Treatments**			**Addition**		
	MD	**Quantity of seeds**	**Y**	**Y**	**Production value [1;2]**	**Costs[3]**
		kg ha^{-1}	**kg ha^{-1}**	**kg ha^{-1}**	**R$ ha^{-1}**	**R$ ha^{-1}**
Fallow (control)	without	-	4,877	-	-	-
Fallow (control)	with	-	5,124	-	-	30.0
Cajanus cajan	without	60	5,154	277	210.84	351.8
Cajanus cajan	with	60	6,074	950	723.11	381.8
Crotalaria juncea	without	30	4,532	-345	-262.60	252.5
Crotalaria juncea	with	30	5,015	-109	-82.97	282.5
Urochloa ruziziensis	without	12	4,118	-759	-577.73	129.8
Urochloa ruziziensis	with	12	4,451	-673	-512.27	159.8
Pennisetum glaucum	without	30	4,018	-859	-653.84	75.9
Pennisetum glaucum	with	30	4,290	-834	-634.81	105.9
Cost for "Winter" bean crop - 2013 Harvest						
Green manure	**MD**	**Quantity of seeds**	**Y**	**Y**	**Production value[1;2]**	**Cost[3]**
Fallow (control)	without	-	1.824	-	-	-
Fallow (control)	com	-	1.698	-	-	30,0
Cajanus cajan	without	60	1.460	-364	-896.35	351.8
Cajanus cajan	com	60	1.589	-109	-268.41	381.8
Crotalaria juncea	without	30	1.649	-175	-430.94	252.5
Crotalaria juncea	com	30	2.381	683	1681.89	282.5
Urochloa ruziziensis	without	12	1.619	-205	-504.81	129.8
Urochloa ruziziensis	com	12	1.907	209	514.66	159.8
Pennisetum glaucum	without	30	1.693	-131	-322.59	75.9
Pennisetum glaucum	com	30	2.158	460	1132.75	105.9

[1] Based on average price paid in the state of São Paulo, rice in the 2012/13 harvest, R$ 45.67 per 60 kg-bag and beans in the 2013 winter, R$ 147.49 per 60 kg bag (IEA, 2015). [2]Price of scarification operations (R$60.00/hour.ha^{-1}) and green manure sowing (R$100.00/hour.ha^{-1} (AGRIANUAL, 2014); [3] Costs with seeds + mechanical sowing of green manure + soil mechanical scarification.

Marked increases were found in bean yield and production values (Table 2) grown with previous cultivations of *Crotalaria juncea* (683 kg ha^{-1} and R$ 1,681.89 ha^{-1}) and *Pennisetum glaucum* (460 kg ha^{-1} and R$ 1,132.75 ha^{-1}) with no mechanical soil scarification with increases in grain yield of 40.22% and 27.09%, respectively, followed by *Urochloa ruziziensis* cultivation with scarification (209 kg ha^{-1} and R$ 514.66 ha^{-1}) with less expression of grain yield (12.31%). No increases were found in grain yield and and production value in the other treatments. This higher grain yield increase in the previous Crotalaria juncea growth was probably due to rapid decomposition of plant residues left on the soil surface and also because it presents low carbon (C)/nitrogen (N) ratio, where N is faster released in the soil, coinciding with the period of the highest demand of the crop (Oliveira *et al.*, 2002).

By analyzing the costs (green manure seeds + mechanical operations of sowing and mechanical soil scarification) for the cultivation of rice and beans (Table 2), it was found that the highest costs occurred in the previous cultivation of *Cajanus cajan*, regardless of scarification, providing a higher cost values (R$ 703.6 ha^{-1} and R$ 763.6 ha^{-1}) for rice and beans in succession. The lowest cost values were obtained with the cultivation of *Pennisetum glaucum*, regardless of scarification (R$ 151.9 ha^{-1} and R$ 211.9 ha^{-1}) for presenting lower cost of seeds (R$ 1.73 kg^{-1} of seeds) in relation to other green manures.

In relation to the profit margin for rice crop (Figure 1A), it was found that most of the treatments had a negative profit margin, except the previous cultivation of *Cajanus cajan* with mechanical soil scarification (R$ 341.33 ha^{-1}), thus they did not economically respond to adopted soil management practices. This was a short-term study, requiring further evaluations in the medium and long term of this soil management technology in no-tillage system established in lowland Brazilian Savannah.

Regarding to profit margin for the "winter" bean crop (Figure 1B), it was observed that the bean crop in succession to *Crotalaria juncea* (R$ 1,399.39 ha^{-1}) and *Pennisetum glaucum* (R$ 1,026.8 ha^{-1}) in the presence of mechanical soil scarification, followed by rice crop,

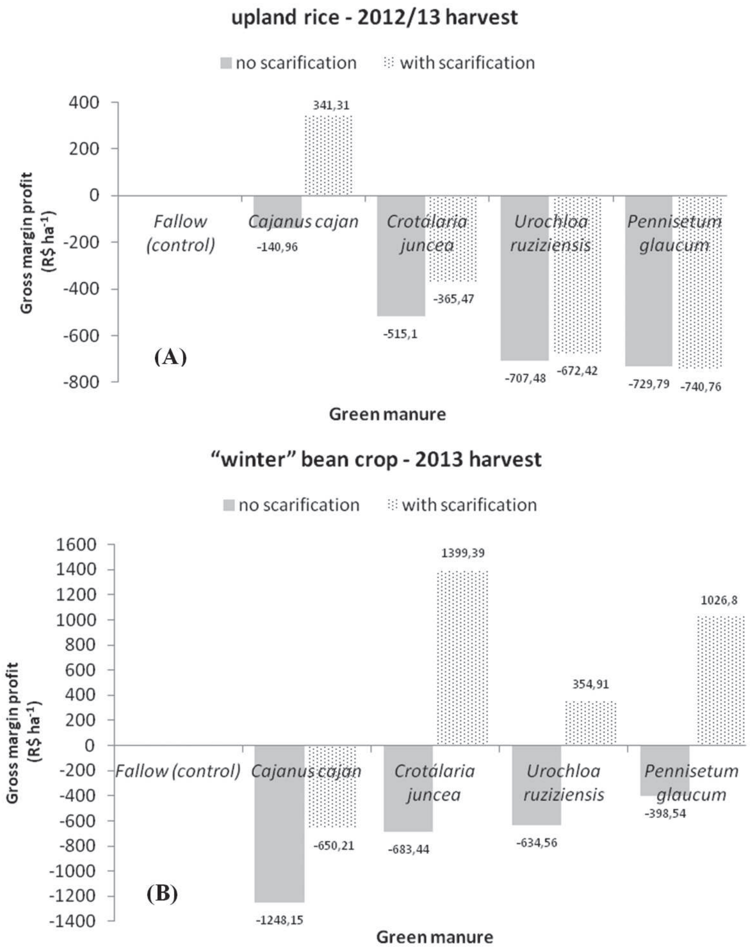

Figure 1. Gross profit margin (R$ ha^{-1}), in the previous cultivations of green manure in spring and soil mechanical decompactation in upland rice (A) and "winter" beans (B), under sprinkler irragation in a non-tillage system established 12 years ago in the lowland Savannah.

provided higher profit margins compared to other green manures studied. The previous cultivation of *Cajanus cajan*, in the presence of mechanical soil scarification, was costly for the bean crop due to the use of larger quantity of seeds (60 kg ha^{-1}) and the high cost of seed (R $ 10.06 kg^{-1}), provided less profit margin.

CONCLUSIONS

The yield of upland rice and "winter" beans were not influenced by the previous crop of green manure in the spring.

The upland rice grown in succession to *Cajanus cajan* in the presence of mechanical soil scarification, provided higher grain yield and higher margin gross profit.

"Winter" beans grown in succession to *Crotolaria juncea* and *Pennisetum glaucum* in the presence of mechanical soil scarification, followed by rice cultivation, provided greater increases in yields and gross profit margins.

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