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Soil mechanical scarification increases the dry matter yield of cover crops under no-tillage

Efecto de la escarificación mecánica del suelo en el rendimento de cultivos de cobertura con cero labranza

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ABSTRACT

Soil mechanical scarification (MS) and cover crop growing (CC) are strategies to minimize compaction in the soil surface layer under the no-tillage system (NTS). The objective of this study was to evaluate the effects of soil mechanic scarification on the yield and nutrient accumulation in the shoot dry matter of cover crops, as well as the persistence of crop residues in NTS, implemented 12 years ago in the Cerrado conditions with low altitude. The study was carried out in Selvíria, Mato Grosso do Sul state, Brazil, in the 2012 and 2013 harvest, in a clay soil classified as Oxisol Red epi-eutrophic alic. The experimental design was a randomized block arranged in a 5 × 2 factorial scheme, with four replicates. The treatments were constituted by the combination of four cover crops (*Cajanus cajan*, *Crotalaria juncea*, *Urochloa ruziziensis* and *Pennisetum glaucum*) and fallow with spontaneous vegetation, with or without MS. Soil MS increases the shoot dry matter yield of *P. glaucum*, *U. ruziziensis* and *C. cajan* in the first crop. The *P. glaucum* species, independently of soil scarification, provide higher yield and accumulation of macronutrients in the shoot dry matter, besides provide higher persistence of crop residues. The *U. ruziziensis* and *C. cajan*, independently of soil scarification, have the potential for accumulation of N, P, K and Ca in the shoot dry matter, although with less persistence of residues on the soil surface.
Keywords: Soil compaction, Green manure, Persistence of crop residues, Nutrient accumulation, Soil conservation management.

RESUMEN

La escarificación mecánica (EM) del suelo y/o el cultivo de plantas de cobertura (PC) son estrategias para minimizar la compactación en la capa superficial del suelo en sistema de saneamiento directo (SPD) consolidado. El trabajo tuvo como objetivo evaluar la influencia de la escarificación mecánica del suelo en la productividad y acumulación de nutrientes de la materia seca de PC, así como la persistencia de residuos de cultivos en SPD implantado hace doce años, en condiciones de baja altitud en el Cerrado. El estudio fue desarrollado en Selvíria, MS, en las cosechas 2012 y 2013, en un oxisol rojo epieutrófico, textura arcillosa. El delineamiento experimental utilizado fue de bloques aleatorios dispuestos en esquema factorial 5x2, con cuatro repeticiones. Los tratamientos fueron constituidos por la combinación de cuatro PC (Cajanus cajan, Crotalaria juncea, Urochloa ruziziensis *y* Pennisetum glaucum) *y barbecho con vegetación espontánea, con y sin EM del suelo. La EM del suelo aumenta la productividad de la materia seca de* P. glaucum, U. ruziziensis *y* C. cajan *en la primera cosecha. La especie P. glaucum, independientemente de la escarificación, proporciona mayor productividad y acumulación de macronutrientes en la materia seca, además de mayor persistencia de residuos de cultivos. La* U. ruziziensis *y* C. cajan*, independientemente de la escarificación, presentaron potencial de acumulación de N, P, K y Ca en materia seca en el brote, aunque con menor persistencia de los residuos en la superfície del suelo.*
Palabras clave: *compactación del suelo, abonos verdes, persistencia de residuos de cultivo, acumulación de nutrientes, manejo conservacionista del suelo.*

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Introduction

The no-tillage system (NTS) allowed the expansion of agriculture to the Cerrado. However, one of the limiting factors to obtain high yields in these areas has been the changes in soil physical attributes, mainly soil compaction, damaging the sustainability of NTS (Silva; Imhoff; Kay, 2004). Soil compaction occurs in the superficial layers, due mainly to the traffic of machines and implements in conditions of high-water content in the soil or by mobilizing it only in the sowing row. However, excess traffic, coupled with the absence of adequate crop rotation planning, also leads to the formation of compacted superficial layers in the soil under the consolidated NTS (Franchini *et al.*, 2012).

After a final diagnosis of soil compaction in agricultural areas, a conservation management system should be used to break this compacted soil layer, especially in clay soils, mobilizing it as little as possible, and maintaining the maximum of crop residues (straw) on the soil surface (Carvalho Filho *et al.*, 2007). This mechanical interference can be performed with scarifiers or subsoilers provided with cutting discs in front of the shanks, preventing the straw being incorporated into the soil. However, the longevity of the effects of soil mechanical scarification (MS) is variable and inconsistent, and may last from a few months (Nicoloso *et al.*, 2008; Reichert *et al.*, 2009a) to some years (Rosa *et al.*, 2008), depending on the rearrangement of the soil particles as a function of climatic conditions, traffic of machines and implements, type of soil and agricultural practices prevailing in the production system.

The growth of isolated cover crops or intercropping systems is promising alternatives to significantly increase dry matter yield and nutrient accumulation in the consolidated NTS (Pereira *et al.*, 2016; Chieza *et al.*, 2017). Plants from Poaceae family such as *Pennisetum glaucum*, *Urochloa ruziziensis* and *Urochloa brizantha* are species of the fast establishment, high dry matter yield, and which are known to promote nutrient cycling (Teixeira *et al.*, 2012; Pereira *et al.*, 2016). Crops from Fabaceae family are also included in production systems, isolated or intercropping with Poaceae plants in the second crop, aiming to increase crop yield in succession, mainly by the availability of nitrogen (Chieza *et al.*, 2017), due to biological nitrogen fixation (BNF), and the low Carbon-Nitrogen (C:N) ratio of the produced straw (Silva *et al.*, 2007; Pacheco *et al.*, 2011).

The objective of this work was to evaluate the effects of soil MS on the yield and nutrient accumulation in the cover crop dry matter, as well as the persistence of crop residues in NTS implanted 12 years ago in low altitude Cerrado conditions.

Material and Methods

The research was carried out in Selvíria, Mato Grosso do Sul state, Brazil, located 51º 22’ west longitude of Greenwich and 20º 22’ south latitude, with altitude of 335 m above sea level, in the 2012 and 2013 harvests, in a clay soil classified as Oxisol Red epi-eutrophic alic (Demattê, 1980; Embrapa, 2018).

The annual historical average values of rainfall, temperature and relative humidity are 1,370 mm, 23.5 ºC and 75%, respectively. According to Köppen, the climate type is Aw, characterized as humid tropical, with the rainy season in summer and dry in winter. The water supply was carried out every three days, or when necessary, by sprinkling, with a fixed central pivot irrigation system with a water depth of 14 mm.

The experimental design was in randomized blocks, arranged in a 5 × 2 factorial scheme, with four replications. The treatments were constituted by the combination of four cover crops (*Cajanus cajan*, *Crotalaria juncea*, *Urochloa ruziziensis* and *Pennisetum glaucum*) and the fallow with spontaneous vegetation, with and without soil mechanical scarification. In the plots with fallow, with and without scarification of the soil, we allowed the development of spontaneous vegetation of weeds. Each plot consisted of 12.0 m long by 7.0 m wide. For the evaluations, it was considered 10 m long and 5.0 m wide.

A composite sample, from 20 simple deformed soil samples, was collected in all experimental area in the 0.00-0.20 m layer, prior to the installation of the experiment on June 14th, 2012. The results of the chemical analysis are as follows: P resin = 25 mg dm^{-3}; pH in $CaCl_2$ = 4.7; K^+ = 1.6, Ca^{2+} = 13.5, Mg^{2+} = 9.5, H+Al = 35.5, SB = 24.6, CEC = 60.1 mmol$_c$ dm^{-3}, respectively; organic matter = 16 g dm^{-3}; and soil base saturation (V%) = 41%. It was applied in all experimental area according to recommendation by Raij *et al.* (1997), 1,600 kg ha^{-1}

of dolomitic limestone ($CaCO_3$ with ECCE 85%), applied on the soil surface using a distributor.

The soil MS in part of the experimental area was performed on August 09th, 2012, before sowing of the cover crops, using a seven-shank scarifier (three in the front bar and four in the back) with inclined shape and tip of chisel type, with 300 mm spacing between shanks and 22º angle of attack, and rolling harrow coupled to the tractor drawbar. The average working depth setting was 0.30 m, and the cutting range width was 2.10 m. The operation was performed when the soil was with moisture content close to the friability point. Then, in the scarified plots, an operation with light disc harrow was carried out.

All cover crops and the fallow were manually sown on August 14th, 2012 and September 09th, 2013, with hand seeder, without application of mineral fertilizer, with 0.45 m row spacing. The sowing density used for *C. cajan* was 60 kg ha^{-1}, for *C. juncea* and *P. glaucum* was 30 kg ha^{-1} and for *U. ruziziensis* was 12 kg ha^{-1}.

All cover crops and the fallow were desiccated at 68 days after sowing (DAS) and at 63 DAS, with the herbicides, glyphosate (1,440 g a.i. ha^{-1}) + 2,4-D (670 g a.i. ha^{-1}). The herbicides were applied with bar sprayer coupled to the tractor, regulated to 200 L ha^{-1} of spray volume. After ten days of the desiccation of the cover crops and the fallow, the management of the shoot dry matter was carried out with the operation of a horizontal straw chopper in all the cover crops and the fallow, with a cutting height of 0.10 m above ground level.

After the cover crop management, the shoot dry matter (SDM) yield was evaluated. Samples were taken at random, using a square of 0.25 m^2 (0.5 x 0.5 m) in four representative points of each plot. Posteriorly, the fragmented material collected was subjected to drying in a forced air oven at a temperature of 65 ºC until reaching the constant mass. The SDM was obtained by the arithmetic average between the four points sampled, with the average values expressed for Mg ha^{-1}.

Macronutrient contents (N, P, K, Ca, Mg and S) of the cover crops were determined after the evaluation of SDM, getting a 30 g sub-sample of DM from each plot. The determinations followed the methodologies described by Malavolta, Vitti and Oliveira (1997). Macronutrient contents accumulated by plants were expressed as g kg^{-1} in the SDM. The macronutrient contents accumulated by the cover crops were obtained by the product of the concentration of the respective nutrients determined in the subsamples (g kg^{-1}) and the SDM of the cover crops (kg ha^{-1}) and the fallow, with the estimated results in kg ha^{-1}.

The persistence of crop residues (PCR) maintained on the soil surface was performed by the Point-quadrat Method (Speeding; Large, 1957), consisting of a square of 0.25 m^2 (0.5 x 0.5 m) with lines fixed every 0.05 m on all sides, forming a grid of 100 points at the intersections of the lines. Two representative points were sampled in each plot every 30 days, being performed at 30, 60, 90 and 120 days after sowing (DAS) of the commercial crop. Thus, the persistence of the residues was obtained by the arithmetic mean between the two points sampled, with the mean values expressed as the percentage (%).

After checking the normality of the data, they were submitted to analysis of variance (*F* test), and the means were compared by the Tukey test at 5% significance level for cover crops (CC) and scarification (MS). When a significant interaction between the sources of variation (CC and MS) was found, we compared the means by the Tukey test, adopting a 5% significance level, according to Pimentel Gomes and Garcia (2002). Statistical analyses were performed using the statistical analysis software Sisvar 5.6 (Ferreira, 2010).

Results and Discussion

There was a marked reduction in shoot dry matter yield in all treatments adopted from the first to the second harvest (Table 1). Probably, this behavior was due to the predecessor corn growth in the first crop, followed by fallow. It was observed that there was an addition of crop residues left on the soil surface by the corn crop in the 2012 harvest.

There was a significant effect ($p \leq 0.05$) of interactions between soil mechanic scarification (MS) and cover crops (CC) for yield and macronutrient accumulation in the shoot dry matter of cover crops in the 2012 and 2013 harvests (Table 1).

About the interaction between the cover crops and the soil mechanical scarification in the 2012 harvest (Figure 1), the species *P. glaucum* (13.84 Mg ha^{-1}), *U. ruziziensis* (11.84 Mg ha^{-1}) and *C. cajan* (11.14 Mg ha^{-1}) under scarified soils and *C. juncea* (11.46 Mg ha^{-1}) under NTS had higher shoot dry matter than the fallow. About the interaction

Table 1. Yield (DM) and macronutrient accumulation in the shoot dry matter of the cover crops as a function of soil mechanical scarification in NTS in the low altitude Cerrado, Selvíria, MS, 2012 and 2013 harvest.

	Harvest 2012						
		Macronutrients accumulation in the shoot dry matter					
	DM	N	P	K	Ca	Mg	S
	Mg ha^{-1}	(kg ha^{-1})					
	Soil mechanical scarification (MS)						
With	10.01	126.9	12.2	72.8	62.2	31.7	32.2
Without	10.38	164.6	15.9	93.4	51.6	26.7	46.6
	Cover crops (CC)						
Fallow	7.99	79.1	8.4	24.9	55.2	26.4	25.9
U. ruziziensis	10.55	148.7	14.7	101.2	53.3	32.2	39.6
P. glaucum	13.05	152.4	13.2	60.6	51.2	21.2	28.4
C. juncea	9.66	196.3	14.6	73.9	58.8	25.3	39.4
C. cajan	9.72	162.0	19.5	149.8	65.9	40.7	63.8
	F-values						
MS	2.69^{ns}	25.12*	30.46*	19.79*	8.89*	16.46*	53.42*
CC	52.22*	25.77*	26.56*	68.31*	2.12^{ns}	30.92*	46.07*
MS × CC	28.46*	19.73*	2.83*	6.66*	3.22*	12.45*	23.69*
CV (%)	7.09	16.31	15.50	18.64	19.73	13.22	15.85
	Harvest 2013						
		Macronutrients accumulation in the shoot dry matter					
	DM	N	P	K	Ca	Mg	S
	Mg ha^{-1}	(kg ha^{-1})					
Without	6.19	97.14	12.5	96.19	38.1	16.5	24.3
With	5.94	90.57	11.8	84.86	33.4	15.8	23.6
	Cover crops (CC)						
Fallow	2.53	26.3	3.48	15.8	15.4	4.1	16.4
U. ruziziensis	5.00	86.9	10.8	112.0	27.2	17.8	17.8
P. glaucum	10.84	127.6	17.7	173.7	35.8	29.7	31.2
C. juncea	5.96	105.4	13.8	78.7	48.4	15.3	24.2
C. cajan	5.96	123.1	15.0	72.4	51.9	13.6	30.0
	F-values						
MS	1.85^{ns}	2.48^{ns}	1.72^{ns}	5.04*	5.71*	0.76^{ns}	0.11^{ns}
CC	219.77*	77.47*	69.95*	105.4*	46.2*	103.2*	8.64*
MS × CC	10.46*	8.76*	5.29*	5.91*	10.8*	4.11*	4.02*
CV (%)	9.49	14.07	15.15	17.63	17.54	15.93	27.31

^{ns} not significant. * significant at the 5% significance level by the *F* test. Means followed by the same letter, for soil mechanical scarification and cover crops, do not differ statistically from each other by the Tukey test at the 5% significance level.

between the cover crops and the soil mechanical scarification in the 2013 harvest (Figure 1), the growth of *P. glaucum* with (10.34 Mg ha^{-1}) and without (11.34 Mg ha^{-1}) soil mechanical scarification promoted increases in shoot dry matter yield.

Similar results to those obtained in this study were verified by Teixeira *et al.* (2012), Pereira *et al.* (2016) and Chieza *et al.* (2017), in which the cultivation of cover crops significantly increased the dry matter yield in the implanted NTS. Reichert *et al.* (2009b) found that soil mechanical scarification in an implanted NTS can be a viable alternative to minimize physical limitations in the soil surface layers to the growth and penetration of the plant

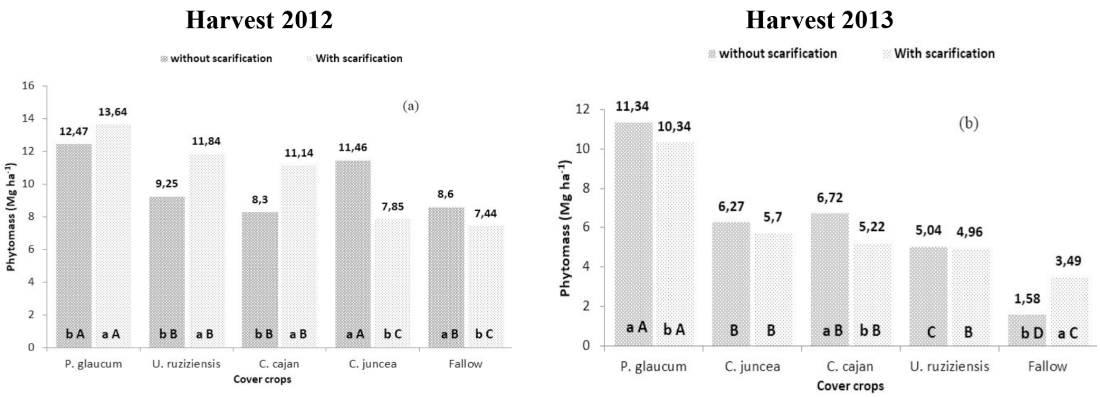

Figure 1. Interactions regarding the shoot dry matter yield of the cover crops (CC), after soil mechanical scarification (MS) in NTS. Means followed by the same lowercase letter, for CC within MS (1.49 and 0.84 Mg ha^{-1}) for 2012 and 2013 harvests, respectively, and uppercase letter, for MS within CC (1.05 and 1.19 Mg ha^{-1}) for the 2012 and 2013 harvests, respectively, did not differ statistically by the Tukey test at 5% significance level.

roots. Some studies have demonstrated significant increases in crop yield (soybeans, corn, wheat, beans) in soils of NTS with scarification. This practice increases the porosity and reduces soil density, while breaking the compacted layers to the depth of 0.30 m, justifying the results obtained.

About the interaction between the cover plants and soil mechanical scarification for N accumulation in the shoot dry matter in the 2012 harvest (Figure 2), it was verified that *C. cajan* (274.38 kg ha^{-1}) and *U. ruziziensis* (171.71 kg ha^{-1}) under soil mechanical scarification and *P. glaucum* (185.81 kg ha^{-1}) under NTS accumulated higher N contents in the shoot, with increases of 188.59, 85.92 and 113.42 kg ha^{-1} of N, respectively, in relation to their respective fallow, independently of soil mechanical scarification.

It was observed that the growth of *C. cajan* under scarified soil and *P. glaucum* under NTS had a higher accumulation of N in the shoot (Figure 2). The main highlight was for the cultivation of *C. cajan* under scarified soil that accumulated 274.38 kg ha^{-1} of N, with the highest increase about the fallow with scarification. The species of *C. Cajan* belongs to the Fabaceae family, thus, it presents higher BNF capacity, besides, it has low C/N ratio and lignin in the dry matter, propitiating greater N release in the crop residues, corroborating with results obtained by Chieza *et al.* (2017), in which they report that the Fabaceae can also be included in production systems, in an isolated and predecessor way, in order to increase the yield of crops in succession, mainly by the supply of nitrogen performed by the biological N fixation.

It was observed that there was a great reduction of N accumulation in the shoot in most cover crops (Figure 2), independent of scarification, in the 2013 harvest. Probably due to the lower dry matter yield of the cover crops, with reflections in lower accumulated N contents.

About the interaction between cover crops and soil mechanical scarification for N accumulation in the shoot dry matter in the 2013 harvest (Figure 2), the soil under *C. cajan* (143.4 kg ha^{-1}) and under *P. glaucum* (142.7 kg ha^{-1}) in NTS promoted greater accumulation of N in the shoot dry matter. In the NTS implemented, one of the basic and extremely important premises is the maintenance of cover crops to protect the soil against the erosive action of rains and also, in the case of the plants of Fabaceae family, to provide higher N quantities to the crops grown in succession, due to the biological nitrogen fixation and low C/N ratio (Silva *et al.*, 2007; Pacheco *et al.*, 2011).

About the interaction between the cover crops and the soil mechanical scarification for P accumulation of the shoot dry matter in both harvests (Figure 2), stands out the predecessor growth with *P. glaucum* and *C. cajan,* independently of the soil scarification, which resulted in highest accumulations of P in the shoot dry matter. This behavior evidences the potential of *P. glaucum* and *C. cajan*, independently of the soil scarification, in promoting greater availability of P in the soil solution. According to the results obtained by Pereira *et al.* (2016) and Chieza *et al.* (2017), the growth of cover crops are promising options to increase nutrient

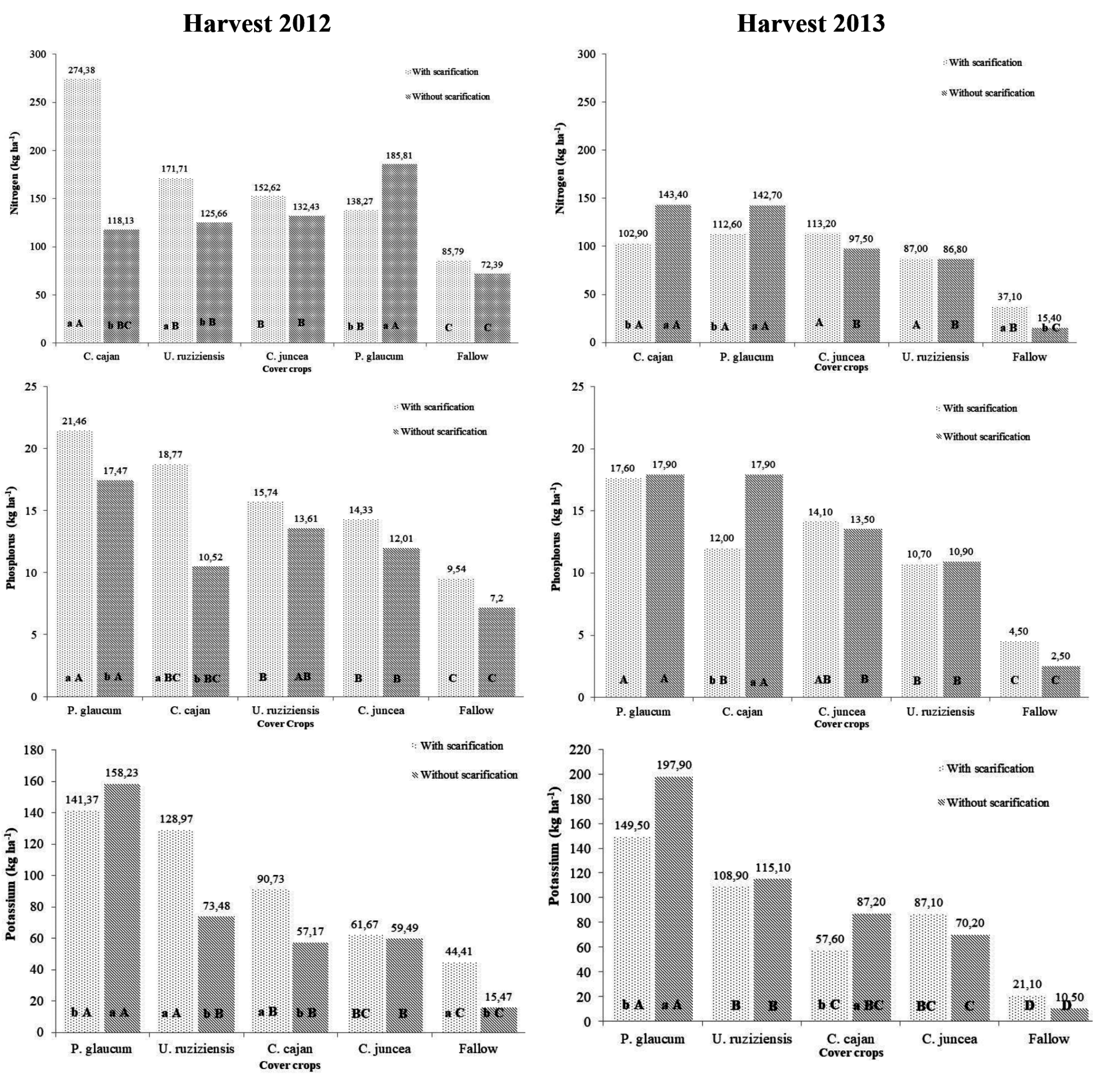

Figure 2. Interactions regarding (N), phosphorus (P) and potassium (K) accumulation in the shoot dry matter of the cover crops (CC) in 2012 and 2013 harvests, after soil mechanical scarification (MS) in NTS. Means followed by the same lowercase letter, for CC within MS (34.48 and 19.15 kg ha^{-1} for N, 3.16 and 2.67 kg ha^{-1} for P, 22.47 and 23.16 kg ha^{-1} for K), in 2012 and 2013 harvests, respectively, and uppercase letter, in MS within CC (49.09 and 27.27 kg ha^{-1} for N, 4.05 and 3.80 kg ha^{-1} for P, 31.99 and 32.97 kg ha^{-1} for K), in 2012 and 2013 harvests, respectively, did not differ statistically by the Tukey test at 5% significance level.

accumulation in the implanted NTS, mainly the phosphorus fixed in the soil colloids for the crops.

About the interaction between cover crops and soil mechanical scarification for K accumulation in the shoot dry matter, in both harvests. It was verified that the cultures of *U. ruziziensis* and *P. glaucum*, independently of the soil scarification, promoted higher accumulations of K in the shoot dry matter than the other cover crops and, mainly, the respective fallows with spontaneous vegetation, providing increases of K contents from 10 to 20 times (Figure 2). According to results obtained by Miguel *et al.* (2018) in the Cerrado of low altitude, which verified that the *U. ruziziensis* promotes a significant increase in the cycling of nutrients, mainly the potassium accumulated in the aerial part.

The inter-harvest with *C. cajan* was promising, however, with a lower magnitude in providing K accumulation in plant shoot. These results confirm the potential of *P. glaucum* and *U. ruziziensis*, independently of scarified soil to be highly efficient plants for cycling and mineralization of K extracted from the soil profile, making it available to the successor crop. In agreement with the results obtained by Pacheco *et al*. (2011), who verified high rates of K release by *P. glaucum* and *U. ruziziensis* species.

About the interaction between cover crops and soil mechanical scarification for Ca accumulation in the shoot dry matter in 2012 harvest (Figure 3), it was observed that the growth of *P. glaucum* (76.09 kg ha^{-1}) in NTS presented highest Ca accumulation of shoot dry matter. For the 2013 harvest, it was observed that the growth of *C. juncea*, independently of soil scarification, promoted a greater accumulation of Ca in the shoots about the other cover crops and the fallows. Also, the soil under *C. cajan* (64.5 kg ha^{-1}) in NTS had a higher accumulation of Ca, even with reductions in shoot dry matter of cover crops in 2013 harvest, without alteration the accumulation of Ca of shoot dry matter. It was noted reductions of dry matter yield of 45.3% and 27.4% for *C. juncea* with and without mechanical soil scarification, respectively, and 19.0% for *C. cajan* in SPD.

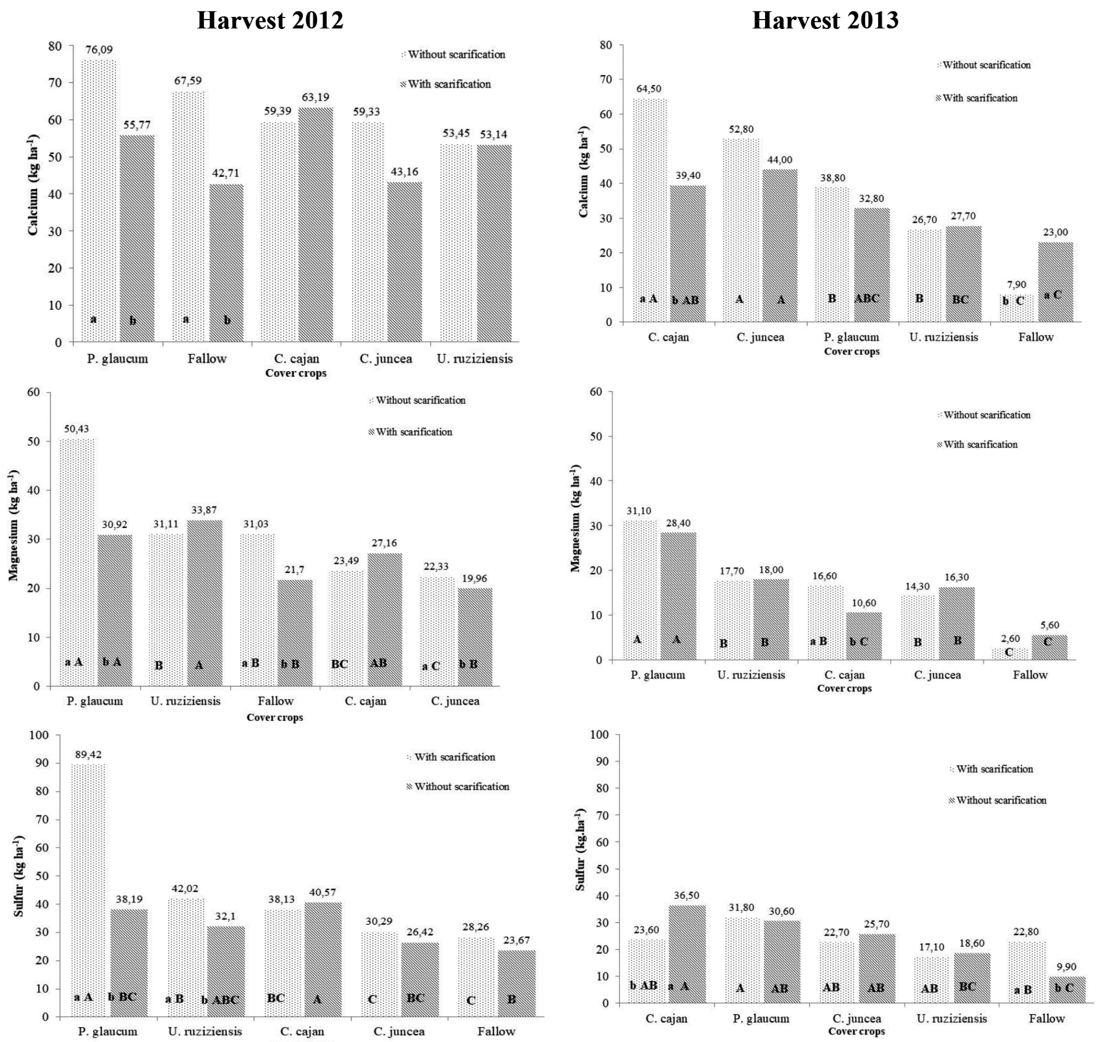

Figure 3. Interactions regarding calcium (Ca), magnesium (Mg) and sulfur (S) accumulation in the shoot dry matter of the cover crops (CC) in 2012 and 2013 harvests, after soil mechanical scarification (MS) in NTS. Means followed by the same lowercase letter, for CC within MS (16.18 and 9.10 kg ha^{-1} for Ca, 5.60 and 3.72 kg ha^{-1} for Mg, 9.06 and 9.48 kg ha^{-1} for S), in 2012 and 2013 harvests, respectively, and uppercase letter, in the MS within CC (12.95 kg ha^{-1} for Ca, for 7.98 and 5.30 kg ha^{-1} for Mg, 12.90 and 13.50 kg ha^{-1} for S) in 2012 and 2013 harvests, respectively, do not differ statistically by the Tukey test at 5% significance level.

About the interaction between soil mechanical scarification and cover crops for accumulation of Mg in the shoot dry matter (Figure 3), it was observed that the growth of *P. glaucum*, independent of soil mechanical scarification, provided greater accumulations of Mg of the shoot dry matter in relation to the other cover crops and the fallows in both years of growth.

About the interaction between soil mechanical scarification and cover crops for accumulation of S in the shoot dry matter in the two harvests (Figure 3), the crops of *U. ruziziensis* (42.02 kg ha^{-1}) and *P. glaucum* (89.42 kg ha^{-1}) under scarified soils in the 2012 harvest and *C. cajan* (36.5 kg ha^{-1}) under NTS in the 2013 harvest had the highest accumulations of S in the shoot dry matter.

It is worth noting that even with sharp reductions and fluctuations of 20% to 40% in the dry matter yield of the cover crops from the harvest 2013 to 2012, there was no change in the accumulation of some nutrients in the shoot, evidencing the potential of the cover plants studied, mainly the species of *P. glaucum*, *U. ruziziensis* and *C. cajan*, independent of the soil mechanical scarification, to be adopted in the planning of the different production systems of grain production and no-tillage system with diagnosis of compaction in the superficial layer of the soil in the spring season in the Cerrado region of Mato Grosso do Sul state with low altitude, in a predecessor crop of the commercial crop in the summer.

There was a significant effect ($p \leq 0.05$) of soil mechanic scarification and cover crops for the persistence of crop residues of cover crops at 30, 60, 90 and 120 days after sowing (DAS) of the commercial crop in both harvests (Table 2).

About the interaction between cover crops and soil mechanical scarification for persistence of crop residues (PCR) in the evaluations of 30 and 60 DAS of the commercial crop in the 2012 harvest (Figure 4), stood out the growing of *C. juncea, U. ruziziensis* and *P. glaucum*, independently of the soil mechanical scarification, they promoted highest PCR at the soil surface, with values higher than 70.4% of PCR (Figure 4). The *C. cajan* in NTS stood out, but with lowest values of PCR, especially when soil mechanical scarification was carried out before its growing.

In the 2013 harvest, it was verified that the cultivation of *P. glaucum* with (72.5 and 54%) and

Table 2. Mean values of the persistence of crop residues in the cover crops (CC) as a function of soil mechanical scarification (MS) in NTS in the low altitude Cerrado at 30, 60, 90 and 120 days after sowing of the commercial crop, Selvíria, MS, 2013.

	Persistence of crop residues (%)							
	Days after sowing of the commercial crop							
	30		60		90		120	
	2012	2013	2012	2013	2012	2013	2012	2013
	Soil mechanical scarification (MS)							
Without	75.6	30.9	59.4	25.9	29.0	21.8	14.7	10.8
With	53.5	30.6	43.7	21.5	18.3	17.3	9.4	10.9
	Cover crops (CC)							
Fallow	48.9	12.6	37.3	9.9	22.8	7.4	12.3	3.3
U. ruziziensis	75.8	16.9	65.4	12.9	24.1	9.0	12.2	3.6
P. glaucum	73.8	22.4	65.7	12.1	20.3	8.9	10.0	5.3
C. juncea	47.9	21.0	24.1	16.5	9.1	13.6	4.9	5.6
C. cajan	76.4	80.8	65.4	67.0	42.0	58.8	20.8	36.4
	F-values							
MS	766.56*	0.03^{ns}	385.16*	36.19*	47.42*	13.83*	41.44*	0.018^{ns}
CC	246.48*	164.21*	478.89*	906.16*	46.33*	271.89*	40.24*	131.31*
MS × CC	188.65*	8.61*	190.89*	70.96*	18.74*	17.09*	19.94*	0.015*
CV (%)	5.51	20.27	6.96	9.66	29.49	19.38	30.15	32.65

^{ns} not significant. * significant at the 5% significance level by the *F* test. Means followed by the same letter, for soil mechanical scarification and cover crops, do not differ statistically from each other by the Tukey test at the 5% significance level.

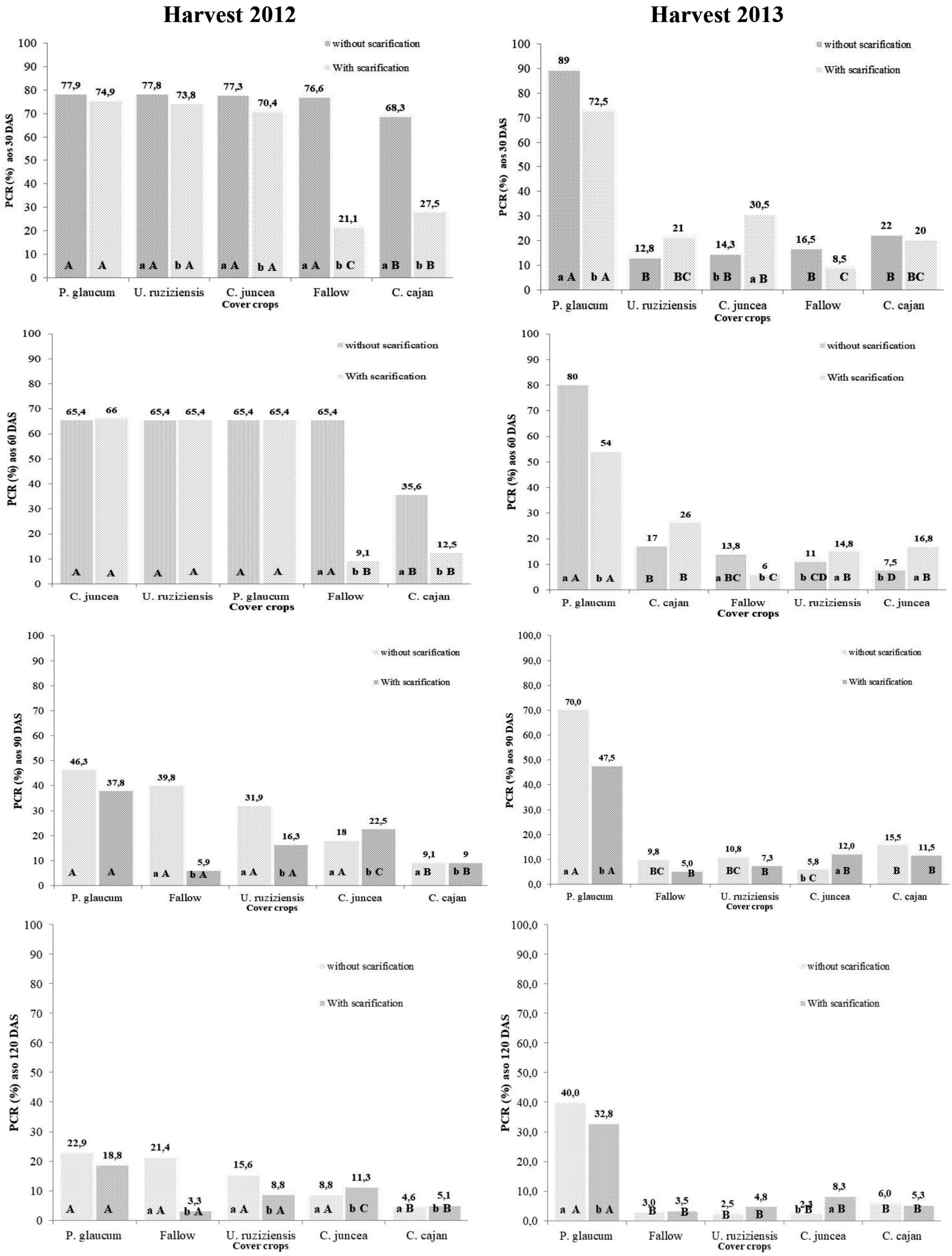

Figure 4. Interactions regarding the persistence of crop residues, PCR (%), at 30, 60, 90 and 120 days after sowing (DAS) of the commercial crop, for cover crops (CC), after soil mechanical scarification (MS) in NTS. Means followed by the same lowercase letter, for CC within MS (3.35 and 9.04 for the 30 DAS, 3.58 and 3.32 for the 60 DAS, 6.65 and 5.49 for 90 DAS, 3, 62 and 5.13 for 120 DAS), in 2012 and 2013 harvests respectively, and uppercase letter, for MS within CC (4.99 and 12.87 for the 30 DAS, 5.03 and 4.72 for the 60 DAS; 9.77 and 7.82 for 90 DAS, 5.62 and 7.30 for 120 DAS) in 2012 and 2013 harvests, respectively, did not differ statistically by the Tukey test at 5% significance level.

without (89 and 80%) mechanical soil scarification, at 30 and 60 DAS, respectively, presented higher PCR than the other cover crops and the fallows (Figure 4). It is worth noting that the soil mechanical scarification operation was only carried out only in 2012. Also, there was addition of crop residues of the corn in the predecessor crop, in the experimental area, followed by fallow, providing a higher persistence of crop residues in the first crop, probably due to the high C:N ratio and high lignin content in the crop residues.

For PCR evaluations at 90 and 120 DAS of the commercial crop in the 2012 harvest (Figure 4), it was observed that soil under *U. ruziziensis* and *P. glaucum* in NTS in the 2012 harvest and under *P. glaucum*, independently of soil scarification, in the 2013 harvest, had higher PCR on the soil surface. This is due to the greater potential of plants from the Poaceae family to produce dry matter and higher PCR capacity in NTS due to the higher C:N ratio and high lignin content in relation to plants from Fabaceae family, in order to provide greater soil protection and erosion control, besides to be excellent options for compacted NTS in the Cerrado of low altitude, with serious problems of water erosion and physical and chemical degradation of the soil.

The growth of *P. glaucum* was highlighted in spring with the highest dry matter yield with results higher than 10.84 Mg ha^{-1}. This behavior is due to the more favorable conditions of climate with high temperatures and humidity in the spring, thus providing the expression of its productive potential. The species of *C. juncea* and *U. ruziziensis* have the potential for dry matter production, but they need further studies due to incipient knowledge in low altitude Cerrado conditions in the spring period.

Conclusions

Soil mechanical scarification increases the yield of *Pennisetum glaucum*, *Urochloa ruziziensis* and *Cajanus cajan* in the first harvest.

The *Pennisetum glaucum* provides higher yield and macronutrient accumulation in the shoot dry matter, as well as greater persistence of crop residues, independently of soil mechanical scarification.

Urochloa ruziziensis and *Cajanus cajan* have the potential of accumulation of N, P, K and Ca in the shoot dry matter, although with less persistence of crop residues, independently of soil mechanical scarification.

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