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The management of cover plant residues for cotton cropped in a no-tillage system

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ABSTRACT. The cutting of plant residue in no-tillage systems under certain environmental conditions becomes necessary to adequately establish and grow crops. This study aims to assess the effect on the yield of different methods of managing millet plant residue in cotton plantations. The study was conducted during the agricultural years 2006/07 and 2007/08, and the treatments included no-mechanical-treatment tillage and the use of a rotary shredder, crimper-roller, and mechanical disintegrator for millet plants before sowing the cotton. Evaluations were performed for the residue fragmentation, emergence speed, percent of soil cover during the cycle and yield of the cotton crop. The emergence speed was faster in the management with the rotary shredder. In 2006/07, the no-tillage treatment showed a rate of loss for soil cover that was 46 percent greater than the disintegrator treatment. The rotary shredder and the disintegrator yielded greater soil coverage during the cultivation cycle, and the yield was highly correlated with the soil cover at 75 days after emergence. The management of the millet residue affected the cotton plants for the two-year study period.

Keywords: soil cover, *Gossypium hirsutum*, *Pennisetum glaucum*.

Manejo da fitomassa da planta de cobertura para semeadura do algodoeiro em sistema plantio direto

RESUMO. O manejo dos resíduos vegetais em sistema plantio direto em certas condições torna-se necessário para o bom estabelecimento e crescimento da cultura. Este estudo visa verificar o efeito de diferentes formas de manejo de resíduos vegetais de milheto na semeadura e produtividade do algodoeiro. Foi conduzido durante os anos agrícolas 2006/07 e 2007/08, sendo que os tratamentos utilizados foram: sem corte mecânico da fitomassa do milheto, uso de roçadora, rolo faca e desintegrador mecânico em plantas de milheto previamentes semeadas na área experimental e antes da semeadura do algodão. Foram efetuadas avaliações de fragmentação dos resíduos, velocidade de emergência, porcentagem de cobertura do solo durante o ciclo e produtividade da cultura do algodão. A velocidade de emergência foi mais rápida no manejo com roçadora. O tratamento sem corte mecânico apresentou uma taxa de perda de cobertura do solo de 46% maior do que o desintegrador em 2006/07. A roçadora e o desintegrador resultaram numa maior cobertura do solo durante o ciclo de cultivo. O rendimento do algodoeiro foi fortemente correlacionado com a cobertura do solo aos 75 dias após a emergência. O manejo dos resíduos do milheto afetou o rendimento do algodoeiro nos dois anos avaliados.

Palavras-chave: cobertura do solo, *Gossypium hirsutum*, *Pennisetum glaucum*.

Introduction

In no-tillage systems, the seeds are directly deposited in soil that has not been mechanically prepared. This particular type of cultivation is considered more than merely a production system, with several authors giving this management the status of a conservationist system (PETTRY, 2007).

According to Furlani et al. (2003), conservationist systems insist on the maintenance of the plant cover (straw) on the soil surface for as long as possible, and the decomposition rate is directly related to the C/N ratio of the crop residues on the soil (BALOTA et al., 2004; BOER et al., 2008; KOGEL-KNABNER, 2002). To this end, the management of plant residue, in addition to spraying and harvesting, is frequently necessary to provide suitable conditions for the establishment and development of the crop.

The residue may be managed chemically or mechanically: chemical methods consist of the application of herbicides for the control of the vegetation present before the seeding of the crop of interest, whereas mechanical methods consist of the use of implements designed specifically for this purpose. The main instruments are the rotary shredder, the disintegrator/chopper and the crimper-roller or roller-chopper, tools that have different characteristics of operation, fragmentation and distribution of the material managed (LINO et al., 1999; SIQUEIRA et al., 1997).

Compared to other annual crops, such as soybean and maize, cotton has a long period between seeding and full cover of the soil. Within this context, the no-tillage system becomes an alternative for minimizing the environmental impact of cotton cultivation while offering a profit similar to or higher than that achieved with conventional soil preparation (BRANQUINHO et al., 2004).

Accordingly, this work aims to verify the effects of different management systems on plant residue production in the no-tillage cultivation and yield of cotton crops under the conditions of the Cerrado.

Material and methods

The study was performed during the agricultural seasons of 2006/07 and 2007/08 at the geographical coordinates of 51°22'W, 20°22'S and an elevation of approximately 335 m in Selvíria, Mato Grosso do Sul State, Brazil. The soil in the experimental area was reclassified as a Latossol (Oxisol typical loamy soil) (EMBRAPA, 2006), and the region has an average annual rainfall of 1,232 mm and a temperature of 24.5°C.

The soil was prepared using a no-tillage system since September of 2005, and this type of preparation was maintained for the purposes of trials in recent agricultural years. The experimental design included random plots, with 4 repetitions for each treatment. The treatments consisted of millet plant residue management using a crimper-roller, rotary shredder, ("Triton™") disintegrator/chopper and no-tillage before the seeding of the cotton crop.

In June 2006, the 0-0.20 m soil layer was sampled, and a chemical analysis produced the following results: resin-extractable P (11.0 mg dm^{-3}), M.O. (16 g dm^{-3}), K (2.4 $mmol_c$ dm^{-3}), Ca (11 $mmol_c$ dm^{-3}), Mg (8 $mmol_c$ dm^{-3}), CEC (44 $mmol_c$ dm^{-3}) and V% (46). In the same month, 1,000 kg of dolomitic limestone, with 80% efficiency, was applied. In the following year, the same soil analysis was performed in September 2007, with the following results: resin-extractable P (10.6 mg dm^{-3}), M.O. (18 g dm^{-3}), K (1.2 $mmol_c$ dm^{-3}), Ca (11 $mmol_c$ dm^{-3}), Mg (7.7 $mmol_c$ dm^{-3}), CEC (51 $mmol_c$ dm^{-3}) and V% (39). In 2007, 2,000 kg ha^{-1} of dolomitic limestone, with 80% efficiency, was applied.

The millet (*Pennisetum glaucum* L.) strain BN-2 was used for the production of plant residue before the seeding of the main cotton crop grown in the experimental area. The millet was seeded mechanically on 22 and 18 September in 2006 and 2007, respectively, with a row space of 0.34 m and a seed density of 15 kg ha^{-1}. The different managements of the millet were performed at 57 and 65 days after the seedings in 2006 and 2007, respectively.

The seeding of the cotton crop was on 17 and 26 November in 2006 and 2007, respectively. A tractor-drawn seeder-fertilizer applicator was employed using 200 and 350 kg ha^{-1} of NPK in the proportion of 8-28-16 in the sowing furrow in 2006 and 2007, respectively. The cotton strain used was DeltaOpal in 2006/07; however, due to the superior performance in the trials of varieties in the area, strain FMT 701 was used in the following season. The number of seeds was 12-13 seeds m^{-1}, with a space of 0.90 m between the rows. The fertilizer coverage comprised 90 kg ha^{-1} of nitrogen and 70 kg ha^{-1} of potassium.

The plots measured 20 m in length and 3.6 m in width (4 sowing rows). The useful area consisted of the two central rows for all of the evaluations during the crop cycle. Only the central rows were taken into consideration for the evaluations.

The yield of millet dry biomass was verified in both years by sampling a portion of the area of the plants in a 0.25 m^2 area at 4 different points per plot. The material obtained was stove-dried, and the production of dry biomass per hectare was calculated. In 2007, the characterization (length and humidity) of the remaining fragments in each management was undertaken. The material for the characterization was collected in a useful area of 0.90 m^{-2} in two different locations per plot before the sowing of the cotton. From this amount, 200 fragments were selected at random from each management for the analyses.

During the cotton crop cycle, the following parameters were evaluated: the emergence speed of the seedlings at 4, 8 and 12 days after seeding; soil cover at 15, 30, 45, 60 and 75 days after emergence (DAE); yield of the crop through the manual harvesting of the central rows, and calculations are presented in kg ha^{-1} of fiber plus seed.

At the end of germination (12 DAE), the plots with the cotton crop consisted of stands of 11 plants m^{-1}. The method used for evaluating the soil cover was a square point composed of a square of 50 x 50 cm with rows set at every five centimeters on all sides, forming a grid of 100 points at the location of the row intersections. Two points per plot were evaluated and labeled for later evaluations. In the statistical analysis, the date of the year of the evaluation was considered as a source of variation in a scheme of subplots, as this was a repeated measurement in the same experimental unit.

After the F-test and significant effects analyses, an average orthogonal contrast (when the sum of the products of the coefficients of the mean is zero) was performed to determine which treatments were better (BANZATTO; KRONKA, 2006).

The data were subjected to a variance analysis by the F-test, mean comparison test (Tukey) and polynomial regression at a significance level of $p < 0.05$, which indicates a 95% probability that the differences noted are not due to chance. The correlation and regression analyses were performed using SISVAR software (FERREIRA, 1999). The regression equations were fit to the significant features, and the best-fitting model was selected by the coefficient of determination.

Results and discussion

The rainfall amount at the period of the seeding operations (September to May) in the two years was 991 mm in 2006/7 and 1,041 mm in 2007/8. The month of January experienced the highest rainfall in both years, with monthly totals of 438 and 433 mm, respectively. The dry material of the millet plots at the moment of cutting was 9,800 and 6,600 kg ha^{-1}, respectively. In 2005, Silva et al. (2006) obtained 7,400 kg ha^{-1} in the same location. In the Distrito Federal, Brazil, the yield of dry biomass millet was 8,770 kg ha^{-1} (UEMURA et al., 2004).

The results of the characterization of the fragments under the different managements are outlined in Figure 1. The crimper-roller fragmented the millet into debris that corresponded to the spacing of its blades (0.35 m between the cutting points). However, shearing did not occur at every point of contact of the plants with the blades, thus generating a majority of fragments with multiple lengths of 0.35 m (Figure 1a).

The disintegrator was the management that produced the greatest fragmentation of the millet, with average lengths of the fragments of 0.13 m (Figure 1b). Using this implement, Siqueira et al. (1997) obtained very similar fragment sizes of 4 types of cover. The rotary shredder generated larger fragments than the disintegrator device and even produced large fragmentation when compared to the no-mechanical-treatment tillage (Figure 1b). The 0.33 m lengths were 70 percent larger than those found by Lino et al. (1999) working with Mombaça grass (capim colonião).

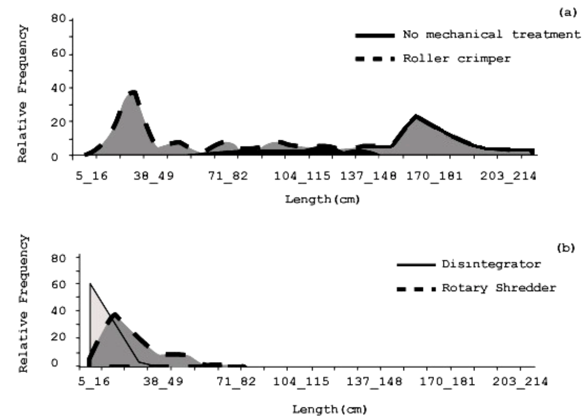

Figure 1. Fragment of millet managed with different implements at 65 days after seeding. Average size of fragments (cm): no mechanical treatment = 165 and crimper-roller = 62 (a); disintegrator = 13 and rotary shredder = 33 (b). Selvíria, Mato Grosso do Sul State, Brazil, 2007/8.

At the time of the management treatment, the plants displayed heights that varied between 0.60 and 2.30 m, with an average of 1.65 m and 77 percent humidity, which characterized the fragments in the no-mechanical-treatment tillage (Figure 2).

The management of the plant residue affected the emergence speed of the seedlings (Figure 2). The rotary shredder resulted in the highest average index of the speed of emergence at four days after seeding, whereas the other managements did not differ among themselves in the same and subsequent evaluations (Figure 2). Branquinho et al. (2004) found no difference in the emergence speed in relation to the management of plant residue in the cultivation of soybean.

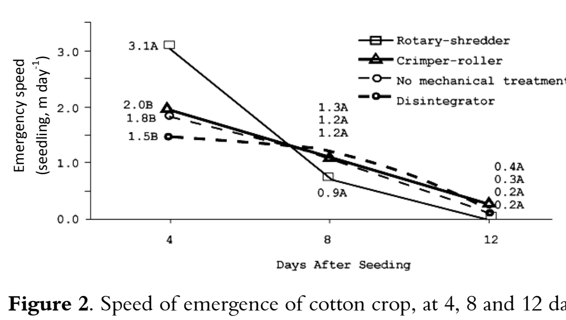

Figure 2. Speed of emergence of cotton crop, at 4, 8 and 12 days after seeding, in different managements of plant residue in no-tillage system. Selvíria, Mato Grosso do Sul State, Brazil, Brazil, 2007/8. Different letters differ in the Tukey test by $p > 0.05$.

Once the crop was established, an evaluation of the soil coverage throughout the crop cycle was undertaken. From the data analysis, it was observed that the management of the plant residues differed among themselves, with significance found for the interaction between the management and the time of year of the evaluation (E*M) for both years, as shown in Table 1.

In the agricultural year 2006/07, the models with the best adjustments of soil coverage during the cotton crop cycle were all linear. The main difference between the treatments was with regard to the rate of loss of soil cover, as evidenced by the linear coefficient of the equations generated (Table 1). The no-mechanical-treatment tillage presented linear coefficients that were 46 and 28 percent greater than the disintegrator and rotary shredder, respectively (Table 1).

The models with the best adjustments for the agricultural year 2007/8 were linear for the management with the disintegrator and rotary shredder and quadratic for the crimper-roller and no-mechanical-treatment tillage (Table 1). There was little difference (12%) in the linear coefficients between the adjusted linear models. We also observed differences in the linear coefficients for the same management between the agricultural years evaluated. The most preponderant factor was most likely the initial quantity of the plant residue, which was less in 2007/8, as reflected in the higher linear coefficients, that is, there were higher rates of coverage loss in that year.

Table 1. The F values of the analysis of variance and regression for soil cover in relation to different managements of plant residue during the cotton crop cycle in no-tillage system. Selvíria, Mato Grosso do Sul State, Brazil, 2006/7 and 2007/8.

	2006/2007				2007/2008			
	Soil cover							
Time of year (E)	220.2	**			580	*		
Management (M)	32.2	**			2.9	**		
E*M	2.5	**			5.5	**		
CV (%)	1.1				1.0			
	Regression							
	Linear		Quadratic		Linear		Quadratic	
Disintegrator	317	**	0.6	ns	280	**	0.8	ns
Rotary shredder	451	**	2.0	ns	177	**	3.11	ns
Crimper-roller	310	**	0.1	ns	329	**	28	**
No mechanical treatment	124	**	0.5	ns	206	**	12	**
	Equations							
Disintegrator	y = 102.20-0.128x				y = 103.3-0.206x			
Rotary shredder	y = 102.5-0.146x				y = 101.9-0.183x			
Crimper-roller	y = 103.2-0.195x				$y = 98.3+0.105x-0.003x^2$			
No mechanical treatment	y = 102.0-0.188x				$y = 99.6+0.030x-0.003x^2$			

*significant to p > 0.05; **significant to p < 0.01; ns not-significant

In the quadratic models (no mechanical treatment and crimper-roller) for 2007/2008, the reduction in the percentage of the soil cover was observed to be more intense after 45 DAE. Up to this time, the percentage of soil coverage decreased by approximately 5 percentage points, whereas, from 45 to 75 DAE, the reduction was 8 and 10 percentage points for the crimper-roller and no-mechanical-treatment tillage, respectively (Figure 3b).

The studies conducted by Ceretta et al. (2002) obtained quadratic models for the decomposition of plant residue (kg ha^{-1} day^{-1}) for three different species of plant cover, demonstrating higher rates of decomposition in the periods closest to the time of the plant residue management. Torres et al. (2005) obtained exponential models for the decomposition of millet, with higher rates also in the initial periods of evaluation.

In the last evaluation of the soil cover, it was noted that the no mechanical treatment and crimper-roller presented lower values compared to the other managements (Figures 3a, b). In contrast, Siqueira et al. (1997) obtained a greater soil cover at 75 days after the cutting of oats (*Avena strigosa* Schieb) with a crimper-roller compared to a disintegrator.

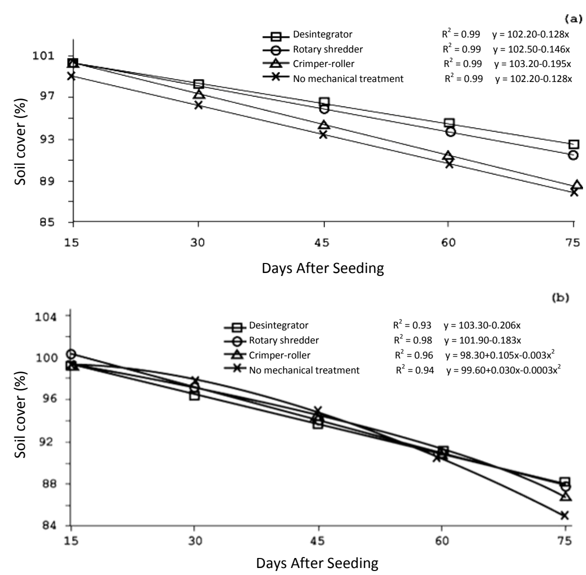

Figure 3. Soil cover in different managements of plant residue during the cotton crop cycle in no-tillage system, Selvíria, Mato Grosso do Sul State, Brazil. 2006/7 (a) and 2007/8 (b). † Tukey test (p > 0.05) at 75 DAE which means that a 95% probability that the differences noted are not due to chance.

The seeding of the millet was undertaken in accordance with the use of a tractor-drawn seeder, in the way recommended by the no-tillage system. In the no-mechanical-treatment tillage and crimper-roller treatment, a flattening of the millet plants occurs along the same line of sowing during the cutting. Thus, there will be a certain concentration of plant residue in the sowing line using these two managements, a fact that is easily observed in the field. Furthermore, the area between the rows will have a lower density of plant residue, resulting in a rapid loss of the soil cover in these locations. Regarding the treatments with the disintegrator and rotary shredder, the distribution of the fragments is more uniform in the seeding row and between the rows.

In relation to the yield of the cotton crop, the cutting of the plant residue was different for this variable in the two agricultural years evaluated (Table 2). From the contrast between the no mechanical treatment and the treatments with the mechanical management of the plant residue, it may be inferred that the millet management has a direct impact on the yield of the cotton crop, 27 and 28 percent increase in 2006/7 and 2007/8, respectively. In 2006/7, the cutting using the disintegrator resulted in the greatest yield, and the no mechanical treatment produced the lowest yield. In the agricultural year 2007/8, the no mechanical treatment also presented the lowest yield among the treatments, with a difference compared to the disintegrator and crimper-roller.

Higher yields of maize and soybean were obtained by Muraishi et al. (2005), who used mechanical management, compared to no mechanical treatment of several plant covers. These authors proposed that the mechanical management by fragmenting the plant cover accelerates the decomposition and cycling of nutrients, favoring the development of the subsequent crop.

Table 2. Values of F and Tukey test for yield of cotton crop under different managements of plant residue in no-tillage system.

		2006/2007		2007/2008	
Management		4.7	*	6.4	**
CV (%)		11.5	ns	20.3	ns
Contrast		12.9	**	9.2	**
D.M.S.		501	ns	312	ns
	Contrast Coefficient	Yield (kg ha^{-1})†			
Disintegrator	1	2,115	a	3,039	a
Rotary shredder	1	2,013	ab	2,447	ab
Crimper-roller	1	2,071	ab	2,832	a
No mechanical treatment	-3	1,621	b	2,162	b

*significant at p > 0.05; **significant at p < 0.01; ns not-significant. †Different letters in the column differ from the Tukey test by p > 0.05.

The yield of the cultivation of soybean under different management systems of plant residue in two consecutive years was evaluated by Branquinho et al. (2004), with no difference in the first year between the types of managements used but higher productivities in the second year using a disintegrator compared to other managements of the plant residue.

The yield of the cotton crop was highly correlated with the soil cover at 75 days after the seeding (Figure 4). Pereira et al. (2002) and Andrade et al. (2002) reported a reduction in the consumption of water and an increase in the water-use efficiency with an increase in the percentage of soil cover in irrigated bean plants. The conditions of the present trial did not include irrigation; that is, the plants were susceptible to water limitations during the cycle, particularly in the final phase. The possible reduction in the demand for water under the managements with higher percentages of soil cover may have led to the increase in yield by delaying or easing the effect of the water restriction suffered by the cotton crop.

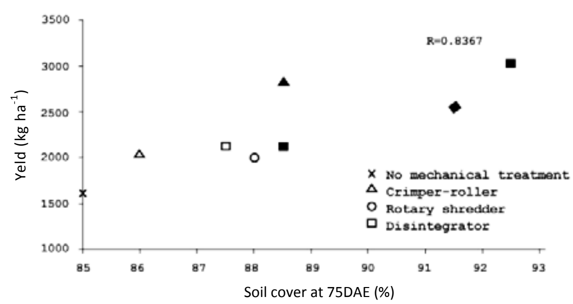

Figure 4. Correlation between cotton crop yield and soil cover 75 days after emergence in no till seeding. Selvíria, Mato Grosso do Sul State, Brazil. Markers with and without data correspond to the years 2006/7 and 2007/8 respectively.

Conclusion

The emergence speed was faster under the management with the rotary shredder.

In 2006/07, the no-tillage treatment showed a rate of loss of soil cover that was 46 percent greater than the disintegrator.

The rotary shredder and disintegrator yielded greater soil coverages during the cultivation cycle. The yield was highly correlated with the soil cover at 75 days after emergence.

The management of the millet residue affected the cotton plant over the course of a two-year study period.

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