Production, decomposition of residues and yield of maize and soybeans grown on cover crops[1]

Produção, decomposição de resíduos e rendimento de milho e soja cultivados sobre coberturas de solo

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ABSTRACT - The residues of cover plants and crops left on the soil surface can influence decomposition, nutrient cycling and follow crop yield. The objective was to evaluate the production of dry biomass (BD), of residues decomposition rate and yield of maize and soybean grown on different soil covers. The experimental design was a randomized block scheme banded, with four covers: Brachiaria, sun hemp, pearl millet and fallow period in autumn/winter, with maize and soybean crop in the spring/summer. We evaluated BD, decomposition through bags of decomposition and yield of maize and soybeans. Pearl millet and sunhemp were the covers which produced more of BD in the fall/winter period. the rate of decomposition of plant residues in maize and soybeans is slow in the dry period and accelerated in the rainy period; maize yield was higher when grown on sunhemp and brachiaria in the years evaluated, while for soybeans there were no differences on any measured coverage; maize and soybeans have grain yields higher than the regional average when grown on different soil covers.

Key words: Intercropping. No-tillage. Productivity. Cerrado.

RESUMO - Os resíduos das plantas de cobertura e das culturas comerciais deixados sobre a superfície do solo podem influenciar a decomposição, ciclagem de nutrientes e a produtividade das culturas subsequentes. Neste estudo objetivou-se avaliar a produção de fitomassa seca (FS), taxa de decomposição dos resíduos e o rendimento de milho e soja, cultivados sobre diferentes coberturas de solo. O delineamento utilizado foi de blocos casualizados no esquema em faixas, com quatro coberturas: braquiária, crotalária, milheto e pousio no período outono/inverno, com milho e soja em sucessão na primavera/verão. Avaliou-se FS, a decomposição através das sacolas de decomposição e o rendimento de milho e soja. Milheto e crotalária foram às coberturas que apresentaram maior produção de fitomassa seca no período outono/inverno; a produção de fitomassa seca de milho e soja não foi influenciada pelas coberturas de solo avaliadas; a taxa de decomposição dos resíduos vegetais de milho e soja é lenta no período seco e acelerada no chuvoso; o rendimento do milho foi superior quando cultivado sobre crotalária e braquiária nos anos avaliados, enquanto que para soja não ocorreram diferenças sobre qualquer cobertura avaliada; Milho e soja apresentam rendimentos de grãos superiores à média regional quando cultivados sobre as diferentes coberturas do solo.

Palavras-chave: Consorciação de culturas. Plantio direto. Produtividade. Cerrado.

INTRODUCTION

The sustainability of the tillage system (SSD) in the Brazilian Cerrado is linked to biomass production in quantities sufficient to provide adequate ground cover to compensate for the high rates of decomposition of plant residues occurring in these regions (CHIODEROLI *et al.*, 2012). This biomass has been derived from the cultivation of plants of roofs and crop residues left on the soil surface after harvest cash crops.

The quantity of biomass produced in winter in the Cerrado has been lower compared to the one quantified in summer. However, some results show that brachiaria, sunnhemp, pearl millet, jack beans and fallow are adapted to the soil and climate of this biome, producing plant residues in high amount in both planting times (BOER *et al.*, 2008; CARVALHO *et al.*, 2011; CHIODEROLI *et al.*, 2012; MENEZES *et al.*, 2009; TEIXEIRA *et al.*, 2012; TORRES; PEREIRA; FABIAN, 2008).

For annual crops (soybean, maize, sorghum, rice and beans) grown in succession to these covers, these have contributed to relative quantity of residues, however, Kluthcouski and Yokoyama (2003) state that these residues are unlikely to reach the quantity and longevity necessary for full protection of the soil surface.

Maize has been presented as a culture of great significance for the consolidation of the SSD in the Cerrado, with production crop residues above 6 Mg ha^{-1} (GUIMARÃES *et al.*, 2006). This material has a low rate of decomposition, providing extended covers of the soil of nutrients and high cycling (SILVA *et al.*, 2008). With respect to soybeans, biomass production is low, reaching 5.5 Mg ha^{-1} (PADOVAN *et al.*, 2006), with high rate of decomposition of its residues (GONÇALVES *et al.*, 2010).

Depending on the soil cover which preceded the cultivation of annual crops and edaphoclimatic conditions of the region, decomposition rates can vary considerably. In southern Brazil, Gonçalves *et al.* (2010) evaluated the decomposition of maize straw and estimated mass low of 40% and 65% after 150 and 360 days, respectively. In the Cerrado, Teixeira Neto (2002) found that after 180 days brachiaria straws intercropped with maize showed decomposition of 66% and 77% of sole maize. Kliemann, Braz and Silveira (2006) in this same consortium, found losses of 56% and 86% after 150 and 360 days, respectively. In a study with soybean, Gonçalves *et al.* (2010) estimated the decomposition of crop residues after 113 days in the field on the SSD by 33% and 51% in the conventional system. Padovan *et al.* (2006) found that the decomposition of soybean straw after 115 days in the field was of.

The maintenance of ground cover plants residues and those of commercial crops on the soil as well as their decomposition has been an important variable in the cycling of nutrients that contributes to the maintenance (CRUSCIOL; SORATTO, 2009; PACHECO *et al.*, 2011), increased maize productivity (CARVALHO *et al.*, 2004a; CARVALHO *et al.*, 2011; TORRES *et al.*, 2005) and soybean productivity (CARVALHO *et al.*, 2004b; CHIODEROLI *et al.*, 2012; TORRES; PEREIRA; FABIAN, 2008), however these values vary for each region and should be evaluated locally. This study aimed to evaluate the production of biomass, the decomposition rate of the waste and yield of maize and soybeans when grown on different cover crops in Cerrado miner.

MATERIAL AND METHODS

The study was conducted in Uberaba-MG, under the coordinates 19°39'19'' S and 47° 57'27'' W, and average altitude of 795m., during the period of April 2007 to March 2009, in an area under direct seeding since the year 2000. The climate is classified as tropical warm according to Köppen, with 1600 mm of precipitation and temperature at 22.6 °C (annual average). (UBERABA, 2009). Rainfall in 2007, 2008 and 2009 was of 1853, 2180 and 1758 mm yr^{-1}, respectively (Table 1).

The soil of the area was classified as dystrophic Red Latosol (SANTOS *et al.*, 2006), sandy clay loam texture, with plow layer (0.0 to 0.20 m), 210 g kg^{-1} clay, 710 g kg^{-1} sand and 80 g kg^{-1} silt, pH H$_2$O 5.9; 15.2 mg dm^{-3} P (Mehlich-1); 2 mmol$_c$ dm^{-3} K; 12 mmol$_c$ dm^{-3} Ca^{2+}; 4.0 mmol$_c$ dm^{-3} Mg^{2+}, 21 mmol$_c$ dm^{-3} H+Al and 19 g kg^{-1} organic carbon.

The experimental design was a randomized, banded in the scheme, with four replications. The treatments used were four soil covers: brachiaria (*Urochloa brizantha* cv. Marandu), sunnhemp (*Crotalarea juncea*), pearl millet ADR 300 (*Pennisetum glaucum* L.) and fallow (spontaneous vegetation with a predominance of Poaceae) into sixteen plots of 180 m^2 (18 x 10 m), which after management (desiccation) were divided into areas of 90 m^2 (9 x 10 m) and seeded maize and soybean crop in succession.

The cover crops were grown in autumn/winter (April/July) period in 2007/08 and 2008/09. Sowing was mechanized in spacing of 0.45 m between rows and density of 50, 25 and 60 seeds per meter brachiaria, sunnhemp, pearl millet, respectively. The covers were desiccated in full bloom, applying a dose of 1440 g ha^{-1} of glyphosate + 600 g ha^{-1} of Paraquat. The evaluation of dry biomass (BD) was performed on an area of 2 m^2 per plot, was harvested where all vegetation, this material was then dried at 65 °C for 72 hours, weighed and the results expressed as Mg ha^{-1}.

Table 1 - Rainfall (mm) in Uberaba-MG. Source: SAGRI-Dec./2009 (UBERABA, 2009)

Year/Month	Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set	Out	Nov	Dez	Total
	--- mm ---
2007	467	232	100	106	25	0	21	0	40	154	266	441	1852
2008	468	362	300	244	67	5	0	21	42	95	146	430	2180
2009	335	338	246	61	44	1	12	11	58	170	156	325	1758

Maize and soybean were sown until November 15 of the years 2007 and 2008 banded day, under cultivation in the spring/summer period. Samples for the evaluation of the dry biomass of maize and soybeans were conducted in the central lines of the plots where all plants were harvested in an area of 10 m² (maize) and 4.5 m² (soybean) when these plants reached full bloom. Then this material was taken to the laboratory, dried at 65 °C for 72 hours to constant weight, weighed and the results were expressed in Mg ha⁻¹. This dry biomass was triturated in pieces of 0.05 m, homogenized and stored for later evaluation of the rate of decomposition. We evaluated the yield at the end of the crop cycle in the second and fourth center lines in March 2008 and 2009, who had their mass values corrected to 13% moisture and the results expressed in Mg ha⁻¹.

We used maize seeds of semi-early cycle from Pioneer, seeded with 0.90m between rows, with 55000 plants ha⁻¹. At sowing 400 kg ha⁻¹ of the formula 05-15-10 + 0.5% Zn were applied. 100 kg ha⁻¹ of N and 80 kg ha⁻¹ K_2O were applied at 20 and 40 days after sowing. For soybeans, the seed used was BRSMG of semi-early cycle, with 0.45m between rows, with 220000 plants ha⁻¹. 200 kg ha⁻¹ of formula 0-20-15 + 2.5% Zn were applied at sowing.

To evaluate the decomposition the bags of decomposition (litter bags) were used (SANTOS; WHILFORD, 1981) with a 2 mm mesh opening, with 0.04 m² (0.20 x 0.20 m), were placed in 20 g of maize and soybean dry biomass. The 24 bags per plot were distributed in early May 2008 and 2009, and harvested four bags per plot at 15, 30, 60, 120 and 240 days after deployment in the field. These materials passed through pre-cleaning screens on and were dried in forced air at 65 °C until constant weight in order to determine the remaining biomass of waste.

In order to describe the decomposition of maize and soybean the mathematical model of the exponential type $X = X_o e^{-kt}$ was applied, where X is the amount of dry biomass remaining after a period of time (t), in days; X_o is the initial amount of dry biomass and k is the constant of the decomposition of the residue (THOMAS;

ASAKAWA, 1993). With the value of k, we calculated the half-life (T½ life) of the remainder dry biomass, using the formula T½ life = 0.693/k (PAUL; CLARK, 1996).

Mathematical equations and regression analyzes were developed with the help of SigmaPlot software, version 10. The results were analyzed for normality and homogeneity of data and subjected to analysis of variance and the averages compared by Tukey test at 5% of probability.

RESULTS AND DISCUSSION

Pearl millet and fallow were the covers that stood out significantly in 2007, which is higher when compared to the values produced of dry biomass in 2008 (Table 2). These values were similar to those reported by Torres, Pereira and Fabian (2008) and Fabian (2009) in the same experimental area. A consequence of higher values and better distribution of rainfall, which were recorded 106 and 25 mm in the month of April, 244 and 67 mm of rain in May in the years 2007 and 2008, respectively, higher values of production of dry biomass for all covers were expected, since these months in the study area are characterized by low rainfall (Table 1).

In studies conducted with the same cover, sowing period and the Cerrado (FABIAN, 2009; PACHECO *et al.*, 2011; SODRÉ FILHO *et al.*, 2004; TORRES; FABIAN; PEREIRA, 2008) values of dry biomass production were observed similar to those observed in this study. However, in some other areas of Cerrado, we have seen high yields of dry biomass, even with the covers sown in the beginning of the dry period (CARVALHO *et al.*, 2004a; KLIEMANN; BRAZ; SILVEIRA, 2006), which are influenced by the local edaphoclimatic conditions.

In the production of dry biomass of maize and soybean on the cover plants there were no differences when analyzed separately the year (2007/08 and 2008/09), however the dry biomass production of maize in 2007/08 was higher on all roofs (Table 3). The production of dry biomass in maize and soybeans

Table 2 - Production of dry biomass cover crops and fallow in crop years 2007 and 2008 in Uberaba-MG

Types of coverage	Dry biomass	
	2007	2008
	-- Mg ha^{-1} --	
Brachiaria	2.0 bA[(1)]	2.6 aA*
Sunnhemp	2.1 bA	2.9 aA
Pearl millet	3.9 aA	2.9 aB
Fallow	3.8 aA	2.8 aB
F	1.38*	1.53*
CV (%)	22.6	15.8

[(1)]Means followed by the same letter in the column and uppercase on the line do not differ by Tukey test at 5% probability. *Significant, ^{ns}not significant (p<0.05)

Table 3 - Production of dry biomass of maize and soybean in crop years 2007/08 to 2008/09, in Uberaba-MG

Types of coverage	Dry biomass			
	Maize		Soybean	
	2007/08	2008/09	2007/08	2008/09
	--Mg ha^{-1}--			
Brachiaria	10.0 aA[(1)]	7.4 aB*	4.5 aA	4.4 Aa
Sunnhemp	9.8 aA	8.3 aB	6.1 Aa	5.9 aA
Pearl millet	9.8 aA	7.9 aB	4.8 aA	4.1 Aa
Fallow	9.2 aA	7.7 aB	4.5 aA	4.6 aA
F	0.14^{ns}	1.30^{ns}	2.16^{ns}	2.51^{ns}
CV (%)	18.1	14.7	7.84	20.6

[(1)]Means followed by the same letter in the column and uppercase on the line do not differ by Tukey test at 5% probability. *Significant, ^{ns}not significant (p<0.05)

is considered high and can be justified by the time the samples were conducted, because plants were in full flowering, with higher amount of green biomass. These values are above 6.0 Mg ha^{-1} obtained by Guimarães *et al*. (2006). Compared to soybean, there was no difference between the production of dry biomass of the crop on the covers. The values obtained were close to 5.5 Mg ha^{-1} of Padovan *et al*. (2006).

The rate of decomposition of crop residues on maize and soybeans covers the years 2007/08 and 2008/09 was evaluated through the remaining dry biomass, that occurred at an accelerated rate in the first 30 days and then slowly until completing 120 days (Figure 1). This behavior can be explained by the decrease in rainfall in the period from May to August (Table 1), with lower ambient temperature. After 240 days, the rate of decomposition increased with the return of precipitation and increasing temperature.

Analyzing the remaining residues within bags of decomposition was observed that the biomass losses for maize in 2007/08 were 22.8, 17.7, 20.3 and 15.0% at 120 days and increased to 33, 5, 23.6, 27.8 and 24.3% at 240 days after the distribution of decomposition bags. These losses for soybeans were 31.0, 23.8, 27.4 and 23.1 at 120 days and increased to 40.3, 36.4, 39.5 and 41.4% at 240 days, over the straw fallow, pearl millet, sunnhemp and brachiaria, respectively.

In 2008/09 the biomass losses for maize were 24.8, 27.5, 30.8 and 29.8% at 120 days and increased to 38.7, 47.4, 39.1 and 37.2% at 240 days. For soybeans, the values were 40.1, 38.5, 42.8 and 42.7 at 120 days and increased 63.2, 53.0, 53.7 and 57.3% at 240 days for fallow, pearl pearl millet, sunnhemp and brachiaria, respectively. The highest values of mass loss observed in this second year are due to the higher volume of rainfall recorded during the period (Table 1), which caused the increase of the rate of decomposition of residues.

Some studies on the decomposition of the straw of maize and soybeans in the southern have lower values of biomass loss, to those observed in this study. In Carambeí-PR, Wisniewski and Holtz (1997) found that at 23, 40, 65, 89, 103 and 149 days after handling the mass losses of maize straw were of 31, 27, 59, 23, 23 and 49%, respectively. In Londrina, Gonçalves *et al.* (2010) estimated the loss of biomass of maize in areas under SSD of 40 and 67% at 150 and 360 days after the handling, respectively, whereas for the soybean the biomass losses were of 33% at 113 days.

These values are justified by the different edaphoclimatic conditions that occur in this region, especially the lowest temperatures, which cause a reduction in the rate of decomposition of residues.

In the Cerrado of Goiás, Kliemann, Braz and Silveira (2006) evaluating the consortium of maize and brachiaria observed biomass losses of maize of 56% at 150 days. In Seropédica-RJ, Padovan *et al.* (2006) evaluated the biomass losses for soybeans at 55, 85 and 115 days after the emergence and found 51, 56 and 40% of the remaining dry biomass. These regions have high temperature and rainfall. These conditions are identical to those observed in this study, thus the values of biomass losses are also similar.

Analyzing the half-life (T ½ life) of maize straw and soybean in 2007/08 and 2008/09, it is observed that the smaller values occurred when cultures were grown on sunnhemp (Table 4). In these areas there was a more rapid decomposition of crop residues due to the larger amount of N available in the soil through biological fixation of sunhemp (BOER *et al.*, 2008; CARVALHO *et al.*, 2011; MENEZES *et al.*, 2009; PACHECO *et al.*, 2011; TORRES *et al.*, 2005) thereby increasing the activity of decomposing organisms of organic matter occurs. Gonçalves *et al.* (2010) emphasize that together with the carbon assimilation, microbial population needs to assimilate N for the synthesis of many compounds,

Figure 1 - Remaining dry biomass (DB) of maize and soybean crops residues on soil coverages, in Uberaba-MG. A = maize and B = soybean in 2007/08; C = maize and D = soybean in 2008/09
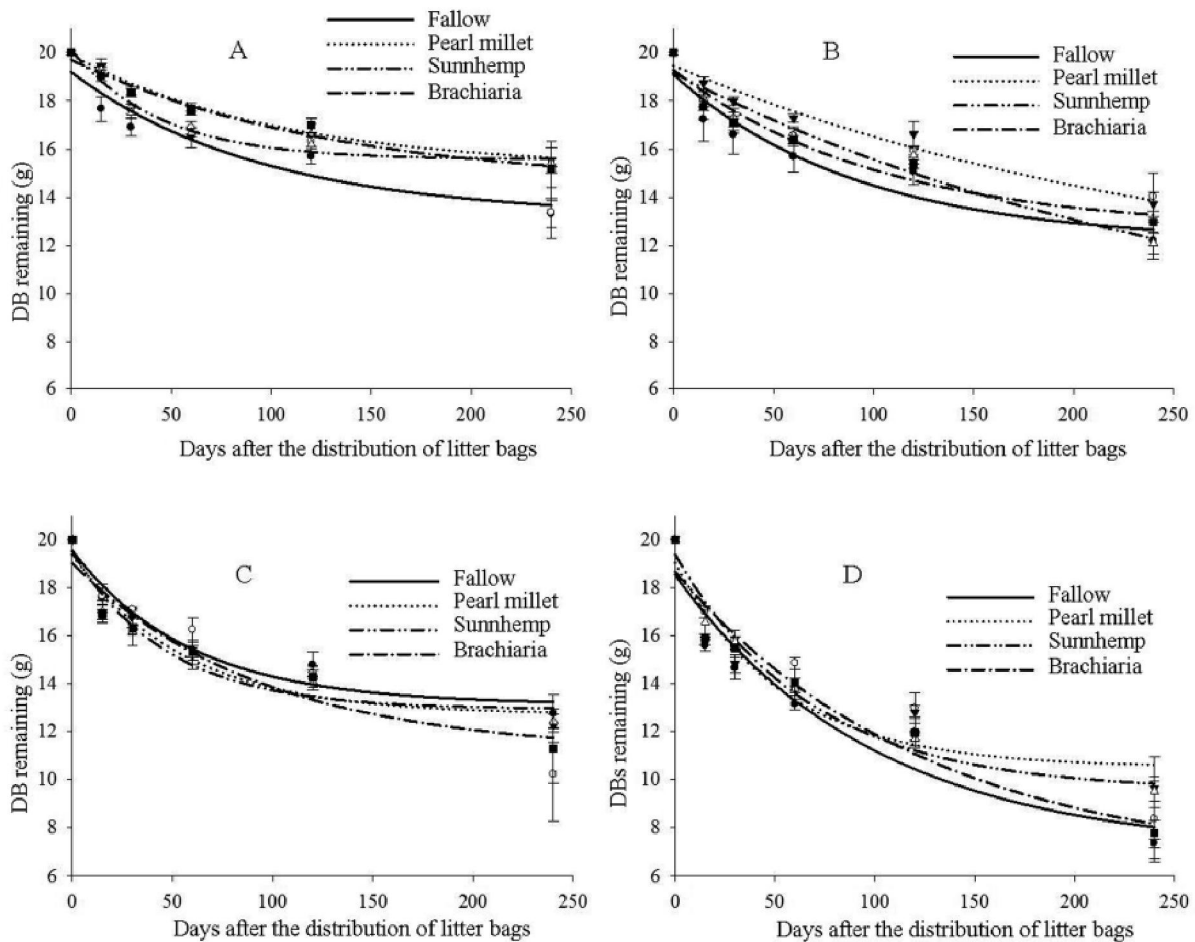
therefore the lower the C/N ratio of the vegetable residue the greater the rate of decomposition.

This pattern can be observed in Table 4, where the highest values of T ½ life of maize straw and soybean occurred on brachiaria and pearl millet in 2007/08, pearl millet and fallow in 2008/09, areas in which a lower availability of N occurs, once they are covers that have higher C / N ratio when compared to sunhemp, as verified by Torres *et al*. (2005) and Carvalho *et al*. (2011).

The C/N ratio of the maize and soybeans straw also influences the residues decomposition, as in maize this relation ranges from 60:1 to 69:1 (SILVA *et al*., 2008), whereas in soybean, values are smaller than 30:1 (GONÇALVES *et al*., 2010). Although not determined in this study, the C/N ratio of these cultures appeared to influence the rate of decomposition because the life T ½ of the maize straw was in most cases larger when compared to soybeans.

The values obtained for the decomposition rate and rainfall showed positive correlations. (Table 5). These correlations show that as rainfall increased (Table 1), the greater were the rates of decomposition and the biomass losses of crop residues of maize and soybeans during the evaluation period.

Various studies have were conducted in Cerrado that proved the influence of rainfall on the rate of decomposition of plant residues of different ground covers (BOER *et al.*, 2008; CARVALHO *et al.*, 2011; MENEZES *et al.*, 2009; PACHECO *et al.*, 2011;

TORRES; PEREIRA; FABIAN, 2008), yet there are few reports that evaluate the decomposition of crop residues left on the soil after harvest of annual crops.

In this study it was observed that the decomposition of maize straw occurs slowly and for soybeans at an accelerated rate, the values increase gradually with increasing precipitation, as observed by other authors (GONÇALVES *et al*., 2010; GONÇALVES; SARAIVA; TORRES, 2011; KLIEMANN; BRAZ; SILVEIRA, 2006; PADOVAN *et al*., 2006; SILVA *et al*., 2008). Furthermore, it was found that this decomposition is influenced by the predecessor cultures, for smaller values of T ½ life of maize straw and soybean occurred on the sunhemp straw because the high fixation capacity of atmospheric N_2 of this culture offers greater amount of N in the soil after being managed, causing increased activity of decomposing organisms (GONÇALVES *et al*., 2010).

The use of grasses as cover crops succeeding other grassy main culture can promote a low N availability in the soil and affect grain yield. This was confirmed in 2007/08 as the highest grain yield maize was observed when the culture was grown on sunnhemp in 2007/08, but was not repeated in 2008/09 because the highest yield occurred on brachiaria. For soybeans there was no difference between the covers in those years (Table 6). The highest yields observed for maize in 2007/08 compared to 2008/09 are justified by better distribution and higher rainfall occurred this year, while the same was not true for soybeans.

Table 4 - Decomposition constant (k) and life-time (T ½ life) of maize and soybean crops residues from 2007/08 to 2008/09, produced on residues of cover crops and fallow, in Uberaba-MG

Coverages	Dry biomass					
	Maize			Soybean		
	k	T½	r²	k	T½	r²
	g g⁻¹	days		g g⁻¹	days	days
--- 2007/08 ---						
Brachiaria	0.0077	90	0.98 *	0.0098	71	0.97 *
Sunnhemp	0.0151	46	0.98 *	0.0130	53	0.97 ***
Pearl millet	0.0092	75	0.98 ***	0.0098	71	0.99**
Fallow	0.0107	75	0.99 **	0.0146	47	0.95 **
--- 2008/09 ---						
Brachiaria	0.0099	71	0.95 **	0.0169	41	0.96 *
Sunnhemp	0.0182	38	0.97 *	0.0207	33	0.95 **
Pearl millet	0.0058	119	0.97 *	0.0171	41	0.99 *
Fallow	0.0137	51	0.98 *	0.0106	65	0.96 **

*, ** And *** = Significant (p <0.01) (p <0.05) (p <0.10) respectively, r2 = coefficient of determination

Table 5 - Correlations of Pearson between rainfall values and decomposition of maize and soybean straw on the coverage in 2008 and 2009, in Uberaba-MG

Coverages	Correlation coeficient	r^2	Correlation coeficient	r^2
	Maize		Soybean	
-- 2008 --				
Brachiaria	0.80	0.97 **	0.91	0.99 *
Sunnhemp	0.72	0.97 **	0.80	0.98 *
Pearl millet	0.66	0.91 **	0.78	0.97 *
Fallow	0.76	0.95 *	0.69	0.98 *
-- 2009 --				
Brachiaria	0.74	0.98 **	0.80	0.99 *
Sunnhemp	0.70	0.97 **	0.70	0.98 *
Pearl millet	0.88	0.96 *	0.82	0.97 *
Fallow	0.82	0.99 *	0.87	0.99 *

* and ** = Significant (p <0.01) and (p <0.05), respectively; r^2 = coefficient of determination

Table 6 - Maize and soybean grain yield, in 2007/08 and 2008/09, produced on residues of coverage plants and fallow, in Uberaba-MG

Types of coverage	Productivity			
	Maize		Soybean	
	2007/08	2008/09	2007/08	2008/09
-- Mg ha^{-1} --				
Brachiaria	9.0 bA	9.5 aA	3.6 aA	3.7 aA
Sunnhemp	11.0 aA	8.4 bB	4.0 aA	5.3 aA
Pearl millet	9.5 bA	8.4 bB	3.3 aA	4.3 aA
Fallow	8.7 cA	7.9 bB	3.2 aA	3.7 aA
F	1.26*	0.73*	1.32^{ns}	1.55^{ns}
CV (%)	9.9	16.9	20.4	24.5

*Significant, ^{ns}not significant; Means followed by the same letter in the column and uppercase on the line do not differ (Tukey, p <0.05)

Grain yield for recorded for maize and soybeans in the two years evaluated is high for the region, which has estimated averages of 6.0 Mg ha^{-1} for maize and 3.0 Mg ha^{-1} for soybean (COMPANHIA NACIONAL DE ABASTECIMENTO, 2011).

Some previous studies were conducted in the same experimental area during 2000/01 and 2001/02, showed average grain yield maize from 5.4 Mg ha^{-1} (TORRES *et al*., 2005), in 2004/05, 2005 / 06 and 2006/07 of 6.9 Mg ha^{-1} by Fabian (2009). For soybeans, the yields observed in this study (Table 6) were similar to those observed by Torres *et al*. (2005) in 2000/01 and Fabian (2009) in 2004/05, 2005/06 and 20006/07, 3.5, 3.6, 3.0 and 4.6 Mg ha^{-1} soybean on the same cover. The results of this study show that is taking place to improve the quality of the soil with the use of cover crops preceding the annual crop.

CONCLUSION

1. Sunhemp and pearl millet were the covers that produced more dry biomass during the autumn/winter period;

2. The dry biomass production of maize and soybeans was not influenced by the soil cover evaluated;

3. The rate of decomposition of plant residues in maize and soybeans is slow in the dry period accelerated in the rainy period;

4. Maize yield was higher when grown on when grown on sunhemp and brachiaria in the years evaluated, while for soybeans there were no differences on any cover evaluated. 5. Maize and soybeans present grain yields higher than the regional average when grown on different soil cover.

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