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ORIGINAL ARTICLE

Production and speed of decomposition of species of soil coverage in direct sowing system

Produção e velocidade de decomposição de espécies de cobertura do solo em sistema de semeadura direta

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ABSTRACT: To keep the system of direct seeding balanced, soil cover plants that develop rapidly and whose vegetal residues persist for an extended period are recommended. In this study, we evaluated the productivity of fresh and dry mass of soil cover plants and the remaining dry mass of plant residues. The study was conducted on a dystrophic Red Latosol [Oxisol] (Rhodic Ferralsol) with a sandy clay loam texture. A randomized block design was conducted with time split-plots with four replications. In the plots, the species of cover plants were allocated, and, in the subplots, the evaluation periods (0, 30, 60, 90, 120, 150 days after desiccation). The evaluated species were pearl millet (*Pennisetum americanum* sin tiphoydes) cv. ADR 300; brachiaria grass ruziziensis (*Urochloa ruziziensis*), pigeonpea (*Cajanus cajan*), forage sorghum (*Sorghum bicolor*); sunnhemp (*Crotalarea juncea*); finger millet (*Eleusine coracana* (L)); jack bean (*Canavalia ensiformis*). The dry mass productivity of cover crops and the rate of decomposition of plant residues were evaluated. Forage sorghum presented the highest dry matter yield of plant residues and, along with sunnhemp, presented the highest values of remaining dry mass of the vegetal residues after decomposition. Finger millet was not an adequate alternative for the direct seeding system in the study region.

RESUMO: *Para manter o sistema de semeadura direta equilibrado é recomendada a utilização de plantas de cobertura do solo que apresentem rápido desenvolvimento e que seus resíduos vegetais persistam por um período prolongado. Neste estudo avaliamos a produtividade de massa fresca e seca de plantas de cobertura e a massa seca remanescente dos resíduos vegetais, em um latossolo vermelho distrófico com textura média. O delineamento utilizado foi o de blocos ao acaso, com parcelas subdivididas no tempo e quatro repetições. Nas parcelas foram alocadas as espécies de plantas de cobertura e, nas subparcelas, as épocas de avaliação (0, 30, 60, 90, 120, 150 dias após a dessecação). As espécies avaliadas foram o milheto (*Pennisetum americanum sin. Tiphoydes*) cv. ADR 300; braquiária ruziziensis (*Urochloa ruziziensis*); feijão guandu (*Cajanus cajan*); sorgo forrageiro (*Sorghum bicolor*); crotalária juncea (*Crotalarea juncea*); capim pé-de-galinha (*Eleusine coracana (L)*) e feijão-de-porco (*Canavalia ensiformis*). Foram avaliadas a produtividade de fitomassa de plantas de cobertura e a velocidade de decomposição dos resíduos vegetais. O sorgo forrageiro apresentou a maior produção de matéria seca de resíduos vegetais e, juntamente com a crotalária, apresentou os maiores valores de massa seca remanescente dos resíduos vegetais após a decomposição. O capim pé-de-galinha não foi uma alternativa adequada para o sistema de semeadura direta na região estudada.*

KEYWORDS
The cerrado biome
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1 Introduction

Agricultural systems that strengthens direct sowing are adopted to increase the organic matter concentration on the soil, decrease pluvial and eolic erosion, and it also acts as a physical barrier for the growth of invasor plants, therefore aiding germination and development of crops.

The great challenge of direct sowing systems in the Cerrado is the difficulty to choose soil coverage plants that produce enough vegetable residues in the period between crops and that have low decomposition rates with a higher half-life time (T½). High temperatures and pluvial precipitation rates condition higher activity of decomposing microorganisms, reducing organic matter concentration in a short period of time, so that at the time of planting, the soil is predominantly uncovered. This way, nutrients recycled by the plants will already be available to the soil, before the sowing and/or the period of demand for the main crop. These nutrients may be lost through volatilization, leaching, adsorption, or runoff due to uncovered soil, thus reducing the system's efficacy.

The positive contribution of the compounds generated by the straw decomposition is accomplished by a proper management, which provides diferente results, allied to the choice of soil coverage plants. One example is the use of *Crotalaria spectabilis* to reduce the incidence of nematodes. Another commonly cited example is the recycling of deep-lying nutrients where the root system of commercial crops (corn and soybeans) cannot reach and absorb.

As to fresh and dry mass productivity, several studies, carried out with millet crop in summer crops in the state of Minas Gerais, produced 28,580 and 9,650 kg ha^{-1} (Moraes, 2001) and 45,760 and 14,180 kg ha^{-1} (Oliveira et al., 2002) of fresh and dry mass, respectively. In the dry season, millet dry matter yield varied from 3,600 kg ha^{-1} (Torres et al., 2005) to 2,900 kg ha^{-1} (Teixeira et al., 2005).

Crotalarea juncea is characterized by the persistence of plant residues due to high lignin content in the stem and by a great accumulation of calcium. This was proven by Soratto et al. (2012), who evaluated the dry mass productivity, macronutrient and silicon decomposition, and release rates in *Crotalarea juncea* plant residues and pearl millet (*Pennisetum glaucum*) in single and intercropping cultivars. Menezes et al. (2009) studied the mass productivity of this species and obtained results of 8,690 kg ha^{-1} in the state of São Paulo, Brazil.

In this study, we evaluated the productivity of fresh and dry mass of soil cover plants and the remaining dry mass of plant residues.

2 Materials and Methods

This experiment was conducted between March and December 2015 in Uberaba, MG, Brazil, in Instituto Federal do Triângulo Mineiro (IFTM) – Uberaba *campus* (19°39'19"S, 47°57'27"W), Datum Córrego Alegre, MG, 795 m above sea level in a dystrophic Red Latosol [Oxisol] (Rhodic Ferralsol, (220 g kg^{-1} of clay, 50 g kg^{-1} of silt and 730 g kg^{-1} of sand) , with the following chemical attributes (0-20 cm): pH 5,9; $H^+ + Al^{+3}$ 2,6 $cmol_c\ dm^{-3}$; Ca^{+2} 1,43 $cmol_c\ dm^{-3}$; Mg^{+2} 0,31 $cmol_c\ dm^{-3}$; K^+ 129 mg dm^{-3}; avaliable P 27 mg dm^{-3} of soil and 11 g kg^{-1} of total C. The KCl extractor was used to determine the Al^{+3}, Ca^{+2}, and Mg^{+2} content, and the $Mehlich^{-1}$ extractor was used to determine the K+ and P content.

The climate is characterized by the Köppen classification, with a dry season of five months, with an average annual precipitation of 1,870 mm in the last 12 years and a mean annual temperature of 22.6°C (Fabian, 2012).

A randomized block design was conducted, with portions subdivided in time, with four repetitions. The first factor analized was soil coverage plant: pearl millet (*Pennisetum americanum* sin. tiphoydes) cultivar ADR 300, brachiaria grass ruziziensis (*Urochloa ruziziensis*), pigeon pea (*Cajanus cajan*), forage sorghum (*Sorghum bicolor*) hybrid AG 1080, sunnhemp (*Crotalarea juncea*), finger millet (*Eleusine coracana* L.), and jack bean (*Canavalia ensiformis*).

The second factor analyzed was the collection time of 0, 30, 60, 90, 120 and 150 days after distribution (DAD). Each block was 10 m wide by 42 m long. The sowing plots of cover plants were 10 m wide and 6 m long.

On March 05th, 2015, the experimental area was desiccated with the herbicide Glyphosate, with a dose of 1.44 kg of the active ingredient ha^{-1}. Sowing of cover crop was performed on March 25th, 2015, at a spacing of 0.5 m between rows, mechanically, except for the jack bean that was sown manually. After twinning, the density of plants per meter was six for jack bean, 16 for the sorghum forage and pigeon peas, 20 for millet and sunnhemp, and 50 for brachiaria and finger millet. No basal fertilization was applied to sowing of cover crops due to residual nutrients provided by the previous crops.

The dessication of cover plants was performed 97 days after sowing, when more than 50% of the plants had flourished, except for brachiaria, using herbicides Glyphosate, in a dose of 1.44 kg of the active ingredient ha^{-1}, and 2,4-D amine, in a dose of 670 g of the active ingredient ha^{-1}, diluted in 200 L ha^{-1} of syrup. This desiccation step was performed five days after the evaluation of fresh mass productivity.

The dry and fresh mass quantification was performed on July 1st, 2015, randomly sampling four segments of 50 cm in the sowing line in each plot, totaling one square meter. Then, the harvested material was weighed to estimate fresh mass production, in kg ha^{-1}. Immediately after weighing in a forced ventilation oven heated at 65 ° C for 72 hours the dry mass was obtained. The distribution of the decomposition bags was carried out on July 13th, 2015.

The litter bag method was used to evaluate vegetable waste decomposition (Thomas & Asakawa, 1993). The decomposition bags were made with 2 mm aperture nylon mesh sizes of 0.25 x 0.25 m. Five bags of decomposition containing 20 g of dry vegetable residues were distributed in each plot soon after desiccation of the cover plants. The dry matter decomposition rate was determined after 0, 30, 60, 90, 120, 150 days after the distribution of the decomposition bags, and the remaining dry mass was also quantified.

To describe a decomposition of plant residues, data were fitted to an exponential mathematical model (1), described by Wieder & Lang (1982), used by Thomas & Asakawa (1993), and quoted by Boer et al. (2008).

$$P = Po \exp(-kt) \quad (1)$$

In the equation, P is the amount of dry mass existing at time t, in days; Po is the fraction of dry mass potentially decomposable; and k is the decomposition constant of the dry mass. To calculate the half-life (T ½), that is, the time required for 50% of the remaining dry mass to be decomposed, equation (2) was used, according to Paul & Clark (1989):

$$T½ = 0,693/k \quad (2)$$

Data were submitted to analysis of variance, test F, at 5% probability, and, when verified a significant effect, the means were compared by the Tukey test at 5% probability. For the statistical analysis, the free statistical computer programming R was used.

3 Results and Discussion

Table 1 shows that forage sorghum presented higher productivity of fresh and dry mass, with values of 12,206 kg ha^{-1} and 3,998 kg ha^{-1}, respectively. These values can be related to the inclusion in the sampling of the panicle mass that presented grains in the phase R5 – farinaceous grain, because not only the silage of the crop was sought, but the formation of soil cover as well. Thus, the possibility of using the species for the maintenance of soil cover is indicated.

Table 1. Productivity (kg ha^{-1}) of fresh and dry mass of cover crops grown in the fall of 2015 in IFTM – Uberaba *campus*, MG.

Tabela 1. Produtividade (kg ha^{-1}) de massa fresca e seca das plantas de cobertura cultivadas no outono de 2015 no IFTM - *campus* Uberaba, MG.

Cover crops	Fresh mass (kg ha^{-1})		Dry mass (kg ha^{-1})	
Forage sorghum	12.206	a*	3.998	a*
Jack bean	11.646	ab	2.970	b
Brachiaria grass	9.542	bc	2.349	bc
Sunnhemp	9.271	c	2.329	bc
Pearl millet	8.344	c	2.185	Cd
Pigeon pea	5.399	d	1.665	de
Finger millet	3.928	d	1.205	e
CV (%)	10.70		11.9	
SMD (5%)	2.15		0.66	

* Averages followed by the same letter in the column do not differ from each other to 5% by the Tukey test. C.V. = coefficient of variation; SMD = significant minimum difference.

Sunnhemp, in this study, produced less dry mass than forage sorghum, though with similar values than those obtained by Sodré Filho et al. (2004) in similar climate conditions and by Fabian (2009) in the same experimental area of this study. Silva et al. (2014) claims that the dry matter productivity is influenced by species, soil attributes, climate and time of cultivation and evaluation.

Jack bean also produced a high amount of mass with average productivity of 11,646 kg ha^{-1} of fresh mass and 2,970 kg ha^{-1} of dry mass, respectively. These values are similar to those obtained by Teixeira et al. (2005), who registered 13,833 kg ha^{-1} of fresh mass and 2,728 kg ha^{-1} of dry mass. Regarding dry biomass, jack bean produced less than forage sorghum and an amount similar to brachiaria grass and sunnhemp.

Even though the finger millet has a good root development characteristic in the preventive management of compaction and/or decompression of the soil, it presented lower dry biomass productivity than the other cover species, producing 1,205 kg ha^{-1}. This amount is much lower than that obtained by Boer et al. (2008), which produced 8,753 kg ha^{-1} of dry mass when grown in Rio Verde, GO, Brazil. The low productivity in our study may be due to unfavorable climatic conditions in which the rainfall accumulated during the course of the cover crops was lower than in Goiás. Therefore, under our conditions, this kind of soil cover was not an adequate alternative for the no-tillage system. However, when the yield of straw produced is high, the amount of remaining dry mass will also be high, since the stem of the finger millet is very lignified, resembling millet (C/N ratio 29:1) (C/N = 34:1 ratio), an important cover plant used in the Cerrado (Boer et al., 2008).

The yield of brachiaria ruziziensis was similar to that produced by jack bean and sunnhemp. This productivity was similar to that obtained by Pacheco et al. (2011) in Rio Verde – GO, Brazil, and higher than that observed by Horvathy Neto et al. (2014), who cultivated in that time.The brachiaria ruziziensis grass was affected by factors similar to those attributed to finger millet, such as water deficit and photoperiod influence.

For millet, dry biomass productivity of 2,185 kg ha^{-1} was similar to that verified by Teixeira et. al. (2005), who obtained 2,907 kg ha^{-1}. Water supply and high temperatures contribute to the greater development of the plants, providing greater accumulation of vegetal material, as verified by Carvalho et al., (2015). These authors obtained 2,330 kg ha^{-1} of dry matter, which are similar to those found in our study, which was 2,185 kg ha^{-1}. The authors attributed low mass productivity to the influence of climatic factors characteristic of the Cerrado, which has an irregular distribution of rainfall. The same authors state that the chemical composition of low lignin cover crops such as brachiaria ruziziensis grass favors the development of subsequent crops due to accelerated release of nutrients present in the plant tissue.

Carvalho et al. (2006) state that several authors report low yields for these cover crop species when sown at the same time as our study in the Cerrado. However, yields may be three times greater when sown at the beginning of the rainy season, or even at the end of the rainy season, when precipitation is high and well distributed.

For the decomposition variable, the sunnhemp resembled the pearl millet and pigeon pea, with the highest values of dry mass remaining 150 days after the distribution of the decomposition bags. The lowest values were verified for brachiaria grass and jack bean (Table 2).

These results may be related to the high C/N ratio and the chemical composition of the species, sunnhemp, millet and pigeon pea, as reported by Carvalho et al. (2011). The pigeon pea and the sunnhemp present higher concentrations of lignin with more recalcitrant carbon in the stem.

Table 2. Residual dry mass (RDM) of vegetal residues of the soil cover plants (g), from July to December 2015 at IFTM Uberaba *campus*, MG.
Tabela 2. Massa seca remanescente (MSR) dos resíduos vegetais das plantas de cobertura do solo (g), no período de julho a dezembro de 2015 no IFTM *campus* Uberaba, MG.

	Days after distribution of decay bags – DAD										
Cover crops	0	30		60		90		120		150	
Sunnhemp	20 a*	19.71	a	16.70	a	14.76	ab	11.91	a	10.73	a
Pearl millet	20 a	19.31	ab	16.66	a	15.08	a	11.28	a	9.82	a
Pigeon pea	20 a	19.00	ab	16.17	a	13.84	ab	11.28	a	10.05	a
Forage sorghum	20 a	18.22	b	14.87	b	14.56	ab	8.66	d	8.05	b
Finger millet	20 a	18.53	ab	16.38	a	13.51	bc	8.27	bc	7.47	bc
Jack bean	20 a	18.90	ab	14.65	b	12.33	c	6.63	d	6.36	c
Brachiaria grass	20 a	19.31	ab	16.66	a	14.18	ab	7.22	c	6.19	c
CV (%) SMD (5%)	2.23	2.35		2.79		3.18 1.18		4.08		5.33	

* Means followed by the same letter in the column do not differ from each other at 5% by the Tukey test. C.V. = coefficient of variation; SMD = significant minimum difference.

In studies conducted in the same experimental area of our study, Fabian (2009) observed that the sunnhemp presented the highest levels of cellulose and lignin in the coverages studied and argued that this occurred due to the morphophysiological characteristics of the crop during its development in the drought period. At that time, the plant showed lower size and fibrous stem, emitting fewer leaves and flowers, according to Silva et al. (2003). The lowest levels of lignin and cellulose occurred in the brachiaria plants. This may be due to the rapid vegetative growth of the plants and the desiccation performed before the plant accumulated lignin and cellulose. These lower contents may facilitate the decomposition of the brachiaria as reported by Matta-Machado et al. (1994) and verified by Torres et al. (2005). The higher content of lignin and cellulose in sunnhemp, when compared with other soils, was also observed by Seguy & Bouzinac (1995) in a study carried out in the north of Mato Grosso State.

The decomposition rate of soil cover plants residues is expressed by the half-life, which is influenced by the composition of the materials, mainly the C/N ratio and lignin contents and the climatic conditions (rainfall, humidity and temperature).

Sunnhemp, millet and pigeon pea species present a half-life superior to the other treatments (Table 3) because of the high concentration of lignin in its integument and high C/N ratio presented by these cover plants, as observed by Fabian (2009). When the objective is rapid decomposition and release of nutrients, jack bean, brachiaria and finger millet are the most appropriate species because they present the shortest decomposition times, which allow accelerated release of nutrients to subsequent summer crops, usually soybeans and corn, sown in November/December after the onset of the rainy season.

When evaluating the nutrient decomposition and release of cover crops in the Northwest Fluminense region, Gama-Rodrigues, Gama-Rodrigues and Brito (2007) verified values of T½ of remaining dry mass of 115 days for the brachiaria and 52 days for jack bean. These results show the great importance of grasses for the formation of straw in the Brazilian Cerrado, because even in high temperatures and humidity, the material presents a high half-life. Thus, the straw remains in the soil, providing physical protection, moisture and increasing organic carbon contents in the soil (Rossi et al., 2013).

Table 3. Half-life time of soil cover plants in the Cerrado.
Tabela 3. Tempo de meia vida de plantas de cobertura do solo no bioma do cerrado.

Crop year 2015/2016				
Cover crop	k (g g^{-1})	T ½ (days)	R²	50% RDM (kg ha^{-1})
Sunnhemp	0.004282	162 a	0.95	1,484
Pearl millet	0.004598	151 a	0.92	1,173
Pigeon pea	0.004702	148 a	0.96	830
Forage sorghum	0.005839	119 b	0.89	1,996
Finger millet	0.006237	111 b	0.91	603
Brachiaria grass	0.006805	102 c	0.86	1,091
Jack bean	0.007477	93 c	0.91	1,162
CV (%)		7,72		

T½: Half-life time; K: Decomposition constant described by Wieder & Lang (1982); RDM: Remaining dry mass.

Remaining dry mass (RDM) values of plant residues (Table 4) showed that although sorghum had a more intense decomposition than millet, pigeon pea, and sunnhemp (Table 3), the amount of remaining dry mass after 150 days was higher than all species due to higher productivity. This is important because of the higher amount of nutrients that will be accumulated and subsequently released by mineralization and by maintaining the soil with the highest amount of remaining dry mass during the period of greatest need (December and January), when soybean and corn crops were not covering the surface of the ground yet.

The high rate of decomposition of the soil cover plants in this biome occurs because of the low dry matter productivity of the species used, which increases the contact surface with the soil, providing an accelerated reduction of the remaining dry biomass.

Table 4. Remaining dry mass (RDM) of the vegetal residues of the species on the soil (kg ha^{-1}) estimated from July to November 2015 at IFTM, Uberaba *campus*, MG.

Tabela 4. Massa seca remanescente (MSR) dos resíduos vegetais das espécies sobre o solo (kg ha^{-1}) estimadas para o período de julho a novembro de 2015 no IFTM, *campus* Uberaba, MG.

	Days after distribution of litter bags – DAD RDM (kg ha^{-1})					
Cover crop	0	30	60	90	120	150
Forage sorghum	3998	3356	2816	2364	1984	1665
Sunnhemp	2970	2612	2297	2020	1777	1562
Pearl millet	2349	2046	1783	1553	1353	1179
Jack bean	2329	1861	1487	1188	950	759
Brachiaria grass	2185	1782	1453	1184	966	787
Pigeon pea	1665	1446	1256	1091	947	822
Finger millet	1205	999	829	687	570	473

It is noteworthy that in tropical regions the maintenance of cultural residues in the soil is very relevant, not only to synchronize the supply of nutrients by cover crops with the demand for commercial crops, but to maintain the humidity and physical protection (Derpsch; Sidiras; Heinzmann, 1985; Calegari et al., 1993; Santos et al., 2007 apud Rossi et al., 2013, p. 1531).

The yield of pearl millet was similar to that obtained with jack bean, although the persistence of millet in the soil was higher. Most of the jack bean mass is found in leaves that are flaccid, soft, and poorly lignified, increasing the decomposable potential of their vegetable residue. The benefit of jack bean is its rapid initial development and soil cover by the aerial part, which is larger when compared with the other soil coverings. However, due to the ease of obtaining seeds and sowing pearl millet in large areas, this kind of cover crop should be grown more often.

4 Conclusions

Forage sorghum presented the highest dry matter yield of plant residues and, along with sunnhemp, presented the highest values of remaining dry mass of the vegetal residues after decomposition.

Finger millet was not an adequate alternative for the direct seeding system in the study region.

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