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STRAW DEGRADATION AND NITROGEN RELEASE FROM COVER CROPS UNDER NO-TILLAGE[1]

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ABSTRACT – Crops used to cover the ground may also release nitrogen into the soil during mineralization. However, it is necessary to identify species that combine fast nutrient release and longer permanence of the straw on the soil surface. The aim of this study was to investigate straw degradation and nitrogen release from cover crops under no-tillage cropping systems. The field trial was performed during two growing seasons in summer (2008/2009 and 2009/2010) in the Cerrado region of Brazil. The experimental design was a randomized block in factorial arrangement. Treatments were the combination of five plants (four cover crops species, 1 - *Panicum maximum*, 2- *Brachiaria ruziziensis*, 3. *Brachiaria brizantha* and 4. *Pennisetum glaucum* [millet], and fallow as a control) with six sampling times (first six weeks after application of glyphosate on the cover crops). *Pennisetum glaucum* and fallow showed faster straw degradation and nitrogen release. The cover crops *Panicum maximum*, *Brachiaria brizantha* and *Brachiaria ruziziensis* stood out in biomass production and in the amount of nitrogen in their shoots but had the lowest coefficients of degradation and persisted longer on the soil surface than *Pennisetum glaucum* and fallow.

Keywords: Nitrogen cycling. Millet. Perennial forage. Mineralization.

DEGRADAÇÃO DE PALHADA E LIBERAÇÃO DE NITROGÊNIO POR PLANTAS DE COBERTURA SOB PLANTIO DIRETO

RESUMO – Culturas de cobertura são usadas para cobrir o solo e também podem liberar nitrogênio para o solo durante a mineralização. No entanto, é necessário identificar espécies que combinem liberação rápida de nutrientes com maior persistência da palhada na superfície do solo. O objetivo deste estudo foi investigar a degradação da palha e a liberação de nitrogênio por culturas de cobertura sob plantio direto. O experimento de campo foi conduzido durante dois anos no verão (2008/2009 e 2009/2010) na região do Cerrado do Brasil. O delineamento experimental foi em blocos ao acaso no esquema fatorial. Os tratamentos foram a combinação de cinco plantas (quatro espécies de plantas de cobertura 1- *Panicum maximum*, 2- *Brachiaria ruziziensis*, 3- *Brachiaria brizantha* e 4- *Pennisetum glaucum* [milheto] e pousio como controle) com seis épocas de avaliação (seis primeiras semanas após a aplicação de glifosato nessas plantas de cobertura). Entre as espécies avaliadas, *Penisetum glaucum* e pousio tiveram rápida degradação da palhada e liberação de nitrogênio. As culturas de cobertura *Panicum maximum*, *Brachiaria brizantha* e *Brachiaria ruziziensis* se destacaram na produção de biomassa e na quantidade de nitrogênio nas suas palhadas, mas apresentaram baixos coeficientes de degradação e persistiram por mais tempo na superfície do solo em relação a *Pennisetum glaucum* e pousio.

Palavras-Chave: Ciclagem de nitrogênio, Milheto, Forrageira perene, Mineralização.

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INTRODUCTION

A no-tillage system (NTS) is a technique of growing plants that is used worldwide (125 million hectares), and is found in Latin America, USA, Canada and Australia (FAO, 2013). An important factor to be considered in NTS is the cover crop, which is used to protect the soil against erosion and to avoid nutrient losses by leaching or runoff (CRUSCIOL et al., 2012; NASCENTE et al., 2013a). Furthermore, cover crops help to conserve soil moisture, suppress weeds, and sequester carbon and can provide improvements in soil chemical quality by increasing the levels of organic matter and nutrient cycling (CARNEIRO et al., 2009; PEREIRA et al., 2009a; NASCENTE et al., 2012a; NASCENTE et al., 2013b).

As an alternative to cover crops, millet (*Pennisetum glaucum*) is a good option due to its rapid release of nutrients, mainly potassium (NASCENTE et al., 2013c). Additionally, grasses of the genus *Brachiaria* and *Panicum* have showed great potential for biomass production as cover crops (PEREIRA et al., 2009b; CRUSCIOL et al., 2012; NASCENTE; CRUSCIOL, 2012). Another important factor to be considered in no-tillage systems is the kinetics of cover crop decomposition, since nutrient cycling allows for better exploitation of nutrients (TORRES et al., 2008; PACHECO et al., 2011).

Nitrogen (N) is the nutrient with the most pronounced dynamic in NTS (D'ANDREA et al., 2004). Most of this nutrient is in the soil organic fraction (90%), with a large pool readily available as ammonia, which is rapidly converted to nitrate after mineralization whether aerobic conditions prevail in the soil environment. These mineral forms (NH_4^+ and NO_3^-), though they account for a small portion of total N, are extremely important, as they are absorbed by plants and microorganisms (MALAVOLTA, 2006). It is noteworthy that the rate of decomposition of crop residues determines the residence time of the mulch on the soil surface. As straw decomposition increases, the rate of nutrient release typically increases as well, which decreases soil protection (KLIEMANN et al., 2006). By contrast, cover crops with high level of lignin content and C/N ratio will provide slow straw decomposition rates and release of N (BOER et al., 2007).

In this context, Boer et al. (2007), Carpim et al. (2008), Torres et al. (2008) and Nascente et al. (2012a) reported that millet and perennial grasses such as *Brachiaria* and *Panicum* genus are important plant coverage and accumulate large amounts of nitrogen (N) in their leaves that can be returned to the soil during the straw degradation process. These cover crops can be sowed and intercropped with the cash crop or in off season (CRUSCIOL et al., 2012; NASCENTE et al., 2013c).

Knowledge of these various N change processes is fundamental for assessing whether these species can be effectively employed as cover crops in the agricultural production system. Such use would require knowing the quantities and timing of N release, as well as its availability to meet crop demands, mainly in the early development of the plants, when sowing or topdressing fertilization is usually performed (NASCENTE et al., 2012a). Moreover, understanding this process will determine the need for additional fertilizer, thereby reducing the production cost (CARPIM et al., 2008). However, information is lacking regarding the effects of field conditions on the dynamics of cover crops in Brazil (AITA et al., 2006). Therefore, the objective of this study was to determine the straw degradation and nitrogen release from cover crops under a no-tillage system during two growing seasons.

MATERIAL AND METHODS

Site descriptions

The field trial was conducted in Santo Antônio de Goiás, State of Goiás, Brazil (16° 27' S, 49º 17' W and 823 m asl). The regional climate is tropical wet and dry, classified as Aw according to the Köppen climate classification system. There are two well defined seasons: the dry season from May to September and a rainy season from October to April. The annual mean rainfall is 1,500 mm. Local annual mean temperature is 22.7 °C, varying annually from 14.2 °C to 34.8 °C. During the experimental period, rainfall and temperature at the site were measured (Figure 1). The soil was a kaolinitic, thermic typic haplorthox in a gently undulating topography (Embrapa, 2006). The soil texture was clayey (540 g kg^{-1} clay, 110 g kg^{-1} silt and 350 g kg^{-1} sand). Before the experiment, the soil was sampled to evaluate its chemical characteristics (Table 1).

The experiment was conducted in an area that had been under a NTS for seven years (2001/2002 - 2006/2007) in crop rotations with corn (2001/2002, 2003/2004 and 2005/2006) and soybean (2002/2003, 2004/2005 and 2006/2007) in the summer and fallow in the winter. In 2007/2008 the area was sowed with the cover crops that were evaluated in this trial.

Experimental design and treatments

The experiment was performed in the same area for two growing season (2008/2009 and 2009/2010). The experimental design was a randomized block in factorial arrangement with five treatments (four cover crops and fallow as a control) and six sampling times (first six weeks after gliphosate application on the cover crops), with three replications, which each plot measuring 6.0 x 10 m. The cover crops included *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf. cv. Marandu, *Brachiaria ruziziensis* R. Germ. and C.M. Evrard, *Panicum*

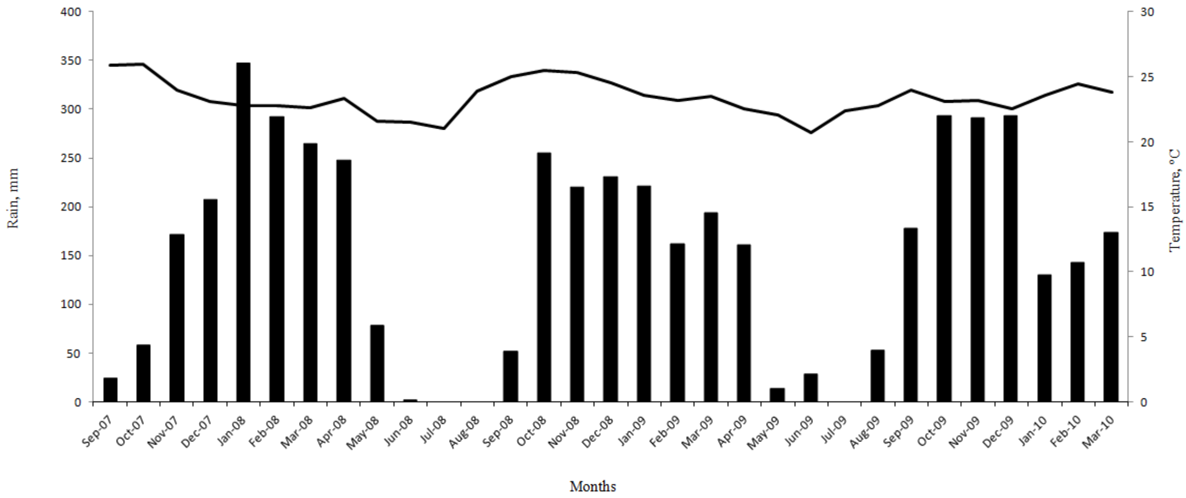

Figure 1. Temperature and rainfall during the trial. Santo Antônio de Goiás, GO, Sep/2007-Mar/2010.

Table 1. Soil chemical properties of the experimental area. Santo Antônio de Goiás, GO.

Depth (cm)	pH water	Ca^{+2} [1]	Mg^{+2}	Al^{+3}	HPO_4^{-2}	K^+	Cu^{+2}	Zn^{+2}	Fe^{+2}	Mn^{+2}	SOM
		.......$cmol_c$ dm^{-3}........				....................mg dm^{-3}..........................					g dm^{-3}
					2008						
0 – 5	6.6	2.5	1.0	0.0	12.1	194.4	1.6	3.9	29.4	20.8	21.1
5 – 10	6.2	1.9	0.7	0.0	14.3	107.7	1.6	3.6	30.2	18.8	20.1
10 – 20	5.9	1.6	0.5	0.1	11.2	69.5	1.7	3.5	29.5	17.7	19.3
					2009						
0 – 5	5.7	2.8	1.4	0.0	14.6	191.9	1.5	4.9	30.6	25.2	23.0
5 – 10	5.7	2.1	0.8	0.0	15.4	144.9	1.8	4.4	32.2	20.9	17.5
10 – 20	5.5	1.8	0.5	0.1	15.9	107.7	1.9	4.0	32.3	18.4	13.5

[1]P and K were extracted with Mehlich1 solution (0.05 mol L^{-1} HC1 in 0.0125 mol L^{-1} H_2SO_4). Phosphorus was determined colorimetrically and K by flame photometry. Ca, Mg and Al were extracted with 1 mol L^{-1} KC1. Aluminum was determined by titration with NaOH and Ca and Mg by titration with EDTA. Micronutrients were determined in the same extract for P by atomic absorption spectrophotometry. SOM – soil organic matter.

maximum Jacq. cv. Colonião, Millet [*Pennisetum glaucum* (L.) R. Br.] cv. BN-2, and a fallow control [spontaneous vegetation, predominantly *Bidens pilosa* L., *Commelina benghalensis* L., *Conyza bonariensis* (L.) Conquist and *Cenchrus echinatus* L.].

Cover crop management

In November 2007 and March 2009, perennial forages were sown; millet (because it is an annual species) was sown in March 2008 and March 2009. Row spacing of 0.20 m was used with a mechanical planter set to distribute 10 kg seeds ha^{-1} (30 % of viable seeds) of the perennial forages and 20 kg seeds ha^{-1} (85 % of germination) of the *Pennisetum glaucum*, as described by Nascente et al. (2013a). Cover crop desiccation was performed approximately 60 days after rain started (November 21st, 2008 and November 13rd, 2009) and was achieved by applying the herbicide glyphosate (Roundup Original®, 1,800 g acid equivalent ha^{-1}, Monsanto Brazil). A boom sprayer with a spray volume of 200 L ha^{-1} was used using flat fan nozzles (Turbo TeeJet 11004).

Sampling and analysis

Cover crop sampling started just after the herbicide application, and was repeated five more times, at the 7th, 14th, 21st, 28th and 35th days. These intervals were chosen once the majority of crops were fertilized with N at the sowing date or at top-dressing close to the sowing date (MALAVOLTA, 2006). At each time, samples of straw were collected from a randomly selected 1.0 x 1.0 m area in each plot. Plant material was collected using a methodology similar to that used by Nascente et al. (2004). The collected plant material was placed in paper bags and dried in a forced ventilation oven at 65 °C and weighed for estimation of dry matter mass in Mg ha^{-1}.

For analysis of C and N in plant material, it was used the method described by Oliveira et al. (2011). The levels of carbon and nitrogen were determined via dry combustion (Dumas method) using an elemental analyzer (CHNS / O 2400 Series II from Perkin Elmer). Each dried sample was milled (Willey type mill with a 2 mm mesh), and four to five milligrams of sample was packed in tin capsules and submitted to analysis.

To evaluate cover crop degradation and nitrogen (N) release, an exponential mathematical model was used (THOMAS; ASAKAWA, 1993; TORRES et al., 2008; PACHECO et al., 2011), according to the following equation:

$y = y_0 . \exp^{(-kt)}$, (1)

Where y is the fraction of initial residue or nutrient existing at time t, y_0 is the proportion of potentially decomposable residue or nutrient and k is the constant of decomposition of the residue or nutrient. With the k value, the half-life (t½ life) of each cover crop straw and remaining nitrogen were calculated using the formula proposed by Paul and Clark (1989):

$t½ \text{ life} = 0.693/k$, (2)

The amount of N in the straw was determined by multiplying the amount of dry matter in the cover crop straw and the nitrogen concentration in the plant residue. With these values, the release of nitrogen to the soil (kg ha^{-1}) in the straw was calculated. Applying the first derivative to the accumulated straw degradation and N release equations, the daily rates of straw degradation and N release in each time interval (0-7, 7-14, 14-21, 21-28 and 28-35 days after herbicide application) were calculated, following the method proposed by Rosolem et al. (2003) and Crusciol et al. (2005).

Statistical analysis

The data were subjected to analysis of variance for a factorial scheme cover crops x sampling time and polynomial regression using the statistical software package SAS (SAS, 1999).

RESULTS AND DISCUSSION

Panicum maximum, *Brachiaria brizantha* and *Brachiaria ruziziensis* stood out in terms of biomass production on day 0 (Figure 2) and *Pennisetum glaucum* (millet) and fallow had the smallest amounts of dry matter, possibly because *P. glaucum* is an annual species and it was sowed at the end of March in both growing seasons. Therefore, after the end of its vital cycle (July), it spreads seeds on the soil, which germinated after rain onset (October). *P. glaucum* did not have enough time to produce larger amounts of dry matter like the perennials forages (*Panicum* and *Brachiaria*), which had already developed a root system that allowed rapid re-growing after rain onset (PACHECO et al., 2011).

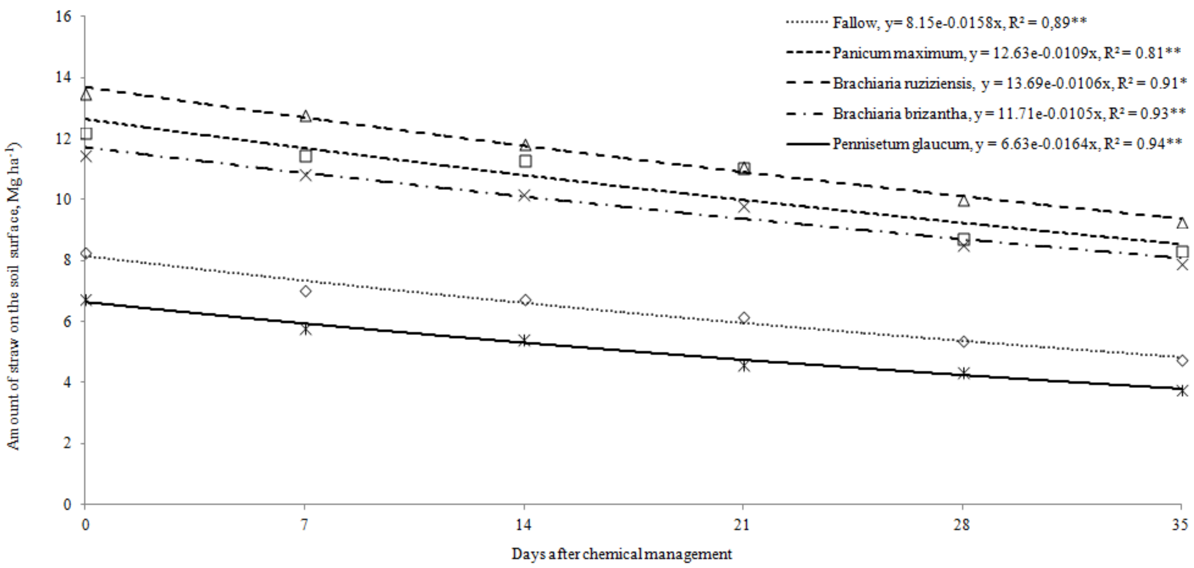

Figure 2. Amount of cover crop straw (Mg ha^{-1}) on the soil surface, as a function of days after herbicide application. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

The straw biomass of the cover crops decreased in all species (Figure 2) with time after chemical management. It is noteworthy that *P. glaucum* (0.0164) and fallow (0.0158) degraded more rapidly and that they had higher rates of decomposition (k) than other cover crop residues. The half-life was 52 days for *P. glaucum* and 54 days for fallow (Table 2). Similar half-life values for millet were obtained by Ferreira et al. (2010) at 49 days and Crusciol et al. (2010) at 51 days. This half-life value indicates that *P. glaucum* exhibits rapid mineralization, and it is likely that it can release nutrients into the soil more quickly, which could have benefits for the following crop (BOER et al., 2007; FERREIRA et al., 2010; PACHECO et al., 2011).

Table 2. Half life ($t_{1/2}$) of cover crop straw and nitrogen release. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

Cover crop	**Straw**	**Nitrogen**
	$t_{1/2}$ (days)	
Fallow	54	58
Panicum maximum	74	50
Brachiaria ruziziensis	75	63
Brachiaria brizantha	76	53
Pennisetum glaucum	52	28

** Significant for p< 0.01 by the test F.

The degradation rate is important characteristic, as more rapid straw decomposition leads to a higher rate of nutrient release, which decreases soil protection (KLIEMANN et al., 2006). On the other hand, it is possible that slower decomposition results in slower nutrient release (AITA et al., 2006). Accordingly, *B. brizantha* (0.0105), *B. ruziziensis* (0.0106), and *P. maximum* (0.0109) stood out as having smaller coefficients of degradation, and it is likely that they will have more persistence on the soil surface (Figure 2). Timossi et al. (2007), Pereira et al. (2009b), Crusciol et al. (2010), Pacheco et al. (2011), Nascente and Crusciol (2012) and Nascente et al. (2012b) reported that these grasses, due their perennial characteristic of producing larger amounts of biomass and remaining longer on the soil surface, are viable alternatives as cover crops in the Cerrado region, which has a dry winter. For example, at day 35, *P. glaucum* and fallow had approximately 30 % straw on the soil surface, and *P. maximum*, *B. brizantha* and *B. ruziziensis* had approximately 50 %. Crusciol et al. (2010), working with *P. glaucum*, *B. brizantha* and *P. maximum* also noted that the persistence of *P. glaucum* straw was lower than all other cover crops. They also found that *P. glaucum* straw released nutrients more quickly.

Overall, the rate of straw degradation was high immediately after herbicide application and reduced with time (Figure 3). From this finding, it is possible to infer that to maximize the use of nutrients released by the straw, subsequent crops should be established as early as possible after the herbicide application of the cover crop (CRUSCIOL et al., 2005; AITA et al., 2006; NASCENTE et al., 2012a). In this sense, it is important to verify if the cover crop used has allelopathic effect on the following cash crop. According to Faria et al. (2009) extracts of velvet bean (*Stizolobium aterrimum*) and *Pennisetum americanum* reduced the hypocotyl and root length in soybean and millet extract decreased the germination percentage and germination rate of beans. Beside it is also important to identify the correct time to sowing the following cash crop, once great amount of cover crop dry mass with high level of moisture content in the leaves could hamper planting operations (Nascente et al., 2012b).

The fast rate of straw degradation immediately before glyphosate application could be a consequence of the C:N ratio (Figure 4). After herbicide application, the C:N ratio is low, and therefore, more N is available to the soil microorganisms that participate in the straw degradation (D'ANDREA et al., 2004). However, as time passes, both N availability and the straw degradation rate decrease (PACHECO et al., 2011). It is important to note that this rate reflects the amount of straw (absolute value) that is degraded per day and that it is directly related to the amount of biomass; in other words, the biomass production is normally as high as the amount of biomass degraded (CRUSCIOL et al., 2005; AITA et al., 2006). Therefore, sowing done close to the herbicide application will meet high level of N in the soil. However, it is important to be careful with great amount of biomass to avoid problems with planting operation and release of allelophatic substances.

Accordingly, the perennial grasses exhibited higher amounts of biomass degradation than *P. glaucum* and fallow. On the other hand, the cover crop straw degradation indicates which cover crop has relatively faster degradation (Figure 3). Pacheco et al. (2011) reported that *P. glaucum* is a species commonly sowed as a cover crop in the "off season" due to its rapid growth, high biomass production and rapid nutrient cycling. Pacheco et al. (2011), working with different cover crops, reported that *P. glaucum* showed higher accumulation of nutrients to be supplied to the soil for subsequent crops than other cover crops. Nascente et al. (2012a) also showed that *P. glaucum* quickly releases nutrients for crops after drying.

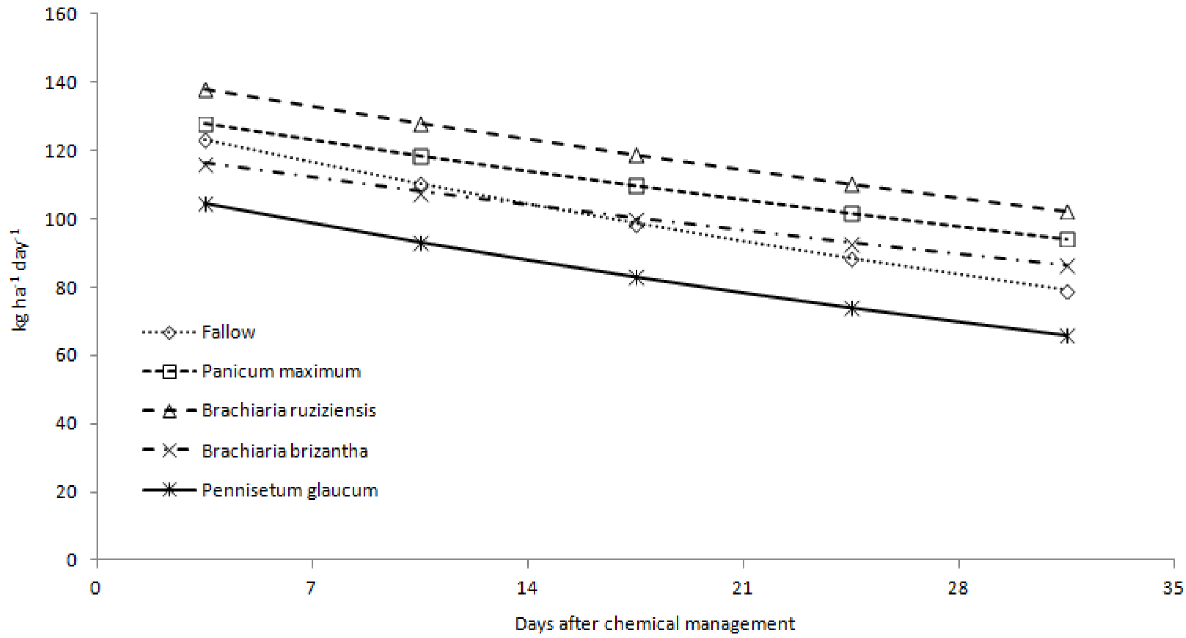

Figure 3. Rate of cover crop straw degradation (kg ha^{-1} day^{-1}) as a function of days elapsed after herbicide application. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

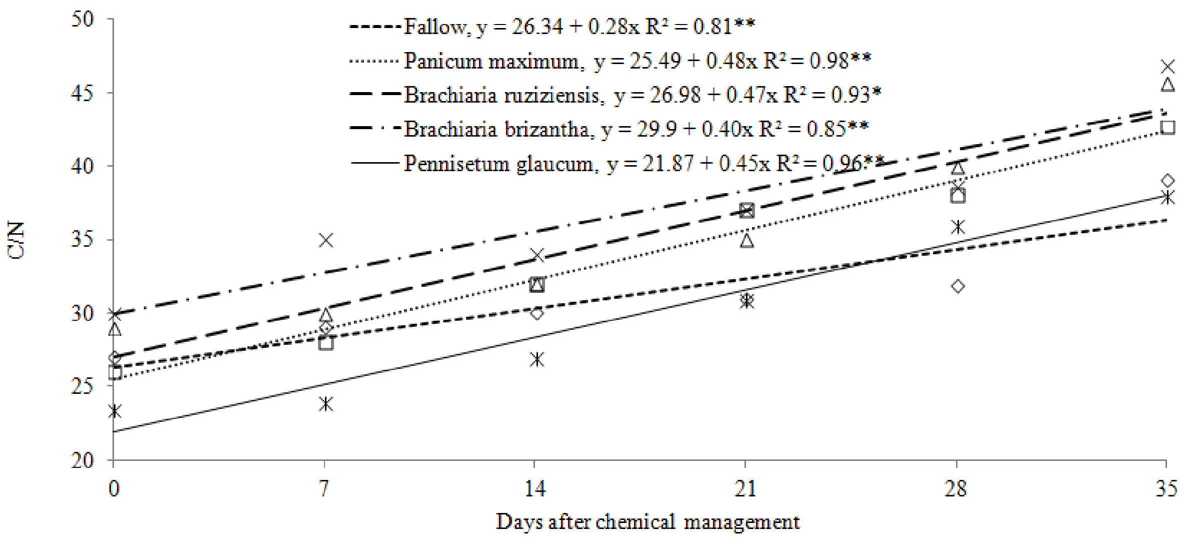

Figure 4. C:N ratio of cover crop straw as a function of days elapsed after herbicide application. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

With respect to fallow, straw degradation can have benefits to the system of production by cycling most of the nutrients. Favero et al. (2000) related that, although wild species are considered to be weeds and to hamper crop development, they can promote the same effects of cover crops, such as biomass production and nutrient cycling. They showed that the weeds *Portulaca oleracea*, *Euphorbia heterophylla*, *Bidens pilosa*, *Commelina benghalensis* and *Melanpodium perfoliatum* stood out in accumulation and nutrient cycling and showed higher levels of potassium, magnesium and phosphorus than the legumes tested (*Canavalia ensiformes*, *Canavalia brasiliensis*, *Mucuna aterrima*, *Dolichos lablab* and *Cajanus cajan*). However, despite the effect weeds had on the accumulation of dry matter that could be used as a straw in a NTS, they also had non-uniform growth due to the varying composition of the species and poor distribution in the soil. Furthermore, if not properly controlled, weeds can compete for water, light and nutrients, causing reductions in crops' grain yield. Moreover, weeds can be pest and disease hosts, hinder harvesting operations and, if they complete the lifecycle, spread their seeds (NASCENTE et al., 2004). Therefore, using fallow for the formation of straw in NTS is not recommended.

The cover crops *B. brizantha*, *B. ruziziensis* and *P. maximum* produced the largest amounts of biomass, had the greatest amounts of N in their shoots (Figure 5) and accumulated more than 150 kg N ha^{-1} (Figure 6). Grasses such as *Brachiaria* and *Panicum* are known to be very good sources of N (Crusciol et al., 2010). Accordingly, although the rate of N release from these perennial forages was slower than that of *P. glaucum*, the amount of N was much higher than *P. glaucum* and fallow, which must be considered when aiming to increase levels of N in the soil. On the other hand, *P. glaucum*, despite having less than 100 kg ha^{-1}, stood out because of its rapid release of N and had the highest coefficient of N release (0.039) and a half-life of 28 days (Table 2). Boer et al. (2007), Torres et al. (2008), Pacheco et al. (2011) and Nascente et al. (2012a) also reported the fast release of N from straw when they used millet as a cover crop.

P. glaucum at 35 days after herbicide application released more than 75 % of N (64 kg ha^{-1} of N released) from its straw (Figure 6). On the other hand, *P. maximum* released approximately 62 % (116 kg ha^{-1} of N released), *B. ruziziensis* released approximately 63 % (130 kg ha^{-1} of N released) and *B. brizantha* released approximately 55 % (100 kg ha^{-1}) of N, which meant that they had higher amounts of N than *P. glaucum* and fallow. Crusciol et al. (2010) also reported that *B. brizantha*, *P. glaucum* and *P. maximum* released 57, 78 and 52 % of N, respectively, into the soil 68 days after herbicide application, demonstrating once again that *P. glaucum* releases this nutrient more quickly than do the others cover crops.

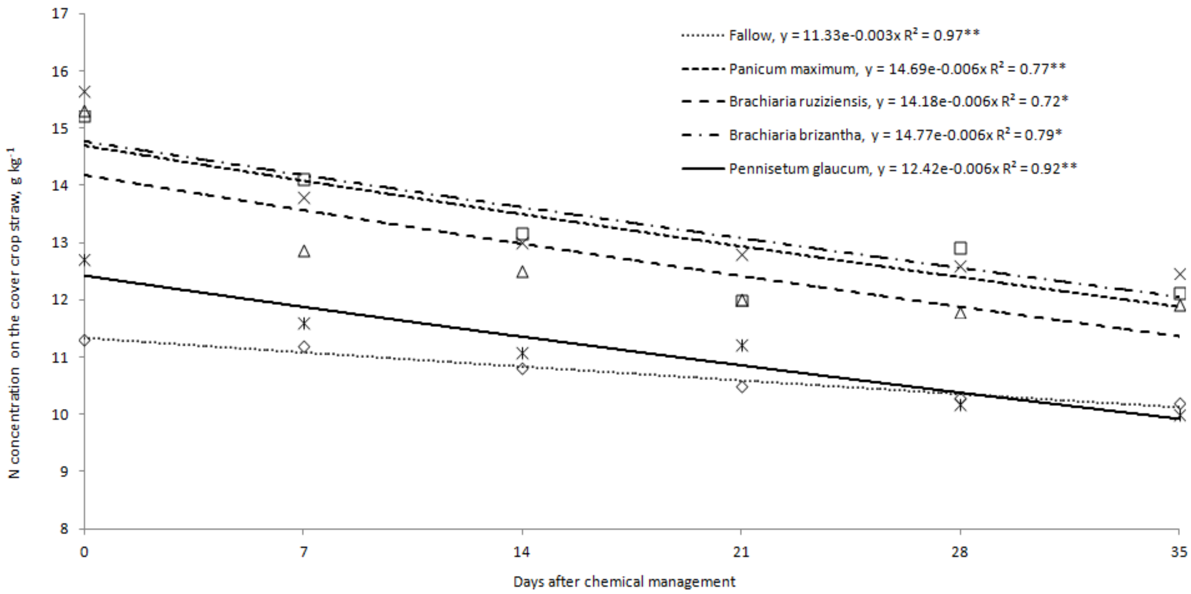

Figure 5. Nitrogen concentration (g kg^{-1}) on the cover crop straw as a function of days after herbicide application. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

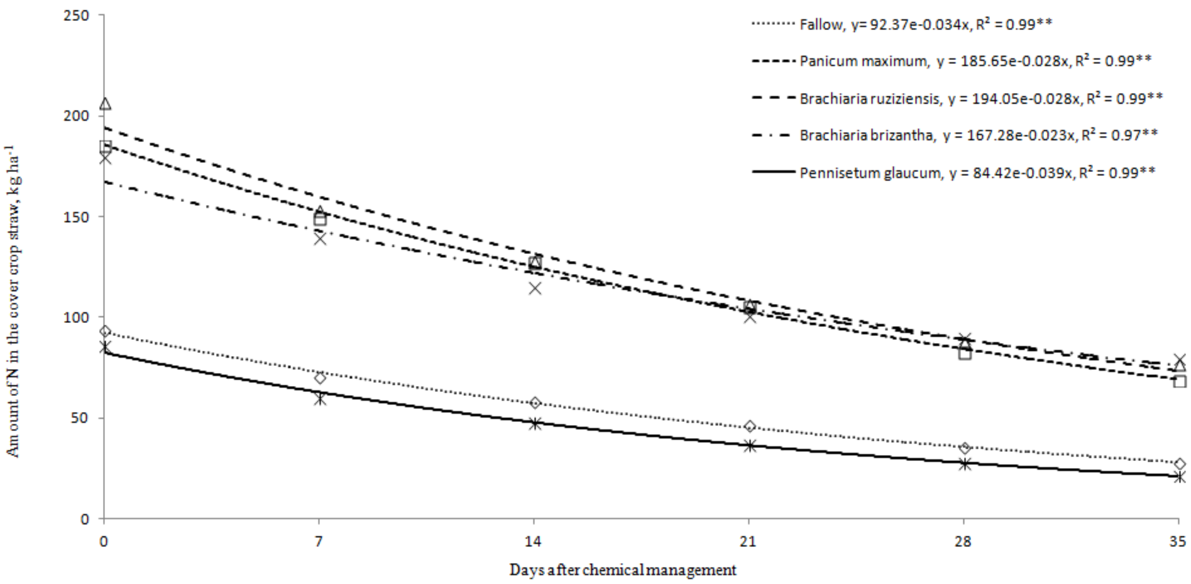

Figure 6. Amount of Nitrogen (kg ha^{-1}) in the cover crop straw as a function of days after herbicide application. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

Similar to what occurred in the straw (Figure 3), the rate of nitrogen release was greater immediately after herbicide application and subsequently decreased (Figure 7). From this finding, it could be inferred that to achieve better utilization of released nitrogen, it is important to sow crops as quickly as possible after herbicide application. However, Nascente and Crusciol (2012) reported that in some cover crops, it is necessary to wait several days after glyphosate application to sow the cash crop, thereby avoiding the herbicide hampering crop development. Corroborating this information Monquero et al. (2010) in soybean and Constantin et al. (2008) in corn recommended sowing these crops two or more weeks after glyphosate application.

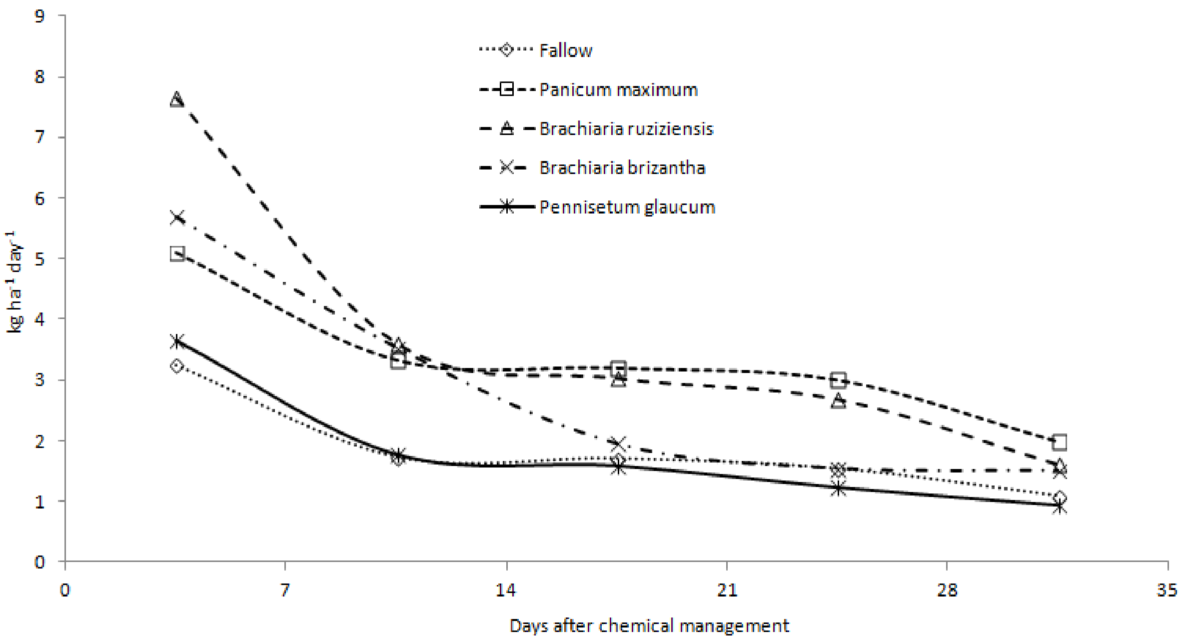

Figure 7. Rate of nitrogen released from the cover crop straws (kg ha^{-1} day^{-1}) as a function of days after herbicide application. Average of the 2008/2009 and 2009/2010 growing seasons. Santo Antônio de Goiás, GO.

B. brizantha, *B. ruziziensis* and *P. maximum* are important cover crops for no-tillage systems because they produce large amounts of dry mass, as observed in this trial (Figure 2), show excellent adaptation to infertile soils, produce straw that persists longer on the soil surface and release nutrients (TIMOSSI et al., 2007; CRUSCIOL et al., 2010). Similarly, Pacheco et al. (2011) observed greater cycling of N and K with the use of *B. brizantha*. However, Oliveira et al. (2011) not that the supply of nutrients by these grasses to the subsequent crop takes longer than the supply by *P. glaucum*, but much larger amounts of N are produced (more than 100 kg ha^{-1} of N 35 days after herbicide application), as observed in this trial (Figures 2 and 5). Typically, using these perennial grasses, the amount of N released after several years and the amount of N in the soil tend to increase (TORRES et al., 2008; PACHECO et al., 2011).

This increased nutrient cycling observed in our trial can translate into increased crop yields. Soratto et al. (2006) and Toledo-Souza et al. (2008) obtained higher common bean yields using *P. maximum* and *B. brizantha* that were previously cropped for mulching. Braz et al. (2006) obtained the best wheat yield under *Brachiaria*. Crusciol et al. (2010) and Nascente and Crusciol (2012) also had better results with soybean sown on *Brachiaria* straw.

In this trial, it can be observed that *P. glaucum* and fallow had the fastest straw degradation and nitrogen release. These high rates can be beneficial for providing nitrogen to the following crop, but they reduce the straw on the surface of the soil. On the other hand, grasses such as *B. brizantha*, *B. ruziziensis* and *P. maximum* remain longer on the soil surface and take longer to release nitrogen; however, the amount of N released is much higher than that released by the other cover crops (*P. glaucum* and fallow), which must be considered in a crop rotation with cover crops. Therefore, it is very important to conduct additional research to evaluate different crop species to identify which cover crop best achieves the correct amount of nitrogen release needed by the crop and leads to better crop yields while reducing costs.

CONCLUSIONS

The cover crops *Panicum maximum*, *Brachiaria brizantha* and *Brachiaria ruziziensis* stood out with respect to biomass production (more than 10 Mg ha^{-1} each) and amount of nitrogen in their shoots (more than 150 kg ha^{-1} of N).

Pennisetum glaucum and fallow exhibited the fastest straw degradation and nitrogen release to the soil.

Panicum maximum, Brachiaria brizantha and *Brachiaria ruziziensis* had the lowest coefficient of degradation and remained longer on the soil surface than millet and fallow.

According to our results, we could infer that *Panicum maximum, Brachiaria brizantha* and *Brachiaria ruziziensis* are the best options as cover crops to be used in the no-tillage system in the Cerrado Region.

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