Nitrogen fertilization on palisadegrass: phytomass decomposition and nutrients release[1]

Claudio Hideo Martins da Costa[2], Carlos Alexandre Costa Crusciol[3], Rogério Peres Soratto[3], Jayme Ferrari Neto[3], Edemar Moro[4]

ABSTRACT

Topdressing or pre-seeding nitrogen (N) application increases phytomass production, providing a higher nutrients accumulation and indirectly favoring the subsequent crop. However, N fertilization can alter the dry matter decomposition and nutrients release dynamics. This study aimed at evaluating the decomposition rate, cellulose, lignin and nutrients release speed from palisadegrass as a function of N fertilization. The experimental design was randomized blocks with four replications, in a factorial scheme constituted by two N fertilization levels and six sampling times after desiccation [0, 14, 34, 41, 51 and 68 days after management (DAM)]. The topdressing N fertilization on palisadegrass increases the dry matter production and N accumulation, but does not alter the decomposition and release speed. N fertilization reduces the C/N ratio, but it does not change the contents of cellulose and lignin and the decomposition and release of N, K, Ca, Mg, C and Si. The amounts of P and S accumulated in the plant and released into the soil increase with N fertilization. The maximum release rates occur within 0-14 DAM, being more intensive for P and S when N is applied. These results demonstrate the high potential of this species for crop-livestock integration systems, with some advantages that can be potentialized with higher N doses.

KEY-WORDS: *Urochloa brizantha*; cellulose; lignin; straw persistence; nutrients recycling.

RESUMO

Adubação nitrogenada em braquiarão: decomposição da fitomassa e liberação de nutrientes

A aplicação de nitrogênio (N) em cobertura ou pré-semeadura aumenta a produção de fitomassa, gerando maior acúmulo de nutrientes e favorecendo indiretamente a cultura em sucessão. Contudo, a adubação com N pode alterar a decomposição e a dinâmica de nutrientes da fitomassa. Objetivou-se avaliar a taxa de decomposição, celulose e lignina e velocidade de liberação de nutrientes da fitomassa do braquiarão, em função da aplicação de N. O delineamento experimental foi em blocos casualizados, com quatro repetições, em esquema fatorial constituído por dois níveis de adubação nitrogenada e seis épocas de coleta após dessecação [0, 14, 34, 41, 51 e 68 dias após o manejo (DAM)]. A aplicação de N em cobertura no braquiarão aumenta a produção de matéria seca e o acúmulo de N, mas não altera a velocidade de decomposição e liberação. A adubação nitrogenada reduz a relação C/N, porém, não altera os teores de celulose, lignina e a decomposição e liberação de N, K, Ca, Mg, C e Si. A quantidade de P e S acumulada na planta e liberada para o solo aumenta com a adubação nitrogenada. As máximas taxas de liberação ocorrem no período de 0-14 DAM, de forma mais intensa para o P e S quando o N é aplicado. Esses resultados evidenciam o elevado potencial dessa espécie para sistemas de integração lavoura-pecuária, com algumas vantagens que podem ser potencializadas com doses maiores de N.

PALAVRAS-CHAVE: *Urochloa brizantha*; celulose; lignina; persistência de palhada; reciclagem de nutrientes.

INTRODUCTION

In a no-tillage system, permanent soil coverage and crop rotation are critical to the stability of the system. However, in regions with dry winters and hot and rainy summers, low water availability and rapid biomass decomposition limit the system success (Boer et al. 2008, Leite et al. 2010). Thus, the most important features of cover crops, particularly in those climatic conditions, are the amount and durability of the biomass produced (Boer et al. 2008, Leite et al. 2010). Also important is the ability to recycle nutrients, notably the mobilization of landfill leachate or poorly soluble elements, releasing them gradually to the subsequent crop (Crusciol et al. 2008).

1. Manuscript received in Jan./2016 and accepted for publication in May/2016 (http://dx.doi.org/10.1590/1983-40632016v4639297).
2. Universidade Federal de Goiás, Regional Jataí, Unidade Acadêmica Especial de Ciências Agrárias, Jataí, GO, Brazil. *E-mail*: c_hideo@hotmail.com.
3. Universidade Estadual Paulista, Faculdade de Ciências Agronômicas, Departamento de Produção e Melhoramento Vegetal, Botucatu, SP, Brazil. *E-mails*: crusciol@fca.unesp.br, soratto@fca.unesp.br, jaymeferrari@hotmail.com.
4. Universidade do Oeste Paulista, Presidente Prudente, SP, Brazil. *E-mail*: edemar@unoeste.br.

The benefits of cover crops have been observed by several authors, either in the chemical and physical properties of the soil, or in the yield of crops planted in succession. These benefits result from cover crop biomass production, accumulation and subsequent release of nutrients by decomposing straw (Crusciol & Soratto 2007 and 2009, Torres et al. 2008). Among the species commonly used, palisadegrass [*Urochloa brizantha* (Syn. *Brachiaria brizantha*)] stands out for its high dry matter production capacity (Andrade et al. 2004, Braz et al. 2004, Bernardes et al. 2010), drought tolerance, nutrient absorption in deeper soil layers and nutrient recycling (Torres et al. 2008). Palisadegrass can grow in environmental conditions under which the majority of grain crops and species used for soil coverage could not (Barducci et al. 2009).

In order to increase the potential of palisadegrass dry matter production, nitrogen (N) should be applied in either topdressing or pre-seeding under regular rain conditions (Ceretta et al. 2002). In these conditions, the fertilizer applied in pre-sowing indirectly favors the subsequent crop, since the mineralized N of soil organic matter and fertilizer, temporarily immobilized in the residues (Lara Cabezas et al. 2004), remains available for the subsequent crop. Nitrogen release from the decomposed residues can be accelerated by nitrogen fertilization.

On the other hand, the application of N to these grasses can change the biomass decomposition rate and the beneficial characteristics of cover crops, primarily their decomposition rate. This is because the decomposition rate of plant residues is directly related to the C/N ratio (Xu & Hirata 2005) and cellulose and lignin content (Kogel-Knabner 2002). Nitrogen fertilization can reduce the C/N ratio, as well as cellulose and lignin content (Maranhão et al. 2009), increasing N mineralization and reducing the concentration of difficult-to-decompose recalcitrant compounds, resulting in accelerated plant residue decomposition.

Therefore, there is a need for studies on the decomposition rate of forage species that are widely used in crop-livestock integration systems. The management system adopted may alter the decomposition rate and promote desynchronization between the amount of nutrients required by the subsequent crop and those released by the cover plant residues.

This study aimed at evaluating the persistence and dry matter yield of palisadegrass with and without N fertilization and the release rate of macronutrients and silicon (Si), as well as the changes in cellulose and lignin content and C/N ratio of dry matter.

MATERIAL AND METHODS

The study was developed in Botucatu, São Paulo State, Brazil (22º58'S, 48º23'W and 765 m of altitude), in a Red Nitosol. The soil chemical characteristics (0-20 cm) were determined before setting up the experiment, and the results were: organic matter = 33.3 g dm^{-3}; pH ($CaCl_2$) = 5.0; P (resin) = 12.0 mg dm^{-3}; K = 1.4 $mmol_c$ dm^{-3}; Ca = 31.0 $mmol_c$ dm^{-3}; Mg = 12.6 $mmol_c$ dm^{-3}; H + Al = 51.3 $mmol_c$ dm^{-3}; base saturation = 47 %.

According to the Köppen climate classification, the predominant climate in the region is Cwa, i.e., a high altitude tropical climate with a dry winter and hot and wet summer. During the experiment, the precipitation and monthly mean temperature in 2003 and 2004 were, respectively, 173 mm and 23.1 ºC in November, 184 mm and 23.5 ºC in December, 302 mm and 22.5 ºC in January, 162 mm and 23.1 ºC in February, 122 mm and 22.3 ºC in March and 114 mm and 22.0 ºC in April.

A randomized blocks experimental design was used with four replications, in a 2 x 6 factorial arrangement, consisting of two nitrogen doses (0 kg ha^{-1} and 60 kg ha^{-1}) and six sampling times of shoot dry matter after desiccation [0, 14, 34, 41, 51 and 68 days after management (DAM)]. The plots size was 50 m^2 (5 m width x 10 m length).

Sowing was carried out on 11/08/2003, and seedlings emerged twelve days later (November 20, 2003). A total of 15 kg ha^{-1} of *Urochloa brizantha* cv. Marandu seeds were planted with a spacing of 0.17 m between rows and a depth of approximately 0.03 m. Nitrogen was applied 50 days after emergence, at a dose of 60 kg ha^{-1}, using ammonium nitrate. At 75 days after emergence (February 3, 2004), glyphosate (1,920 g ha^{-1} a.i.) was applied for weed control.

Plant shoots were collected on the day of the herbicide application (02/03/2004 - 0 DAM) and on 02/17/2004 (14 DAM), 03/08/2004 (34 DAM), 03/15/2004 (41 DAM), 03/25/2004 (51 DAM) and 04/11/2004 (68 DAM). Three samples per plot were taken on each date (Crusciol et al. 2005), from an internal area of 0.25 m^2 (simple samples). Within the experimental units, sampling was performed at random points along diagonal crosswise lines, excluding 0.50 m at either end (border). The three sampled areas were pooled and used to estimate the plot shoot biomass.

Collected plants were washed according to Malavolta et al. (1997), without detergent. Samples were separated in three portions, shaken for a few seconds in deionized water and then placed on paper towel. Detergent was not used to reduce shaking time in water and number of successive portions, in order to reduce the probable K losses from shoot dry matter as much as possible. The samples were placed in paper bags and dried in a forced air circulation oven at 60 ºC, until constant weight, for determination of shoot dry matter. The material was ground in a Willey mill for determining the levels of macronutrients (Malavolta et al. 1997), carbon (C) (Tedesco et al. 1995), silicon (Si) (Korndörfer et al. 2002), lignin and cellulose (Van Soest 1963).

The contents of macronutrients, C and Si in the shoot dry matter were determined by the product of the amount of shoot dry matter by the concentration of the plant residue elements of each sampling. With these values, the degradation of shoot dry matter and content of elements in it were calculated, and the data were expressed in kg ha^{-1}. This result was also expressed in percentage by the calculation: remaining content of shoot dry matter or of each nutrient from the initial content in each time period multiplied by 100.

To describe the shoot dry matter decomposition and amount of the elements (N, P, K, Ca, Mg, S, C and Si) in it, in kg ha^{-1} and %, the exponential mathematical model described by Thomas & Asakawa (1993) was used: $X = X_o e^{-kt}$, in which X is the content of shoot dry matter or of elements amount after a period of time t, in days; X_o is the initial quantity of shoot dry matter or of elements; and k is the constant of residue decomposition or elements release. The half-life time was calculated based on the equation $t½ = 0.693/k$ (Paul & Clark 1989), which expresses the period of time necessary for half of the plant residue to decompose or for half of the elements contained in the shoot dry matter to be released. Applying the first derivative to the fitted functions, the daily rates of shoot dry matter decomposition and of elements release after cover crop desiccation were calculated (Kliemann et al. 2006).

The data were initially tested with regard to the normality of error distribution (Lilliefors test/ SAEG 5.0) and homogeneity of their variances (Cochran and Bartlett tests/SAEG 5.0), to check if they met the requirements for the analysis of variance (Table 1). The mean values of the treatments of nitrogen fertilization were compared by the LSD test at 5 %. For shoot dry matter and elements content data, mathematical functions were fitted at 5 %.

RESULTS AND DISCUSSION

The amount of dry matter was greater with N application (Table 1). Similar results were reported by Santos et al. (2009), using different N doses. The small biomass accumulation of palisadegrass occurred because the herbicide was applied at 75 DAM, in order to leave enough time to plant a summer crop in succession. Nitrogen, one of the nutrients most required by palisadegrass (Crusciol & Soratto 2007), has a direct effect on dry matter production (Santos et al. 2009). However, there was no significant interaction between time and fertilization (Table 1).

Moreover, the daily biomass decomposition rate was slow, leaving 66 % of the amount of dry matter in the last evaluation with an average estimated half-life of 123 DAM (Figures 1A, 1B and 1C). This value was similar to that observed by Leite et al. (2010), in a study conducted in the Brazilian Savannah region of the Maranhão State, where about 48 % of the biomass had been decomposed at 100 DAM.

This finding is based on the results from the qualitative parameters of decomposed plant residues, such as C/N ratio ($r = -0.71$, $p < 0.01$) and cellulose ($r = -0.64$, $p < 0.01$) and lignin ($r = -0.57$, $p < 0.01$) content, which showed a high negative correlation and a direct influence on biomass mineralization (Gupta & Singh 1981). It is important to underscore that nitrogen fertilization reduced the C/N ratio and increased lignin content (Table 1). However, these parameters were not changed by the interaction between fertilization and time, exhibiting average values of 26.5 for the C/N ratio, 333 g kg^{-1} for cellulose and 28 g kg^{-1} for lignin at desiccation, increasing linearly with time (Figures 1D, 1E and 1F). The increase in lignin and cellulose occurs because they are more resistant and tend to remain in plant residues longer (Miyazaka 1983).

Table 1. Dry matter amount, C/N ratio, cellulose, lignin, nutrient content and amount of nutrients in straw of *Urochloa brizantha* cv. Marandu under different nitrogen fertilizations. The mean values are the average of all samples after management.

Variable	With N	Without N	F value			CV (%)
			Fertilization (A)	Time (E)	A x E	
Dry matter (Mg ha^{-1})	4.732 a	4.269 b	12.677**	23.738**	0.346^{ns}	9.99
C/N ratio	30.4 b	35.3 a	35.882**	21.502**	0.620^{ns}	8.61
Cellulose (g kg^{-1})	356.8 a	359.5 a	0.262^{ns}	8.396**	2.002^{ns}	5.13
Lignin (g kg^{-1})	36.6 a	25.1 b	178.529**	3.623**	1.403^{ns}	9.68
N content (g kg^{-1})	14.1 a	12.2 b	34.436**	32.812**	1.456^{ns}	8.19
P content (g kg^{-1})	0.97 a	0.67 b	25.472**	106.144**	6.315**	25.45
K content (g kg^{-1})	7.7 a	7.9 a	0.232^{ns}	194.587**	1.894^{ns}	17.51
Ca content (g kg^{-1})	5.1 a	5.1 a	0.208^{ns}	8.896**	0.202^{ns}	12.23
Mg content (g kg^{-1})	3.1 a	3.1 a	0.208^{ns}	8.896**	0.202^{ns}	20.13
S content (g kg^{-1})	4.1 a	3.6 b	8.859**	280.626**	3.464*	14.64
C content (g kg^{-1})	418.0 a	424.0 a	4.085^{ns}	5.230**	0.179^{ns}	2.78
Si content (g kg^{-1})	15.8 b	18.9 a	196.839**	47.150**	1.331^{ns}	4.45
N amount (kg ha^{-1})	68.0 a	54.0 b	36.359**	48.945**	0.972^{ns}	13.71
P amount (kg ha^{-1})	4.9 a	3.1 b	32.837**	114.530**	6.187**	26.91
K amount (kg ha^{-1})	41.0 a	36.0 a	2.352^{ns}	113.699**	1.263^{ns}	27.09
Ca amount (kg ha^{-1})	24.0 a	22.0 a	3.516^{ns}	28.656**	0.115^{ns}	15.38
Mg amount (kg ha^{-1})	15.0 a	14.0 a	1.253^{ns}	22.697**	0.128^{ns}	22.00
S amount (kg ha^{-1})	22.0 a	17.0 b	14.939**	231.985**	5.206**	20.87
C amount (kg ha^{-1})	1,982.0 a	1,817.0 b	8.466**	29.538**	0.379^{ns}	10.31
Si amount (kg ha^{-1})	73.0 a	79.0 a	15.980**	2.797*	0.273^{ns}	6.92

^{ns} Non-significant; * $p < 0.05$; ** $p < 0.01$.

With respect to the contents of biomass elements, N fertilization increased N, P, C and S levels, and there was a significant interaction between fertilization and time for P and S contents (Table 1). Nitrogen fertilization increased P and S levels up to palisadegrass desiccation. However, there was a gradual reduction in the concentration of these elements over time, until the values were very similar (Figures 2B and 2F).

According to Arnon (1975), N application increases P absorption faster than dry matter production, possibly by promoting better root development, such that the concentration increases in plants. In soils with adequate S levels, N fertilization can increase P absorption, mainly because this nutrient is directly linked to plant protein synthesis through metabolic pathways (Crawford et al. 2000).

Pariz et al. (2011) studied split N application in palisadegrass intercropped with corn and they also observed a higher availability of P on the soil surface with N fertilization, after the last cut of palisadegrass.

There was a gradual reduction in all macronutrients and an increase in Si content in the remaining biomass (Figure 2). This occurred as the amount of biomass on the ground decreased (Figure 1A). Similar results were observed in several studies on different cover crops, such as sun hemp and millet (Costa et al. 2012, Soratto et al. 2012), as well as pigeonpea and pearl millet intercropping (Ferrari Neto et al. 2012). Thus, the average levels of N, K, Ca, Mg and C declined by 36 %, 90 %, 29 %, 44 % and 6 %, respectively, between the first and last evaluations.

Nitrogen application decreased Si concentration, in contrast to the amount of biomass, indicating a dilution effect of this nutrient (Table 1, Figure 2H). During the sampling periods, there was a 29 % increase in Si concentration from 0 to 68 DAM (Figure 2H), probably due to the rise in phytolith concentration, as the biomass was degrading. Several studies have also found increased Si concentration over time in different species (Costa et al. 2012, Ferrari Neto et al. 2012, Soratto et al. 2012).

The amounts of N, P, K, Ca, Mg, S, Si and C decreased exponentially over time, with 39 kg ha^{-1}, 1 kg ha^{-1}, 6 kg ha^{-1}, 15 kg ha^{-1}, 8 kg ha^{-1}, 1 kg ha^{-1}, 73 kg ha^{-1} and 1,680 kg ha^{-1}, respectively, remaining in the final evaluation (Figure 3). Torres et al. (2008) observed remaining quantities of 54 kg ha^{-1}, 3 kg ha^{-1}

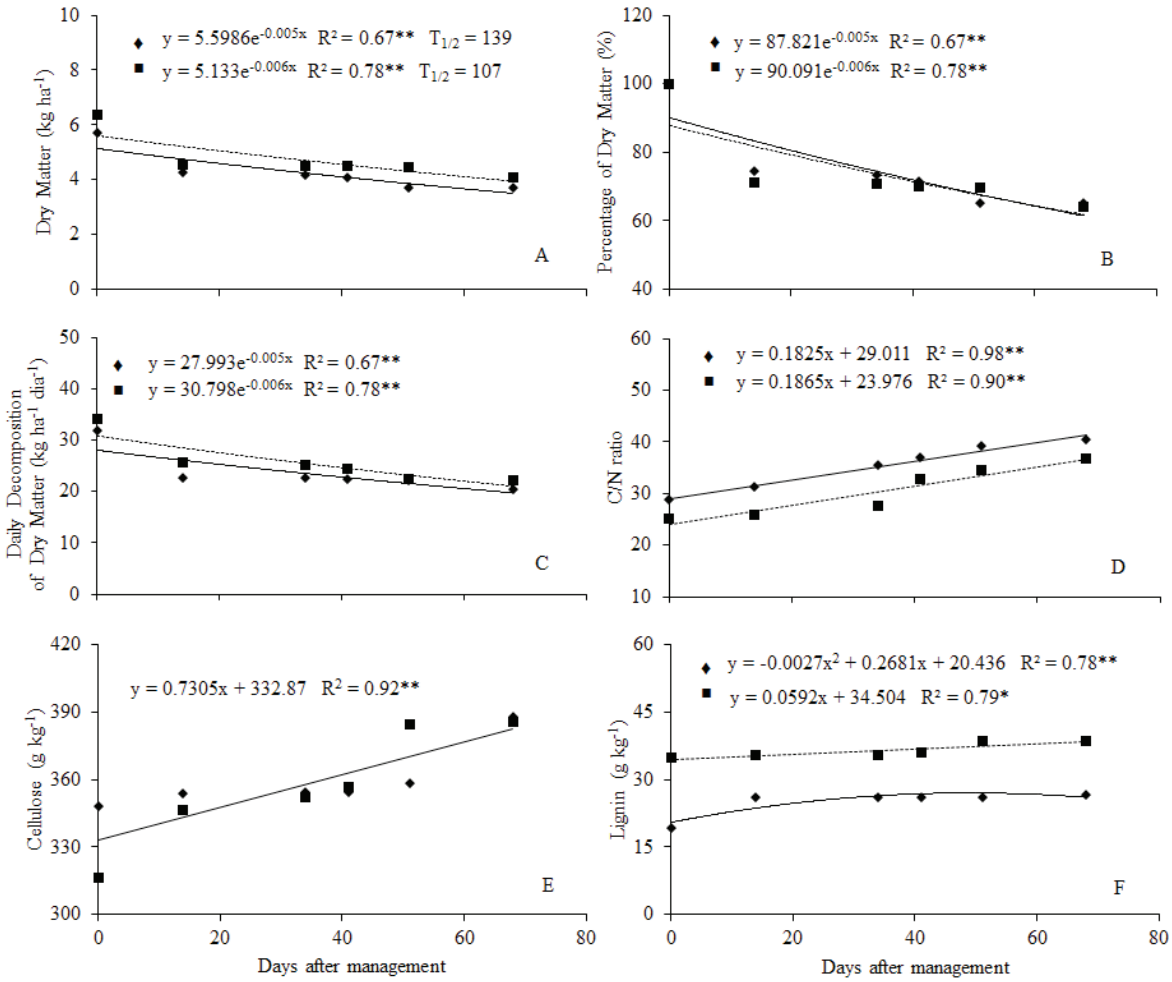

Figure 1. Dry matter (A), percentage of dry matter (B), daily decomposition of dry matter (C), C/N ratio (D), cellulose (E) and lignin (F) contents of palisadegrass straw without (♦) and with (■) N application, depending on the time after management. For Figure E, the mathematical function was fitted considering the average of treatments. **, *: Significant at 1 % and 5 % by the F test, respectively.

and 0.3 kg ha^{-1} for N, Ca and Mg, respectively, which differ from those obtained here.

At 68 DAM, 55 %, 92 %, 94 %, 54 %, 63 %, 98 %, 36 % and 10 % of N, P, K, Ca, Mg, S, C and Si, respectively, had already been released from the palisadegrass phytomass. It was observed that significant portions of nutrients were retained and recycled, minimizing the risk of leaching losses (Aita et al. 1994). Thus, the cover crop can partially meet the needs of the subsequent crop. Palisadegrass released an average of 50 % of total N, P, K, Ca, Mg and S accumulated in biomass to the soil, respectively at 58, 19, 16, 61, 47 and 12 DAM (Figure 3). Torres et al. (2008) studied the production and decomposition of palisadegrass biomass, and found that the release of 50 % of total N, P, Ca, Mg and S accumulation occurred, respectively, at 53, 117, 25, 11 and 18 DAM. The difference in nutrient release rates observed by these authors may be related to the weather conditions after cover crop management (Boer et al. 2008, Leite et al. 2010).

If compared with other species commonly used as cover crops, such as pearl millet, pigeonpea (Crusciol et al. 2013) and sun hemp (Costa et al. 2012), palisadegrass exhibits significant nutrient cycling potential, especially S. Palisadegrass has a low decomposition and nutrient release rate, particularly for N, Ca, Mg and Si. Therefore, in regions with dry winters and hot and rainy summers, as well as low water availability, this species is a promising alternative for the continuity and sustainability of a no-tillage system, since

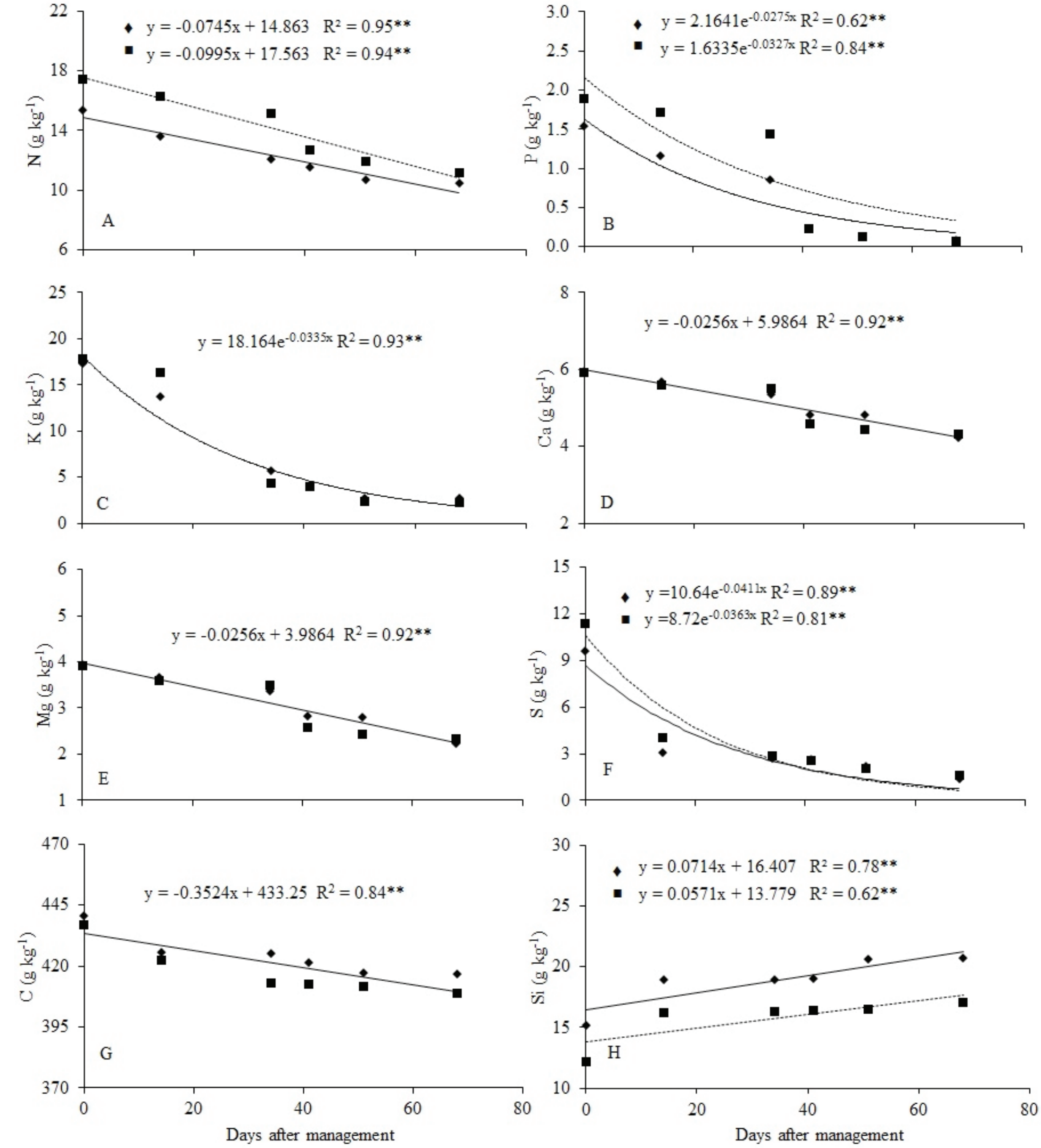

Figure 2. Contents of N (A), P (B), K (C), Ca (D), Mg (E), S (F), C (G) and Si (H) of palisadegrass straw without (♦) and with (■) N applicaton, depending on the time after management. For Figures C, D, E and G, the mathematical functions were fitted considering the average of treatments. ** Significant at 1 %, by the F test.

it provides greater soil protection and a gradual release of nutrients to the subsequent crop.

The greatest release rate exhibited by N, P, K, Ca, Mg, S, Si and C occurred between 0 and 14 DAM (Figure 4). Applying nitrogen to palisadegrass increased the speed of daily release of P and S. These elements are released more quickly immediately after desiccation, with a continuous reduction and subsequent tendency toward stabilization. Several authors have observed similar results with other species, with the highest speed of daily nutrient release occurring in the first evaluation period (Costa et al. 2012, Ferrari Neto et al. 2012, Soratto et al. 2012).

Daily release rates of N, K, Ca, Mg, Si and C from the biomass were 1.04 kg ha^{-1} day^{-1}, 3.74 kg ha^{-1} day^{-1}, 0.37 kg ha^{-1} day^{-1}, 0.32 kg ha^{-1} day^{-1}, 0.13 kg ha^{-1} day^{-1} and 65 kg ha^{-1} day^{-1}, respectively, between 0 and 14 DAM (Figures 4A, 4C, 4D, 4E and 4G). With respect to P and S in the first assessment period, N application resulted in release rates of

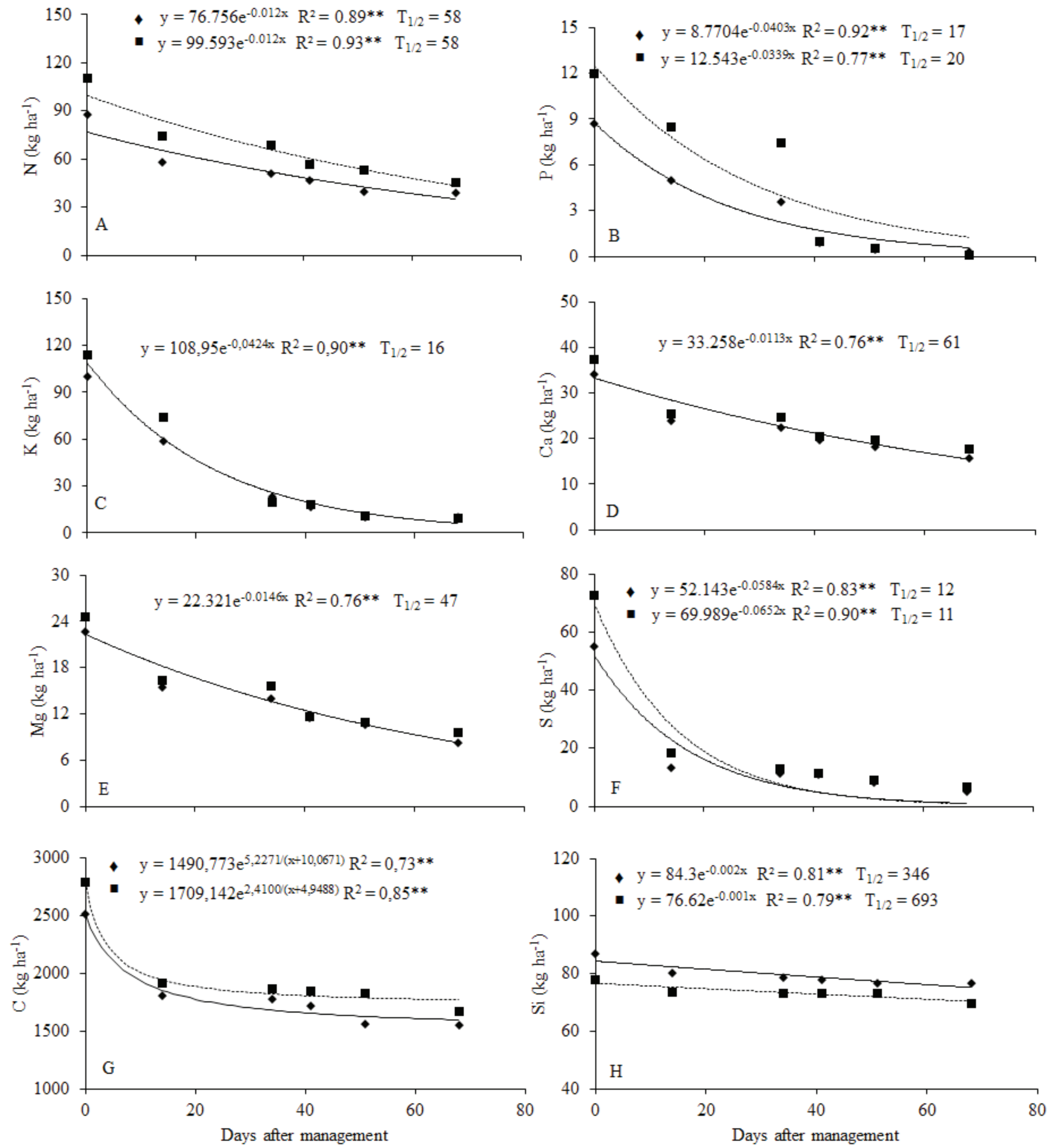

Figure 3. Amounts of N (A), P (B), K (C), Ca (D), Mg (E), S (F), C (G) and Si (H) of palisadegrass straw without (♦) and with (■) N application, depending on the time after management. For Figures C, D and E, the mathematical functions were fitted considering the average of treatments. ** Significant at 1 % by the F test. $T_{1/2}$ refers to half-life time, in days after management.

0.36 kg ha^{-1} day^{-1} and 3.22 kg ha^{-1} day^{-1}, respectively, higher than those observed in the absence of N fertilization, which were 0.29 kg ha^{-1} day^{-1} and 2.24 kg ha^{-1} day^{-1}, respectively (Figures 4B and 4F).

The manner, amount and speed at which each macroelement was released, irrespective of nitrogen fertilization, allow us to infer that, in order to maximize the benefit of these nutrients, the succession crop should be planted immediately after palisadegrass desiccation with herbicide, or up to 14 DAM. It is noteworthy that N application produced higher amounts of dry matter, providing greater N, P and S accumulation, but did not increase the decomposition and N mineralization rates of palisadegrass. This demonstrates the potential of using N doses above 60 kg ha^{-1} to increase the benefits of this technique, such as improved soil protection, recycling and nutrient release to the subsequent crop.

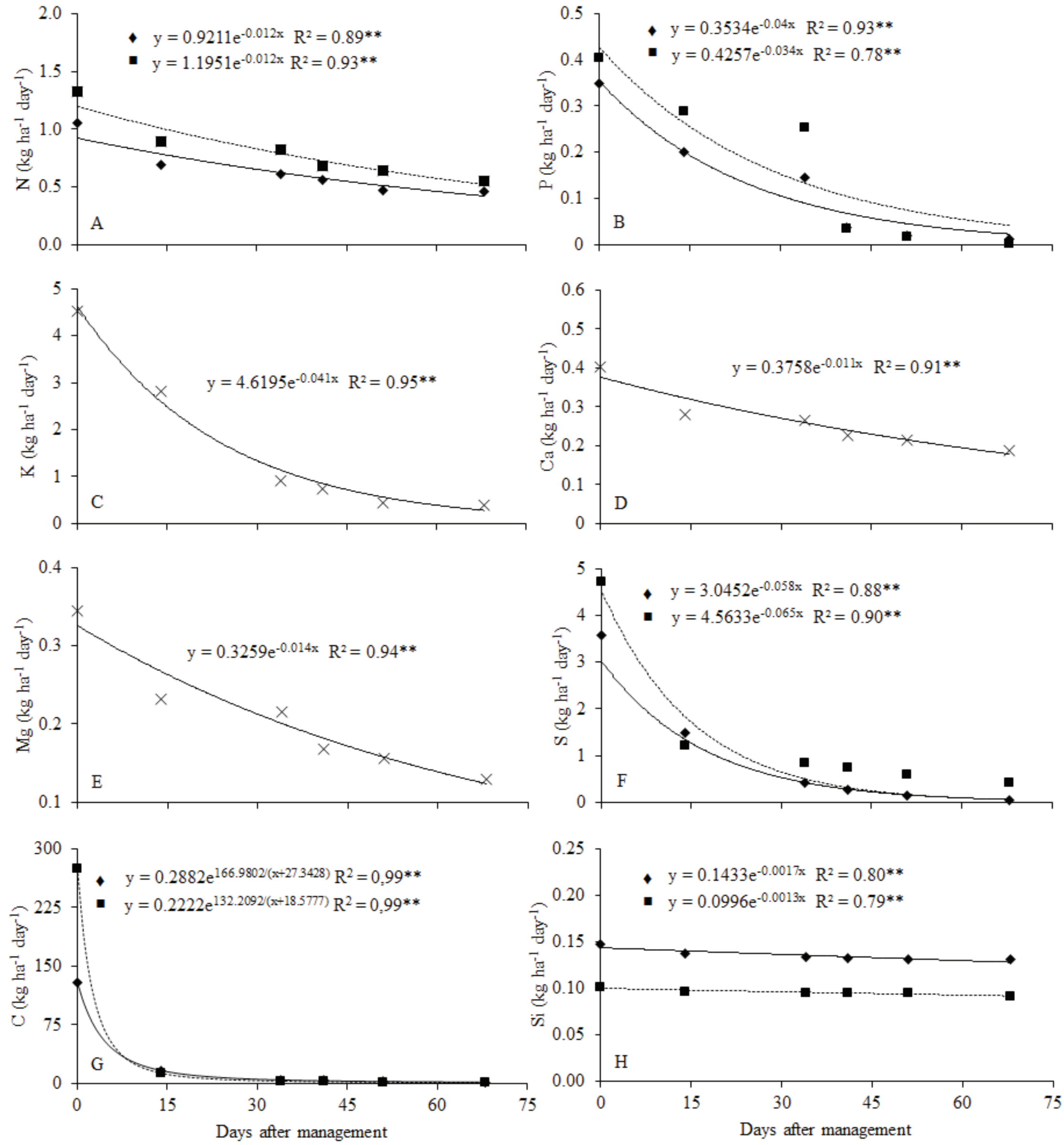

Figure 4. Daily release rates of N (A), P (B), K (C), Ca (D), Mg (E), S (F), C (G) and Si (H) of palisadegrass straw without (♦) and with (■) N application, depending on the time after management. For Figures C, D and E, only the average (x) of treatments was considered.

CONCLUSIONS

1. Nitrogen application to palisadegrass increases dry matter production and N accumulation, but does not change the decomposition and nutrient release rates.
2. The C/N ratio decreases with N fertilization, but does not change cellulose and lignin contents or the decomposition and release of N, K, Ca, Mg, C and Si.
3. Nitrogen fertilization increases the accumulated amounts of P and S in the plant and the release of these nutrients to the soil.
4. The maximum release rates of nutrients occur between 0 and 14 days after management, suggesting a succession planting immediately after palisadegrass desiccation.

ACKNOWLEDGMENTS

To the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), for financial support (Registry number: 03/11739-5, 03/11738-9), and to the Conselho Nacional de Desenvolvimento Científico e Tecnológico

(CNPq), for providing scholarships to the sencond and third authors.

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