SEÇÃO IV - FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS

BERMUDA GRASS SOD PRODUCTION AS RELATED TO NITROGEN RATES[1]

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SUMMARY

Of all nutrients, N has the strongest effect on grass growth and an adequate N fertilization can reduce the time required for the formation of high-quality mats. This study aimed to evaluate the influence of N fertilization on Bermuda grass sod production and quality. The experiment was conducted in an area of commercial sod production, in Capela do Alto, state of São Paulo. *Cynodon dactylon* (Pers) L., known as Bermuda grass, was evaluated in a randomized complete block design with five treatments and four replications. Treatments consisted of five N rates: 0, 150, 300, 450 and 600 kg ha^{-1}. Increasing N applications to Bermuda grass increased the soil cover rate, reducing the time required for mat formation. The accumulation of rhizome + root + stolon dry matter was highest at a rate of 354 kg ha^{-1} N and the mat resistance to breakage at a rate of 365 kg ha^{-1} N. Nitrogen rates between 354 and 365 kg ha^{-1} increased mat resistance and consequently the suitability for postharvest handling, tending to improve the efficiency in the area.

Index terms: *Cynodon dactylon* (Pers) L., fertilization rate, soil cover.

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(1) Recebido para publicação em janeiro de 2009 e aprovado em fevereiro de 2010.

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RESUMO: *PRODUÇÃO DE TAPETES DE GRAMA BERMUDA EM FUNÇÃO DE DOSES DE NITROGÊNIO*

O N é o nutriente que proporciona as maiores respostas no crescimento das gramas, e a adubação nitrogenada adequada pode proporcionar a formação do tapete com boa qualidade em menor tempo. Neste trabalho, objetivou-se avaliar a influência da adubação nitrogenada na produção e qualidade de tapetes de grama-bermuda. O experimento foi instalado e conduzido em área de produção comercial de grama, localizada na cidade de Capela do Alto, SP. A grama utilizada foi a Cynodon dactylon *(Pers) L., conhecida como grama-bermuda. O delineamento experimental utilizado foi o de blocos casualizados, com cinco tratamentos e quatro repetições. Os tratamentos foram constituídos por cinco doses de N: 0, 150, 300, 450 e 600 kg ha^{-1}. O aumento das doses de N aumentou a taxa de cobertura do solo pela grama-bermuda, reduzindo o tempo para formação do tapete. O máximo acúmulo de matéria seca de rizomas + estolões + raízes foi proporcionado pela dose de 354 kg ha^{-1} de N, e a resistência dos tapetes, pela dose de 365 kg ha^{-1} de N. Doses de N entre 354 e 365 kg ha^{-1}, aumentaram a resistência dos tapetes e, com isso, a capacidade deles serem manuseados após a colheita, podendo promover assim maior rendimento da área.*

Termos de indexação: Cynodon dactylon *(Pers) L., fertilização, taxa de cobertura do solo.*

INTRODUCTION

Bermuda grass (*Cynodon dactylon* L.) is a warm-season species with the main traits: narrow leaves, bright green color and rapid growth of stolons and rhizomes, propagation by seeds or mats, plugs or sprigs (stolons). Its advantages are high heat and drought tolerance, excellent resistance to trampling and great regenerative capacity from injuries (Lauretti, 2003). In Brazil, Bermuda grass was first introduced in golf courses and is now already one of the most commonly used grasses in the country's sports fields, both for football and golf (Godoy, 2005). The economic importance of Bermuda grass is directly related to the planting and renovation of sport lawns, and according to Zanon (2003), it is one of the four main grasses grown in the country.

Grass, as any other plant, needs nutrients in the correct amounts for a full growth and development. The nutrient demand is influenced by species and varieties. The summer species used in Brazil differ somewhat in the nutritional demand; Bermuda grass and Bermuda hybrids are more demanding than other grasses due to the high growth rate (Godoy & Villas Bôas, 2003). In the classification of lawns according to their nutritional requirements, nutrient requirements of sod production areas are considered high, because aside from the mowing during the production cycle, the mat is removed from the area with all absorbed nutrients, together with the nutrients contained in the soil that are removed along with the mat.

According to Carrow et al. (2001), N is the nutrient with the greatest influence on color, growth and shoot density, and root, rhizome and stolon growth, carbohydrate reserves, tolerance to low temperatures, drought resistance, tolerance to soil compaction and trampling, thatch accumulation, and recovery potential of grasses.

Of all nutrients, N is required in highest amounts by grasses, and adequate levels are improve the vigor, visual quality and injury recovery. However, the amount of available soil N is insufficient to meet the high demands of the lawn, so regular applications of nitrogen fertilizers are needed to increase grass growth (Bowman et al., 2002; Easton & Petrovic, 2004). Therefore, an ideal lawn quality (color, density and texture) requires an intensive fertilization program with high N rates and irrigation (Exner et al., 1991; Quiroga-Garza et al., 2001).

In lawns fertilized with higher N rates, shoot growth was faster and plant and leaf density higher. This characteristic is very important in grass production systems in which mats should be produced in the shortest possible time, to increase productivity (Godoy, 2005). On the other hand, excessive N rates boost shoot growth, requiring a greater number of cuts (mowing), which is a drawback for the root system and rhizome and/or stolon growth, reducing the suitability for postharvest handling, and consequently the yield in the area (Koske, 1994; Christians, 1998; Carrow et al., 2001). In sod production, the growth of grass roots and rhizomes is more important than of the shoots, in view of the greater influence on mat resistance, which is directly related to postharvest handling and the yield of the area (Christians, 1998).

Godoy (2005) found that St. Augustine and Zoysia grass sods with good quality were produced with N applications between 350 and 400 kg ha^{-1} in periods of six and ten months, respectively. Nitrogen rates > 400 kg ha^{-1} reduced the accumulation of root dry matter of both grasses. Godoy et al. (2007) tested rates of 0, 200, 400 and 600 kg ha^{-1} and found that with the application of 408 kg ha^{-1} it took 6.6 months until Zoysiagrass covered the soil completely, less than with the other rates. Backes et al. (2009) tested increasing N rates in organic form and found that Zoysiagrass sods grew in the shortest time and their resistance was greatest at a rate of 31 t ha^{-1} sewage sludge (equivalent to 310 kg ha^{-1} N).

As there is no fertilization recommendation for sod production in Brazil and N rates must be adjusted according to the species, this study aimed to evaluate the influence of nitrogen fertilization on yield and quality of Bermuda grass sods.

MATERIAL AND METHODS

The experiment was installed in an area of commercial sod production of Bermuda grass, *Cynodon dactylon* [Pers] L., in Capela do Alto, SP (23 ° 28 ' South latitude, 47 ° 44 ' West longitude, average altitude 625 m asl), on a medium texture Oxisol (Embrapa, 2006).

The species Bermuda grass *Cynodon dactylon* [Pers] L., variety Celebration was used, which is rhizomatous and can therefore be harvested from the entire area, since the subsurface rhizomes remaining in the ground are capable of resprouting to cover the ground again after the harvest. The root system of this variety is also vigorous, grows fast in production fields and recovers quickly from mechanical damage caused by golf clubs, machinery and equipment traffic or trampling. It is also moderately shade-tolerant, which is rather unusual for a grass of the genus *Cynodon* (Bermuda).

Prior to the experiment, soil analysis determined the chemical properties in the layer 0–10 cm as follows: pH($CaCl_2$) of 4.8; 18 g dm^{-3} of organic matter; 26 mg dm^{-3} of resin-extractable P; 37 H + Al; 1.6 K^+; 16 Ca^{2+}; 8 Mg^{2+}; 63 $mmol_c$ dm^{-3} CEC and base saturation of 41 %. In September 2007, 0.70 t ha^{-1} lime was applied (RNV = 91 %) to raise the V value to 60 % in the 0–10 cm layer. Fertilization was carried out 30 days after liming with the application of 80 kg ha^{-1} P_2O_5 (as triple superphosphate).

The experiment was arranged in a randomized block design with five treatments and four replications. The treatments consisted of five N rates (0, 150, 300, 450, and 600 kg ha^{-1} N) split in three cumulative applications along the crop cycle. Forty days after cutting the previous mat (DAC), rates of 0, 50, 100, 150, and 200 kg ha^{-1} N were applied, 89 DAC: 0, 100, 200, 300, and 400 kg ha^{-1} N 124 DAC, the remaining N was applied to complete the total rates of 0, 150, 300, 450, and 600 kg ha^{-1} N. The N source was urea (44 % N) applied manually to the soil surface and thereafter the area was irrigated with water at a level of about 20 mm. Potassium fertilization at 200 kg ha^{-1} K_2O was also divided in three and applied together with N fertilization.

The 2.5 x 5.0 m experimental plots, with borders of 0.5 m, were marked with polyethylene ropes along the plot perimeter. Irrigation frequency and water level were determined based on rainfall amounts and crop demand, according to the management system (no specific crop coefficient has been determined for grass soil cover rates) and applied by a gun sprinkler. The experimental area was weeded by hand.

The mat was mechanically cut by a harvester coupled to the tractor. The day before cutting, the area was irrigated and compaction rollers were passed over the experimental area thrice until the mats met market standards.

The rate of grass soil cover was assessed by image analysis 89 days (November 07), 124 days (December 07), 138 days (January 08) and 161 days (February 08) after cutting the previous mat. Digital images were recorded by a Sony DSC-W30 6 megapixel digital camera fixed to the end of an inverted "L" structure so that the images were obtained parallel to the lawn surface, at a height of 1.6 m, avoiding shadows, resulting in a digital image of an area of about 2 m^2. Each image was analyzed by Corel Photo Paint v. 10,410 according to the method of Richardson et al. (2001), by which the number of dots (pixels) of a certain color is counted. Thus, the soil cover rate (SCR) of the grass was determined by selecting the green and straw-colored pixels. Monitoring the SCR of the grass in sod production systems can provide information on the development stage of a grass mat, that is, a rate of 100 means that the mat is ready to be cut (Godoy, 2005).

To determine the N concentration grass blades were collected, washed, packed in paper bags and dried in a forced-air oven at 65 °C for 72 h. After drying, the blades were ground and sent to the plant nutrition laboratory of the Faculdade de Ciências Agronômicas (FCA) of the State University of São Paulo (UNESP) for N determination by the analytical methods described by Malavolta et al. (1997). The N leaf concentration was determined 89 days (November/07), 124 days (December/07) and 161 days (February/08) after cutting the previous mat.

At the time of sod harvest, four grass plugs (diameter 6.8 cm) per plot were collected with an auger sampler (stainless steel tube, length 50 cm, diameter 8 cm tapering towards the end to diameter 6.8 cm) to determine the dry matter. The plugs were washed to remove the soil adhered to the material. Subsequently, the forceps were separated into stems and leaves + rhizomes + roots + stolons. Each part was dried in a forced-air oven at 65 °C for 72 h, after which the dry matter was weighed. Furthermore, the mat resistance to breakage (kgf) was determined in three mats per replication, according to the method described by Backes (2008).

All results were subjected to analysis of variance followed by regression, fitting the equations to the data obtained from the N rates using SISVAR version 4.2 (Ferreira, 2000). In the fitting of the regression models, rates of 0, 50, 100, 150 and 200 kg ha^{-1} N were considered for the characteristics evaluated 89 DAC, of 0, 100, 200, 300, and 400 kg ha^{-1} N for the characteristics evaluated 124 DAC and the total rates of 0, 150, 300, 450, and 600 kg ha^{-1} N for 138 and 161 DAC. Pearson's correlations were calculated using SigmaStat 3.1.

RESULTS AND DISCUSSION

The soil cover rate (SCR) was significantly influenced by N rates in a comparison of the four evaluations. The quadratic model explained the variation of the soil cover satisfactorily, as related to the N rates (Figure 1). When the first of the three fertilization rates had been applied 89 DAC, the soil cover of the mats was not complete. According to the fitted equation, the maximum cover rate (96 %) was reached with 140 kg ha^{-1} N.

After two of the three N split rates, 124 DAC, the application of 275 kg ha^{-1} N resulted in the best soil grass cover (98 %), according to the adjusted equation. Although SCR varied with the N rates at this time, there was little change compared to 89 DAC, and the increase was only 2 % compared to the previous evaluation. In the plots fertilized with 300 kg ha^{-1} N or more, the soil was fully covered 138 DAC and reached the highest value at a rate of 415 kg ha^{-1} N. It is noteworthy that, even at lower rates (300 kg ha^{-1} N), as estimated by the equation, 100 % SCR was achieved. The effect of the rate of 411 kg ha^{-1} N was also quadratic 161 DAC, resulting in a maximum rate of soil grass cover (Figure 1). Similar results of soil cover were observed for 408 kg ha^{-1} by Godoy et al. (2007), who tested the same N rates on Zoysiagrass. With an application of 300 kg ha^{-1} N to Zoysiagrass, Backes (2008) observed 100 % soil cover.

In sod production, the most important aspect is the production time rather than productivity, since N deficiency would cause no drop in the number of mats collected, but extend the production time (Godoy, 2005). According to Koske (1994), the fertilization time and rate are market-dependent, in other words, when the demand is high, the grass should be fertilized with high rates, but when it is low, minimal amounts of fertilizer should be applied to keep costs with irrigation and cutting as low as possible. Thus, the evaluation of soil cover during the crop cycle may be an interesting characteristic for the adjustment of N to be applied in side dresssing. The amount of fertilizer can be tailored according to the desired speed of mat formation.

It was observed that 161 DAC soil cover by Bermuda grass was 100 % in all plots but those without N fertilization and those treated with 150 kg ha^{-1} N (Figure 2).

For the grass not treated with N side dressing, the application of the highest rate (600 kg ha^{-1} N) resulted in an increase of Bermuda grass soil cover rate of 40 %, underscoring the importance of N application in the full growth stage. Godoy et al. (2007) found that Zoysiagrass not treated with N base fertilization covered only 12 % of the soil surface. Bermuda grass without N applications covered only 60 % of the soil surface 161 days after cutting the previous mat (Figure 2).

Aside from the soil cover, the Bermuda grass dry matter produced on the basis of N rates should be taken into account. By applying the total amount of N, it was found that there was influence of rates of this nutrient on dry matter accumulation on the different plant parts (Figure 3).

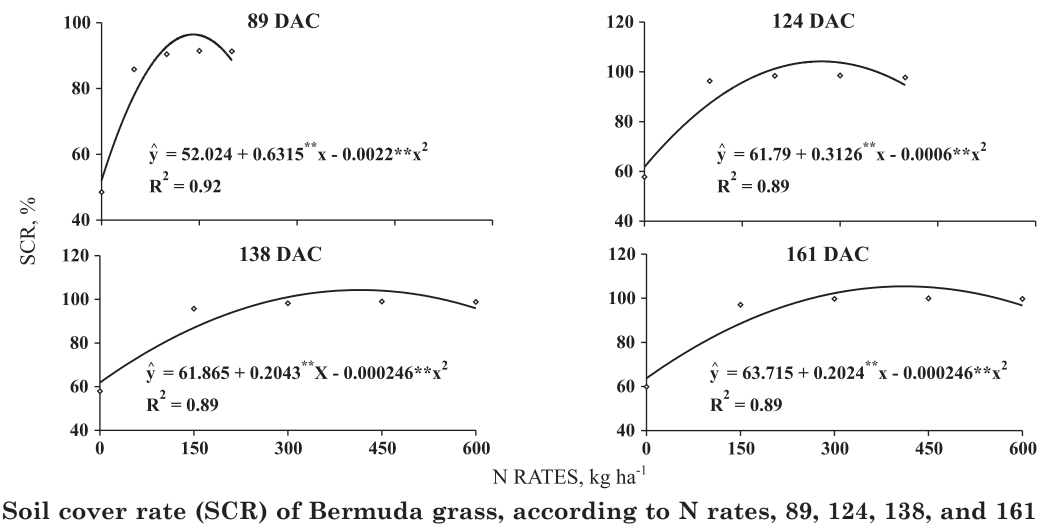

Figure 1. Soil cover rate (SCR) of Bermuda grass, according to N rates, 89, 124, 138, and 161 days after cutting.

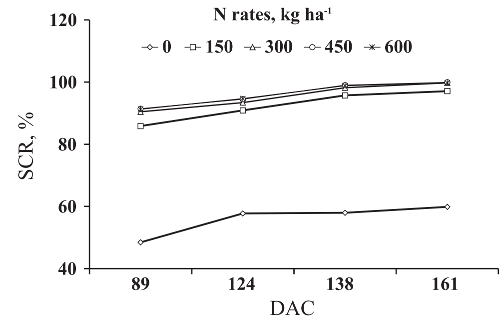

Figure 2. Bermuda grass soil cover rate during the crop cycle in relation to N applications.

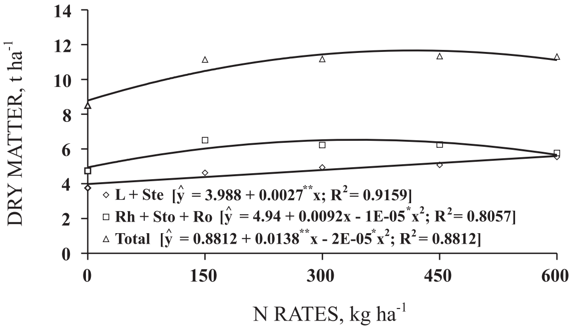

Figure 3. Dry matter accumulation of leaves + stems (L + Ste), rhizomes + stolons+ roots (Rh + Sto+ Ro) and total of Bermuda grass, in relation to N rates.

It was observed that the leaf + stem dry matter (Lf + Ste) adjusted linearly to N rates, reaching a maximum of 5.54 t ha^{-1}. The highest N rate applied (600 kg ha^{-1}) resulted in increased leaf + stem production and a reduction in the production of rhizomes + stolons+ roots (Rh + Sto + Ro). Dry matter production was highest (6.57 t ha^{-1}) at a rate of 354 kg ha^{-1} N. Godoy (2005) studied N applications to Zoysiagrass and found that N levels of over 400 kg ha^{-1} reduced the accumulation of root and rhizome dry matter.

The stolons, rhizomes and roots are the most important parts in grass production, because they underlie the structure and resistance of the mats for postharvest handling (Christians, 1998). Therefore, studies on mat formation should also consider the time of formation of these structures to ensure adequate mat resistance. Thus an estimated rate of 355 kg ha^{-1} N, resulting in a maximum amount of stolons, rhizomes and roots, may be recommended for Bermuda grass sod production of good quality.

Rates exceeding 355 kg ha^{-1} N can result in a reduced rhizome and root production and increased leaf and stem production, which is not desirable due to the increased requirement for cuts of leaves (mowing), raising the production costs (Quiroga-Garza et al., 2001). The cuts also deplete the carbohydrate pool in lawns which is a reserve for stress periods (Qian & Fry, 1996). The total dry matter also fitted to the quadratic model at a rate of 406 kg ha^{-1} N, providing the maximum accumulation of 11.59 t ha^{-1} (Figure 3).

Resistance to breakage (35 kg) was highest at a rate of 365 kg ha^{-1} N (Figure 4). Higher N rates reduced resistance, most likely due to greater leaf growth at the expense of stolons, rhizomes and roots. At zero N, resistance was weakened by the fact that the mats were not fully formed. Backes et al. (2009) evaluated the resistance of Zoysiagrass sods produced with sewage sludge applications, and observed the same resistance to breakage (35 kg) at a sewage sludge rate of 31 t ha^{-1} (equivalent to approximately 310 kg ha^{-1}N).

It was found that the difference between the rate that obtained maximum production of stolon, rhizome and root dry matter and the rate that maximized mat resistance was only 10 kg ha^{-1} N. It can be assumed that the increased production of stolons + rhizomes + roots was responsible for an increased mat resistance (Figure 5). According to Koske (1994), the use of high N rates and a very rapid mat formation can affect the suitability for handling (“liftability”) by reducing rhizome growth.

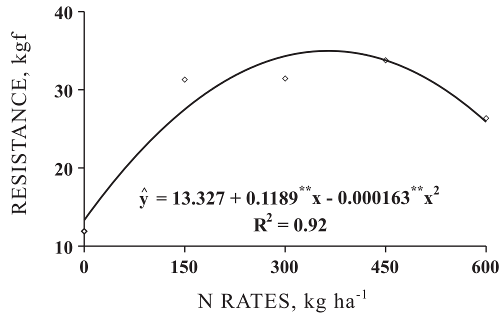

Figure 4. Resistance of Bermuda grass mat, in relation to N rates.

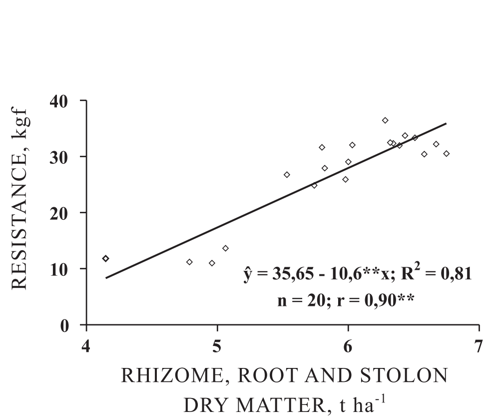

Figure 5. Relationship between mat resistance and rhizome, root and stolon dry matter of Bermuda grass.

An assessment of the soil cover rate (Figure 1) showed that applications of 415 and 411 kg ha^{-1} N resulted in the maximum soil cover 138 and 161 DAC, respectively. However, stolon, rhizome and root production and mat resistance were highest at rates of 354 and 365 kg ha^{-1} N. As the application of 300 kg ha^{-1} N also resulted in a full soil cover (100 % SCR) of the mat, rates that increase the suitability for mat handling should be chosen. Godoy (2005) found that at rates of 450 and 600 kg ha^{-1} N marketable mats of St. Augustine grass were formed in the same period of time (10 months), although root and stolon dry matter was higher at the lower rate. The N concentration in Bermuda grass leaf blades was significantly influenced by N rates at all sampling times. At 89 DAC the N concentration in the leaf blade increased linearly, with the addition of 2.2 g kg^{-1} N for every 50 kg ha^{-1} N applied (Figure 6). The evaluation of the leaf N concentration during the crop cycle can be used to monitor the plant status. Higher N amounts indicate higher chlorophyll concentrations and, consequently, increased carbohydrate production required for increased grass growth and mat formation.

Although the quadratic model had been adjusted to the N concentration in relation to the rate 124 DAC, the highest concentration was reached according to the equation, with rates exceeding those studied here (Figure 6). After all N had been applied 161 DAC, the rate of 541 kg ha^{-1} N resulted in the highest N concentration in Bermuda grass leaf blades (40 g kg^{-1}). Nitrogen concentrations in Bermuda grass leaf blades are within the range considered adequate by Mills & Jones Jr. et al. (1996), which is 22–40 g kg^{-1}. This concentration of 40 g kg^{-1} N in the leaf blade shortly before cutting the mat, results in a more intense green grass color and can accelerate rooting of the mats after transplantation.

Ahmad et al. (2003), using maintenance fertilization, also observed an increase in Leaf N concentration in Bermuda grass, var. Dacca, as the amount of fertilizer was increased. The maximum leaf concentration observed by these authors was only 20 g kg^{-1}, at the highest N rate (300 kg ha^{-1}).

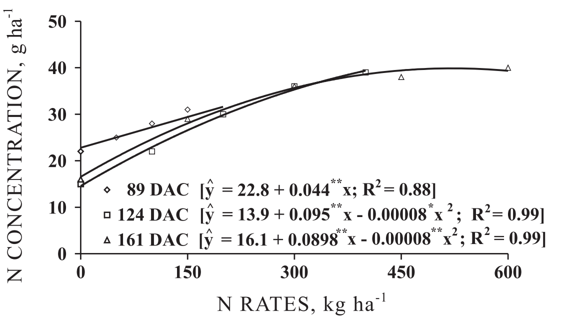

Figure 6. N concentration in Bermuda grass leaf blades, after N applications, in three evaluations.

The range of leaf N concentration associated to over 90 % soil grass cover, in December and February (Figure 7) was 22–41 g kg^{-1} N; lower leaf N concentrations (15–21 g kg N) associated to < 90 % soil cover (SCR) in December and February can be adopted to express N deficiency conditions. In the sod production areas, N deficiency was observed for most of the time until the grass covered the soil, forming the mat (Godoy & Villas Bôas, 2003).

In St. Augustine grass, also treated with increasing N rates, Godoy (2005) found that foliar concentrations from 20 to 26 g kg^{-1} N resulted in higher rates of soil cover while values of 14 - 19 g kg^{-1} N were considered deficient. McCrimonn (2004) observed that at concentrations of 16.9 - 18.3 g kg^{-1} for cultivar "Palmetto" and 15.9–18.4 g kg^{-1} for "Raleigh" the soil cover rates were lower, indicating stress conditions. For Zoysiagrass, concentrations of 19–22 g kg^{-1} N were considered sufficient to provide adequate soil cover (95 %) 165 days after the application of sewage sludge, in an experiment conducted by Backes (2008). The differences in concentrations were due to the different species used and the different experimental conditions.

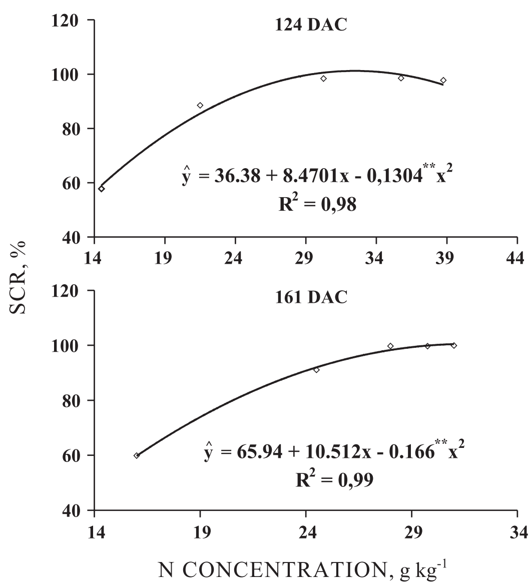

Figure 7. Soil cover rate in relation to the N concentration in Bermuda grass leaf blades 124 and 161 days after cutting.

CONCLUSIONS

1. Increasing N rates increased the soil cover rate of Bermuda grass by reducing the formation time of the mat.

2. The accumulation of rhizome + root + stolon dry matter was highest at a rate of 354 kg ha^{-1} N and the mat resistance best at 365 kg ha^{-1}.

3. A growth period of approximately 5.5 months, with N fertilization rates between 354 and 365 kg ha^{-1} N, was considered ideal for Bermuda grass mats with good quality.

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