SILICATE AND PHOSPHATE COMBINATIONS FOR MARANDU PALISADEGRASS GROWING ON AN OXISOL

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ABSTRACT: One of the greatest problems for pasture establishment and maintenance are the extremely low concentrations of available phosphorus in soils. The objective of this study was to evaluate the influences on productive and physiologic attributes during Marandu palisadegrass (*Brachiaria brizantha*) establishment, following changes in phosphorus availability in the soil through the applications of phosphate and silicate. To achieve this, a fractionated factorial 5^2 design was used, with 13 combinations for silicon and phosphorus, respectively, in mg dm^{-3}: 150 and 10; 150 and 170; 150 and 330; 225 and 90; 225 and 250; 300 and 10; 300 and 170; 300 and 330; 375 and 90; 375 and 250; 450 and 10; 450 and 170 and 450 and 330, distributed according to randomized blocks, with four replications. The experiment was carried out in a greenhouse using samples of a Typic Haplustox (760 g kg^{-1} sand, 40 g kg^{-1} silt and 200 g kg^{-1} clay). Wollastonite was used as the source of silicate and the sources of phosphorus were $Ca(H_2PO_4)_2$, KH_2PO_4 and NaH_2PO_4. Marandu palisadegrass was grown during the summer and two harvests were made during the growing season. Significant interaction between phosphorus and silicate rates was found for the number of tillers and expanded green leaves, total leaf area, dry mass production of leaf laminae and culms with sheaths, and dry mass production of plant tops. Maximum responses of the analyzed variables were reached in the combination of the intermediate rates of phosphorus (170 and 250 mg dm^{-3}) with high rates of silicon (375 and 450 mg dm^{-3}).
Key words: *Brachiaria brizantha*, leaf area, phosphorus, production, silicon

COMBINAÇÕES DE SILICATO E FOSFATO PARA CULTIVO DO CAPIM-MARANDU NUM LATOSSOLO

RESUMO: Um dos maiores problemas no estabelecimento e na manutenção de pastagens está nas concentrações extremamente baixas de fósforo disponível nos solos. Objetivou-se avaliar os atributos produtivos e fisiológicos durante o estabelecimento do capim-Marandu (*Brachiaria brizantha*), em seguida à alteração na disponibilidade de fósforo, por meio das aplicações de silicato e fosfato. Utilizou-se um esquema fatorial 5^2 fracionado, com as 13 combinações assim definidas, para silício e fósforo, respectivamente, em mg dm^{-3}: 150 e 10; 150 e 170; 150 e 330; 225 e 90; 225 e 250; 300 e 10; 300 e 170; 300 e 330; 375 e 90; 375 e 250; 450 e 10; 450 e 170 e 450 e 330, as quais foram distribuídas segundo delineamento estatístico de blocos ao acaso, com quatro repetições. O experimento foi instalado em casa de vegetação, utilizando um Latossolo Vermelho-Amarelo Distrófico. A fonte de silício utilizada foi a wollastonita e as fontes de fósforo foram $Ca(H_2PO_4)_2$, KH_2PO_4 e NaH_2PO_4. O capim-Marandu foi cultivado durante o verão e foram realizados dois cortes no capim. A interação foi significativa entre as doses de fósforo e de silício para o número de perfilhos e de folhas verdes expandidas, a área foliar total, a produção de massa seca das lâminas foliares e colmos mais bainhas e a produção de massa seca da parte aérea total. As máximas respostas das variáveis estudadas foram alcançadas na combinação das doses medianas de fósforo (170 e 250 mg dm^{-3}) com doses altas de silício (375 e 450 mg dm^{-3}).
Palavras-chave: *Brachiaria brizantha*, área foliar, fósforo, produção, silício

INTRODUCTION

The successful establishment and maintenance of forages is the extremely affected by low availability of phosphorus in some soils. The dynamics of phosphorus in soils, mainly its reactions with soil constituints contributes to the need for high rates of phosphate in order to establish good pastures.

Silva (1996) studied the effects of phosphorus supply in the production of *Brachiaria decumbens* and *Brachiaria brizantha*, for two subsequent periods (34 and 28 days), and observed that increasing phosphorus rates resulted in increases in the number of tillers, in dry mass production and in phosphorus concentration in the grass leaves for both species.

The use of calcium silicate ($CaSiO_3$) or magnesium silicate ($MgSiO_3$) in acid soils enhances phosphorus availability to the plants, decreasing the fixation of the ortophosphate ion (Carvalho, 1999). In a study related to the interaction of silicate-phosphorus (Si-P) in an Oxisol, under laboratory conditions, Leite (1997) verified phosphorus displacement by silicon and vice-versa, recommending the need of the inclusion of silicon sources in fertilization programs with phosphorus for Oxisols, especially those of low silicon availability.

Positive silicate effects are usually associated with increases of silicon availability and increases in soil pH (Smyth & Sanchez, 1980), with more erect leaves (Yoshida, 1969), with higher availability of phosphorus (Roy et al., 1971), and with tolerance by plants to excess aluminum and iron in the soil (Mengel & Kirkby, 2001). The benefits to the plants of silicon are due to its contributions to the structure of cell walls of roots and leaves since this element does not have a defined metabolic role and it has been acting as a mechanical barrier against both, water loss and pathogens (Marschner, 1995).

The objective of this research was to study the relationship between phosphorus and silicon supplies and the establishment of *Brachiaria brizantha* cv. Marandu, evaluated through the number of tillers and leaves, leaf area and dry mass production of this forage.

MATERIAL AND METHODS

A greenhouse experiment carried out in Piracicaba, SP, Brazil (22°42'30" S, 47°38'00" W, and approximately 546 m elevation) during the summer season, using samples of a Typic Haplustox, collected to the depth of 0.20 m, and having 5 mg dm^{-3} available phosphorus and 4.1 mg dm^{-3} soluble silicon. Seeds of Marandu palisadegrass were germinated in plastic trays containing washed sand, which were periodically irrigated with deionized water. Fourteen days after sowing, 12 seedlings were transplanted to a plastic pot of 3.6 L capacity, containing 5.5 kg of the soil (760 g kg^{-1} sand, 40 g kg^{-1} silt and 200 g kg^{-1} clay) sieved through a 2 mm screen, and without holes for drainage. Seedlings were thinned to five plants per pot. Water was supplied twice a day, controled by weight. Average minimum and maximum temperatures were 22 and 37ºC, respectively.

A fractionated factorial 5^2 design was used (Littell & Mott, 1975) with 13 combinations of silicon and phosphorus rates, distributed in randomized blocks with four replications. The combinations for silicon and phosphorus, respectively, in mg dm^{-3} were: 150 and 10; 150 and 170; 150 and 330; 225 and 90; 225 and 250; 300 and 10; 300 and 170; 300 and 330; 375 and 90; 375 and 250; 450 and 10; 450 and 170, and 450 and 330. Wollastonite was used as silicon source (Si = 243 g kg^{-1}) and the analytical reagents $Ca(H_2PO_4)_2$, KH_2PO_4 and NaH_2PO_4 were used as phosphorus sources. Plant nutrients calcium and potassium were supplied at fixed rates (550 and 115 mg dm^{-3}, respectively) to all the pots. Soil pH (in 0.01mol L^{-1} $CaCl_2$ solution) ranged from 4.4 to 5.8, phosphorus (resin) availability ranged between 8 and 180 mg dm^{-3}, and soluble silicon (in 0.01 mol L^{-1} $CaCl_2$ solution) ranged between 17 and 32 mg dm^{-3}, as rates of application of these elements changed from the lowest to the highest.

The first harvest of plants (cut to a height of 3 cm above soil surface) took place 35 days after transplanting, with the second harvest 34 days after the first (at soil level). The number of tillers and the number of expanded green leaves per pot were counted for each growth period. Leaf area was determined through a digital area integrator system. For both harvests the plant top was separated into leaf laminae and culms plus sheaths. All collected plant material was dried for 72 hours in a stove with forced air circulation at 65ºC, and weighed after drying.

Statistical analyses were performed by using the SAS program - System for Windows 6.11 (SAS Institute, 1996). ANOVA was performed and the interaction between phosphorus and silicon was tested. Polynomial regression (surface response) was made through the command RSREG at $P < 0.05$.

RESULTS AND DISCUSSION

The interaction between phosphorus and silicon rates was significant for all the response variables and the results were fitted to polynomial models.

Tillers

The maximum number of tillers in the first harvest (Figure 1a) occurred with two combinations of silicon and phosphorus rates: 1) high rates of silicon combined with median rates of phosphorus and 2) high rates of phosphorus combined with lower rates of silicon. At the second harvest (Figure 1b), the maximum number of tillers occurred only in the combination of the low rates of silicon with high rates of phosphorus.

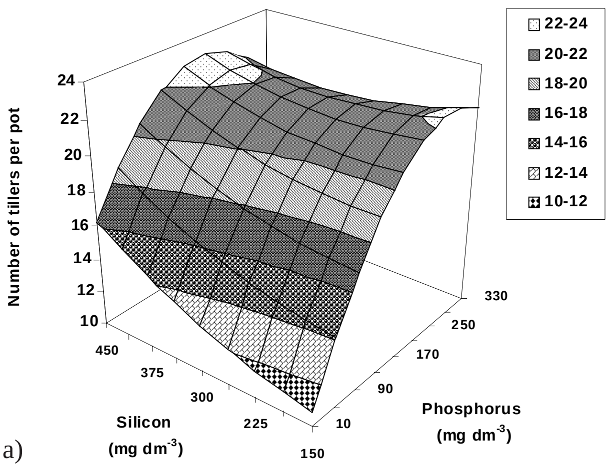
Mesquita et al. (2004) found that the number of tillers of Marandu palisadegrass increased as phosphorus rates increased from 0 to 330 mg dm^{-3}. Similar results were found by Corrêa & Haag (1993), who reported an increase in the number of tillers of the Marandu palisadegrass due to an increase in phosphorus rates (P_2O_5 from 0 to 640 kg ha^{-1}) applied in an Oxisol. Monteiro et al. (1995) grew Marandu palisadegrass in nutrient solution with a complete treatment and also with the omission of each nutrient. They reported that the omission of phosphorus limited lateral tillering to just one culm per plant. Phosphorus is very important for forages, mainly in the initial periods of development of the plant (Werner, 1986). When phosphorus availability in the soil is low, so is plant growth.

The greater number of tillers at the second harvest compared to the number at the first harvest can be explained by the fact that at the first harvest the apical bud was removed and the basal buds were stimulated, enhancing a larger production of tillers (Gomide & Gomide, 1999). Tiller renewal in pastures occurs with the removal of the apex of the plant, enhancing the activation of basal buds and resulting in increase in the number of tillers (Lemaire & Chapman, 1996).

Green leaves

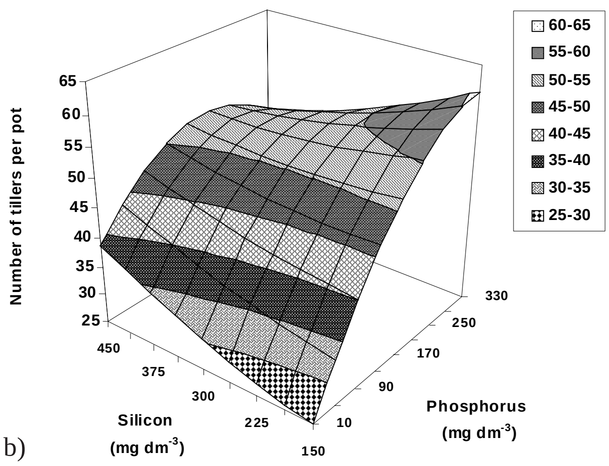
The greatest number of expanded green leaves at the first harvest (Figure 2a) was reached with the phosphorus rate of 140 mg dm^{-3} combined with the highest silicon rate (450 mg dm^{-3}), and phosphorus rate of 250 mg dm^{-3} with the silicon at 375 mg dm^{-3}. This demonstrates a lower need of phosphate fertilization when it is applied together with silicon.

For the number of expanded green leaves at the second harvest, the response showed that at a phosphorus rate of 210 mg dm^{-3} or higher, the number of expanded green leaves did not change, regardless of the rate of silicon. Phosphorus at 170 mg dm^{-3} combined



a)

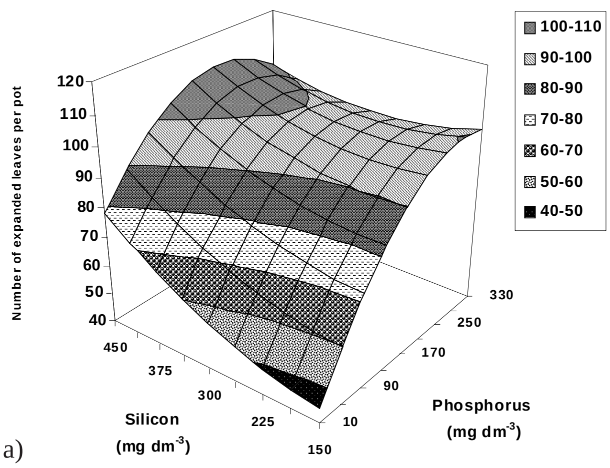
Y=9.50-0.00243*Si+0.00004*Si*Si+0.10288*P-0.00017*P*P-0.00007*P*Si
R^2 = 0.64



b)

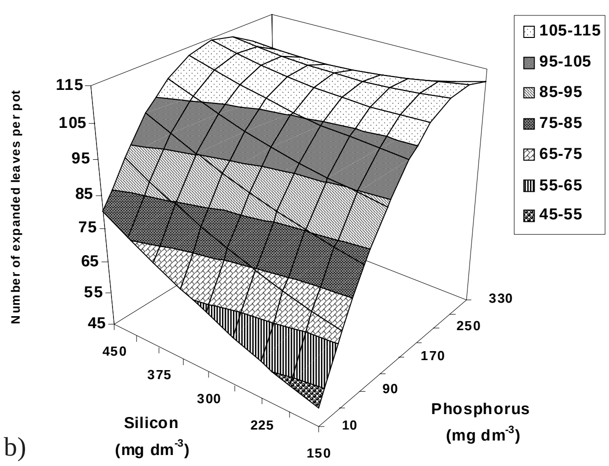
Y=18.01+0.01951*Si+0.00005*Si*Si+0.27460*P-0.00034*P*P-0.00029*P*Si
R^2 = 0.62

Figure 1 - Total number of tillers per pot in the first (a) and second (b) harvests of Marandu palisadegrass as related to combinations of silicon and phosphorus rates.



a)

Y=41.43-0.04064*Si+0.00026*Si*Si+0.45570*P-0.00070*P*P-0.00033*P*Si
R^2 = 0.74



b)

Y=37.45+0.04101*Si+0.00010*Si*Si+0.53788*P-0.00084*P*P-0.00040*P*Si
R^2 = 0.64

Figure 2 - Total number of expanded leaves per pot in the first (a) and second (b) harvests of Marandu palisadegrass as related to combinations of silicon and phosphorus rates.

with the silicon rate of 412.5 mg dm^{-3} resulted in the maximum number of expanded green leaves (Figure 2b).

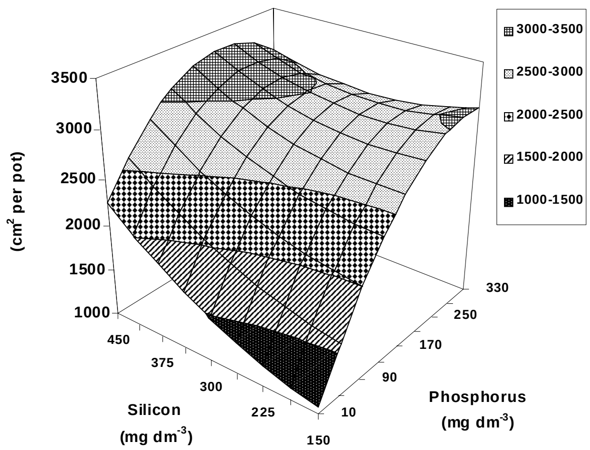
Leaf area

At the first harvest (Figure 3a), phosphorus at the rate of 130 mg dm^{-3} combined with the silicon rate of 450 mg dm^{-3} presented the same leaf area as found with the phosphorus rate of 290 mg dm^{-3} combined with the silicon rate of 150 mg dm^{-3}. The combination of high rates of both phosphorus and silicon provided a leaf area almost 3.5 times higher than that obtained in the lowest rates of these two elements.

At the second harvest, the maximum leaf area range was found at the phosphorus rate of 130 mg dm^{-3} combined with any silicon rate, and the largest value of leaf area was twice that of the minimum value (Figure 3b). Leaf area is an important parameter in plant growth analysis, because the larger the leaf area, the greater is the surface to capture sunlight, which generally results in a higher growth rate and, consequently, in a higher yield (Mengel & Kirkby, 2001).

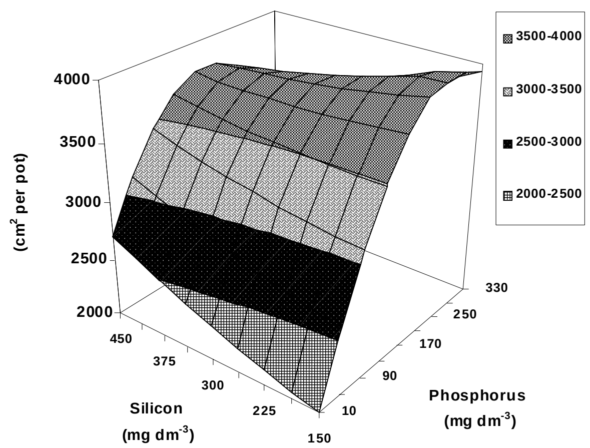
At the second harvest, the leaf area was larger than at the first harvest, which agreed with Batista (2002), who studied effects of nitrogen and sulfur for Marandu palisadegrass growth in nutrient solution. The results showed that the maximum leaf area occurred at the second harvest, being 50.9% higher than that obtained at the first harvest. A similar result was reported by Santos (2003), who demonstrated an increase of 69.4% in leaf area at the second harvest as compared to the first.

a)



$$Y=869.29-0.80528*Si+0.00807*Si*Si+15.78944*P-0.02304*P*P-0.01208*P*Si$$
$$R^2 = 0.60$$

b)



$$Y=1570.09+1.33160*Si+0.00206*Si*Si+19.38165*P-0.03223*P*P-0.01557*P*Si$$
$$R^2 = 0.55$$

Figure 3 - Leaf area of Marandu palisadegrass in the first (a) and second (b) harvests as related to combinations of silicon and phosphorus rates.

Leaf laminae production

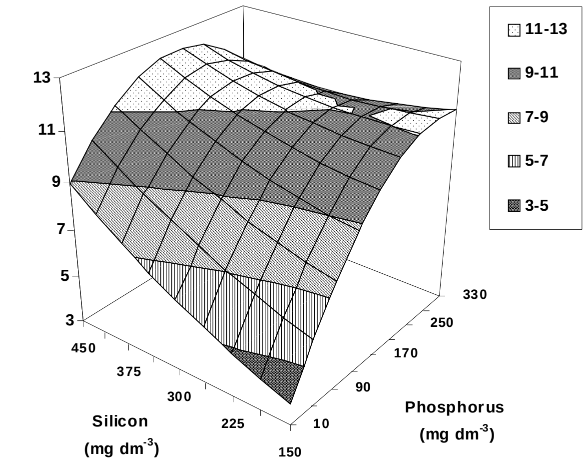
At the first harvest, the largest increment in the production of dry mass of leaf laminae was observed with the increase of the phosphorus rates from 10 to 90 mg dm^{-3}, when silicon was applied at the highest rates (Figure 4a). Phosphorus rates of 90 mg dm^{-3} combined with silicon rates of 450 mg dm^{-3} provided the same values of laminae dry mass as the higher phosphorus rates were combined with the smaller silicon rates. Gheri et al. (2000) studied phosphorus rates varying from 0 to 140 mg dm^{-3} for dry mass production of Tanzânia guineagrass (*Panicum maximum*). The largest increase in dry mass production occurred with the application of phosphorus of 35 mg dm^{-3}. Also, Costa et al. (1983) reported the largest increase in the production of Colonião guineagrass (*Panicum maximum*) when the phosphorus application was raised from 0 to 50 mg dm^{-3}.

The laminae dry mass of Marandu palisadegrass was higher during the second period of plant growth than during the first. By the second harvest, the plant had formed its structure, and the root system was able to absorb larger amounts of nutrients. As occurred in the first harvest, at the second harvest the largest dry mass production of leaf laminae was found with two combinations of phosphorus and silicon rates (Figure 4b).

Culms plus sheaths production

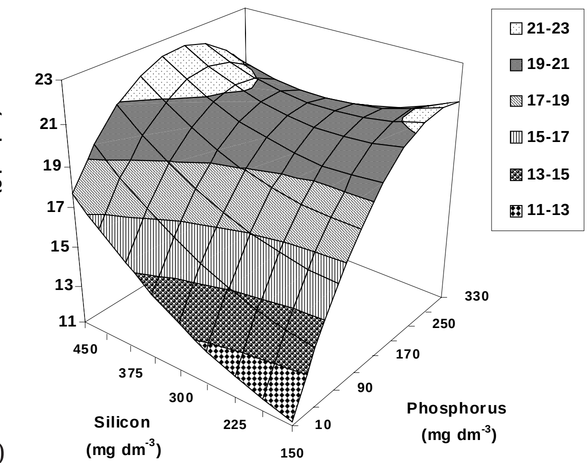
At the first harvest, the maximum culms plus sheaths production was reached (Figure 5a) with a low phosphorus rate (50 mg dm^{-3}) combined with the highest silicon rate (450 mg dm^{-3}), and also in the highest phosphorus rates (250 and 330 mg dm^{-3}) combined with the lowest silicon rates (150 mg dm^{-3}).

For the second harvest of Marandu palisadegrass, the phosphorus rate of 90 mg dm^{-3} combined with the silicon rate of 450 mg dm^{-3} provided about the same dry mass of culms plus sheaths pro-



a)

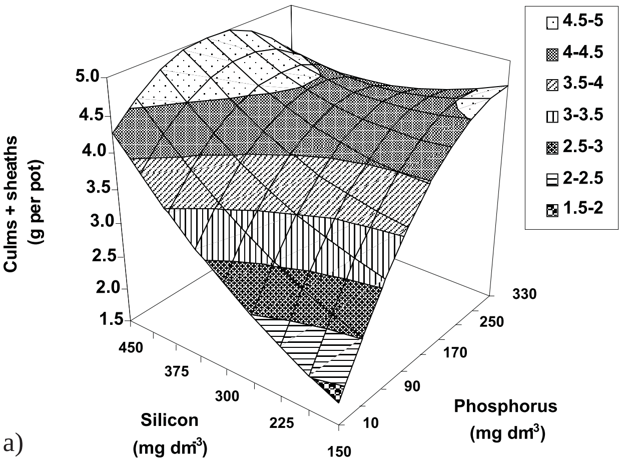
Y=1.99+0.00604*Si+0.00002*Si*Si+0.06286*P-0.00009*P*P-0.00006*P*Si
R^2=0.73



b)

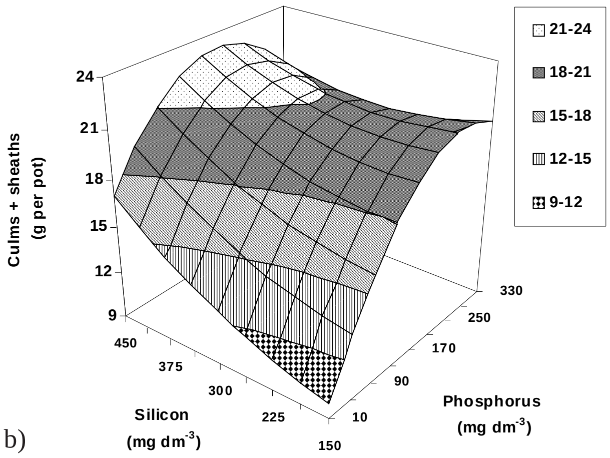
Y=10.31-0.00576*Si+0.00005*Si*Si+0.08821*P-0.00013*P*P-0.00008*P*Si
R^2=0.57

Figure 4 - Leaf laminae dry mass production of Marandu palisadegrass in the first (a) and second (b) harvests as related to combinations of silicon and phosphorus rates.



a)

Y=1.19+0.00126*Si+0.00001*Si*Si+0.02304*P-0.00003*P*P-0.00003*P*Si
R^2=0.56



b)

Y=8.65-0.00396*Si+0.00005*Si*Si+0.10131*P-0.00017*P*P-0.00007*P*Si
R^2=0.65

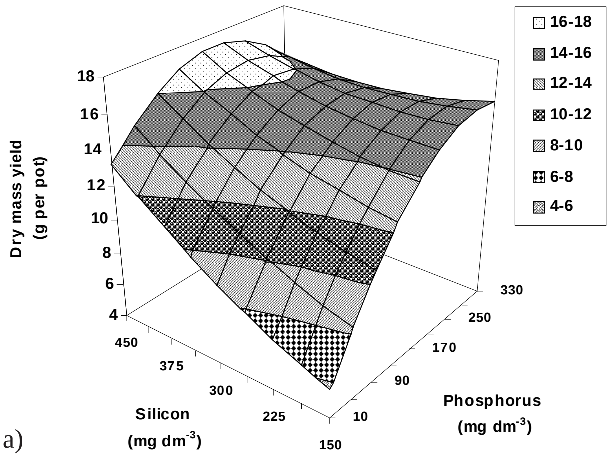
Figure 5 - Culms plus sheaths dry mass production of Marandu palisadegrass in the first (a) and second (b) harvests as related to combinations of silicon and phosphorus rates.

duction as phosphorus at 250 mg dm^{-3} combined with the silicon rate of 337.5 mg dm^{-3} (Figure 5b). The production of culms plus sheaths at the second harvest was 4.8 times higher than in the first harvest of the Marandu palisadegrass. Lavres Jr. et al. (2004) also mentioned production of culms plus sheaths 4.33 times higher at the second than at the first harvest of Aruana guineagrass (*Panicum maximum*).

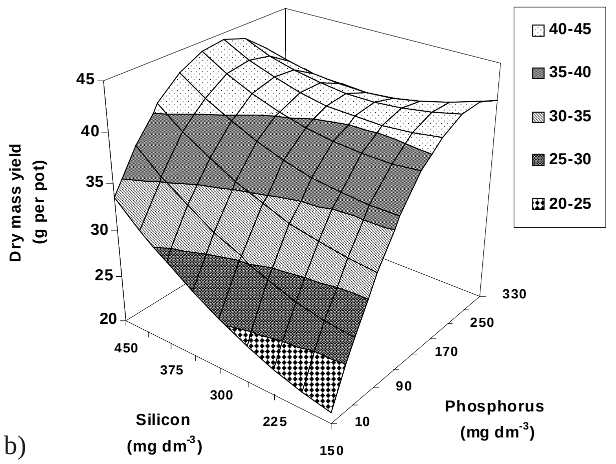
Plant tops

The dry mass production of plant tops at the first harvest was higher than that obtained with the highest rates of phosphorus with low rates of silicon (Figure 6a) when intermediate rates of phosphorus were combined with high rates of silicon. High phosphorus rates (250 and 330 mg dm^{-3}) combined with low and median rates of silicon (150 to 337.5 mg dm^{-3}) did not result in an increase in the dry mass production of plant tops. The dry mass production of plant tops with low rates of both phosphorus and silicon was about 3.2 times lower in relation to phosphorus and silicon rates that promoted the maximum production. The amount of phosphate fertilizer may be lowered when silicate is applied together with phosphate for Marandu palisadegrass.

Corrêa & Haag (1993) presented a great response in dry mass production for Marandu palisadegrass at the first harvest, with the increase of the phosphorus rate up to 140 mg dm^{-3}. Rossi (1995) also observed increases in dry mass production for Marandu palisadegrass when the phosphorus rate increased up to 300 mg dm^{-3} using triple superphosphate, and up to 700 mg dm^{-3} with the Araxá rock phosphate supply. Rossi & Monteiro (1999) reported that phosphorus rates in a nutrient solution resulted in a linear increase in the dry mass production of Signal grass (*Brachiaria decumbens*) and Colonião guineagrass



Y=3.18+0.00731*Si+0.00003*Si*Si+0.08589*P-0.00012*P*P-0.00009*P*Si
$R^2 = 0.72$



Y=18.96-0.009717*Si+0.00009*Si*Si+0.18952*P-0.00030*P*P-0.00015*P*Si
$R^2 = 0.66$

Figure 6 - Plant top dry mass production of Marandu palisadegrass in the first (a) and second (b) harvests as related to combinations of silicon and phosphorus rates.

(*Panicum maximum*) as phosphorus rates were increased.

Dry mass production at the second harvest (Figure 6b) showed a similar response to these two elements as in the first harvest, that is, a median rate of phosphorus (170 mg dm^{-3}) combined with high rates of silicon (450 mg dm^{-3}) resulted in maximum dry mass production, which was higher than in the first harvest.

Combining the lowest rate of phosphorus with the highest rate of silicon, the production was 1.63 times higher in dry mass than the one obtained with the smallest rates of both phosphorus and silicon. When phosphorus rates were higher than 210 mg dm^{-3}, the increase in silicon rates did not change the dry mass production. This shows a greater response to silicon when low and intermediate rates of phosphorus are used. In an experiment with Marandu palisadegrass in complete nutrient solution and with individual nutrient omissions, Monteiro et al. (1995) reported that the omission of phosphorus completely inhibited tillering and limited the dry mass production of plant tops.

Mesquita et al. (2004) verified an increase in the dry mass production of the plant tops of Marandu palisadegrass grown in an Oxisol, when phosphorus supply was increased from 0 to 110 mg dm^{-3}. Almeida et al. (1996) studied the effects of two lime rates (1000 and 4000 kg ha^{-1}) and two rates of phosphorus (35 and 140 kg ha^{-1}) plus the untreated, in an Oxisol, for Signal grass (*Brachiaria decumbens*) and Marandu palisadegrass (*Brachiaria brizantha*) and other eight accesses of *Brachiaria* sp., and reported that phosphorus was the main input for the dry mass production. Silva (1996) supplied rates of phosphorus for *Brachiaria brizantha* and *Brachiaria decumbens*, and verified increases in plant top dry mass production of both grasses. Korndörfer et al. (2001), in a Typic Haplustox, determined an increase of 17% in the dry mass production of *Brachiaria decumbens* after surface application of calcium silicate at 2000 kg ha^{-1}.

CONCLUSIONS

The rates of phosphorus and silicon applied in a Typic Haplustox interacted for the physiologic and productive variables for two harvests of Marandu palisadegrass grown in a greenhouse. The greatest increase in the number of expanded green leaves, leaf area and dry mass production of leaf laminae can be obtained with the application of intermediate rates of phosphorus together with high rates of silicon. Extensive grass tillering is highly dependent on the high phosphorus supply.

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