Yield, nutritional status and soil chemical properties as response to cattle manure, reactive natural rock phosphate and biotite schist in Massai grass

Adônis Moreira[(1)], Nand Kumar Fageria[(2)], Gilberto Batista de Souza[(1)] e Alfredo Ribeiro de Freitas[(1)]

[(1)]Embrapa Cattle-Southeast, P.O. Box 339, 3560-970 São Carlos, São Paulo State, Brazil. E-mail: adonis@cppse.embrapa.br, gilberto@cppse.embrapa.br, ribeiro@cppse.embrapa.br. [(2)]Embrapa Rice and Bean, São Antônio de Goiás, Goiás State, Brazil. E-mail: fageria@cnpaf.embrapa.br.

Session V: New fertilizers and fertilization management in Organic Farming

ABSTRACT

In animal production, grasses planted in the pasture lands have especial value to improve aggregate value of products. This paper evaluates the effects of applying cattle manure, reactive natural phosphate and biotite schist on soil fertility, yield and nutritional content of *Megathyrsus* spp. cv. Massai. The experiment was conducted under field conditions, in a dystroferric Red Latosol (Oxisol). The experimental design was randomized blocks with the treatments confounding, with one replicate. The treatments consisted of three rates of natural reactive rock phosphate from Algeria - Djebel-Onk (0, 100 and 200 kg ha^{-1} of P_2O_5), three biotite schist rates (0, 150 and 300 kg ha^{-1} of K_2O) and three cattle manure rates (0, 20 and 40 Mg ha^{-1}). The application of reactive natural rock phosphate increased dry matter yield (DMY), however, this effect was not observed for cattle manure and biotite schist. The foliar contents of N, K and Mg (cattle manure), P and B (natural rock phosphate) and K (biotite schist) were significantly influenced by the treatments. The same effect was found forP levels in soil, dry matter of the aerial part, Mg and B content in the dry matter.

INTRODUCTION

In intensive cattle dairy system, grazing capacity of the pasture needs to be improved by adopting adequate management practices. Adequate rates of fertilizers including limestone, N, P and K and micronutrients are necessary to improve growth of pasture grasses. Werner et el. (1996) recommend in pasture formation applying 40, 100 and 60 kg ha^{-1} of N, P_2O_5 and K_2O to soils with low fertility, while for maintenance these figures are necessary 80, 50 and 50 kg ha^{-1}, respectively.

In the dairy industry, constant fluctuations in the price of milk make it advisable to introduce new products with higher aggregate value. Although organic milk is a promising product, with demand growing by 30% a year, it is still restricted to a small niche in relation to conventional milk (Castro et al., 2008). The same observation holds for organic meat and other animal products. In the case of fertilization, studies have showed that the application of manure and/or reactive natural rock phosphates can boost the productivity of pastures (Scherer et al., 1984; Moreira et al., 2001). But in organic systems, the sources of potassium are restricted to ashes, potassium sulfate, vinasse (from sugarcane processing) and mulch (AAO, 2000), making it difficult to add nutrients to the system. Studies are thus necessary to find new alternative sources of K.

In Brazil, the majority of pastures are formed of *Urochloa* spp. and *Megathyrsus* spp. In th case of *Megathyrsus* spp., the Massai cultivar, a natural hybrid of *Megathyrsus maximu* and *Megathyrsus infestam*, has proved to be a promising alternative forages for tropic edaphoclimatic conditions, because it has lesser seasonal variation, with good raw protei content and good growth even in soils with low natural fertility (Valentim et al., 2001). Th objective of this study was to evaluate the effect of applying cattle manure, reactive natur rock phosphate (RNRP) and biotite schist on the production, nutritional value and so fertility of a hybrid of *Megathyrsus* spp., Massai cultivar.

MATERIAL AND METHODS

The experiment was conducted in São Carlos, São Paulo State, Brazil, above a Oxisol Typic Hapludox, with medium texture (483 g kg^{-1}). After correction with dolomiti limestone, the top layer (0-20 cm) presented the following chemical characteristics: pH i $CaCl_2$ = 6.0; P = 16.1 mg dm^{-3}; K = 0.8 $mmol_c$ dm^{-3}; Ca = 45.0 $mmol_c$ dm^{-3}; Mg = 21. $mmol_c$ dm^{-3}; H+Al = 22.0 $mmol_c$ dm^{-3}; and CTC = 88.9 $mmol_c$ dm^{-3}. The treatmen consisted of three rates (0, 100 and 200 kg ha^{-1} of P_2O_5) of reactive natural rock phosphat (RNRP) from Algeria (Djebel-Onk), with 29% P_2O_5 (9% being soluble in citric acid) an 12% of Ca, three rates (0, 150 and 300 kg ha^{-1} of K_2O) of biotite schist (2.0 mm - crushed pH_{H2O} = 8.5, K_2O = 4.3%, CaO = 2.8%, MgO = 15.1%, P_2O_5 = 0.01%, PN = 0% and SiC = 54.6%, and three rates (0, 20 and 40 Mg ha^{-1}) of cattle manure: N = 5.0 g kg^{-1}, P = 2.6 kg^{-1}, K = 6.0 g kg^{-1}, S = 1.0 g kg^{-1} and Ca = 2.0 g kg^{-1}. The full rates of natural roc phosphate, $^2/_3$ of the cattle manure and $^2/_3$ of the potassic rock were incorporated 20 day before planting. After the third cutting, the remaining $^1/_3$ of the potassic rock and $^1/_3$ of th cattle manure were applied as top dressing to complete the treatments.

The experimental consisted of a randomized block design with the treatment confoundin with one replicate and an additional treatment with cattle manure, natural rock phosphat and potassium chloride, in proportions of 40 Mg ha^{-1}, 100 kg ha^{-1} of P_2O_5 and 150 kg ha of K_2O. The quantities of KCl and cattle manure were applied similarly in the treatment The first cuttings occurred 60 days after planting the Massai cultivar, a spontaneous hybri between *Megathyrsus maximum* and *Megathyrsus infestum* (Valentim et al., 2001). Si cuttings (harvest) were made. After collection, the vegetable material was weighed an dried at ±65°C to determine the dry matter yield (DMY). Before planting and after eac cutting (harvest), samples were taken from the topsoil at a depth of 0-20 cm to determin the pH ($CaCl_2$), available P and exchangeable K, Ca, Mg and H+Al, soil organic matt (SOM) and S-SO_4 (Raij et al., 2001). After each cut, cattle were allowed to graze on th parts of the plots not sampled. After being dried, the samples from the aerial part wer ground and submitted to chemical analyses. The total N was extracted by sulfur digestio and measured by the micro-Kjeldahl method (Bataglia et al., 1983). The total P, K, Ca, M S, Cu, Fe, Mn and Zn were extracted according to the method described by Malavolta et a (1997). The data were submitted to variance analysis and the mean least squares obtaine were compared by Tukey test and regression analysis at 5% and 10% probability an finally, Pearson correlation coefficients between the dry matter yield and the levels available and exchangeable elements in the soil and plants were also calculated.

RESULTS AND DISCUSSION

The variance analysis showed a significant effect of applying natural rock phosphate on th dry matter yield of the Massai grass, while the use of up to 40 Mg ha^{-1} of cattle manure an

300 kg ha^{-1} of K_2O in the form of biotite schist and their interactions showed no influence of the treatments (Table 1). In the case of RNRP, there was a 25% increase in forage volume, which is equivalent to an estimated enhance of 2.3 Mg ha^{-1} $year^{-1}$. Similar increases in DMY with the addition of phosphorus on *Urochloa decumbens* were obtained by Yost et al. (1982), with the incorporation of 150 kg ha^{-1} of natural rock phosphate from North Carolina (30% of P_2O_5). Similar quantities to that of triple superphosphate (soluble source – 40% of P_2O_5) were also obtained with the use of RNP (Arad and North Carolina) by Moreira & Malavolta (2001) with alfalfa (*Medicago sativa*) and Brazilian butterfly peas (*Centrosema pubescens)*. These gains in production are due to the function of phosphorus in plant metabolism. It plays an important role in the energy storage and transfer, acting mainly in the form of adenosine diphosphate (ADP) and triphosphate (ATP) on plants' respiration, photosynthesis, synthesis of nucleic acids and transport of ions through cell membranes (Hopkins, 1995; Fageria, 2009).

The lack of a significant increase in dry matter yield with the addition of cattle manure (Table 1) is possibly due to the predominantly organic form of the N present after incorporation of the manure into the soil (Kiehl, 1999). For N to be assimilated from fresh manure, mineralization or ammonification of the soil organic matter (SOM) must occur first, but in this period the N becomes immobilized by the decomposing microorganisms, which is intimately related to the metabolism of carbon (Aita & Giacomini, 2007). This reduces the availability of nutrients to the plants, principally the C_4 plants, which greatly aid growth and are highly efficient in speeding assimilation of N (Hopkins, 1995).

The effects manure application have also been analyzed by other authors (Scherer et al., 2006; Oliveira et al., 2007). In these studies, was obtained a quadratic effect, showing a significant increase in productivity, except at the highest rates applied, which caused a reduction. Machado et al. (1983) also observed the effect of cattle manure with the application of 20 Mg ha^{-1}, where the yield of two harvests of irrigated rice (*Oryza sativa*) was similar to that of the control plants. In the case of biotite schist, although other authors have found significant enhancement of dry matter yield of sunflowers and soybeans, in other crops such as corn (Resende et al., 2006) there was no significant effect, irrespective of the rate applied. According to Straaten (2007), in biotite schist's structure, the K is present in the phyllosilicates between the tetrahedron layers of Al and octahedron layers of Si or Mg, hindering the nutrient's release and availability to the plants. In this study, the production of DMY with application of biotite was similar to that with application of KCl (Table 1).

Under the edaphoclimatic conditions studied, the seasonal variation of the forage yield of the Massai grass was 61.2% in the spring and summer and 38.8% in the fall and winter. This phenomenon, which occurs in the majority of tropical forage species, is determined mostly by climatic limitations, particularly those caused by water and temperature fluctuations (Müller et al., 2002). The analyses of the DMY of the aerial part showed that the addition of cattle manure raised the concentration of N e K and reduced the Mg (Table 2). The application of natural rock phosphate caused an increase in the P and a reduction in the B, while the addition of biotite schist significantly raised only the K concentration (Table 3). The three types of fertilizers did not influence the concentrations of Ca, S, Cu, Fe, Mn and Zn in the DMY (Tables 2 and 3). The smaller B concentration with the addition of phosphate is possibly due to the limitation of the nutrient itself in the soil, because of the positive interaction of the P and B, enhancing the absorption of the latter (Fageria, 2009).

In the absence of foliar concentration indicated as standards on the evaluation o nutritional state of Massai grass in Brazilian conditions, the average concentrations ir plant tissue (aerial dry matter) presented the following order of macronutrients upt K>N>Mg>P>Ca>S (Table 2), and in the micronutrients themselves the sequence Fe>Mn>Zn>B>Cu (Table 3). Assuming as adequate the nutrient concentratio *Megathyrsus* spp., regardless of the cultivar, were found that the average of N, P, K, M Fe and Zn were above those found by Gallo et al. (1974) and Pinkerton et al. (1997), v those of Ca, B and Mn were considered low (Tables 2 and 3). The application of c manure boosted the content of SOM and available S in the soil, while the pH, availab K, Ca, Mg and exchangeable H+Al were not influenced by the treatments (Table 4). addition of 20 and 40 t ha^{-1} of cattle manure (treatments) increased the organic m content by approximately 2 and 4 t ha^{-1} of C, respectively, without considering the m and manure left by the grazing animals after each cutting. In the case of the enha content of S-SO_4 in the soil verified, it is estimated that over 95% of the S in soi contained in organic compounds, with plant residues and animal droppings constitutin major source. The levels of available P, exchangeable H+Al and SOM increased wit higher rates of natural rock phosphate (Table 4). This enhance of available P to the p was directly related to the natural rock phosphate rates. In the case of exchangeable H considering which ammonia is one of the first products formed, the application of P have been accelerated the initial decomposition of the soil organic matter, increasin soil acidity. When the ammonia is converted into nitrate, H^+ ions are released, tempor raising the exchangeable and non-exchangeable acidity of the soil (Sousa et al., 2007).
The application of biotite schist raised the concentration of exchangeable K in the soil 0.8 mmol$_c$ dm^{-3} to 1.1 mmol$_c$ dm^{-3} (Table 4). Although this rock contains high quantiti Ca (2.8%), Mg (15.1%) and SiO_2 (54.6%) and has a high pH_{H2O} index (8.5), these varia were not influenced ($p > 0.05$) by the treatments. The rock's mineral structure li hinders solubilization of these elements (Straaten, 2007), which are more easily absorb the surface of clays when compared to K. The DMY was positively relationship wit available P and concentration of P and Mg in the dry matter, and negatively with t concentration in the plants (Table 5). The maximum estimated yield was obtained whe concentration of available P in the soil and plants and of Mg in the plants were 29.5 mg ^{3}, 18.3 g kg^{-1} and 14.3 g kg^{-1}, respectively. For the foliar B, the lowest production of D estimated was obtained with a foliar content estimated at 8.5 mg kg^{-1}. In the absenc data, these values can be used a reference to define the suitable levels of these elemen the soil and plants.

LITERATURE CITED

AAO. Manual de Certificação da Associação de Agricultura Orgânica. São Paulo: Associação de Agric Orgânica, 2000. 24p.

Aita, C.; Giacomini, S.J. Matéria orgânica do solo, nitrogênio nos sistemas de exploração agrícol Yamada, T.; Abdalla, S.R.S.; Vitti, G.C. (Eds.). Nitrogênio e enxofre na agricultura brasileira. Piraci Potafos, 2007, p.1-41.

Bataglia, O.C.; Furlani, A.M.C.; Teixeira, J.P.F. et al. Métodos de análise química de plantas. Cam Instituto Agronômico, 1983. 48p.

Castro, C.R.T.; Pires, M.F.A.; Aroeira, L.J. Produção de leite orgânico. Planeta org http:/www.planetaorganico.com.br/trab-leiteorganico.htm. acesso em 27/10/2008.

Fageria, N.K. The use of nutrients in crops plants. Boca Raton: CRC Press, 2009.

Gallo, J.R.; Hiroce, R.; Bataglia, O.C. et al. Composição química inorgânica de forrageiras do Estado d Paulo, Bol. Ind. Animal, 31:115-137, 1974.

Hopkins, W.G. Introduction to plant physiology. New York: John Wiley & Sons, 1995.

Kiehl, E.J. Fertilizantes organominerais. Piracicaba: Degaspari, 1999.

Machado, M.O.; Gomes, A.S.; Turatti, A.L. et al. Efeito da adubação orgânica e mineral na produção do arroz irrigado e nas propriedades químicas e físicas do solo de Pelotas. Pesq. Agropec. Bras., 18:583-591, 1983.

Malavolta, E.; Vitti, G.C.; Oliveira, S.A. Avaliação do estado nutricional das plantas: princípios e aplicações. Piracicaba: Potafós, 1997.

Moreira, A.; Malavolta, E. Fontes, doses e extratores de fósforo em alfafa e centrosema. Pesq. Agropec. Bras., 36:1519-1527, 2001

Müller, M.S. et al. Produtividade do *Panicum maximum* cv. Mombaça irrigado, sob pastejo rotacionado. Sci. Agric., 59:427-433, 2002.

Oliveira, A.P. et al.. Produção da batata doce adubada com esterco bovino e biofertilizante. Ci. Agrotec., 31:1722-1728, 2007.

Pinkerton, A. et al. Pasture species. In: Reuter, D.J.; Robinson, J.B. (Eds.). Plant analysis an interpretation manual. Collingwood: CSIRO, 1997. p287-346.

Resende, A.V. et al. Rochas como fontes de potássio e outros nutrientes para culturas anuais. Espaço & Geografia, 9:135-161, 2006.

Scherer, E.G. et al. Efeito da adubação com esterco de suínos, nitrogênio e fósforo em milho. Florianópolis: EMPASC, 1984.

Sousa, D.M.G. et al. Acidez do solo e sua correção. In: Novais, R.F. et al.. (Eds.). Fertilidade do solo. Viçosa: SBCS. 2007. p.205-274.

Straaten, P. van. Agroecology; the use of rocks for crops. Ontario: Enviroquest, 2007.

Valentim, J.F. et al. Capim Massai (*Panicum maximum* Jacq.); nova forrageira para diversificação das pastagens no Acre. Rio Branco: Embrapa Acre, 2001.

Yost, R.S. et al.. Availability of rock phosphate as measured by an acid tolerant pasture grass and extractable phosphorus. Agr. J., 74:.462-468, 1982.

Werner, J.C. et al. Forrageiras. In: Raij, B. van. et al. Recomendação de adubação e calagem para o Estado de São Paulo. IAC, 1996. p.245-258.

Table 1 - Least square means of dry matter yield (DMY) of Massai grass obtained under different treatments.

Cattle manure	Dry matter yield	Natural rock phosphate	Dry matter yield	Biotite schist	Dry matter yield
Mg ha^{-1}	Mg ha^{-1}	P_2O_5 - kg ha^{-1}	Mg ha^{-1}	K_2O - kg ha^{-1}	Mg ha^{-1}
0	10446.28	0	8929.17b	0	9943.84
20	10075.74	100	10278.86ab	150	9714.94
40	9880.21	200	11194.20a	300	10743.45
Cattle manure		Natural rock phosphate			
40	9800.28	100	9800.28	[illegible]	9800.2[illegible]
Analysis of variance					
Variable					
Cattle manure (a)					
Natural rock phosphate - RNRP (b)					
Biotite schist (c)					
a x b					
a x c					
b x c					
CV%				16.63	

*,NS Significant at the 5% probability and non significant, respectively. [1]Means followed by the same letter in the each column are not significantly different at the 5% probability level by Tukey test. Σ of six harvests.

Table 2 - Least square means of N, P, K, Ca, Mg and S concentration in aerial dry matter o[f] forage (Massai grass) under different treatments.

Variable	N	P	K	Ca	Mg	S
	g kg^{-1}					
Manure, Mg ha^{-1}						
0	**19.53b**	**8.07**	**17.76b**	**6.17**	**17.77b**	**3.25**
20	**20.68ab**	**7.55**	**24.06a**	**6.34**	**13.29a**	**2.99**
40	**20.95a**	**7.53**	**24.59a**	**6.25**	**12.91a**	**2.99**
F test	*****	**NS**	*****	**NS**	*****	**NS**
Phosphate, kg ha^{-1}						
0	19.91	6.70c	21.62	6.27	14.03	3.06
100	20.63	7.64b	21.66	6.22	14.40	2.90
200	20.63	8.82a	23.13	6.26	15.53	3.25
F test	NS	*	NS	NS	NS	NS
Biotite, kg ha^{-1}						
0	20.32	8.04	21.09	6.31	15.50	3.23
150	20.40	7.12	21.13	6.32	14.45	2.99
300	20.44	8.00	24.19	6.12	14.02	3.00
F test	NS	NS	**	NS	NS	NS
CV%	5.56	22.91	21.00	5.89	21.91	15.80
CPK[(2)]	20.37	6.97	27.26	5.65	11.27	2.67

*, **, [NS]Significant at the 5 and 10% probability; and non significant, respectively. Natural rock phosphate – quantity i[n] P_2O_5, biotite schist – quantity in K_2O. [1]Means followed by the same letter in the each column are not significantl[y] different at the 5% probability level by Tukey test. [2]CPK = Cattle manure (40 Mg ha^{-1}), Natural rock phosphate (100 k[g] ha^{-1} of P_2O_5) and potassium chloride (150 kg ha^{-1} of KCl)

Table 3 - Least square means of B, Cu, Fe, Mn and Zn concentration in aerial dry matter o[f] forage (Massai grass) under different treatments.

Variable	B	Cu	Fe	Mn	Zn
	mg kg^{-1}				
Manure, Mg ha^{-1}					
0	6.17	5.89	251.58	65.86	24.49
20	5.94	6.11	284.87	71.17	24.35
40	6.04	6.13	297.61	62.70	24.60
F test	NS	NS	NS	NS	NS
Phosphate, kg ha^{-1}					
0	6.69a	6.03	284.80	65.99	24.99
100	6.11a	5.93	279.57	62.98	24.06
200	5.35b	6.17	299.61	70.84	24.39
F test	*	NS	NS	NS	NS
Biotite, kg ha^{-1}					
0	6.17	5.87	297.31	64.47	23.76
150	5.95	6.12	284.37	69.44	25.02
300	6.04	6.24	282.30	64.50	24.66
F test	NS	NS	NS	NS	NS
CV%	11.98	7.27	20.11	13.61	7.97
CPK[(2)]	6.01	5.88	307.77	88.19	21.81

*, **, [NS]Significant at the 5 and 10% probability levels and non significant, respectively. Natural rock phosphate - quantity in P_2O_5, biotite schist – quantity in K_2O. [1]Means followed by the same letter in the same column are not significantly different at the 5% probability level by Tukey test. [2]CPK = Cattle manure (40 Mg ha^{-1}), Natural rock phosphate (100 k[g] ha^{-1} of P_2O_5) and potassium chloride (150 kg ha^{-1} of KCl).

Table 4 Least square means of pH_{CaCl_2}, P, K, Ca, Mg, H+Al, MOS and $S\text{-}SO_4$.

	Cattle manure, Mg ha^{-1}			F test	CPK[(2)]	CV
	0	20	40			%
pH ($CaCl_2$)	5.92	5.72	5.73	NS	5.77	6.03
P (mg dm^{-3})	21.00	17.22	21.78	NS	23.00	23.86
K (mmol$_c$ dm^{-3})	0.77	0.94	1.19	NS	3.07	19.27
Ca (mmol$_c$ dm^{-3})	41.22	36.33	35.67	NS	37.00	20.32
Mg (mmol$_c$ dm^{-3})	20.22	17.11	17.00	NS	19.33	20.73
H+Al (mmol$_c$ dm^{-3})	20.78	23.11	23.00	NS	21.33	19.83
$S\text{-}SO_4$ (mg kg^{-1})	3.00c	5.33b	8.11a	*	6.00	20.04
MOS (g kg^{-1})	32.78b	34.33ab	35.89a	**	37.00	9.77
	RNRP, kg ha^{-1} - P_2O_5					
	0	100	200			
pH ($CaCl_2$)	5.82	5.78	5.78	NS		
P (mg dm^{-3})	14.56b	19.11b	26.33a	*		
K (mmol$_c$ dm^{-3})	1.24	0.82	0.83	NS		
Ca (mmol$_c$ dm^{-3})	38.00	35.78	39.44	NS		
Mg (mmol$_c$ dm^{-3})	17.78	18.33	18.22	NS		
H+Al (mmol$_c$ dm^{-3})	22.67a	35.22b	35.78b	*		
$S\text{-}SO_4$ (mg kg^{-1})	5.89	5.44	5.11	NS		
MOS (g kg^{-1})	32.00b	35.22a	35.78a	*		
	Biotite schist, kg ha^{-1} - K_2O					
	0	150	300			
pH ($CaCl_2$)	5.76	5.83	5.76	NS		
P (mg dm^{-3})	19.00	22.89	18.11	NS		
K (mmol$_c$ dm^{-3})	0.80b	1.00ab	1.10a	**		
Ca (mmol$_c$ dm^{-3})	37.56	39.56	36.11	NS		
Mg (mmol$_c$ dm^{-3})	18.11	18.22	18.00	NS		
H+Al (mmol$_c$ dm^{-3})	23.44	22.22	21.22	NS		
$S\text{-}SO_4$ (mg kg^{-1})	4.11	6.44	5.89	NS		
MOS (g kg^{-1})	34.56	34.11	34.33	NS		

*, **, NS Significant at the 5 and 10% probability levels and non significant, respectively. [1]Means followed by the same letter in the each line are not significantly different at the 5% probability level by Tukey test. [2]CPK = Cattle manure (40 Mg ha^{-1}), Natural rock phosphate - RNRP (100 kg ha^{-1} of P_2O_5) and potassium chloride (150 kg ha^{-1} of KCl).

Table 5 - Relationship between principal soil and plant chemical properties (x) with forage aerial dry matter yield ($\hat{y}$) of Massai grass[1].

Variables	Regression equation	r
P (mg dm^{-3})	$\hat{y} = 8.422.04 + 132.90x - 2.25x^2$	0.45**
K (mmol$_c$ dm^{-3})	$\hat{y} = 10548.63 - 484.14x$	-0.26^{NS}
$S\text{-}SO_4$ (mg kg^{-1})	$\hat{y} = 10301.68 - 58.32x$	-0.13^{NS}
MOS (g kg^{-1})	$\hat{y} = 6977.94 + 86.74x$	0.18^{NS}
N – DMY (g kg^{-1})	$\hat{y} = 11312.02 - 65.39x$	-0.04^{NS}
P – DMY (g kg^{-1})	$\hat{y} = 1243.57 + 1463.51x - 39.98x^2$	0.66*
K – DMY (g kg^{-1})	$\hat{y} = 8577.53 + 61.878x$	0.17^{NS}
Ca – DMY (g kg^{-1})	$\hat{y} = 17591.16 - 1229.63x$	0.29^{NS}
Mg – DMY (g kg^{-1})	$\hat{y} = 18639.13 - 1274.17x + 44.50x^2$	0.61*
S – DMY (g kg^{-1})	$\hat{y} = 10417.28 - 144.47x$	0.04^{NS}
B – DMY (mg kg^{-1})	$\hat{y} = 10794.49 - 1127.73x$	-0.47*

[1]The values are average of six soils and plant collections. DMY – Dry matter yield.

*, **, NS Significant at the 5 and 10% probability levels and non significant, respectively.