

Selenium in soils of São Paulo state and its application to forage legume

Pedro Henrique de Cerqueira Luz^A, Letícia de Abreu Faria^B, Felipe Barros Macedo^C, Jairo Antônio Mazza^D, Valdo Rodrigues Herling^E and Marcos Roberto Ferraz^F

^AEscola Superior de Agricultura Luis de Queiroz da USP, Piracicaba, SP, Brasil, Email lefaria@usp.br

^BFaculdade de Zootecnia e Engenharia de Alimentos da USP, Pirassununga, SP, Brasil, Email phcerluz@usp.br

^CFaculdade de Zootecnia e Engenharia de Alimentos da USP, Pirassununga, SP, Brasil, Email felipebmacedo@yahoo.com.br

^DEscola Superior de Agricultura Luis de Queiroz da USP, Piracicaba, SP, Brasil, Email jamazza@esalq.usp.br

^EFaculdade de Zootecnia e Engenharia de Alimentos da USP, Pirassununga, SP, Brasil, Email vrherlin@usp.br

^FFaculdade de Zootecnia e Engenharia de Alimentos da USP, Pirassununga, SP, Brasil, Email mrferraz@usp.br

Abstract

The objective of this research was to evaluate Selenium (Se) levels in the form of Sodium Selenate in Selenium-deficient soils applied to *Stylosanthes capitata* cv. Campo Grande analyzing the effects of Se on mineral nutrition of the plant, which has a direct correlation with animal nutrition. The soils used were selected after sampling the main soils in the São Paulo state. The experimental design used was randomized blocks in a factorial 3x3x2 with four repetitions. The treatments comprised of three soils (NITOSSOLO VERMELHO eutroférico, LATOSSOLO VERMELHO Distroférico and ARGISSOLO AMARELO Distrófico Abruptico), three levels of Se (0, 10 and 20 g/ha) and two cuts (30 and 80 days after plant uniformity). The analyses were performed by the proc mixed (SAS, 2004) system. The leguminous presented great capacity of Se absorption, being that the dose of 10 g/ha was enough for the plant to reach the required level for animal nutrition; nevertheless, this increase was followed by reductions of protein levels. The doses did not alter dry matter production; however, they affected the levels of Ca, S, Fe, Mn in the plant. It was observed that soil fertilization with doses of up to 20 g/ha of Se in pastures with legumes can favor Se consumption by animals. This was verified by the reduction of foliar levels as the maturation stage advanced.

Key Words

Brazil, *Stylosanthes capitata*, sodium selenate.

Introduction

Selenium essentiality in plants has been reported by Malavolta (2006), however Se is an essential micronutrient in human and animal nutrition (Terry *et al.* 2000). The geographic origin of the animals is a more important determinant of the Se concentration in beef than the presence or absence of supplemental Se (Hintze *et al.* 2001). Dry matter of forage plants in 12 regions of the São Paulo state, presented levels of 0.076 and 0.052 ppm of Se in the wet and dry seasons respectively, showing general deficiency (Lucci *et al.* 1984). However, data on the soil were not collected, which made it impossible to establish a correlation between Se in the soil and the plant. There is a need for more research to investigate the role of bacteria found in the rhizosphere, which may facilitate selenate absorption through the root, possibly supplying key-protein, besides promoting the conversion of SeCys to SeMet, facilitating, therefore selenite volatility (Terry *et al.* 2000). The deficit of information on Se levels in the soil and the fact that there are factors related to soils which are able to affect its absorption by plants, require the need to verify the behavior of a leguminous forage grass applied to different soils submitted to doses of Se.

Methods

Based on a study on Se in soils of São Paulo state, we investigated the behavior of *Stylosanthes capitata* cv. Campo Grande in Se-deficient soils, submitting them to levels of Se application using the sodium selenate as a source in pots (7 kg) in a greenhouse. The experimental design used was randomized blocks with four repetitions. The treatments comprised of three soils (NITOSSOLO VERMELHO eutroférico, LATOSSOLO VERMELHO Distroférico and ARGISSOLO AMARELO Distrófico Abruptico), three levels of Se (0, 10 and 20 g/ha) and two cuts (30 and 80 days after plant uniformity). The statistical analyses were performed by the proc mixed (SAS, 2004) system. The averages were compared utilizing orthogonal contrasts and significance level of 10%.

Results

The soils evaluated did not present Se levels high enough to supply desirable amounts to the forage plants (Table 1), considering the requirement of 100 µg/kg of Se in the dry matter for beef cattle (NRC 2000). The criterion of deficiency is defined whenever there is less than 500 µg/kg of Se in the soil (Millar 1983).

Table 1. Chemical analyses for soils from depths of 0-20 and 20-40 cm.

Soils classification	Localization	Prof.	pH	M.O	P	S	K	Ca	Mg	H+Al	Al	CTC	SB	V	m	B	Cu	Fe	Mn	Zn	Se soil	Se plant
		(cm)	CaCl ₂	g.dm ⁻³	mg.dm ⁻³																	
ARGISSOLO AMARELO Distrófico Abrupto	22°38,366'S 47°49,852'W	0-20	4,4	14	4	6	1,1	6	3	30	3	40	10	25	21	0,15	1,3	73	2,1	0,7	67,9	10,4
		20-40	4,5	15	3	8	0,4	7	3	24	1	34	10	30	12	0,13	1,1	60	2,9	0,3	84,6	
NITOSSOLO VERMELHO Eutroférrico	22°42,407'S 47°37,438'W	0-20	5,5	27	5	12	5,2	41	6	27	-	79	52	66	-	0,19	7,5	28	28,5	1,9	220,2	61
		20-40	5,2	21	4	13	3,5	24	5	29	1	62	33	53	4	0,16	6,2	15	21,1	0,9	219,4	
CAMBISSOLO HÁPLICO Tb Álico	22°38,404'S 47°49,024'W	0-20	5,5	31	7	17	1,7	58	8	35	-	103	68	66	-	0,24	1,9	75	50	3,5	108	62,5
		20-40	5,3	24	5	12	1,2	55	9	35	-	100	65	65	-	0,16	1,7	53	49,5	2,1	138,4	
NEOSSOLO QUARTZARÊNICO Distrófico	22°04,961'S 47°34,736'W	0-20	4,7	18	3	8	0,5	8	4	31	1	43	12	29	7	0,08	1,3	43	0,9	0,5	159,6	79,7
		20-40	4,4	19	3	7	0,3	4	3	41	4	48	7	15	36	0,16	1,4	51	0,6	0,9	142,1	
GLEISSOLO HÁPLICO Tb Distrófico	22°15,054'S 47°52,044'W	0-20	4	65	6	6	0,4	3	2	240	5	245	5	2	49	0,36	1,9	76	0,6	0,7	80,3	58,5
		20-40	3,9	32	4	6	0,3	5	3	105	1	113	8	7	12	0,21	2,1	34	0,2	0,3	72,9	
LATOSSOLO AMARELO Distrófico textura média	21°56,630'S 47°28,506'W	0-20	5,5	24	4	8	1,1	39	6	23	-	69	46	67	-	0,16	1,8	39	2,9	3,4	77,6	46,3
		20-40	5,4	20	3	10	1,0	29	5	20	-	55	35	64	-	0,13	1,6	22	1,1	0,6	101,7	
LATOSSOLO VERMELHO Distroférrico	21°57,768'S 47°26,866'W	0-20	5,3	28	33	9	1,2	40	8	29	1	78	49	63	2	0,16	8,3	40	7,1	5,7	197,1	61,9
		20-40	5,3	21	9	8	0,9	21	4	27	1	53	26	49	4	0,10	6,3	22	6	1,8	158,8	
ARGISSOLO AMARELO Latossólico Distrófico	21°35,278'S 48°26,054'W	0-20	4,2	12	2	5	2,6	7	4	128	1	142	14	10	7	0,10	0,8	11	2,6	0,2	97,8	65,1
		20-40	4,2	12	2	5	2,3	6	3	151	2	162	11	7	17	0,07	0,6	10	1,3	0,1	80,5	

Table 2. Chemical analyses of *Stylosanthes capitata* submitted to Se treatments during the period (Averages followed by the same letter in the column did not statistically differ from one another by the Tukey (10%) test.

		P	S	K	Ca	Mg	Cu	Fe	Mn	Zn	Se
		g.kg ⁻¹					mg.kg ⁻¹				µg.kg ⁻¹
Doses of Se (g/ha)	0	1,2 ^a	1,0 ^b	37 ^a	18 ^b	1,8 ^a	8 ^a	56,4 ^b	60,9 ^{ab}	96 ^a	34,8 ^b
	10	1,3 ^a	1,2 ^b	37 ^a	18 ^b	1,8 ^a	9 ^a	52,8 ^b	58,6 ^b	99 ^a	113,6 ^{ab}
	20	1,3 ^a	1,4 ^a	37 ^a	20 ^a	1,8 ^a	9 ^a	68,6 ^a	70,2 ^a	89 ^a	135,9 ^a
Evaluation time (days)	30	1,1 ^a	1,1 ^a	45 ^a	21 ^a	1,9 ^a	9 ^a	66,0 ^a	46,7 ^b	119 ^a	159,8 ^a
	60	1,5 ^a	1,4 ^a	29 ^b	17 ^b	1,7 ^b	9 ^a	52,6 ^b	79,7 ^a	71 ^b	29,8 ^a

The doses applied provided a curved linear response in foliar Se levels. There was reduction from 160 µg/g in the first cut to 30 µg/g in the second cut. Se levels decrease as the maturation stage advances (Correia 1986). The Se doses had an effect on levels of S, Ca, Fe and Mn in the plant (Table 2). The average S levels in the plant were low (Raij *et al.* 1996) as a consequence of the absence of S in the fertilizer. However the treatments with Se doses (p=0.0001) presented a positive linear effect in S concentration (Table 2) against the expectation of a reductions which due to competition for the same absorption paths as Se (Malavolta 1980). Selenate is the predominant form of Se in plant absorption and, unlike selenite, in the soil, it does not attach to Fe which may have allowed for higher absorption by Fe oxides due to selenate application. Among the chemical attributes related to soil fertility, only P, Mn and Zn showed response to the doses, while Se levels in the soil showed only a tendency to decrease (Table 3).

Table 3. Average levels of chemical attributes of soil fertility for the soils cultivated with *Stylosanthes capitata* and submitted to Se treatments (Averages followed by the same letter in the column did not statically differ from one another by Tukey 10% test).

Doses of Se (g.ha ⁻¹)	pH	M.O.	P	S	K	Ca	Mg	H + Al	Al	CTC	SB	V	m	B	Cu	Fe	Mn	Zn	Se
	CaCl ₂	g.dm ⁻³	mg.dm ⁻³																µg.kg ⁻¹
0	5,2 ^a	26 ^a	24 ^b	6 ^a	2,1 ^a	21 ^a	7 ^a	27 ^a	1 ^a	57 ^a	30 ^a	51 ^a	4 ^a	0,17 ^a	5,8 ^a	39 ^a	9,3 ^a	6,1 ^b	38,4 ^a
10	5,3 ^a	27 ^a	29 ^a	5 ^a	2,0 ^a	20 ^a	7 ^a	25 ^a	1 ^a	52 ^a	28 ^a	55 ^a	6 ^a	0,21 ^a	4,8 ^a	40 ^a	7,4 ^a	6,7 ^a	34,1 ^a
20	5,2 ^a	26 ^a	24 ^b	6 ^a	1,9 ^a	19 ^a	7 ^a	25 ^a	1 ^a	54 ^a	29 ^a	53 ^a	5 ^a	0,21 ^a	5,6 ^a	43 ^a	11,1 ^a	6,1 ^b	23,8 ^a

Among the soils evaluated, there were differences in the Se levels in the plants (p=0.0010) and in the soil (p=0.0004), as shown in Figure 1. The levels obtained in the soils (Figure 1) are low, considering the deficiency criterion (Millar 1983) which suggests low levels whenever they are lower than 500 µg/kg. Despite the low levels in the soil, the foliar levels of the plants receiving Se doses were high enough to supply the minimum requirements for animal nutrition, considering the requirement established by NRC (1996) for beef cattle which is 100 µg/kg of Se in the dry matter.

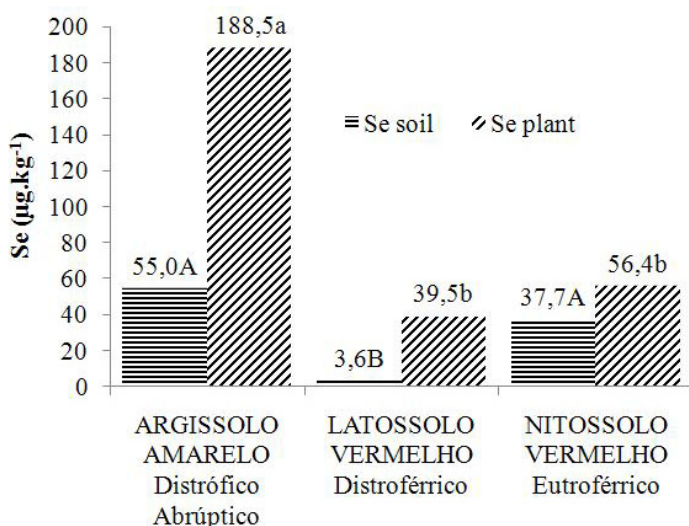


Figure 1. Average levels of Selenium in the soil and in *Stylosanthes capitata* submitted to treatments with Se (Averages followed by the same letter in the column did not statically differ from one another, Tukey 10% test).

There is a relationship between the Se in the soil and the Se in the plants (Robberecht *et al.* 1981). The relationship ($y = 2.563x + 12.51$) has a correlation coefficient of 0.675. The results obtained for the plants demonstrated the possibility of supplementing Se to animal diets through Se application via fertilizer. There is a possibility to elevate Se levels in the blood of animals through the increase of Se levels in pasture with more efficiency than through mineral supplements to animals (Selênio 2002). The production of dry matter, the residual dry matter and evaluations of plant roots, such as length and weight, did not show effects from Se application. The crude protein level responded to the treatments ($p = 0.0195$) presenting a decreasing linear behaviour with the averages 10.4; 9.4 and 8.8% for the control (0 g/ha of Se) and doses of 10 and 20 g/ha of Se respectively. The control value is significantly different from the highest dose, following the equation $y = -0.8x + 11.13$ ($R^2 = 0.979$). The CP reduction in the plants due to the increase of Se level can be explained by the connection of this element with the UGA codon codification, suggested as an agent for ceasing protein synthesis. This interpretation requires further in-depth studies in the genetics field (Hatfield *et al.* 1992). We can not disregard any intervention of Se in the biological fixation process.

Conclusion

Some of the main soils in São Paulo state have low levels of Se. The Se dose applied did not alter the solubility of the element in the soils, but the dose of 10 g/ha was enough for plants to reach the required level for animal nutrition, but this increase was associated with a reduction in the level of protein. The doses did not affect dry matter production; however, they changed the chemical composition of the plant interfering in levels of Ca, S, Fe and Mn. Se supply through fertilization is effective in elevating foliar levels of Se in *Stylosanthes capitata* cv. Campo Grande. Soil fertilization with doses up to 20 g/ha of Se to pastures may increase Se consumption by animals, however, the reduction of foliar levels from the first to the second cut must be considered.

References

- Correia AAD (1986) Bioquímica nos solos, nas pastagens e forragens. In 'Lisboa: Fund. Calouste Gulbenkian'. pp.240-254.
- Hatfield D, Choi IS, Mischke O, Owens LD (1992) Selenocysteyl-tRNAs recognize UGA in Beta vulgaris, a higher plant, and in Gliocladium virens, a filamentous fungus. *Biochemical and Biophysical Research Communications* **184**, 254-259.
- Hintze KJ, Lardy GP, Marchello MJ, Finley JW (2001) Areas with high concentrations of selenium in the soil and forage produce beef with enhanced concentrations of selenium. *Journal of Agricultural and Food Chemistry* **49**, 1062-1067.
- Lucci CS, Moxon AL, Zanetti MA, Franzolin Neto R, Maracomini DG (1984) Selênio em bovinos leiteiros do estado de São Paulo. II. Níveis de selênio nas forragens e concentrados. *Revista da Faculdade de Medicina Veterinária e Zootecnia da Universidade de São Paulo* **21**, 71-76.
- Malavolta E Selênio (1980) In 'Elementos de Nutrição Mineral de Plantas' (Ed Agrônômica Ceres). pp. 211-

- Malavolta E Selênio (2006) In Manual de nutrição mineral de plantas. (Ed Agronômica Ceres) pp. 396-401.
- Millar KR (1983) Selenium In 'The Mineral Requirements of Grazing Ruminants' (Ed Grace ND) pp. 38-47. (New Zealand Society of Animal Production: New Zealand).
- National Research Council - NRC. (2000) 'Nutrient Requirements of Dairy Cattle'. 7 edition. (National Academy of Sciences: Washington, D.C.).
- Raij B van, Cantarella H, Quaggio JA, Hiroce R, Furlani MC (1996) 'Recomendações de adubação e calagem para o Estado de São Paulo'. 2. edition. Campinas: Instituto Agronômico. (IAC. Boletim Técnico, 100).
- Robberecht H, Vanden Berghe D, Deelstra H (1981) Selenium in the Belgian soils and its uptake by ray-grass. *Pedosphere* **16**, 646-653.
- SAS Institute Inc. (2004) 'SAS OnlineDoc® 9.1.3'. (SAS Institute Inc.: Cary, NC).
- Selênio Tradução condensada de "Fertilizer International", maio/jun 2002, por Fernando P. Cardoso. Disponível em: <<http://www.abcz.org.br>>. Acesso em: 21 ago. 2006.
- Terry N, Zayed AM, Souza MP, Tarun S (2000) Selenium in higher plants. *Annual Review of Plant Physiology and Plant Molecular Biology* **51**, 401-432.