academicJournals

Vol. 9(19), pp. 1461-1466, 8 May, 2014
DOI: 10.5897/AJAR2014. 8505
Article Number: 9E39DB344532
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Phosphorus and potassium fertilization in culture of soybean plants in the Oxisol

Leandro Rampim[1]*, Rubens Fey[2], Maria do Carmo Lana[1], Marcos Vinícius Mansano Sarto[3], Jean Sérgio Rosset[4], André Luiz Piva[1], Éder Júnior Mezzalira[1], Jessica Koppo[1], Paulo Vitor Dal Molin[1], Jeferson Klein[5], Jolimar Antonio Schiavo[6], Jaqueline Rocha Wobeto[1], Adriano Mitio Inagaki[1] and Thaísa Muriel Mioranza[1]

[1]State University of West Parana, Unioeste, CCA/PPGA, Pernambuco Street No. 1777, P.O. Box 9, Zip Code 85960-000, city of Marechal Candido Rondon, Parana state, Brazil.
[2]Federal University of South Border - UFFS, city of Laranjeiras do Sul, Parana state, Brazil.
[3]State University Paulista Júlio de Mesquita Filho - UNESP, Lageado Farm, Alcides Soares Highway, Km 3, Zip Code 18610-300, city of Botucatu, São Paulo state, Brazil.
[4]Federal Institute of Education, Science and Technology of Parana, Civica Avenue, 475, Civic Center, Zip Code 85935-000, city of Assis Chateaubriand, Parana state, Brazil.
[5]Professor, Pontifical Catholic University, PUC, city of Toledo, Parana state, Brazil.
[6]State University of Mato Grosso do Sul, city of Aquidauana, Mato Grosso do Sul state, Brazil.

Received 13 January, 2014; Accepted 16 April, 2014

It is recommended to use phosphorus and potassium fertilization on soybean; however it has been common to verify the absence of effect on crop productivity, especially in no-tillage system. Thus, the study aimed to evaluate the effect of doses of superphosphate and potassium chloride in the leaf tissue nutrient content and yield of soybean growing in Oxisol. The experiment was installed in October 2011 in a randomized block design in split-bands with two factors (4x4), with four replications, totaling 64 plots, being Factor 1 with doses of superphosphate (0, 136, 331 and 700 kg ha^{-1}) at sowing and Factor 2 with doses of potassium chloride (0, 160, 320 and 800 kg ha^{-1}) released with cultivar Vmax RR (SYN 7059RR). In the experiment, the variables evaluated were Ca, Mg, K, P, S, Cu, Zn, Mn and Fe in leaf tissue and grain yield. The fertilization with superphosphate and potassium chloride do not interfere in leaf nutrient content and yield of soybean cultivar Vmax RR (SYN 7059RR) grown on an Oxisol of clayey with levels of P and K classified as high. In these cases, it is advisable to keep only the maintenance fertilization according to the values of P and K exported by grain.

Key words: Chemical fertilizer, tillage systems, organic mineral fertilizer, superphosphate, potassium chloride.

INTRODUCTION

The soybean (*Glycine max* L.) constitutes the most important oilseed grown as protein source in the world (AGRIANUAL, 2009). On the world stage, Brazil is the second largest producer and a major exporter of grains

*Corresponding author. E-mail: rampimleandro@yahoo.com.br

Table 1. Chemical and texture attributes of the Oxisol collected in the 0-0.2 m depth layer Guaira – PR, 2011.

$pH^{(1)}$	C	$P^{(4)}$	$Ca^{2+(2)}$	$Mg^{2+(2)}$	$K^{+(4)}$	$Al^{3+(2)}$	$H+Al^{(3)}$	SB	CTC
	$g\ dm^{-3}$	$mg\ dm^{-3}$	--------------------- $cmol_c\ dm^{-3}$ -----------------------						
5.50	19.09	11.50	8.14	1.58	0.82	0.00	4.28	10.54	14.82
$Cu^{(4)}$	$Zn^{(4)}$	$Fe^{(4)}$	$Mn^{(4)}$	$S^{(5)}$	V	Clay $^{(6)}$	$Silt^{(6)}$	$Sand^{(6)}$	
------------------ $mg\ dm^{-3}$ ------------------					%	------------- $g\ kg^{-1}$ -------------			
11.50	4.40	22.00	254	9.50	71.12	660	200	140	

(1) pH in $CaCl_2$, the ratio 1:2.5, (2) Extractor KCl 1 mol L^{-1}, (3) Extractor calcium acetate 0.5 mol L^{-1} pH 7.0, (4) puller Mehlich-1 , (5) Extractor Ca (H_2PO_4) 2 500 mg L^{-1} P in (HOAc) 2 mol L^{-1}, (6) the hydrometer method (EMBRAPA, 2009).

(USDA, 2013; IBGE, 2013). Among the cultural practices, increased amounts of fertilizer especially potassium and phosphate have been used to achieve increases in productivity (Malavolta, 2006). These elements have a very important role for increasing soybean yield since the phosphorus (P) acts as a constituent of stores high energy compounds such as adenosine triphosphate (ATP) and potassium (K) acts as an activator of enzymes and osmotic regulation (Taiz and Zeiger, 2013).

For the phosphorus, the mobility in the soil is minimal causing accumulation of P over a few years of cultivation through the residual effect or left of the preceding year not used by the plant as well as because due to dry matter accumulation on the surface of soil and organic matter in the topsoil (Novais et al., 2007; Rosolem and Merlin, 2011). According to Galvani et al. (2008) and Olibone and Rosolem (2010), the dynamics of soil P can be modified on systems with no-tillage, in the case of P applied to the soil surface to optimize the operation of machines, detecting elevation of P bound to calcium and organic carbon. Fontana et al. (2008) observed decreased adsorption and precipitation of P in Red Hapludox managed under no-tillage soybean/oats succession. The adoption of management systems that provide an increase in the content of soil organic matter may decrease the adsorption P, the formation of complexes that block adsorption sites on the surface of iron oxides and aluminum (Tirloni et al., 2009). The use of cover crops can cause an increase in no-tillage, the levels of total organic carbon and thereby decreasing the adsorption of phosphate and foster the levels of Prem (Pereira et al., 2010).

On the other hand, potassium fertilization on soybean has been performed at sowing (Bernardi et al., 2009). However, due to the salt effect and high solubility of potassium salts commonly used, this practice has led to often reduce plant growth because salinity near the roots to the point that it has been used to haul the application especially in high doses (EMBRAPA, 2010).

According to Marschner (2012), K is the second mineral nutrient required by plants in terms of quantity but is not incorporated into the soil organic matter with a straw and significant reservoir of K in the short-term tillage system (SPD) (Rosolem et al., 2003).

It is an opportunity to check the response of potassium and phosphorus fertilization as the yield potential of soybeans increases especially in no-till which has gradual recovery of organic matter in addition to improving the physical, chemical and biological soil system detecting whether to perform the correction fertilization to increase soil fertility or its relevant only perform maintenance fertilization.

Thus, the study aimed to evaluate the effect of doses of superphosphate and potassium chloride in the leaf tissue nutrient content and yield of soybean cultivar Vmax RR (SYN 7059RR) grown on an Oxisol.

MATERIALS AND METHODS

This research was performed in Guaira western Paraná with the following coordinates 24° 21'S and 54° 10'W with an altitude of 259 m. The farm uses no tillage for 25 years in succession of crops using soy in summer and wheat /corn in the winter. The soil in the area is classified as Oxisol very clayey (EMBRAPA, 2013) and the particle size characteristics of the soil and the result of the chemical analysis of the property are shown in Table 1.

According to the Climate Division of the State of Paraná, the region is under the influence of the climate Cfa (humid tropical zone) well distributed rainfall during the year and hot summers with maximum average annual temperature of 28.5ºC and average minimum of 16.6°C (Caviglione et al., 2000). The rainfall recorded during the conduct of the experiment between October 2011 and February 2012 was 997 mm (Figure 1).

The experiment was conducted under direct seeding system and the area was previously occupied by wheat crop during the winter. Soybean cultivation was performed 20 days after wheat harvest with sowing in seven October 2011 in six lines with five feet long spaced 0.45 m. The plots were evaluated total area of 13.50 m^2 and floor area of 5.40 m^2 for the soybean crop excluding 0.5 m of edging and a line on each side.

The installation of the experiment was performed in October 2011 in randomized block design on track with two factors (4×4) with four replications totaling 64 experimental plots. Factor 1 corresponds to the phosphorus fertilizer in the form of single superphosphate (SFS: 18% P_2O_5): 0, 136, 331 and 700 kg ha^{-1} of chemical fertilizer applied at sowing. For Factor 2, four doses of potassium chloride (KCl: 60% K_2O) were used 0, 160, 320 and

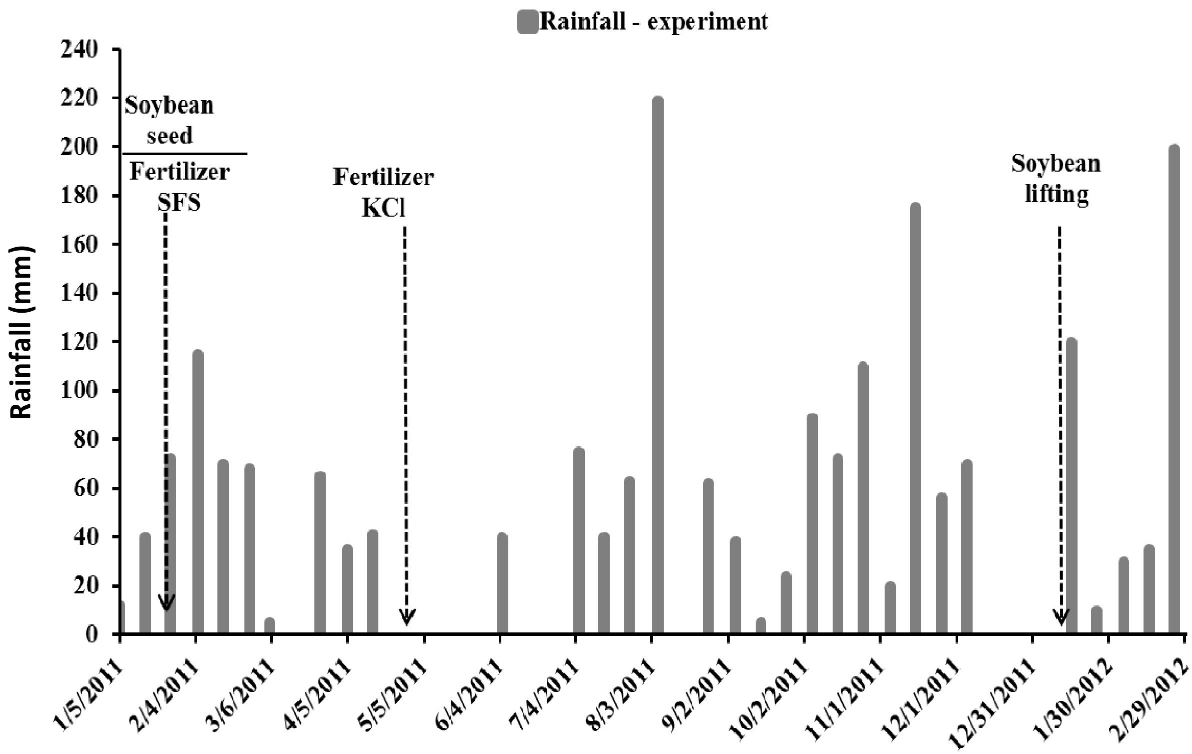

Figure 1. Rainfall (mm) in the experimental area during the conduct of soybean between 10/01/2011 to 03/01/2012.

800 kg ha^{-1} of fertilizer being applied to haul on November 11, 2011 during Stage V4 vegetative soybean crop.

In conducting the experiment carried out in the summer of 2011/12 which made soybean seeding more appropriate for the region transgenic variety Vmax RR (SYN 7059RR) as agroclimatic zoning of Paraná (MAPA, 2011). For seed treatment fungicide Maxim XL (25 g l^{-1} with fludioxonil and 10 g l^{-1} with metalaxyl-M) at a dose of 100 mL per 100 kg of soybean used and the monitoring of pests diseases and weeds was performed according to the recommendations for soybean (EMBRAPA, 2010).

Soybean leaf samples was collected in full bloom as recommended procedures regarding the time and leaves sample according to Malavolta et al. (1997) for the determination of Ca, Mg, K, P, S, Cu, Zn, Mn and Fe (EMBRAPA, 2009) and total nitrogen (Tedesco et al., 1995). At the point of collection, the aerial part of soybean collected on February 15, 2012 was held on the threshing thrashing Winner B-150 to obtain the grain. Grain samples were measured in mass in order to determine productivity with subsequent standardization of the moisture content of the grain samples to 14%.

Statistical analysis of results was performed with the aid of SAEG 8.0 software (SAEG, 1999), data were subjected to analysis of variance, significant doses of SFS and KCl affect analysis were conducted using regression. Models were tested based on the F test significance considering the levels of 5 and 1% probability.

RESULTS AND DISCUSSION

The highest volume of precipitation concentrated in the month of November at the vegetative stage of soybean and in late February after harvest and lower values in the months of December 2011 and January 2012 (Figure 1). At the time of flowering, grain filling decreased soil water due to the occurrence of periods with no rain. The average yield obtained in the experimental area was 2,689.76 kg ha^{-1} closed to the national average (IBGE, 2013), that is the situation of culture in Brazil and assessment opportunity of the effect of fertilizers.

When analyzing the results, the absence of response to application of superphosphate (SFS) and potassium chloride (KCl) both as foliar nutrient concentrations in grain yield was verified (Tables 2 and 3). The levels found in leaves are suitable within the sufficiency range for soybeans for all nutrients (EMBRAPA, 2003) including the control treatment, except magnesium which was observed in the range of low level averaging 2.08 (sufficiency range: 2.60 to 10.00 g kg^{-1}).

Lack of action of fertilization with phosphorus (P) and potassium (K) are probably due to the experimental areas that have soil with high nutrient content (Malavolta, 2006) as shown in Table 1. These results corroborate with other authors as Fontoura et al. (2010) in soybean who found no activity of phosphate fertilizers on yield of annual crops in crop rotation on soil with high P content (8.7 mg dm^{-3}) system.

When analyzing data of Table 3, it was verified interaction with respect to the application of KCl and SFS, comprising the use of a multiple linear equation for foliar Ca content, but there was no significant effect on any of the possible equations to represent the effect doses of SFS and KCl in Ca content of the use of higher doses of

Table 2. F values, coefficient of variation (CV%) and phosphorus (P), potassium (K), sulfur (S), calcium (Ca) and magnesium (Mg) in the leaf tissue of soybean, arising from the application of increasing doses superphosphate (SFS) and potassium chloride (KCl) in soybeans in crop year 2011/2012 Guaira - PR 2012.

Source of variation	P	K	S	Ca	Mg
	---------------------------------- g kg^{-1} -----------------------------				
Factor SFS					
--- kg ha^{-1} P_2O_5 ---					
0	4.87	22.16	3.29	7.47	2.03
136	4.88	20.44	3.31	7.56	2.00
331	4.66	21.52	3.33	7.98	2.16
770	4.95	20.76	3.67	8.26	2.15
Factor KCl					
--- kg ha^{-1} K_2O ---					
0	4.79	21.42	3.49	7.97	2.32
80	4.81	21.39	3.05	8.01	1.97
160	4.85	21.01	3.45	7.75	1.99
320	4.87	21.04	3.58	7.52	2.04
			Mean		
	4.83	21.21	3.39	7.81	2.08
		F Test			
Fator SFS	1.13^{ns}	0.83^{ns}	1.26^{ns}	1.03^{ns}	1.00^{ns}
Fator KCl	0.06^{ns}	0.05^{ns}	0.58^{ns}	0.08^{ns}	1.12^{ns}
SFS x KCl	0.52^{ns}	0.91^{ns}	0.52^{ns}	2.78*	1.66^{ns}
$C.V._{SFS}$ (%)	11.54	14.93	20.32	19.02	17.78
$C.V._{KCl}$ (%)	19.69	17.98	29.86	32.00	32.16
$C.V._{SFS\ x\ KCl}$ (%)	14.01	11.02	22.64	17.04	27.44

* And **: significant at 5% and 1%, respectively, by F test ns not significant at the 5% level by F test.

SFS provided greater amount of Ca in the leaf tissue of soybean, probably by the roots have absorbed Ca soluble fertilizer (Ferdandes, 2006).

However, with increasing doses of KCl and tended to reduce the levels of Ca, a fact that can be directly related to competition for absorption of cations by roots of soybean (Novais et al., 2007). At elevated K occur in the soil, derived KCl, may have been competition between K and Ca cations to be absorbed, so that the increasing levels of KCl does not reflect in a significant increase in Ca content (Table 2).

The magnesium content may have the same explanation given to calcium since these nutrients have similarities to the soil behavior and potassium suffers from competition with the soil (Novais et al., 2007) (Table 1). The Mg content contained in soybean leaves in the control was approximately 15% higher than those who received doses of potassium (Table 2). This result corroborates with the findings from Scherer (1998) who observed an increase of the Mg content in soybean leaves with the decrease in K availability in the soil.

In several recent works, no effect has been observed with the use of phosphate and potassium fertilization on soybean in areas with tillage (Sfredo, 2008; Guareschi et al., 2008; Pauletti et al., 2010; Vieira et al., 2013). For example, in the State of Paraná, Sfredo (2008) states that for the system of succession soybean / wheat-oats-barley-corn double-cropping system was suppressed with P and K fertilization for soybean in SPD in soil with phosphorus above 18.0, 14 and 9 mg dm^{-3} in soils with less than 20% clay, 20% to 40% and more than 40%, respectively, and potassium when content was above 0.30 $cmol_c$ dm^{-3}. Vieira et al. (2013) that analyzed 15 experiments, also concluded that if the content of P in the soil is equal to or greater than 6 mg dm^{-3} and K less than 0.30 $cmol_c$ dm^{-3}, it was possible to establish relative income above 90% for the soybean crop in Oxisol with over 15 years of tillage.

Likewise, Guareschi et al. (2008) observed that the yield of soybean under Dystroferric Red Latosol was also similar in the presence or absence of fertilization with P and K. In Oxisol cultivated with soybean for seven years (Pauletti et al., 2010), the productivity of the soybean crop was not affected by phosphorus and potassium fertilization in situations in which the content of P and K were considered high and medium in ground,

Table 3. F values, coefficient of variation (CV%) and-copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) in leaf tissue of soybean and grain yield, arising from the application of increasing doses of superphosphate (SFS) and potassium chloride (KCl) in soybeans in crop year 2011/2012 Guaira - PR 2012.

Fonte de Variação	Cu	Zn	Mn	Fe	Yield
	-------------------- mg kg^{-1} --------------------				--- kg ha^{-1} ---
Factor SFS					
--- kg ha^{-1} P_2O_5 ---					
0	16.47	44.69	74.31	160.13	2,712.03
136	15.77	42.83	74.71	161.03	2,485.18
331	15.71	37.66	74.23	177.12	2,811.11
770	14.73	41.08	63.11	158.13	2,711.11
Factor KCl					
--- kg ha^{-1} K_2O ---					
0	14.93	36.25	66.66	154.22	2,808.64
80	14.89	47.17	77.16	162.79	2,519.38
160	16.30	39.58	69.98	163.96	2,649.38
320	16.56	43.27	72.56	175.45	2,741.97
Mean					
	15.67	43.27	72.56	164.45	2,689.76
F test					
Fator SFS	1.48^{ns}	0.96^{ns}	3.12^{ns}	0.67^{ns}	1.46^{ns}
Fator KCl	0.87^{ns}	0.79^{ns}	1.05^{ns}	0.36^{ns}	1.99^{ns}
SFS x KCl	1.17^{ns}	0.71^{ns}	1.53^{ns}	1.78^{ns}	0.39^{ns}
$C.V._{SFS}$ (%)	16.69	29.34	17.89	26.11	17.02
$C.V._{KCl}$ (%)	25.81	51.07	24.14	35.44	13.26
$C.V._{SFS\ x\ KCl}$ (%)	20.77	34.07	35.14	29.33	13.86

* and **: significant at 5% and 1%, respectively, by F test ns not significant at the 5% level by F test.

respectively. These results demonstrate the importance of the role of organic matter cycling and accumulation of nutrients in surface-tillage system, and make them available in the organic plant uptake forms (Rosolem and Merlin, 2011), providing sustainability in soybean. This situation demonstrates lack of response of fertilization in soils with high fertility allowing omission of maintenance fertilization during cultivation, reaching situations that allow seven years of cultivation in the absence of fertilization (Pauletti et al., 2010). However, it should be noted that the nutrients extracted by crops are not fully supplied by the existing cycling in sustainable farming systems such as no-tillage, with fertilization being essentially maintained.

The neutrality of the content of most nutrients in leaf tissue and soybean yield before the doses of P and K (Tables 2 and 3) also show that the demand of nutrients required by the cultivar used which was supplied is extremely important as it can be diagnosed with cultivar, had nutritional condition to express their potential especially at conditions in which the work was grown. Recently, Alcantara-Neto et al. (2010) detected quadratic response of grain yield to P levels in Oxisol cultivated for only two years with annual culture in area of degraded pasture with maximum yield at a dose of 94.8 kg ha^{-1} of P_2O_5.

It is noteworthy still, that the absence of interference in productivity with the use of phosphorus and potassium fertilization is also related to the ability of the roots of soybean plants act in depth, a fact that provides culture, explore the soil volume in which lets meet demand nutritional (Castro and Kluge, 1999), even with high horizontal variability for chemical P and K existing in agricultural soils due to fertilization in the seed (Schlindwein and Anghinoni, 2000) online, especially in cultivated soils in tillage (Rosolem et al., 2003; Olibone and Rosolem, 2010).

In general, crops in areas with incorporated fertility and tillage performed with crop rotation, fertilization maintenance shall be the focus in fertilization correction. Excessive use of fertilizers on the basis of P and K may reduce the absorption of other nutrients as observed in this study with Ca and Mg. However, in the case of the state of Paraná, there are few sources of reference to guide practitioners as to maintain doses that should be applied based on soil nutrient uptake by soybean.

Conclusions

The fertilization with superphosphate and potassium chloride do not interfere in leaf nutrient content and yield of soybean cultivar Vmax RR (SYN 7059RR) grown on an Oxisol of clayey with levels of P and K classified as high. In these cases, it is advisable to keep only the maintenance fertilization according to the values of P and K exported by grain.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

Authors acknowledge the coordination of improvement of Higher Education Personnel (CAPES), National Council for Scientific and Technological Development (CNPq) and Araucaria Foundation for Scientific and Technological Development of Paraná (Araucaria Foundation) for their support.

REFERENCES

AGRIANUAL (2009). Anuário da Agricultura Brasileira. IFNP: São Paulo.

Alcantara-Neto F, Gravina GA, Souza NOS, Bezerra AAC (2010). Phosphorus fertilization in the soybean crop at the micro region of Alto Médio Gurguéia. Rev. Ciência Agron. Fortaleza 41(2):266-271.

Bernardi ACC, Oliveira Júnior JP, Leandro WM, Mesquita TGS, Freitas PL, Carvalho MCS (2009). Potassium fertilization of soybean, pearl millet, and cotton in a no-till rotation system in the cerrado region. Pesqui. Agropecuária Trop. Goiânia 39(2):158-167.

Castro A, Kluge G (1999). Ecofisiologia de cultivos anuais: trigo, milho, soja, arroz e mandioca. Editora Nobel, São Paulo, P. 126.

Caviglione JH, Kiihl LRB, Caramori PH, Oliveira D (2000). Cartas climáticas do Paraná. Londrina: IAPAR.

EMBRAPA (2003). Empresa Brasileira de Pesquisa Agropecuária. Tecnologias de produção de soja: Região Central do Brasil 2004. Londrina, EMBRAPA SOJA, P. 239

EMBRAPA (2009). Empresa Brasileira de Pesquisa Agropecuária. Manual de análises químicas de solos, plantas e fertilizantes. 2nd ed. Brasília, Informação Tecnológica, P. 628.

EMBRAPA (2010). Empresa Brasileira de Pesquisa Agropecuária. Tecnologias de produção de soja região central do Brasil 2011. Londrina: EMBRAPA Soja: EMBRAPA Cerrados: EMBRAPA Agropecuária Oeste, P. 255.

EMBRAPA (2013).Empresa Brasileira de Pesquisa Agropecuária. Sistema brasileiro de classificação de solos. 3rd ed. Brasília, EMBRAPA, P. 353.

Ferdandes MS (2006). Nutrição mineral de plantas. Sociedade Brasileira de Ciências do Solo, Viçosa, P. 432.

Fontana A, Pereira MG, Salton JC, Loss A, Cunha TJF (2008). Carbon, light organic matter and remaining phosphorus in different soil management systems. Rev. Bras. Agrociência 14(1):1-6.

Fontoura SMV, Vieira RCB, Bayer C, Ernani PR, Moraes RP (2010). Agronomic performance of phosphate fertilizers in an oxisol under no-tillage. Rev. Bras. Ciência do solo, Viçosa 34(6):1907-1914.

Galvani R, Hotta LFK, Rosolem CA (2008). Phosphorus sources and fractions in an oxisol under no-tilled soybean. Sci. Agrícola Piracicaba 65(4):415-421.

Guareschi RF, Gazolla PR, Souchie EL, Rocha AC (2008). Phosphate and potassium at sowing and anticipated on soybean grown in soil from Cerrado. Semina, Londrina 29(4):769-774.

IBGE - Instituto Brasileiro de Geografia e Estatistica (2013). Disponível em:[http://www.ibge.gov.br/estadosat/temas.php?sigla= pr&tema=lavouratemporaria2 011] Acesso em: 27 de fev. 2013.

Malavolta E (2006). Manual de nutrição mineral de plantas. São Paulo: Agronômica Ceres P. 638.

Malavolta E, Vitti GC, Oliveira AS (1997). Avaliação do estado nutricional das plantas, princípios e aplicações. Piracicaba, Associação Brasileira para a Pesquisa da Potassa e do Fosfato, P. 319.

Marschner H (2012). Mineral Nutrition of Higher Plants. 3. Ed. London: Academic Press P. 651.

MAPA-Ministério da Agricultura, Pecuária e Abastecimento. Coordenação-geral de Zoneamento Agropecuário (2011). Zoneamento Agrícola de Risco Climático para a cultura de soja no Estado do Paraná, ano-safra 2011/2012. Portaria Nº 275, de 28 de julho de 2011.

Novais RF, Alvarez VVH, Barros NF, Fontes RLF, Cantarutti RB, NEVES JCL (2007). Fertilidade do solo. Soc. Bras. Ciências do Solo, Viçosa P. 1017.

Olibone D, Rosolem CA (2010). Phosphate fertilization and phosphorus forms in an Oxisol under no-till. Sci. Agrícola, Piracicaba 67(4):465-471.

Pereira PG, Loss A, Beutler SJ, Torres JLR (2010). Carbon, light organic matter and remaining phosphorus in different soil management systems. Pesquisa Agroepcuária Brasileira, Brasília, 45(5):508-514. http://dx.doi.org/10.1590/S0100-204X2010000500010

Pauletti V, Serrat BM, Mottai ACV, Favaretto N, Anjos A (2010). Yield response to fertilization strategies in no-tillage soybean, corn and common bean crops. Braz. Arch. Biol. Technol. Curitiba 53(3):563-574. http://dx.doi.org/10.1590/S1516-89132010000300009

Rosolem CA, Merlin A (2011). Adubação fosfatada em sistemas de produção com semeadura direta. IN: Fonseca AF; Caires EF; Barth G (2011). Fertilidade do Solo e Nutrição de Plantas no Sistema Plantio Direto. 1a. edição. Ponta Grossa: Associação dos Engenheiros Agrônomos dos Campos Gerais e Universidade Estadual de Ponta Grossa pp. 217-248.

Rosolem CA, Calonego JC, Foloni JSS (2003). Potassium leaching from green cover crop residues as affected by rainfall amount. Rev. Bras. Ciências do Solo, Viçosa 27(2):355-362.

Scherer EE (1998). Critical level and crop yield response to potassium in a typic Hapludalf under no-tillage. Rev. Bras. Ciências do Solo 22(1):57-62.

SAEG (1999). Sistema para análises estatísticas. Versão 8.0. Viçosa, MG, Universidade Federal de Viçosa.

Schlindwein JA, Anghinoni I (2000). Horizontal variability of soil fertility attributes and soil sampling under a no-tillage system. Rev. Bras. de Ciências do Solo, Viçosa 24(1):85-91.

Sfredo GJ (2008). Soja no Brasil: Calagem, adubação e nutrição mineral. Documentos 305. EMBRAPA Soja, Londrina P. 147.

Taiz L, Zeiger E (2013). Fisiologia vegetal. Porto Alegre: Artmed, P. 918.

Tedesco MJ, Gianelo C, Bissani CA, Bohnen H, Volkweis SJ (1995). Análises de solo, planta e outros materiais. 2ª. ed. Porto Alegre, UFRGS, Departamento de Solos. P. 174. (Boletim técnico, 5).

Tirloni C, Vitorino ACT, Novelino JO, Tirloni D, Coimbra DS (2009). Phosphorus availability due to additions of liming and soil bioactivator. Ciência e Agrotecnologia, 33(4):977-984. http://dx.doi.org/10.1590/S1413-70542009000400006

USDA - United States Departament of Agriculture. World Agricultural Production – may of 2013. Disponível em: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1860. Acessado em: 18 jun. 2013.

Vieira RCB, Bayer C, Fontoura SMV, Anghinoni I, Ernani PR; De Moraes RP (2013). Liming criteria and critical levels of phosphorus and potassium in oxisoils under no-till system of the south-central region of Paraná state, Brazil. Rev. Bras. Ciências do Solo, Viçosa., 37(1):188-198.