Crop fertilization with P is a practice that constantly needs to be improved because of its high cost, natural reserve constraints, and environmental impact caused by the excessive use of nutrients. Phosphorus rates (0, 120, 240, 360, 480, 600, and 720 kg P$_{2O_5}$ ha$^{-1}$) in the cultivation of ‘Fuyutoyo’ cabbage (Brassica oleracea L. var. capitata) in a P-rich Eutrustox soil (93 mg P dm$^{-3}$) in Jaboticabal (21°15’22” S, 48°15’58” W; 575 m a.s.l.), São Paulo, Brazil, were evaluated in an experiment with a randomized complete block design with three replicates. Phosphorus rates influenced plant characteristics and soil P content. Maximum leaf and soil P content was obtained with 720 kg P$_{2O_5}$ ha$^{-1}$, but maximum values of leaf area, leaf dry mass, cabbage head mass, and productivity were obtained with 420, 310, 430, and 437.5 kg ha$^{-1}$ P$_{2O_5}$, respectively. Results indicate that even crops grown in a P-rich soil benefit from applying P fertilizer, which has a positive effect on the growth and productivity of the ‘Fuyutoyo’ cabbage.

**Key words:** Brassica oleracea var. capitata, excess phosphorus, plant nutrition.

### INTRODUCTION

Cabbage (Brassica oleracea L. var. capitata) is the main commercial species of the Brassicaceae family and is among the most economically important vegetable crops in Brazil. It is also one of the crops for which information on soil fertilization is still inadequate.

Phosphorus is a strategic nutrient for cabbage plant management even though only small quantities are absorbed (Khan et al., 2002). The levels of this nutrient in diagnostic leaves for cabbage optimal growth are between 4 and 7 g kg$^{-1}$ (Trani and van Raij, 1997) and between 3 and 5 g kg$^{-1}$ for herbaceous plants in general (Hawkesford et al., 2012). Phosphorus is an important nutrient in crop productivity and is used in several metabolic processes such as photosynthesis, respiration, cell division, biosynthesis, and ionic absorption. It is also a component of structural phospholipids, nucleic acids, coenzymes, and phosphoproteins (Sanchez, 2006; Fageria, 2009; Hawkesford et al., 2012).

The response of crop species to P depends on the species and on P soil availability (Wang and Li, 2004). Crop species growing in P-deficient soils generally respond well to P fertilization, but plants do not usually respond when P levels in the soil are greater than 70 mg dm$^{-3}$ (Castellane et al., 1988). However, Deenik et al. (2006) reported that cabbage plants subjected to rates of 0 to 198 kg P ha$^{-1}$ in soil containing 351 mg P dm$^{-3}$ responded positively to rates of up to 50 kg ha$^{-1}$ and that responses diminished above that rate. These results can be due to the low efficiency of some genotypes in absorbing and using P (Sanchez, 2006; Fageria, 2009). The positive response is one of the reasons why farmers use high P fertilizer rates.

Plant P availability is also hampered in highly weathered soils, such as tropical soils, that are usually acidic with a high potential of iron and aluminum oxides to absorb P (Valladares et al., 2003; Raij, 2004; Hopkins and Ellsworth, 2005). This strong interaction with the soil is why P is applied at the highest rates to crops in tropical areas (Rao et al., 1999). In addition, vegetable crops usually have short cycles so that their demand for nutrients is concentrated over a short period of time (Sanchez, 2006).

Cabbage plant response to P in highly weathered tropical soils warrants further study because the excessive use of P has a high potential for polluting and causing the eutrophication of bodies of water (Sharpley et al., 2003; Fageria, 2009). Decreases in biomass have been reported to be associated with excessive P levels and reduced micronutrient levels (Hopkins and Ellsworth, 2003; Sanchez, 2006; Fageria, 2009). High P levels are usually observed in soils frequently cultivated with vegetable crops (Deenik et al., 2006).

The objective of this research study was to evaluate the effects of the P rate on ‘Fuyutoyo’ cabbages grown in P-rich typical clay Oxisol.

---

1Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias, Via de acesso Prof. Paulo Donato Castellane, s/n, 14.884-900, Jaboticabal, São Paulo, Brasil.

*Corresponding author (rutra@fcav.unesp.br).

Received: 27 November 2012.

Accepted: 19 June 2013.

doi:10.4067/S0718-58392013000300012
The experiment was conducted at the Experimental Farm of the São Paulo State University (UNESP) in Jaboticabal (21°15'22"S, 48°15'59"W; 575 m a.s.l.), São Paulo State, Brazil. The soil of the experimental area is typical clay Oxisol (Soil Survey Staff, 1975) with 560, 250, and 190 g kg⁻¹ clay, silt, and sand, respectively. The initial soil chemical characteristics in the 0 to 20 cm layer were 4.0 pH(CaCl₂), 14.0 g dm⁻³ organic matter; 93.0 mg dm⁻³ P₂O₅; 0.33, 1.5, 0.6, 0.1, 3.8, and 6.23 cmol dm⁻³ of K, Ca, Mg, Al, H + Al, and cationic exchange capacity, respectively; 0.3, 3.9, 15.0, 18.9, 2.1, and 9.0 mg dm⁻³ of B, Cu, Fe, Mn, Zn, and S-SO₄²⁻, respectively; and a base saturation of 39%. According to Raij et al. (1997), soil P level was high. Seven P rates were evaluated: 0, 120, 240, 360, 480, 600, and 720 kg P₂O₅ ha⁻¹. These rates followed the recommendation of 200 kg ha⁻¹ by Trani et al. (1997) for cabbage when soil P level is greater than 60 mg P dm⁻³.

This field experiment was conducted with a randomized complete block design of seven treatments and three replicates. Each plot was 285 × 1.10 m in size with two rows of seven plants for a density of 35 340 plants ha⁻¹. The first and last plants in each row were not included in the analyses to avoid edge effects.

Hybrid ‘Fuyutoyo’ cabbage seedlings were raised in 200-cell polypropylene trays. Following the recommendation by Trani et al. (1997), soil from the experimental area was limed to raise the soil base saturation to 80%. Agricultural lime (total neutralizing power of 126%) was distributed over the entire area and incorporated with a harrow. The soil was plowed, harrowed, and finally formed into seed beds with a rotavator. No organic fertilizers were added. Before transplanting the seedlings, 60 kg N ha⁻¹ (ammonium sulfate), 120 kg K₂O ha⁻¹ (potassium chloride), and 4 kg pulverized B ha⁻¹ (borax) were applied to each seed bed. The applied P rates (triple superphosphate) corresponded to those of the treatments. These applications were incorporated into the soil to a depth between 10 and 15 cm.

Row spacing in the plots was 0.60 m, and planting distance was 0.35 m. Seedlings were transplanted on 17 February 2009 and irrigated soon afterwards with a sprinkler irrigation system. Nitrogenous and K fertilizers were equally applied to the plants as side dressings at 15, 30, and 45 d after transplanting (DAT). Nitrogen fertilizer (ammonium sulfate) was applied at a total rate of 180 kg ha⁻¹ and K fertilizer (potassium chloride) at a total rate of 120 kg ha⁻¹. Weeds were hoed when necessary and insecticides were sprayed to control Plutella xylostella, Diabrotica speciosa, Brevicoryne brassicae, and Bemisia argentifolii. Fungicides were required to control Alternaria spp. Cabbages were harvested on 6 May 2009, 79 DAT and 120 d after seeding the polypropylene trays. All treatments were harvested on the same day. Cabbages were harvested when 80% of the heads in one treatment were considered suitable for commercial purposes.

The following characteristics were measured: 1) Leaf P content (g kg⁻¹): One leaf from 10 plants per plot was collected as recommended by Trani and Raij (1997). Leaves were washed in tap water and then with deionized water, placed in paper bags, and dried in a forced-ventilation oven at 65 °C to constant weight. Leaves were then ground and extracted to determine P content. 2) Leaf area (LA; dm² plant⁻¹): At harvest, leaf areas of the head external leaves (photosynthetically active leaves) of four plants per plot were measured with an electronic area meter (LI-3100C, LI-COR, Lincoln, Nebraska, USA). 3) Dry mass of head external leaves (LDM; g plant⁻¹): After harvest, leaves of four plants per plot were washed and dried in a forced-ventilation oven at 65 °C to constant weight. 4) Plant head fresh mass (HFM; g plant⁻¹): After harvest, heads of all 10 plants per plot were weighed. 5) Productivity (PROD; kg m⁻²): The total of all 10 cabbage head masses per plot. 6) Phosphorus soil content (mg dm⁻³): Ten soil samples were collected at the end of the experiment from each plot and bulked to form a composite sample to determine soil available P content in accordance with Raij et al. (2001). 7) Phosphorus accumulation in leaves, stems, and heads, and total P (mg plant⁻¹): At harvest, leaves, stems, and heads from four plants from each plot were separated and washed in tap water and then with deionized water. These materials were dried in a forced-ventilation oven at 65 °C to constant weight and then ground. The P levels were determined. Accumulated P was calculated by multiplying P levels in the leaves, stems, and heads by the corresponding dry masses of each part. Total P accumulated in the plants corresponded to the sum of the quantities of P accumulated in the leaves, stems, and heads. Phosphorus exportation (%) corresponded to the quantity of P accumulated in the cabbage head.

Data were analyzed by ANOVA F-tests and polynomial regression. The equation with the highest level of significance was chosen to represent an association.

RESULTS AND DISCUSSION

The LAs and LDMs of ‘Fuyutoyo’ cabbages were significantly influenced by the P rate (Table 1) and quadratic equations were significantly adjusted to the observed means (Figure 1). A rate of 420 kg P₂O₅ ha⁻¹ produced the highest LA (75.05 dm² plant⁻¹), which represented an increase of 39.5% as compared with the control (0 kg P₂O₅ ha⁻¹; 53.8 dm² plant⁻¹) (Figure 1). Leaf dry mass increased to 65.25 g plant⁻¹ at 310 kg P₂O₅ ha⁻¹. Above this rate, LDM decreased with increasing P₂O₅ rates; at 720 kg P₂O₅ ha⁻¹, LDMs were 69% and 49% lower than those of the control treatment and the highest LDM, respectively (Figure 1). The effects on LA and LDM are due to the functions P has in plants, that is, photosynthesis, cell division, ion
Phosphorus also plays a role in root growth, especially of secondary roots, which makes water and nutrient absorption easier and more efficient with a direct effect on the growth of aboveground tissues (Sanchez, 2006; Fageria, 2009; Hawkesford et al., 2012). On the other hand, ‘Fuyutoyo’ cabbages did not continue to respond to increased P rates perhaps because cabbage plants have an internal regulation system by which P transporters block P absorption when the amount of soil P is higher than what is required for optimal growth (Hawkesford et al., 2012). Leaf P content was significantly influenced by the P rate (Table 1) and the quadratic equations were adjusted. A rate of 720 kg P2O5 ha-1 produced the highest leaf P content (4.3 g plant-1) (Figure 2). Dechassa et al. (2003) evaluated the effects of six P rates (0, 12, 27, 73, 124, and 234 mg kg-1) applied to soil with 16 mg P kg-1 (extractor calcium-acetate-lactate) and also found that P content of aboveground tissues of cabbage plants increased significantly with increased soil P.

In accordance with the polynomial regression, leaf P contents were inadequate, although no symptoms of P deficiency were observed. Adequate P levels have been estimated as 3.0 (Malavolta et al., 1997) and 4.2 mg kg-1 (Martinez et al., 1999) when the nutritional status is evaluated in the intermediate leaf (recently matured or recently developed) (Trani and Raij, 1997). The polynomial adjustment observed for leaf P levels in the diagnostic leaf is the opposite of that observed in the LA and LDM adjustments. This reduction in leaf P content coincides with the range of the highest growth values, which is probably due to a dilution effect. An insufficient amount of P in the plants was unlikely.

Plant head fresh mass (HFM) and PROD were significantly influenced by the P rate (Table 1) and showed polynomial quadratic adjustments (Figures 1 and 2). A rate of 430 kg P2O5 ha-1 produced the highest HFM (1910 g plant-1) (Figure 1). This rate is 115% higher than that recommended by Trani et al. (1997), that is, 200 kg P2O5 ha-1 for P-rich soils with P content greater than 60 mg dm-3. However, the rate needed to produce cabbage heads weighing 95% of the maximum mass was 197 kg P2O5 ha-1; this confirms the rate recommended by Trani et al. (1997). A rate of 437.5 kg P2O5 ha-1 yielded maximum PROD (9.10 kg m-2). Rates above this level, up to 720 kg ha-1, led to decreases in productivity (8.40 kg m-2) of up to 7.6% (Figure 2). Growth and productivity data indicated that ‘Fuyutoyo’ cabbages responded well to P fertilizers even in a P-rich Eutrustox soil (93 mg P dm-3) (Raij et al., 1997). Deenik et al. (2006) also reported a good response in cabbages in soil with 351 mg P dm-3.

Phosphorus accumulation in the stem, different from accumulation in leaves, heads, and whole plants, was significantly influenced by the P rate (Table 1) and the quadratic equations were adjusted. A rate of 720 kg P2O5 ha-1 produced the highest leaf P content (4.3 g plant-1) (Figure 2). Dechassa et al. (2003) evaluated the effects of six P rates (0, 12, 27, 73, 124, and 234 mg kg-1) applied to soil with 16 mg P kg-1 (extractor calcium-acetate-lactate) and also found that P content of aboveground tissues of cabbage plants increased significantly with increased soil P.

In accordance with the polynomial regression, leaf P levels resulting from rates lower than 16 and higher than 484 kg P2O5 ha-1 are within the range considered to be adequate (between 4 and 7 g kg-1) by Trani and Raij (1997). When rates were between 17 and 483 kg P2O5 ha-1, P contents were inadequate, although no symptoms of P deficiency were observed. Adequate P levels have been estimated as 3.0 (Malavolta et al., 1997) and 4.2 mg kg-1 (Martinez et al., 1999) when the nutritional status is evaluated in the intermediate leaf (recently matured or recently developed) (Trani and Raij, 1997). The polynomial adjustment observed for leaf P levels in the diagnostic leaf is the opposite of that observed in the LA and LDM adjustments. This reduction in leaf P content coincides with the range of the highest growth values, which is probably due to a dilution effect. An insufficient amount of P in the plants was unlikely.

Table 1. Leaf area (LA), leaf dry mass (LDM), leaf P content (LP), head fresh mass (HFM), and productivity (PROD) of ‘Fuyutoyo’ cabbage plants affected by P fertilizer rates.

| P2O5 kg ha-1 | LA (dm² plant-1) | LDM (g plant-1) | LP (g plant-1) | HFM (g plant-1) | PROD (kg m-2) |
|--------------|------------------|------------------|----------------|------------------|--------------|
| 0            | 49.43            | 42.49            | 3.83           | 1630.23          | 7.76         |
| 120          | 68.31            | 59.03            | 4.13           | 1655.87          | 7.88         |
| 240          | 77.97            | 72.97            | 3.63           | 1948.02          | 9.27         |
| 360          | 70.41            | 68.06            | 3.40           | 1760.50          | 8.38         |
| 480          | 73.28            | 49.88            | 3.70           | 1968.55          | 9.37         |
| 600          | 68.08            | 51.89            | 4.03           | 1935.35          | 9.21         |
| 720          | 69.02            | 39.18            | 4.33           | 1710.92          | 8.15         |

Table 2. Nutrient accumulation in ‘Fuyutoyo’ cabbage plants affected by P fertilizer rates.

| P2O5 kg ha-1 | N (g plant-1) | P (g plant-1) | K (g plant-1) | Ca (g plant-1) |
|--------------|---------------|---------------|---------------|---------------|
| 0            | 120           | 700           | 1200          | 300           |
| 120          | 130           | 750           | 1400          | 350           |
| 240          | 140           | 800           | 1600          | 400           |
| 360          | 150           | 850           | 1800          | 450           |
| 480          | 160           | 900           | 2000          | 500           |
| 600          | 170           | 950           | 2200          | 550           |
| 720          | 180           | 1000          | 2400          | 600           |

**Significant at P ≤ 0.01; *significant at P ≤ 0.05; NS non significant.

Figure 1. Leaf area (LA), leaf dry mass (LDM), and head fresh mass (HFM) of ‘Fuyutoyo’ cabbage plants affected by P fertilizer rates.

Figure 2. Phosphorus content of the diagnostic leaf (LP) and productivity (PROD) of ‘Fuyutoyo’ cabbage plants affected by P fertilizer rates.
Table 2. Phosphorus stem accumulation (PSA), P leaf accumulation (PLA), P head accumulation – exportation (PEX), P total accumulation (PTA) of ‘Fuyutuyo’ cabbage plants and soil P content (PS) affected by P fertilizer rates.

| P2O5 | PSA | PLA | PEX | PTA | PS  |
|------|-----|-----|-----|-----|-----|
| kg ha⁻¹ | mg plant⁻¹ | mg dm⁻³ | kg ha⁻¹ | mg plant⁻¹ | mg dm⁻³ |
| 0    | 14.35 | 143.28 | 310.99 | 468.63 | 144.67 |
| 120  | 21.18 | 148.03 | 373.71 | 542.93 | 156.00 |
| 240  | 27.64 | 154.75 | 375.21 | 557.60 | 168.03 |
| 360  | 46.10 | 182.64 | 450.49 | 682.56 | 165.33 |
| 480  | 36.08 | 169.41 | 389.25 | 594.75 | 211.00 |
| 600  | 37.49 | 183.23 | 338.98 | 559.69 | 222.00 |
| 720  | 39.90 | 177.25 | 370.32 | 587.48 | 232.00 |

Treatments 3.90* 0.75 NS 0.63 NS 0.85 NS 5.26**

1° degree regression 15.32** 3.35 NS 0.18 NS 1.34 NS 29.09**

2° degree regression 4.01 NS 0.32 NS 1.89 NS 2.02 NS 0.37 NS

3° degree regression 0.00 NS 0.11 NS 0.36 NS 0.15 NS 0.33 NS

CV, % 30.93 20.20 25.37 21.15 14.29

**Significant at P ≤ 0.01; *significant at P ≤ 0.05; NS non significant.

Figure 3. Phosphorus stem accumulation (PSA) of ‘Fuyutuyo’ cabbage plants affected by P fertilizer rates.

in total P accumulation obeyed the following order: heads (exportation) contributed 65% (372.7 mg plant⁻¹), leaves approximately 29% (165.5 mg plant⁻¹), and stems 6% (31.8 mg plant⁻¹).

Soil P content after harvesting was significantly influenced by the P rate (Table 2). Soil P content was found to be adjusted to a linear equation with proportional increases as the P2O5 rates increased. Soil P content varied between 139 and 232 mg dm⁻³ (Figure 4). Deenik et al. (2006) also found that adding P fertilizers to the soil led to soil P levels above the basal level of 351 mg dm⁻³ (where no P was applied) to 530 mg dm⁻³ (where the highest P2O5 rates had been applied). According to these authors, the use of completely formulated fertilizers is likely to increase soil P levels over time in several areas where horticultural production is intense.

CONCLUSIONS

Results indicate that applying P fertilizers increases the productivity of ‘Fuyutoyo’ cabbages even in P-rich soils.

ACKNOWLEDGEMENTS

We thank the Graduate Program in Agronomy (Plant Production) of the Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP), Jaboticabal Campus, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for providing a doctoral scholarship and our colleagues Ivan Soares de Araujo, Sergio Mendonça Mendes, and Filipe Noberto Ayres de Freitas.

LITERATURE CITED

Castellane, P.D., M.E. Ferreira, e A.H. Maeda. 1988. Diagnose da fertilidade dos solos cultivados com olerícias em Atibaia (SP). Horticultura Brasileira 6:50.

Dechassa, N., M.K. Schenk, N. Claassen, and B. Steingrobe. 2003. Phosphorus efficiency of cabbage (Brassica oleracea L. var. capitata), carrot (Daucus carota L.), and potato (Solanum tuberosum L.) Plant and Soil 250:215-224.

Deenik, J., R. Hamasaki, R. Shimabuku, S. Nakamoto, and R. Uchida. 2006. Phosphorus fertilizer management for head cabbage. Soil and Crop Management 16:1-6.

Fageria, N.K. 2009. The use of nutrients in crop plants. 430 p. Taylor & Francis Group, Boca Raton, Florida, USA.

Hawkesford, M., W. Horst, T. Kichey, H. Lambers, J. Schjoerring, I. Skrumsager Moller, and P. White. 2012. Function of macronutrients. p. 135-178. In Marschner, P. (ed.) Marschner’s mineral nutrition. 3rd ed. Elsevier Ltd., Oxford, UK.

Hopkins, B.G., and J.W. Ellsworth. 2003. Phosphorus nutrition in potato production. p. 75-86. In Robertson, L.D., et al. (eds.) Proceedings of the Winter Commodity Schools – 2003. University of Idaho-Cooperative Extension System, Moscow, Idaho, USA.

Hopkins, B., and J.W. Ellsworth. 2005. Phosphorus availability with alkaline/calcareous soil. p. 88-93. In 6th Western Nutrient Management Conference, Salt Lake City, Utah 3-4 March. Potash and Phosphate Institute, Norcross, Georgia, USA.

Khan, R., S. Ahmed, S. Khan, F. Ahmed, M. Zaman, and B.A. Khan. 2002. Effect of different levels of nitrogen, phosphorus and potassium on the growth and yield of cabbage. Asian Journal of Plant Sciences 1:548-549.

Malavolta, E., G.C. Vitti, e S.A. Oliveira. 1997. Avaliação do estado nutricional das plantas: princípios e aplicações. 319 p. 2° ed. POTAFOS, Piracicaba, São Paulo, Brasil.

Martinez, H.E.P., J.G. Carvalho, e R.B. Souza. 1999. Diagnose foliar. p. 143-168. In Ribeiro, A.C., et al. (eds.) Recomendações para o uso de corretivos e fertilizantes em Minas Gerais - 5ª aproximação. Comissão de Fertilidade do Solo do Estado de Minas Gerais, Viçosa, Minas Gerais, Brasil.

Raij, B. van. 2004. Fósforo no solo e interação com outros elementos. p. 107-108. In Yamada, T., e S.R.S. Abdalla (eds.) Fósforo na agricultura brasileira. POTAFO, Piracicaba, São Paulo, Brasil.
Raij, B. van, J.C. Andrade, H. Cantarella, e J.A. Quaggio. 2001. Análise química para avaliação da fertilidade de solos tropicais. 285 p. Instituto Agronômico & Fundação IAC, Campinas, São Paulo, Brasil.

Raij, B. van, A.J. Quaggio, H. Cantarella, e C.A. Abreu. 1997. Interpretação de resultados de análise de solos. p. 8-13. In Raij, B. van, et al. (eds.) Recomendações de adubação e calagem para o Estado de São Paulo. Boletim Técnico 100. 2ª ed. Instituto Agronômico & Fundação IAC, Campinas, São Paulo, Brasil.

Rao, I.M., D.K. Friesen, and M. Osaki. 1999. Plant adaptation to phosphorus-limited tropical soils. p. 61-95. In Pessarakli, M. (ed.) Handbook of plant and crop stress. 2nd ed. Marcel Dekker, New York, USA.

Sanchez, C.A. 2006. Phosphorus. p. 51-90. In Barker, A.V., and D.J. Pilbeam (eds.) Handbook of plant nutrition. Taylor & Francis Group, Boca Raton, Florida, USA.

Sharpley, A.N., T. Daniel, T. Lemunyon, R. Stevens, and R. Parry. 2003. Agricultural phosphorus and eutrophication. 38 p. 2nd ed. Agricultural Research Service, Washington D.C., USA. Available at http://www.ars.usda.gov/is/np/Phos&Eutro2/agrophosphate2ed.pdf (accessed January 2012).

Trani, P.E., F.A. Passos, J.A. Azevedo, e M. Tavares. 1997. Brócolos, couve-flor e repolho. In Raij, B. van et al. (eds.) Recomendações de adubação e calagem para o Estado de São Paulo. Boletim Técnico 100. p. 175. Instituto Agronômico & Fundação IAC, Campinas, São Paulo, Brasil.

Trani, P.E., e B. van Raij. 1997. Hortaliças. In Raij, B. van, et al. (eds.) Recomendações de adubação e calagem para o Estado de São Paulo. Boletim Técnico 100. p. 157-164. Instituto Agronômico & Fundação IAC, Campinas, São Paulo, Brasil.

Soil Survey Staff. 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. Handbook 436. 754 p. Natural Resources Conservation Service, U.S. Department of Agriculture, Washington, D.C., USA.

Valladares, G.S., M.G. Pereira, e L.H.C. Anjos. 2003. Adsorção de fósforo em argila de atividade baixa. Bragantia 62:111-118.

Wang, Z., and S. Li. 2004. Effects of nitrogen and phosphorus fertilization on plant growth and nitrate accumulation in vegetables. Journal of Plant Nutrition 27:539-556.