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Cauliflower and broccoli productivity as influenced by phosphorus fertilizer doses in a P-rich soil

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Abstract

Although being little accumulated by cauliflower and broccoli plants, phosphorus (P) is one of the most important nutrients influencing growth and productivity of these species. The information in the literature concerning doses of P demanded by those species is scarce and conflicting. Therefore, two experiments were conducted in the field, in 2010, in Jaboticabal, Brazil, aiming to evaluate five P doses (0, 80, 160, 240, and 320 kg ha^{-1} P_2O_5) on cauliflower and broccoli. For each experiment, brassica, the experimental design was a randomized complete block with four replications. At the beginning inflorescence stage, the P level in the leaves was verified to be significantly influenced by P dose only in cauliflower plants. Cauliflower (35 970 kg ha^{-1}) and broccoli (11 425 kg ha^{-1}) maxima productivities resulted from the respective doses of 245 and 320 kg ha^{-1} P_2O_5. In both experiments, after harvest of cauliflower and broccoli, significant effects of P doses were observed in soil P content, mass and diameter of the inflorescence, and productivity. The broccoli and cauliflower crops respond positively to P doses even in P-rich soils and that they demand different amounts of phosphorus to reach maximum productivity and inflorescence diameter and mass.

Keywords: *Brassica oleracea* var. *botrytis*; *Brassica oleracea* var. *italica*; excess phosphorus; plant nutrition.
Abbreviations: P_Phosphorus; Zn_Zinc; K_Potassium; Ca_Calcium; Mg_Magnesium; H_Hydrogen; Al_Aluminum.

Introduction

Although absorbed in small amounts by plants (Castoldi et al., 2009; Takeishi et al., 2009; Marković et al. 2012), P is usually applied at high doses due to the low efficiency of phosphorus fertilization. This low efficacy is explained by the high capacity P shows to form stable components with soil colloidal particles, mainly in highly weathered tropical soils – the positive charges of iron and aluminium oxide attract and bind phosphorus, thus reducing its availability to the plants (Sharpley et al., 2003; Anghinoni and Bissani, 2004; Hopkins and Ellsworth, 2005). This fact, plus its importance in all plant physiological processes (Taiz and Zeiger, 2010), makes it the second most important nutrient limiting crop productivity in tropical soils (Novais and Smyth, 1999). Thus, proper P management is crucial for yield and productivity in crops (Demchak and Smith, 1990; Abdissa et al., 2012). According to Islam et al. (2010) and Marković et al. (2012), P is important not only to floral initiation but also to inflorescence growth. P in excess, on the other hand, is not only a cause of nutritional unbalance in the plant but also a cause of micronutrient deficiency, especially Zn, which becomes more diluted in the plant tissues (Marschner, 1995). Phosphorus accumulation on farms has built up soil P to levels that often exceed crop needs. The main problem of P in excess is that it may be transported by erosion to springs, causing them to undergo eutrophication and leading to depleted dissolved oxygen (Sharpley et al., 2003; Bolster and Sistani, 2009). Soils showing excessive levels of P are usually found in areas of horticultural crops - most of those species are short cycled, and this allows them to be cultivated two to three times a year, with high doses of fertilizers being applied at each cycle. Although cauliflower and broccoli are two of the most important brassicas, information concerning P-fertilizer doses is scarce. For the same levels of P in the soil (low, medium, and high), recommendations found in the literature are conflicting as to the adequate P dose to be applied (Trani et al., 1997; Fontes, 1999a,b). Another relevant aspect is that frequently the same dose of phosphorus is recommended for both species with no consideration to differences in plant population, the accumulation of biomass, and productivity. In addition, modern cultivars are more productive than the old ones, thus justifying the use of high fertilizer doses. The objective of this research was to study the effects of doses of phosphorus on the productivity of cauliflower and broccoli plants cultivated in a P-rich soil.

Results and Discussion

The P_2O_5 dose had a significant effect on foliar P content, inflorescence mass and diameter, productivity of cauliflower and broccoli, and soil P content. Hassan et al. (2013) also verified that the application of phosphate fertilizer affected broccoli vegetative growth parameters (plant height, leaf number and area, and fresh and dry weights of whole plants) as well as diameter and weight of the head.

Soil and foliar P level

P level in the soil was verified to be significantly and linearly adjusted to P_2O_5 dose both in the cauliflower ($P \leq 0.05$) and the broccoli ($P \leq 0.05$) experiments. P availability in the soil grew with P_2O_5 dose (Fig. 1). P level in the soil for all the P_2O_5 doses was within the range of values considered as very high for horticultural crops, that is, above 120 mg dm^{-3} (Raij et al., 1997). P level in the plant leaf showed an adjustment to the linear model ($P \leq 0.05$) only for cauliflower, or, in other words, increments in P_2O_5 dose from 0 to 320 kg ha^{-1} brought about proportional increments in P level in the cauliflower leaves (Fig. 2). When P_2O_5 was applied up to 320 kg ha^{-1} P_2O_5, P level in the leaf went from 2.9 to 3.4 g kg^{-1} in cauliflower. P levels in the cauliflower leaf either with or without phosphorus fertilization of the soil were lower than those considered adequate (between 4 and 7 g kg^{-1}) by Hochmuth et al. (2012), but no visible symptoms of deficiency were observed in the plants. Probably the low P levels observed were due to the nutrient dilution in the plant-tissue dry matter, since even when no phosphorus was applied, the levels of P in the soil were high (103 mg dm^{-3}). Avalhães et al. (2009) reported that the P level of 1 g kg^{-1} in cauliflower leaf dry matter was enough to cause visible symptoms of deficiency. In broccoli, the mean P level in the leaf was 3.2 g kg^{-1} (Fig. 1), that is in the adequate range (between 3 and 5 g kg^{-1}) according to Hochmuch et al. (2012).

Agronomic characteristics

For inflorescence diameter, significant adjustments to second-grade equations were observed both for cauliflower ($P \leq 0.01$) and broccoli ($P \leq 0.05$). According to those equations, maximum inflorescence in cauliflower (0.2 m) and broccoli (0.147 m) would be attained with doses of 244 and 320 kg ha^{-1} P_2O_5, respectively (Fig. 3). These diameters are, respectively, 12.5 and 30% larger than those reached by the plants when no P was applied to the soil. Hassan et al. (2013) also verified the adjustment of second-grade equations for broccoli head diameter, when evaluated rates were between 50 and 125 kg ha^{-1} P_2O_5. The positive effects of P on inflorescence diameter were also reported by Islam et al. (2010) in a study of broccoli plants submitted to doses of P_2O_5 from zero to 200 kg ha^{-1}. Cauliflower ($P \leq 0.05$) and broccoli ($P > 0.05$) inflorescence mass increased with second-degree polynomial adjustments to the increments in P_2O_5 doses (Fig. 3). Maximum cauliflower (1010.7 g) and broccoli (313 g) inflorescence masses were attained when P_2O_5 doses were 257 and 320 kg ha^{-1}, respectively. In comparison with the check treatment (no P applied), the doses of 257 and 320 kg ha^{-1} caused increments of 31 and 35% in the inflorescence mass of cauliflower and broccoli, respectively. The results observed are explicated by P functions in the vegetal metabolism because is used in several processes such as photosynthesis, respiration, cell division, biosynthesis, and ionic absorption. It is also a component of structural phospholipids, nucleic acids, coenzymes, and phosphoproteins (Fageria, 2009; Hawkesford et al., 2012). Marković et al. (2012) verified high correlation between inflorescence stage and uptake P by cauliflower, and the positive effects of P corroborate results published by Demchak and Smith (1990), Islam et al. (2010) and Katiyar et al (2012). Cauliflower and broccoli productivities, similar to what was verified for inflorescence mass and diameter, showed a second-degree equation adjustment to P_2O_5 doses (Fig. 4).

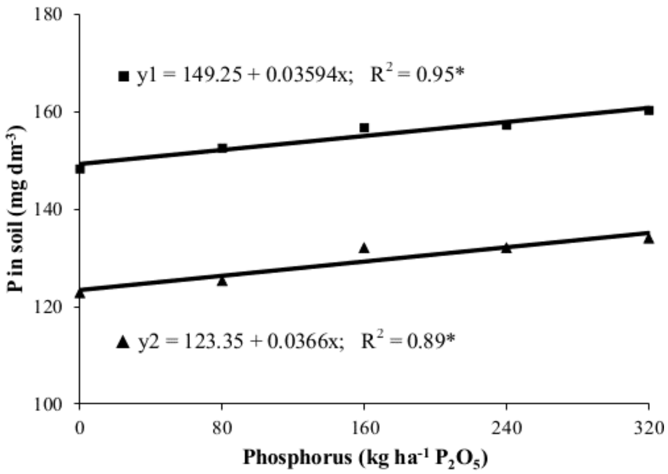

Fig 1. Soil phosphorus level as a function of P_2O_5 doses for cauliflower 'Verona' (y1) and broccoli 'BRO 68' (y2) crops.

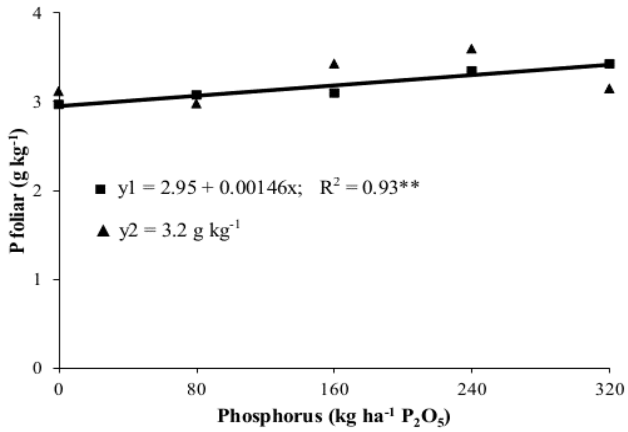

Fig 2. Phosphorus foliar level in cauliflower 'Verona' (y1) and broccoli 'BRO 68' (y2) as a function of P_2O_5 doses.

Dhakal et al. (2012) and Hassan et al. (2013) also verified the adjustment of second-grade equations for cauliflower and broccoli productivity, respectively, for doses between 50 to 125 kg ha^{-1} P_2O_5 and 0 to 90 kg ha^{-1} P_2O_5. Maximum cauliflower (35 970 kg ha^{-1}) and broccoli (11 425 kg ha^{-1}) resulted from the doses of 245 and 320 kg ha^{-1} of P_2O_5, respectively. These are doses higher than that recommended by Trani et al. (1997) and Fontes (1999a, b) for phosphorus-rich soils, that is, 200 kg ha^{-1} P_2O_5. Maximum cauliflower and broccoli productivities were 42% superior to that of the check treatment, representing 10 617 and 3 412 kg ha^{-1} more cauliflower and broccoli, respectively. Increments in broccoli productivity were also reported by Demchak and Smith (1990) in a study in which they were evaluating liming and the effects of doses of P and K on productivity and verified P to be the main nutrient influencing productivity. Islam et al. (2010) also reported productivity increments when the doses of P increased from zero to 200 kg ha^{-1} P_2O_5. According to the results, the P doses used in this experiment were not enough to produce the highest broccoli productivity, i.e. doses higher than 320 kg ha^{-1} P_2O_5 would be necessary to find out which dose would maximize broccoli productivity. Cauliflower maximum productivity, on the other hand, was attained at a dose of 245 kg ha^{-1} P_2O_5.

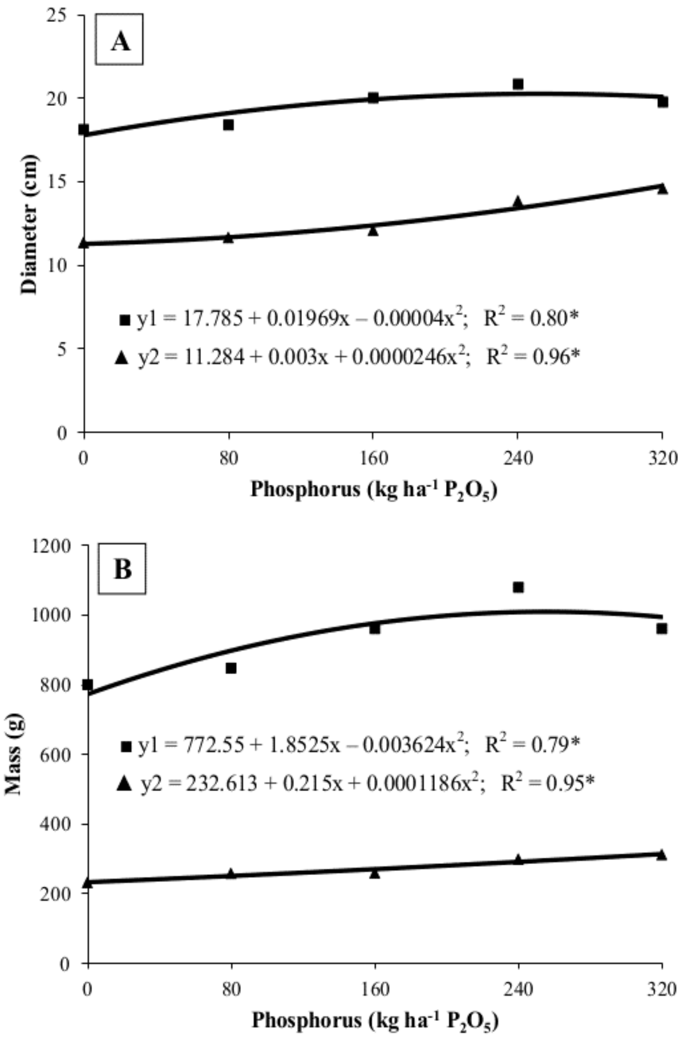

Fig 3. Diameter (A) and mass (B) of head cauliflower 'Verona' (y1) and broccoli 'BRO 68' (y2) as a function of P_2O_5 doses.

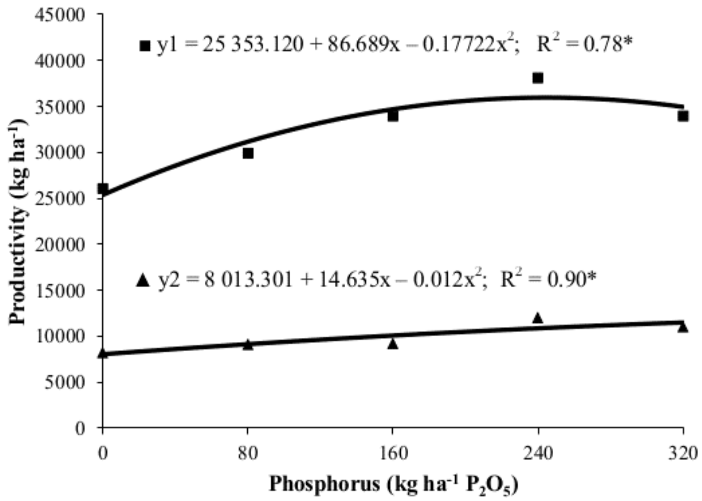

Fig 4. Productivity of cauliflower 'Verona' (y1) and broccoli 'BRO 68' (y2) as a function of P_2O_5 doses.

These two species, notwithstanding the fact that they are no more than botanical varieties of the same species with similar cycles, architectures, and products to be commercialized, should be analysed separately when recommending phosphorus fertilization of the soil.

Materials and Methods

Experimental site

From February, 2 to May, 20 of 2010 at the UNESP of Jaboticabal, state of São Paulo, Brazil (21°15'22'' S, 48°15'59'' W), two experiments (cauliflower and broccoli) were carried out.

Type and characteristics of the soil

The soil of the experimental area was classified as Rhodic Eutrudox (Soil Survey Staff, 1999). The chemical and textural analyses of the soil conducted with samples taken at depths between 0 and 0.2 m before the experiment was installed showed the following results: sand = 253 g kg^{-1}, silt = 132 g kg^{-1}, clay = 615 g kg^{-1}, pH($CaCl_2$) = 5.4, organic matter = 20 g kg^{-1}, P(resin) = 103 mg dm^{-3}, K = 3.6 mmol$_c$ dm^{-3}, Ca = 25 mmol$_c$ dm^{-3}, Mg = 7 mmol$_c$ dm^{-3}, H + Al = 28 mmol$_c$ dm^{-3}, cation exchange capacity = 64 mmol$_c$ dm^{-3}, and soil base saturation = 56%.

Treatments and experimental design

Doses of 0, 80, 160, 240, and 320 kg ha^{-1} P_2O_5 were evaluated, which were adopted taking into consideration the recommendations of Trani et al. (1997), which recommended 200 kg ha^{-1} of P_2O_5 for cauliflower and broccoli when the P content in the soil was high. In each of the experiments, the experimental units were distributed in the field according to a randomized complete block design with four replications.

The experimental unit was composed of two six-plant rows, of which only the four central plants were used to obtain the experimental data.

Planting, crop management and harvesting

The seedlings of 'Verona' cauliflower and 'BRO 68' broccoli cultivars were grown in propylene trays with space enough for 200 seedlings in BIOPLANT organic mineral substratum.

Cauliflower seedlings were placed at a distance of 0.7 m between rows and 0.50 m between plants. Broccoli seedlings were disposed at a distance of 0.7 m between rows and 0.35 m between plants in the row. The distance between seed beds was 0.5 m. Transplantation to the seed bed took place on February 1, 2010 when the seedlings exhibited four leaves. Cauliflower was harvested from 14 to 20, May, and broccoli from 2 to 13, April, 2010. Soil liming of the whole area was made to raise soil base saturation to 80%. Calcined lime with a neutralization power of 124% and CaO and MgO contents of 48 and 16%, respectively, was used.

The mineral fertilization of the seed beds took place immediately before the seedling transplantation, and the amounts of fertilizers used were based on recommendations by Trani et al. (1997). N, P, and K sources were, respectively, urea, triple superphosphate, and potassium chloride. No organic fertilizer was applied. The side dressing of fertilizers also obeyed recommendations by Trani et al. (1997), although the doses were applied only at 15, 30, and 45 days after transplantation. Irrigation was provided by a sprinkler system during the plant life cycle.

Characteristics evaluated

Phosphorus foliar content was measured in the leaf developed immediately after the inflorescence started to grow, according to instructions found in Trani and Raij (1997). Phosphorus soil content was determined after harvest, according to the methodology proposed by Raij et al. (2001). Mass and diameter of the inflorescence and also productivity were determined.

Data analysis

Analyses of variance and polynomial regressions of the data were made. The equation with a significant F and with the highest determination coefficient was chosen.

Conclusion

Broccoli and cauliflower plants responded positively to phosphorus fertilization even in a P-rich Rhodic Eutrudox, and the botanic varieties of *Brassica oleracea* demanded different amounts of phosphorus to reach maximum productivities and inflorescence diameters and masses.

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