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CROP PRODUCTION

Phosphate fertilization on production and quality of cauliflower seeds

Adubação fosfatada na produção e qualidade de sementes de couve-flor

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ABSTRACT

Due to the scarcity of information related to the effect of fertilizers on production and quality of vegetable seeds, mainly on species which present an increase in the cycle, like cauliflower, more studies are necessary about the influence of nutrients rates which provide high production of high-quality seeds. This research aimed to evaluate the influence of rates of phosphorus (P) on the production and quality of cauliflower seeds. Five rates of phosphorus were studied (0, 300, 600, 900 and 1200kg ha^{-1} of P_2O_5), in a randomized complete block design, with four replications. Production and quality (weight of a thousand seeds, germination test, first count of germination test and emergence in substrate) of the seeds and soil chemical characteristics were evaluated. The higher the rate of phosphorus, the higher P content in the soil and values of sum of bases, cation exchange capacity and saturation of bases were observed at the end of the cycle. Seed quality was not affected by P fertilization, with the exception of the weight of a thousand seeds which was adjusted to a linear model. For seed production quadratic effect was obtained. The highest weight of seeds per plant was estimated for the rate of 862kg ha^{-1} of P_2O_5.

Key words: ***Brassica oleracea***, *seed germination, soil chemical characteristics.*

RESUMO

Devido à escassez de informações relacionadas com o efeito de fertilizantes na produção e qualidade de sementes de hortaliças, principalmente de espécies que apresentam aumento no ciclo, como a couve-flor, são necessários mais estudos sobre a influência das doses de nutrientes que fornecem alta produção de sementes com alta qualidade. Este trabalho teve como objetivo avaliar a influência de doses de fósforo sobre a produção e qualidade de sementes de couve-flor. Foram estudadas cinco doses de fósforo (0, 300, 600, 900 e 1200kg ha^{-1} de P_2O_5), em delineamento em blocos casualizados, com quatro repetições. Foram avaliadas a produção e a qualidade (massa de mil sementes, germinação, primeira contagem de germinação e emergência em substrato) das sementes e características químicas do solo. Quanto maior a dose de fósforo, maior o teor de P no solo e os valores de soma de bases, capacidade de troca catiônica e saturação de bases foram observados no final do ciclo. A qualidade das sementes não foi afetada pela adubação com P, com exceção da massa de mil sementes, que ajustou-se ao modelo linear. Foi obtido efeito quadrático para a produção de sementes. Maior massa de sementes por planta foi estimada para a dose de 862kg ha^{-1} de P_2O_5.

Palavras-chave: ***Brassica oleracea***, *germinação, características químicas do solo.*

INTRODUCTION

Although studies on nutrition and fertilization recommendations for the commercial production of cauliflower and other vegetables are available, studies about the nutrient effects on production and quality of seeds are rare (CARDOSO, 2011). Well fertilized plants are able to produce more seeds, with higher quality. However, some reports state that the seeds produced under marginal conditions are usually as viable and vigorous as those produced under more favorable situations. In this case, fertilization influence would occur basically on the number of seeds produced, and it would not affect

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the quality. This response, reduction on production without affecting quality, was observed in lettuce for potassium (KANO et al., 2006), phosphorus (KANO et al., 2012) and organic compost (QUADROS et al., 2012), and in broccoli, also with rates of organic compost (MAGRO et al., 2010). Some reports stated that nutritional effect on the quality of seeds can be observed after some period of seed storage (KANO et al., 2011; MAGRO et al., 2012).

In cauliflower, the amounts of nutrients required for seed production may be different from those employed for commercial production, since the crop has a higher development cycle, formation of new structures, flowers and seeds, and, probably, a greater nutrient uptake. In broccoli, the same species of cauliflower, MAGRO et al. (2009, 2010) obtained higher seed production with much higher rates of organic compost than recommended for commercial inflorescence production, and higher extraction of all macronutrients in relation to a commercial crop.

In the seed, phosphorus is stored in the salts of phytic acid, constituting phytin, which, during germination, is degraded to release these nutrients in order to be used in the development of embryo and seedling (CARVALHO & NAKAGAWA, 2000). Phosphorus deficiency usually causes delay in flowering and reduction in number of seeds and fruits in many species.

Due to the scarcity of information on nutritional requirements of cauliflower grown for seed production, yield and quality of seeds may not be currently reaching the highest potential. So, this research aimed to evaluate the influence of rates of phosphorus on the production and quality of cauliflower seeds.

MATERIALS AND METHODS

The experiment was carried out at the Experimental Farm São Manuel, located in the municipality of São Manuel, belonging to Faculdade de Ciências Agronômicas (FCA), Universidade Estadual Paulista (UNESP). The geographical coordinates of the area are: 22° 46' South latitude, 48° 34' West longitude and altitude of 740m. The predominant climate of the region of São Manuel is Cfa, humid subtropical (mesothermal) climate, according to Köppen's classification (CUNHA & MARTINS, 2009).

Plants were grown in a metallic unheated greenhouse, covered with transparent low density polyethylene film, with 20m long, 7m wide and 1.8m high, which stood with sides opened to allow the entry of pollinating insects. The extraction, clean up and analysis of seed quality were carried out in the Horticulture Department of FCA/UNESP.

The soil chemical analysis, prior to the experiment, showed: $pH_{(CaCl2)} = 5.8$; $P_{resin} = 11mg\ dm^{-3}$; organic matter = 5g dm^{-3}; base saturation = 74%; and the values of H + Al; K; Ca; Mg; sum of bases and CEC, expressed in $mmol_c\ dm^{-3}$, respectively of: 11; 2.2; 21; 8; 31 and 42. For these results, the initial P content in the soil ($11mmol_c\ dm^{-3}$) is considered low, according to RAIJ et al. (1997) criteria.

The fertilization at planting consisted of the supply of 20t ha^{-1} of organic compost, 60kg ha^{-1} of N and 240kg ha^{-1} of K_2O, as recommended by RAIJ et al. (1997), in the form of ammonium sulfate and potassium chloride, respectively. The chemical analysis of the compost showed pH values of 8.2 and values of organic matter, N, P_2O_5, K_2O, Ca, Mg and S, expressed in % of dry matter, respectively of: 13.3; 0.43; 0.62; 0.48; 1.61; 0.17 and 0.20. The ratio Carbon/Nitrogen (C/N) was of 19/1 and the compost moisture content of 38%.

A randomized complete block design, with five treatments (rates of P_2O_5) and four replications, with three plants per plot, was used. For definition of treatments, the rate recommended by RAIJ et al. (1997) for the production of cauliflower (600kg ha^{-1} of P_2O_5) was used as a reference, considering a low P content in the soil (11mg dm^{-3}) resulting in the following treatments: T0: treatment without P application (zero of P_20_5); T300: half P rate recommended (RR) by RAIJ et al. (1997) (0.5 x RR = 300kg ha^{-1} of P_20_5); T600: the recommended rate (RR= 600kg ha^{-1} of P_20_5); T900: one and half time the recommended rate (1.5 x RR = 900kg ha^{-1} of P_20_5); T1200: twice the recommended rate (2.0 x RR = 1200kg ha^{-1} of P_20_5). Triple superphosphate (42% of P_2O_5) was used as P source.

The cultivar 'Piracicaba Precoce' was used. Sowing was carried out on March 01, 2011 in polypropylene trays of 162 cells (31cm^3 each cell), containing commercial substrate for vegetable seedling production. Seedlings were transplanted on March 31, 2011 in pots with a volume of 13L, with one plant per pot, spaced 1.0m between rows and 0.5m between plants (center to center of the pots).

Top dress application of nitrogen (200kg ha^{-1} of N) and potassium (100kg ha^{-1} of K_2O) was carried out, divided into three applications, on April 08 and 20 and May 12, 2011, using ammonium sulphate (21% of N) and potassium chloride (60% of K_2O), respectively. In seedling phase, spray applications with boric acid (1g L^{-1}) and sodium molybdate (1g L^{-1}) were made, as well as at 15 days after transplanting. Disease and pest control were carried out according to the needs of the crop. Drip irrigation was performed.

Seeds were harvested when approximately 50% of siliques in each plant were yellowish, not completely dry, and the seeds showed dark brown or black color. The seeds were manually extracted and have benefited in seed separator density with the model unit “De Leo Type 1”. These classified seeds were taken to a drying chamber at 40% relative humidity and at temperature of 20ºC, to better preserve them and provide stabilization of water content in 7%, which was determined by the method of oven at 105°C for 24 hours, according to the Rules for Seed Analysis (BRAZIL, 1992). They were placed about one gram of seeds in each container with two replications for each treatment. After one month in this environment, the evaluation of seed production (with the results expressed in number and seed weight per plant), one thousand seed weight were obtained. Some characteristics related to physiological quality of these seeds were also evaluated: germination, first count of germination and emergence in substrate.

The seed germination test was carried out according to the Rules for Seed Testing (BRASIL, 2009), using gerbox-type boxes in a germinator at 20°C, being sowed 50 seeds per plot, with four replications. The first count of normal seedling was carried out at 5 days and the second count, at 10 days.

Emergence test was also performed, in polypropylene trays of 162 cells ($31cm^3$ each cell), containing substrate for vegetable seedling production. A hundred seeds per plot were sowed. The seedlings were considered emerged when the cotyledonary leaves were fully opened. For statistical calculations, total of seedlings until the 10^{th} day after sowing (DAS) was considered. Emergence at 5^{th} DAS was also evaluated, simulating the first count usually held in the germination test.

Besides the evaluation of production and physiological quality of the seeds, the effects of P_20_5 rates on the soil chemical characteristics were also studied. Sub samples were taken, at a depth of 0-20cm, from all pots, 15 days after the transplantation, which were mixed, in order to constitute a single sample which represents the plot. Samples were taken to the laboratory of soil analysis of Departament of Soil and Environmental Resources - FCA/UNESP, to determine phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), hydrogen + aluminum (H + Al) contents, pH values and to calculate the sum of bases (SB), cation exchange capacity (CEC) and base saturation (V%).

Data were subjected to analysis of variance and regression to verify the effect of phosphorus rates on the characteristics evaluated. The original data were processed by Sisvar 5.0 program.

RESULTS AND DISCUSSION

Chemical characteristics of soil

At 15 days after seedling transplantation, it was observed that the treatments did not affect potassium (average of $4.4mmol_c$ dm^{-3}) and magnesium (average of $11.7mmol_c$ dm^{-3}) contents and base saturation (average of 83.1%). Value of K, Mg contents and V%, regardless of the treatment, can be considered high, according to RAIJ et al. (1997), not being limiting for plant growth and seed production.

A linear reduction in pH value, in relation to P_20_5 rates, was obtained (Figure 1). For each increase of 100kg ha^{-1} of P_2O_5 applied to the soil, a decrease of 0.029 pH units was observed, that means, a relatively small value. The dissolution of triple superphosphate, fertilizer used in this experiment, decreases the pH around granules, due to the release of H^+ (MANTOVANI et al., 2007), while increasing the concentration of potential acidity, H+Al (Figure 1). Despite these changes in pH, values ranged from 6.22 to 6.56, all within the optimum range for the crop, both for the commercial production (RAIJ et al., 1997) and for seed production (GEORGE, 2009), values which showed better nutrient availability for the plants.

A linear increase in Ca content of the soil was obtained, with an increase of $0.59mmol_c$ dm^{-3} for each 100kg ha^{-1} of P_2O_5 applied to the soil (Figure 1). It is important to remember that when phosphorus fertilizer application is performed, using fertilizers as triple superphosphate, phosphorus is not the only nutrient which is added, but other nutrients which are contained in superphosphate, such as calcium (Ca), because this fertilizer presents 12% CaO. With an increase in calcium cation in the soil, a linear increase in SB and CTC was also observed (Figure 1).

For the phosphorus content, according to expected, a linear increase with P_2O_5 rates applied to the soil was observed, with an increase of 12.25mg dm^{-3} for each 100kg ha^{-1} of P_2O_5 applied to the soil (Figure 1). The soil used in this study (836, 116 and 48g kg^{-1} of sand, silt and clay, respectively) is a sandy soil, with a small proportion of clay, finer fraction of soil and most responsible for setting P (AMORIN et al., 2008), which should have favored this linear response and large increase in the content of this element available to plants.

According to criteria of RAIJ et al. (1997), the phosphorus contents evaluated at 15 days after

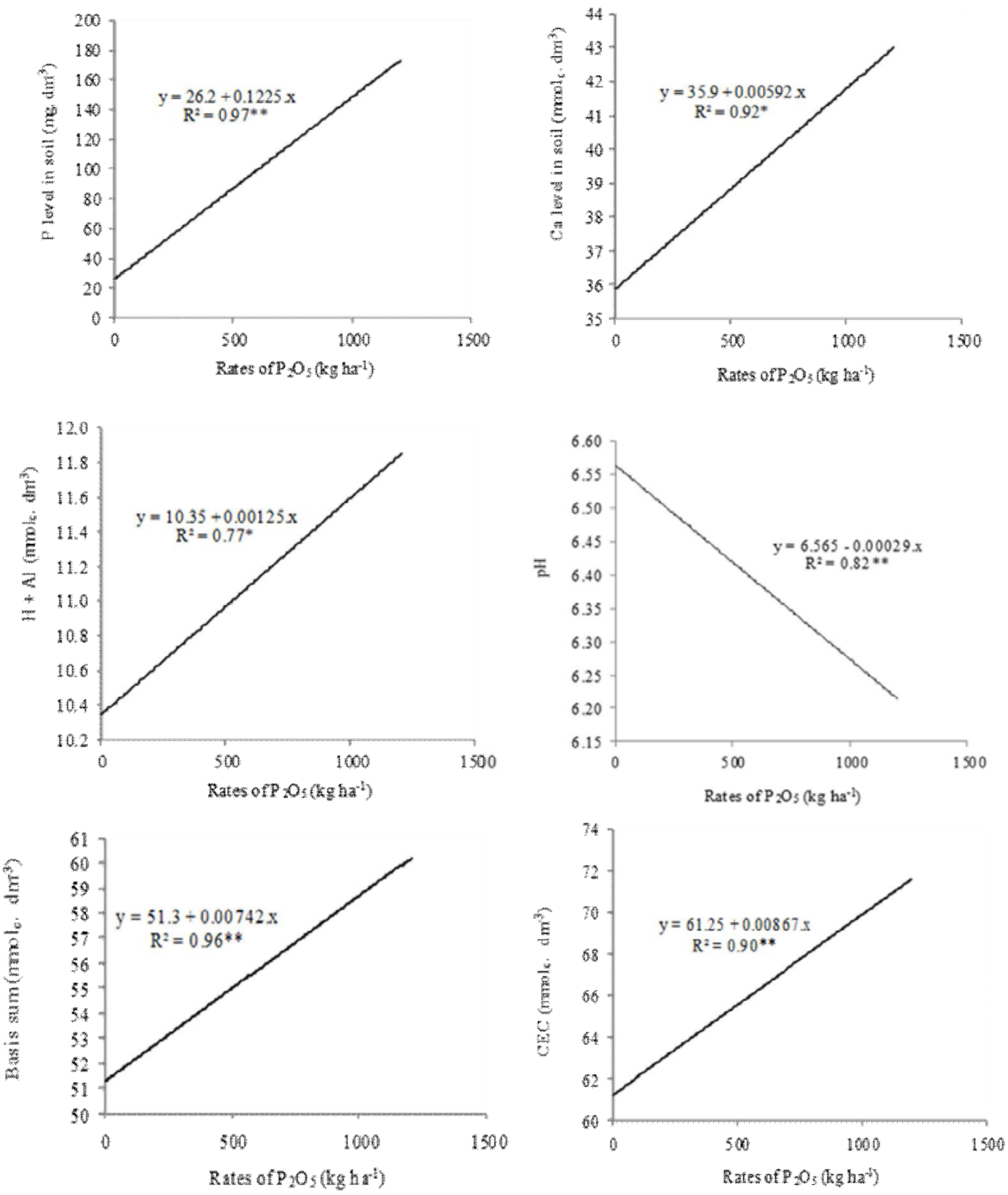

Figure 1 - Levels of phosphorus, calcium and H + Al, pH, basis sum and cation exchange capacity (CEC) in soil 15 days after transplantation of cauliflower seedlings, in function of phosphorus (P_2O_5) rates.

the transplant changed from low P content (control without P) to high content with only 300kg ha^{-1} of P_2O_5 and from high to very high content at rates higher than 900kg ha^{-1} of P_2O_5 (Figure 1).

Seed production and quality

Seed production adjusted to a quadratic model (Figure 2), with maximum estimated production of 20.72g $plant^{-1}$ for 862kg ha^{-1} of P_2O_5. This rate (862kg ha^{-1} of P_2O_5) is higher (almost 50%) to the maximum rate (600kg ha^{-1} of P_2O_5) recommended by RAIJ et al. (1997) for cauliflower production in soils with low phosphorus contents, confirming the greater necessity of this nutrient when the objective is seed production. At the beginning of the reproductive phase the nutritional requirement, for most species, becomes more intense, being more critical in seed formation when considerable amount of nutrients, such as

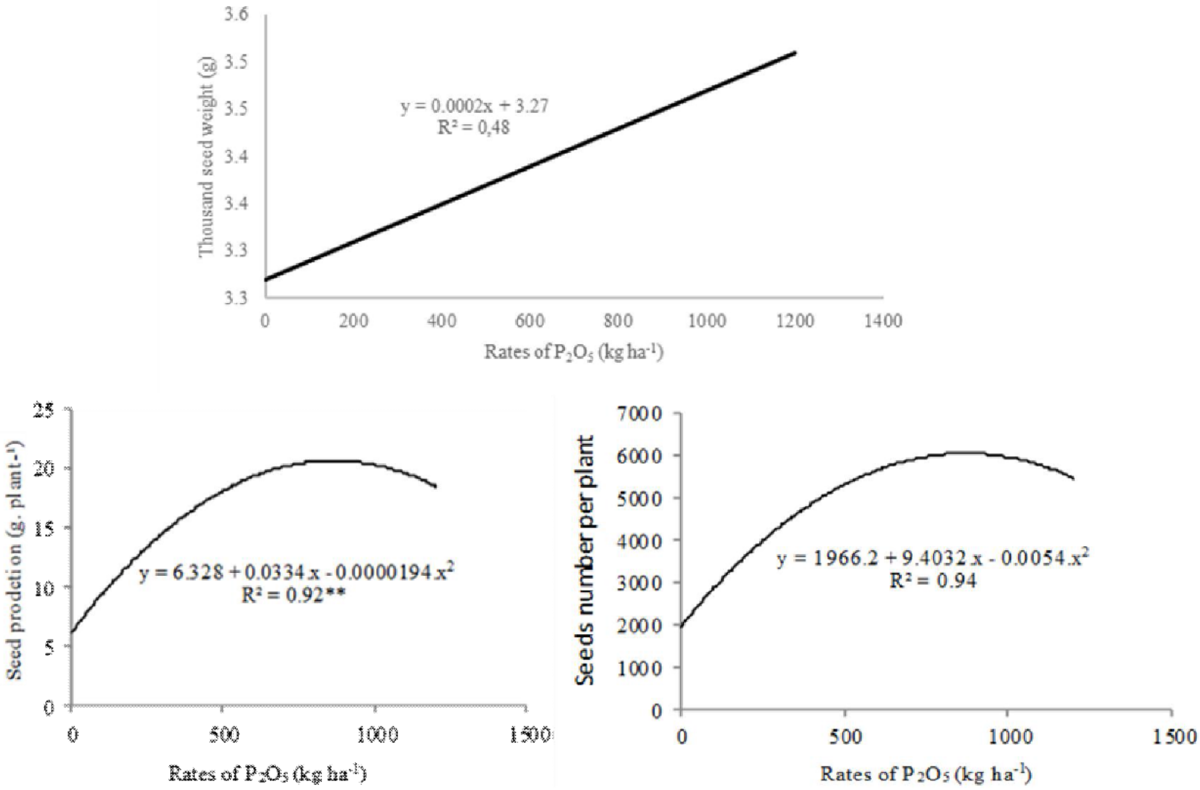

Figure 2 - Cauliflower seed production (weight and number) per plant and a thousand seed weight, in function of phosphorus (P_2O_5) rates.

phosphorus, are translocated to them (CARVALHO & NAKAGAWA, 2000; CARDOSO, 2011).

JAMWAL et al. (1995), aiming to verify the influence of phosphorus rates (0 to 150kg ha^{-1}) on cauliflower seed production, obtained linear response. JANA & MUKHOPADHYAY (2002) verified significant increase in cauliflower seed production with an increase of P rates (0 to 120kg ha^{-1} of P_2O_5) and concluded that for seed production phosphorus requirement was higher than for commercial production. All these authors studied lower rates than the ones in this research and obtained linear effects, that means, probably, maximum yield had not been reached. In addition, soil and climatic conditions are different.

Considering spacing of 1.0 x 0.5m, the maximum estimated yield is 414.4kg ha^{-1}, value considered good by MALUF & CORTE (1990), for a summer cultivar in Brazil.

The maximum seed production was estimated at a rate of 862kg ha^{-1} of P_2O_5 (Figure 2). For this rate, P content in soil was estimated at 131.8mg dm^{-3} (Figure 1), value classified as high by RAIJ et al. (1997).

Seed number per plant (Figure 2) showed a direct relationship with weight production, also fitting the quadratic model according to the phosphorus rates used. The maximum estimated seed production (6060 seeds per plant) occurred at a rate of 870kg ha^{-1} of P_2O_5, similar to maximum weight production (g $plant^{-1}$).

For most of the traits related to quality evaluated (first count of germination, total germination, emergence in tray at 5th and 10th DAS) no significant statistical differences were observed, thus, it can be concluded that seed quality was not influenced by P_2O_5 rates used, with the exception of one thousand seed weight which showed difference.

For one thousand seed weight, linear effect was obtained; however, with low coefficient of determination, $R^2 = 0.48$ (Figure 2). The increase was of 0.02g (or 20mg) for one thousand seed weight for each 100kg ha^{-1} of P_2O_5 applied to the soil. JANA & MUKHOPADHYAY (2002) also verified an increase in one thousand seed weight of cauliflower with an increase of phosphorus rates. Average in the present research was 3.4g, value higher than the one (2.8g) reported by GEORGE (2009) for cauliflower.

GRANT et al. (2001) point out that plants respond to phosphorus deficiency with adaptations that enable them to maximize the probability of producing some viable seeds. Generally, phosphorus stress decreases more the total seed production than the seed size. In fact, the effect on seed number was more pronounced. The difference between the lowest rate (control = 1966 seeds per plant), and the rate for maximum production (870kg ha^{-1} of P_2O_5 = 6060 seeds per plant) was of 4094 seeds per plant, that means, an increase of 208%. For one thousand seed weight, the increase between control and the highest value was only 7%.

The average of seeds germinated in the first count (5th DAS) was of 96%, which can be considered high. The same was observed for the final germination percentage (10th DAS), with average of 97%. The high values obtained in the first count of germination and germination showed the excelent quality and vigor of seeds. Germination obtained was much higher than the minimum (70%) required by the Ministério da Agricultura Pecuária e Abastecimento (MAPA) for the marketing of cauliflower seed. Effect of levels of phosphorus fertilization on seedling emergence was also not verified, both at 5th (average 69%) and at 10th (average 87%) DAS.

These results are similar to those reported by other authors in vegetable seed production who also observed difference in seed production related to fertilization, but they did not find differences in quality of its seeds (KANO et al., 2006, 2012 and QUADROS et al., 2012 in lettuce; MAGRO et al., 2010 in broccoli) and helped to confirm the theory of DELOUCHE (1980) which states that the seed produced under marginal conditions are usually as viable and vigorous as those produced under more favorable conditions. In this case, the influence of fertilization would be basically on the number and weight of seeds produced, and this fertilization would not affect seed quality.

Another aspect that may be providing no quality difference is the seed classification. Most often, the seeds harvested in experiments are processed with the removal of empty and damaged, prior to the evaluation of production and quality. Through this procedure, a uniformity of lots of different treatments is obtained because the worst seeds are discarded. Seed processing procedure is routinely done by companies, because seeds need to be processed to be marketed (CARDOSO, 2011).

CONCLUSION

It is concluded that phosphorus rates did not affect germination and vigor of the seeds, however seed production, which was adjusted to quadratic model with maximum estimated yield with rate of 862kg ha^{-1} of P_2O_5.

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