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Phosphorus rates on yield and quality of lettuce seeds

Cristiaini Kano[1]; Antonio Ismael Inácio Cardoso[2]; Roberto L Villas Bôas[3]

[1]Embrapa Amazônia Ocidental, C. Postal 319, 69010-970 Manaus-AM; [2]UNESP-FCA, Depto. Produção Vegetal, Setor Horticultura, C. P.ostal 237, 18610-307, Botucatu-SP; [3]UNESP-FCA, Depto. Recursos Naturais, Setor Ciência do Solo; criskano@hotmail.com; ismaeldh@fca.unesp.br; rlvboas@fca.unesp.br

ABSTRACT

Because of lack of information about phosphorus fertilization in lettuce from the standpoint of seed production, this study was undertaken. The work was carried out in Botucatu, São Paulo state, Brazil, from September 25, 2003 to February 19, 2004, in order to study the influence of crescents phosphorus rates on yield and quality of lettuce seeds, cultivar Verônica. The experimental design was randomized blocks with five treatments (0; 200; 400; 600 and 800 kg ha^{-1} of P_2O_5) and five replications. The following characteristics were evaluated: seed production per plant (g $plant^{-1}$), number of seeds per plant and quality (percentage of germination and seed vigor). A linear increasing was observed on production and number of seeds per plant of lettuce with phosphorus rates, but these rates did not affect the seed physiological quality evaluated on weight of 1,000 seeds (average = 0.91 g), first count of germination (98%), standard germination test (99%), seed germination speed index (68.5), seedling emergence speed index (97.0) and emerged seedlings (49.3%).

Keywords: *Lactuca sativa*, phosphorus fertilization, P_2O_5, germination, vigor.

RESUMO

Doses de fósforo na produção e qualidade de sementes de alface

Este estudo foi conduzido devido à falta de informações sobre a adubação em plantas de alface do ponto de vista da produção de sementes. O trabalho foi conduzido em área da UNESP, em Botucatu, de 25/09/03 a 19/02/04 com o objetivo de avaliar a influência de doses crescentes de fósforo na produção e qualidade de sementes de alface, cultivar Verônica. O delineamento experimental utilizado foi blocos casualizados, com cinco tratamentos (0; 200; 400; 600 e 800 kg ha^{-1} de P_2O_5) e cinco repetições. Foram avaliadas as características de produção de sementes por planta (g $planta^{-1}$), número de sementes por planta e a qualidade (percentagem de germinação e vigor de sementes). Foi observado aumento linear na produção e no número de sementes por planta com as doses de P_2O_5, mas estas doses não afetaram a qualidade fisiológica das sementes avaliada pela massa de mil sementes (média de 0,91 g), primeira contagem da germinação (98%), germinação (99%), índice de velocidade de germinação (68,5), índice de velocidade de emergência (97,0) e taxa de plântulas emergidas (49,3%).

Palavras-chave: *Lactuca sativa*, adubação fosfatada, P_2O_5, germinação, vigor.

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There are some studies about fertilization of lettuce (*Lactuca sativa*), but few researches have been made to study lettuce seed yield and quality. Such information is very important, because the quantity of phosphorus or another nutrient used for the production of lettuce heads can be quite different from the quantities necessary for seed production, because the development cycle is longer and, probably, the nutrient extraction greater for the latter than for the former case. Usually, at the beginning of the reproductive stage, nutritional demand in most species is more intense and becomes critical at seed formation when significant amounts of nutrients, like phosphorus, are transported to seeds (Carvalho & Nakagawa, 2000).

Phosphorus stimulates root development and its deficiency usually causes blooming delay and reduction in number of seeds and fruits. Phosphorus is stored in seeds, along with other nutrients, in phytic acid (Copeland & McDonald, 1995; Malavolta, 2006).

Phosphate fertilization has increased seed yield of common beans (Zucareli *et al*., 2006). In lettuce, there is no information about effects of phosphorus rates on seed production, unlike information on other nutrients. Kano *et al*. (2006) related that increasing doses of potassium (0; 1.0; 1.5; 2.0 and 2.5 g $plant^{-1}$ of K_2O) resulted in a linear increase in seed yield. However, these potassium rates did not influence seed quality. Similar result was observed by Soffer & Smith (1974). Harrington (1960) related reduction in lettuce seed yield and quality under severe nutrient deficiencies. Carvalho (1978) studied the effect of nitrogen fertilization and related that it did not affect seed yield

or quality.

The objective of this work was to study the influence of phosphorus rates on the yield and quality of lettuce seeds.

MATERIAL AND METHODS

The work was carried out at the Experimental Farm São Manuel, from the Universidade Estadual Paulista, São Paulo state, Botucatu, Brazil (22º46'S, 48º34'W, altitude 740 m) (Cunha & Martins, 2009).

Chemical soil analyses showed pH ($CaCl_2$)= 4.0; P_{resyn} = 2 mg dm^{-3}; organic matter = 5 g dm^{-3}; base saturation = 16%; and H+Al; K; Ca; Mg; basis sum and cation exchange capacity values, in $mmol_c$ dm^{-3}, of 28; 0.2; 4.0; 1.0; 5.0 and 33, respectively. The soil is sandy with 761 g of sand per soil kg.

The experimental design was of randomized blocks with five treatments (0, 200, 400, 600 and 800 kg ha^{-1} of P_2O_5) designated as T0, T200, T400, T600 and T800, respectively and five replications. Respectively rates of P_2O_5 represent zero, half, full, one and a half and twice the rate recommended by Raij *et al*. (1996) for fresh market lettuce.

Considering that plants were grown in plastic pots of 13 L, these treatments corresponded to 0; 1.3; 2.6; 3.9 and 5.2 g of P_2O_5 in each pot (T0, T200, T400, T600 and T800, respectively). The treatments with higher rates than the rates recommended for commercial production of lettuce, were used because of the longer cycle of the plant in seed production. All phosphorus was applied at planting date, using triple superphosphate.

Soil preparation with high reactivity limestone (neutralization capacity = 90%) was done 30 days before seedling transplantation in order to raise base saturation to 80% as recommended by Raij *et al*. (1996).

Fertilization corresponded to a supply of 0.26 g $plant^{-1}$ of N (ammonium sulfate), 1.6 g $plant^{-1}$ of K_2O (potassium chloride) and 500 g $plant^{-1}$ of Biomix® as a source of organic matter. The results of Biomix® chemical analysis showed pH of 7.7 and the percentages of organic matter; N; P_2O_5; K_2O; Ca; Mg and S were 53; 1.30; 0.90; 0.47; 6.80; 0.25 and 0.34, respectively. The C/N ratio was 23/1 and the humidity 60%. In top-dressing, made every other week, plants received a total of 3.6 g $plant^{-1}$ of N and 4.8 g $plant^{-1}$ of K_2O in the form of calcium nitrate and of potassium nitrate.

Seeds of loose leaf lettuce, cultivar Veronica, were sown on September 25, 2003 and seedlings were transplanted to 13 L plastic pots on October 30, 2003. Seeds were manually harvested at physiological maturity, according to George (2009), starting on the 84th and ending on the 112th days after transplant (DAT). After cleaning, seeds were stored in a dry chamber at a relative humidity of 40% and temperature of 20°C.

After the water content had stabilized at 7.7%, the seeds were counted, weighted (with results given in seed number and seed weight per plant and a thousand seed weight) and used to evaluate their physiological quality (germination and vigor).

Seed germination test was done according to the Brazilian rules for seed analysis (Brasil, 2009). Five replicates of 100 seeds of each treatment were placed in a germination box (gerbox) at 20°C. Counting of normal seedlings number was carried out on the fourth and seventh day after sowing (DAS). Evaluations were made daily until the 7th DAS in order to obtain the seed germination speed index (GSI) which is a vigor indicator (Maguire, 1962).

Seed quality was also assessed by the percentage of seedlings emerged in expanded polystyrene trays with Plantmax® (a commercial substrate for vegetable seedlings production). One hundred seeds were sown per replicate and the trays were kept in a greenhouse during the test. Seedlings were considered emerged when cotyledonary leaves were totally open. Evaluations were made until the 10th DAS in order to obtain the seedling emergence speed index (ESI), following Maguire (1962). Also, on this test, 40 seedlings per plot were collected at transplantation stage (30 DAS) to evaluate fresh and dry mass of the aerial part.

The data were subjected to an analysis of variance and, when F-test for treatments was significant, a regression analysis was applied.

RESULTS AND DISCUSSION

Soil was analyzed again before seedling transplantation. The following levels of P_{resyn}: 8; 14; 44; 66 and 90 mg dm^{-3} for treatments T0, T200, T400, T600 and T800, respectively, were recorded. At the end of the culture cycle soil was reanalyzed and the following levels of P_{resyn}: 6; 12; 35; 48 and 57 mg dm^{-3} for treatments T0, T200, T400, T600 and T800 were observed, respectively. These results showed an increase in phosphorus availability according to phosphorus rates applied.

Seed yield per plant, and number of seeds per plant, increased linearly with the increase of phosphorus rates (Figures 1 and 2), demonstrating that

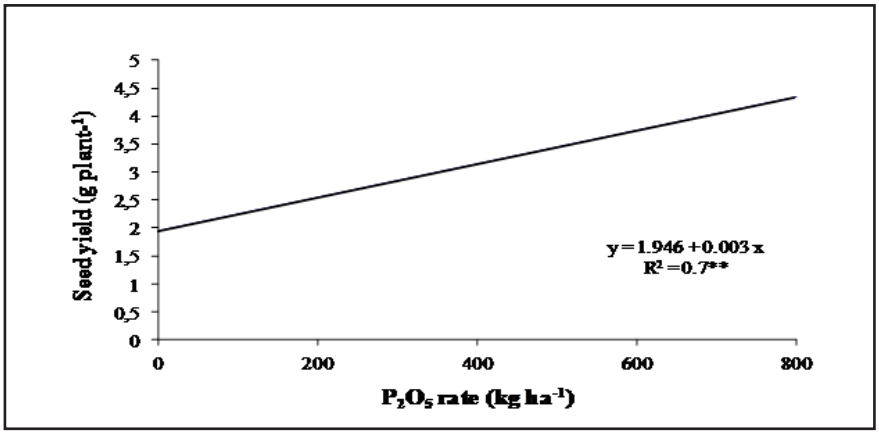

Figure 1. Yield of lettuce seeds (g $plant^{-1}$) depending on phosphorus rates (produção de sementes de alface (g $planta^{-1}$) em função de doses de fósforo). São Manuel, UNESP, 2003-2004.

the need for phosphorus for seed production was greater than that for consumption *in natura*, where T400 is the rate recommended. In comparison to control (T0), seed production was doubled with the largest rate tested (800 kg ha^{-1} P_2O_5). However, it must be stressed that the experiment was carried out in a soil with 2 mg dm^{-3} (P_{resyn}), a value considered very low by Raij *et al*. (1996), and the culture cycle was about three times longer than the usual cycle for fresh market cultures. Also, Kano *et al*. (2006) reported a linear increase in the production of Veronica lettuce seeds with increase in K_2O rate in this same soil.

In terms of seed quality, phosphorus rates did not cause a significant effect, by F test, in any evaluated characteristics: one thousand seeds weight (mean 0.91 g), first count of germination (98%), standard germination test (99%), germination speed index (68.5), number of plants emerged on the 10th day after sowing at tray (49.3%) and seedling emergence speed index (97.0), demonstrating that the quality of seeds was not affected by phosphorus rates (Table 1). The excellent quality of the seeds obtained can be verified by the high values from the first germination counting (≥98% for all treatments) and by the total germination values (≥99% for all treatments).

Quadros (2010) evaluate rates of organic compound, with and without phosphorus added to the soil, on the production and quality of lettuce seeds.

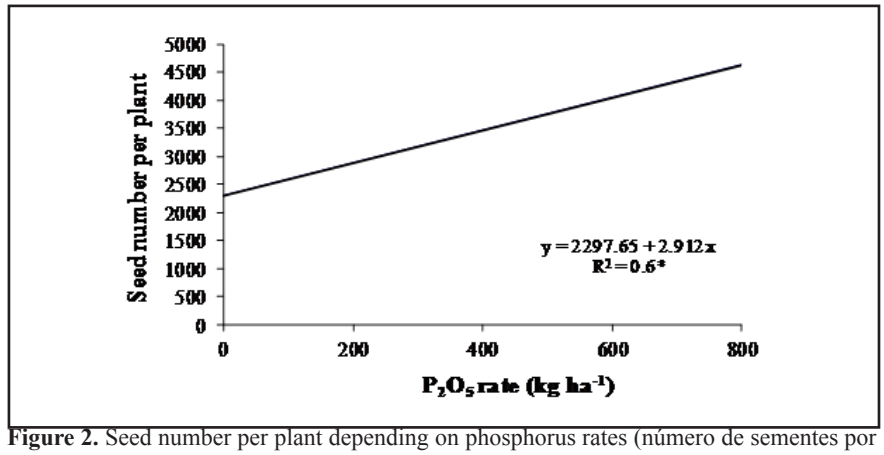

Figure 2. Seed number per plant depending on phosphorus rates (número de sementes por planta em função de doses de fósforo). São Manuel, UNESP, 2003-2004.

The author observed that the seed quality was not affected by both soil fertilization with organic compound as with phosphorus. However, these fertilization with phosphorus affected nutrient content in seeds (Quadros *et al*., 2011).

Also, the phosphorus rates did not influence fresh (1.17g) or dry (0.09g) weights of seedlings obtained at transplantation stage (30 DAS) in the emergence test. When determining the effects of seed vigor in the formation of lettuce seedlings, Franzin *et al*. (2005) concluded that seed lots with higher vigor, as detected by laboratory germination and vigor tests, produced seedlings with greater weight. So, it is possible that in the current experiment the absence of differences in seedling fresh and dry weights among treatments was attributable to no initial difference in the quality of seeds.

The influence of fertilization in the yield, but not in the quality of lettuce seeds, was also found by Kano *et al*. (2006), who observed no effect of potassium rates on the quality of lettuce seeds. Also, Soffer & Smith (1974) found that an increase in fertility of the soil increased lettuce seed yield but did not cause a corresponding increase in vigor.

Harrington (1960) grew lettuce, carrots and pepper in two types of nutrient solutions: complete and deficient in nitrogen, phosphorus, potassium and calcium. He noted that the seed yield was reduced in treatments with deficient nutrient solution. Moreover, the rate of normal seedlings was not affected by the nutrient solution deficient in phosphorus. Phosphate fertilization has also increased yield, but not quality

Table 1. Means of lettuce seed physiological quality depending on phosphorus rates (médias da qualidade fisiológica de sementes de alface em função de doses de fósforo). São Manuel, UNESP, 2003-2004.

Treatment (kg/ha of P_2O_5)	1,000 seeds weight (g)	Seed germination test (%)		GSI	ESI	Emerged seedlings (%)
		First count	Standard germination test			
T0 (0)	0.87 a	99 a	99 a	73.3 a	97.6 a	49.4 a
T200 (200)	0.88 a	99 a	99 a	67.8 a	96.3 a	49.3 a
T400 (400)	0.91 a	98 a	98 a	67.2 a	95.7 a	48.8 a
T600 (600)	0.90 a	99 a	100 a	67.8 a	98.0 a	49.4 a
T800 (800)	0.95 a	99 a	99 a	66.5 a	97.3 a	49.4 a
F	0.92^{ns}	0.74^{ns}	0.68^{ns}	0.45^{ns}	0.95^{ns}	0.60^{ns}
CV (%)	7.7	1.6	1.7	13.2	2.3	1.6

GSI= seed germination speed index (índice de velocidade de germinação); ESI= seedling emergence speed index (índice de velocidade de emergência).

of seeds in common beans (Zucareli *et al*., 2006).

Vieira *et al*. (1987) found that larger rates of phosphorus did not affect germination, emergence speed index and plant dry weight of soybean seedlings. A similar result was obtained by Bevilaqua *et al*. (1996), who concluded that fertilization had no influence on germination percentage and emergence speed rate and dry weight of soybean seedlings, demonstrating that, as in the current experiment, the rates of phosphorus given to the soil did not affect the quality of seeds.

According to the latest references consulted, it is quite evident that fertilization usually has a positive influence on seed yield. However, responses relative to seed quality, when evaluated, did not always show improvements (Carvalho & Nakagawa, 2000). According to Delouche (1980), plants have developed an extraordinary adaptability in adjusting seed production to available resources. A plant's typical response to low soil fertility is a reduction in seed number and, only after that, a reduction in quality happens. The few seeds produced under marginal conditions are usually as viable and vigorous as those produced under optimal one. From the evolutionary standpoint, the seed production adjustment to the available resources has a high survival value. The few high quality seeds would have good chances of germinating and developing under adverse conditions. However, according to Zucarelli (2005), effect of fertilization on seed quality is observed after some storage time of seeds. This was confirmed by Magro *et al*. (2012) in broccoli seeds.

The results obtained led to the conclusion that phosphorus affects the production and number of seeds per plant of lettuce, but does not affect their quality.

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