Effects of soil, root mycorrhization, organic and phosphate fertilization, in organic lettuce production

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Abstract

The influence of organic and phosphate fertilization, and root mycorrhization, in organic lettuce production, was assessed with factorial treatment combinations of: soil type (SOP – soil from organic and SCP – soil from conventional production) and organic fertilizer (0, 2 and 4 t ha^{-1}) in the first trial; mycorrhizal inoculation (mycorrhized and non-mycorrhized plants) and Gafsa phosphate (0, 100 and 200 kg P_2O_5 ha^{-1}) in the second. Lettuce yield decreased in the SCP with the application of increasing rates of organic fertilizer due to the very high electrical conductivity (50.1 dS m^{-1}) and lack of maturation of this fertilizer. However, the harmful effects of the organic fertilizer were minimized in the SOP. The application of increasing rates of Gafsa phosphate increased lettuce yield and nutrient uptake. However, the mycorrhization did not increase lettuce yield and, for mycorrhized lettuces, yield did not increase with the highest rate of Gafsa phosphate application.

Introduction

The use of synthetic fertilizers modifies the balance of the soil ecosystem (Lampkin, 1990). Despite the benefits of amending the soil with organic fertilizers, farmers should consider the amount and quality of organic materials to use as soil amendments because its indiscriminate application can cause phytotoxicity problems (Brito, 2001). Lettuce is a vegetable of great importance in Portugal but is seldom cultivated in organic agriculture (OA). To increase organic lettuce yield producers need information to decide on this crop fertilization and there is lack of experimental results to support fertilizer recommendations in OA. This study evaluated the effects of a certified organic fertilizer applied both to a soil from organic production (SOP) and to a soil from conventional production (SOC), on lettuce yield. Simultaneously, the effects of Gafsa phosphate and mycorrhization on lettuce growth and nutrient uptake were quantified to investigate whether the mycorrhization of lettuce may increase lettuce production in different conditions of soil available phosphorus.

Material and methods

Lettuce (Lactuca sativa L.) trials were established in pots inside a greenhouse (unheated). The first trial was a randomized block design with four blocks and six treatments from the factorial structure of two factors: (i) soil of farms with different production methods (organic and conventional); and (ii) organic fertilizer (0, 2 and 4 t ha^{-1}). The organic fertilizer was produced with concentrated vinasse waste and chicken manure. Lettuce variety "Ariel" was transplanted in the beginning of spring and lettuces were harvested 28 and 45 days after transplanting. The SOP showed increased OM content compared to the SCP which in turn showed higher NO_3^--N content (Table 1). Total N content, C/N ratio and pH value, were higher in the SOP compared to the SCP. The electrical conductivity (50.1 dS m^{-1}) and the concentration of NH_4^+-N (18395 mg kg^{-1} DM) of this organic fertilizer were extremely high in relation to the maximum recommended EC less than 3 dS m^{-1} (Soumaré et al. 2002) and NH_4^+-N less than 400 mg kg^{-1}DM (Zucconi and Bertoldi, 1987) for compost use.

The second trial had a randomized block design also with four blocks and six treatments from the factorial structure of: (i) Gafsa phosphate levels (0, 100 and 200 kg P_2O_5 ha^{-1}) and mycorrization (mycorrhized and non-mycorrhized plants). The soil was collected from the same organic farm used for the first trial. Lettuce cv. Maravilla de Verano was sown in the beginning of spring and harvested 28 and 53 days after transplanting. The mycorrhizal inoculum was Glomygel Hortalizas (Mycovitro S.L.) and was applied close to plant roots with the help of a pipette, 7 days after transplanting.

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Table 1. Soils and organic fertilizer characteristics (mean and standard deviation (SD)

	DM	pH	EC	OM	N	NH_4^+-N	NO_3^-- N	C/N	P	K	Ca	Mg
	%		dS m^{-1}	g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}		g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
Soil from organic production												
Mean	81.9	7.1	0.6	64.5	2.4	7	46	16.4	0.9	3.8	2.3	2.0
SD	0.9	0.1	0.1	0.5	0.6	0.8	2.1	0.5	0.1	2.9	1.1	1.4
Soil from conventional production												
Mean	89.3	6.3	0.6	26.5	1.7	3	81	9.2	0.9	5.6	2.9	3.2
SD	0.4	0.1	0.1	0.1	0.6	0.4	3.3	0.1	0.5	2.2	1.7	1.5
Organic fertilizer												
Mean	92.2	5.7	50.1	546	39.5	18395	80	7.7	30.3	30.0	23.3	4.0
SD	0.1	0.1	1.4	11.2	11.5	6933	5	0.5	7.7	13.2	8.3	0.2

SD = Standard deviation
Organic matter (OM) and nutrient contents are expressed on dry matter basis.

Results

A negative effect of the highest rate of organic fertilizer application to SCP on lettuce growth (Fig.1) showed that this fertilizer should not be recommended. The SOP had characteristics which allowed lettuce to better resist the harmful effects of the organic fertilizer in comparison to the SCP. It is likely that the detrimental effect of this specific fertilizer resulted from a combination of the extreme value of electrical conductivity (EC = 50.1 dS m^{-1}) found for this fertilizer and other factors such as ammonia toxicity or the liberation of toxic volatile organics which will probably be correlated with E.C (Brito, 2001). Zucconi et al. (1987) suggested an upper limit of 0.4 g kg^{-1} of NH_4^+-N for municipal solid waste composts which is much lower than NH_4^+-N content found for this organic fertilizer (18 g kg^{-1} DM). In the presence of toxic concentrations of ammonia, the plant reacts by lowering its metabolic rate and decreasing enzymatic activities (Sairam and Tyagi, 2004), reducing root respiration and nutrient uptake.

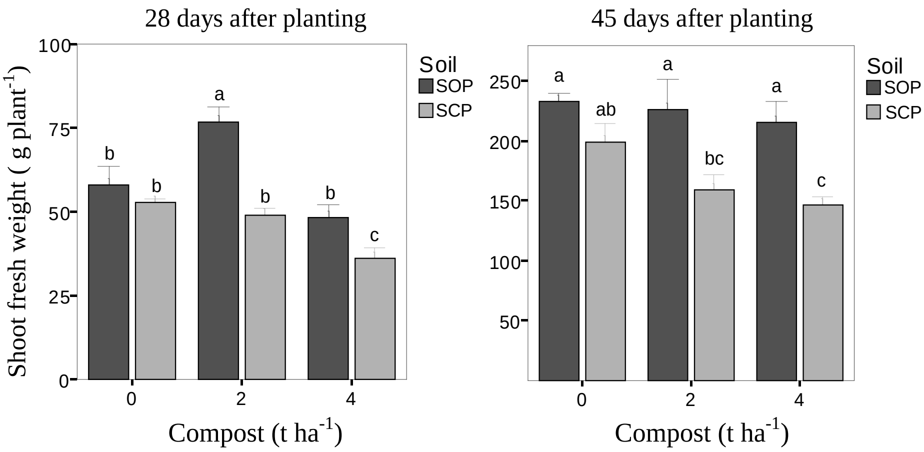
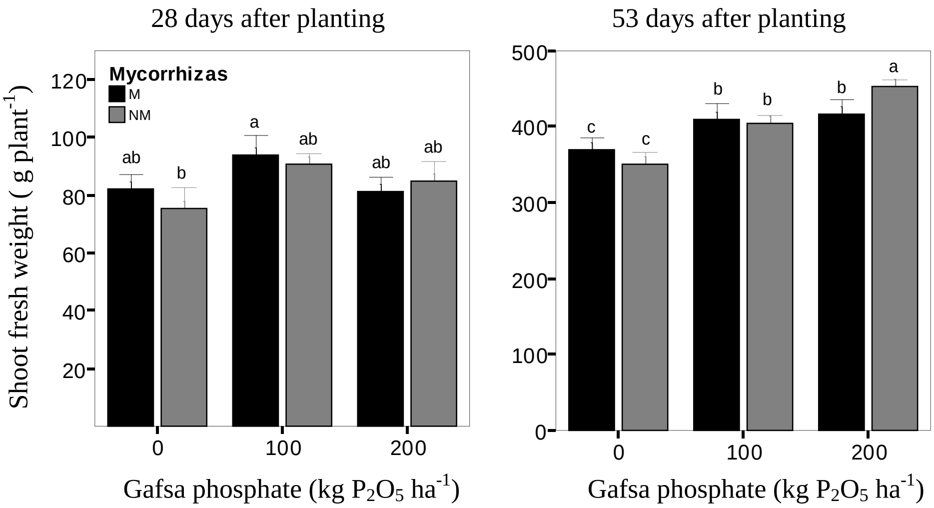


Figure 1. Lettuce shoot fresh weight in soil SOP and SCP with organic fertilizer (0, 2 and 4 t ha^{-1}). Different letters over de bars mean significant weight differences (P <0.05).

The SOP showed greater resistance to harmful effects of the organic fertilizer, probably because of its higher OM content (64.5 g kg^{-1} DM) compared to SCP (26.5 g kg^{-1} DM). The higher OM content, in addition to being a reservoir of nutrients, contributed to increase cation exchange capacity, soil permeability and water retention capacity which favored increased root growth. The harmful effect of the organic fertilizer was not so clear based on shoot and root dry weight as it was on fresh weight. This corroborates that yield loss was related to greater difficulty in absorbing water in the presence of the organic fertilizer. Nutrient uptake with the application of 4 t ha^{-1} of organic fertilizer also decreased for SCP compared with the SOP. Nutrient uptake with the application of 4 t ha^{-1} of organic fertilizer decreased for SCP compared with the SOP because lettuce growth, the water taken up by plant roots and nutrient mass flow decreased in consequence of the high EC of the organic fertilizer.



For the highest rate of Gafsa phosphate application, yield of mycorrhized plants decreased compared with non-mycorrhized. While the increase in lettuce yield with phosphate between 0 and 100 kg ha^{-1} P_2O_5 and also between 100 and 200 kg ha^{-1} P_2O_5 was significant for non mycorrhized plants, for plants inoculated with mycorrhiza the plant fresh weight difference was not significant between the application of 100 and 200 kg ha^{-1} P_2O_5 (Fig. 2). The fresh weight of roots was increased ($P < 0.05$) with the application of the highest rate of Gafsa phosphate in non-mycorrhized plants in the second harvest, but this was not true for mycorrhized plants. These results are in agreement with the findings of Azcón et al. (2003). According to this author, the application of higher rates of N and P to the soil decreased the uptake of N, P and K in mycorrhized compared to non-mycorrhized plants. Lettuce shoot and root nutrient content showed no significant differences ($P < 0.05$) between treatments, except for magnesium in one treatment, nor were there consistent differences either with the application of phosphate or with mycorrhization. Numerically, it was found that the shoot N content of mycorrhized lettuces, in both harvests, was higher than that of non-mycorrhized lettuces, for the same rate of application of phosphate. The same was true for P content, except in second harvest for the highest rate of phosphate.

Figure 2. Lettuce shoot fresh weight in mycorrhized (M) and non-mycorrhized (NM) plants with Gafsa phosphate (0, 100 and 200 kg P_2O_5 ha^{-1}). Different letters over de bars mean significant difference ($P < 0.05$)

Discussion

The very high EC and high ammonia content of this organic fertilizer, decreased lettuce growth, on the SCP but the high quality of the SOP demonstrated ability to withstand disturbances and final lettuce yield significantly increased in this soil compared to SCP. This study shows that there are organic fertilizers on the market that lack quality to be certified for organic farming and should not be recommended either for organic or for conventional vegetable production. The application of increasing rates of Gafsa phosphate increased non-mycorrhized lettuce yield. However, for mycorrhized plants, the application of 200 kg ha^{-1} P_2O_5 showed a detrimental effect on lettuce growth and nutrient uptake. This suggests that high soil available P content may have harmful effects on the activity of mycorrhizal fungi in lettuce. More research is needed for a better understanding of mycorrhizae growth and activity to recommend their use for organic lettuce production.

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