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Nutritional Efficiency of Phosphorus in Lettuce

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Abstract

This work aimed to evaluate the efficiency of phosphorus absorption, translocation, and utilization in lettuce. A greenhouse experiment was arranged in a completely randomized design in a 5x2 factorial scheme to test five phosphorus doses (0, 100, 200, 300, and 500 mg dm^{-3}) and two lettuce varieties (Lisa and Americana). The soil was incubated with limestone for pH correction. Following this procedure, a phosphate fertilization was carried and the lettuce seedlings were transplanted. Fertilization with nitrogen and potassium were applied as cover. Forty days after seedling transplantation, the plants were separated into root and aerial part to determine the following characteristics: aerial part dry matter (APDM); root dry matter (RDM); phosphorus content in the aerial part (PCAP); phosphorus content in the root (PCR); phosphorus accumulation in the aerial part (PAAP); phosphorus accumulation in the roots (PAR); phosphorus absorption efficiency (PAE); phosphorus translocation efficiency (PTE); phosphorus use efficiency in the aerial part (PUEAP) and root-aerial part ratio (R/AP). The results obtained allowed to conclude that RDM and R/AP had a significant interaction between the varieties and the P doses, with Lisa presenting the highest values of these characteristics at the lowest doses evaluated. The characteristics PCAP, PAAP and PAE presented a significant difference between the varieties, with the Americana presenting the highest values. The characteristics PCAP, PAAP, EAP, APDM and PUEAP presented a significant difference between the P doses, with the highest values found at the dose of 500 mg dm^{-3}, except for PUEAP, whose dose was 0 mg dm^{-3}.

Keywords: mineral nutrition, phosphorus use efficiency, phosphorus acquisition

1. Introduction

Lettuce is a leafy vegetable known and cultivated worldwide. It is adapted to mild temperature and adequate to fall/ winter cultivation. It is currently one of the most popular vegetables, being cultivated throughout Brazil (Lima, 2005). In the summer, its reduced offer/demand ratio generally provides higher prices. Its consumption is mostly "in natura" (Filgueira, 2003).

Since lettuce is originated from temperate climate, its adaptation to high temperature regions has generated obstacles to its growth and development, preventing the culture from expressing its total genetic potential. Protected cultivations and the use of cultivars adapted to different conditions of cultivation allow this culture to be available in the market throughout the year (Filgueira, 2003). Lettuce cultivation is of easy management, presenting a short cycle that ensures a rapid return of the capital invested. Among the leafy vegetables, lettuce is the most planted and consumed by the Brazilian population. The state of São Paulo is Brazil's main vegetable producer and has the largest consumer market (Camargo Filho & Camargo, 2008).

Lettuce nutrition is of the utmost importance to guarantee quality production. Thus, fertilization management must be known and planned for this purpose. Besides, nutrition with phosphorus presents peculiarities such as differences in absorption between genotypes (Cock, Amaral Júnior, Smith, & Monnerat, 2002) and their capacity of adsorption in tropical soils, decreasing its availability. This decreases the phosphorus contents available for the plant in the soil's solution. Without considering type of lettuce, the use of 200 to 400 kg ha^{-1} of P_2O_5 has been recommended for phosphate fertilization, according to type of soil and availability of this nutrient in the soil (Filgueira, 2003). Lettuce can be considered quite phosphorus-demanding, especially at the final phase of its cycle, since this macronutrient occurs in various compounds and metabolic reactions (Marschner,1995).

Phosphorus deficiency reduces plant growth, causing head malformation, opaque-green coloration of the old leaves, possibly presenting bronze- red or purple coloration (Katayama, 1993). Absence of P causes a significant reduction in fresh matter production of the plant's aerial part and roots, significant reduction in the plant's diameter and of its content in the leaves, evidencing lettuce's great demand for this nutrient (Lana, ZanãoJúnior, Luz, & Silva, 2004).

Thus, the objective of this work was to evaluate the efficiency of phosphorus absorption, translocation, and use in two lettuce varieties and at different doses of phosphorus.

2. Material and Methods

This work was conducted in 3dm^3 vases, from May to June 2012, under greenhouse conditions, at the Agrarian Sciences Center of the Universidade Federal do Espírito Santo, in Alegre-ES, with geographic coordinates of latitude 20º45' South, longitude 41º48' West and altitude 147 m. The soil used was collected from Red-Yellow Latosol, from which a sample was taken and sent to the laboratory for determination of the chemical attributes (Table 1) and texture (Table 2), according to the methodology described by Brasilian Company Agropecuaria-Embrapa (2009).

Table 1. Chemical attributes of the soil used in the experiment

pH	P	K	Na	Ca	Mg	Al	H+Al	t	T	SB	V	m
H_2O	-----mg dm^{-3}-----		--------------------cmol$_c$dm^{-3}--------------------								------%-----	
5.5	15.03	32.0	2.0	2.37	0.32	0.2	5.78	2.98	8.56	2.78	32.53	6.7

Where, t = Effective cationic exchange capacity; T = Cationic exchange capacity at pH 7 (CTC); SB = Sum of exchangeable bases; V = Saturation Index in bases and m =Saturation Index in aluminum.

Table 2. Texture of the soil used in the experiment

Sand	Silt	Clay	Texturalclass
----------%---------			
46	9	45	(clayey)

Due to its high clay content (45%-Table 2), what would hinder root development, the soil used in the experiment was mixed with washed sand (3:1 (soil: sand)). After the soil was air-dried, loosened, homogenized, and sieved in 2 mm net sieve, acidity was corrected by applying dolomite clay, increasing base saturation up to 60%, according to recommendation by Prezotti, Gomes, Dadalto, and Oliveira (2007) for green leaf cultivation in the state of Espírito Santo. Following limestone addition, the vases were submitted to a period of twenty-one-day incubation.

The experiment was set up in a factorial scheme 5 x 2, with 5 doses of phosphorus and 2 lettuce cultivars in a completely randomized design, with four repetitions. Phosphate fertilization was performed at the end of the incubation, with the phosphorus levels in the treatments being: 0, 100, 200, 300, and 500 mg dm^{-3}. The P doses and fertilization procedures were calculated and carried out according to methodology proposed by Novais, Neves and Barros (1991) for vase fertilization. Phosphorus was added in the form of potassium dihydrogen phosphate p.a. (KH_2PO_4). The seedlings of the Lisa and Americana lettuce varieties were transplanted after these procedures.

Nitrogen and potassium fertilizations were applied under cover top, 15 days after transplanting, according to recommendation by Novais, Neves and Barros (1991). Ammonium sulfate p.a. ($(NH_4)_2SO_4$) was used as a source of nitrogen, and potassium sulfate p.a. (K_2SO_4) was used as a source of potassium, so as to complement this nutrient's dose supplied by the source utilized for phosphorus. Daily irrigations were carried out up to a day before harvest, 40 days after seedling transplanting.

The lettuce plants were separated at the stem base for a separate analysis of the aerial part and roots, which were washed with distilled water, packed in individual paper bags previously identified and placed inside a forced air circulation stove at a temperature of 70ºC for 48 hours for drying and dry mass determination. The dried material was ground in a Willey type mill to determine the phosphorus content of the aerial part and roots, which, in turn, was colorimetrically obtained using an UV-visible spectrophotometer, by the method of phosphomolybdate reduction by ascorbic acid, as described by Embrapa (2009).

The following characteristics were evaluated: (a) aerial part dry matter (APDM); (b) root dry matter (RDM); (c) phosphorus content of the aerial part (PCAP); (d) phosphorus content of the root (PCR); (e) phosphorus accumulation of the aerial part (PAAP), obtained by dividing between dry matter and phosphorus content of the aerial part; (f) phosphorus accumulation of the roots (PAR), obtained by dividing between dry matter and phosphorus content in the root; (g) phosphorus absorption efficiency (PAE), obtained by dividing between total phosphorus accumulation and root dry matter; (h) phosphorus translocation efficiency (PTE), obtained by dividing between phosphorus accumulation in the aerial part and total phosphorus content; (i) phosphorus use efficiency in the aerial part (PUEAP), obtained by dividing between aerial part dry matter and phosphorus content in the aerial part; and (j) root/aerial part (R/AP), obtained by dividing between root dry matter and aerial part dry matter

The results were submitted to analysis of variance (ANOVA) and to the Tukey test, with regression test being applied for the significant values at 5% probability. The statistical analysis was carried out using the computational program SAEG 9.1 (Federal University of Viçosa-UFV, 2007).

3. Results and Discussion

Root dry matter (RDM) and root-aerial part (R/AP) presented a significant interaction ($p < 0.05$) between the two varieties and the P doses applied (Table 3). On the other hand, the other characteristics evaluated did not show a significant interaction, with some presenting the factor variety as significant (Table 4), and others the factor P dose (Table 5). Thus, for these characteristics, the factors were studied separately.

Table 3. Interaction of Lisa and Americana lettuce varieties with the P doses for the characteristics root dry matter (RDM) and root-aerial part ratio (R/AP)

Variety	Phosphorus doses (mg dm^{-3})				
	0	100	200	300	500
	RDM (g)				
Lisa	1.04 Aab	1.13 Aa	0.72 Abc	0.49 Ac	0.44 Ac
Americana	0.53 Ba	0.31 Ba	0.38 Ba	0.37 Aa	0.39 Aa
	R/AP (g g^{-1})				
Lisa	0.41 Aa	0.34 Aa	0.21 Ab	0.15 Ab	0.14 Ab
Americana	0.21 Ba	0.09 Ba	0.12 Ba	0.10 Aa	0.11 Aa

Same upper-case letters in the column and lower-case letters in the line do not differ at 5% probability by the Tukey test.

The analysis of variance indicated a significant difference in RDM and R/AP in relation with the doses used in the Lisa variety (Table 3), which, at the dose of 100 mg dm^{-3}, presented a RDM significantly higher than the others, not differentiating only from the control. Consequently, R/AP was superior at the two lowest doses (0 and 100 mg.dm^{-3}). The varieties differed at the three lowest doses studied, with Lisa being superior in the two characteristics evaluated, showing that the amount of phosphorus in its root is higher than in the Americana. Marschner (1995) emphasizes that the genotypic differences are related to P absorption, transport and utilization inside the plant, which are affected by morphological and physiological factors, as well as by the plant's nutritional demand.

Table 4 shows that Americana was superior in the three characteristics showing significance (PCAP, PAAP and PAE), showing it presents a higher absorption of P, with most of it being found in its aerial part.

Table 4. Characteristics evaluated for the Lisa and Americana varieties

	Varieties	
Characteristics	Lisa	Americana
PCAP (g kg^{-1})	1.12 b	1.19 a
APDM (g)$^{n.s}$	3.09 a	3.25 a
PAAP (mg)	3.53 b	4.00 a
TPR (g kg^{-1})$^{n.s}$	1.54 a	1.38 a
PAAP (mg)$^{n.s}$	1.25 a	0.56 a
PAE (mg g^{-1})	7.86 b	12.23 a
PTE (mg g^{-1})$^{n.s}$	0.24 a	0.27 a
PUEAP$^{n.s}$	3.28 a	3.43 a

Same letters in the line do not differ at 5% probability by the Tukey test. $^{n.s}$Values were non-significant at 5% probability by the F test.

Phosphorus content in the aerial part (PCAP) was affected by the amount of P applied (Table 5), increasing significantly with P dose increase, and being higher at the dose of 500 mg dm^{-3}. Due to PCAP contribution for PAAP calculation, this characteristic followed the same pattern observed previously, showing no difference only between treatments 100 and 200 mg dm^{-3}.

Phosphorus Absorption Efficiency (PAE) also increased with dose increase, with the highest efficiency occurring at the two highest doses, with no significant difference between them.

Table 5. Characteristics evaluated for the phosphorus doses

	P doses (mg dm^{-3})				
Characteristics	0	100	200	300	500
PCAP (g kg^{-1})	0.48 d	0.78 cd	1.11 bc	1.48 b	1.92 a
APDM (g)	2.54 b	3.30 a	3.23 a	3.46 a	3.32 a
PAAP(mg)	1.22 d	2.57 c	3.55 c	5.08 b	6.40 a
PAR (g kg^{-1})$^{n.s}$	1.21 a	0.93 a	1.85 a	1.99 a	1.31 a
PCR(mg)$^{n.s}$	1.04 a	0.82 a	1.29 a	0.80 a	0.56 a
PAE (mg g^{-1})	2.98 c	6.23 bc	9.61 b	14.30 a	17.11 a
PTE(mg g^{-1})$^{n.s}$	0.23 a	0.25 a	0.26 a	0.25 a	0.28 a
PUEAP	5.41 a	4.26 ab	2.99 bc	2.38 c	1.73 c

Same letters in the line do not differ at 5% probability by the Tukey test. $^{n.s}$Values were non-significant at 5 % probability by the F test.

The aerial part dry mass (APDM) was statistically lower at dose 0 mg dm^{-3}, presenting no significant difference in the other treatments, influencing phosphorus use efficiency in the aerial part (PUEAP), which was significantly higher at the two lowest doses, decreasing with dose increase. This fact was due to DMAP constancy and to PAAP growing increase, according to the doses. The characteristics PCR, PAR, and PTE presented no significant difference among the P doses used in the experiment. Fresh and dry matter production by the plant, P absorption and use efficiencies are influenced by the use of micronutrients (Yuri et al., 2002). Micronutrients, such as boron and zinc, influence P absorption at different dosages, as verified by Moreira, Fontes and Camargos (2001) showing the importance of studies on P absorption in the presence of micronutrients.

P absorption efficiency increased for the two lettuce varieties (R^2 = 0.96 and 0.98, respectively) with P dose increase. Decreased absorption tended to occur above the dosage of 400 mg dm^{-3} for the Americana variety, which presented a higher P absorption efficiency than the Lisa variety. The latter had a lower P absorption efficiency which increased linearly with P dose increase (Figure 1).The aerial part dry matter of the Americana variety increased exponentially ($R^2 = 0.87$) with P dose increase.

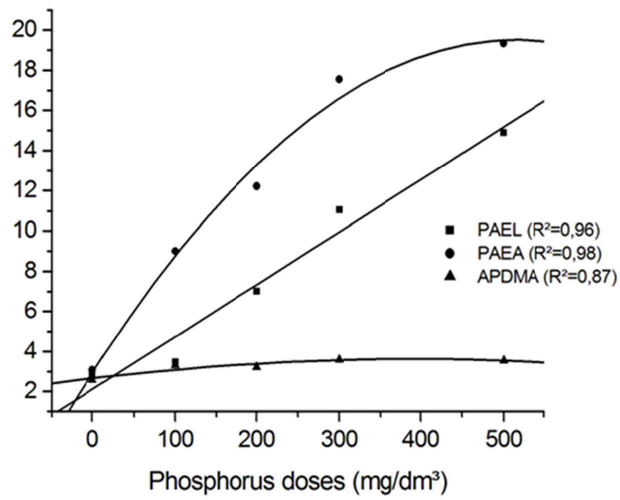

Figure 1. Mean values of phosphorus absorption efficiency of the Americana and Lisa varieties (PAEA and PAEL), respectively, and aerial part dry matter of the Americana cultivar (APDMA)

Mota et al. (2003) verified that the Americana variety presents a larger cycle of phosphorus development and extraction than the lettuce belonging to the group of smooth or curly leaves, demanding more P than other varieties. According to Prado (2008), P is intimately linked to the synthesis of amino acids and carbohydrates in the plant, and its deficiency leads to reduced matter production. P content in the aerial part of the Lisa and Americana varieties increased with phosphorus dosage (R^2 = 0.99 and 0.99, respectively). However, P use efficiency by the aerial part of the two varieties decreased exponentially (R^2 = 0.98 and 0.99, respectively), with phosphorus dosage increase (Figure 2). This may be related to the number of days the plants were cultivated (40 days), which may not have been sufficient to meet their nutritional needs (Mota et al., 2003).

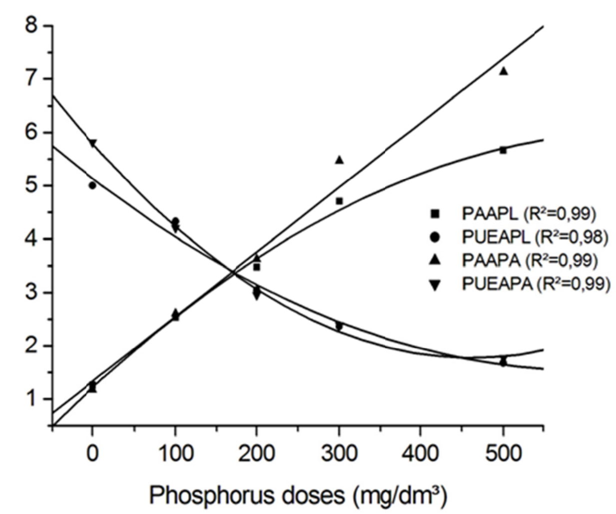

Figure 2. Mean values of the phosphorus accumulation in the aerial part (PAAPL and PAAPA) and phosphorus use efficiency by the aerial part (PUEAPL and PUEAPA) by the Lisa and Americana varieties, respectively

Phosphorus translocation in the aerial part increased linearly for the two varieties (R^2 = 0.99 and 0.99, respectively). Above the dosage of 150 mg dm^{-3}, translocation was higher in the cultivar Americana than in the Lisa, with increased P dosage (Figure 3). P translocation efficiency by the variety Lisa had an exponential increase (R^2 = 0.99) with increased P dosage.

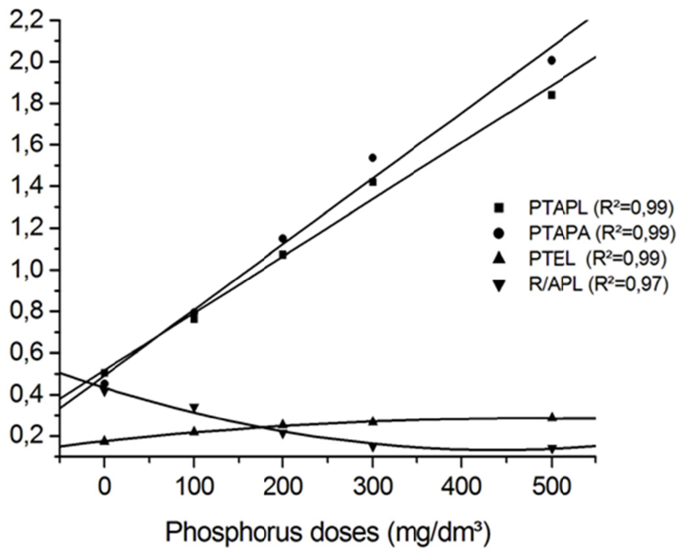

Figure 3. Mean values of phosphorus translocation in the aerial part (PTAPL and PTAPA) of the varieties Lisa and Americana, respectively, and phosphorus translocation efficiency (PTEL) and root/aerial part (R/APL) of the variety Lisa

On the other hand, root/aerial part of the Lisa variety decreased exponentially (R^2 = 0.99) with P dosage increase (Figure 3). This shows that this dosage promoted differences in root and aerial part absorption, a fact also verified by Cock et al. (2002, 2003) and Mota et al. (2003), when evaluating the nutritional efficiency of phosphorus in lettuce.

4. Conclusions

- Root dry matter (RDM) and root/aerial part(R/AP) were influenced by the interaction between the varieties and the P doses, with Lisa presenting the highest values of these characteristics at the lowest doses evaluated.
- The characteristics PCAP, CONTPA and EAP presented a significant difference between the varieties, with Americana presenting the highest values.
- The characteristics PCAP, PAAP, PAE, APDM, and PUEAP presented a significant difference between the P doses, with the highest values being found at dose 500 mg dm^{-3}, except for PUEAP, which was 0 mg dm^{-3}.

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