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Comparison of different sources of phosphorus in the implantation of a citrus orchard
Comparaison de différentes formes de phosphore lors de l'implantation de vergers de citrus

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Introduction

Phosporous is, of the three primary micronutrients, the one that is least required by the plants. But it is the nutrient that is most used in Brazil, where one of the greatest problems in soil fertility refers to the low contents of phosphorous in the soil and its high fixation (Raij, 1991). According to Malavolta (1980), only 5 to 20% of the applied phosphorous (P) is used by the plants, mainly due to fixation.

Citric plants have a relatively low phosphorous requirement, existing in a ton of fruit only 200g of this element, consequently a mean production of 40 tons of fruit can remove approximately 8 kg/ha of P.

Apart from the leaf symptoms, the accentuated lack of P causes the reduction in the growth rhythm of the plants, probably due to the P being the constituent of some nucleoproteins found in all the plants cells, causing a reduction in cellular division (Smith, 1966).

Another limiting factor is the excess of acidity in the great majority of the citric soils in Brazil (Raij, 1991), aggravating the problems of toxicity caused by the excess of aluminum ions and/or manganese, and reducing the efficiency of the fertilizers.

Calcium is the nutrient that the citric plants present in highest quantity, it has a great importance in the root development and, thus, essential to the growth of the plants (Epstein, 1975; Koo, 1979).

In relation to magnesium, a close relation can be found between this element and P, due to the fact that Mg acts as a phosphate transporter (Malavolta, 1979). This is explained by the fact that magnesium is mobile in the plant and that the parts of the plant that contain high phosphorous quantities (seeds and meristematic tissues) also contain high levels of magnesium.

Among the micronutrients, zinc, manganese and boron are the ones that need to be supplemented in brazilian citriculture. Smith & Rasmussen (1959) observed that the application of manganese and zinc to the soil up to the depth of 20cm supplied the necessity of these elements for various years. In relation to boron, this practice was more efficient when applied to the soil (Barnard et al., 1973).

The purpose of this study was to evaluate the efficiency of P sources associated with micronutrients in the presence and absence of lime in the implantation of a citrus orchard.

Materials and Methods

The implantation of the experiment was done on an epieutrofic endoalic Dark Red Latosol with an umbric A horizon and clayey texture (Haplustox) using citrus of the Natal variety (*Citrus sinensis* L.), grafted on Cravo lemon (*Citrus limonis* L.).

The plots were formed by five useful plants spaced at 4m, nine treatments were applied with four repetitions, in a total of 36 plots.

The treatments used in the experiment (Table 1) were applied before the planting of the scions supplying 60g of P_2O_5 per meter of furrow (240 g of P_2O_5 per plant) in the presence or absence of 250g of lime per meter of furrow (1000g of lime per plant). The chemical characteristics of the products are in Table 2.

The plants received after implantation, during the experimental period, fitossanitary treatments, foliar application of Zn and Mn and fertilizations that supplied adequate quantities of N and K.

Twenty four months after planting evaluations were done consisting of plant measurements (height, trunk superior diameter - 5cm above the grafting point- and trunk inferior diameter- 5cm below the grafting point); soil sampling (in a radium of 45cm from the trunk, and at the depths of 0 to 20cm and 20 to 40cm) and soil chemical analysis. Leaf sampling, removal of the mature branches with approximately six months of age, and posterior chemical analysis were done 8 and 24 months after planting.

Results and Discussion

1. Plant development

Table 3 presents the results of the plant measurement 24 months after planting. No significant differences were found between the treatments for the parameters inferior and superior height and diameter, respectively, indicating that all the treatments had an equivalent plant development during the first two years after planting.

2. Soil chemical attributes

The results of the chemical analysis at the depths of 0-20cm and 20-40cm, 24 months after planting can be found in Tables 4 and 5, respectively. The results of pH($CaCl_2$), P (resin), Ca, Mg, Al, B (hot water), Zn and Mn (DTPA) are presented.

The associated application of lime in the furrow in each treatment resulted in a higher pH (0-20cm) value when compared to the application isolated from phosphorous. This corrective effect of lime was not observed in the 20-40cm depth once that no significant differences were detected in the pH values between the treatments at this depth.

For P, it was observed that thermophosphates applied in the form of powder and absence of lime resulted in lower soil contents of this element. This is explained by the higher fixation of this form. When the thermophosphate was applied in the granulated form, the result was inverse, because in this form the surface contact of the phosphate with the soil was reduced, reducing, consequently, its fixation. In this case the inclusion of lime was negative, because the increase in pH diminished the solubilization conditions of the thermophosphate. In the layer 20-40cm the highest phosphorous contents were found in soils that received a soluble source (SSP).

In general the Ca contents were higher in the soils that received lime and a source of P in the 0-20cm layer. In the 20-40cm layer there seemed to be a tendency of higher values in the areas that received SSP plus lime, probably due to the effect of the presence of phosphogypsum moving Ca to deeper layers. In the case of Mg, the application of lime as well as thermophosphate resulted in higher soil contents of this element, being that the highest values were found in soils the received the application of both. Apparently no correlation was found for Mg in the 20-40cm layer.

The application of thermophosphate plus lime resulted in lower soil Al contents, this was observed mainly in the 20-40cm layer.

The highest contents of soil B and Zn were found, even after 24 months after their application, in the treatments that received sources of these micronutrients, indicating the good residual effect of the silicated oxides. There was no significant difference for Mn between the treatments, indicating its low recuperation when applied to the soil.

3. Plant nutritional state evaluation

In Tables 6 and 7 the results of the mean leaf contents of P, Ca, Mg, B, Mn and Zn can be observed. The samplings were done 8 and 24 months after planting.

The treatments did not differ in relation to the leaf content of P at 8 and 24 months after planting, reaching values considered high (above 1,6g/kg), indicating an adequate maintenance of the P supply to the plant from all the sources used.

In the first sampling (8 months), the leaf contents of Ca were high (above 45g/kg), presenting higher values the treatments that received lime plus SSP, probably due to the supply of Ca to the system by this last source. At 24 months after planting this tendency continued, although the leaf contents were low (lower than 35g/kg). This fall can be explained by the dilution effect caused by the plant’s high vegetative state.

At 8 months, the treatments with thermophosphate caused excessive leaf contents of Mg (above 5g/kg), and presented a tendency to higher values in the treatments with lime showing the effect of Mg contained in these sources on the plant’s nutritional state. In the second sampling (24 months) the content continued high (above 4g/kg) with no differences between them. The occurrence of high Mg leaf contents during all the experimental period was accompanied by contents equally high of P, as observed by Malavolta (1989).

Adequate leaf contents of B were observed 8 months after planting in all the treatments, with exception to the one that received this nutrient together with SSP revealing, inclusively, toxicity levels. This shows the high efficiency of this source (FTE) when applied to the soil, as well as the necessity of special care in its mixture and distribution uniformity. At 24 months the positive residual effect of the silicated oxide boron source was well characterized, once that in all the treatments the supply of this nutrient maintained an adequate plant nutritional state of B. The toxicity found initially was eliminated thanks to the effect of dilution occurred during the plant's growth.

No significant differences were found for Mn and Zn 8 months after planting. The leaf contents of these micronutrients were considered high (above 50mg/kg). After 24 months, significant differences were found in the Zn leaf content, although all the values continued high. The maintenance of the high levels of these micronutrients without correlation between the treatments can be explained by the permanent leaf supplementation done during the experimental period for these elements, as well as the low application efficiency of these two elements to the soil.

The application of thermophosphate enriched with micronutrients during the planting of the scions was quite interesting from the operational point of view, because in only one operation we applied P, Mg and B, reducing the risk of fitoxicity as was observed when B was applied associated to an exclusive source of P.

Conclusions

- The supply of phosphorous using thermophosphate in the implantation of citrus was as efficient as the most soluble source (single superphosphate);
- The application of boron to the soil at planting was an efficient practice to maintain the adequate boron supplementation to the plant;
- The use of thermophosphate enriched with boron presented the advantage of supplying both nutrients in the same operation and a better distribution, reducing the toxicity risk, when compared to the isolated application of boron.

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Table 1. Treatments used in the experiment.

Treatment	P_2O_5 source	Lime(*)
1	Termophosphate Mg (powder)	+
2	Termophosphate Mg (powder)	-
3	Termophosphate Mg + micro (powder)	+
4	Termophosphate Mg + micro (powder)	-
5	Termophosphate Mg +micro (granulated)	+
6	Termophosphate Mg + micro (granulated)	-
7	SSP	+
8	SSP	-
9	SSP + Zn (FTE) + B (FTE)	+

(*) 250 g/m of furrow

Table 2. Chemical characteristics of lime and fertilizers.

Product	P_2O_5		Ca	Mg	SiO_2	S	B	Zn	Mn
	Total	HCi							
	....	....	....	....	%	....	....	....	....
Termophosphate-Mg	18.0	16.5	20	9	25	-	-	-	-
Termophosphate-Mg + micro	17.5	16.0	20	9	25	-	0.1	0.55	0.12
SSP	18.0	-	19	-	-	11	-	-	-
B (FTE)	-	-	-	-	-	-	10	-	-
Zn (FTE)	-	-	-	-	-	-	-	20	-
Lime	-	-	30*	15*	-	-	-	-	-

*Values expressed in Ca and Mg oxides.

Table 3. Height and superior and inferior diameters of the plant trunks 24 months after planting.

Treatment	Height	Superior diameter	Inferior diameter
	....	cm	....
1	186.00	4.90	5.47
2	182.25	4.77	5.18
3	182.75	4.83	5.48
4	170.50	3.96	4.52
5	200.25	5.08	5.75
6	179.75	4.58	5.06
7	178.25	4.79	5.37
8	178.75	4.80	5.43
9	172.25	4.35	5.02
C.V. (%)	10.76	14.67	14.43

Table 4. Mean values of the soil pH, P, Ca, Mg, Al, B, Zn and Mn 24 months after planting, at the 0-20 cm depth.

Treatment	pH ($CaCl_2$)	P mg/dm^3	Ca	Mg ....mmolc/dm^3...........	Al	B	Zn ....mg/dm^3................	Mn
1	5.65 a	305 a	79 a	46 ab	0 e	0.08 d	2.37 bcd	24.68 ab
2	5.40 a	139 cd	56 ab	30 bc	1.00 de	0.08 d	1.57 cd	19.99 ab
3	5.40 a	79 cd	78 a	35 bc	0 e	0.42 a	6.55 b	23.85 ab
4	4.32 c	39 d	29 b	11 d	5.50 a	0.21 bc	4.50 bcd	26.20 ab
5	5.00 abc	183 bc	76 a	60 a	1.50 cd	0.15 bcd	6.45 bc	24.49 ab
6	4.58 bc	378 a	74 a	43 ab	2.25 c	0.24 b	6.21 bcd	27.95 a
7	5.03 ab	180 bc	55 ab	34 bc	1.00 de	0.10 d	1.49 d	21.65 ab
8	4.58 bc	91 cd	34 b	17 cd	3.50 b	0.12 cd	2.47 bcd	19.41 ab
9	4.98 abc	143 cd	55 ab	29 bc	2.00 cd	0.43 a	25.03 a	17.28 b
C.V. (%)	5.66	31.10	9.06	22.18	25.29	22.40	32.17	17.53

Table 5. Mean values of the soil pH, P, Ca, Mg, Al, B, Zn and Mn 24 months after planting, at the 0-40 cm depth.

Treatment	pH ($CaCl_2$)	P mg/dm^3	Ca	Mg ....mmolc/dm^3...........	Al	B	Zn ....mg/dm^3................	Mn
1	4.75	13 c	23 b	17 bc	1.25 d	0.09 b	0.40 c	5.23
2	4.85	16 bc	30 b	20 abc	2.00 cd	0.08 b	0.30 c	4.38
3	5.03	16 bc	34 b	18 abc	1.00 d	0.26 b	1.38 abc	5.65
4	4.20	11 c	23 b	14 c	6.00 a	0.17 b	2.41 a	8.25
5	4.85	16 bc	47 ab	27 a	2.50 cd	0.15 b	1.27 abc	4.78
6	4.45	27 bc	42 ab	25 ab	4.00 abc	0.22 b	1.94 ab	6.40
7	4.48	60 a	50 a	18 abc	3.00 bcd	0.09 b	0.52 bc	5.67
8	4.25	38 ab	23 b	11 c	5.00 ab	0.11 b	1.43 abc	6.84
9	4.38	34 bc	27 ab	12 c	4.00 abc	0.84 a	1.27 abc	5.32
C.V. (%)	8.92	39.45	30.79	22.76	31.38	39.59	52.18	30.91

Table 6. Mean leaf contents of P, Ca, Mg, B, Mn and Zn 8 months after planting.

Treatment	P	Ca ....g/kg...................	Mg	B	Mn ....mg/kg................	Zn
1	2.03	52.68 ab	7.00 ab	36.50 b	170.00	80.25
2	2.05	46.73 b	5.65 ab	34.00 b	141.50	80.75
3	1.88	59.50 a	7.28 a	53.50 b	157.50	69.75
4	1.93	57.35 ab	6.23 ab	49.75 b	148.75	75.00
5	1.83	49.13 ab	6.00 ab	40.50 b	143.50	72.25
6	1.88	55.63 b	6.68 ab	42.50 b	129.75	71.00
7	1.93	59.78 a	5.83 ab	36.00 b	134.00	70.00
8	2.03	57.05 ab	5.55 b	38.50 b	143.50	75.75
9	1.93	60.93 a	5.68 ab	344.00 a	139.25	92.25
C.V. (%)	7.41	9.4	11.04	16.78	17.89	17.68

Table 7. Mean leaf contents of P, Ca, Mg, B, Mn and Zn 24 months after planting.

Treatment	P	Ca	Mg	B	Mn	Zn
	......................g/kg....................			..........................mg/kg.................		
1	1.78	22.35 ab	5.03	19.75 ef	99.25	75.25 c
2	1.96	22.58 ab	4.48	18.25 f	115.25	131.50 a
3	2.05	23.50 ab	5.03	42.75 bc	99.00	87.50 bc
4	1.93	21.15 b	4.30	37.75 bcd	93.25	90.50 abc
5	1.70	23.55 ab	4.68	34.25 cd	88.75	102.00 abc
6	1.88	24.08 ab	4.85	48.75 b	95.75	112.00 abc
7	1.98	26.58 a	4.85	28.00 def	121.75	127.25 ab
8	1.88	24.88 ab	4.33	32.75 cde	91.25	104.25 abc
9	1.98	24.03 ab	4.40	83.00 a	102.25	97.75 abc
C.V. (%)	11.86	9.06	7.97	14.27	14.64	16.62