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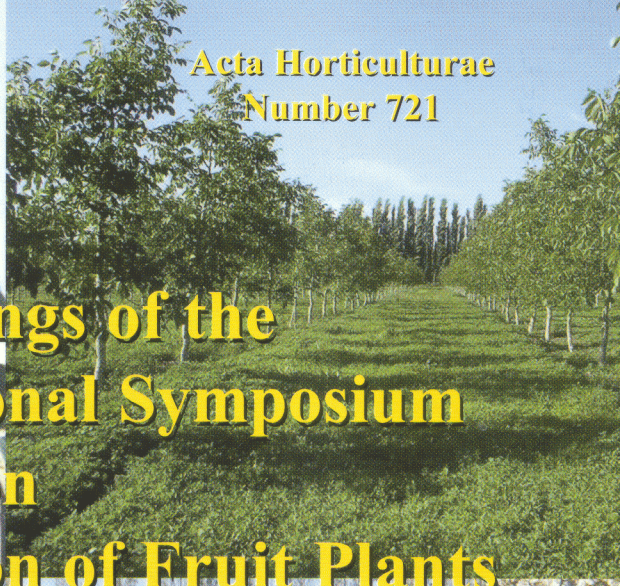
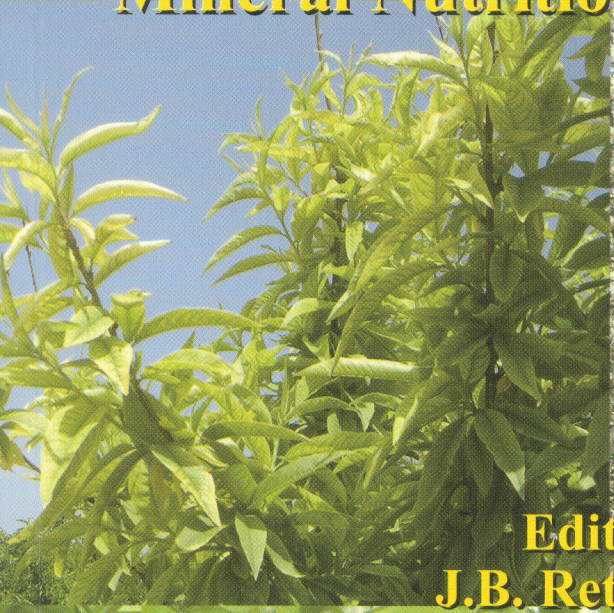
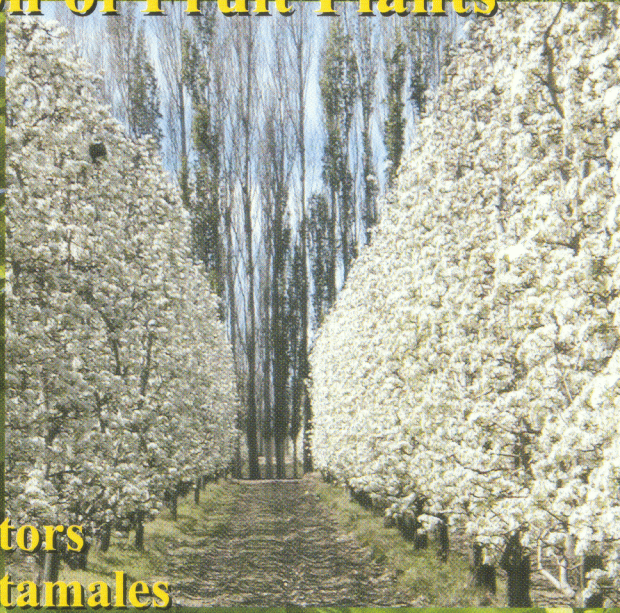

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1, 2, 4. Pear orchards in Neuquén, Argentina. Photographs by courtesy of Enrique Sanchez.
3, 5, 6. Iron deficiency in peaches. Photographs by courtesy of Javier Abadía.

Efficiency of Nitrogen Fertilization on Citrus Orchards

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Keywords: ^{15}N-fertilizer, ^{15}N-recovery, ^{15}N-fate, ^{15}N-dynamic, ^{15}N-ammonium sulfate

Abstract

Nitrogen fertilization has been extensively adopted in Brazil and has resulted in increased fruit production of citrus trees. Studies on the fate of applied N fertilizer and validation of the N dose recommendations are scarce both in the Brazilian and the international literature. In the present work, the dynamics of ^{15}N (ammonium sulfate), applied to soil surface, in the citrus orchard and the response of citrus trees to N fertilization rates were studied. Three- to four-year-old 'Pêra' sweet orange trees grafted on Rangpur lime were fertilized with 300 g of N tree^{-1} (as ammonium sulfate) labeled with 4.917 atom % ^{15}N at fruiting stage to study the fate of N in the soil-orange tree system. Additionally, 0, 150, 300, 450 and 600 g of N per tree, split in three applications, were supplied from early spring to summer. Fruit yield for different N treatments were evaluated. The trees that received ^{15}N were destructively harvested and separated into trunk, old twigs, new twigs, leaves, fruits and roots. Plant and soil samples were analyzed for ^{14}N/^{15}N isotope ratio and total N. The effect of N fertilization on fruit yield, the amounts of ^{15}N taken up from fertilizer and localization of this nutrient within the parts of the trees, and the ^{15}N remaining in the soil were determined. The highest fruit yield (30 kg tree^{-1}) was obtained with N rate of 400 g tree^{-1}. The efficiency of applied N ranged from 20-27%, with the lowest value corresponding to the application previous to a heavy rainfall. Nitrogen remaining in the soil within the 0.60 m depth layer was 34% of applied N rate. Fruit exported approximately 34% of N from fertilizer accumulated in the whole tree.

INTRODUCTION

Fertilizer application, particularly nitrogen, has been extensively adopted in Brazilian citrus orchards. For the initial 3 to 4 years after tree planting in the field, until fruit production period starts, the amount of N recommended is 300 g tree^{-1}. For perennial plants, such as citrus trees, there are three sources of N available to supply nutrient demands for plant growth: N from reserves remobilized within the tree, N from the soil and N from fertilizer. Information on N remobilization in citrus was reported by Legaz et al. (1995), who demonstrated that more than 70% of N accumulated in new organs during the spring came from N stored in old organs, mostly old leaves (the main reserve organs), and contributed to 40-50% of the total remobilized N to new organs. Available information on citrus absorption of N from soil (Boaretto et al., 1999) and from fertilizer (Boaretto et al., 1999; Martínez et al., 2002; Quiñones et al., 2003 a, b) has mainly been carried out in pots or lysimeters with different varieties. Under these conditions, data obtained on soil or fertilizer contribution to the tree N may not be realistic, and provided significantly different conclusions than data shown by Mattos Jr. et al. (2003) in an experiment carried out with citrus trees grown in a sandy soil.

When nitrogenous fertilizers are applied to soil, part of the added N is taken up by trees and other is subjected to losses by leaching, surface runoff, denitrification and ammonia volatilization. After absorption of N by trees, N can be lost to the atmosphere by volatilization of ammonia through leaf cuticle or returned to soil with fallen organs (petals, calices, ovaries, young fruits and leaves). When fruits are harvested, a significant amount of N in tree biomass is exported from the orchard.

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The objectives of this work were: to validate the N rate recommended for citrus orchard at the end of the growth period and starting the production period; b) to follow the fate of N fertilizer applied in the soil-citrus tree system.

MATERIALS AND METHODS

The experiment was carried out in a commercial citrus orchard planted in May 1999 with 'Pêra' sweet orange [*Citrus sinensis* (L.) Osb.] grafted on Rangpur lime rootstock [*Citrus limonia* Osb.] at 7 by 2.85 m spacing (500 trees ha^{-1}). The soil is a Hapludox (see chemical characteristics in Table 1). The nutritional status of the orange trees at the beginning of the study was adequate (Table 1). Drought period is common in the region of the experiment, with mean annual rainfall of 1600 mm. Treatments were arranged in a randomized complete block design with five replicates. The treatments consisted of five N rates (g $tree^{-1}$) as follow: 0 (= control), 150, 300, 450 and 600 applied as ammonium sulfate. The N rates were divided into three applications (40% of the rate on September 12th, 2002, 30% on November 28th, 2002 and 30% on April 2nd, 2003) and applied on the soil surface, around the tree, 50 to 200 cm away from the tree trunk. The experimental plots contained five trees in a row with the middle three used for sampling.

Fruit yield was evaluated by summing up the weight of the two harvests (September and October 2003). Fruit were evaluated for juice quality, including total soluble solids (TSS) content, total acidity (TA) and TSS/TA ratio (Reed et al., 1986).

In the same orchard, three uniform trees were fertilized with 300 g of ^{15}N, as ammonium sulfate labeled with 4.914 atom % ^{15}N, distributed in the same way as mentioned above, as follow:

- Tree #1: 120 g $tree^{-1}$ of ^{15}N (September 12th, 2002), 90 g $tree^{-1}$ of ^{15}N (November 28th, 2002 and April 2nd, 2003);
- Tree #2: 120 g $tree^{-1}$ of non-labeled N fertilizer (September 12th, 2002), 90 g $tree^{-1}$ of ^{15}N (November 28th, 2002 and April 2nd, 2003);
- Tree #3: 120 g $tree^{-1}$ and 90 g $tree^{-1}$ of non-labeled N fertilizer (September 12th, 2002 and November 28th, 2002, respectively) and 90 g $tree^{-1}$ of ^{15}N (April 2nd, 2003).

After the second harvest of fruits (October, 2003), the ^{15}N labeled trees were destructively harvested for evaluation of dry mass distribution of tree components (leaves, new twigs, old twigs and trunk). Samples of orange fruits and tree components were collected in the field and placed in sealed plastic bags to prevent water loss. Later, in laboratory, the same material was weighed, washed and dried in an oven (65°C) for dry mass determination.

The roots of ^{15}N labeled trees were sampled, after collecting the above ground parts of these trees, using a steel cylinder (16 cm diameter and 60 cm height). Samples were taken from soil surface up to 60 cm depth, surrounding the tree, and were separated from soil by washing them in a 0.2 cm mesh screen. The clean root samples were dried in an oven (65 °C) and weighed for obtaining the dry mass of fibrous root. Total dry mass of fibrous roots was estimated by multiplying the values obtained for a volume of soil of 11.97 m^3 (19.95 m^2 x 0.60 m). The taproot was also separated from the soil, after excavating the soil in a circular area around the trunk. The taproot was also washed, weighed and sampled for the dry mass determination using similar treatment given to aboveground parts of the trees.

Soil samples were taken in the area around the trees where ^{15}N was applied, from soil surface up to 60 cm depth. These samples were dried under the shade at room temperature. The amounts of N or ^{15}N remaining in the soil was estimated for a volume of 11.97 m^3, which was obtained multiplying the area occupied by a citrus tree times soil depth (= 0.60 m).

The concentration of N and N isotopic ratio of dry material and soil were determined with a mass spectrometer according to standard procedures (Martinez et al., 2002; Bataglia et al., 1983).

RESULTS AND DISCUSSION

The average fruit yield was 15 t ha^{-1}, considered normal for 3 to 4–year-old citrus trees. Fruit yield increased with increased rates of N fertilizer (Fig. 1). Even though ammonium sulfate contains N and S, the increase in fruit yield was attributed to N supply, considering the following reasons: the orchard had been fertilized with single superphosphate, which contains S; the S concentration in the diagnostic leaves was within the adequate range for the citrus crop; and the S rate of 50 kg ha^{-1} is sufficient for supplying this nutrient to the majority of agronomic crops, which was exceeded in the first rate of N fertilizer applied.

The N rate recommended in the São Paulo State for 3 to 4-year-old citrus trees is 300 g $tree^{-1}$ (Raij et al., 1997). Using the equation estimated for orange fruit yield as a function of N rates, it was possible to determine that maximum yield was attained at N = 403 g $tree^{-1}$. This result indicated that the current recommendation for N fertilization does not meet the N requirement of trees for maximum fruit yield. Additionally, increasing N rates caused a decrease in fruit weight and an increase in the number of fruits per box (Fig. 2). Therefore, higher N rates may not be the best nutrient management strategy for producing fruits for *in natura* consumption. Other fruit and juice qualities were not affected by N rates (data not shown).

The largest proportion of total aboveground dry mass (AG) was 78% compared to 22% of total belowground dry mass (BG). Fruit represented 33% of whole tree dry mass and 25% of AG (Table 2). Mattos Junior et al. (2003) and Quiñones et al. (2003a, b) reported similar results for other citrus plant material.

Nitrogen concentrations in tree organs ranged from 4.3 g kg^{-1} (trunk) to 29.8 g kg^{-1} (leaf) and they were similar for all trees supplied with ^{15}N-fertilizer. The values of nitrogen derived from fertilizer (Npdff) were highest in tree #1 and Npdff was lowest for tree #3, which received, respectively, the greater and the lesser amounts of labeled fertilizer (Table 2). Results from this experiment corroborate previous reports (Legaz et al., 1995; Martínez et al., 2002; and Quiñones et al., 2003a, b), since as shown by the ^{15}Npdff values, during the growing period, most of N taken up from the fertilizer accumulates in new organs (Table 2).

Data on total N and N derived from fertilizer in different plant organs or in soil are shown in Table 3. Aboveground and BG organs accumulated, respectively, on average, 80% and 20% of N in the whole tree. Similar results were reported by Quiñones et al. (2003a) for an 8-year-old orange tree, and by Legaz et al. (1995) and Martínez et al. (2002), both for 3-year-old orange trees. The three trees accumulated similar N amounts in the following order: fruit>leaf>roots>twigs>trunk.

The highest amount of N from fertilizer, 76% of whole tree, was accumulated in the new organs (fruit, leaves and new twigs), followed by roots (16%) and 10% in old organs (trunk and old twigs).

The N recovery in whole tree ranged from 20-27% at the end of one year after starting the application of N fertilizer. For an irrigated orchard, grown in a sand soil, Mattos Jr. et al. (2003) reported values slightly higher than the ones shown here. However, the recovery data shown here are lower than those reported by Boaretto et al. (1999) and Martinez et al. (2002) from experiments carried out in controlled conditions.

In order to estimate the N amount recovered from the first ^{15}N application, the N recovered in the tree #2 (35g), which received ^{15}N fertilizer in the last two applications, was subtracted from the ^{15}N recovered in the whole tree #1 (80 g), which received three applications of ^{15}N. The same approach was used to estimate the N amount recovered from the second ^{15}N application by subtracting the ^{15}N recovered in the tree #3 (21g), which received ^{15}N fertilizer only at last application, from the ^{15}N recovered in the tree #2. Therefore, the N use efficiency was estimated considering the applied ^{15}N rate for each application. For the N fertilizer applied in September 2002, November 2002 and April 2003 the recovered N values were, respectively, 38%, 16% and 23%. The high rainfall which occurred after N fertilizer application in November 2002 probably contributed to N leaching below the root zone. This may explain the low recovery rate

observed for that period. Part of N fertilizer (34% of applied N) was recovered in the 0.60 m soil depth layer.

The total N recovery in soil-tree system was 61% of applied N. The unaccounted N from fertilizer might have been lost by leaching, denitrification and volatilization of ammonia from leaves. When the fruits are harvested, a substantial portion of N absorbed goes out the orchard system, corresponding 10% from applied N fertilizer or 34% of N derived from fertilizer accumulated in the whole tree.

CONCLUSIONS

The N rate of 300 g $tree^{-1}$, currently recommended for 3 to 4-year-old citrus orchard in Brazil, was not sufficient for maximum fruit yield in the experiment.

The efficiency of applied N ranged from 20-27%, depending on the time of fertilizer application with the lowest value corresponding to the application followed by heavy rainfall. Nitrogen remained in the soil within the 0.60 m depth layer was 34% of applied N rate. Fruit exported approximately 34% of N from fertilizer accumulated in the whole tree.

ACKNOWLEDGEMENTS

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Literature Cited

Bataglia, O.C., Furlani, A.M.C., Teixeira, J.P.F., Furlani, P.R. and Gallo, J.R. 1983. Métodos de análise químicas de plantas. Instituto Agronômico, Campinas, SP. (Boletim Técnico 78).

Boaretto, A.E., Schiavinatto-Neto, P., Muraoka, T., Trivelin, P.C.O. and Bissani, C.A. 1999. Eficiência da aplicação de ^{15}N-uréia no solo e nas folhas de laranjeiras jovens. Laranja 20:477-498.

Legaz, F., Serna, M.D. and Primo-Milo, E. 1995. Mobilization of the reserve N in citrus. Plant and Soil 173:205-210.

Martínez, J.M., Bañuls, J., Quiñones, A., Martín, B., Primo-Milo, E. and Legaz, F. 2002. Fate and transformations of ^{15}N labelled nitrogen applied in spring to *Citrus* trees. Journal of Horticultural Science & Biotechnology 77:361-367.

Mattos Junior, D., Graetz, D.A. and Alva, A.K. 2003. Biomass distribution and nitrogen-15 partitioning in citrus trees on a sandy entisol. Soil Sci. Soc. Am. J. 67:555-563.

Quiñones, A., Bañuls, J., Primo Millo, E. and Legaz, F. 2003a. Effects of ^{15}N application frequency on nitrogen uptake efficiency in Citrus trees. J. Plant Physiol. 160:1429-1434.

Quiñones, A., Bañuls, J., Primo Millo, E. and Legaz, F. 2003b. Seasonal dynamic of 15N applied as nitrate with different irrigation systems and fertilizer management in citrus plants. Food, Agriculture & Environment 3&4:155-161.

Raij, B., Andrade, J.C., Cantarella, H. and Quaggio, J.A. 2001 Análise químicas para avaliação da fertilidade de solos tropiciais. Instituto Agronômico, Campinas, SP. 285p.

Raij, B., Cantarella, H., Quaggio, J.A. and Furlani, A.M.C. 1997. Recomendações de adubação e calagem para o Estado de São Paulo. 2.ed. Campinas: Instituto Agronômico/ Fundação IAC, 285p. (Boletim técnico 100).

Reed, J.B., Hendrix Jr., C.M. and Hendrix, D.L. 1986. Quality control manual for citrus processing plants. v.1. Intercit Inc., Safety Harbour, FL.

Tables

Table 1. Selected chemical characteristics of soil and nutritional status of orange trees before starting the experiment.

Soil (0-20 cm depth) - Methods described by Raij et al. (2001)					
P-resin	K	Ca	Mg	H+Al	BS[1]
mg dm^{-3}	---------- mmol dm^{-3} ----------				%
59	15.9	40	8	18	78

Leaf analysis - Leaf sample was collected based on criteria suggested by Raij et al. (1997) and analyzed according to Bataglia et al. (1983).

N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
---------- g kg^{-1} ----------						---------- mg kg^{-1} ----------				
23	1.8	15	42	2.7	3.0	61	3	83	74	92

[1] Soil base saturation

Table 2. Dry mass of 4-year-old 'Pêra' sweet orange on Rangpur lime rootstock trees fertilized with ^{15}N-ammonium sulfate.

Tree organs	DM[1]	SE[2]	DM	Tree 1		Tree 2		Tree 3	
				Total N[5]	Npdff[6]	Total N	Npdff	Total N	Npdff
	----- g ------		%	g kg^{-1}	%	g kg^{-1}	%	g kg^{-1}	%
Fruit	5792	206	25	16.1	30.9	15.1	9.6	16.0	7.5
Leaf	2641	510	12	28.2	27.4	29.2	12.9	29.8	9.1
New twig	2832	749	12	11.7	25.2	13.0	15.2	10.4	7.6
Old twig	3855	639	17	6.2	22.3	7.7	9.8	4.9	5.3
Trunk	2695	16	12	4.3	15.7	5.6	7.4	4.7	3.5
Fibrous root	1223	278	5	12.7	24.4	11.2	14.3	12.7	8.4
Taproot	3848	760	17	13.4	17.7	11.4	6.0	10.9	3.9
Total AG[3]	17815	-	78	-	-	-	-	-	-
Total BG[4]	5071	-	22	-	-	-	-	-	-
AG + BG	22886	-	100	-	-	-	-	-	-

[1] Dry mass.
[2] Standard error of the mean (n = 3).
[3] Total aboveground dry mass.
[4] Total belowground dry mass.
[5] Mean of three replicates.
[6] N in tree organs derived from fertilizer (3 replicates), for fruit (6 replicates) and for fibrous root (12 replicates).

Table 3. Average total N and ^{15}N recovery of biomass components of 4-year-old 'Pera' sweet orange on Rangpur lime rootstock trees fertilized with ^{15}N-ammonium sulfate.

Tree organs or Soil	Tree 1 Total N	Tree 1 ^{15}N	Tree 1 $^{15}NR^1$	Tree 2 Total N	Tree 2 ^{15}N	Tree 2 $^{15}NR^1$	Tree 3 Total N	Tree 3 ^{15}N	Tree 3 $^{15}NR^1$
	---- g tree^{-1} ----		%	---- g tree^{-1} ----		%	---- g tree^{-1} ----		%
Fruit	95	29	10	86	11	6	90	8	9
Leaf	82	22	7	77	10	6	70	6	7
New twig	33	9	3	38	6	3	29	2	2
Old twig	23	5	2	30	3	2	19	1	1
Trunk	12	2	1	13	1	1	15	1	1
Fibrous root	16	3	1	13	1	1	12	1	1
Taproot	51	10	3	43	3	2	43	2	2
Total AG[2]	245	67	23	244	31	18	204	18	20
Total BG[3]	67	13	4	56	4	2	55	3	3
AG + BG	312	80	27	300	35	20	259	21	23
Soil N	3227	101	34	3325	50	28	3129	14	16

[1] N from fertilizer recovered in each tree organs or soil:
$^{15}NR = \{^{15}N$ (g tree^{-1}) / ^{15}N amount applied (g tree^{-1})$\}100$.
^{15}N amount applied: Tree 1 = 300 g, Tree 2 = 180 g, and Tree 3 = 90 g.
[2] Total aboveground dry mass.
[3] Total belowground dry mass.

Figures

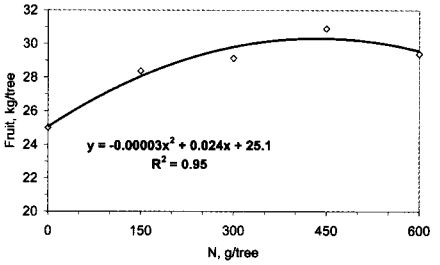

Fig. 1. Orange fruit yield as a function of applied N rates.

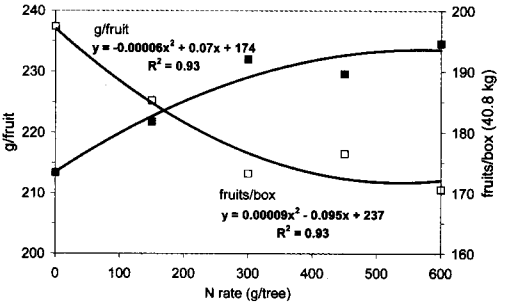

Fig. 2. Orange fruit weight and number of fruits per box (40.8 kg) as affected by nitrogen rates.