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Effect of orchard soil management on citrus root system and yield in a Brazilian oxisol
Effet du mode de gestion d'un oxisol du Brésil sur la production fruitière et le développement du système racinaire d'un citrus

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A trial with 'Poncã' tangerine (*Citrus reticulata* Blanco) on 'Rangpur Lime' (*Citrus limonia* Osbeck*)* rootstock was carried out in Londrina - PR - Brazil in an oxisol. Five treatments were used: permanent cover with *Indigofera campestris* Benth; permanent cover with *Arachis prostrata* Bong. ex Benth; *Stizolobium pruriens* during spring and summer; alternate mowing (rainy season) /tillage (dry season); and bare soil (by hand weeding). The soil received lime and fertilizers according soil analysis. Plant yield and fruit quality were not affected by treatments. There was a tendency of greater yield in the mowing /tillage plots. Probably the chemical fertilization (that was the same for all treatmens) was more important for plant nutrition and yield than soil management. Treatments did not have any consistent effect on chemical characteristics of the soil except soil organic matter, that was significantly higher in *A. prostrata* and alternate mowing / tillage. The profile wall method was used to determine root quantity and distribution. The roots were counted (area and lenght) in digitized video images of the profile by SIARCS program. Total root amount had no differences among treatments but root distribution was significantly different. Trees maintained vegetation-free had the most spread out root systems. The presence of perennial leguminous plants in the inter-rows limited the presence of citrus roots to the region of the profile where roots of the cover plants were absent. This was compensated by a significant increase in the citrus root system deepening in the *A. prostrata* treatment.

Key words: Citrus, soil management, ground covers, yield, fruit quality, root system.
Mots clés: Citrus, gestion du sol, plantes de couverture, production, qualité des fruits, système racinaire.

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Introduction

The regions of citrus production at Paraná state are in tropical and subtropical climates, with rains occurring during spring and summer, when it is important to maintain the soil protected, reducing the risks of erosion. The most used soil management system in the citrus orchards is a combination of mowing and tillage during rainy and dry season respectively (Negri, 1988). Many producers, however, intensify the use of disk tillage, creating compaction problems, reduction in the water infiltration rate, increase of erosion risks and damages to the root system.

Ground covers protect the soil against erosion, avoid the infestation of weeds, reduce soil compaction (depending on the species used) and fix atmospheric nitrogen. Yield reduction has not been observed when leguminous ground covers are used in citrus orchards. In some cases an increase of yield has been detected (Castro & Lombardi Neto, 1992).

Studies done in Brazil have shown that the most prejudicial system for citrus yield is the mowing of the natural vegetation all year long (Rodriguez, 1969; Passos et al., 1973; Koller et al., 1977). The use of mulch has given the highest yields, but it is considered of low economical viability for citrus. Other systems (mowing or incorporating cover crops, tillage, and mixed systems of tillage and mowing) have presented conflicting responses, varying with the location and period of observation (Rodriguez, 1969; Passos et al., 1973).

The root distribution of citrus plants vary with the chemical and physical characteristics of the soil, rootstock, plant's age and occurrence of diseases. Other fruit species present differences in the root system due to soil management, but these influences on citrus plants have not been properly studied.

The effect of soil management systems, including ground cover species recommended for the State of Paraná (Calegari, 1995) on the soil chemical attributes, root system, yield and fruit quality of ‘Poncã’ tangerine, were evaluated in Londrina, Paraná.

Materials and Methods

The region’s climate (23°23’S and 51°11’W), according to Koppen’s classification, is of the Cfa type, humid subtropical, with rain in all seasons, with a possible dry season in winter. The experiment took place at the Londrina State University campus, on a clayey haplortox (latossolo roxo). The orchard was composed of 10 year old trees of ‘Poncã’ tangerine (*Citrus reticulata* Blanco) grafted on ‘Rangpur’ lime (*Citrus limonia* Osbeck), with a 6.0 x 6.5m spacing. The treatments, since orchard planting, were: a) perennial leguminous *Indigofera campestris* Benth.; b) perennial leguminous *Arachis prostrata* Bong. ex Benth.; c) ‘mucuna cinza’ (*Stizolobium pruriens*) in the rainy season; d) alternated use of the mower (three or four times in the rainy season) and of one tillage by disk harrow (dry season); e) bare soil by manual weeding. Treatments were replicated four times in a completely randomized design with two sampled plants per plot. Mineral fertilization and liming were the same for all treatments. Yield was evaluated by the number of fruits per plant. On a sample of 10 fruits/plant the mean weight, juice content, soluble solids content (SS), total acidity and the SS/total acidity ratio were determined. Six soil samples were collected from each plot, making up one compound sample per replication for the chemical analysis (C, N, P, K, Ca, Mg, H+Al, pH, SB, CEC, and SBS%). Sampling was done in two areas of each plot: underneath the tree canopy and in the inter-rows, at the depth of 0-20cm and 20-40cm.

To study the root system, the profile wall method (Bhöm, 1979) was used, with three profiles per treatment. Each profile was opened perpendicularly to the tree row, with a 1.0m depth and a 3.25m length, from the tree’s row to the middle of the inter-row. The amount of exposed roots was evaluated through images obtained with a video camera using 25x25cm squares limited by nylon thread in a wooden frame fixed to the profile (Cintra & Neves, 1996). The images were digitized and the root area and length were determined using the SIARCS program (Crestana et al., 1994).

Results and Discussion

A fruit yield of 114-143 kg $plant^{-1}$ $year^{-1}$ (Table 1) is considered satisfactory for ‘Poncã’ tangerine (Hiroce et al., 1981). The treatments did not present any significant differences, but the use of the mowing/tillage showed a tendency of a higher yield when the harvests were averaged. This performance can be attributed to the absence of vegetation during the dry season, that must have diminished the water and nutrient competition, as observed by Vasconcelos et al. (1976) and Santinoni & Silva (1995). Passos et al. (1973) obtained a better orange yield in one of the harvests with the mowing treatment during the wet season and tillage during the dry season, but this behavior was not repeated every year, probably due to the climatic conditions. Mustaffa (1988) obtained better tangerine yields with mulch and less with mowing natural vegetation. This was attributed to the soil moisture, that was significantly higher when the soil was covered with mulch, given the water stress conditions caused by the climate.

In the results obtained in this study, if there was a water and nutrient limitation in the presence of the cover plants, it was not strong enough to cause significant differences among treatments. This tendency had already been observed in earlier harvests of the orchard in study (Nilo Gonzalez & Neves, 1992). Similar yields for different types of soil management in citrus have already been found elsewhere (Passos et al., 1973; Bouma & McIntyre, 1963). The quality of 'Poncã' tangerine fruits was not influenced by soil management (Table 2). The alterations on the soil are a secondary factor on the quality of citrus fruits, whereas the main role is played by the climatic conditions (Reuther,

Table 1. 'Poncã' tangerine yield for treatments and years of observation, in kg of fruits per plant (mean of four replications) and length of roots in cm (mean of three replications) for the soil management treatments.

Treatment	**Yield (kg plant^{-1})**					**Roots**
	Year					
	1992	**1993**	**1994**	**1995**	**92-95**	**cm**
I. campestris	119.2 a*	112.9 a	134.9 a	160.9 a	132.0 a	1,329.22 a
A. prostrata	110.0 a	89.5 a	139.3 a	119.1 a	114.5 a	1,826.52 a
Mucuna cinza	118.8 a	105.9 a	111.3 a	133.6 a	117.4 a	1,097.89 a
Mow/tillage	178.8 a	115.7 a	130.0 a	148.3 a	143.2 a	1,284.31 a
Weeding	145.0 a	112.3 a	127.6 a	127.7 a	127.9 a	1,468.45 a
M.D.S.	79.58	69.32	112.02	121.08	58.62	1,738.65
C.V. (%)	27.11	29.64	39.86	40.18	21.13	46.22

* Numbers followed by the same letter, in the vertical, are not significantly different, by the Tukey test, at a 5% significance level; M.D.S.= minimum difference for significance; C.V.= coefficient of variation.

Table 2. Soluble solids content (in ^{o} Brix), total acidity content (in %, w/v) and ratio soluble solids/total acidity of 'Poncã' tangerine fruits for the soil management treatments and years of observation (mean of four replications).

Treatment	**Soluble Solids (^{o}Brix)**			**Acidity (%)**			**Ratio**		
	Year			**Year**			**Year**		
	1992	**1993**	**1995**	**1992**	**1993**	**1995**	**1992**	**1993**	**1995**
I. campestris	9.0a*	9.9a	10.3a	0.60a	0.45a	0.45a	15.11a	21.79a	23.32a
A. prostrata	9.1a	10.2a	10.8a	0.61a	0.46a	0.47a	15.18a	24.12a	23.38a
Mucuna	9.1a	9.9a	10.8a	0.64a	0.49a	0.51a	14.50a	20.41a	21.56a
Mow/tillage	9.0a	10.1a	10.7a	0.56a	0.46a	0.42a	16.32a	21.86a	26.11a
Weeding	8.8a	10.1a	10.4a	0.60a	0.43a	0.37a	14.85a	23.03a	28.66a
M.D.S.	0.67	1.64	1.68	0.15	0.08	0.12	5.17	4.37	7.36
C.V. (%)	3.43	7.34	7.29	11.50	8.46	12.26	10.64	13.17	13,69

* Numbers followed by the same letter, in the vertical, are not significantly different, by the Tukey test, at a 5% significance level; M.D.S.= minimum difference for significance; C.V.= coefficient of variation.

Table 3: Soil chemical analysis of the inter-rows of the orchard at the depths of 0-20cm and 20-40cm, when submitted to different soil management treatments (mean of four replications).

Treatment	**O. M.**	**pH**	**P**	**K**	**Ca**	**Mg**	**H+Al**	**SB**	**CEC**	**SBS**
	g dm^{-3}		**mg dm^{-3}**	**mmol$_c$ dm^{-3}**						**%**
					0-20 cm					
I. campestris	28.4b*	6.15a	11.50a	3.9a	66.3a	26.7a	25.5a	96.9a	122a	79.0a
A. prostrata	35.3a	5.88a	6.45a	2.5a	64.7a	24.2a	24.3a	91.1a	116a	78.7a
Mucuna	29.3b	5.63a	9.53a	3.5a	49.4a	22.9a	26.7a	75.8a	102a	73.4a
Mow/tillage	31.0ab	5.78a	9.15a	4.5a	58.1a	25.3a	21.5a	87.9a	109a	80.8a
Weeding	27.1b	5.66a	9.05a	4.4a	51.0a	20.3a	32.6a	75.7a	108a	69.6a
M.D.S.	5.15	0.81	5.52	2.6	27.4	12.1	17.8	37.6	39.3	16.04
C.V. (%)	7.80	6.36	27.64	32.41	21.68	23.10	31.22	20.11	16.11	9.62
					20-40 cm					
I. campestris	23.3a	5.55a	5.85a	2.2a	45.7a	24.3a	33.0a	72.3a	105.3a	68.3a
A. prostrata	27.2a	5.48a	2.78a	1.9a	35.3a	12.3b	26.7a	49.5a	76.3a	65.7a
Mucuna	24.1a	5.33a	4.73a	2.5a	35.7a	13.8b	27.1a	52.3a	79.3a	65.3a
Mow/tillage	25.0a	5.58a	4.48a	3.4a	41.0a	14.2b	24.0a	58.5a	82.8a	71.8a
Weeding	22.3a	5.24a	3.45a	2.2a	32.7a	10.8b	39.5a	45.8a	85.0a	54.4a
M.D.S.	5.81	0.72	3.51	2.2	23.8	8.3	26.4	28.6	31.0	27.28
C.V. (%)	10.92	6.09	37.80	41.16	28.64	25.29	40.16	23.51	16.56	19.18

* Numbers followed by the same letter, in the vertical, are not significantly different, by the Tukey test, at a 5% significance level; M.D.S.= minimum difference for significance; C.V.= coefficient of variation; SB= soil basis; SBS= soil basis saturation.

1973; Koller et al., 1977; Santonini & Silva, 1995).

The soil chemical analysis of the orchard inter-rows (Table 3) showed that the nutrient content for both depths analyzed was not influenced by the soil management. The use of *A. prostrata* and mowing/tillage had a positively significant effect on soil organic matter content at the depth of 0-20cm in relation to the rest of the treatments, reflecting the good contribution in green matter given by these treatments. The organic matter content increased from 29.2g dm^{-3}, at the beginning of the experiment, to 35.3g dm^{-3} with *A. prostrata* and to 31.0g dm^{-3} with mowing/tillage, in the 0-20cm depth sampling. The treatments with *I. campestris* and 'mucuna' maintained approximately the same content, whereas the permanently bare soil by hand weeding had the organic matter content reduced in relation to initial conditions. For the 20-40cm sampling depth there were no differences between the treatments, but with a tendency to repeat the outcome presented by the upper layer. The increment in soil organic matter was also observed in citrus orchards by Koller et al. (1977) with mowing natural vegetation, and by Silva (1995) with seven annual leguminous species. Thus, the adequate use of ground covers in an orchard can contribute to the sustainability of the productive system. Soil organic matter is one of the factors that can be used to evaluate the maintenance, in the long run, of the soil chemical and physical factors that give conditions for the maintenance of crop yields (Feller, 1995).

The yield performance probably reflects the root total quantity, that was not affected by the soil management systems (Table 1). However, in terms of distribution (Figure 1A), the treatment with *A. prostrata* differed from the rest in the first three distances, with a higher concentration of roots up to 0.75m from the trunk. From this

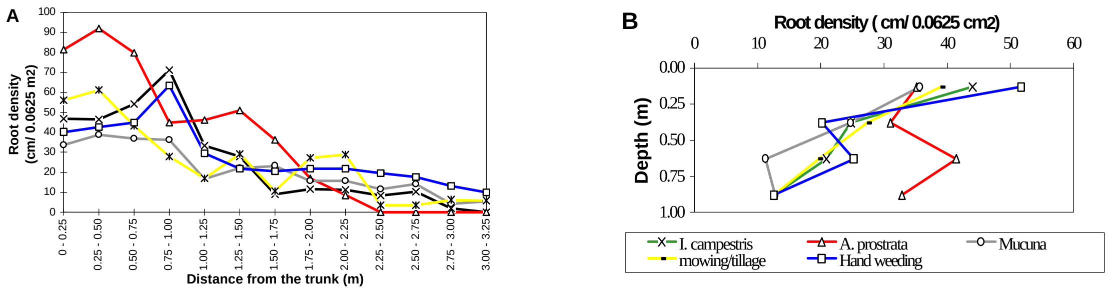

Figure 1: Root distribution of ‘Poncã’ tangerine on ‘Rangpur’ lime rootstock in different soil management systems. A) For depths. B) For the distances from the trunk.

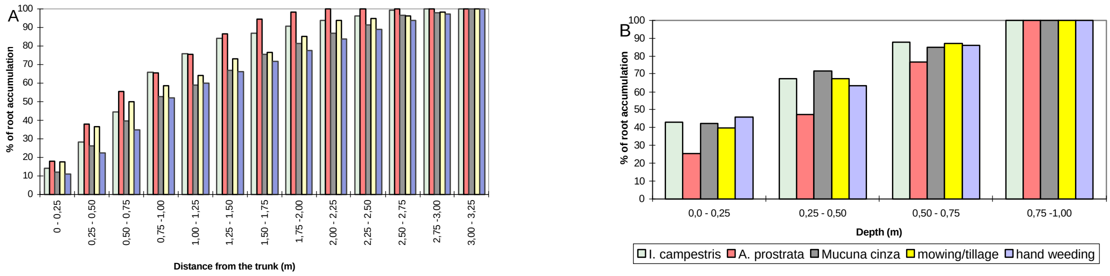

Figure 2: Percentage of root accumulation (%) of ‘Poncã’ tangerine grafted on ‘Rangpur’ lime in different soil management systems. A) for distances from trunk. B) for depths.

distance and up to 1.75m, this treatment continued presenting higher quantities, although with no significant differences. This higher quantity of roots ceases abruptly at 2.25m and no roots were found up to 3.25m. This abrupt interruption of citrus roots coincides with the beginning of the presence of *A. prostrata* root system, that is very abundant and vigorous. The data of the root distribution in depth (Figure 1B) show that no differences were caused by the management systems up to the depth of 0.50m.

For 0.50-0.75 and 0.75-1.00m depths *A. prostrata* caused a deepening of the root system, with significant differences in relation to the other treatments, except weeding,that had an intermediate behavior. A compensatory growth occurred (Russel, 1981) probably as a result of a horizontal restriction caused by the intense root growth of *A. prostrata*. This compensation was observed in citrus planting density trials by Kauffman et al. (1972) and by Castle (1980), with a higher concentration and depth of roots in dense planting spacings, compensating in this way the smaller available area of soil. This mechanism can be explained in terms of source-sink relationship and the action of growth inhibitors (Russel, 1981; Drew, 1990).

Sixty to seventy percent of the root system was present up to the distance of 1.0 m from the trunk when *A. prostrata* and *I. campestris* were used. In the rest of the treatments this same percentage was reached at a distance of 1.5m (Figure 2A). In terms of depth (Figure 2B), most of the root system (from 60 to 70%) of the plants were found at 0-0.50m, with exception of the treatment with *A. prostrata*, that did not follow the pattern with a deepening of the plant root systems. At this depth the roots reached 47.2% of the total, and 71.5% at the depth of 0.75m.

Conclusions

1) Soil management treatments did not significantly influence the total quantity of roots, yield, nutritional status and fruit quality of 'Poncã' tangerine in Londrina, PR, but there was a tendency of higher yield in the mowing treatment in wet season and tillage in the dry season.

2) Soil organic matter content in the 0-20cm layer increased significantly with *A. prostrata* and mowing/tillage treatments.

3) Root system distribution was significantly different among treatments: the presence of perennial leguminous plants in the inter-rows limited the presence of citrus roots to the region of the profile where roots of the cover plants were absent. This was compensated by a significant increase in the citrus root system deepening in *A. prostrata* treatment.

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