Effect of EM on Soil Quality, Fruit Quality and Yield of Orange Trees in a Brazilian Citrus Orchard

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Abstract

A field investigation was conducted during 1993-94 on citrus in the State of São Paulo, Brazil, to evaluate the interactions of EM with soil, leaves, mite populations, fruit quality and yield of orange trees. The study was designed to test the ability of Effective Microorganisms (EM) to significantly change a number of soil parameters in the citrus agroecosystem. Climate of the site is a CWa type. The predominant soil is a Typic Hapludox, a well-drained clay soil with high hydrogen and aluminum content, low base saturation, and a moderate organic matter content. The sweet orange trees were the Pera variety (Citrus sinensis Osbeck) grafted to Cravo lemon rootstock (Citrus limonia Osbeck). The experimental design was a randomized complete block design (RCBD), with four replicates for each of the following treatments: 1) Control (C); 2) EM applied to soil (EMS); 3) EM applied to citrus trees (EMP); and 4) EM applied to soil and to citrus trees (EMPS). The EM culture used in the experiment was a modified mixture of the three basic cultures and was applied at monthly intervals.

Analyses of soil chemical properties showed: 1) a highly significant increase in the soil organic matter content due to EM, especially in the fall season; 2) a highly significant increase in soil pH due to EM in the fall of 1993 which tended to decline in the summer of 1994; 3) a significant increase in the levels of some soil macronutrients due to EM, including Ca, Mg and K; 4) a highly significant increase in soil cation exchange capacity (CEC) due to EM, especially in the fall of 1993; 5) a significantly lower soil base saturation for the EMS and EMP treatments, probably due to the high levels of H^+ and Al^{+3} ions; and 6) no significant differences in the levels of soil P and micronutrients due to EM treatment.

There were no significant differences in soil physical properties between EM treatments and the control. However, soil penetration resistance to an impact penetrometer tended to be less in the EM-treated plots than the controls. There were no significant differences in the nutrient content of citrus leaves for EM treatments and the controls. An exception was Zn which was lower at times for the EMS, EMP and EMPS treatments compared with the control.

Populations of the citrus rust mite (Phyllocoptruta oleivora Ashmead) on green fruits were higher for the EMP and EMPS treatments compared with the control and EMS. Foliar-applied EM increased the rust mite populations while soil-applied EM decreased their numbers. Consequently, farmers are advised to cease foliar application of EM and use only soil-applied EM when rust mite populations are highest, i.e., from February to May.

Yields of oranges harvested in late August 1994, after 18 EM applications, were significantly higher in the EMS and EMPS plots. The higher yields can be correlated with improved soil chemical and physical conditions. Fruit quality analyses indicated a significant increase in juice content from the EM treatments and fruit peels were thinner due to EM compared with the control.

Introduction

Previous papers (Paschoal et al., 1993, 1996) have presented some preliminary results on how Effective Microorganisms known as EM (a mixed culture of beneficial microorganisms applied as soil and plant inoculants) can affect soil properties and nutrient cycling in a citrus agroecosystem. The concept and theory of EM and its benefits in nature farming have been reported earlier (Higa and Wididana, 1991). The present study was conducted in the State of Sao Paulo, Brazil and covered only one season, from March through June 1993. The paper reports an extension of the earlier study and a more thorough evaluation of the interactions of EM with soil properties, nutrient cycling, plant mite populations, fruit quality and yield of orange trees over four seasons during

1993-94. The data reported in this paper covers a one-year period, i.e., from March 1993 to March 1994. The main objective of the study was to determine the capacity of EM to elicit statistically significant changes in soil properties as well as fruit yield and quality in a citrus agroecosystem. The principles of Kyusei Nature Farming were adhered to throughout the study and no chemical fertilizers or pesticides were applied.

A study conducted by Higa (1988) reported the effect of EM on Unshu oranges in Japan. Concentrates of EM 2 and EM 3 were diluted 1:2,000 with water and sprayed on the trees at monthly intervals at a rate of 10,000 liters/ha. The soil had been previously amended with compost. Fruit yields from EM were equal to or greater than those of conventional orchards where only chemical fertilizers and pesticides were used. The EM treated orchard was reported to be virtually devoid of plant diseases and pests; leaves were thick and erect; fine roots were numerous; and soil physical properties had markedly improved. In their earlier study, Paschoal et al. (1993, 1996) reported significantly higher levels of soil organic matter, soil pH and soil cation exchange capacity (CEC) in plots treated with EM compared with the control. This paper assesses the consistency of these beneficial effects of EM on soil properties and also investigates how EM affects other parameters that are indicative of soil fertility, fruit yield and fruit quality.

Materials and Methods

The experimental site is a 17-hectare commercial citrus orchard located in Limeira County in the State of Sao Paulo, Brazil. The climate is a CWa type, with a dry period in the fall and winter seasons, (April to September) and a wet period in spring and summer (October to March). Annual precipitation is 1,408 mm; the driest month is July and the wettest is December. Soil moisture deficits usually occur from June until September. Relative humidity is between 62 and 77 percent and the average temperature ranges from 11^oC in the winter to 29^oC in the summer. The soil is a Typic Hapludox (dark-red Latosol) which is a deep, well-drained clay soil, with a high H + Al content, low base saturation, and moderate organic matter content. The nutrient content is low to moderate, except for iron which is very high. The topography is gentle with a 6 percent slope.

The orchard is five years old. Orange trees are of the Pera variety (*Citrus limonia* Osbeck) grafted to Cravo lemon rootstock (*Citrus limona* Osbeck). Trees are spaced 6 x 4 m (417 trees/ha). No chemical fertilizer, lime or pesticides have been applied to the orchard since 1991. The average yield per plant is 40 kg (17 tons/ha). A randomized complete block design (RCBD) was utilized with 4 replicate plots for each of the four treatments. Each plot in the 4 blocks had 32 orange trees of which only the 10 central trees were treated. The average tree size was 2.75 m high with an overall foliar radius of 17m.

The following treatments were applied:

- C (control) - Water was sprayed on the orange trees at a rate of 5 liters/tree and on the soil at a rate of 0.25 liters/m^2. Application to the soil covered an area of 2.5 x 4.0 m to ensure that each tree would receive 5 liters of water (i.e., 5 liters/20 m^2).
- EMS (soil treatment) - EM concentrate was diluted 1:100 with water and sprayed on the soil at a rate of 0.25 liters/m^2, equivalent to 2.5 ml of EM/m^2.
- EMP (plant treatment) - EM concentrate was diluted 1:1,000 with water and foliar-applied at a rate of 5 liters/tree, equivalent to 5 ml of EM/tree or about 0.20 ml of EM/m^2 of tree surface.
- EMPS (plant and soil treatment) - EM concentrate was diluted 1:1,000 with water and applied to trees at the same rate as for EMP; EM was diluted 1:1,000 and applied to soil at the same rate as for EMS.

The EM used in this study was formulated by the Mokichi Okada Foundation Center at lpeúna and is referred to as Kyusei EM; it was applied to the treatments at monthly intervals.

Prior to the experiment, soil samples and leaf samples of the orange trees were collected from each plot on March 3, 1993 for chemical analyses. This procedure was repeated quarterly, at the end of each season. Soil samples were taken from two depths (0-20 cm and 20-40 cm) with an auger and composite samples were prepared for analysis. Leaf samples taken were always the first oldest apical leaves from top branches bearing no fruits. Soil penetration resistance at a known soil moisture content was evaluated at two points per plot with an impact penetrometer. Soil samples were taken at depths of 0- cm and 20-24 cm using 50 cm^2 capacity rings for determination of bulk density, macropores and micropores.

Populations of the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), were assessed monthly, from February to June 1994, by field counting of adult mites on green fruit of the four tree quadrants. Counts were made on 8 fruits/plot and 2 cm^2/fruit for each observation. Fruit yield was determined by weighing at harvest in late August. Parameters of fruit quality including juice content, brix. citric acid, pulp and peel were determined by standard laboratory methods.

Results and Discussion

The chemical properties of soil at the 0-20 cm and 20-40 cm depths prior to the application of EM treatments are shown in Table 1. These values are for the first sampling of soil conducted on March 3, 1993. The following is an account of how certain soil properties changed during the study due to the EM treatments:

Table 1. Mean Soil Chemical Properties at Depths of 0-20 cm and 20-40cm Prior to the Application of EM to Soil (EMS), to Citrus Plants (EMP), and to Both Soil and Citrus Plants (EMPS).

Soil chemical properties	C (control)		EMS (soil)		EMP (plant)		EMPS (plant-soil)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
OM (g kg^{-1})	28.3	25.3	25.9	21.2	27.1	23.4	25.6	22.8
pH ($CaCl_2$)	4.4	4.4	4.3	4.3	4.3	4.2	4.5	4.9
P (resin)(mg dm^{-3})	7.3	1.1	6.4	1.2	19.2	1.3	17.1	16.3
K ($cmol_c$ kg^{-1})	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3
Ca ($cmol_c$ kg^{-1})	1.5	1.3	1.3	1.0	1.3	0.9	1.9	2.5
Mg ($cmol_c$ kg^{-1})	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.6
H+Al ($cmol_c$ kg^{-1})	5.3a	7.4ab	6.9a	8.6b	7.7ab	9.8b	6.6a	6.0a
SB ($cmol_c$ kg^{-1})	2.5	2.3	2.3	2.0	2.2	1.7	2.9	3.5
CEC ($cmol_c$ kg^{-1})	8.5	9.7	9.3	10.5	9.9	11.6	9.6	9.5
V (%)	31.6	23.6	25.9	18.7	22.0	15.1	30.8	37.1
B (mg kg^{-1})	0.6	-	0.5	-	0.5	-	0.6	-
Cu (mg kg^{-1})	2.5	-	1.8	-	2.4	-	1.9	-
Fe (mg kg^{-1})	70.1	-	53.4	-	65.5	-	59.4	-
Mn (mg kg^{-1})	21.1	-	17.5	-	26.8	-	16.5	-
Zn (mg kg^{-1})	1.4	-	1.9	-	1.8	-	1.9	-

CEC = Cation exchange capacity. OM = Soil organic matter. SB = Sum of bases.
V = Son base saturation. V = 100 SB / CEC
Means for a specific soil property having common letters are not significantly different.
Data are the least squares means for each treatment in the field experimental design; first sampling conducted March 3, 1993.

Soil Organic Matter

Table 2 shows that there was a highly significant ($P < 0.05$) increase in the organic matter content of the EM-treated plots for both soil depths compared with the control during the fall season of 1993 (second sampling). However, there were no significant differences between the EM treatments. This result can be attributed primarily to the recycling of organic amendments including grasses and weeds, reduced tillage, and the rapid conversion of organic materials into humus by EM (Higa and Kinjo, 1991). Whenever possible, EM was applied to surface residues when they were still green which helps to facilitate a rapid conversion to humus. Nevertheless, significant increases in soil organic matter were observed only in the fall season (March to June, 1993) as shown in Table 2, and not during the summer (January to March 1994) as shown in Table 3.

Table 2. Effect of EM on Soil Chemical Properties at Depths of 0-20 cm and 20-40 cm after Five Applications of EM to Soil (EMS), to Citrus Plants (EMP), and to Both Soil and Citrus Plants (EMPS).

Soil chemical	C (control)		EMS (soil)		EMP (plant)		EMPS (plant-soil)	
properties	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
OM (g kg^{-1})	20.1a	16.8a	23.3b	20.4b	24.1b	19.4b	24.4b	19.9b
pH ($CaCl_2$)	3.2a	3.3a	4.8b	5.3b	5.3b	5.1b	5.0b	5.8b
P (resin)(mg dm^{-3})	3.7	1.8	5.8	1.7	3.5	1.7	3.8	1.5
K ($cmol_c$ kg^{-1})	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Ca ($cmol_c$ kg^{-1})	0.8	1.0	0.8	0.9	0.9	1.0	0.7	1.1
Mg ($cmol_c$ kg^{-1})	0.3	0.5	0.4	0.5	0.4	0.6	0.4	0.6
H+Al ($cmol_c$ kg^{-1})	5.3	4.4	5.6	5.7	6.9	5.7	6.2	6.0
SB ($cmol_c$ kg^{-1})	1.4	1.8	1.5	1.7	1.6	1.8	1.4	1.9
CEC ($cmol_c$ kg^{-1})	6.7a	6.2a	7.1ab	7.2b	8.3b	7.4b	7.9b	8.0b
V (%)	21.7	28.5	21.0	22.6	19.9	24.2	19.3	24.7
B (mg kg^{-1})	0.5	-	0.6	-	0.5	-	0.6	-
Cu (mg kg^{-1})	3.8	-	3.8	-	3.1	-	4.4	-
Fe (mg kg^{-1})	221.0	-	211.3	-	205.7	-	222.5	-
Mn (mg kg^{-1})	16.8	-	18.7	-	14.5	-	20.7	-
Zn (mg kg^{-1})	1.0	-	0.9	-	0.8	-	1.2	-

CEC = Cation exchange capacity. OM = Soil organic matter. SB = Sum of bases.
V = Soil base saturation. V = 100 SB / CEC
Means for a specific soil property having common letters are not significantly different.
Data are the least squares means for each treatment in the field experimental design; second sampling conducted March 4 through June 22, 1993.

Table 3. Effect of EM on Soil Chemical Properties at Depths of 0-20 cm and 20-40 cm after Fourteen Applications of EM to Soil (EMS), to Citrus Plants (EMP), and to Both Soil and Citrus Plants (EMPS).

Soil chemical	C (control)		EMS (soil)		EMP (plant)		EMPS (plant-soil)	
properties	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
OM (g kg^{-1})	33.9	24.0	33.9	19.4	35.1	21.0	35.3	22.4
pH ($CaCl_2$)	4.3	4.4	4.3	4.2a	4.3	4.2a	4.4	4.4b
P (resin)(mg dm^{-3})	6.1	1.4	7.1	1.2	7.3	1.1	7.5	1.2
K ($cmol_c$ kg^{-1})	0.4	0.2	0.4	0.2	0.4	0.2	0.5	0.3
Ca ($cmol_c$ kg^{-1})	1.2	0.6a	1.5	1.0a	1.2	1.3a	1.8	2.5b
Mg ($cmol_c$ kg^{-1})	0.6	0.4a	0.7	0.5a	0.4	0.6ab	0.7	0.9c
H+Al ($cmol_c$ kg^{-1})	8.1	7.6a	8.8	10.8bc	8.3	9.1ab	9.3	8.2a
SB ($cmol_c$ kg^{-1})	2.2	1.2a	2.5	1.7ab	2.0	2.2b	2.9	3.7c
CEC ($cmol_c$ kg^{-1})	10.4	10.4	11.4	12.4	10.7	10.9	11.6	10.8
V (%)	23.3	27.3c	23.2	13.8a	25.0	16.9ab	20.7	24.7bc

CEC = Cation exchange capacity. OM = Soil organic matter. SB = Sum of bases.
V = Soil base saturation. V = 100 SB / CEC
Means for a specific soil property having common letters are not significantly different.
Data are the least squares means for each treatment in the field experimental design; fifth sampling conducted January 3 through March 23, 1994.

Soil pH

There was a highly significant increase ($P < 0.01$) in soil pH of the EM-treated plots for both soil depths compared with the control (C) at the second sampling (Table 2). However, there were no significant differences between the EM treatments. Moreover, no significant differences in soil pH were found at the third and fourth samplings (data not shown). The fifth sampling (Table 3) showed that there were highly significant differences ($P < 0.01$) between the following pairs of treatments, at the 20-40 cm depth: EMS-C, EMP-C, EMS-EMPS and EMP-EMPS. No difference was found between EMPS and C. The soil pH values for the EMS and EMP treatments at the 20-40 cm depth were lower than the control and EMPS. Changes in soil pH due to EM reported earlier by Paschoal et al. (1993, 1996) are confirmed by these results. However, we are unable to explain why soil pH for all EM treatments increased to significantly higher levels than the control in the fall (Table 2), and then sharply declined in the winter to the same level as the control (data not shown).

Although sharp fluctuations in soil pH did occur over the two seasons and thereafter, the soil pH values at the end of the experiment in March 1994 (Table 3) were not significantly different at the 0-20 cm depth from those at the outset (in March 1993) (Table 1). For samples taken at the 20-40 cm depth, highly significant differences ($P < 0.05$) were observed only for EMPS compared with EMS and EMP (Table 3).

Soil Macronutrients

Calcium.

Highly significant differences in soil Ca levels at the 0-20 cm depth, were found at the fourth sampling between the following pairs of treatments: EMPS-C, EMPS-EMS ($P < 0.01$), and EMPS-EMP ($P < 0.05$). At the 20-40 cm depth, there were significant differences between EMPS-C and EMPS-EMS ($P < 0.01$). There was no difference between EMPS and EMP. At the fifth sampling (Table 3), there were highly significant differences ($P < 0.01$) at the 20-40 cm depth only, between treatments EMPS-C, EMPS-EMS and EMPS-EMP. In the period from March 1993 to March 1994 (Table 4), significant differences ($P < 0.05$) were found, at the 20-40 cm depth, between treatments EMPS-EMS and EMPS-EMP.

Table 4. Effect of EM on Soil Chemical Properties at Depths of 0-20 cm and 20-40 cm One Year after the Experiment Began. Data Represent the Overall Changes that Occurred after Fourteen Applications of EM to Soil (EMS), to Citrus Plants (EMP), and to Both Soil and Citrus Plants (EMPS).

Soil chemical	C (control)		EMS (soil)		EMP (plant)		EMPS (plant-soil)	
properties	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
OM (g kg^{-1})	31.1	24.7	29.9	20.3	31.1	22.2	30.4	22.6
pH ($CaCl_2$)	4.3	4.4ab	4.3	4.2a	4.3	4.2a	4.4	4.7b
P (resin)(mg dm^{-3})	6.7	1.2	6.7	1.2	13.2	1.2	15.5	11.7
K ($cmol_c$ kg^{-1})	0.3	0.3	0.4	0.3	0.4	0.2	0.4	0.3
Ca ($cmol_c$ kg^{-1})	1.4	1.6ab	1.4	1.0a	1.3	1.0a	1.8	2.5b
Mg ($cmol_c$ kg^{-1})	0.6	0.7	0.6	0.5	0.5	0.5	0.6	0.7
H+Al ($cmol_c$ kg^{-1})	7.0	7.5a	7.9	9.7b	8.0	9.5b	7.9	7.1a
SB ($cmol_c$ kg^{-1})	2.4	2.6ab	2.4	1.8a	2.2	1.8a	2.8	3.6b
CEC ($cmol_c$ kg^{-1})	9.4	10.1	10.3	11.4	10.3	11.2	10.6	10.1
V (%)	27.4	25.4ab	24.6	16.2a	23.5	16.0a	25.7	30.9b

CEC = Cation exchange capacity. OM = Soil organic matter. SB = Sum of bases.
V = Soil base saturation V = 100 SB / CEC
Means for a specific soil property having common letters are not significantly different.
Data are the means of values reported in Tables 1 and 3 and represent the changes in soil physical properties due to EM (14 applications) over a period of 12 months.

Magnesium.

The interaction of EM with Mg was similar to that of Ca. Generally, higher soil Mg levels were associated with EMPS relative to EMS and to EMP, but not to C. No other difference was found. At the fifth sampling (Table 3) highly significant differences ($P < 0.01$) occurred at the 20-40 cm depth. Higher means were associated with EMPS relative to C, EMS and EMP, and also with EMP relative to C. In the period from March 1993 to March 1994 (Table 4) no significant differences were detected.

Potassiuln.

Higher K levels were associated with EMP and EMPS treatments relative to EMS, but not to C. No EM treatment was significantly different than the control. In the period from March 1993 to March 1994 (Table 4) no statistical differences were found between treatment means.

It is apparent from these findings that the EMPS treatment was associated with the highest level of soil macronutrients, probably due to the higher population and activity of EM microorganisms that were applied in this treatment, i.e., twice that of the EMS and EMP treatments. One can reason that the additional Ca, Mg, and K nutrients became available in the soil after microbial mineralization of the organic debris from weed cuttings.

Soil Micronutrients

No statistically significant differences in the levels of soil micronutrients were found for any of the treatments. Consequently, these data are reported only for the first and second samplings (Tables 1 and 2) and omitted elsewhere (Tables 3 and 4).

Sum of Bases

Because of the higher levels of Ca, Mg and K due to EM applications, the sum of bases (SB) increased accordingly. At the fourth sampling (October 1993 to January 1994) the SB levels were significantly higher at both soil depths for the EMPS treatment compared with C, EMS and EMP. However, EMPS and EMP were not significantly different at the 20-40 cm depth. At the fifth sampling (January to March 1994) highly significant differences ($P < 0.01$) occurred only at the 20-40 cm depth (Table 3). The SB levels were significantly higher for the EMPS treatment compared with C, EMS and EMP.

Soil Cation Exchange Capacity

At the second sampling (Table 2) the CEC was significantly higher ($P < 0.05$) for most EM treatments at both soil depths compared with the control. A single exception was EMS at the 0-20 cm depth which was not significantly different from the control. In the period from March 1993 to March 1994 (Table 4) there were no significant differences in CEC for any of the treatments. The higher CEC values were correlated with a higher soil organic matter content which, in turn, was enhanced by EM activities as suggested earlier by Paschoal et al. (1993, 1996).

Soil Base Saturation

The soil base saturation values at the fifth sampling (Table 3) were significantly lower ($P < 0.05$) for most EM treatments at the 20-40 cm depth compared with the control. An exception was the EMPS treatment which was not significantly different from the control. While the lowest value was found for the EMS treatment, it was not statistically different from EMP, but it was different from EMPS. These findings can be explained by the relatively large amount of H + Al ions present in EMS and EMP compared with C and EMPS (Table 3). From March 1993 to March 1994 (Table 4) the soil base saturation (V%) was significantly higher for the EMPS treatment at the 20-40 cm depth compared with EMS and EMP. At this time, the soil H + Al level was significantly lower for EMPS compared with EMS and EMP.

Soil Physical Properties

An impact penetrometer was used to determine whether the EM treatments had caused any measurable changes in soil physical properties. Results show that there were no significant differences between treatment means. This may not be too surprising since there was no regular addition of organic materials with any of the treatments except for weed and grass residues. Nevertheless, a summary of the data (Table 5) indicates that the average number of strokes/decimeter was slightly less for the EM treatments compared with the control. This trend toward less resistance to penetration due to EM suggests that EM microorganisms were becoming established and starting to influence soil physical parameters.

Table 5. Mean Number of Strokes with an Impact Penetrometer to Penetrate One Decimeter of EM-Treated Soil Compared with the Untreated Control Soil.

Soil depth (cm)	Soil moisture (%)	No. strokes dm^{-1}	
		Control	EM treatment
11	16.7	5.8	5.1
31	17.6	4.8	4.7
51	19.2	5.1	4.1

EM treatment was a composite ot EMS, EMP and EMPS.

Nutrient Content of Citrus Leaves

Chemical analyses of citrus leaves indicated that in most cases no statistically significant differences could be detected in the levels of either macro- or micronutrients (data not shown). An exception was Zn. where some significant differences (.P < 0.05) were found. In one sample, the control leaves had a significantly higher Zn content than EMS and EMP, but not different than EMPS. In another sample, there was no difference between the control and EMPS, but the Zn content of EMPS leaves was significantly higher than EMS or EMP.

Mite Population on Fruits

Population assessments of the citrus mite, *Phyllocoptruta oleivora* Ashmead, from February to June 1994, indicated that the EMP and EMPS treatments increased the mite population on green fruits. This is probably because some component in the EM formulation (e.g., molasses) attracts the insect after foliar application. Conversely, EM applications to soil (EMS treatment) were associated with lower mite populations on fruits. Statistical analyses using least squares means revealed the following number of mites per cm^2: C 7.11a; EMS 6.57a; EMP 8.45b; and EMPS 8.68b. Mite populations for EMP and EMPS were significantly higher than C (P < 0.05) and EMS (P < 0.01).

Based on this preliminary result, farmers are advised to replace foliar EM applications with soil EM applications during times when rust mite populations are normally at their highest. In the State of São Paulo, this period coincides with high rainfall and high temperatures, i,e., the late summer and fall seasons (February to May).

Yield and Fruit Quality

There were highly significant differences (P < 0,05) in orange yields 18 months after the experiment began and after 18 EM applications (Table 6). Highest yield was for the EMPS treatment closely followed by EMS; both treatment means being significantly higher than the control. The relative yield increases over the control were: EMPS, 15%; EMS, 14%; and EMP, 4%. The higher yields for the EM treatments were somewhat correlated with improved soil chemical and physical properties. For example, the soil organic matter content, major nutrients (Ca, Mg, K and P) and sum of bases were always higher (but not always significant) in the EMPS plots compared with other treatments. Moreover, soil resistance to the impact penetrometer was always less in the EMPS plot, suggesting more favorable soil conditions for plant growth.

Table 6. Yield and Quality of Oranges Harvested in August 1994, 18 Months after the Experiment Began and after Eighteen Applications of EM to Soil (EMS), to Citrus Plants (EMP), and to both Soil and Citrus Plants (EMPS). Data are the Least Square Means for Each.

Yield / Quality parameters	C (control)	EMS (soil)	EMP (plant)	EMPS (soil-plant)
Yield (kg/10 plants)	503.0a	575.6b	526.5ab	580.0b
Weight of 8 fruits (g)	1,210.0	1,270.0	1,178.0	1,210.0
Weight of 1 fruit (g)	151.2	158.7	147.3	151.2
Weight of juice (g)	573.1a	639.9b	638.7b	672.8b
Weight of peel (g)	597.3b	526.0ab	458.8a	442.7b
Weight of pulp (g)	32.7	96.2	78.9	85.5
Weight of seeds (g)	6.7	7.2	7.3	8.7
Citric acid (%)	1.3	1.2	1.1	1.2
Brix (%)	10.7	11.5	10.4	11.3
Ratio (%)	8.4	9.9	9.5	9.7

Means for a specific parameter having common letters are not significantly different.

Significant differences (P < 0.05) were found for fruit juice and peel weights. The EM treatments increased the juice content over the control by 17% in EMPS and by 11 % in the EMP and EMS plots. The relationship of juice weight to fruit weight for each treatment indicated the percentages of juice in the fruit as: EMPS, 55%; EMP, 54%; EMS, 50%; and C, 47%. The net percentage increase in juice compared with the control was: EMPS, 8%; EMP, 7%; EMS, 3%. The fruit peel weights of the EMPS and EMP treatments were lower than the control, indicating that the oranges in these treatments had a thinner peel than the control.

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