Improved Soil Chemical and Physical Conditions and their Relations to Yield and Fruit Quality of Oranges in a Field under Kyusei Nature Farming and EM Technology in Brazil

Adilson D. Paschoal
University of Sao Paulo,"Luiz de Queiroz" Agriculture College, Piracicaba, SP, Brazil

Abstract

Field investigations were conducted with citrus, since 1993, in Sao Paulo, Brazil, on the use of Nature Farming and EM technology. EM cultures applied to the soil (EMS), to plants (EMP) and to both plants and soil (EMPS) were compared with the control (C). Under natural soil conditions, i.e., with no fertilizer, no lime and no pesticide, yield of oranges and fruit quality parameters were analyzed comparatively, after one and a half years from the beginning of the experiment and after 18 EM applications. Statistical analyses indicate highly significant differences ($P < 0.05$) in yield, in treatments EMPS and EMS; relative percentage increases were 15% and 14% respectively. Regarding the EM treatments, higher yields can be correlated with improved soil chemical and physical conditions. Highly significant differences ($P < 0.05$) in treatment means were also detected for weights of juice and peel. EM treatments raised orange juice content by 17% (EMPS) and 11% (EMP and EMS). Related to the control, the percentage increases in juice content were 8% (EMPS), 7% (EMP) and 3% (EMS). EM treated fruits also presented thinner peels.

Introduction

In previous papers (Paschoal et al. 1993, 1994, 1995, 1996) we presented the results of a field investigation dealing with the use of EM on a citrus grove in the State of Sao Paulo, Brazil. In the present paper a correlation is established between yield, fruit quality and improved soil chemical and physical conditions determined by the use of EM. This study attempts to bring new knowledge to the way EM behaves in the soil to improve crop yields and food quality.

Materials and Methods

General features of the experimental site were given elsewhere (See Paschoal et.al, 1993).

The experimental design was a Randomized Complete Block Design, with 4 replicates for each of the following treatments :-

C (control): Water sprayed over the citrus plants at a rate of 5 L/plant, and over the soil at a rate of 0.25 L/m^2. The application on the soil surface was made to cover an area 2.5 m wide and 4.0 m long, on each side of a plant, in such a way that each plant would get 5 L (5L/20 m^2).

EMS (soil) : EM diluted 1:100 sprayed over the soil at a rate of 0.25 L/m^2, equivalent to 2.5 ml of EM/m^2, the same way as for the control.

EMP (plant) : EM diluted 1:1,000 sprayed over the citrus plants at a rate of 5 L/plant, equivalent to 5 ml of EM/plant, or about 0.20 ml of EM/m^2 of the tree surface (the average plant was 2.75 high with a radius of 1.70 m).

EMPS (plant–soil): EM diluted 1:1,000 sprayed over the citrus plants, at the same rate as for EMP, plus EM diluted 1:100 sprayed over the soil at the same rate as for EMS. EM culture used in the experiment was a modified mixture of the three basic cultures, developed in Brazil at the Mokiti Okada Foundation Centre, in Ipeuna, Sao Paulo, called EM4 or simply EM (Kyusei-EM, in Japan). EM spray frequency was at monthly intervals.

Soil and plants were kept under natural conditions at all times, receiving no fertilizer nor lime or pesticides. Weeds were chopped and let to decay at soil surface as dead mulch, no herbicide or disc harrowing being allowed. Whenever possible, EM applications were made on top of this material, in treatments EMS and EMPS, while it was still green.

Soil samples for chemical analyses were taken from two different depths (0-20 and 20-40 cm) with the aid of an auger. Soil penetration resistance, at a determined soil moisture content level, was evaluated comparatively, on the same day, by means of an impact penetrometer. Two points per plot were sampled under the tree-tops, for resistance to penetration. Soil density was assessed at 0-4 and

20-24 cm depths; 50 cm^2 capacity rings were used for sampling bulk density, macropores and micropores.

To determine yield, ripened fruits were harvested in late August 1994 and weighed directly in the field. Oranges were picked from all 10 trees in each plot (Paschoal et al, 1993) being transferred to standard plastic boxes with a holding capacity of 28 kg each. The number of boxes, weighing 28 kg, and yield (kg/plants) were determined per block and per treatment. Statistical analyses were then applied to data. Variables in which the F test resulted significant, the multiple comparison technique through the Tukey test, was used so to allow the comparisons between the means.

Fruit quality was evaluated by sampling trees, one fruit being picked at randon from each of 8 trees in each plot, two marginal trees being disregarded to avoid the border effect. Sampled fruits were all of the same size, being equally ripened and criteriously taken from the same quadrant, at the same plant height, and brought to the laboratory for analysis the day after harvesting. Several features were determined: weight of juice, weight of peel, weight of pulp, weight of seeds, citric acid, brix and ratio.

Data presented in this paper cover a period of one and a half years, from March 03, 1993 to August 23, 1994.

Results and Discussion

Data on the number of boxes (28 kg/box) of oranges per block and per treatment, yields (kg/plant) per block and per treatment are presented in Table 1. Regarding the mean yield of oranges the analysis of variance resulted significant for the variable treatments. The Tukey test resulted analyses are displayed in Table 1.

Highly significant differences ($P < 0.05$) in yield of oranges were obtained for treatments EMPS (53.0 kg/plant) and EMS (52.5 kg/plant) in relation to C (45.9 kg/plant) (Table 1). EMP treatment (48.3 kg/plant) was not statistically different from the control and the other EM treatments. Relative increases in yield of oranges per plant, in relation to the control, were as follows : 15 per cent for EMPS, 14 per cent for EMS, and 4 per cent for EMP. Considering that : 1) the increase in yield for treatment EMPS in relation to C is 7.1 kg/plant; and 2) the number of plants per hectare is 416, the resulting elevation in productivity is 2,953 kg/ha equivalent to 105 boxes. This may represent an extra revenue of about U$ 315 per hectare, at the regular price of U$ 3.00/box priced in 1994. It is worth stressing that this rise in productivity was achieved without the addition of any amendment but EM to the soil or to the plant.

Data on quality of the orange fruits harvested in later August 1994 are presented in Table 2. Regarding the mean weight of juice and weight of peel, the analyses of variance were significant for the variable treatments. The Tukey test resulted analyses are shown in Table 2.

Highly significant differences ($P < 0.05$) in weight of juice were obtained for treatments EMPS (672.83 g), EMS (639.94 g) and EMP (638.74 g) relative to C (573.11 g) (Table 2). All three EM treatments did not differ from each other. Relative increases in weight of juice, in relation to the control, were as follows: 17 per cent for EMPS, 11 per cent for EMS and 11 per cent for EMP. Relative weights of juice to the weights of the fruits they were extracted from showed the following percentages of juices in the fruits: 55 per cent for EMPS, 54 per cent for EMP, 50 per cent for EMS and 47 per cent for C. Related to the control, the percent increases in juice content were as follows: 8 per cent for EMPS, 7 per cent for EMP, and 3 per cent for EMS.

Highly significant differences ($P < 0.05$) in the weight of peel were also obtained for treatments EMPS (442.67 g) and EMP (454.83 g) relative to C (597.28 g) (Table 2). No statistical differences were found between treatment EMS (525.96 g) and the control. Once again the EM treatments were not significant to each other. Lower peel weights means thinner peels.

The assumed fruit uniformity was corroborated by the results of the analyses of variance. No statistical differences were found for fruit weight (Table 2).

Table 1. Number of Boxes of Oranges (28 kg), and Yield (kg/plant) per Block and per Treatment, after 18 months from Commencement of the Experiment and 18 EM Applications.

C (control)				EMS (soil)				EMP (plant)				EMPS (plant-soil)			
1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Number of Boxes/block															
13	17	18	22	17	21	20	22	15	18	21	21	16	22	20	22
Number of boxes/treatment															
	70					80			75					80	
Yield (Kg/plant)/ block															
33.6	43.5	49.7	56.8	43.2	52.6	55.0	59.4	38.2	46.9	53.9	54.2	42.5	57.5	53.3	57.9
Yield (kg/plant)/treatment															
	45.9a					525 b				48.3 ab				53.0 b	

Means with the same letter are not significantly different.

Table 2. Quality of Oranges Harvested in August 1994, after 18 months from the Beginning of the Experiment, and Eighteen EM Applications. Data Represent the Least Squared Means for the Treatments.

Characterists	**C (control)**	**EMS (soil)**	**EMP (plant)**	**EMPS (plant-soil)**
Weight of 8 fruits (g)	1.209.71	1.269.30	1.179.80	1.209.70
Weight of 1 fruit (g)	151.12	158.66	147.28	151.21
Weight of juice (g)	573.11a	639.94b	638.74b	672.83b
Weight of peel (g)	597.28b	525.96ba	454.83a	442.67a
Weight of pulp (g)	32.66	96.20	78.90	85.53
Weight of seeds (g)	6.66	7.20	7.33	8.66
Citric acid (%)	1.27	1.16	1.10	1.18
Brix (%)	10.70	11.45	10.35	11.25
Ratio (%)	8.40	9.88	9.46	9.68

Means with the same letter are not significantly different.

Higher yields, greater juice contents and thinner peels in the EM treatments, can be correlated with improved soil chemical and physical conditions, determined by the use of effective microorganisms. At the time the citrus plants were in bloom and fruits were forming in late winter, soil organic matter, soil pH and soil C.E.C. were significantly higher in all the EM treatments relative to the control (Table 3). The organic matter content of the soil and soil pH increased to highly significant levels ($P < 0.05$ and $P < 0.01$ respectively) at both depths, in the plots treated with EM over that of the control, EM treatments being not significant to each other (Paschoal et al, 1995). Related to the control, the soil cationic exchange capacity (C.E.C) means were significantly higher ($P < 0.05$) for all EM treatments, at both depths, EMS excepted at 20 – 40 cm depth, EM treatments being not significant to each other. This finding suggests that citrus plants treated to EM were taking more nutrients out of the soil.

Regarding soil penetration resistance to impact penetrometer a tendency existed for EM treatment means to be lower than the control. The average means strokes per dm, at 0-51 cm depths, indicated EMPS, EMS and EMP soils to be 11 per cent, 7 per cent and 6 per cent less resistant to penetration than the control. The average figures were as follows: EMPS 4.83 s/dm; EMS 5.04 s/dm; EMP 5.13 s/dm; and C 5.45 s/dm (See Paschoal et al, 1995 for further details). This tendency probably indicates that effective microorganisms were able to improve soil physical conditions, reducing compaction. Best results were obtained for EMPS plot where introduced EM culture volumed twice that of the other EM treatments.

Table 3. Effects of EM on Chemical Characteristics of Soil, at 0-20 cm and 20-40 cm Depths, after Five EM Applications. Data Represent the Least Squares Means for the Treatments, Second Samples (March 4 to June 22, 1993), in Fall Season. Data of Assessment: June 22.

Characteristics		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
O.M	(g kg^{-1})	20.07a	16.78a	23.34b	27.44b	24.11b	19.44b	24.44b	19.87b
pH	($CaCl_2$)	3.17a	3.27a	4.77b	5.25b	5.27b	5.08b	4.97b	5.76b
P	(resin)(mg dm^{-3})	3.73	1.81	5.75	1.68	3.54	1.66	3.79	1.51
K	($Cmol_{-c}$ kg^{-1})	0.30	0.25	0.36	0.27	0.30	0.26	0.29	0.26
Ca	($Cmol_{-c}$ kg^{-1})	0.83	0.98	0.82	0.85	0.91	0.97	0.73	1.07
Mg	($Cmol_{-c}$ kg^{-1})	0.28	0.52	0.37	0.49	0.40	0.57	0.42	0.57
H+Al	($Cmol_{-c}$ kg^{-1})	5.28	4.42	5.55	5.67	6.95	5.56	6.16	6.02
S.B.	($Cmol_{-c}$ kg^{-1})	1.42	1.75	1.53	1.65	1.64	1.80	1.44	1.91
C.E.C.	($Cmol_{-c}$ kg^{-1})	6.66a	6.17a	7.06ab	7.24b	8.31b	7.42b	7.93b	8.00b
V	(%)(2)	21.73	28.52	20.98	22.56	19.92	24.18	19.25	24.71
B	(mg kg^{-1})	0.47	-	0.63	-	0.48	-	0.63	-
Cu	(mg kg^{-1})	3.76	-	3.76	-	3.05	-	4.42	-
Fe	(mg kg^{-1})	220.96	-	211.29	-	205.66	-	222.51	-
Mn	(mg kg^{-1})	16.78	-	18.68	-	14.46	-	20.71	-
Zn	(mg kg^{-1})	0.99	-	0.87	-	0.84	-	1.17	-

(1) S.B. = Sum of bases
(2) V = 100 S.B/C.E.C.(Soil base saturation)
Means with the same letter are not significantly different

At the time fruits were developing and maturing, from spring to fall, significant differences were noticed for the major nutrients Ca, Mg and K. Higher Ca and Mg levels were associated with EMPS in spring and summer times; higher K levels occurred in spring but only for EMP and EMPS relative to EMS. Due to increased major nutrients in soil, the sum of bases increased accordingly. Higher S.B. means were associated with EMPS (See Paschoal et al, 1995 for further details). It is yet too early to try to correlate these findings with improved fruit quality. Perhaps not plant uptake of ions but complex molecules of organic nature would be more desirable to investigate.

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