The effects of the use of organic solid wastes on the growth of citrus trees

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Abstract: Two types of organic solid wastes were selected to be applied in a citrus orchard: the sewage sludge (the most common on the settlements) and the manure (the most common on the agricultural fields). The sewage sludge is a residue originated from the wastewater treatment – the solid phase. Its application as an organic fertilizer may represent an alternative to the pollution effects in nature. In an orchard of orange-trees (*Citrus sinensis* [L.] Osbeck), the application of sludge was compared with the application of manure and with the control in order to observe the growth response of the trees. Biometric methods where used – number of leaves per tree, diameter of the trunk, leaf area, specific leaf areas and leaf chlorophyll content. In general, the citrus plants response to the application of sewage sludge and manure was positive for the plant growth, compared to the control. The application of the manure, and especially the sewage sludge (once this fertilizer / soil amendment is available in larger amounts) may be a profitable alternative application to the use of mineral fertilizers and to other soil amendments. Moreover, as the possible destinations of sewage sludge (sea, deposition in land fields, incineration) provoke environmental problems, its agricultural reuse is essential to avoid those problems, when correctly applied in relation to trace elements and to pathogenic parameters. The reuse of this solid waste may be a clean and a safe technique to preserve the environment contamination.

Key-Words: citrus leaves, manure, plant development, sewage sludge, soil organic amendments

1 Introduction

In the last years, especially in the last two decades, improving efficiency of fertilizers use has been a trend in most agricultural studies related to soil organic fertilizer *versus* amendment management [1, 2].

Meanwhile, low N use efficiency and nitrate pollution are problems in intensive crop production systems, because N application rates, through inorganic and fertilisers, often exceed crop's demand with subsequent impacts on soil, such as soil salinization, soil acidification, and groundwater quality –

nitrate contamination [3, 4, 5].

Fertilisers' production consumes energy and its resources are limited. Innovation in agrotechnology using controlled release fertilisers in crop production is one of the solutions related to the impacts on soil and water quality. However, this type of fertilisers is expensive and their use is less than 1% of total world fertiliser consumption [6].

Concerning to pathogens, some potential health risks can be related to the reuse of sludge as a vehicle of some pathogenic micro-organisms like *Escherichia coli*, *Salmonella* spp., *Clostridium perfringens* and *Listeria monocytogenes* [7, 8].

The presence of certain elements, namely heavy metals, such as Cd, Cr, Ni, and Pb might limit their application to crops, since those elements are toxic to man. For example, cadmium, which is not regarded as essential to human life is able to accumulate itself in the kidneys [9] and in the liver [10]; and it is known that it produces health problems on the respiratory system and it has been associated also with bone diseases [11].

The appropriate agricultural use of soil amendments and/or organic fertilizers can become advantageous, because it allows the waste recycling. Besides lessening the pollution problems it also improves the physical, chemical and biotic conditions of the soils [12]. The correct use in crop production must be investigated, not only at nutrients and salinity levels but also concerning trace elements, when present [13, 14]. By using sewage sludge, as soil substrate, less chemical hazardous pollution was demonstrated when compared with the application of inorganic fertilizers [15].

In the Algarve region, it was studied the effects of manure and treated sewage sludge application on a citrus orchard, and it was shown that there was not an increase in soil concentration of trace elements; moreover, the levels of the different chemical elements were not increased significantly [16]; on the other hand, this work aims to show the effects of treated sewage sludge application on the growth of the citrus orchard.

2 Material and methods

2.1 Experimental procedure

An experimental plot was established in an orange (*Citrus sinensis* L.) orchard, in the Algarve, southern Portugal, on the same conditions, as related in by Costa *et al* [16]. A 20 ha plantation (6 x 2 m) took place in May where twelve trees were chosen to conduct the experiments. A drip irrigation system was used – Ram Netafim self-compensating drippers, incorporated in the pipes, at a distance of 0.75 cm with a constant 2.3 L h^{-1} discharge. The irrigation periods occurred six months per year between May and October. The amount of irrigation was 4.6 L per tree and day (700 m^3 ha^{-1} $year^{-1}$). Two different types of organic soil amendments were tested: sewage sludge (L) and manure (E), which were compared with the control treatment (T; without organic soil application). The experimental procedure was a randomized block design with 3 treatments x 4 replications, in a total 12 young orange trees. The soil was analysed for texture, pH(H_2O), organic matter (OM, %), electric conductivity (EC, dSm^{-1}), total N (%), P_2O_5 (ppm), K_2O (ppm), Fe (ppm), Mn (ppm), Zn (ppm), total lime (%), active lime (%), C (%), exchangeable cations (cmol[+]kg^{-1}), cation exchange capacity (CEC, cmol[+]kg^{-1}), and trace elements – Cd, Ni, Pb and Cr (ppm). The ratio of C to N, the total exchangeable bases (TEB), and the percent base saturation (BS, %) were also calculated. These results are presented in Table 1.

2.2 Soil

The soil of the experimental site was classified as Fluvisoil [17], defined by an alluvial soil, up to 1 m depth, characterized by a “Terric” superficial layer (FLtr), originated from calcareous materials.

Table 1 – Soil physical and chemical parameters before orange trees plantation.

Soil Parameters	Values
Texture	Silt loam
Sand (%)	28.1
Silt (%)	45.5
Clay (%)	26.3
pH (H_2O)	8.0
OM (%)	1.8
EC (dS m^{-1})	0.9
N (%)	0.1
P_2O_5 (ppm)	29.1
K_2O (ppm)	617
Fe (ppm)	250
Mn (ppm)	128
Zn (ppm)	4.0
Total lime (%)	21.1
Active lime (%)	10.2
C (%)	1.0
C/N	12.3
Ca (cmol[+]kg^{-1})	7.5
Mg (cmol[+]kg^{-1})	4.4
Na (cmol[+]kg^{-1})	1.7
K (cmol[+]kg^{-1})	0.7
TEB (cmol[+]kg^{-1})	14.3
Exchangeable H (cmol[+]kg^{-1})	0,0
CEC (cmol[+]kg^{-1})	14.7
BE (%)	100

2.3 Amendments

The sludge was collected from the urban wastewater treatment plant of Vilamoura (Algarve). The manure came from a cattle stable near the experimental site. These amendments were applied to the soil at a depth between 0.5 and 1.0 m during the plantation of the trees. The physical and chemical parameters of the soil amendments are shown in Table 2.

Table 2 – Physical and chemical parameters of the soil amendments.

Parameters	Sludge (L)	Manure (E)
pH (H_2O)	6.6	7.4
OM (%)	55.7	72.4
EC (dSm^{-1})	14.5	21.2
Water content (%)	12.3	7.5
N (%)	3.17	2.38
P (%)	1.45	0.97
K (%)	1.09	3.10
Ca (%)	5.25	2.81
Mg (%)	0.16	0.32
C/N	17.6	30.4

The amounts of sludge and manure applied per tree (g) and respective nutrient contents (N, P_2O_5, K_2O and Mg) are presented in Table 3. Sewage sludge and manure were applied and incorporated to the soil at one meter depth before the citrus tree plantation.

2.4 Plant analysis

Several plant biometric determinations were done on the end of the 2nd experimental year in November, as follows: number of leaves per tree (NFA); trunk perimeter (PT); leaf area (AF); specific leaf area (AEF) and specific leaf disk area (AED).

Table 3 – Amounts and nutrient contents of sludge (L) and manure (E) applied per tree (g).

	Sludge (L)	Manure (E)
Amount (g)	9500	12600
N (g)	300	300
P_2O_5 (g)	314	280
K_2O (g)	124	470
Mg (g)	15	40

The number of leaves per tree (NFA) is a biologic parameter used to define the vegetative development of the trees. The trunk perimeter (PI) is measured at a 20 cm height and it was used to define the trees vigour.

Leaf area (AF) is considered as a biometric parameter which defines the vegetative development, in function of time and of the experimental treatments. The LA was measured using a leaf area measurer "AT Delta-T" (Devises Lda., Burwell, Cambridge, UK).

The specific leaf area (AEF) is defined as the ratio between the leaf area (AF) and their dry weight [18]; this parameter is useful to evaluate the vegetative development, as a function of time and of the experimental treatments; there were collected 5 leaves per tree, oven dried at 60ºC, and weighted.

The specific leaf disk area (AED) of 50.3 mm^2 were obtained, through a mechanical outlet apparatus, in different leaves and oven dried at 60º C, and weighted. in a precision scale.

The degree of leaf chlorosis was evaluated using a portable SPAD-502 meter (Minolta Co., Osaka, Japan). The evaluation principle of this apparatus consists on measurement of the transmitted light through a leaf, after the sequential submission to two radiation types: the first – a short wave radiation, on the red range (~ 650 nm), which corresponds to the pick of absorption of the chlorophyll molecules, and, after, with a longer wave radiation, on the infrared range (~ 940 nm), that works as a reference. The light intensity transmitted by the leaf is converted in electric signs, and after in SPAD units, through a microprocessor, according to Minolta.

2.5 Statistical analysis

The effects of treatments were evaluated using analysis of variance (ANOVA) and the means compared using the Duncan Multiple Range Test (DMRT) at the 95% significance level, using the SPSS 11.0 [26].

3. Results

Table 4 shows the averages of three of the studied growth parameters, among the three treatments – control (T), sludge (L), and manure (E). The number of leaves per tree (NFA), specific leaf area (AEF), and SPAD values were not significantly affected by the treatments. Moreover, the SPAD values were within the range obtained by Pestana *et al* [19] for green leaves in citrus trees, indicating an adequate nutritional level of the plants in this experiment.

Table 4 - Number of leaves per tree (NFA); specific leaf area (AEF, $cm^2\ g^{-1}$) and total leaf chlorophyll (SPAD) for each treatment: sewage sludge (L), manure (E) and control (T).

	NFA	AEF	SPAD
T	396	54	76,4
L	510	52,1	75,6
E	447	53,1	74,9

Fig. 1 shows the variation of the perimeter of the trunk values (PT, cm) among treatments. A positive response was observed by the wastes application. In relation to the perimeter of the trunks values (PT), it was observed that manure (M) and sludge (L) were both significantly higher than the control treatment (T).

The young citrus plants amendment with tested wastes presented higher values of trunk perimeter (about 69%) compared to the control plants.

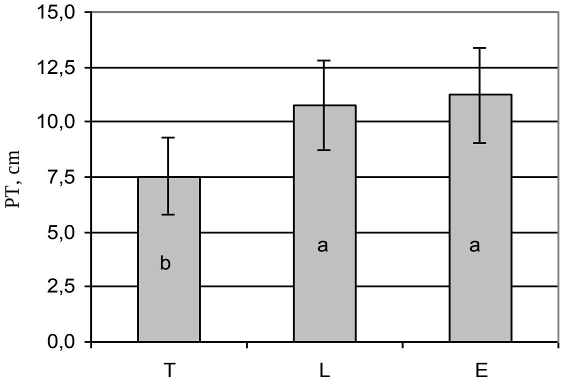

Fig. 1 – Trunk perimeter (PT, cm) values for the treatments: T- control, L – sewage sludge, E – manure. Columns with the same letter were not significantly different at P<0.05 (Duncan Test).

Fig. 2 shows the values of leaf area (AF, cm^2) for each treatment. The leaf area increased with wastes application. It was shown that, in general, the sewage sludge and manure application improve the growth of young citrus plants, compared to the control. These applications led to plants with higher trunk perimeter and larger leaves. However, it was only observed significantly higher leaf area values in the sludge treatment (L) when compared to the control (T).

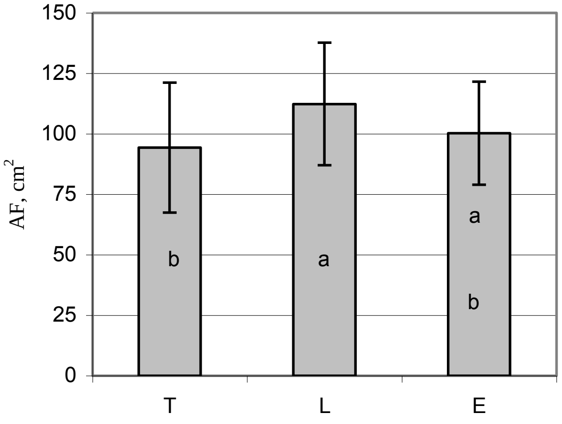

Fig. 2 – Leaf area (AF, cm^2) values for the different treatments: T- control, L – sewage sludge, E – manure. Columns with the same letter were not significantly different at P<0.05 (Duncan Test).

Fig. 3 shows the specific leaf disk area values (AED). The AED was significantly lower in plants treated with sludge, compared to manure (E) treatment. This means that the leaves of plants treated with sludge were thicker than those where manure was applied.

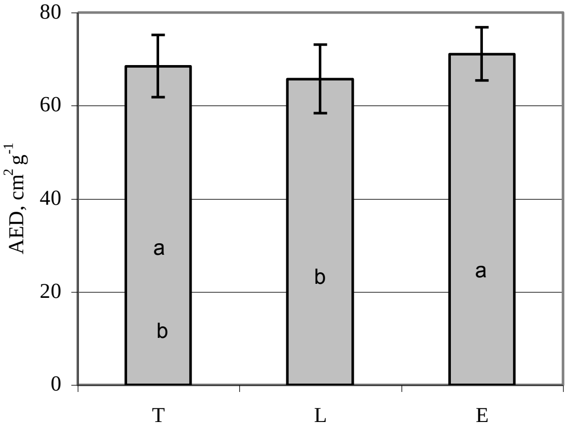

Fig. 3 – Specific leaf disk area (AED, cm^2 g^{-1}) values for the different treatments: T- control, L – sewage sludge, E – manure. Columns with the same letter were not significantly different at P<0.05 (Duncan Test).

4. Conclusions

This work shows that the sewage sludge is a good soil organic amendment. The use in soils with poor organic matter contents is of maximal importance, once it will increase the level of the soil fertility. The response of citrus young plants to these soil amendments was positive, concerning the responses of the perimeter of the tree trunk, leave area and thickness. These organic wastes application represents a profitable alternative to the use of mineral fertilisers, especially the sewage sludge, since it is available in larger amounts. Moreover, as the possible destinations of sewage sludge is the deposition in land fields. Its agricultural reuse is essential to avoid environmental problems, when agronomical correctly applied.

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