Effects of manure and sludge application on a citrus orchard

MANUEL COSTA
Rua Padre António Vieira, 24
8100-611, Loulé
PORTUGAL
mscosta2000@hotmail.com

JOSÉ BELTRÃO, JOÃO CARRASCO DE BRITO, CARLOS GUERRERO, LÍDIA DIONÍSIO
Faculty of Engineering of Natural Resources (FERN)
University of Algarve
Campus de Gambelas, 8005-139 Faro
PORTUGAL
jbeltrao@ualg.pt, jbrito@ualg.pt, cguerre@ualg.pt, ldionis@ualg.pt

Abstract: The urban sludge is a solid residue originated from wastewater treatment – its application as an organic fertilizer may decrease the pollution effects in nature, when compared to mineral fertilizers and other soil amendments. An orchard of orange-trees (*Citrus sinensis* [L.] Osbeck) was used to compare the effects of sludge and manure application. The chemical responses of the soil-plant-atmosphere system were observed. Hence, analysis of soil were performed in order to study the variation of soil salinity (ECs) and other parameters such as pH, organic matter OM, N, P_2O_5, K_2O, Fe, Mn, Zn, Ca, Mg and Na. Trace elements (Cd, Ni, Pb and Cr) were also analyzed in the soil. In the citrus leaves, when sludge and manure were applied, N and Cl^- parameters showed no significant variation, but an increase of Pb in the first year of the experiments was noticed. In the soil no significant chemical differences was observed, in relation to the different treatments, except the increase in salinity levels, when sludge and manure were applied. This effect was observed after the first experimental year, but not after the second year. Therefore no relevant disadvantages was found, at the end of the experiments, related to nutrients, salinity and trace elements, in the soil and in the citrus leaves, due to the application of urban sludge and manure. On the contrary, these residues represent a profitable alternative for the use of mineral fertilizers and other soil amendments. An overall and flexible legislation is an essential tool in order to integrate resources, users and environment.

Key-Words: citrus leaves, nutrients, organic fertilizers, salinity, soil, soil amendments, trace elements.

1 Introduction

In the last years, especially in the last decade, improving efficiency of fertilizers use has been a trend in most agricultural studies related to soil organic fertilizer / amendment management [1, 2, 3]. Total World consumption of N, P_2O_5 and K_2O fertilizers, in 1998, was 82, 32 and 22 million tons, respectively [4]. With the world population's growth, the demand of fertilizers was expected to rise, by the same amount, in the same period; however, since 1990/91, the total World consumption of N, P_2O_5 and K_2O fertilizers, which was 78, 37 and 26 million tons per year [5], respectively, remained relatively constant. The population increase and the industrial development produced an enormous amount of organic residues which nowadays generate great environmental problems. Inorganic fertilizers production consumes energy and its resources are limited. Innovation in agrotechniques using controlled release fertilizers in crop production is one of the solutions related to the impacts on soil and water quality [6, 7]. However, this type of fertilizers is expensive and their use is less than 1% of total World fertilizers consumption [8]. Another potential alternative for fertilizers consists in a better use of the organic residues, resulting from human activities, such as sewage sludge, a product from water plant treatment systems and manure from animal production. Manure [9, 10] and sludge [11, 12] are being applied in several crops in Mediterranean areas, and other organic fertilizers are being applied in some orchards [13, 14, 15]. In the Algarve, the application of sludge, in a citrus orchard, resulted in an increase of plant growth by 38%. The appropriate agricultural use of soil amendments / 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 [16]. The correct use in crop production must be investigated, not only at nutrients and salinity levels but also concerning trace elements, when present [17, 18]. By using sewage sludge, as soil substrate, less hazardous pollution was demonstrated when compared with the application of inorganic fertilizers [19].

2 Materials and methods

2.1 Experimental procedure

An experimental plot was established in an orange (*Citrus sinensis*, L.) orchard, in the Algarve, in the south of Portugal. The 20 ha plantation took place in May where twelve trees were chosen to conduct the experiments. The experimental procedure was a randomized block design with 12 young orange trees – 3 treatments; 4 trees per treatment – Sludge (S), Manure (M) and Control (C) each comprised of 4 replications. Experiments began immediately after plantation took place (6 x 2 m). 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 / fertilizers were tested, as follows: sludge (S), and manure (M), which were compared with the control (C).

2.2 Climate

The climate of the Algarve can be considered as Mediterranean and in particular the south shore. After Köppen, it is classified as Csa, with semi-arid characteristics, identified by mild rainy winters and by warm and dry summers. Snow and frost are not expected. The annual average temperature, in Faro, ranges between 12º C in January and 23º C in August, a difference of only 11º C [20]. The annual value for potential evapotranspiration ETp (Penman Monteith) was 1280 mm, and the precipitation was around 500 mm. Additionally, the values of potential evapotranspiration ETp and precipitation show opposite distribution during the year. During the hottest semester, when the photosynthesis is more efficient and the water is more essential for plant growth, this resource is less available; irrigation is the only solution to balance this situation. The average of the shortage of water, defined by the difference between the values of evapotranspiration and precipitation rates, verified between March and October, may reach 940 mm per year.

2.3 Soil

Soil physic /chemical characteristics – texture, pH (H_2O), organic matter (OM, %), soil solution electric conductivity (CE, dSm^{-1}), N (%), P_2O_5 (mg kg^{-1}), K_2O (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}), total calcareous (%), active calcareous (%), C (%), ratio C/N, exchangeable cations – Ca (cmol[+]kg^{-1}), Mg (cmol[+]kg^{-1}), Na (cmol[+]kg^{-1}) and K (cmol[+]kg^{-1}), sum of exchange bases (SBT), exchange H, cation exchange capacity (CTC, cmol[+]kg^{-1}), saturation rate (GSB, %) and trace elements – Cd, Ni, Pb and Cr (mg kg^{-1} of soil) are presented in Table 1.

The ground of the experimental site was classified as Fluvisoil [21], defined by an alluvial soil, up to 1 m depth, characterized by a "Terric" superficial layer (FLtr), originated from calcareous materials, according to its high Ca concentration (1550 mg kg^{-1}). The chemical reaction is slightly alkaline – pH 8, and the soil salinity (ECs), at the saturation point is moderate – 0.9 dSm^{-1}. Soil texture is heavy – silt loam and silt clay loam. Soil structure is moderate. Soil color was uniform and was classified according to the color values of the "Standard Soil Color Charts" [22]; color values were: dry soil - 2,5 Y 5/3 and wet soil –2,5 Y 4/3.

Under the first soil layer, a pedological change can be observed, consisting in a marine formation "Thionic" (FAO-ISSS-ISRIC, 1998). This acidic (pH 3-4) second layer, of clayish texture, is very impermeable and characterised by a very low hydraulic conductivity.

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
ECs (dSm^{-1})	0.9
N (%)	0.1
P_2O_5 (mg kg^{-1})	29.1
K_2O (mg kg^{-1})	617
Fe (mg kg^{-1})	250
Mn (mg kg^{-1})	128
Zn (mg kg^{-1})	4.0
Total calcareous (%)	21.1
Active calcareous (%)	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
SBT (cmol[+]kg^{-1})	14.3
Exchange H (cmol[+]kg^{-1})	0.0
CEC (cmol[+]kg^{-1})	14.7
GSB (%)	100
Cd (mg kg^{-1})	0.231
Ni (mg kg^{-1})	6.537
Pb (mg kg^{-1})	14.551
Cr (mg kg^{-1})	4.418

2.2 Amendment / fertilizers

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 / fertilizers were applied to the soil, during the plantation of the trees, at a depth between 0.5 and 1.0 m.

Physical parameters, nutrients and trace elements of the soil amendments / fertilizers are shown in Table 2.

The concentration of trace elements – Cd, Ni, Pb and Cr (mg kg^{-1} of dry matter), were also determined in the sludge and in the manure – Table 2.

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

Parameters	Sludge (S)	Manure (M)
pH (H_2O)	6.58	7.35
OM (%)	55.70	72.36
EC (dSm^{-1})	14.50	21.12
Water content (%)	12.28	7.45
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	17.57	30.40
Cd (mg kg^{-1})	0.855	0.049
Ni (mg kg^{-1})	13.807	2.477
Pb (mg kg^{-1})	40.458	2.096
Cr (mg kg^{-1})	17.208	2.56

The amounts of sludge (9.5 kg) and of manure (12.6 kg), applied per tree (g) and respective nutrients – N, P_2O_5, K_2O and Mg are presented in Table 3.

In Table 4, the concentrations of trace elements are compared among sludge, manure, soil and the limit values of these parameters present in sludge destinated to agriculture activities – Portuguese legislation (Anexo II da Portaria n. 176/96, 2.ª série, do Ministério da Agricultura, do Desenvolvimento Rural e das Pescas e do Ambiente, 1996).

The Portuguese legislation (Portaria n.°176/96, 1996) indicates the unitary limit amounts (kg) of trace elements, which can be applied to agricultural soils (10 years average). Table 5 compares those limit values with the amounts of trace elements applied to the soil, through the experimental sludge (7.9 tons per ha) and manure (10.5 tons per ha).

Table 3 – Sludge (S) and Manure (M) and respective nutrients – N, P_2O_5, K_2O, Mg applied per tree (g).

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

Table 4 – Limit values of trace elements (mg kg^{-1} of dry matter) in the sludge destined to agriculture activities, in the sludge, in the manure and in the soil used in these experiments.

Parameter	Limit values	Sludge	Manure	Soil
Cd	20	0.855	0.049	0.231
Ni	300	13.807	2.477	6.537
Pb	750	40.458	2.096	14.551
Cr	1000	17.208	2.56	4.418

Table 5 – Limit values (mg kg^{-1}) for the annual quantities of trace elements which can be applied in agricultural soils and respective amounts applied through the experimental sludge and manure amounts.

Parameter	Limit value	Sludge(S)	Manure(M)
Cd	0.15	0.00674	0.00051
Ni	3	0.1089	0.02602
Pb	15	0.31909	0.02202
Cr	4.5	0.13572	0.02689

2.4 Chemical analysis

In order to study the soil physical and chemical data, 4 samples were collected before and one and two years later at each experimental point, at 0.50 m depth and around 0.3 m from the trunk of the trees.

The soil texture, macronutrients and some micronutrients concentrations, pH, soil solution electrical conductivity (EC) and the organic matter (OM) content were determined as described by [23] and [24]. Organic matter (OM) was determined by the modified Tinsley method [25]. Trace elements (Cd, Ni, Pb and Cr) were analysed, according to [26]. Their concentrations were evaluated through atomic absorption spectrophotometry.

Samples of orange tree leaves, manure and sludge were incinerated at 550ºC. The ashes were treated with HCl – 1M, and after filtration, P, K, Na, Ca and Mg levels were determined as described by [26]. Chloride content of the orange trees leaves, were evaluated through the Mohr [27] and Rump and Krist methods [28].

Within sludge, manure and leaves, the trace elements were analysed by direct measurement, through atomic abortion spectrophotometry [26]. The "Atomic Absorption / Flame Emission Shimadzu AA-680" model was used.

2.5 Statistical analysis

The statistical program SPSS 11.0 [29] was used for the analysis of the obtained data, at the start of the experiments, and one and two years after the experiments took place. Multifactor and one-way (ANOVA) were used to analyze values and averages were compared by Duncan Multiple Range Test (DMRT).

3 Results

3.1 Effects of manure and sludge on the soil

The analyses of soil chemical parameters were performed after the 1st and after the 2nd experimental years. The variations of these concentrations were computed and Tables 6 and 7 shows the averages and the standard deviations of the data collected, among the three treatments – sludge (L), manure (M) and control (C).

The ANOVA statistical analysis was used to study the variation averages of the values of soil chemical parameters and of nutrients in the 1st year. The number of samples was 4 in each treatment and parameter. No significant differences were observed among the analytical average values of the physic-chemical parameters of the soil, except for soil electrical conductivity (ECs).

Table 6 – Averages and standard deviations of the variations of soil chemical parameters, after the 1st year of the experiments.

Parameters	Control(C)	Sludge(S)	Manure(M)
pH (H_2O)	0.23 ± 0.10	0.18 ± 0.10	0.15 ± 0.13
MO (%)	0.53 ± 0.28	0.40 ± 0.26	0.60 ± 0.26
ECs(dSm^{-1})	-0.08 ± 0.06	0.35 ± 0.06	0.28 ± 0.33
N (%)	0.06 ± 0.07	0.09 ± 0.02	0.08 ± 0.04
P_2O_5 (mg kg^{-1})	20.50 ± 15.42	24.75 ± 4.99	40.25 ± 22.63
K_2O (mg kg^{-1})	41.50 ± 73.33	30.00 ± 122.26	138.50 ± 31.89
Fe (mg kg^{-1})	4.25 ± 32.78	-7.75 ± 5.85	-18.75 ± 45.11
Mn (mg kg^{-1})	-12.25 ± 29.57	0.75 ± 5.56	19.75 ± 21.31
Zn (mg kg^{-1})	-0.30 ± 0.41	0.23 ± 0.48	0.05 ± 0.49
Ca (cmol[+]kg^{-1})	2.59 ± 2.81	4.46 ± 3.12	1.79 ± 3.24
Mg (cmol[+]kg^{-1})	-0.55 ± 1.53	0.73 ± 0.89	0.66 ± 0.38
K (cmol[+]kg^{-1})	0.93 ± 0.55	0.11 ± 0.21	0.40 ± 0.43
Na (cmol[+]kg^{-1})	-0.91 ± 1.48	0.21 ± 0.67	0.43 ± 0.38

The Duncan test was used to evaluate the variation values of ECs in the 1st year (Fig.1). The average values of ECs, in the soil, when sludge (S) and manure (M) were applied, were significantly higher in relation to the control (C).

The ANOVA statistical analysis was used to study the variation averages of the values of soil physic and nutrients parameters, in the 2st year. The number of samples was 4 in each treatment and parameter. No significant differences were observed among the analytical average values of all the parameters.

The increase of the salinity levels in the soil, in the 1st experimental year, can be explained by the higher EC valuesobserved in the sludge (ECs = 21,1 dSm^{-1}) and in the manure (ECs = 14,5 dSm^{-1}). The reason why this effect was not observed in the 2nd year must be attributed to the leaching effect, provoked by the winter rainy season.

Upon analyzing the level of nutrients in the soil and after comparison with the analytical results obtained prior to the addition of the nutrient rich sludge / manure, it was observed that nutrient concentrations were rather similar. This can be explained by radicular absorption. Actually a faster growth (38%) was observed among the trees where sludge or manure was applied.

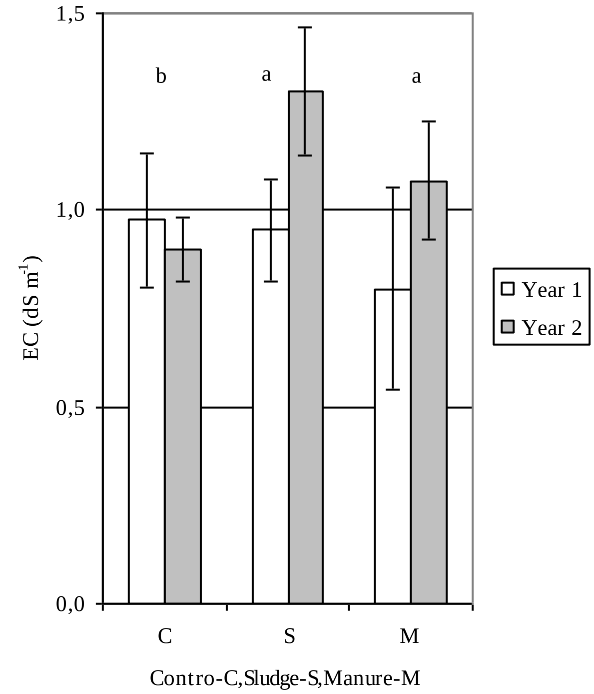

Fig. 1 – Averages and standard deviations of the variations of the soil electrical conductivity (ECs, dSm^{-1}) after the 1st experimental year.

Table 7 – Averages and standard deviations of the variations of soil chemical parameters after the 2ndt year of the experiments.

Parameter	Control(C)	Sludge(S)	Manure(M)
pH (H_2O)	-0.33 ± 0.10	-0.20 ± 0.24	-0.38 ± 0.19
OM (%)	0.15 ± 0.29	0.10 ± 0,08	0.38 ± 0.70
ECs (dSm^{-1})	-0.38 ± 0.17	-0.65 ± 0.39	-0.38 ± 0.34
N (%)	0.00 ± 0.06	-0.07 ± 0.08	0.01 ± 0.06
P_2O_5 (mg kg^{-1})	104.50 ± 107.80	91.50 ± 103.93	197.75 ± 298.73
K_2O (mg kg^{-1})	141.75 ± 172.11	289.25 ± 417.42	323.25 ± 138.51
Fe (mg kg^{-1})	-13.75 ± 54.64	-11.25 ± 16.76	1.75 ± 29.75
Mn (mg kg^{-1})	6.25 ± 17.23	-27.75 ± 40.29	-2.00 ± 45.59
Zn (mg kg^{-1})	1.50 ± 0.85	1.30 ± 0.93	3.58 ± 5.09
Ca (cmol[+]kg^{-1})	-0.01 ± 3.75	-1.71 ± 1.63	-3.60 ± 1.88
Mg (cmol[+]kg^{-1})	0.22 ± 1.09	-0.99 ± 0.32	-1.61 ± 1.10
K (cmol[+]kg^{-1})	0.46 ± 0.54	0.58 ± 0.67	0.41 ± 0.58
Na (cmol[+]kg^{-1})	0.02 ± 0.55	-0.16 ± 0.99	-0.45 ± 0.47

During the 2nd experimental year, the variations of the concentrations of trace elements in the soil – Pb, Cd, Cr and Ni (averages and standard deviations) were compared with control (C), when sludge (S) and manure (M) were applied to the soil. These values are shown in Table 8.

Table 8 – Averages and standard deviations of the annual variations (mg kg^{-1}) of soil trace elements parameters (Pb, Cd, Cr and Ni), among the three treatments – sludge (L), manure (M) and control (C).

Parameter	Control (C)	Sludge (S)	Manure(M)
Pb (mg kg^{-1})	11.54 ± 2.94	7.08 ± 2.27	8.22 ± 1.55
Cd (mg kg^{-1})	-0.17 ± 0.08	-0.12 ± 0.05	-0.27 ± 0.20
Cr (mg kg^{-1})	-2.13 ± 0.12	0.42 ± 4.53	-0.69 ± 0.30
Ni (mg kg^{-1})	2.78 ± 1.08	2.32 ± 3.01	-0.50 ± 0.93

The ANOVA statistical analysis was used to study the variation averages of the parameters values of soil chemical parameters. The number of samples was 4 in each treatment and parameter. No significant differences were observed among the analytical average values of trace elements of the soil.

These results can be explained by the very low concentrations, in the sludge and in the manure, of all the trace elements analysed. These values are considered very low and as such, are unable to cause harm or to put at risk either the public health or the local environment.

The insignificance of the heavy metals levels in the sludge and in the manure can be shown with the example of Cd, whose concentration in the sludge is closer to the legal limit values for agriculture application, according to the Portaria nº 176/96, 1996 [30]. If the legal limit value of sludge was to be applied (175.519 kg ha^{-1} per year), the concentration of Cd would still be 67 times inferior to the limit value … thus bellow any significant risk.

The amount of sludge applied to the soil, in these experiments (7900 kg ha^{-1}) represents also a small portion of the recommended limit by Paramasivam et al., 2003, for Australia, as soil amendment (100,000 kg ha^{-1}) [31].

3.2 Effects of Manure and Sludge on the citrus leaves

The analysis of nitrogen (N) and chloride (Cl^-), in the citrus leaves were performed during the 2nd experimental year. The variations of these concentrations were computed and Table 9 shows the averages and the standard deviations of the variations of those nutrients, throughout the 3 treatments – sludge (L), manure (M) and control (C).

Table 9 – Averages and standard deviations of the annual variation (%), of the parameters nitrogen (N) and chloride (Cl^-), on orange trees leaves, among the three treatments – sludge (L), manure (M) and control (C).

Treatment	N (%)	Cl^- (%)
Control (C)	3.33 ± 0.06	1.12 ± 0.03
Sludge (S)	2.91 ± 0.24	1.21 ± 0.16
Manure (M)	2.95 ± 0.24	1.39 ± 0.35

The ANOVA statistical analysis was used to study the variation averages of the parameters values of N and of Cl^- concentrations in citrus leaves. The number of samples was 4 for each treatment. No significant differences were observed among the analytical values. The nitrogen N content in orange trees leaves was slightly higher on the control (C). On the other hand, chloride Cl^- content was slightly higher on the manure (M) treatment.

The annual variations of the concentrations of trace elements in the leaves (averages and standard deviations), was compared, when sludge and manure were applied to the soil. These values are shown in Table 10.

Table 10 – Average and standard deviations of the annual variations (mg kg^{-1}) of trace elements (Pb, Cd, Cr and Ni), in the leaves, among the three treatments – sludge (L), manure (M) and control (C).

Parameter	Control (C)	Sludge (S)	Manure (M)
Pb (mg kg^{-1})	0.48 ± 0.65	-5.01 ± 2.95	-15.44 ± 3.75
Cd (mg kg^{-1})	0.71 ± 0.53	-0.16 ± 0.06	-0.06 ± 0.50
Cr (mg kg^{-1})	-0.75 ± 0.71	0.35 ± 0.92	2.03 ± 4.49
Ni (mg kg^{-1})	6.03 ± 1.89	3.67 ± 1.86	5.36 ± 1.64

The ANOVA statistical analysis was used to study the annual variation averages of the parameters values of trace elements in the leaves. The number of samples was 4 in each treatment and parameter. No significant differences were observed among the analytical average parametric values, except among Pb values.

The Duncan test was used to evaluate the variation values of Pb (Fig.2). The decrease of Pb concentration, after the second year, was very significant when manure was used and less significant when sludge was applied to the soil.

Thus it can be concluded that the values of Pb, in the first year, were higher when sludge and especially manure were applied, but that effect was highly reduced throughout the second year of the experiments.

The Pb concentration in the manure (2.1 mg kg^{-1}) was inferior to the one observed in the sludge (40.5 mg kg^{-1}), and thus, we should expect a more significant response from the plants, in relation to the sludge. This contradictory result can be explained by the very low concentrations of toxic elements, in the sludge and in the manure.

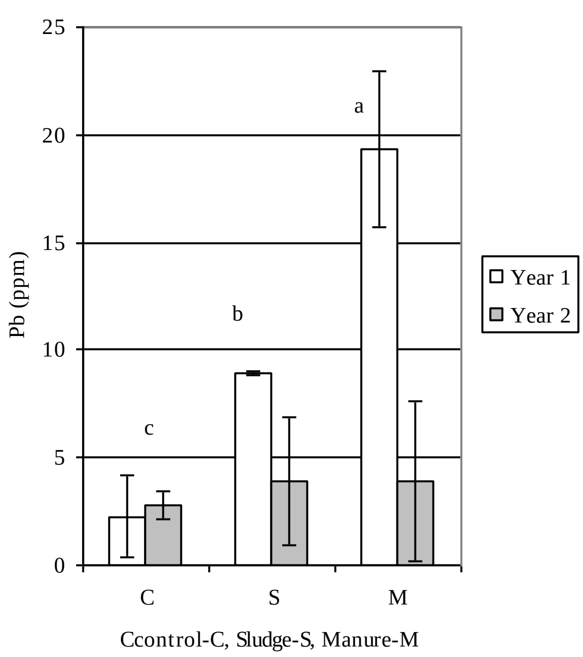

Fig. 2 – Averages and standard deviations of the annual variations of the concentrations of Pb, in the leaves, when sludge and manure were applied.

4 Conclusions

Sludge originated from regions without heavy industry, such as the Algarve, are characterized by very low concentrations of heavy metals, thus low harm could occur for the public health or for the environment due to trace elements originated from the sludge or manure application in the soil.

As expected, the application of sludge or of manure did not increase substantially the concentration of trace elements (Cd, Ni, Pb and Cr) in the soil as in the leaves of the citrus. Actually, the only exception occurred, during the first year, where an increase of Pb, in the leaves, when sludge and specially manure was applied to the soil was detected. This effect, however, was levelled in the second year of the experiments.

After the first experimental year, an increase of soil solution EC values was observed, when the organic fertilizers / soil amendments were applied. This effect was more noticeable in the sludge treatments, besides the relatively higher salinity observed in the manure. This response is probably related to the faster mineralization of sludge, due to its lower C/N ratio. Therefore, a larger release of nutrients, into the soil solution was verified, which provoked an increase in soil salinity. Nevertheless, this effect was not significant in the second year, and it may be concluded that the application of sludge did not increase significantly the levels of the different chemical elements in the soil, after the two years of experiments.

Hence, this investigation showed that the manure and the urban sludge are good soil organic amendments, and their use, especially in soil with low contents of organic matter, is of maximal importance.

At the end of the experiment, it was shown that the nitrogen N content on orange trees leaves was slightly higher on the control (C); probably due to the lower concentration of chloride in the soil. On the other hand, chloride Cl^- content of citrus leaves was slightly higher on the manure (M) and on the sludge (S) treatments, as a result of the salinity present in these amendments.

These conclusions were, in general, alike other investigation realized in Portugal and in other countries [33, 34, 35, 36, 37, 38, 39].

The effects on the plant-soil system by applying these soil amendments / fertilizers show no inconveniences for the soil and for the citrus. Its application represents, not only a potential increase in the crop production, but also a profitable alternative for the use of mineral fertilisers, especially the urban sludge (once this fertilizer / soil amendment is available on larger amounts). Moreover, the possible destinations of urban sludge (landfills and incineration) provoke environmental damage.

Therefore, its agricultural use is essential to avoid this problem.

An overall and flexible legislation is an essential tool in order to integrate resources, users and environment [32].

The Portuguese legislation (Decreto-Lei 446/91, 1991 [40]; Portaria 176/96, 1996 [30]; and Portaria 177/96, 1996 [41]) is dealing with the soil, agriculture and underground water protection in relation to trace elements. Table 4 presents values included in the Portaria 176/96, 1996 [30]. However to fallow the legislation is not enough and the good agriculture practices must be adopted by the user of sludge, in order to keep the sustainability of the soil and water and to protect the public health.

The European Community (Aquarec, 2006) [42] and The World Health Organisation directives [43] represent an important didactic document concerning wastewater and related residues. When the application is in agriculture, the safety of consumers, rural workers, respective families and neighbour communities must be taken in consideration.

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