EFFECTS OF CO-COMPOSTED SEWAGE SLUDGE AMENDMENT ON MEDITERRANEAN AGRICULTURAL SOILS. A SOIL MICROCOSM EXPERIMENT

Aranda V.[1*], Pérez-Lomas A.L.[2], Párraga J.[2], Delgado R.[2], Almendros G.[3], Delgado G.[2]
[1]Department of Geology, University of Jaén, Spain, [*]corresponding author: varanda@ujaen.es
[2]Department of Soil Science and Agricultural Chemistry, University of Granada, Spain
[3]Department of Soils, CCMA-CSIC, Spain

1 INTRODUCTION

Southern Spain includes large areas of cultivated soils with high summer temperatures, low rainfall and an inappropriate agricultural management; all these factors originate processes of degradation. On the other hand, the production of sewage sludge from waste water in Spain was 1.012.157 Mg (http://wastebase.eionet.eu.int/, 2009). The production of co-compost (i.e., sewage sludge transformed with woody plant waste from tree pruning as bulking structuring agent) involves the recycling of residues, leading to organic matter, which, compared to the original waste, behaves as a more stable (aerobic fermentation), more beneficial (matured organic matter) and value-added substrate. The amendment of soil with compost is an environmentally-friendly option for organic farming in soils, contributing to enhanced soil fertility and further crop development, thus producing both economic and environmental benefits (Brunetti et al., 2007).

In the present work, it is study the effect of co-compost from sewage sludge and plant pruning remains, on biological activity (dehydrogenase activity, DSH) and quantity of soil organic carbon (SOC). Also, a sequential fractionation for organic matter was performed, in order to measure the presence of dihydroperilenquinones (DHPQ), humic acids fraction formed under fungal activity (Almendros, 2000).

Topsoil samples (0-20 cm depth) were collected from four agricultural soils in Andalusia (Spain). Control soil samples (no co-compost addition) and soil samples treated with co-composts (equivalent to 140 Mg ha^{-1}), were incubated for 90 days at two temperatures: 5 and 35ºC. The need to control all soil-independent factors has led to the use of the soil microcosm, especially suitable for the provision of controlled experimental conditions in terms of time, temperature, compost amendments and moisture (Sonnleitner et al., 2003). Therefore, this experimental design involves the analysis of four factors: soil type, addition of co-compost, time and temperature of incubation. 2^3 factorial design was used in order to interpret the results.

2 MATERIALS AND METHODS

Soils S1 and S2, are typical for growing olive trees, located in Jaén (Spain) whereas the other two, S3 and S4, are used for tropical crops on the coast of Granada (Spain). Soil S1 is a relatively evolved soil [Hypocalcic Luvic Calcisol (Siltic, Chromic) (FAO, 2006)]. Soil S2 is a soil from eroded materials [Calcaric Regosols (Siltic) (FAO, 2006)], soil S3 is an alluvial soil [Epigleyic Fluvisol (Calcaric, Hypereutric) (FAO, 2006)] and soil S4 is a man-made soil built in terraces [although classified as Haplic Regosols (Calcaric, Hypereutric) (FAO, 2006)]. The soils were air-dried and screened (2 mm diameter). The co-compost used was manufactured by *Biomasa del Guadalquivir, S.A.* (Santa Fé, Granada, Spain). Sludge from treatment plants in Granada and Motril (Granada) was air-dried to reduce its moisture to less than 20%, mixed with chopped remains of plant pruning (mainly olive and pine) in 1:1 (v/v) and placed in stacks of about 3-4 meters high, turning regularly to prevent anaerobic processes. The co-compost with 10-11 months of maturation was air-dried and sieved (2 mm-holes).

The standard analyses were determined according to the Soil Conservation Service (1972). The dehydrogenase activity was measured employing a spectrophotometric determination of 2,3-triphenylformazan (TPF). The sequential fractionation procedure to extract humic acid from organic matter was described by Zancada et al. (2004) and Aranda and Oyonarte (2006). Purified HA (solutions of 66.6 mg L^{-1} in 0.02*M* NaOH) was analyzed in a Shimadzu UV-240 spectrophotometer in order to obtain the derivative spectra, where it was measured the intensity of peaks at 528, 570 and 617 nm, corresponding to DHPQ.

With a 2^3 factor analysis, eight soil samples were tested against three factors at two different levels: 0 days incubation (t-) or 90 days (t+), temperature: 5 ºC (T-) or 35 ºC (T+), and doses of co-compost: 0 Mg ha^{-1} (c-) or 140 Mg ha^{-1} (c+). The effects and interactions between factors were considered to be significant when various criteria, described by Box et al. (1978) and Almendros (1989), coincided. 2^3 factorial analysis was performed using Statgraphics Plus version 2.1.

3 RESULTS AND DISCUSSION

The differences between the sampled soils, including genetic characters, are reflected in the analytical data of the arable layer (Table 1). The soils showed some common characters, such as the relatively low content of soil organic matter, the exchange complex dominated by Ca^{2+} (data not shown) and the slightly basic pH.

TABLE 1 **Analytical dates of soils and co-compost**

Characteristics		Units	Soil 1	Soil 2	Soil 3	Soil 4	Co-compost
Texture	Sand	(%)	31.0	15.0	27.4	19.2	19.2
	Silt	(%)	28.5	39.2	56.9	48.2	48.2
	Clay	(%)	40.5	45.8	15.7	32.6	32.6
Organic matter		(%)	2,58	1.19	1.98	3.08	35.3
Nitrogen		(%)	0.30	0.11	0.13	0.21	2.2
C/N			5,00	6.29	8.86	8.53	9.33
Available P		(mg kg^{-1})	13.2	3.0	21.2	81.4	3074.2
pH			8.6	8.0	8.3	8.0	7.7
E.C. 25ºC		S m^{-1}	0.5	0.5	4.0	4.0	9.0
Exchangeable bases		cmol $^{(+)}$ kg^{-1}	47.47	59.71	46.25	37.56	50.27
CEC		cmol $^{(+)}$ kg^{-1}	31.52	28.91	27.68	27.21	46.35

The co-compost (Table 1) showed a percentage of organic matter (35.3) slightly higher than that required for commercial compost (Moreno-Casco and Moral-Herrero, 2008). The values of N (2.2%), pH (7.7), C/N (9.3), available phosphorus (3074 mg kg^{-1}) and exchangeable bases were similar to Fernández et al. (2007) and Moreno-Casco and Moral-Herrero (2008).

3.1 Evolution of Dehydrogenase activity (DSH) and Soil Organic Carbon (SOC)

Figure 1 shows DSH and SOC evolution during the incubation of soil microcosm in different conditions of soil types, time, temperature and amendment (of co-compost).

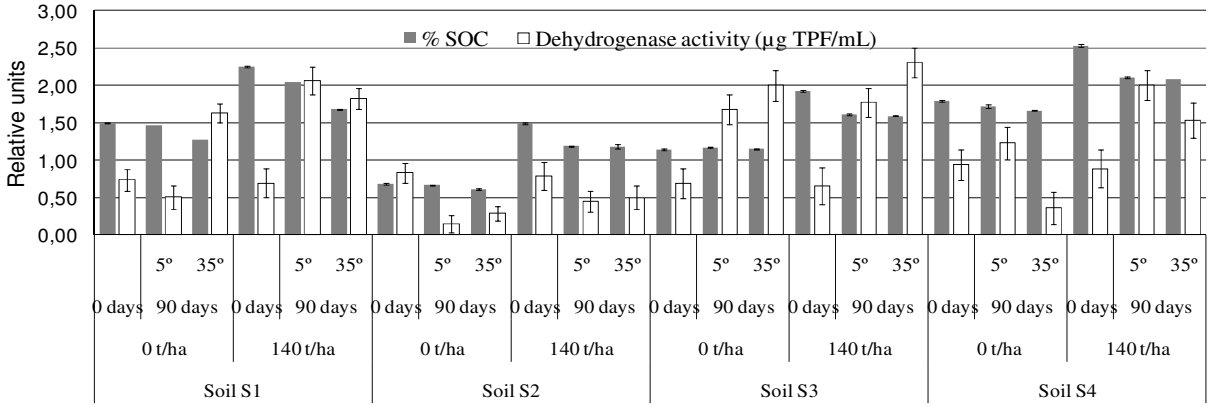

FIGURE 1 **Percentage of SOC and DSH in the different soil microcosm**

The 2^3 factorial analysis let us quantify the factors: incubation (t), temperature (T) and co-compost amendment (c), and the combinations of these factors ("t×T", "t×c", "T×c") on DSH and SOC evolution, in each soil (Table 2).

In general, the incubation in the microcosm is associated to SOC mineralization, since it causes a significant decrease of SOC (factor t, table 2). In our experiments, the mineralization is higher in the soil with

comparatively larger amounts of SOC (S1 and S4) and in the amended soils (factor t×c, Table 2), what is agreed with Busby et al. (2007). The higher temperature (35 ºC), as report Franzluebbers et al. (2001), increases the SOC mineralization (factors T and t×T, Table 2).

Incubating soil materials in microcosm, regardless of the addition of co-compost and temperature factor, enhances biological activity, as evidenced by the increasing of DSH in all samples studied (factor t, Table 2; figure 2A and B). Furthermore, the activity of soil microorganisms is increased, generally, by the addition of co-compost (S1, not significant) (factor c and t × c, Table 2; figure 2A) and by the higher temperature (35ºC), except S4 and amended S1 (factors T and t × T, Table 2; figure 2B).

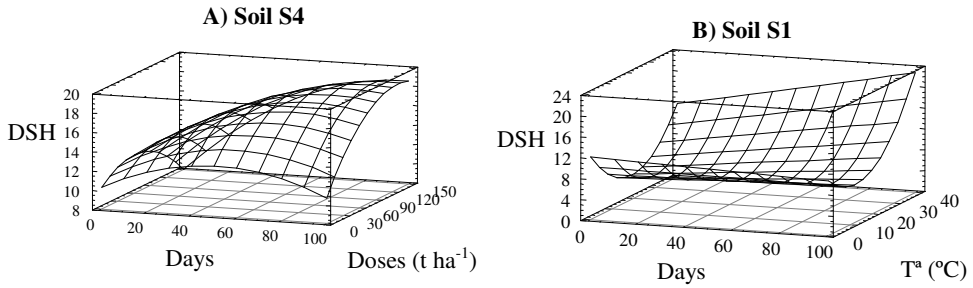

FIGURE 2 **Samples of DSH (µg de TPF/mL) evolution (2^3 factorial analysis)**

TABLE 2 **Main effects and interactions between factors influencing the evolution of soil organic matter**

		Main factors			Two-factor interactions				Statistical data	
		t	T	C	t × T	t × c	T × c	Average	r^2 (%)	*DW*
Soil S1	**SOC**	-0.26	-0.14	0.63	-0.14	-0.13	Ns	1.75	99.3	1.75
	DSH	3.31	5.05	Ns	3.54	Ns	-3.87	6.33	55.9	1.70
Soil S2	**SOC**	-0.18	-0.01	0.67	-0.01	-0.13	Ns	1.00	99.9	2.50
	DSH	1.47	1.82	1.04	Ns	1.22	Ns	4.29	72.9	1.96
Soil S3	**SOC**	-0.15	-0.01	0.61	-0.01	-0.17	Ns	1.46	99.9	1.50
	DSH	12.78	2.59	Ns	Ns	4.85	Ns	2.49	82.1	1.83
Soil S4	**SOC**	-0.26	-0.02	0.57	-0.02	-0.17	Ns	2.03	99.9	1.25*
	DSH	5.66	-3.66	2.90	-3.59	4.31	Ns	16.99	81.4	2.63

t: time of incubation; T: temperature of incubation; c: co-compost application; DW: Durbin-Watson coefficient. Ns: not significant; *not significant, but it shows a trend.

3.2 Evolution of Dihydroperilenquinones (DHPQ)

In regard to figure 3, we can comment:

- Co-compost has similar levels of DHPQ to sampled soils; the presence of these compounds on co-compost has not been described previously, and it evidence than composting process (sewage sludge and pruning remains) is relatively similar to the natural soil evolution (White arrow in figure 3).
- Soils from Jaén (S1 and S2) show bigger concentration of DHPQ than coast soils (S3 and S4); the explanation more possible is than the first ones are more evolved (old terraces of Guadalquivir River).
- Incubation of amended S1and amended S2 to 35ºC originate a DHPQ reduction (black arrows in figure 3), while than the other soils (S3 and S4) scarcely modify their DHPQ levels. Maybe S3 and S4 have been previously irrigated with wastewater or amended with organic waste, leading to extensive hampering of soil biological processes. Another possibility, co-compost incorporates new microorganisms to S1 and S2, which originates a degradation of this type of humic acids, while S3 y S4 could be not affected by their previous contact.

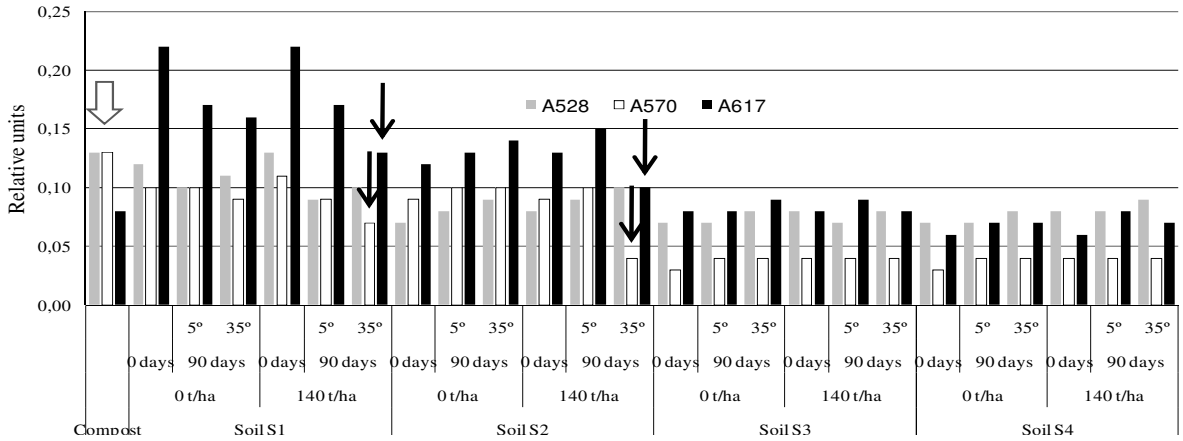

FIGURE 3 **Evolution of DHPQ (A_{528}, A_{570}, A_{617})**

3.3 Pearson correlation coefficient

Finally, it was studied the relationship between the properties: Dehydrogenase Activity, Soil Organic Carbon and Dihydroperilenquinones. Table 3 shows Pearson correlation coefficient; we observe that DSH has a elevate grade of correlation with SOC, the regression analysis shows a lineal equation (DSH = -1.40 + 9.70 x SOC) with a elevate grade of signification (0.01). We also notice than DSH is related negatively, although scarcely, with DHPQ, what indicates a possible degradation of these compounds by the microbial activity.

TABLE 3 **Pearson correlation coefficient between DSH against SOC and DHPQ**

	SOC (%)	A_{528}	A_{570}	A_{617}
DSH (µg TPF/mL)	0.579**	-0.180	-0.460*	-0.252

*The correlation is significant at level 0.05; the correlation is significant at level 0.01; n=24.

4 CONCLUSIONS

The effect on the soil of the addition of co-compost is influenced by various factors, mainly soil type (origin, evolution degree and initial organic carbon content) and temperature; both modify properties as DSH and SOC evolution. Similar conclusion was anticipated by Busby et al. (2007).

A major content of SOC in the native soils originates a bigger DSH, what carries an elevated SOC mineralization. Generally, the co-compost amendment also increases significantly the SOC mineralization, as a result of increased biological activity (stimulated by the own amendment).

The incubation time and the higher temperature generally stimulate the microbial activity (DSH), although there is a great dependency of the soil type. This situation let us choose between a rapid increase in nutrients through mineralization (promoting the DSH), or a stabilization and preservation of the SOC (improving soil properties and carbon sequestration), selecting the environmental temperature (season for amendment).

It is concluded that: a) It is necessary more investigation about the organic amendment in relation to soil types and environmental conditions, in order to select the best conditions in each case. b) Soil microcosm is a suitable method for studying the SOC evolution under controlled laboratory conditions, which is a first step towards predicting its evolution under field conditions.

ACKNOWLEDGEMENTS

This work has been supported by MICIN of Spain (Project CGL2008-04456/BTE)

REFERENCES

Almendros G 1989. An analysis of (…) soil and plant. The Science of the Total Environment 81/82, 569-578.

Almendros G 2000. Procesos de transformación (…) agrícolas e inalterados, in: Quintero-Lizaola, R. et al. (Eds.), La Edafología y sus Perspectivas al Siglo XXI. 1ª ed. Universidad Nacional Autónoma de México.

Aranda V, Oyonarte C 2006. Characteristics of organic matter (…) and different vegetation types from the Mediterranean high-mountains in SE Spain. European Journal of Soil Biology 42, 247-258.

Box EP, Hunter WG, Hunter JS 1978. Statistics for Experimenters.Wiley. New York. Chapter 9, 291-391.

Brunetti G, Plaza C, Clapp CE, Senesi N 2007. Compositional and functional features of humic acids from organic amendments and amended soils in Minnesota, USA. Soil Biology & Biochemistry 39, 1355-1365.

Busby RR, Torberth HA, Gebhart DL 2007. Carbon and nitrogen mineralization of non-composted and composted municipal solid waste in sandy soils. Soil Biology & Biochemistry 39, 1277-1283.

Fernández JM, Hernández D, Plaza C, Polo A 2007. Organic matter in degraded agricultural soil amended with composted and thermally-dried sewage sludge. The Science of the Total Environment 378, 75-80.

Franzluebbers AJ, Haney RL, Honeycutt CW, Arshad MA, Schomberg HH, Hons FM 2001. Climatic influences on active fractions of soil organic matter. Soil Biology & Biochemistry 33, 1103-1111.

Moreno-Casco J, Moral-Herrero R 2008. Compostaje. Ediciones Mundi-Prensa. Madrid.

Sonnleitner R, Lorbeer E, Schinner F 2003. Effects of straw, vegetable oil and whey on physical and microbiological properties of a Chernozem. Applied Soil Ecology 22, 195-204.

Zancada MC, Almendros G, Sanz J, Román R 2004. Speciation of lipid and humus-like (…) in a forest soil reclaimed with municipal solid waste compost. Waste Management & Research 22, 24-34.