Physical and Chemical Properties in Soils in Conversion to Organic Management

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ABSTRACT

Interest in organic soil management has grown appreciably in recent years. The transition from conventional to organic farming is accompanied by changes in soil physical and chemical properties and processes that could affect soil fertility. Nevertheless, the organic systems is very complex and very few studies has been studied this process. Understanding of physical and chemical processes involved in the transition process is important for ameliorating the management of the organic farming systems.

This work studies the effect of the transition conventional to organic farming on physical and chemical properties of a loam soil (Xerofluvent) located in the Guadalquivir River Valley, Sevilla, through a succession of six crops cycles over a three year period. Two mature composts (plant and animal compost) were used for the organic fertilization. Crop rotation and varieties were identical in the two systems.

At the end of the study, the organic farming management resulted in a higher soil organic carbon, N and P, K and Mg available. Electrical conductivity and pH are not significant differences between treatments. The use of organic farming resulted in higher available Fe, and Zn. The available Mn and fundamentally Cu do not show significant differences. The organic treatment also showed lower bulk density and higher available water content.

This study demonstrated that the use of organic compost results in an increase of soil organic matter, storage of nutrients, and produce positively effect in physical soil properties than with conventional management , which can provide long-term fertility benefits.

Keywords: organic farming; compost; nutrients

INTRODUCTION

The soil quality determines the sustainability and productivity of agroecosystems. The excessive use of mineral fertilizers in intensive agriculture has reduced the soil organic matter in most of the Mediterranean soils leading to an increase of erosion risk and fertility losses (Nachtergaele et al., 2002). One of the most important ways of soil regeneration involves the addition of organic materials to conserve organic matter and maintain or enhance soil fertility (Lampkin, 1998).

Organic farming is an alternative to conventional farming and has been adopted in a wide range of climate and soil types (Altieri, 1995). The transition from conventional to organic farming is accompanied by changes in an array of soil chemical properties and processes that affect soil fertility (Clark et al., 1998). These changes affect nutrient availability to crops either directly by contributing to nutrient pools, or indirectly by influencing the chemical and physical environment of the soil (Bulluck et al., 2002). Studies that compare organic and mineral fertilization in soils show higher SOC, total N and macronutrients content for organic-amended soils (Edmeades, 2003; Herencia et al., 2007). On the other hand, although studies showed the influence of organic amendment on availability of micronutrients (Kabata Pendias and Pendias, 2000) very little information exists in organic agriculture (Herencia et al., 2008).

It is well established that the addition of OM improves physical properties (Celik et al., 2004). The intensive cropping systems based on mineral fertilization and elimination of residues of crops frequently lead to a diminution of SOM which adversely affects the soil physical properties. (Haynes et al., 1991). Nevertheless, as well as chemical parameters, the effects of organic matter additions on physical properties of soils depend on climate, soil characteristics and rate and type of organic amendments.

In addition, many studies show the effect of additions of sewage sludge, urban waste compost, or manure in soil fertility, but very few agronomic studies are available with application of vegetal compost (Herencia et al,. 2007).

The aim of this work is to determine the influence of organic versus conventional farming on the physical, physicochemical and chemical properties of a calcareous soil during the three years of the transition period with two different organic amendment.

MATERIALS and METHODS

The field study was carried out on a loamy soil classified as a Xerofluvent (Soil Survey Staff 1999). The study site (latitude: 37º 8´ 33´´ N and longitude: 5º 16´ 4´´ W) was located in the Guadalquivir River Valley (SW Spain), at the CIFA "Las Torres-Tomejil" farm in Alcalá del Río (Seville).

A crop rotation was conducted in plots of 10m x 20m. The data reported in this study include the results from 2001 to 2003. The following crops were grown: potato (*Solanum tuberosum* var. spunta) (spring 2001), lettuce (*Lactuca sativa* var. oreja de mulo) (autumn 2001); carrot (*Daucus carota* var. nantesa) (spring 2002); spinach (*Spinacia oleracea* var. gigante de invierno) (autumn 2002); tomatoes (*Lycopersicon lycopersicum* var. plato de Egipto) (spring 2003); and vetch-oat (*Vicia sativa* L. - *Avena sativa* L) as a cover crop (autumn 2003).

Three treatments were tested: one conventional treatment (CN), and two organics treatments (VT) and (MT). Four replicates per treatment were established randomly.

The organic treatment VT was vegetal compost (pruning waste and crop residues) and MT was manure compost (stables and cow barns), both applied by superficial tillage each crop cycle (30 t ha^{-1}). The CN was managed with normal doses of chemical fertilizers and pesticides used for these crops (Maroto 1995). The organic system was managed organically (Regulation (EEC) No. 2092/91). The soil and compost characteristics are show in Table 1. The soil was mouldboard ploughed to a depth of 20-25 cm after each crop harvest. In general, all crops were irrigated by surface irrigation each crop cycle.

Table 1. Soil (0.0-0.15 m depth) characteristics at the beginning of the experiment (n=12), and elemental analysis of vegetal and manure composts (dry wt. basis) used during the study (n=18*)

		Soil**		Vegetal Compost		Manure Compost	
Parameter	Units	Means	±SD	Means	±SD	Means	±SD
Moisture	g kg^{-1}	-	-	245.8	24.3	295.6	96.9
pH (1: 2.5)		8.04	0.06	7.7	0.3	7.9	0.6
EC (1: 2.5)	dS m^{-1}	0.19	0.04	2.2	1.0	6.6	2.0
TOC	g kg^{-1}	7.56	0.40	168.0	35.8	175.4	54.9
TN	g kg^{-1}	0.88	0.07	9.0	2.4	11.9	4.9
P	g kg^{-1}	19.51	2.10	3.7	1.3	5.1	1.6
Mg	g kg^{-1}	0.29	0.03	5.2	1.9	6.4	0.9
K	g kg^{-1}	0.38	0.03	4.6	0.7	9.9	3.8
Fe	mg kg^{-1}	5.62	0.79	8184.8	371.6	8522.6	903.5
Cu	mg kg^{-1}	1.56	0.18	21.2	2.2	36.3	6.2
Mn	mg kg^{-1}	7.11	2.04	289.8	59.1	345.8	61.8
Zn	mg kg^{-1}	0.88	0.12	48.8	4.7	73.2	25.7

S.D.: Standard Deviations; EC: electrical conductivity; TOC: total organic carbon.
*Data are the mean of three samples by each crop (six crop cycles).
** Soil P is available content (mg kg^{-1}); soil K is available content in ammonium acetate and soil Fe. Cu. Mn and Zn are available content in DTPA.

Soil samples (0.0-0.15 m deep) were taken for analysis at the beginning of each new crop. Soil samples were air-dried, sieved to 2 mm, and stored in plastic containers before analysis. The compost characteristics and soil nutrients content (pH, EC, OC, Kheldahl N, P olsen, available K, Mg, Fe, Cu, Mn and Zn) were determined by the methods of MAPA (1994). For Bulk density (Bd), undisturbed soil cores from the upper horizon (0-15 cm) were collected from the subplots in rings of known volume (Henin et al., 1972). Soil water content were determined in undisturbed samples placed in a 5.5 cm ring on 33 kPa (FC, field capacity) and and 1500 kPa (PWP, wilting point) pressure plates, respectively (Klute, 1986). Available water content (AWC) was calculated as percentage by find the differences between moisture % at field capacity and wilting point.

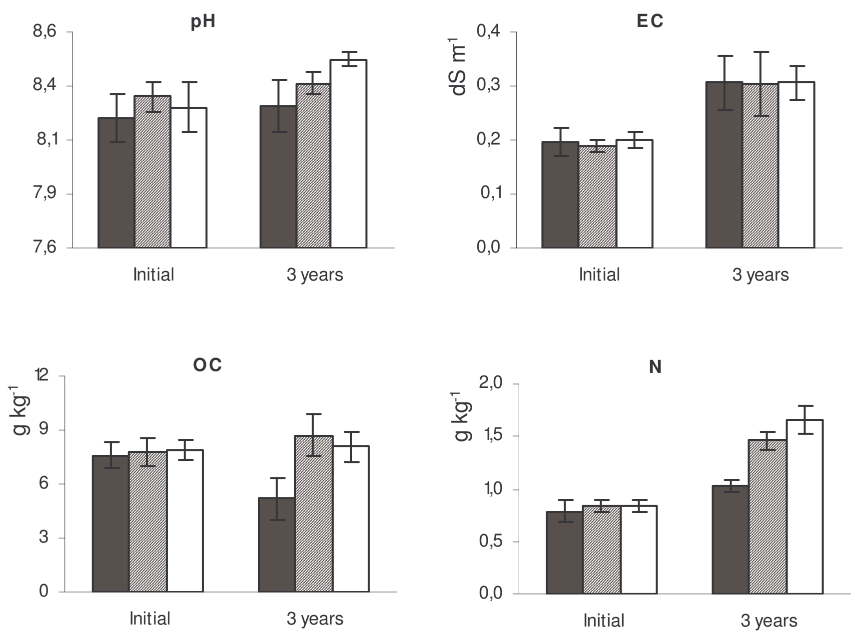
The results were analysed by ANOVA, considering the treatments as the independent variable. All statistical analyses were carried out with the program SPPS 11.0 for Windows. All values are expressed as mean values. Significant statistical differences of all variables between the different treatments were established by the Tukey`s test at $P<0.05$.

RESULTS and DISCUSSION

Soil pH and Electrical Conductivity (EC)

The pH values in organic amended soils were slightly higher than values in conventional fertilized soils (Fig. 1). The values showed an increase in all treatment in the last cycle although significant differences were only observed between MT and CN treatments. The slightly increase in pH in organically fertilized soils is due to basic cations in compost. Bulluck et al. (2002) showed an increase in pH in soils amended organically due to the complexation of Al and increases of basic cation in the soil solution. However, this pH increase is small due to the buffer character of the SOM and the high carbonate content of these soils.

No significant differences in electrical conductivity (EC) values were found between the organic and conventional treatments (Fig. 1). It is interesting to observe that, at the end of study, the EC values increased in all treatment and they were higher than from the beginning of the study, independently of the type of fertilization. Organic fertilization does not appear to cause soil salinization. The slightly increase is probably due to the fertilization rates. However neither inorganic nor organic fertilization appeared to cause soil salinization at the end of study.



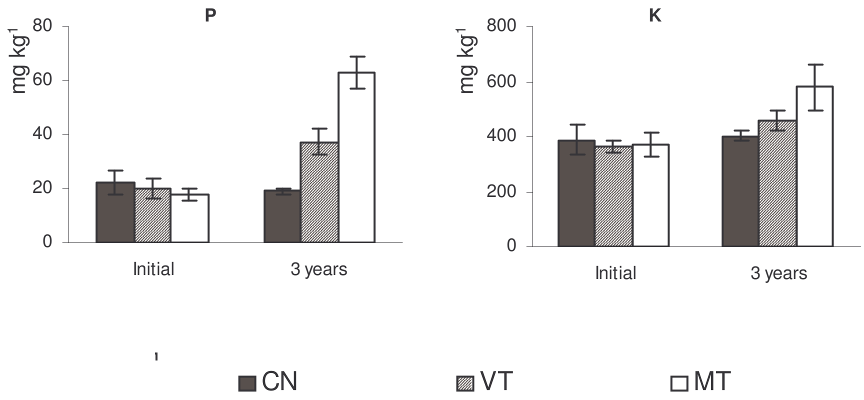


Fig 1. Values of pH. electrical conductivity (EC). organic carbon (OC). Kjeldahl nitrogen (N). available phosphorus (P) and potassium (K) to the beginning (Initial) and at the end of the experiment (3 years). Conventional management plots (CN); organic management plots fertilized with vegetal compost (VT) or manure compost (MT). Error bars indicate standard deviations of means.

Organic Carbon

At the three years, the Organic carbon content (OC) was found to be considerably greater in organic plots compared with those receiving mineral fertilizer (Fig. 1)

The addition of organic amendment in continuous cycles increases slightly the OC content in the soil. On the contrary, the mineral fertilization cycles (no addition of OM), showed a decrease of OC in the last cycle. The continuous addition of organic matter is important to maintain the content of SOM, which can be easily oxidized under the climatic conditions of our soils, located in the Mediterranean region.

This increase is particularly important in Andalusia, the region of our study, where the levels of organic matter in agricultural soils are normally <10 g kg^{-1} (Costa et al., 1991). Organic management systems have been shown to maintain SOM at higher levels than inorganic fertilization (Edmeades, 2003).

Soil Nitrogen

In all cases, comparing to the initial content in soil, significant increases in N content was observed in the last cycle and specially in the organically amended plots. Significant differences between CN and organic treatments were observed. The N content of organic plots is about twice the N content of the mineral fertilized plots.

Although inputs of N were very similar in organic and conventional treatment (CT=959 kg ha^{-1}; VT=1025 kg ha^{-1}; MT=1190 kg ha^{-1}), the addition of organic N favoured the increase of the N reserves in soils.

Available Soil phosphorus

The available phosphorus (P) in the organically fertilized plots was significantly higher compared with the mineral ones, on the order of 2 to 3 times in VT and MT respectively (Fig.1). At the end of the experiment, P values showed statistical differences between all treatments, according to the following order: MT > VT > CT.

The addition of OM to calcareous soils can increase available-P and decrease P-insolubilisation (Braschi et al., 2003). Tan (1998) indicated that P can be fixed in calcareous soils; however, the organic anions from organic amendments decrease the fixation of P. In calcareous soils it seems to be more advantageous to apply these organic amendment rather than mineral fertilizer to improve the availability of P to plants, due to the high retention of P in this soil type.

In addition, the higher availability of P in MT than in VT treatment could be explained by the higher amounts of P added through the manure compost (Table 1).

Available Soil Potassium and Magnesium

We are represented only available Potassium (K) because available Magnesium (Mg) showed very similar results. The K and Mg content in the organically fertilized plots was significantly higher compared with the conventional ones (Fig.1) the MC treatment showed the highest values. The higher availability of K and Mg in MC than in VC treatment could be explained by the higher amounts of Mg and, fundamentally K, added through the manure compost (Table 1)

It is interesting to denote that although the supply of K is very similar or lower with organic fertilization (CT=870 kg ha^{-1}; VT=525 kg ha^{-1}; MT=997 kg ha^{-1}), K availability is higher in the soil organically fertilized. The results obtained indicate that the increase of K comes both from the K released from organic amendment and increasing of K availability after addition of this organic amendment. Some authors have also shown an increase in K and Mg after organic amendment (Bulluck et al., 2002; Edmeades, 2003) They attributed the result to the high nutrients content of the compost and the increase of exchange sites due to organic matter added.

Available Micronutrients

The available Cu and Mn were similar among treatment (Table 2). The Mn in the organic plots, fundamentally in VT was slightly higher than in CT, but the differences were not significant. It is interesting to observe that in the last cycles the Cu and Mn values were lower than the beginning in all treatments.

The higher values of Fe and Zn in MT are in agreement with other authors that indicate that OM exerts a significant and direct effect on micronutrients availability (Wei et al., 2006) The Zn content in the organically fertilized plots was higher than in mineral plots for both organic treatments. The Fe were statistically higher in the MT treatment (Table 2).

The OM can interact with heavy metals in two contrasting ways, either increasing the solubility of the former or contributing to their immobilization (Madrid, 1999). The amendment of our soils with compost resulted in an increase of TOC and Cu that can form stable complexes with humic acids, which would give rise to metal immobilization.

The addition of OM with functional groups with the ability to form complexes promotes Zn availability in soils (Almas et al., 2000). In addition, the higher amount of Zn in MT could be due to the higher Zn concentration in the manure compost (Table 1).

The higher values of Fe obtained in MT are in agreement with the those of other authors, which indicate that OM is the main source of the plant available form (Kabata-Pendias and Pendias, 1992). The amount of Fe added with either compost (Table 1) was similar; nevertheless, the Fe was higher in MT (Table 2), indicating the importance of the composition of the compost.

Table 2. Mean values of soil available micronutrients (mg kg^{-1}) to the beginning (Initial) and at the end of the experiment (3 years)

	Fe		Cu		Mn		Zn	
Treatment	Initial	3 years	Initial	3 years	Initial	3 years	Initial	3 years
CN	5.25 a	4.27 b	1.53 a	1.02 b	7.25 a	4.69 b	0.88 a	0.88 a
VT	5.91 a	3.55 b	1.59 a	1.04 b	7.05 a	5.90 abc	0.89 a	1.33 b
MT	5.50 a	7.41 c	1.51 a	1.08 b	6.99 a	5.20 bc	0.86 a	2.22 c

CN=Conventional treatment; VT= vegetal compost treatment; MT=manure compost treatment. Values of different elements followed by the same letter do not differ significantly ($p < 0.05$).

Bulk Density (Bd) and Available Water Content (AWC)

The Bd values was found to be lower in organically fertilized plots compared to plots receiving mineral fertilizer but the differences are statically different only with MT (Table 3).

The values of AWC in the plots managed organically were higher (Table 3), than the corresponding values of the plots with conventional nutrition, but the differences were not significant except for VT; therefore, it is evident that the porosity of organically fertilized plots was significantly higher than in the plots fertilized with synthetic fertilizers, as evidenced by the differences in the Bd. An increase of the water retention at tensions of FC mainly is due to the augmentation of the number of small pores. At higher tensions, near PWP, almost all the pores are full of air and water retention is determined by the surface area and the water pellicle thickness on these surfaces (Khaleel et al., 1981). After OM addition, the number of pores and the area of specific surface enlarges, resulting in an increase of AWC.

Table 3. Bulk density (Bd). water content at field capacity (Fc). permanent wilting point (PWP). and available water content (AWC) after three years of different treatment

Treatment	Bd (g cm^{-3})	Fc (%)	PWP (%)	AWC
CN	1.49 a	27.9 a	12.2 b	15.6 a
VT	1.42 ab	29.6 b	12.4 b	17.3 b
MT	1.30 b	28.7 ab	12.4 b	16.3 ab

CN=Conventional treatment; VT=vegetal compost treatment; MT=manure compost treatment. Values of different parameters at the same column followed by the same letter do not differ significantly ($p < 0.05$).

The main conclusions from this work are that the organic management (Regulation [EEC] No 2092/91) characterized by the incorporation of organic matter through compost (animal, vegetal), crop rotation, weed control by mechanical tillage maintain soil organic matter at higher levels than inorganic fertilization.

The type and amount of organic amendment described in this research is suitable to maintain an adequate level of SOM, Kjeldahl N and available P, K and Mg in soil, even higher than that obtained by application of the mineral fertilizer. The use of organic farming resulted in higher available Zn but, available Fe were higher only with manure compost and the available Mn and fundamentally Cu do not show significant differences, indicating the importance of the composition of the compost. No clear differences were found in pH and electrical conductivity for both fertilization types. The results after three years of organic fertilization indicate that the use of organic amendment produced a decrease of bulk density and an increase of available water content.

Soils under organic fertilization showed an improvement in soil fertility. However, further studies must be carried out in the next years to confirm the positive long-term effect of organic fertilization in order to maintain or improve soil quality.

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