A short-term comparison of organic v. conventional agriculture in a silty loam soil using two organic amendments

J. F. HERENCIA1, J. C. RUIZ1, S. MELERO1, P. A. GARCIA GALAVÍ1 AND C. MAQUEDA2*

1Centro de Investigación y Formación Agraria ‘Las Torres-Tomejil’ (CIFA), P.C. 41200, Alcalá del Río (Sevilla), Spain
2Instituto de Recursos Naturales y Agrobiología (CSIC), Apdo 1052, P.C. 41080, Sevilla, Spain
(Revised MS received 20 June 2008; First published online 30 September 2008)

SUMMARY

The transition from conventional to organic farming is accompanied by changes in soil chemical properties and processes that could affect soil fertility. The organic system is very complex and the present work carries out a short-term comparison of the effects of organic and conventional agriculture on the chemical properties of a silty loam soil (Xerofluvent) located in the Guadalquivir River Valley, Seville, Spain, through a succession of five crop cycles over a 3-year period. Crop rotation and varieties were compared in a conventional system using inorganic fertilizer and two organic systems using either plant compost or manure. At the end of the study, organic farming management resulted in higher soil organic carbon (OC), N and available P, K, Fe and Zn. The available Mn and especially Cu values did not show significant differences. In general, treatment with manure resulted in more rapid increases in soil nutrient values than did plant compost, which had an effect on several crop cycles later. The present study demonstrated that the use of organic composts results in an increase in OC and the storage of nutrients, which can provide long-term fertility benefits. Nevertheless, at least 2–3 years of organic management are necessary, depending on compost characteristics, to observe significant differences. Average crop yields were 23% lower in organic crops. Nevertheless, only two crops showed statistically significant differences.

INTRODUCTION

Environmental, economic and social concerns have increased the need for an alternative to conventional agriculture (Pimentel et al. 2005). Although reduced cultivation is becoming more popular, conventional farming often involves repeated tillage and reliance on repeated applications of fertilizers and pesticides. These practices can damage the soil structure, leading to soil erosion, organic matter (OM) loss and reduced soil fertility (Bullock 1997; Hollinger et al. 1998). In addition to the effects of management, climatic conditions in the Mediterranean area also increase OM oxidation (Garcia et al. 2000). Strategies for preserving and increasing soil OM are needed to maintain soil fertility (De Costa & Sangakkara 2006).

Organic farming is an alternative to conventional farming and has been adopted in a wide range of climates and soil types (Altieri 1995). Organic production systems are increasing in the European Union, with an annual growth rate of 0·26 (MAPA 2006). The area of Spain dedicated to organic management increased from 4235 ha in 1991 to 733 182 ha in 2004 (MAPA 2006).

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 (Bullock et al. 2002). The increase in OM during the
transition period occurs slowly, generally after several years (Drinkwater et al. 1995; Werner 1997), and can have a sizeable effect on long-term productivity (Tiessen et al. 1994). The amount of OM accumulated in the soil and the nutrient content depends mainly on OM decomposition rate, the amendment type applied and farm management (Haynes & Naidu 1998; Stockdale et al. 2001).

Soil OM is an important source of nutrients for plant growth that needs to be maintained for agricultural sustainability (Whitehead et al. 2003). In recent years, the effect of organic amendments on soil properties has received renewed attention. Studies that compare organic and conventional farming practices in soils show higher OM and macronutrient content for organic farming (Clark et al. 1998; Edmeades 2003; Herencia et al. 2007). However, some studies indicate different trends (Gosling & Shepherd 2005). Although several studies have demonstrated the influence of organic amendment on the availability of micronutrients (Madrid 1999; Kabata-Pendias 2000; Rodriguez-Rubio et al. 2003), very little information exists on organic agriculture, especially with respect to the use of plant residue compost (Andrews et al. 2002; Herencia et al. 2008).

As indicated previously, the incidence of organic farming has increased. This fact, together with the limitations in the amendments that can be applied in organic farming and the limited availability of organic livestock farms, could create a short-term organic fertilizer shortage. In addition, manure can represent a substantial cost to organic producers (Archer et al. 2007). For these reasons, plant compost is considered in the present work to be a very promising organic amendment, because farmers could be self-sufficient and produce compost on their own farms. Many studies have shown the influence of different organic amendments on soil fertility, but there is very little information available about the application of compost from plant residues. Both qualitative and quantitative differences can be found in the flow and processing of nutrients from the use of manure and plant compost and the elimination of synthetic fertilizers and pesticides.

Some studies have found that organically managed systems are less productive than conventional systems (Mäder et al. 2002), while others have indicated that they can be as productive as conventional ones (Pimentel et al. 2005; Posner et al. 2008). During the transition from conventional systems to organic systems, crop yield frequently falls, followed by a recovery in production (Altieri 1995). Archer et al. (2007) indicated that organic systems could be profitable.

Comparisons of organic with conventional systems are complex and difficult (Watson et al. 2008). The literature consists of studies with differences in soil types, crops, edaphic and climatic conditions, type of amendments and the amounts applied, so it is very difficult to compare one study with another. The current study attempted to reduce the number of potential factors affecting nutritional values, by using the same cultivar, planting system, soil and climatic conditions. The aim of the present work was to determine the influence of organic v. conventional farming on nutrient availability and crop yields in a calcareous silty loam soil during the first years of organic treatment with two different organic amendments (plant and manure composts).

### MATERIALS AND METHODS

**Location and management of the systems**

The field study was carried out on a silty loam soil classified as a Xerofluvent (Soil Survey Staff 1999). The study site (latitude: 37°8′33″N and longitude: 5°16′4″W) was located in the Guadalquivir River Valley (SW Spain), at the Andalusia Research Centre of Agriculture (CIFA Las Torres-Tomejil) farm in Alcalá del Río (Seville). The textural and chemical characteristics of the soil are shown in Table 1.

Three treatments were tested: one inorganic treatment (C) and two organic treatments (PC) and (MC). Treatment PC utilized plant compost (pruning waste and crop residues) while MC utilized manure compost (from stables and cow barns). A completely randomized experimental design (four replicates per treatment) was conducted in 12 subplots each of 10 × 20 m.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Values ± s.d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>(g/kg)</td>
<td>440 ± 45</td>
</tr>
<tr>
<td>Silt</td>
<td>(g/kg)</td>
<td>296 ± 23</td>
</tr>
<tr>
<td>Clay</td>
<td>(g/kg)</td>
<td>264 ± 22</td>
</tr>
<tr>
<td>pH (1:2.5)</td>
<td></td>
<td>8.04 ± 0.06</td>
</tr>
<tr>
<td>EC (1:2.5)</td>
<td>(dS/m)</td>
<td>0.19 ± 0.04</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>(g/kg)</td>
<td>249 ± 21</td>
</tr>
<tr>
<td>TOC</td>
<td>(g/kg)</td>
<td>7.56 ± 0.4</td>
</tr>
<tr>
<td>Kjeldahl-N</td>
<td>(g/kg)</td>
<td>0.88 ± 0.07</td>
</tr>
<tr>
<td>Olsen-P</td>
<td>(mg/kg)</td>
<td>19.5 ± 2.1</td>
</tr>
<tr>
<td>AAE-K</td>
<td>(mg/kg)</td>
<td>382 ± 32</td>
</tr>
<tr>
<td>Fe</td>
<td>(mg/kg)</td>
<td>6.50 ± 0.8</td>
</tr>
<tr>
<td>Cu</td>
<td>(mg/kg)</td>
<td>1.60 ± 0.2</td>
</tr>
<tr>
<td>Mn</td>
<td>(mg/kg)</td>
<td>12.1 ± 2.0</td>
</tr>
<tr>
<td>Zn</td>
<td>(mg/kg)</td>
<td>0.88 ± 0.1</td>
</tr>
</tbody>
</table>

s.d. = standard deviation; EC = electrical conductivity; TOC = total organic carbon, AAE-K = Ammonium acetate extractable K.

Fe, Cu, Mn and Zn are DTPA-extracted.
The data reported in the present study include the results of five cropping periods from 2001 to 2003. The following crops were grown: potato (*Solanum tuberosum* (L.) cvr. Spunta; February–June 2001), lettuce (*Lactuca sativa* (L.) cvr. Oreja de Mulo; September–December 2001); carrot (*Daucus carota* (L.) cvr. Gigante de Invierno; October 2002–February 2003); spinach (*Spinacia oleracea* (L.) cvr. Gigante de Invierno; February–July 2002); spinach (*Spinacia oleracea* (L.) cvr. Plato de Egipto; May–August 2003).

Both organic treatments were applied by superficial tillage in each crop at (30 t/ha). The characteristics of the two composts are shown in Table 2. The inorganic treatment used normal doses of chemical fertilizers for these crops (Maroto Borrego 1995). The organic system was managed organically (European Economic Community 1991). Weed control in organic treatments was performed by mechanical tillage, whereas it was carried out by herbicides in the inorganic treatment. The plots were separated with a 3 m spontaneous grass strip, mechanically controlled, to minimize cross movement of fertilizers and pesticides. The fertilization and pesticides used in the study are shown in Table 3. The doses of nutrients (N, P and K) applied per hectare to the inorganic and organic plots are shown in Table 4. The soil was mouldboard ploughed to a depth of 200–250 mm after each crop harvest. In general, all crops were irrigated by surface irrigation: the water applied from the first to fifth crops was 320, 80, 240, 40, and 880 mm, respectively. Additionally, the crops received a total rainfall of 214, 296, 170, 458, and 2 mm, respectively.

### Table 2. Elemental analysis of plant and manure composts (dry weight basis) used for each crop during the study

<table>
<thead>
<tr>
<th></th>
<th>Potato</th>
<th>Lettuce</th>
<th>Carrot</th>
<th>Spinach</th>
<th>Tomato</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PC</strong></td>
<td><strong>MC</strong></td>
<td><strong>S.E.D.</strong></td>
<td><strong>PC</strong></td>
<td><strong>MC</strong></td>
<td><strong>S.E.D.</strong></td>
</tr>
<tr>
<td>Moisture (g/kg)</td>
<td>248</td>
<td>420</td>
<td>41-0</td>
<td>217</td>
<td>175</td>
</tr>
<tr>
<td>pH</td>
<td>7.8</td>
<td>7.6</td>
<td>0.12</td>
<td>7.3</td>
<td>7.9</td>
</tr>
<tr>
<td>EC (dS/m)</td>
<td>1.3</td>
<td>6.4</td>
<td>1.03</td>
<td>4.8</td>
<td>4.1</td>
</tr>
<tr>
<td>TOC (g/kg)</td>
<td>148</td>
<td>156</td>
<td>7.7</td>
<td>163</td>
<td>124</td>
</tr>
<tr>
<td>TN (g/kg)</td>
<td>9.6</td>
<td>18.7</td>
<td>1.89</td>
<td>11.2</td>
<td>7.6</td>
</tr>
<tr>
<td>C/N</td>
<td>15.4</td>
<td>8.3</td>
<td>1.58</td>
<td>14.6</td>
<td>16.4</td>
</tr>
<tr>
<td>P (g/kg)</td>
<td>3.2</td>
<td>4.3</td>
<td>0.21</td>
<td>4.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Na (g/kg)</td>
<td>1-1</td>
<td>2.8</td>
<td>0.30</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Ca (g/kg)</td>
<td>101</td>
<td>41</td>
<td>15.9</td>
<td>123</td>
<td>39</td>
</tr>
<tr>
<td>Mg (g/kg)</td>
<td>4.1</td>
<td>7.5</td>
<td>0.84</td>
<td>2.4</td>
<td>7.1</td>
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<tr>
<td>K (g/kg)</td>
<td>3.8</td>
<td>11.9</td>
<td>1.72</td>
<td>5.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Fe (g/kg)</td>
<td>8.4</td>
<td>9.9</td>
<td>0.43</td>
<td>8.3</td>
<td>9.1</td>
</tr>
<tr>
<td>Cu (mg/kg)</td>
<td>20.1</td>
<td>42.0</td>
<td>4.67</td>
<td>17.8</td>
<td>40.1</td>
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<tr>
<td>Mn (mg/kg)</td>
<td>305</td>
<td>304</td>
<td>5.6</td>
<td>221</td>
<td>335</td>
</tr>
<tr>
<td>Zn (mg/kg)</td>
<td>54.5</td>
<td>108.7</td>
<td>11.87</td>
<td>47.1</td>
<td>50.5</td>
</tr>
</tbody>
</table>

* PC = plant compost; MC = manure compost. † Data are the mean of three samples (by each crop d.f. = 5). EC = electrical conductivity; TOC = total organic carbon.

The fertilization and pesticides used in the study are shown in Table 3. The doses of nutrients (N, P and K) applied per hectare to the inorganic and organic plots are shown in Table 4. The soil was mouldboard ploughed to a depth of 200–250 mm after each crop harvest. In general, all crops were irrigated by surface irrigation: the water applied from the first to fifth crops was 320, 80, 240, 40, and 880 mm, respectively. Additionally, the crops received a total rainfall of 214, 296, 170, 458, and 2 mm, respectively.

### Sampling and soil analysis

At the beginning of each crop period, before fertilization, soil samples from the upper layer (0–150 mm deep) were taken for analysis. Four soil cores were randomly taken in each plot and bulked to make a composite sample. Soil samples were air-dried, sieved to 2 mm, and stored in plastic containers before analysis.

The organic residues were determined by the methods of MAPA (1994). Soil pH and electrical conductivity were determined using a 1:2 soil/water extract. Total N content was determined by Kjeldahl digestion and organic carbon (OC) by potassium dichromate oxidation using the Walkley & Black method, as modified by Jackson (1958). Available P was measured using the Olsen *et al.* (1954) method and available K was measured using extraction with ammonium acetate (MAPA 1994). Particle size distribution was measured by the Boyoucos densimeter (MAPA 1994) and total carbonate content by the manometric method (MAPA 1994). The extractable elements (Cu, Zn, Fe and Mn) were determined using 0-05 m diethylenetriaminepentaaacetic acid (DTPA)+0-01 M CaCl2+0-1 M triethanolamine, adjusted to pH 7.0 (Lindsay & Norvell 1978).
Concentration of the elements was performed using an inductive coupled plasma atomic emission spectrometer (ICP-OES).

**Statistical analysis**

The results were analysed by analysis of variance (ANOVA), with treatments as the independent variable. All statistical analyses were carried out with the program SPSS 11.0 for Windows. All values are expressed as mean values. The statistical significance of differences between the different treatments were established using Tukey’s test at a significance level of $P<0.05$. Results in the Figures and in Table 1 are expressed as means ± standard deviations.

**RESULTS**

Prior to starting the experiments, the soil homogeneity of the plots was studied, and the results (Table 1) showed a high uniformity among the soil from the different plots under study. The soil was a silty loam soil with high carbonate content and was classified as Xerofluvent.

### Organic carbon

The total OC supplied was 5% higher with PC than with MC (Table 4). From the second crop onwards, the soil samples from the organic treatments contained a higher proportion of OC than did the samples from conventional treatment, but the samples were not statistically different until the beginning of the fourth or fifth crop for MC and PC, respectively (Fig. 1).

### Nitrogen

The proportion of N applied with MC was about 15% higher than with PC and the N applied as
mineral fertilizer was about 20% lower than with the manure (Table 4). Soil nitrogen followed a similar pattern as OC. Soil nitrogen was significantly higher in samples from organic treatments than in samples from conventional treatment from the beginning of the fourth and fifth crop for MC and PC, respectively (Fig. 1).

**Phosphorus**

The supply of phosphorus in MC was 21% higher than in PC, mostly in the last two cycles (Table 4). The content of available phosphorus (P) in the organically managed plots were higher than in conventional plots (Fig. 1), but significant differences were not seen until the beginning and the end of the fifth crop cycle in MC and PC, respectively. At the end of the experiment, the values for amount of available P on organic plots was two to four times higher than on the conventional plots.

**Potassium**

Available potassium (K) in organically managed plots was generally higher for the MC plots than for the plots using inorganic fertilizer (Fig. 1), but in general the differences were not significant except for MC during autumn 2001, spring 2002 and autumn 2003. The variability affected all treatments in the same manner. It is remarkable that the supply of K was lower with the PC and higher with MC than with C (Table 4); however the availability of this element was equal or higher in the organically managed soil.

**Available micronutrients**

**Copper**

The Cu added by MC was higher than that added by PC (Table 5). The available Cu in the soil samples extracted by DTPA (Fig. 2), ranged from 1.0 to 2.3 mg/kg. The content of available Cu in the organic plots was slightly higher than in conventional plots, but the differences were significant only for the autumn 2002 crop (Fig. 2). It is interesting to observe that in the last crops the values were similar among treatments.

**Manganese**

The available Mn, extracted by DTPA, ranged from 3.5 to 12 mg/kg (Fig. 2). In general, there were no

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**Fig. 1. Values of (a) organic carbon (OC), (b) Kjeldhal Nitrogen (N), (c) available phosphorus (P) and (d) available potassium (K) with different management across different cultivation cycles ranging from spring (S) 2001 through autumn (A) 2003. Conventional management plots (-- - ); organic management plots fertilized with plant compost (---○---) or manure compost (-- ---). Error bars indicate standard deviations of means.**
statistically significant differences among treatments. The organic treatments showed higher values, mainly in the PC plot over the two last cycles.

**Iron**

The Fe added with both composts was similar (Table 5). The Fe extracted from soil samples ranged from 5.8 to 7.8, 3.6 to 6.8, and 3.3 to 5.7 mg/kg for MC, PC, and C, respectively, and was generally statistically higher in the MC treated plots (Fig. 2). The available Fe for PC was not significantly higher than that for C.

**Zinc**

The applications to MC had a higher Zn content than either PC or C (Table 5). The available Zn in the organically managed plots was higher, especially in MC, than in the plots with inorganic fertilizer (Fig. 2).
The percentage increase of soil N was much higher in the present experiment than previously shown in the literature, for the same reason as for OC (low OM of the original soil). The higher values for MC amendment are correlated with a higher content in N.

Similarly, at the end of the present experiment, soil nitrogen was higher in the organic than in the conventional plots. A strong relationship between the behaviour of N and OM was found for the organic amended soils, in agreement with other studies (Reganold et al. 1993; Drinkwater et al. 1995). Knudsen et al. (2006) indicated that in general, organic arable farms increased their soil N pool through management practices. Other authors have also reported a higher N content in soil amended with organic residues (Scheller & Raupp 2005; Warman 2005).

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### DISCUSSION

The soil was initially very uniform in physical and chemical characteristics (Table 1), implying that any crop or soil differences identified during the experiments were due to the treatment and not to soil heterogeneity.

The samples from organic treatments showed higher OC than did the samples from conventional treatment. Andrews et al. (2002) reported that the application of 11.2–22.5 t/ha per year of different composts increased OC by 16% in organic soil as compared with mineral-fertilized soil for the third year. However, after 15 years, Gosling & Shepherd (2005) did not observe differences in OM with different types of fertilization; this is not surprising because the composition of soil, climate condition and the doses and composition of organic amendments were quite different.

The increase in OC of the samples receiving organic treatments was higher than those reported in previous experiments, but the dose of organic amendment applied in the experiment was 30 t/ha and the original OC of the soil was very low (Table 1). Consequently, a small increase represents a high proportion as compared with the original soil. In addition, the continuous application of OM to the soils studied in the present work was very important because the oxidant conditions in the Mediterranean climate rapidly reduce soil OM content (Fernández 1998). It is very important to control the type and amount of OM added to the soil, and fundamentally, it is important to maintain an adequate level of soil OM because a rich and equilibrated soil can supply the nutrients necessary for crops. The higher soil OM content and microbial biomass in the organic plots (Melero et al. 2006) may provide important fertility benefits.

Table 6 shows the crop yields obtained in conventional and organic plots from 2001 to 2003. Across all the experiments, the crop yields were higher in the conventional system than in the two organic systems. However, the differences were significant only for two spinach and tomato yields (Table 6). The potato yield was significantly lower for the PC as compared with the C. The variability for carrot yield among the plots was large and so the differences between treatments were not significantly different. The average crop yield for the organically amended plots was about 23% lower than for the conventional one.

In agreement with the reference values of agronomic production in the Guadalquivir River Valley (CAP 2000–2004), the crop yields in conventional plots were acceptable, while the organic crops yields were lower than referenced values, except for lettuce and spinach.

### CROP YIELDS

Table 6 shows the crop yields obtained in conventional and organic plots from 2001 to 2003. Across all the experiments, the crop yields were higher in the conventional system than in the two organic systems. However, the differences were significant only for two spinach and tomato yields (Table 6). The potato yield was significantly lower for the PC as compared with the C. The variability for carrot yield among the plots was large and so the differences between treatments were not significantly different. The average crop yield for the organically amended plots was about 23% lower than for the conventional one.

<table>
<thead>
<tr>
<th>Crop (Cycle)</th>
<th>Treatment*</th>
<th>Yields (t/ha)</th>
<th>Reference Yields†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>C</td>
<td>21-69</td>
<td>22-28</td>
</tr>
<tr>
<td>(spring 2001)</td>
<td>PC</td>
<td>15-65</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>19-34</td>
<td></td>
</tr>
<tr>
<td>s.e.d. (D.F. = 11)</td>
<td>1-17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lettuce</td>
<td>C</td>
<td>17-61</td>
<td>36-39</td>
</tr>
<tr>
<td>(autumn 2001)</td>
<td>PC</td>
<td>14-56</td>
<td>(17-5)</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>15-37</td>
<td></td>
</tr>
<tr>
<td>s.e.d. (D.F. = 11)</td>
<td>0-85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>C</td>
<td>24-36</td>
<td>37-41</td>
</tr>
<tr>
<td>(spring 2002)</td>
<td>PC</td>
<td>24-54</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>17-80</td>
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</tr>
<tr>
<td>s.e.d. (D.F. = 11)</td>
<td>2-34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td>C</td>
<td>34-72</td>
<td>15-18</td>
</tr>
<tr>
<td>(autumn 2002)</td>
<td>PC</td>
<td>20-82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>24-41</td>
<td></td>
</tr>
<tr>
<td>s.e.d. (D.F. = 11)</td>
<td>2-62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>C</td>
<td>68-12</td>
<td>64-68</td>
</tr>
<tr>
<td>(spring 2003)</td>
<td>PC</td>
<td>46-97</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>43-66</td>
<td></td>
</tr>
<tr>
<td>s.e.d. (D.F. = 11)</td>
<td>3-60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* C = conventional; PC = plant compost; MC = manure compost.
† Reference values of agronomic yields in the Guadalquivir River Valley (CAP 2000–04).
‡ In 2001, yields were specially lower in the agronomics zone (17-5 t/ha).

The values in the last crop ranged from 0.8 in C to 1.3 and 2.2 mg/kg in PC and MC, respectively (Fig. 2), and the organic plots showed a continuous increase over the study. The differences in Zn content were statistically different starting with the fourth crop in MC and the last crop in PC.

**Crop yields**

Table 6 demonstrates the crop yields obtained in conventional and organic plots from 2001 to 2003. Across all the experiments, the crop yields were higher in the conventional system than in the two organic systems. However, the differences were significant only for two spinach and tomato yields (Table 6). The potato yield was significantly lower for the PC as compared with the C. The variability for carrot yield among the plots was large and so the differences between treatments were not significantly different. The average crop yield for the organically amended plots was about 23% lower than for the conventional one.

In agreement with the reference values of agronomic production in the Guadalquivir River Valley (CAP 2000–2004), the crop yields in conventional plots were acceptable, while the organic crops yields were lower than referenced values, except for lettuce and spinach.
It should be noted that the N applied with the organic amendment is not immediately available to the plant because it must first be mineralized. The mineralization rate is variable and depends on several factors such as soil properties, type of compost and environmental conditions (Sims 1995) and it is largely mediated by soil micro-organisms (Stockdale & Brookes 2006). Hadas & Portnoy (1994) indicated that mineralization rates of composted manure were only 11–29 mg/g in the first year, because part of the decomposed N is immobilized in OM (Van Delden et al. 2003).

The content of available phosphorous (P) in the organically managed plots was higher than in conventional plots for the later crops. Andrews et al. (2002) indicated that organic management increased the available P content by 14% in the third to fourth years. That increase was less than that found in the present study mainly due to a lower application of organic amendment. In a 3-year study, Gliessman et al. (1996) found significant differences after the second year with annual compost application of 18·5 and 37 t/ha/year.

Most of the P in soil exists in strongly adsorbed or insoluble inorganic forms (Sharpley 2000). In calcareous soils (as in the present study), the majority of P added with mineral fertilizers is mainly precipitated as calcium phosphate. There is considerable evidence in the literature to suggest that the application of organic material to soil may increase P solubility (Sanyal & De Datta 1991). There are various mechanisms to explain the increase of available P in the present study. Composts rich in P were supplied to the organic plots, in order to have an appropriate N source for crops. Consequently, the great availability P in the organic plots, (primarily in MC) was due in part to the use of organic amendments. In addition, manure increases the availability of P in calcareous soils because of the increase in the organic forms (Meek et al. 1982). The decomposition of organic amendment resulted in concentrations of organic acids that effectively reduced P adsorption to the soil and increased P availability (Laboski & Lamb 2003). Nevertheless, the application of mineral fertilizer to calcareous soil results in a high retention of P; consequently, the addition of OM is recommended for improved availability of P.

The P uptake by crops from the different treatments (data not shown) is very similar and hence nutrient availability in the later crops is not affected by the crop yields.

The results indicate that improvements in available K come either from K released from organic inputs (mainly observed in MC) or from increased availability of native K following the addition of organic fertilizer (observed in PC) (Table 4). Either way, the higher content of available K is related to the OM content. Most of the simple cationic forms of nutrients present in the soil at any time are in exchangeable forms associated with clay minerals and the organic fraction of the soil; these can be rapidly exchanged with the cations in the soil solution. In temperate soils, the organic fraction of soils normally is responsible for 0·30–0·65 of the total cation exchange capacity (Stockdale et al. 2002).

The OM exchange sites do not fix K as do illite-type clay minerals which are dominant in the soil of the present study (data not shown); similar conclusions have been reported by Reganold (1988). Andrews et al. (2002) found higher K in organic systems. They attributed this result to high K content of the compost and the increased exchange sites due to OM.

The K uptake by the crops from the two organic treatments (data not shown) is similar; however, the K uptake from conventional plots was higher from the fourth crop cycle and hence could have affected nutrient availability in these plots.

The slightly higher levels of Cu and Mn extracted in the organically managed plots could be due to the formation of Cu and Mn organic complexes with the organic amendments. According to Kabata-Pendias (2000), in high pH soils (e.g. in calcareous soils as in the present study) complexation promotes maintenance of Cu and Mn in dissolved forms, increasing the availability in soil. However, this increase is slight because Cu can also form stable complexes with humic acids and peat and the metal becomes immobilized. Rodriguez-Rubio et al. (2003) concluded that carbonate was the main component responsible for Cu retention in calcareous soil and availability was enhanced by application of organic wastes. The results in the present study suggest that by yielding soluble complexes, the supply of organic composts could give rise to a more available element after the first crops, but in the last crops the OM primarily promotes the most stable complexes. In soils with low amounts of OM, including normal mineral soils, available Cu increases as OM increases. In a previous experiment at the present location, an increase was found in available Cu with the application of PC over 6 years (Herencia et al. 2008). It may therefore be necessary to study more than 3 years in order to show differences in Cu availability with organic fertilization. The role of OM in complexing Mn is important because OM can affect the redox status of soils. The microbial decomposition of added OM in continuous crops creates reducing conditions, which favour Mn solubilization (Mandal & Mitra 1982). Microbial soil activity is known to be largely responsible for the oxidation and reduction of manganese compounds (Bromfield 1978). In the present study, the microbial activity was greater in the organic plots than in the conventional plots (Melero et al. 2006).

The higher values of DTPA-extracted Fe and Zn in MC treatment are in agreement with other authors
who indicate that OM exerts a significant and direct effect on micronutrient availability (e.g. Wei et al. 2006). A highly significant difference between Fe and Zn extracted by DTPA and the OM content of soils has been found by several authors (Katyal & Sharma 1991; Sharma et al. 2000). The Fe can be in oxidized or reduced forms. Therefore, due to its acidic and reducing characteristics, an increase in soil OM could increase the more available reduced form of iron-Fe²⁺. Soil Fe has a strong tendency to form mobile organic complexes and chelates (Kabata-Pendias 2000). These compounds are responsible for the supply of Fe to plant roots, especially in neutral and calcareous soil. The amount of Fe added with either compost (Table 4) was similar; nevertheless the available Fe was higher in the MC treatment (Fig. 2), indicating the importance of the composition of the compost.

The higher amount of available Zn in MC could be due to the higher Zn concentration in MC (Table 5). The addition of exogenous OM containing functional groups with the ability to form complexes promotes Zn availability in soils with a high pH range. In the present results, the highest values of Zn were noted in the organically managed plots as compared with the conventional ones (Fig. 2). In a previous study conducted over 6 years, it was found that the addition of organic amendments influenced the distribution of Zn in the different fractions by moving Zn from the less soluble fractions to more plant-available forms (Herencia et al. 2008).

The average crop yields over the experimental period were lower for the organic treatments than for the conventional treatment. Mäder et al. (2002) reported that lower yields for organic systems as compared with conventional systems appear to be caused by lower nitrogen nutrient inputs in the organic systems. According to Pimentel et al. (2005), organic systems may create nitrogen shortages over the short term, which temporarily reduce crop yields. It is necessary to note that the N applied in the organic amendment is not immediately available to the plant because it must first be mineralized.

In addition to nitrogen deficiency, the weed competition in organic plots is another problem related to lower yields (Pimentel et al. 2005; Taylor et al. 2006). The difficulty of weed management in organic crops is seen as a limitation to the wider adoption of organic cropping systems (Beveridge & Naylor 1999). The present authors had problems with the establishment of carrot and spinach crops from seeds because of weed competition.

Vogtmann et al. (1993) reported that organic treatments lowered vegetable yields during first 2 years of treatment, but yields did not differ after the third year. Recovery of productivity may be associated with beneficial changes in soil OM and OM-dependent soil properties (De Costa & Sangakkara 2006). In a 3-year study, Gliessman et al. (1996) indicated that strawberry production was initially lower in organic systems, but this difference decreased progressively in such a way that, considering the superior prices of the organic fruit, the final result was economically favourable for the organic systems. Taylor et al. (2006) reported that organic farming with an appropriate crop rotation system can be agronomically and financially sustainable.

The main conclusions from the present work are that the use of two different composts (plant and manure) in the amounts used in this study increased soil fertility. Organic farming management resulted in higher soil OM, N, and available P and K, but at least 2 or 3 years are necessary to realize significant effects. The use of organic amendments also resulted in higher available Fe and Zn. The MC generally showed greater values. Nevertheless, plant compost is a very interesting organic amendment because it does not depend on external farm inputs. The availability of Mn, and especially Cu, did not increase significantly, possibly due to the great stability of the organic complex formed.

A decline in crop yield was found throughout the present experiment for the plots with organic amendments. This was due to the longer times necessary for the changes in chemical, physical, and biological properties of soil to occur, which enhance nutrient cycling and plant growth. Soil fertility and weed management could be the most important factors limiting yields in the organic systems. More research is needed on the aspect of profitability. If, during the first years of organic soil amendments, an appropriate crop rotation system is applied (i.e. planting legume crops or crops with a low nitrogen demand) and this is coupled with a higher price for organic crops, a system that is both agronomically and financially sustainable can be achieved.

The authors wish to thank Mr J. M. Molina and J. Aragon for assistance in soil determinations and systems management. The financial support of the Spanish Commission of Science and Technology (CICYT) under project no. AGL-2000-0493 and the Government of Andalusia through Projects PAI RMN 166, and exp. 92162/1 are acknowledged.

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Comparison of organic v. conventional agriculture


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