Composts as alternative to inorganic fertilization for cereal crops

T. Hernandez, C. Chocano, C. Garcia

Centro de Edafología y Biología Aplicada del Segura. Consejo Superior de Investigaciones Científicas (CEBAS-CSIC). Campus Universitario de Espinardo, Edificio nº 25, P.O. Box 164, 30100, Espinardo, Murcia (Spain)
Keywords: barley yield, microbial activity, grain quality, soil quality,
Presenting author email: mthernan@cebas.csic.es

The management of soil organic matter by using composted organic waste is the key for sustainable agriculture (Nyamangara et al., 2003). Several works have highlighted the beneficial effects of organic waste application for crop production. In addition to its slow release nutrient capability, organic matter is largely responsible for aggregation, as well as for the improvement of various soil physical properties, including soil moisture holding capacity (Basso and Ritchie, 2005; Tejada et al., 2006). Therefore, increasing soil organic matter content must be the first step in any farming practice. If productivity is to be maintained, it is essential to develop an agricultural system able to preserve satisfactory physical conditions in the soil. Organic matter additions are the only means of making some soils economically productive (Rathod et al., 2013). Nevertheless, organic waste application as a substitute for conventional mineral fertilization is sometimes problematic because some crops have high nutrient needs or punctual needs throughout their growth cycle. As a result, large quantities of organic material would be necessary to satisfy the overall needs of the crop, and/or the organic wastes would not supply sufficient quantities of nutrients at the right moment. Combining organic amendment applications with nitrogen mineral fertilizer with the aim to meet crop N needs can be a suitable alternative for replacing conventional mineral fertilizers. The use of treated organic wastes as a fertilizer and soil amendment not only results in economic benefits for the small-scale farmer, but it also reduces pollution due to reduced nutrient run-off and N leaching (Nyamangara, 2003).

The feasibility of using organic wastes as fertilizers has been evaluated at field level, in barley and soft wheat crops (two successive cultivations of each crop). The following treatments have been tested by quadruplicate: T1: Addition of 25 t/ha of sewage sludge compost (SSC) before sowing; T2: Addition of 14 t/ha of SSC before sowing + 45 kg N/ha (NAC27: ammonium calcium nitrate 27%) (barley) or 60 kg N/ha (NAC27) (wheat) applied in two different physiological stages of plant growth: tillering and first node formation (half dose each time); T3: Addition of 38 t/ha of compost from sheep and goat manure (MC); T4: Addition of 21 t/ha of MC before sowing + 45 kg N/ha (NAC27) (barley) or 60 kg N/ha (wheat) applied in two different physiological stages of plant growth: tillering and first node formation (half dose each time); T5; Addition of 350 kg/ha of a complex N-P-K inorganic fertilizer (8-24-8) before showing + 90 kg N/ha (barley) or120 kg N/ha (wheat) applied in two different physiological stages of plant growth: tillering and first node formation (half dose each time). Twenty plots for each crop (barley or soft wheat) were established, treatments being randomly distributed in 4 blocks. Barley seeds variety PEWTER R2 was sown at rate of 400 seeds/m^2 for barley crop whilst wheat seeds variety CALIFA SUR R2 were sown at rate of 550 seed/m^2 in the case of wheat crop. Nutrients added to soil with the different treatments are shown in Table 1.

Table 1. Macronutrient supplied to both, crops with the different fertilizing treatments (kg/ha)

Treatments		N		P		K	
	Fertilizer	barley	wheat	barley	wheat	barley	wheat
T1	SSCd1	500	500	216	216	181	181
T2	SSCd2	325	370	121	121	101	101
T3	MCd1	500	500	123	123	872	872
T4	MCd2	325	370	68	68	482	482
T5	Complex 8-24-8	118	148	84	84	28	28

For each barley and wheat crop, parameters such as moisture, pH, EC, total C and N, organic C (C_{org}), total and available elements (P, K, Fe, Mn, Mg, B, S, Ca and Na) anions and heavy metals were determined in the soil before fertilizing treatment application, as well as before seed sowing and after harvesting. Samples of soil, vegetal material and grain were collected after harvesting for nutrients and heavy metal content analysis. The harvest index, as well as other parameters indicators of grain quality (grain protein content and grain specific weight) were also determined. In addition, parameters such as soil microbial respiration, microbial biomass C and dehydrogenase activity, indicators of soil microbial population size and activity as well as hydrolase activities involved in nutrient cycles were also determined in soils after each harvesting to evaluate the incidence of composts on soil microbiological quality. Some physical parameters were also determined after the two successive crops.

In both barley crops soils treated with composts showed higher C_{org} contents than the inorganically fertilized soil. Little differences were observed between treatments with respect the rest of analyzed macronutrients and heavy metal content. Organically treated soils showed, in general terms, higher nitrate and total K contents than the inorganically treated soil, as well as higher contents of soluble Ca, K, Mg, Mn, Na and S than the soils treated with inorganic fertilizer, particularly MC.

Grain yield was expressed as yield H13%, that is, the grain yield by surface unit (kg/ha) normalized to 13% moisture. In both successive crops, all treatments led to similar yields of total barley and wheat plant (straw+ears) and grain, differences between treatments being not statistically significant ($p \leq 0.05$) (Figure 1). This suggests that the amount of N liberated from composts through organic matter mineralization has been enough to meet plant N requirements. This leads to think that about 25-30% compost organic matter has been mineralized liberating about 125-150 kg N/ha in treatments T1 and T3 and about 70-84 kg N/ha in treatments T2 and T4, which in addition have received 45 Kg of inorganic N by hectare (115-129 kg N/ha in total), providing in this way a N amount similar to that provided with the conventional inorganic fertilization.

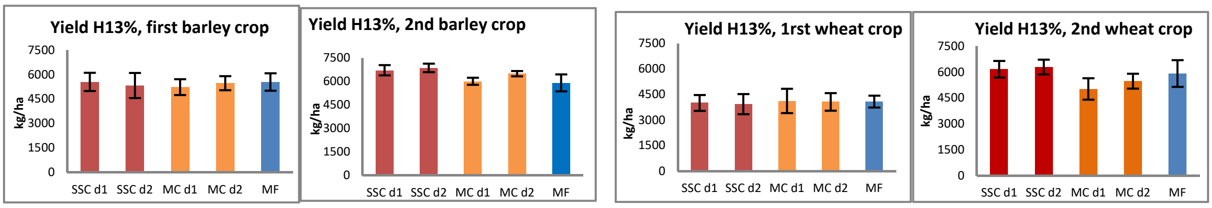

Figure1. Average barley and wheat grain yield H13% (kg/ha) obtained with treatments in each crop

The harvest index (grain weight/total vegetal material) was also quite similar in all treatments ranging from 0.44 in T1 (S+ 25 t/ha SSC) to 0.49 in T5 for barley crop and from 0.39 in T1 (S+SSCd1) to 0.33 in T5 for wheat. Grain quality was similar in all treatments. The commercial quality of grain is stablished by its specific weight (SW). According to the Spanish standards of quality two groups are stablished for barley: group 1 for SW > 62 kg/Hl, and group 2 for grains with SW < 62 kg/Hl, and 4 degrees of quality are stablished for wheat: Degree 1 for grain SW >80 kg/Hl, degree 2: SW> 78 kg/Hl, degree 3: SW > 75 kg/Hl and degree 4: < 75 kg/Hl. Barley grain SW was > 62 kg/Hl in all treatments in both crops, values ranging from 62.5 (T4) to 65.0 (T1) in the first crop and from 70.3 (T4) to 72.1 (T1) in the second crop. The highest values of SW were found in barley from soils treated with SSC although differences with the rest of treatments were not statistically significant ($p< 0.05$). The average weight of barley grain was also similar for all the assayed treatments. Wheat grains from plants grown in organically treated soils showed values of SW significantly higher than that of plants grown in inorganically fertilized soil. The highest values of specific weight were found in wheat from soils treated with the higher dose of composts (T1 and T3) although differences between doses were not statistically significant ($p< 0.05$). Grain quality obtained in the second crop was higher than that of the first crop and the grain SW was significantly higher in plants grown in organically treated soils than in plants grown in the conventionally fertilized soil. The average weight of wheat grain was also higher in plants grown in organically treated soils (from 35.3 g to 36.7g in the first crop and from 34.3 g to 36.6 g in the second crop) than in plants grown in the soil conventionally fertilized (32.6 g and 33.2). The nutritional composition of barley and wheat straw as well as its heavy metal content was quite similar in all treatments without significant differences between treatments. As regards grain nutrient content, grains from T5 showed slightly higher N content than grain from plants grown in organically treated soils in all crops, although differences were not statistically significant. Significant differences between treatments as regards grain nutrient or heavy metal contents were not observed.

It can be concluded that quality organic wastes can be used, at suitable rates, alone or in combination with inorganic fertilizers, as a good alternative to inorganic fertilization for cereal cultivation, improving soil characteristics whilst giving similar yield and crop quality than conventional inorganic fertilization. It can be also concluded that organic waste addition increases the efficiency of inorganic fertilizers, the combined addition of organic waste and mineral fertilizers giving rise to higher yields than the inorganic fertilizer used alone. The saving of inorganic fertilization represents a clear benefit from an environmental (reduced risk of contamination) and energetic (less energetic consume for inorganic fertilizers fabrication) point of view.

Acknowledgements. This work was supported by the Spanish Ministry of Economy, Industry and Competitively within the project: AGL2014-54636-R, And the EU within the project WASTEREUSE, Life 10 ENV/GR/594. Authors also thanks "Fundación Séneca" for his financial support as Excellence Research Group.

References

Basso, B., Ritchie, J.T. 2005. Impact of compost. manure and inorganic fertilizer on nitrate leaching and yield for a 6-year maize-alfalfa rotation in Michigan. Agric. Ecosyst. Environ. 108. 329–341.

Nyamangara, J., Bergstrom, L.F., Piha, M.I., Giller, K.E.. 2003. Fertilizer use efficiency and Nitrate Leaching in a Tropical Sandy Soil. J. Eniviron. Qual. 32. 599-606.

Tejada, M., García, C., Gonzalez, J.L., Hernández, M.T. 2006. Organic amendment based on fresh and composted beet vinasse: influence on soil properties and wheat yield. Soil Sci. Soc. Am. J., 70.