Agriculture, Ecosystems and Environment 196 (2014) 178–184

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Towards a more sustainable fertilization: Combined use of compost and inorganic fertilization for tomato cultivation

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ARTICLE INFO

Article history:
Received 3 May 2014
Received in revised form 9 July 2014
Accepted 10 July 2014
Available online 19 July 2014

Keywords:
Compost
Combined fertilization
Tomato yield
Fruit characteristics
Soil microbiological characteristics

ABSTRACT

The feasibility of using combined organic and inorganic fertilizers as an alternative to conventional inorganic fertilization was tested for tomato crops. To do this, two different composts (compost from a mixture of cow manure + alperujo + olive prunings and compost from sheep and goat manure) were added to an agricultural soil either, alone or along with inorganic fertilization, for tomato cultivation in greenhouse conditions. Conventional inorganic fertilization was used as reference. When used alone, the organic fertilizers led to lower N concentrations in leaves and fruits than the conventional inorganic fertilization. The combined use of compost and inorganic fertilizer, however, produced higher yields and better fruit quality than soils that underwent the respective inorganic treatment when used alone. In addition, soils with combined fertilization showed higher values of microbial biomass C, basal respiration and dehydrogenase activity than the respective inorganic treatment. The conjunctive use of compost and inorganic fertilizer made it possible to reduce inorganic fertilization by about 40% while obtaining similar fruit quality and amounts in addition to improving soil characteristics.

1. Introduction

Intensive cultivation and the failure to implement effective soil conservation practices have led to soil degradation and a decline in productivity because of excessive soil erosion, nutrient run-off and a decrease in stable soil organic matter. Efforts must be made to halt the decline in soil productivity and to restore the productivity of degraded soils in the shortest possible time. This could be achieved through proper management and recycling of organic wastes on land to protect agricultural soils. The efficient and effective use of organic wastes as soil conditioners and fertilizers constitutes one of the best means for maintaining and restoring soil productivity (Passarini et al., 2014; Kumar et al., 2014).

The utilization of organic wastes in agriculture depends on several factors, including the characteristics of the waste such as its organic matter, nutrient and heavy metal content, its energy value, the odor generated by the waste, its benefits to agriculture, its availability and the transportation costs and regulatory considerations. Although the importance of these factors can vary by type of organic waste, the considerations for use are similar for most organic wastes. Organic amendments affect soil properties in numerous and variable ways. These effects can be due to the intrinsic properties of the organic amendment (direct effect) or as a consequence of the beneficial effect of the organic amendment on the physical, chemical and biological properties of the soil (Stewart et al., 2000; Tejada et al., 2006, 2009). Organic wastes do several things to benefit the soil that synthetic fertilizer cannot do. First, they add organic matter, which improves the way water interacts with the soil. In sandy soils, organic wastes act as a sponge to help retain water in the soil that would otherwise drain down below the reach of plant roots, thus protecting the plant against drought. In clay soils, compost helps to add porosity to the soil, making it drain more easily so that it does not stay waterlogged and does not dry out into a brick-like substance. Organic wastes also inoculate the soil with vast numbers of beneficial microbes (bacteria, fungi, etc.) that promote the biological activity of the soil (Siddiqui et al., 2009; Jain et al., 2014). These microbes are able to extract nutrients from the mineral part of the soil and consequently make them available for plant uptake. Furthermore, when properly processed, organic wastes reduce soil-borne diseases without the use of chemical control (Pascual et al., 2000; Garcia et al., 2004; Suarez-Estrella et al., 2013). Beside nutrients, organic amendments add organic matter to the soil, contributing to the improvement of soil quality and fertility, as compared to the use of mineral fertilization alone.

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

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http://dx.doi.org/10.1016/j.agee.2014.07.006
0167-8809/

slow release nutrient capability (Eghball, 2000; Choi et al., 2014), organic matter is largely responsible for aggregation, as well as for the improvement of various soil physical properties, including soil moisture holding capacity (Aggelides and Londra, 2000; Borken et al., 2002; Cuevas et al., 2003; 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. Bazzoffi et al. (1998) found that urban refuse compost produced a lower maize grain yield than mineral fertilization, whereas maize produced lower yield when compost was applied, as compared to mineral fertilization (Businelli et al., 1990).

Combining organic amendment applications with a nitrogen mineral fertilizer with the aim to meet crop N needs can be a suitable alternative for replacing conventional mineral fertilizer. 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 et al., 2003).

The objective of this study was to assess the feasibility of using combined organic (compost) and inorganic fertilizers as an alternative to the conventional inorganic fertilization used for the nutrition and production of tomato plants.

2. Materials and methods

2.1. Experimental design

A greenhouse experiment with tomato plants was conducted from the beginning of June to the beginning of October 2013 (162 days) at the CEBAS-CSIC experimental field site located in La Matanza (Santomera) in South East Spain. Five-week-old red-round tomato plants (*Lycopersicum esculentum* Mill. cv. “Optima”) were moved to a greenhouse without artificial lighting. The greenhouse temperature was maintained between 19 °C and 29 °C by computer control. Minimum temperatures occurred between 6 a.m. and 7 a.m. (19–19.5 °C) and maximum temperatures between 5 p.m. and 6 p.m. (28.6–29 °C). Three tomato plants were transplanted into special containers of expanded polystyrene (l × w × h = 110 cm × 25 cm × 23.5 cm) containing 40 kg of a sandy loam soil with the following characteristics: 2.19% moisture; water holding capacity = 29.63%; pH 8.23; electrical conductivity = 696.3 μS/cm (extract 1/5); total C = 6.07% (dw); and organic C = 0.31% (dw). This soil was representative of agricultural soils of SE Spain. Plants were trained around a vertical string, and suckers were pruned every week.

The following two organic wastes were used as organic fertilizers: compost from sheep and goat manure (R1) and compost obtained from a mixture of cow manure + alperujo + olive prunings (R2). The doses were such that the same amount of total N was added to the soil with each compost (10.2 g total N per container). The main characteristics of the wastes used are shown in Table 1.

Inorganic fertilization consisted of irrigation with a Hoagland’s solution in the following manner: always (H100); in two of every three waterings (H60); or in one of every five waterings (H20). The macronutrients supplied to each plant with inorganic fertilization throughout the tomato cultivation period are shown in Table 2. As can be observed, nutrient amounts for H60 and H20 are not exactly 2/3 or 1/5 of that of H100 due to the different durations of watering throughout the cultivation period.

The following nine treatments (3 treatments with mineral fertilization only; 2 treatments with organic fertilization only; and 4 treatments combining organic and inorganic fertilization) were performed in quadruplicate: (1) H100: Ferti-irrigation with 100% of the standard ferti-irrigation solution for tomato (Hoagland’s solution); (2) H60: Ferti-irrigation with the standard Hoagland’s solution in two out of three waterings; (3) H20: Ferti-irrigation with the Hoagland’s solution every five waterings; (4) R1: Compost from sheep and goat manure at a rate of 50.5 t/ha (wet weight) (equivalent to 10.2 g of total N per container) without mineral fertilization (irrigated with water only); (5) R1 + H60: R1 at a rate of 50.5 t/ha plus irrigation with the Hoagland’s solution every two waterings; 6) R1 + H20: R1 at a rate of 50.5 t/ha plus irrigation with the Hoagland’s solution every five waterings; (7) R2: Compost from a mixture of alperujo + manure + olive prunings at a rate of 40 t/ha (wet weight) (equivalent to 10.2 g of total N per container) without mineral fertilization (irrigated with water only); (8) R2 + H60: R2 at a rate of 40 t/ha plus irrigation with the Hoagland’s solution every two waterings; (9) R2 + H20: R2 at a rate of 40 t/ha plus irrigation with the Hoagland’s solution every five waterings.

A completely randomized block design was applied with 4 replications. Irrigation was performed using a controlled, automated drip-irrigation system.

2.2. Harvest

The harvest of fruits was started on 91-day-old plants. Throughout the following 70 days, fully ripe red tomatoes were harvested and the following characteristics were recorded for each collected fruit: fresh fruit weight, the number of fruits per plant,

Table 1
Main characteristics of the organic wastes (dwt).

	Compost R1	Compost R2
pH	7.68	8.6
Electrical conductivity (μS/cm)	9300	5340
Moisture (%)	39.25	12.28
Organic carbon (g/100 g)	26.88	30.15
Total nitrogen (g/100 g)	2.18	1.89
Total P (g/100 g)	0.53	0.84
Total K (g/100 g)	3.78	2.38
Ammonium (g/100 g)	0.55	0.07
C/N	12.3	16.0
Heavy metals (mg/kg)		
Cd	<0.5	<0.5
Cu	23.66	95.76
Cr	16.68	39.52
Ni	5.53	13.37
Pb	6.09	7.21
Zn	74.04	156.92
Pathogens		
Escherechia Coli (ufc/g)	<10	<10
Salmonella (25 g)	Absence	Absence

Table 2
Macronutrient supplied to individual plants with inorganic fertilization throughout the cultivation period.

Treatment	N (g)	P (g)	K (g)	Ca (g)	Mg (g)	Fe (g)
H100	8.23	2.09	18.29	7.50	0.79	1.25
H60	5.04	1.28	11.20	4.59	0.48	0.76
H20	1.45	0.37	3.23	1.32	0.14	0.22