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Essential and non-essential element composition of tomato plants fertilized with poultry manure

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ABSTRACT

Poultry manure (PM) must be disposed of from poultry farms, but is a potentially valuable source of macro- and micronutrients for plant growth. The objective of this study was to examine the effects of poultry manure on the growth of tomato (*Lycopersicon esculentum*) plants. Yields of fruits and vegetative material of plants grown in soil with 0, 10, 20 and 40 g kg^{-1} PM added were measured. Concentrations of N, P, K, Ca, Mg, S, Fe, Zn, Cu, Mn, Mo, Cl, Si, Br, Rb, Sr and Ba in leaves at flowering and at final harvest and in fruits were determined by polarized energy dispersive X-ray fluorescence (PEDXRF). Poultry manure fertilization improved tomato shoot growth and also fruit yield and increased leaf N concentrations at the harvest stage. In addition, P concentrations of the leaves and fruits were increased as the application rate of PM was increased. Fruit Ca and Mg were significantly reduced by increased rate of PM application, but not to the extent to cause the calcium deficiency disorder blossom end rot. Applied high levels of PM slightly increased the concentrations of leaf Mo and Br at the harvest stage. Poultry manure applications had a positive effect on the concentrations of leaf Zn, Cu, Cl and Rb at both sampling stages, but leaf Si concentration was reduced by PM treatments. The concentrations of Zn and Rb were increased in the fruits by PM treatments, but the concentrations of Br were decreased. Applied PM levels had no significant effects on the concentrations of K, S, Fe, Sr or Ba in tomato plants. It is concluded that the increased fruit yield, and the increased concentration of Zn (an element required in the human diet) and the lowered concentration of potentially harmful Br in the fruit make poultry manure a valuable growing medium for tomato production.

1. Introduction

Rapid expansion of the poultry industry has caused increasing concern about the disposal of poultry wastes. Poultry manure has useful nutrients, and is therefore used as organic fertilizer (Moore et al., 1995), but although it is one of the best organic fertilizer sources available, excessive applications of manure can cause environmental problems. In addition to N, P and K, poultry manure also contains some secondary elements and also trace or heavy metals (Edwards and Daniel, 1992; Stephenson et al., 1990; Gupta and Gardner, 2005).

Poultry litter and manure are known to give increased yields of many different crops. However, data about the essential element composition of vegetables fertilized with poultry manures are less comprehensive, and for non-essential elements even less is known. For sustainable management of poultry manure, it is important to evaluate and understand the chemical composition of manure and reactions of manure with soil nutrients, and consequently the transformation of essential and non-essential elements from manure to vegetables.

The use of manures can change concentrations of plant-available elements by changing both the physical and biological characteristics of the soil. In many circumstances these changes improve soil physical structure and water holding capacity, resulting in more extensive root development and enhanced soil micro flora and faunal activity, all of which can affect the levels of micronutrients available to plants (Zeidan, 2007). Whereas supply of the macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) is almost invariably beneficial to the growth of plants, supply of micronutrient elements such as iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo) and chlorine (Cl) can improve plant growth when they are in low supply but can cause toxicity to plants at higher concentrations (Marschner, 1995). Some heavy metals (e.g. Fe, Zn, Cu) can be in short supply in the human diet, so increasing their concentrations in plant products could be beneficial to human health. Kingery et al.

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(1993) found elevated levels of K, Ca, Mg, Cu, and Zn in soils heavily fertilized with poultry manure. According to Uprety et al. (2009), application of poultry manure (and other manures) can considerably increase the Cu and Zn concentrations in soil because these elements are commonly given as supplements in animal feeds, and are present in the faeces. Elevated levels of heavy metals in the soil will result in increased uptake by plants, which may be consumed by animals or man. Manures used to grow crops could also potentially be the source of elements that are beneficial to plants, such as silicon (Si), elements to which some plants are known to be sensitive such as bromine (Br) (Mengel and Kirkby, 2001) and other elements that may be taken up by plants and which are dangerous to humans consuming plant products. This latter group includes radioactive elements such as rubidium (Rb), strontium (Sr) and barium (Ba).

The principal objectives of this study were to determine the effects of poultry manures on growth and essential (N, P, K, Ca, Mg, S, Fe, Zn, Cu, Mn, Mo and Cl) and non-essential element (Si, Br, Rb, Sr and Ba) compositions of shoot and fruit tissues of tomato plants.

2. Materials and methods

2.1. Growth conditions and treatments

Tomato plants (*Lycopersicon esculentum* Mill. cv Natura F1, a cultivar widely grown under glass on the Mediterrean coast of Turkey for tomato fruit for the table) were grown from May 21 to August 15, 2008 in a naturally lighted glasshouse (approximate day conditions during the span of time; 32–34 °C air temperature, 400–450 μmol m^{-2} s^{-1} photon flux density and 60% relative humidity) at the Faculty of Agriculture, Ankara University. The experiment was carried out in plastic pots (30 cm diameter) holding 10,000 g air-dried soil. The soil was taken from the plough layer (0–20 cm) of experimental fields of the Agricultural Faculty, Ankara (39°57′44.51″ N; 32°51′ 46.95″ E). Some characteristics of the soil and poultry manure are given in Table 1. Pelletized dry poultry manure was applied at the rates of 0, 10, 20 and 40 g kg^{-1} soil and incorporated into the soil before seedling transplantation. For the basal fertilization, 200 mg N kg^{-1} soil from NH_4NO_3 and 50 and 62.5 mg P and K kg^{-1} soil from KH_2PO_4 were applied before seedling transplantation. Tomato seeds were germinated in seedling trays filled with 1:1 (v/v) mixture of peat and perlite. Four week-old uniform seedlings were transplanted at a rate of one plant per pot. A small number of randomly selected pots were weighed every day, and tap water was added to all pots at the volume required to reach 70% of field capacity. No pesticides were used.

The youngest fully developed leaf on each plant was sampled for mineral element determinations at the beginning of flowering and the youngest, next youngest and third youngest leaves were harvested at the end of the experiment. Ripening fruits were collected, weighed and dried during the experiments. At the end of the experiments, plants were harvested and separated into shoot and unripened fruits. After weighing, the shoots were washed once with tap water and twice in deionized water. Mineral element determination was performed in only ripening fruits, so unripened fruits were omitted after weighing. Shoot and fruit samples were dried in a thermo-ventilated oven at 60 °C, and subsequently ground (200 μm sieve) for total N and PEDXRF elemental analysis.

2.2. Total nitrogen determination

Total nitrogen concentrations of the shoot and fruit tissues were determined according to the Kjeldahl procedure (Walinga et al., 1989) using a Gerhardt digestion block and Gerhardt Vapodest VAP 30 distillation unit.

2.3. Mineral element determination by PEDXRF

Sieved leaf and root sub-samples were pressed into thick pellets of 32 mm diameter using wax as a binder. USGS Standards, Leaf Standards, GBW 7109 and GBW-7309 sediment as reference standard materials were also pressed into pellets in a similar manner as the samples, and used for quality assurance.

Mineral element concentration was determined by polarized energy dispersive XRF. The spectrometer used in this study was a Spectro XLAB 2000 PEDXRF spectrometer which was equipped with a Rh anode X-ray tube, 0.5 mm Be side window. The detector of the spectrometer is Si (Li) cooled by liquid N_2 with a resolution of <150 eV at Mn Kα, 5000 cps. The spectrometer configures d as the source beam, scattered beam and fluorescent beam all at mutually orthogonal angles.

Table 1
Some physical and chemical properties of the experimental soil and poultry manure.

Properties (method)	Amount/quantification		Properties (method)	Amount/quantification	
	Soil	Manure		Soil	Manure
Field capacity	240 g kg^{-1}	–	Total-Mn (X-RF)	0.76 g kg^{-1}	452 mg kg^{-1}
Texture	Clay loam	–	Total-S (X-RF)	0.46 g kg^{-1}	11.76 g kg^{-1}
$CaCO_3$ (Scheibler)	57.3 g kg^{-1}	–	Total-Mo (X-RF)	4.40 mg kg^{-1}	9.4 mg kg^{-1}
pH (1:2.5 water)	7.98	6.55	Total-Mg (X-RF)	11.5 g kg^{-1}	9.66 g kg^{-1}
EC (1:2.5 water)	0.44 dS m^{-1}		Total-Al (X-RF)	51.8 g kg^{-1}	1718 mg kg^{-1}
Organic matter	7.60 g kg^{-1}	560 g kg^{-1}	Total-Si (X-RF)	178.1 g kg^{-1}	12.15 g kg^{-1}
Total-N (Kjeldahl)	0.92 g kg^{-1}	28.0 g kg^{-1}	Total-Cl (X-RF)	0.58 g kg^{-1}	7.06 g kg^{-1}
K (NH_4OAc-ext.)	0.47 g kg^{-1}	–	Total-Ti (X-RF)	4.53 g kg^{-1}	120 mg kg^{-1}
Total-K (X-RF)	14.7 g kg^{-1}	47.41 g kg^{-1}	Total-V (X-RF)	0.12 g kg^{-1}	8.4 mg kg^{-1}
Ca (NH_4OAc-ext.)	2.56 g kg^{-1}	–	Total-Cr (X-RF)	0.15 g kg^{-1}	39 mg kg^{-1}
Total-Ca (X-RF)	33.8 g kg^{-1}	97.92 g kg^{-1}	Total-Ni (X-RF)	63.9 mg kg^{-1}	14.8 mg kg^{-1}
Na(NH_4OAc-ext.)	64.0 mg kg^{-1}		Total-Co (X-RF)	28.0 mg kg^{-1}	11.9 mg kg^{-1}
Total-Na (X-RF)	0.29 g kg^{-1}	0.85 g kg^{-1}	Total-As (X-RF)	19.1 mg kg^{-1}	2.60 mg kg^{-1}
P ($NaHCO_3$-available)	8.54 mg kg^{-1}	–	Total-Br (X-RF)	4.20 mg kg^{-1}	22.3 mg kg^{-1}
Total-P (X-RF)	0.76 g kg^{-1}	20.7 g kg^{-1}	Total-Rb (X-RF)	65.8 mg kg^{-1}	35.1 mg kg^{-1}
Zn (DTPA-ext.)	0.72 mg kg^{-1}	–	Total-Sr (X-RF)	273 mg kg^{-1}	248 mg kg^{-1}
Total-Zn (X-RF)	77.2 mg kg^{-1}	670 mg kg^{-1}	Total-Zr (X-RF)	191 mg kg^{-1}	6.6 mg kg^{-1}
Fe (DTPA-ext.)	6.36 mg kg^{-1}	–	Total-U (X-RF)	6.60 mg kg^{-1}	7.3 mg kg^{-1}
Total-Fe (X-RF)	38.9 g kg^{-1}	2752 mg kg^{-1}	Total-Ba (X-RF)	459 mg kg^{-1}	39.8 mg kg^{-1}
Cu (DTPA-ext.)	1.01 mg kg^{-1}	–	Total-La (X-RF)	29.3 mg kg^{-1}	31.2 mg kg^{-1}
Total-Cu (X-RF)	33.7 mg kg^{-1}	74 mg kg^{-1}	Total-Pb (X-RF)	26.6 mg kg^{-1}	7.9 mg kg^{-1}
Mn (DTPA-ext.)	24 mg kg^{-1}	–			