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Use of compost to manage Fe nutrition of pear trees grown in calcareous soil

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ABSTRACT

The aim of this study was to evaluate the effectiveness of soil applied compost in preventing Fe chlorosis of pear trees. The effect of the treatment was evaluated in field conditions on tree growth, nutritional status, yield, fruit quality and soil parameters. A 3-year long field trial was carried out in a mature commercial pear orchard of the cv. Abbé Fétel grafted on quince (*Cydonia oblonga*) BA29 located in the South Eastern Po Valley (Italy). In a completely randomized block design (5 replicates), including an untreated control, the following soil-applied treatments were compared: (i) Fe chelates (1.65 g Fe tree^{-1} year^{-1} as Fe–EDDHA) applied yearly and split in two applications in spring; (ii) organic amendment (compost) applied yearly at a rate of 12 kg fw tree^{-1} at bud break. Leaf Fe concentration and green color were increased by soil applied Fe chelate and, from the second season, by compost. Considering the whole experiment data of leaf Fe concentration and SPAD index showed a positive ($P \leq 0.001$) linear correlation ($r = 0.84$). The supply of Fe chelate decreased significantly leaf K, Mn, fruit K and Cu concentration as well as fruit weight but raised tree yield. Compost showed intermediate values of tree crop load and higher fruit weight in comparison to Fe chelate. Iron deficiency reduced fruit sucrose and total carbohydrates concentration. Only compost addition stimulated soil microbial C biomass. Results demonstrate that composted organic wastes yearly applied improved Fe nutrition of pear trees grown in calcareous soils.

1. Introduction

Lime induced iron (Fe) chlorosis represents the most important nutritional disorder of susceptible fruit crops especially when cultivated in alkaline calcareous soils (Rombolà and Tagliavini, 2006). It is estimated that up to 50% of the high value fruit tree crops in the Mediterranean basin suffer from Fe deficiency. Many fruit tree species are considered susceptible to Fe deficiency and, when quince (*Cydonia oblonga*) is adopted as rootstock, pear is one of the most sensitive species to this disorder (Rombolà and Tagliavini, 2006). In Italy, more than 90% of the pear varieties yearly released by the nurseries adopts quince selections as a rootstock to achieve higher density plantation (reduced tree vigor), earlier bearing and larger fruit size compared to clonal pear (*Pyrus communis*) rootstocks. Fe chlorosis negatively affects canopy light absorption, leaf photosystem II and Rubisco carboxylation, thus leaf photosynthetic and transpiration rate are impaired (Larbi et al., 2006). Furthermore, recent findings pointed out physiological alterations of leaf morphology, stomatal control, xylem vessel morphology, leaf hydraulic conductance and leaf water potentials of chlorotic peach leaves, indicating that Fe deficiency implies pronounced disturbances in leaf water relations (Eichert et al., 2010). Disturbances caused by Fe deficiency are responsible for reduction of tree growth, losses of tree yield, depression of fruit quality and shortening of orchard lifetime (Álvarez-Fernández et al., 2006; Tagliavini and Rombolà, 2001). Fe chlorosis in crops occurs mainly as a consequence of a scarce solubility of mineral Fe sources in the soil (Röemheld and Nikolic, 2007) and of a reduced Fe uptake by the symplast, conditioned by the soil active lime fraction (Tagliavini and Rombolà, 2001).

The traditional application of either soil and/or foliar synthetic Fe chelates (i.e. Fe–EDDHA) to overcome Fe deficiency, although effective (Abadía et al., 2011), pose both economic and environmental concerns (Tagliavini and Rombolà, 2001). Hence, sustainable and cost effective alternative strategies to prevent Fe chlorosis of susceptible crops are required. It is widely accepted that soil organic matter (OM), improves soil Fe availability and contributes to alleviate the risk of Fe chlorosis (Tagliavini and Rombolà, 2001) since Fe can be complexed with organic ligands (Lindsay, 1991). It is generally acknowledged that organically Fe bound forms are more available to plants than the inorganic insoluble pools (Varanini and Pinton, 2006). These organic ligands include organic acids, humified fractions (Stevenson, 1991; Varanini and Pinton, 2006) and microbial siderophores showing high affinity for ferric ions (Shenker et al., 1992). As a response to low Fe availability in the environment, many studies pointed out the effectiveness of the microbial siderophores synthesized by a wide range of

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microorganisms (mainly bacteria and fungi) in improving root Fe uptake and consequently Fe nutrition of crops (Bar-Ness et al., 1991; Crowley, 2001; Chen et al., 1998, 2000). Furthermore, Masalha et al. (2000) stressed the importance of the soil microbial biomass in Fe nutrition for plants showing that soil exposed to a sterilization process of the microflora fraction, resulted in severe impairment of Fe nutrition in both mono and dicot species. In addition, improving soil aeration, OM may prevent the recrystallization of ferrihydrite to more crystalline oxides under alkaline conditions (Schwertmann, 1966).

Traditionally, animal manure has been used to enhance and restore soil OM and fertility in fruit trees ecosystems but, recently, due to its scarcity other organic sources have been proposed as soil amendments (Diacono and Montemurro, 2010). Compost is a stabilized organic amendment resulting from the aerobic biodegradation (>3 months) of a wide range of organic substrates (wastes). Compost represents a high quality OM source which can be profitably adopted for its fertilization value in agriculture (Baldi et al., 2010; Caballero et al., 2009; Diacono and Montemurro, 2010). Moreover, compost permits to recycle municipal solid and agri food industry related wastes, offering environmental advantages and reduction of social costs. In addition, the use of compost as amendment potentially represents a valuable strategy to sequester C in the soil.

The aim of this study was to evaluate the effectiveness of yearly soil-applied compost in preventing Fe chlorosis of pear trees and particularly, the effect of the treatment was evaluated on tree nutritional status, tree yield, fruit quality and soil parameters in a mature commercial orchard.

Table 1
Soil physical and chemical characteristics of the orchard.

Parameters	Method[a]	Unit	Value
Sand		$g\,kg^{-1}$	412
Silt		$g\,kg^{-1}$	248
Clay		$g\,kg^{-1}$	340
Organic matter		$g\,kg^{-1}$	13.2
C/N ratio			4.55
pH (in water)			7.66
Ca		$cmol_c\,kg^{-1}$	10.1
Mg		$cmol_c\,kg^{-11}$	4.93
K		$cmol_c\,kg^{-1}$	0.26
Na		$cmol_c\,kg^{-1}$	0.36
Electrical conductivity		$mS\,cm^{-1}$	0.44
Salinity		$mg\,L^{-1}$	284
Active lime		$g\,kg^{-1}$	73.8
Cation exchange Capacity (CEC)		$cmol_c\,kg^{-1}$	15.6
Organic C		$g\,kg^{-1}$	7.6
Total N	Kjeldahl	$g\,kg^{-1}$	1.68
P exchangeable[b]	Olsen	$mg\,kg^{-1}$	26.8
K exchangeable[c]	Barium Chloride	$mg\,kg^{-1}$	102
Ca exchangeable[c]	Barium Chloride	$mg\,kg^{-1}$	2017
Mg exchangeable[c]	Barium Chloride	$mg\,kg^{-1}$	600
Na exchangeable[c]	Barium Chloride	$mg\,kg^{-1}$	83.4
Fe exchangeable[c]	Citrate-dithionite	$mg\,kg^{-1}$	9
Mn exchangeable[c]	Citrate-dithionite	$mg\,kg^{-1}$	0.4
Cu exchangeable[c]	DTPA	$mg\,kg^{-1}$	7.8
Zn exchangeable[c]	DTPA	$mg\,kg^{-1}$	4.4
B soluble[b]	Azometin H	$mg\,kg^{-1}$	0.6

[a] Analysis were performed according to National Official Methods (D.M. 13/09/1999 G.U. N, 248 of 21/10/1999).
[b] Determined spectrophotometrically.
[c] Determined by AAS (Atomic Absorption Spectrophotometry).

2. Materials and methods

2.1. Plant material and growth conditions

A 3-year (2008–2010) long field trial was carried out in a mature commercial pear (*P. communis* L.) orchard of the cv. Abbé Fétel grafted on quince (*C. oblonga* Mill.) BA 29 planted in 1996 with a frame of 3.5 m × 1.3 m (2.198 trees ha^{-1}) and pollinated by cv. Bartlett. The orchard was located in the South Eastern Po Valley (Massalombarda, Ravenna, 44°46′N, 11°83′E, 13 m a.s.l.) on a Inceptisols (*Udifluventic Haplustepts*) (Soil Survey Staff, 2010). The main physical and chemical characteristics of the soil were determined by and external laboratory and reported in Table 1. The climate of the area is classified as temperate sub continental with cold winter and humid, warm summer. During the experiment, the air temperatures were in average 25.3 °C in summer and 3.4 °C in winter, while annual precipitation ranged between 600 and 780 mm, mainly concentrated in spring and autumn. Besides, a late spring hail storm occurred in June 2010. Trees were trained as in a palmette system, drip irrigated and with the alleys maintained with spontaneous grass species whereas the tree rows were herbicided by glufosinate ammonium twice per year. Trees were not thinned and managed in terms of nutrition, pruning, irrigation as well as pest and disease control according to the regional advises of Integrated Crop Management (ICM, 2008). Trees did not receive exogenous Fe input for at least 5 years prior the beginning of our trial, so that leaf Fe deficiency symptoms were often observed.

2.2. Experimental design

In a completely randomized block design, with 5 replicates of 5 trees each arranged in 2 alternate tree rows, the following soil applied treatments were compared with an untreated control: (a) commercial Fe chelate (1.65 g Fe $tree^{-1}$ $year^{-1}$ as Fe–EDDHA 5.5% Fe in the ortho–ortho isomer) split in 2 applications and supplied in fertigation from bud burst); (b) organic amendment (compost), applied yearly at a rate of 12 kg fw $tree^{-1}$ (26.3 t fw ha^{-1}) in spring, on the 2 m wide tree row and incorporated into the soil at 20 cm of depth. The compost used in the experiment was obtained by the aerobic biological decomposition of organic municipal wastes mixed with pruning material from urban ornamental trees and garden management, after a 3-month stabilization. Main physical and chemical characteristics of the compost were provided by the supplier and are summarized in Table 2.

In each experimental plot, only the central 3 trees were used for data collection, while consecutive plots along the row were separated by 2 untreated trees.

2.3. Fe chlorosis incidence and tree nutritional status

Tree Fe chlorosis incidence was evaluated in summer by a non-destructive estimation of the leaf chlorophyll (Chl) concentration made by a handheld Chl meter (SPAD 502, Minolta Co. Ltd., Osaka, Japan) on 30 apical leaves per tree and, in addition 20 random fully expanded leaves per tree were sampled from annual shoots. Collected leaves were immediately closed into polyethylene bags and transported to the laboratory in a portable refrigerator. Petioles were removed and leaf area was determined (LI 3000, Li-Cor Inc., Lincoln, Nebraska, USA). Leaf laminas were washed in a HCl (0.1 N) and surfactant (Tween 20, Sigma–Aldrich, Milan, Italy) (0.1%) solution according to Álvarez-Fernández et al. (2001), rinsed 3 times in tap water and finally in deionized water then oven dried (65 °C). Specific leaf weight (SLW) was calculated dividing leaf dry weight by leaf area. Dried leaves were milled (0.2 mm mesh) and analyzed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), Fe, manganese (Mn), zinc (Zn) and copper (Cu) concentration. The metals were extracted by wet mineralization according to US EPA Method 3052 (Kingston, 1988) by treating 0.5 g dw of tissue with 8 mL of nitric acid (65%) and 2 mL of hydrogen peroxide (30%) at 180 °C in an Ethos TC microwave lab station (Milestone, Bergamo, Italy) and determined by atomic