Biowaste compost in long-term soil fertilization: nutrients and non-essential elements in crops

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Biowaste compost provides obvious benefits to municipalities seeking to dispose of what would otherwise be organic wastes (Ozores-Hampton et al., 2005). Employed in agriculture, composts are a relatively inexpensive source of soil organic matter and crop nutrients but their composition is quite variable depending upon origin, feed materials and process (Gaskell et al., 2000). Even if benefits of biowaste compost to soil physico-chemical and biological properties (Bellino et al., 2015), as well as to crop yield (Ozores-Hampton et al., 2005), have been demonstrated, concerns over possible contamination still exist when crops are grown in amended soils (Baldantoni et al., 2016a). Indeed, metals present in compost may accumulate in soil or be taken up and accumulated in edible crops, posing a potential threat to consumers (Ozores-Hampton et al., 2005). Fate of metals in soil is affected by an array of interactive and simultaneous processes (Jiao et al., 2012) difficult to predict (Mantovi et al., 2005). Considering metal persistence characteristics, threshold concentrations in fertilizers do not seem exhaustive. Other gaps lie in lacking of threshold values of metal concentrations in agricultural soils, as total and/or bioavailable fraction (Baldantoni et al., 2016b). Moreover, in addition to fertilization practices and environmental conditions, also plant species and cultivars, organs and age, significantly affect crop uptake and accumulation of metals (Dudka and Miller, 1999).

The aim of this research was to study the effects of long-term soil fertilizations on nutrient and non-essential element concentrations in edible parts of three crops important in human diet. In addition to fruits of tomato, bulbs of onion and of fennel were analyzed in order to evaluate the possible chemical element accumulations in edible hypogeum organs. Previous results on element concentrations in the studied agricultural soils highlighted that soils treated with biowaste compost (alone or in combination with mineral fertilizers) show higher total Cu concentrations and lower available Cu concentrations, together with higher available Cd, Fe, K, Mn and Zn concentrations (Baldantoni et al., 2016a).

In the CREA experimental station of Scafati (southern Italy), four soil fertilization treatments, with four replicates, were performed according to a randomized-block design in plots of 50 m^2 each: amendment with biowaste compost at the dose 30 Mg ha^{-1} y on dry weight basis in the first 3 years and 15 Mg ha^{-1} y in the following 4 years (CMP); amendment with biowaste compost at the dose 15 Mg ha^{-1} y plus mineral nitrogen at half dose of that supplied in mineral fertilization (INT); mineral NPK fertilization (MIN); unfertilized control (CNT). Soil fertilization treatments were repeated for seven consecutive years (2007-2014), where horticultural crops were rotated. From each plot, 6-8 plants of tomato (*Solanum lycopersicum* cv San Marzano) in summer 2011 and 2012, of onion (*Allium cepa* cv Bianca di Pompei) in winter 2012 and 2013, and of fennel (*Foeniculum vulgare* cv Orbit) in winter 2014 were collected. From each plot and sampling time, tomato fruits, onion bulbs and fennel bulbs were pooled together, dried and pulverized. Oven-dried samples (75 °C up to constant weight) were digested by a HF and HNO_3 mixture in a microwave oven (Milestone Ethos). Macronutrient (Ca, K, Mg), micronutrient (Cr, Cu, Fe, Mn, Na, Ni, V, Zn) and non-essential element (Cd, Pb) concentrations were determined by AAS (PerkinElmer AAnalyst 100) or ICP-OES (PerkinElmer Optima 7000DV). A two-way multivariate analysis of variance (MANOVA) based on the Pillai's statistic was performed using the R 3.1.1 programming environment (R Core Team, 2016) to evaluate the differences in element concentrations among the three edible crops and the four soil treatments. Subsequently, the differentiation among crops or soil treatments, as well as in the case of their interactions, was evaluated with canonical variates analysis (CVA), with the superimposition of confidence circles (for $\alpha = 0.05$).

MANOVA showed significant differences both among crops ($P < 0.001$) and soil treatments ($P < 0.05$), as well as in relation to their interactions ($P < 0.001$). The CVA clearly differentiated the three crops mainly in relation to the higher concentrations of Ca, K, Mg and Na in fennel bulbs and the higher concentrations of Cd, Cr, Mn, Ni, Pb and Zn in tomato fruits (Fig. 1). These results are not surprising, considering that wide variations in chemical element concentrations among plant species have been known for many years (Barker and Pilbeam, 2015). Regarding element concentrations in the studied crops in relation to soil fertilization, the confidence circles for the four treatments were clearly differentiated only in the case of fennel (Fig. 1), whose bulbs, characterized by the highest Cr and Na concentrations in MIN plants, showed the highest Ni and V

concentrations in CNT plants, followed by MIN and then by INT and CMP plants. The concentrations of the two non-essential elements studied, carcinogenic to human beings (IARC, 2012), were compared with the maximum concentrations deduced by the EU 488/2014 and EU 1005/2015 Regulations on food quality. Tomato fruits analyzed in both the years showed Cd concentrations up to 9-fold (CNT plants sampled in 2011) higher than the permitted values.

Findings of the present study showed a different susceptibility of the three crops to soil fertilization treatments, appearing element concentrations in fennel bulbs overall more influenced by soil treatments than onion bulbs and tomato fruits. Anyway, temporal variations in element concentrations observed in each crop (tomato and onion) analyzed in two consecutive years were often wider than those attributable to soil fertilization treatments, possibly hiding them. Overall, this study highlighted the need to perform analyses on different crops in the evaluation of long-term soil fertilization treatments on chemical composition of edible organs. The obtained findings pointed out that soil fertilization mostly affects micronutrient concentrations, generally lower in plants grown on soils amended with compost, either alone or in combination with mineral fertilizers. This result, together with the lowest non-essential element concentrations in crops grown on amended soils, reassures on the effectiveness to employ biowaste compost in agriculture.

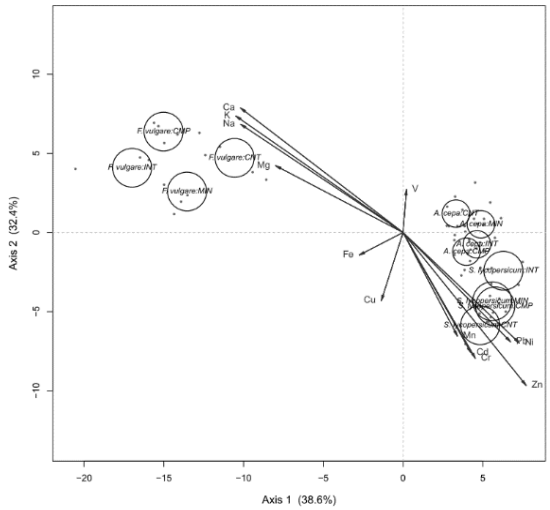

Fig. 1 Biplot of CVA highlighting the differentiation of samples, according to their element concentrations, in relation to the 3 crops and the 4 soil treatments.

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