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Cultivar, soil type, nitrogen source and irrigation regime as quality determinants of organically grown tomatoes

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ABSTRACT

Organic farming is claimed to be more sustainable and to produce fruits and vegetables that are healthier than conventional farming. However, scientific evidence in support of such claims is rather scarce. With respect to the nutritional aspects of organic products, there is a broad variability of responses in terms of accumulation of valuable molecules under organic cultivation so that it is not possible to establish unequivocal links between farming system and production of these metabolites. Considering that there is a physiological potential of organic products to systematically accumulate nutritional metabolites in response to this specific farming system, we began to categorize those cultural conditions that may facilitate the expression of such potential. In three different experiments carried out over three years, here we address the effect of cultivar, N fertilization, irrigation regime and soil texture on yield and quality parameters of organically grown tomatoes. Although yield was generally higher in conventional farming, there were not much yield differences between the two farming systems under low N fertilization and different irrigation levels. In addition, the sandy soil seemed to be more appropriate than clayey soil to obtain a competitive yield in organic tomato. Cultivars may respond differently in terms of accumulation of antioxidant molecules. Moreover, under organic farming, the level of these molecules was tightly dependent on the growing season. Overall, under limiting agricultural inputs (low N and water), organic farming may have a competitive advantage *vs.* conventional farming in terms of yield and nutritional quality. Nonetheless, in order to achieve significant qualitative improvements, soil type and proper cultivar selection should be considered as key determinants under organic farming.

1. Introduction

The debate on the higher quality of organic fruits and vegetables, and their improved nutritional value with respect to those conventionally grown, is animated by a number of contrasting reports that, so far, did not succeed in settling this dispute (Rembialkowska, 2007; Peregrin, 2008). Although in principle conventional products are as nutritious and safe as the organic ones (Dangour et al., 2009), an improved quality in response to organic farming has been reported, especially concerning the accumulation of antioxidants and vitamins (Bourn and Prescott, 2002). The concentrations of ferulic and *p*-coumaric acids, for instance, has been shown to increase in wheat grown under organic farming (Zuchowski et al., 2011). Similarly, organic cultivation seemed to enhance the quality of potatoes by increasing their vitamin C, chlorogenic acid and glycoalkaloids levels (Hajšlová et al., 2005; Maggio et al., 2008). These and more examples prove that the farming system has a potential to determine modest to moderate increments of valuable nutrients as also confirmed by Benbrook and McCullum-Gómez (2009), who reviewed a significant number of publications comparing the nutritional value of organically and conventionally grown produce.

A physiological basis linking the farming system to an improved nutritional value of agricultural products has been proposed, also. Accumulation of secondary plant metabolites such as lycopene and phenolic compounds may function as defense mechanisms against both abiotic and biotic stresses to which organically grown plants may be more exposed (Lundegårdh and Mårtensson, 2003; Gravel et al., 2010). Although this hypothesis could be proven by experimental evidence (Bourn and Prescott, 2002; Gravel et al., 2010), it must be pointed out that many interfering environmental/cultivation variables impede us to establish an unequivocal cause-effect relationship between the specific cultivation system and quality parameters, which could overall strengthen the mar-

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keting competitive advantage of organic products (Lundegårdh and Mårtensson, 2003).

Some reports have also contributed to raise confusion in this respect (Benbrook and McCullum-Gómez, 2009). For instance, the beneficial effect of organic farming has been recently associated to reduced nitrogen levels used under this cultivation regime compared to conventional farming and the consequent concentration effect on valuable molecules (Clark et al., 1999; Mitchell et al., 2007). Such reasoning, however, does not attribute any specific quality value to the farming system *per se* but rather to the practice of nitrogen fertilization. Based on this rationale, a farming system-specific evidence for the product's nutritional value cannot be provided since reduced nitrogen availability under conventional farming could also increase the concentration of these molecules (Mitchell et al., 2007). Similarly, although Straus et al. (2012) have demonstrated that the reduced nitrogen availability associated to organic farming, may enhance the concentration of free radical scavengers with high antioxidant capacity, it has been argued that most likely it is the general stress experienced by organic crops the true determinant of their quality profile (Rossi et al., 2008). Stress induced molecules are also important to human health (Sharma et al., 2012; Hunter and Burritt, 2012) and therefore they may indirectly attribute an extra value to basic nutritional properties of fruit and vegetables (Lairon, 2010). This aspect can therefore be more relevant under organic farming.

The multifaceted nature of the interaction between cultivation system and cultivation variables has been addressed in several reports (van Bueren et al., 2011). Nevertheless, our full understanding of the specific cultural conditions that would activate synthesis and accumulation of antioxidants and other valuable molecules and ameliorate the overall product quality is far from complete. Moreover, margins for improving the yield of organic farming systems are large as demonstrated by recent meta-analyses in which 5–50% yield reductions in organic *vs.* conventional farming were reported (Benbrook and McCullum-Gómez, 2009; Seufert et al., 2012). With the overall objective of identifying cultivation protocols that could help standardizing yield and product quality stability, we have begun a systematic assessment of cultivation variables under organic farming that may affect relevant quality parameters. We have earlier demonstrated that cultivar, fertilization and soil type/structure play a critical role in profiling and improve the nutritional quality of several vegetables (Maggio et al., 2013). To further contribute in cataloguing crop responses specific to organic cultivation, here we address the effects of cultivar, soil texture, N fertilization and water availability on tomato yield and quality.

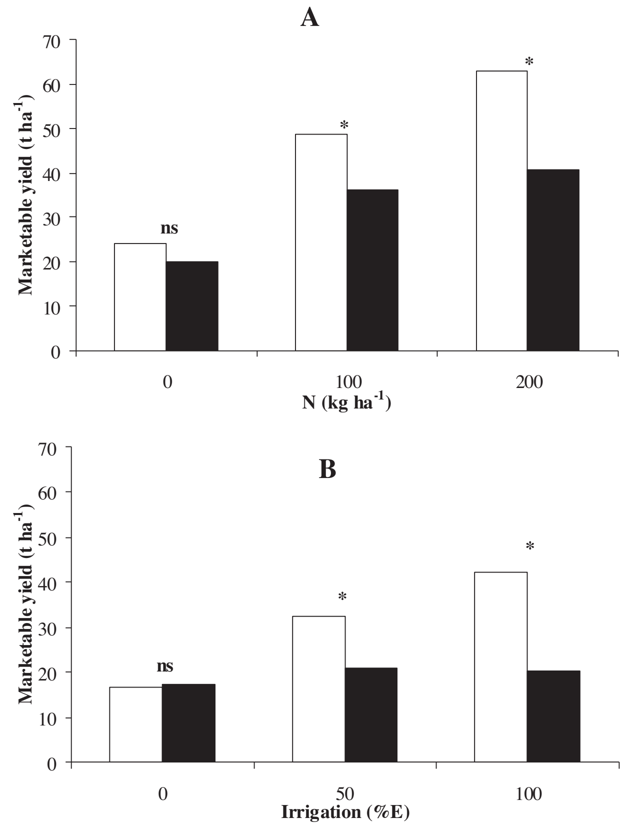

Fig. 1. Yield of tomato as affected by conventional (white bars) and organic (black bars) management. Response to N-fertilization and irrigation treatments during experiments 2 (A) and 3 (B). *Significant differences at $P \leq 0.05$; ns = not significant.

2. Materials and methods

2.1. Soil texture and N fertilization

Experiments 1 and 2 were designed to assess the effects of soil texture and N fertilization on organic *vs.* conventionally grown tomatoes. The experiments were carried out at the experimental station of the Department of Agricultural Science of the University of Naples Federico II located in Portici (Naples), Italy (latitude 40°49′N; longitude 14°20′E). With the objective of monitoring the evolution of soil variables under conventional and standard cultivation regimes, eight growing tanks (each 10 m length × 5 m width × 2 m depth) were filled with two different soils in 1968 (forty years ago): four with clayey soil (sand 42.3%; silt 23%; clay 34.7%; limestone 1.8%; pH 7.47; organic matter 1.7%; nitrogen 0.76% (Kjeldahl); P_2O_5 36 ppm (Olsen); K_2O 214 ppm; field capacity of 33.4% at −0.3 MPa and wilting point of 17.0% at −1.5 MPa) and four with sandy soil (sand 67.6%; silt 22.8%; clay 9.6%; limestone 3.4%; pH 7.45; organic matter 1.9%; nitrogen 0.84% (Kjeldahl); P_2O_5 33 mg/kg (Olsen); K_2O 297 ppm; field capacity of 22.0% at −0.3 MPa and wilting point of 12.7% at −1.5 MPa). The organic and conventional tanks were maintained under the same cultivation regimes, organic or conventional, for over 10 years. The treatments included two farming systems: conventional (CONV) and organic (ORG), three different rates of nitrogen fertilizers: 0 (0N), 100 (100N) and 200 (200N) kg N ha^{-1} and two processing tomato cultivars (*Lycopersicon esculentum* Mill.). In experiment 1 the cultivar Licata (cherry tomato hybrid) and CH2000 (plum tomato hybrid) were used, whereas in experiment 2 the cultivar Licata and Sansone (plum tomato hybrid) were used. All seeds were purchased by COIS'94 (Belpasso, CT, Italy). For both experiments, the experimental design was a split-split-split-plot with two replications. The soils were assigned to the main plots, the farming systems were assigned to the sub-plots, the different nitrogen levels were assigned to the sub-sub-plots and the cultivars to the elementary plots. The organic farming regime was managed according to the European Community (EC) regulation (REG. 2092/91). The conventional farming system was managed according to the local standard cultivation protocol (Maggio et al., 2004).

Nitrogen was applied before transplanting using organic N (a mix of oil seeds after oil extraction, feathers and torrefied bone-meal, 10.5% N) or inorganic N (ammonium nitrate, 33% N) sources, for the organic and conventional farming systems respectively. In addition, both systems received 150 kg P_2O_5 ha^{-1} and 150 kg K_2O ha^{-1} as chemical (CONV) or organic (ORG) fertilizers. Plants were irrigated at 3-day intervals using a self-compensating drip micro-irrigation system with 0.5 L h^{-1} emitters. The total amount of water applied during the growth season was 250 in Experiment 1 and 375 mm in Experiment 2. Average temperature