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Effects of organic vs. conventional farming system on yield and quality of strawberry grown as an annual or biennial crop in southern Italy

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ABSTRACT

Organic foods represent a significant market segment within the global food industry, since these products are often believed to be safer and more nutritious than their conventional counterparts. Due to the growing importance of organic strawberry cultivation for several agricultural areas in Italy, we carried out a four year research (2008–2011) on *Fragaria* × *ananassa* grown under tunnel in Campania (southern Italy), with the purpose of assessing the effects of two farming systems (organic or conventional) combined with propagation material (fresh or cold stored plants) and crop duration (annual or biennial) on yield and quality. The experimental treatments were randomized in a split-plot design, assigning the farming systems to the main plots and the propagation material in factorial combination with the crop duration to the subplots, with three replicates.

The conventional system produced the highest yield, as a consequence of the higher fruit number per plant, while the organic management resulted in increased berry mean weight. Organic fruits showed higher values of dry and optical residue and higher content of glucose, sucrose, vitamin C and ß-carotene but lower nitrate. Fresh plant crops produced a lower yield than the cold stored ones; moreover, the fruit production of fresh plants was higher when grown as an annual crops compared with a biennial cycle, independently on the farming system. In the case of cold stored plants, no yield differences were recorded between annual and biennial cultivations under conventional management, whereas organic crops from cold stored plants showed higher yields as annual crops compared with the biennial cycle. Fruit dry residue as well as sucrose, malic acid and mineral element content attained higher values in the fruits harvested from biennial crops than from the annual ones.

The choice of organic system as an alternative to the conventional practice could be justified by the better fruit quality, lower environmental impact and higher market prices. Moreover, the biennial crop duration could be a cost effective option when the crop is started from cold stored plants under organic management.

1. Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is a major crop in Italy with a total area devoted to this crop of 5878 ha in 2012 (2638 ha in the field and 3240 ha in protected environment), mainly located in Campania (1539 ha), Veneto (817 ha) and Emilia Romagna (592 ha) (ISTAT, 2013). In addition, nearly all of the Italian strawberry production is obtained from conventional farming practice, generally involving soil fumigation; however, in the years 2000 to 2012 there has been an increase in the area devoted to organic strawberry from 14.0 to 33.3 ha (respectively, 2.0 and 5.6% of the total strawberry surface area) according to the CSO database (CSO, 2013).

Soil borne pathogens and weeds are a major concern to strawberry producers throughout the world. It has been estimated that fungal diseases and nematodes can cause severe yield losses (up to 20–30%) in commercial strawberry production (Carpenter et al., 2000; De Los Santos et al., 2003; Maas, 1998; Manici et al., 2005). In order to optimize the balance between fruit yield and quality, it is needed to identify and evaluate effective nonchemical farming strategies with moderate environmental impact (Medina et al., 2009; Samtani et al., 2012). In particular, soil solarization is reported to be not so effective as chemical fumigation in terms of yield, while it does not affect fruit quality attributes (Palha et al., 2009). However, nonchemical soil disinfection could be potentially

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useful both under conventional and organic strawberry management (Subbarao et al., 2007), since the effect of the farming system on production depends mainly on the different fertilizer form (Caruso et al., 2011).

As the market demands a continuous supply of strawberries and higher prices are paid for out-of-season production (Meesters and Pitsioudis, 1997), Italian growers are motivated to cultivate fresh plants as an alternative to the cold stored propagation material. In fact, unlike the cold stored plants being planted in August–September (Ilgin and Kaska, 2002), the fresh plants are planted in October–November (Ozdemir and Kaska, 2002) following a chilling treatment which stimulates a vigorous growth during the short days of winter. Consequently, fresh plants produce fruits from winter to summer whereas the berries production of cold stored plants starts in the spring. In some research, it was reported that higher yields and better fruit quality were obtained from cold stored plants (Voth and Bringhurst, 1990) but in other trials (Palha et al., 2002) no effect of the different types of planting material both on production and on fruit quality was observed. Moreover, fresh plants have a lower cost of field establishment, since they are cheaper than cold stored plants and the crop management requires fewer labour expenses owing to the shorter cycle. Lastly, the later planting date of fresh plants compared to the cold stored plants allows growers to include strawberries in their crop rotation systems (Palha et al., 2002). The choice of strawberry crop duration is based on the consideration that a biennial cycle allows for a lower management cost in the second year, since transplanting and mulching are avoided. In addition, the cold storage of the plants induces early fruit ripening at the second year in comparison with the first year production. This effect is profitable within a conventional system, but it not quite appreciated by organic consumers who expect to buy safer, more nutritious and better tasting food in their natural ripening season.

Strawberries are considered a good source of essential minerals and vitamins (Tulipani et al., 2008) which together with the organoleptic properties make this fruit particularly desirable to the consumer (Panico et al., 2011). The overall taste of the berries is a major factor that drives consumer preferences with respect to fruit consumption and it is markedly affected by the content of reducing sugars and organic acids, which are regarded as good indicators of fruit quality (Montero et al., 1996). Strawberry quality is also affected by the crop management (Wang et al., 2002) and special attention should be paid to the undesirable accumulation of nitrates, which are considered a potential threat for human health (Lundberg et al., 2004) and their acceptable daily intake (ADI) is 222 mg for a 60 kg adult (Scientific Panel on Contaminants, 2008). In this respect, the choice of the appropriate organic fertilizer form may prevent nitrate accumulation in the plant edible organs (Caruso et al., 2011).

To our knowledge, no research to date has examined the interaction between propagation material and crop duration on strawberry production in southern Italy. Therefore we conducted field trials in Campania region on short-day strawberry cultivar Camarosa, with the objective of investigating the effects on plant growth, yield and fruit quality of: (a) organic or conventional farming method; (b) annual or biennial crop duration from cold stored or fresh plants.

2. Materials and methods

2.1. Plant material and growth conditions

Strawberry (*Fragaria* × *ananassa* Duch.) cultivar Camarosa was chosen for the greenhouse trials which were carried out in Giugliano (province of Naples, Southern Italy), 40°55′N, 14°11′3E, 56 m a.s.l.), in a Mediterranean or Csa climate according to the Köppen classification scheme (Peel et al., 2007). The trials were carried out in the years 2008–2011 on a sandy-loam soil (Table 1); the monthly means of temperature (day/night) recorded at the plant level are shown in Table 2.

Eight experimental treatments, obtained from the factorial combination of two farming systems (conventional or organic), two propagation materials (fresh or cold stored plants) and two crop durations (annual or biennial) were established. The experimental treatments were randomized in a split-plot design, assigning the farming systems to the main plots and the propagation material in factorial combination with the crop duration to the sub-plots. The main plots measured 10 m by 20 m and each plot included eight 1 m wide raised beds separated from each other by 0.25 m aisles. Each main plot was divided into four sub-plots, measuring 5 m by 10 m. A total of six main plots, corresponding to three replicates for each farming system (conventional or organic) were grown under six separate two-span greenhouses measuring 10 m by 20 m and 2.5 m high, covered by thermal triple-skin polyethylene (Lirsalux). Strawberry plants were grown on raised beds mulched with 0.05 mm black polyethylene film; plants were arranged in double rows, 0.3 m apart with 1.25 m between the middle line of each double row, plant spacing was of 0.3 m along the row, corresponding to 5.3 plants m^{-2}. On each sub-plot 265 plants were grown, totalling 1060 plants in each main plot. Each year the fertilization supplied 280 kg ha^{-1} of N, 130 kg ha^{-1} of P_2O_5 and 460 kg ha^{-1} of K_2O. In the first year, half of the fertilizer dose was given two days prior to planting, while the remaining 50% was applied on dressing at two week intervals between 15 March and 6 June, with a total of 13

Table 1
Soil analysis of the experimental fields: mean values of years 2008 and 2009.

		Conventional	Organic
Coarse sand	g	19.2	19.3
Fine sand	g	53.9	53.9
Silt	g	24.0	24.0
Clay	g	2.9	2.9
Organic matter (Walkley and Black method)	g	1.8	2.2
Total nitrogen (N)–Kjeldahl method	g	0.11	0.13
Available phosphate (P_2O_5)–Olsen method	mg	4.8	5.2
Available potassium (K_2O)–ammonium acetate method	mg	35.2	36.7
Total lime	g	4.4	4.2
Active lime	g	1.9	1.8
Reaction	pH	7.0	6.9
Electrical conductivity at 25 °C	mS cm^{-1}	0.30	0.35

Analysis of ≤2 mm soil fraction; results per 100 grams of air dried soil sample. Soil analysis results in years 2008 and 2009 were not significantly different, hence mean values for both years are shown here.

Table 2
Temperature at the plant level in Giugliano (Naples, Italy), mean values of years 2009–2011.

Month	Temperature (°C)	
	Min	Max
January	6.1	21.1
February	4.6	22.0
March	6.7	24.6
April	8.4	27.6
May	11.4	30.5
June	16.4	34.0
July	18.8	36.1
August	19.1	36.2
September	15.9	33.6
October	11.8	30.3
November	9.6	27.0
December	6.4	22.8