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Original research article

The effect on tuber quality of an organic *versus* a conventional cultivation system in the early crop potato

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ABSTRACT

Understanding the nature of the perceived quality advantage of organically-grown early crop potatoes over conventionally-grown ones is of relevance given the expansion in demand for foodstuffs produced by environmentally friendly agricultural practices. The effect of the cultivation system on the colour and nutritional value of potato tubers was explored in a field trial conducted at two locations involving seven yellow-fleshed cultivars. The performance of 'Arinda' cultivar was examined across locations and cultivation systems. A principal component analysis was able to distinguish organically- from conventionally-grown material. The organic cultivation system produced tubers of higher nutritional value, specifically exhibiting a higher total phenolics content (5.76 *vs.* 4.28 g kg^{-1} dry matter, averaged across locations and cultivars) and a lower nitrate content (0.64 *vs.* 1.04 g kg^{-1} dry matter, averaged across locations and cultivars), and displaying a more attractive colour of both the skin and flesh. Among the cultivars, 'Arinda' and 'Fontane' were the best performers under the organic cultivation system. However, there was a distinct influence of climatic conditions over the quality of the organically-grown crop. The effect of cultivar choice and environmental conditions in determining the overall quality of organically-grown early potato tubers is relevant for the conduct of breeding programmes and consumers' choice.

1. Introduction

Organically produced food is experiencing an upsurge in consumer interest, despite a lack of reliable data supporting claims that its quality is superior to that of conventionally produced ones (Dangour et al., 2009). The contradictory nature of the conclusions drawn by various studies is likely explained by inconsistencies arising from the use of non-standard sets of cultivars, from a lack of control over the growing environment and from differences in the procedures applied at and after harvest (Pieper and Barrett, 2009). The environmental benefits of organic production are much less controversial, as summarized by Reganold and Wachter (2016) in a recent meta-analysis of more than four decades of relevant literature. There remains a need to objectively compare the nutritional value of organic and conventional foodstuffs in order to guide consumer choice in a rational manner (Lester and Saftner, 2011).

Among the arable crops, potato (*Solanum tuberosum* L.) has lent itself best to organic production (Dvořák and Tomášek, 2011; Hagman et al., 2009; Lombardo et al., 2012a; Maggio et al., 2008). In addition, it represents a major food crop in many countries where the demand for organic food is increased worldwide (Lernoud and Willer, 2016). In the Mediterranean Basin, potato cultivation occupies about 1 Mha, producing ~32 Mt of tubers (FAO, 2014), most of which is produced in the period March to June to take advantage of the early crop potato market (Ierna et al., 2011). The high content of ascorbic acid in the tuber, along with that of the minerals potassium, phosphorus and calcium (Lombardo et al., 2013, 2014) and that of polyphenols and carotenoids (Buono et al., 2009) is an attractive feature of the early crop potato. Conventional producers of the crop typically rely heavily on the use of inorganic fertilizers and pesticides (Mauromicale and Ierna, 1999), which can result in the build-up of undesirable residues both in the tubers and in the soil (Canali et al., 2010; Hepperly et al., 2009; Rosen and Allan, 2007). As a result, the share of the early crop potato harvest taken by organic producers has been increasing. In addition, high disease pressure has been shown to result in only a limited loss of yield in organic crops (Lombardo et al., 2012a). In Italy, organically grown early crop potato can be sold at a premium of 200–250 € per tonne (Lombardo et al., 2012a), relying on the perception that their sensory and nutritional quality is superior to that of the conventionally grown equivalent. Cultivar choice needs to be directed to those which can yield reliably under a low input regime, while maintaining a high level of tuber quality (Hagman et al., 2009; Lombardo et al., 2012a).

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Table 1
Local mean maximum and minimum temperatures and rainfall in the locations under study.

Meteorological variables	Location	Month					
		January	February	March	April	May	June
Max. air temperature (°C)	Siracusa	16.6	14.3	17.4	20.7	25.7	28.2
	Ispica	15.6	14.9	17.5	20.7	26.8	30.1
Min. air temperature (°C)	Siracusa	9.9	9.2	11.8	14.8	19.9	22.6
	Ispica	8.4	8.3	10.8	11.8	16.1	17.0
Rainfall (mm)	Siracusa	54	148	105	1	3	0
	Ispica	117	128	42	1	1	5

Therefore, the present research was designed to evaluate the content of dry matter, sugars, protein, ascorbic acid, total phenolics and nitrate, along with the level of antioxidant activity and the skin and flesh colour in the tuber of a set of cultivars grown both organically and conventionally. Since the growing environment has a known influence over these traits, the experiments were replicated in two sites, both located in a major production area in the Mediterranean Basin.

2. Materials and methods

2.1. Plant material and growing conditions

The set of field experiments was conducted during the 2015 growing season, sited on four commercial farms in the coastal plain of south-eastern Sicily; two were located in the neighbourhood of Siracusa (36° 55′ N, 15° 20′ E, 20 m a.s.l.; Trial 1) and the other two in the neighbourhood of Ispica (36° 45′ N, 14° 48′ E, 60 m a.s.l.; Trial 2). The local climate features a mild winter and a hot, dry summer; detailed meteorological data pertaining to the period January to June 2015 are given in Table 1. Notably, the mean minimum air temperature during the cropping period was ~2.6 °C higher at the Trial 1 site. Based on USDA Soil Taxonomy classification (1999), the soils at the two sites are, respectively, a Calcixerollic Xerofluven and a Vertic Xerofluvent; at both sites, the texture was loam soil. Six cultivars (‘Arinda’, ‘Elodie’, ‘Erika’, ‘Fontane’, ‘Marabel’ and ‘Ranomi’) were evaluated in Trial 1 and two (‘Arinda’ and ‘Spunta’) in Trial 2, under both a conventional (CONV) and an organic (ORG) cultivation system (Table 2). The CONV cultivation system followed local commercially used procedures, while that for the ORG followed current EU regulations. Details of the provenance and quality characteristics of the cultivars are given in Table 3.

Table 3
Tuber ‘seed’ provenience and main tuber sensory characteristics of the nine potato cultivars under study.

Cultivar	Tuber ‘seed’ provenience[a]	Skin colour	Pulp colour	Cooking type[b]
Arinda	Agrico, NL	yellow	yellow	B
Elodie	Bretagne Plants, FR	yellow	yellow	AB
Erika	Nos, AT	yellow	yellow	A
Fontane	Agrico, NL	yellow	yellow	CB
Marabel	Europlant, DE	yellow	yellow	AB
Ranomi	Agrico, NL	yellow	yellow	BA
Spunta	HZPC, NL	yellow	yellow	B

[a] AT: Austria; DE: Germany; FR: France; NL: Netherlands.
[b] According to the E.A.P.R. (European Association for Potato Research) cooking type scale: A = firm texture (suitable for steaming, microwaving and boiling); B = fairly mealy texture (multi-purpose cooking), C = mealy texture (suitable for frying).

The four commercial farms were chosen on the basis of their production history. The two used for the ORG experiments had been certified for organic management for at least four years. The ORG and CONV farms at each site lie within 2 Km of one another. Disease-free, non pre-sprouted seed tubers were manually planted in January at a rate of 4.5 plants m^{-2}, and were arranged in a randomized block design with three replications. The whole plot size was 42 × 45 m. Drip irrigation was provided once the accumulated daily evaporation rate (derived from measurements of an unscreened class A-Pan evaporimeter) had reached 30 mm. In Trial 1, 120 mm water was applied over the whole growing period, while in Trial 2, the amount was 142 mm. Five irrigation applications were performed at each location for both cultivation systems. At both locations, tubers were harvested ~120 days after planting, corresponding to a time when 70% of the haulms were dry. At this point, the tubers were classified, according to their diameter, as either undersized (< 35 mm), marketable (35–70 mm) or over-sized (> 70 mm) (Gonnella et al., 2009). Tubers which were either green, misshapen, damaged or weighing < 20 g were regarded as unmarketable (Lombardo et al., 2013). A sample of at least 20 marketable tubers per replicate (within cultivation system and cultivar) was used to perform subsequent colour measurements and chemical analyses.

2.2. Tuber colour measurements

Skin and flesh colour was evaluated on five fresh tubers for replication according to the CIE (Commission Internationale deL’Eclairage, 1986) L*, a*, b* scale and using a CR 300 colorimeter (Minolta Co., Ltd., Tokyo, Japan), equipped with a D_{65} illuminant and calibrated with a reference white tile (x = 83.47; y = 84.43; z = 95.16). Three measurements on the skin of each tuber (at the distal

Table 2
Crop management program of the cultivation systems at the two locations under study.

Cultivation system	Agricultural practice	Active ingredient	Phenological stage of application	Dose rate per application (kg ha^{-1})
Conventional	Herbicides	Pendimethalin (38.7%) + Metribuzin (35%)	at pre-emergence	0.5 + 1.4
	Pesticides	Copper hydroxide (25%)	during crop growth	3
		Cymoxanil (30%)	during crop growth	0.35
		Phosethyl-Al	during crop growth	3
		Deltamethrin (2.8%)	during crop growth	0.42
		Pencicuron (23.2%)	at sowing	4
		Pyraclostrobin (3.8%) + Dimetomorf (6.8%)	during crop growth	0.25
	Fertilizers	Superphosphate (19% P_2O_5) + Potassium sulphate (50% K_2O)	before sowing	250 + 150
		Ammonium sulphate (21% N)	at 6th leaf stage and at the tuber bulking stage	300 and 200
Organic	Herbicides	None[a]	–	–
	Pesticides	Tribasic copper sulphate (15.2%)	during crop growth	3.8
	Fertilizers	SUMMUS®[b]	before sowing	3200

[a] Weeds were removed by mechanical methods (hoeing + hilling).
[b] SUMMUS® (Choncimer s.r.l., Macerata, Italy) composition: organic N 3.1%; P_2O_5 3%; K_2O 2%; S 2%; Ca 2%; Mg 0.7%.