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Crop growth and tuber yield of "early" potato crop under organic and conventional farming

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ABSTRACT

Intensive applications of farming inputs are generally associated to potato cultivation in several Mediterranean countries for "early" potato production. Recently, the enhanced interest for environmentally sustainable production systems has led to a major expansion in the organic farming sector. With the aim to identify cultivars which can be suitable for organically early potatoes crop in Mediterranean environment, a three-season experiment was carried out in Sicily (Southern Italy) to study the effects of comparison between organic and conventional cultivation systems on crop growth and tuber yield on five genotypes. These included three cultivars (Ditta for organic Arinda and Marabel for conventional cultivation systems) and two new genotypes, Bionica (Dutch cultivar specifically targeted for organic farming) and an Italian breeding clone ISCI 4F88 suitable for organic cultivation. The response of the 'early' crop potato to organic farming was genotype- and season-dependent. The organic cultivation system was less productive than the conventional one across the 3-season (−5% season I, −50% season II and −25% season III), due to a less availability of N and to appearance time and severity level of late blight infection. Moreover ISCI 4F88 deserve specific consideration due to its higher stability traits than the cultivar Ditta under organic cultivation system during the three seasons. Our results indicate that organic cultivation of 'early' potatoes can deliver acceptable agronomic performances. Further studies are still needed to assess the behavior of other genotypes adapted to "early" potato cropping as selection of appropriate cultivars is one of the key aspects to optimize this environmentally friendly production system.

1. Introduction

The potato (*Solanum tuberosum* L.) is a very important crop as staple food in the Mediterranean Basin, occupying an overall area of about 1 million ha and produces 28 million tons of tubers (FAO, 2011). In several countries such as Tunisia, Egypt, Cyprus, Israel, Lebanon, Turkey and southern Italy (Sicily, Campania and Apulia regions), potatoes are not grown in the spring-summer cycle due to high air and soil temperatures and considerable demand of water by irrigation management, but are largely grown in a winter-spring cycle (planting from November to January with harvesting from April to June) for "early" production. Early potatoes, defined as "*potatoes harvested before they are completely mature, marketed immediately after harvesting and whose skin can be easily removed without peeling*" (UNECE, Fresh Fruit and Vegetables – 30/2001), are highly appreciated and mainly exported to northern European countries, with considerable profit (Ierna, 2009). The high commercial value of the product prompts potato growers to adopt major farming inputs (Ierna et al., 2011) which have undoubtedly been responsible for increased early potato yields in recent decades. Moreover conventional cultivation can result in undesirable residues in both the tubers (Lombardo et al., 2013) and the soil (Navarro Pedreño et al., 1996). As a result, organic cultivation of "early" crop potato production is on the rise, because the potato is also one of the most highly demanded products on the organic market (Tamm et al., 2004).

In organic potato farming, theoretically could be used known or traditional cultivars, which tuber seeds had been obtained as organic seeds for organic management. However, organic production of 'early' crop potatoes requires to breed cultivars specifically for the organic farming. Parisi et al. (2002) have suggested that such cultivars need to show a reliably high yield in a low-input production system, high efficiency in nutrient uptake and good level of resistance/tolerance to the common biotic and abiotic stresses. In particular cultivars should be characterized by a high degree of tolerance against foliage and tuber late blight caused by oomycete *Phytophthora infestans* (Mont.) de Bary, early blight (*Alternaria solani* Sorauer) and leaf blight caused by *A. alternata* (Fries.) Keissler,

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which are difficult to control with fungicides allowed for organic farming.

Yield levels are typically lower in organic systems than in conventional high input ones (Maggio et al., 2008), even if some papers have reported that yield performance has not been compromised by the absence of high inputs (Maggio et al., 2008; Warman and Havard, 1998). Moreover, results on the effects of organic cultivation system on crop growth and tuber yield of main crop potatoes, reported in the literature, cannot be used for "early" potato crops. Weather conditions during off-season cultivation may have an appreciable effect on plant growth, substantially modifying the morphological and phenological traits of the plants compared to those cultivated in the spring-summer cycle (Mauromicale et al., 2003). A little knowledge (Lombardo et al., 2013; Caliskan et al., 2004) is available on the effects of organic cultivation on crop growth and tuber yield of "early" potato crop.

This research could be an important contribution to current knowledge, since a number of EU-based breeding companies have recently released cultivars (e.g., Athlete, Carolus, Bionica, Lady Balfour, Stirling and Toluca) targeted to organic farming, but their potential yield for 'early' crop potato production is uncertain. There is the need to have information regarding the behavior of different potato cultivars to identify genotypes which can be suitable for organically early potatoes crop in Mediterranean environment. The aim of this research was evaluate the effects, over a three-year period, of the cultivation system (organically grown 'early' potato crop in comparison to conventional one) on crop growth and tuber yield of several potato genotypes.

2. Materials and methods

2.1. Site, climate and soil

Experiments were carried outover three growing seasons in 2009, 2010 and 2011 (hereafter referred as season I, season II and season III, respectively), at the experimental field of the Strategic Field Crops Section of I.S.A.Fo.M. – CNR (National Research Council) on the coastal plain, south of Siracusa (37° 03′ N, 15° 18′ E, 15 m a.s.l.). This is a typical area for off-season potato cultivation in southern Italy. The climate is semi-arid Mediterranean, with mild winters, and commonly rainless springs. The soil type is Calcixerollic Xerochrepts (USDA Soil Taxonomy, 1975). Soil analysis were made before the start of the trials in a layer, 0.25 m thick (from 0.05 to 0.30 m) indicating the following characteristics: clay 27%, silt 40%, sand 33%, organic matter 2.3%, pH 7.6, total nitrogen 1.5‰, available P_2O_5 53 kg ha^{-1}, exchangeable K_2O 366 kg ha^{-1}. All analyses were performed according to procedures approved by the Italian Society of Soil Science (Violante, 2000). The plots used for organic cultivation were converted fully to organic farming in 2001 by a three-year transition period with a crops rotation including potato, faba bean and globe artichoke. The conventional plots (involving the same crop rotation) were separated from the organic ones by a distance of 50 m.

2.2. Experimental design and plant material

Over three growing seasons in each cultivation system (conventional and organic) the plant material was arranged in a randomized block experimental design with three replications. Each block included five genotypes (Arinda, Bionica, Ditta, ISCI 4F88 and Marabel), with a plot size of 4.9 m × 4.5 m with120 plants. Arinda and Marabel are cultivars well-adapted to Mediterranean growing conditions rather used for conventional production of "early" potato crop (Ierna, 2009). Bionica is a recent table stock variety specifically targeted for organic potato market. Ditta is a salad type cultivar well-known and popular between the Italian organic potato growers market-oriented to export in Germany. ISCI 4F88 is a new Italian breeding clone from potato breeding program at Industrial Crops Research Centre (CRA-CIN) in Bologna focused on release of new potato genotypes well-adapted to organic farming systems (Ranalli and Parisi, 2007). This clone is currently under two-year technical evaluations necessary to enter in the Italian National List of Varieties.

2.3. Management practices

In the three growing seasons, organic and conventional certified A class sprouted seed-tubers were hand-planted at 0.3 m in the rows and 0.7 m between the rows (equivalent to a plant density of 4.76 plants m^{-2}). Planting was on 6 February in season I, 31 January in season II and 2 February in season III. In the three seasons the conventional cultivation system (**Con**) was managed according to local farming practices. Prior to planting, active ingredient benfuracarb was used as granular insecticide to control wireworms (Coleoptera, Elateridae) damages. Prior plants emergence herbicide treatment with active ingredient clomazone was included to control weeds, and cimoxanyl, dimetomorf, zoxamide were applied to control late blight [*P. infestans* (Mont.) de Bary], both prophylactically and curatively. Aphids [*Myzuspersicae* (Sulzer), *Macrosiphum euphorbiae* (Thomas), *A. solani* (Kaltenbach), *Aphis nasturtii* (Kaltenbach)] and the Colorado potato beetle [*Leptinotarsa decemlineata* (Say)] infestations were prevented by foliar spraying with active ingredients cipermethrin and imidacloprid.

The crop management of the organic cultivation system **(Org)** followed current EU regulations (CE 834/2007, CE 889/2008, CE 967/2008, CE 1235/2008 and CE 1254/2008). No herbicide treatment was given, since the crop was kept free of weeds through hand-hoeing when necessary. Late blight was controlled by weekly foliar spraying with copper after plants emergence and throughout the plant development entire period; in particular seven foliar spraying treatments with copper at the dose of 5 kg ha^{-1} were carried out. The same fertiliser regime was applied in **Con** and **Org**, namely pre-planting application of 100 kg ha^{-1} N, 70 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K_2O in the form of either NPK synthetic fertilizer (**Con**) or a mixture of feathers and torrefied bone and meat meal (**Org**). N was applied as urea. Urea and a mixture of feathers and torrefied bone and meat meal are the most utilized fertilizers in **Con** and **Org**, respectively in our environment. A further 50 kg ha^{-1} N was supplied at the tuber initiation stage in the form of ammonium nitrate (**Con**) or a mixture of dried manure and hydrolysed pelt (**Org**). Drip irrigation was initiated once the accumulated daily evaporation rate had reached 40 mm and the total water supplied was 220 mm, 170 mm and 180 mm in seasons I, II and III, respectively.

2.4. Data collection

2.4.1. Crop phenology and growth

Emergence date was expressed as the number of DAP (day after planting) when the stems break through soil surface. Crop maturity date (in DAP) was defined when the plants were at beginning of leaf yellowing. To provide information on crop growth the fresh weight (FW) of shoots was determined at about 60, 75 and 90 DAP. In addition the number of stems were determined at about 90 DAP.

2.4.2. Crop disease, yield and quality

No attempt was made to manually defoliate plants infected with late blight, in order to allow for a proper evaluation of plant susceptibility at about 90–95 DAP using the International Potato Center (CIP) scale (Estrada-Ramos et al., 1983). The latter measures the intensity of foliar blight caused by *P. infestans* by assessing the