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Agronomical, physiological and fruit quality responses of two Italian long-storage tomato landraces under rain-fed and full irrigation conditions

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ABSTRACT

Drought is the major environmental stress that adversely affects crop productivity in the Mediterranean region. Adopting water saving strategies, such as deficit irrigation or even no irrigation (rain-fed) and using drought-tolerant genotypes and/or landraces may represent effective tools to save water without substantial reduction of yield. An experiment was conducted in two consecutive growing seasons (2013 and 2014), to assess soil water content and matric potential of soil, physiological parameters, growth, yield and fruit quality of two Italian long-storage tomato landraces: “Locale di Salina 6” (LS; 2013 and 2014) and “Piennolo del Vesuvio” (PV; 2014) under rain-fed (RF) and full irrigation (FI) conditions. Leaf water potential, CO_2 assimilation, stomatal conductance, photosynthetic efficiency and growth were moderately impaired under rain-fed conditions, while intrinsic water use efficiency slightly increased. The marketable yield of LS in both growing seasons, and PV in 2014 under RF conditions was slightly reduced (by 6%) as compared with the FI treatment, indicating a drought tolerance of both landraces. In the 2014 experiment, the marketable yield was significantly higher by 55% in PV than in LS landrace. When averaged over landraces, the fruit quality traits in particular fruit dry matter, total soluble solids and total ascorbic acid contents increased by 21, 33 and 55%, respectively under RF compared to FI. The results can play an important role in selecting tolerant genotypes for use under limited water supply in order to save water and improve fruit quality without affecting the crop productivity.

1. Introduction

Water is an increasingly scarce resource worldwide, in particular in the Mediterranean basin due to the greater incidence of drought caused by human activities and climate change (Hoerling et al., 2012). Under these conditions, the increased competition for water among agricultural, urban and industrial consumers requires the optimization of water resource allocated for irrigation purposes (Fereres and Evans, 2006). Vegetable production in the Mediterranean region depends on irrigation; however unsuitable water supply can induce water stress (Rouphael et al., 2008; Karam et al., 2009).

Water stressful conditions disturb morphological, physiological and biochemical processes in vegetables leading to drastic yield reductions (Costa et al., 2007; Karam et al., 2011). Particularly, soil water deficit causes impairment of plant water status, and decrease in growth, stomatal conductance, net photosynthesis as well as inhibition of the photosystem II activity, thereby reducing the production and allocation of carbohydrates to the aerial parts including fruits (Shaw et al., 2002; Zgallai et al., 2005; Costa et al., 2007; Patanè et al., 2011). On the other hand, mild water stress could be considered an effective practice that may improve vegetable quality with sustainable yield loss (Costa et al., 2007). Enhancing fruit quality traits (i.e. phytochemical compounds) in vegetables

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has generated high interest among scientists and consumers owing to health promoting properties (Rouphael et al., 2012).

Under a scenario of limited water supply, there is an urgent need to assure productivity of vegetable crops with concomitant conservation of water resources, thus enhancing the water use efficiency – WUE (Costa et al., 2007; Mukherjee et al., 2010). Optimizing WUE could be attained by adopting water-saving strategies such as deficit irrigation (English and Raja, 1996; Casa and Rouphael, 2014) or opt for rain-fed operations (Agele et al., 2011). It is well known that field-grown processing tomato under water deficit could increase fruit quality with acceptable yield reduction, resulting in a sustainable agronomic WUE (Mitchell et al., 1991; Patanè and Cosentino, 2010; Lahoz et al., 2016).

Other strategies to optimize water resources in horticulture are the selection of drought-tolerant genotypes (Rahman et al., 1999; Solankey et al., 2015) and/or landraces (Galmés et al., 2011, 2013). In a Mediterranean environment, long-storage tomato landraces, so-called for their extended shelf-life, provide a *niche* product combining unique taste and potential bioactive value (Siracusa et al., 2012, 2013). The berries of long-storage tomato are linked together to form the traditional bunch hanging. These tomato landraces are traditionally cultivated under rain-fed water regime and may represent an interesting genetic source in breeding and/or biotechnological improvements for drought tolerance as pointed out by Siracusa et al. (2012). Despite the importance of long storage tomato among the traditional Mediterranean foods, there is an absence of studies in the international literature concerning their yield, physiological and quality traits responses to different soil water conditions.

Therefore, the aim of the paper was to investigate the agronomical, physiological and fruit quality responses and to assess the trade-off between yield reduction and berry quality of two long storage tomato landraces under a limited water supply, as compared to full irrigation.

2. Materials and methods

2.1. Experimental site and climatic data

An open-field experiment was carried out in two consecutive growing seasons, one in 2013 and another in 2014 at the experimental farm of "Arca 2010" located in Acerra-Naples, South Italy (40°57′N, 14°25′E, 26 m above sea level). The deep soil developed on volcanic material has a loam texture with 40.9% sand, 32.8% silt and 26.3% clay, and it is characterised by high chemical and physical fertility. For a depth up to 45 cm, the soil was characterised by a bulk density of $1.07\,g\,cm^{-3}$, $278\,mg\,kg^{-1}$ (P_2O_5 available), $\sim 2000\,mg\,kg^{-1}$ (K_2O), 0.29% (w/w) N and 3.1% (w/w) organic matter. The volumetric soil water contents at field capacity was $0.39\,m^3\,m^{-3}$ while the permanent wilting point was $0.13\,m^3\,m^{-3}$, measured at soil matric potential (ψ_m) of −0.03 and −1.5 MPa, respectively.

The climate is typically Mediterranean; during the spring and summer seasons, 16-year average monthly rainfall, air temperature and relative humidity were 50 mm, 22.5 °C and 68%, respectively (data not shown). Data of both 16-year period and 2013 were collected from an agrometeorological station belonging to the Se.S.I.R.C.A. – C.A.R. of the Regione Campania (Italy), located 500 m from the experimental site. In 2014 data were recorded by a radiation-shielded mini weather station (Watchdog 450 datalogger, Spectrum technologies Inc., Plainfield, IL, U.S.A.), located in the middle of the experimental site.

2.2. Plant material

Two Italian long-term storage tomato (*Solanum lycopersicum* L.) landraces were tested: "Locale di Salina 6" (LS; in 2013 and 2014) originating from Sicily, belonging to the germplasm collection at the CNR-IVALSA of Catania (Italy), and "Piennolo del Vesuvio" provided by Arca 2010 of Acerra (Naples, Italy) (PV; in 2014) originating from Campania. LS landrace has a round fruit shape, without any apex with small fruits weighing 10–20 g (Siracusa et al., 2013). PV landrace has an oval fruit shape with the characteristic apex at the bottom, and fruit weight ranging between 20 and 35 g.

2.3. Cultural practices, irrigation treatments, and experimental design

Tomato seedlings were transplanted at the four-leaf stage on 19 April 2013 and 22 April 2014 at a plant density of 16000 plants ha^{-1} and watered to reach soil field capacity in the 0–40 cm depth layer. In both growing seasons, preplant fertilizer was broadcast ($kg\,ha^{-1}$; 25N-50P) and incorporated into the soil. During planting additional fertilizer was applied ($kg\,ha^{-1}$; 65N-40P-30Mg). The tomato plants were trained using the stake and weave trellising system. In both seasons, weeds were controlled with hand hoeing.

Plants were submitted to full irrigation (FI) or non-irrigated rain-fed (RF) water regimes. Irrigation for FI treatment was applied on the base of the amount of water lost by evapotranspiration, calculated by multiplying reference evapotranspiration (ET_o) by crop coefficient (K_c). ET_o was calculated according to the Hargreaves equation (Hargreaves and Samani, 1985). Crop coefficient was applied according to Doorenbos and Pruitt (1977) as follows: 0.4–0.7 from transplanting to establishment; 0.7–1.1 from establishment to beginning of flowering; 1.1-0.8 from beginning of flowering to beginning of fruit setting; 0.8–0.6 from beginning of fruit setting to maturity.

RF treatment was irrigated only twice at crop establishment in both years, by suppling 58 and 42 mm in 2013 and 2014, respectively. FI was irrigated with 628 (22 times) and 410 mm (18 times) in 2013 and 2014, respectively. In 2013, irrigation started 7 days after transplanting (DAT), while in 2014 it started at 23 DAT, due to frequent rainfall. In both growing seasons, irrigation was stopped in late August. Water was supplied by drip irrigation with thin-wall drip tapes, which were placed at a distance of 0.10 m from the plant row. The emitter spacing along the tape was 0.10 m and the emitter flow rate was $1.2\,L\,h^{-1}$ at the operating pressure of 0.1 MPa.

A randomized complete block (RCB) design with one treatment (irrigation regime) and four replicates was adopted in 2013 experiment. In 2014 experiment, 2^2 factorial treatment combinations of two irrigation regimes and two landraces with four replicates per treatment in RCB design was adopted. Each experimental unit consisted of 4 rows, 20 m length.

2.4. Soil moisture measurements

In the 2014 experiment, the volumetric soil water content (θ, $m^3\,m^{-3}$) was automatically measured by using a time domain reflectometer (TDR 100, Campbell Scientific Inc. Logan, UT, USA) connected to soil probes by means of 4 multiplexers (SDMX50SP, Campbell, Scientific Inc. Logan, UT, USA). Data were recorded by a datalogger (CR1000, Campbell Scientific Inc. Logan, UT, USA). Three-wire probes, 15 cm long, were vertically placed in the 20–35 cm soil layer at three sites for each treatment at 0.05 m from the irrigation drip. In both experiments soil matric potential (Ψ_m, kPa) was measured by tensiometers (Irrometer 212 AAS for 0.30 m length, Riverside, CA USA). Tensiometers were installed by positioning the cup in the soil at 0.35 m depth in the middle of plant rows at three sites for each treatment. The depths were chosen to take into account the main root distribution region for tomato (Oliveira et al., 1996). Gauge readings were manually recorded three times per week at 8:00–10:00 a.m.