Scientia Horticulturae 190 (2015) 161–172

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Physiological responses of processing tomato in organic and conventional Mediterranean cropping systems

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ARTICLE INFO

Article history:
Received 19 January 2015
Received in revised form 23 March 2015
Accepted 20 April 2015
Available online 15 May 2015

Keywords:
Processing tomato
Organic system
Conventional system
Crop physiology

ABSTRACT

Processing tomato is a globally important horticultural crop. It is generally grown in high-input conventional systems, and there is little knowledge regarding its physiological responses in organic cultivation. Therefore, the aim of this work was to determine the influence of organic management on the physiological behavior of cultivars of processing tomato usually cultivated in conventional management in a Mediterranean area. The study was performed by means of: (1) field testing of a set of commercial cultivars for 2 years, in two systems, in one location in Southern Italy, and (2) crop physiological investigations during the growth cycle of processing tomato. Results of the two-year trials indicate that, under the organic cropping system, processing tomato showed, as 2 years average, higher intercellular CO_2 concentration (Ci) (+10.3%), transpiration (E) (+15.5%) and stomatal conductance (gs) (+16.5%). Average net assimilation (A) was similar in the two systems and differences were only observed depending on years. In contrast, average leaf area index (LAI) and water use efficiency (WUE) were lower in the organic cropping system (−42% and −17.8%), as were average fruit (FDW) and total (TDW) dry weight (−37.5% and −29%). In our conditions, LAI at the end of the cultivation was highly correlated with total and fruit dry weight. As differences in fruit and total dry weight of processing tomato cannot be explained by differences in net assimilation *per* leaf area unit, other reasons may be linked to the effects of the organic management on the crop as weeds and pathogens.

1. Introduction

The continuous and great use of external inputs such as water, fertilizers and pesticides, is diminishing and polluting the natural resources with a significant impact on environmental and agricultural sustainability. The urgent need for agricultural sustainability has been highlighted in several reports (Dale et al., 2012; Kates et al., 2001; Murmu et al., 2013; Tilman et al., 2002). Therefore, to study how to improve alternative agro-ecosystems, such as low input or organic systems, could help to support long-term ecological balance of agro-ecosystems. Organic systems that minimize the environmental effects on cropping environment and maintain soil health and fertility (Mehdizadeh et al., 2013), can represent a possible solution to produce food with fewer external inputs. Processing tomato (*Solanum lycopersicum* L.) is an important and widely consumed vegetable crop throughout the world (Gould, 1992). During the green revolution, breeding programs developed hybrids and/or pure line cultivars with a high yield potential *per* hectare, with increased disease tolerance and longer shelf life, so these improved plant materials showed a high response to synthetic fertilizers and water supply (Dorais et al., 2008). Therefore, almost all commercial tomato cultivars are suitable for systems that use high amounts of external inputs, as in conventional systems, and few cultivars are now suitable for cultivation in organic systems. Tomato requires large quantities of mineral nutrients, which are supplied by synthetic fertilizers in conventional cultivation,

Abbreviations: A, net assimilation; Ci, intercellular CO_2 concentration; E, transpiration; FDW, fruit dry weight; gs, stomatal conductance; LAI, leaf area index; TDW, total dry weight; WUE, water use efficiency.

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http://dx.doi.org/10.1016/j.scienta.2015.04.027
0304-4238/

while in organic cropping only organic fertilizers are permitted (Bettiol et al., 2004; De Ponti et al., 2012). There are few studies on the crop physiology of processing tomato cultivated in organic *vs.* conventional systems, probably because a correct comparison between organic and conventional cropping systems entails plants being cultivated in similar soils and under similar climatic conditions. These are difficult to obtain especially for soil, because of the drastically different management of fertilization in the two systems that affects soil organic matter. Despite these issues, studies of crop physiology are crucial in order to understand the adaptation and possible use of cultivars developed for high input in low input systems. Crop physiology lays behind the application of agronomic techniques, which have great influence on total plant dry matter production and distribution (Heuvelink, 1996). Dry matter production is an important parameter to compare crops in different cultivation systems or different treatments. Creamer et al. (1996) reported that conventional systems produce more dry matter than organic systems. Moreover, Bettiol et al. (2004), De Ponti et al. (2012), Murphy et al. (2007) and Seufert et al. (2012) reported that organic crop yield is lower than conventional. Dry matter production during cultivation depends on several physiological processes (as photosynthesis, respiration, and translocation) evaluated with parameters such as net assimilation (A), intercellular CO_2 concentration (Ci), transpiration (E), stomatal conductance (gs) and water use efficiency (WUE). Other important crop parameters, such as leaf area index (LAI), are also useful for understanding differences in crop responses with different treatments or in different agro-ecosystems. To evaluate such physiological traits, gas exchange analysis is an approach used by several agronomists and physiologists to study crop behavior using different treatments, or to study specific aspects of plant metabolism (Magliulo, 1996).

In fresh-market tomato cultivated in greenhouse conditions, gas exchange parameters such as Ci, A, E, gs, were reported in a single study as higher in organic systems than in conventional systems, while other correlated parameters such as WUE, were higher in conventional system than in organic one (Acatrinei, 2010). LAI is an important parameter linked to gas exchange. For processing tomato, LAI is higher in conventional than in organic systems (Cavero et al., 1996). In detailed surveys of organic and conventional systems, Drinkwater et al. (1995) and Stanhill (1990) concluded that other factors, such as the different management techniques used, soil type and fertility, water availability, cultivar and yearly weather conditions, have also a great influence on organic and conventional systems. Additional and deep crop physiology research is needed for sustainable agriculture. In this view, the worldwide economically important crop processing tomato can be a reference for the study of crop physiological behavior, to understand how elite commercial cultivars that require high external inputs can adapt and yield in organic and low input systems. Thus, the aim of this work was to determine, in a 2-year field experiment, the physiological behavior of elite processing tomato hybrid cultivars, in organic and conventional Mediterranean cropping systems.

Table 1
Cultivars tested in the organic and conventional cropping systems. Resistances as declared by the seed companies.

Cultivar	Company	Resistances	Vegetative vigor
Long fruit			
Auspicio F1	CLAUSE	V, F1-2, N, Pto, TSWV[a]	High
Regent F1	ISI SEMENTI	V, F1, N, Pto	Medium
Sibari F1	SATIVA	V, F2	High
Blocky fruit			
Augurio F1	CLAUSE	V, F1-2, N, Pto[a], TSWV	Medium
Wally Red F1	ESASEM	V, F1-2, N[a]	Medium/high
Alican F1	ISI SEMENTI	V, F1	High

V, *Verticillium* spp.; F, *Fusarium oxysporum* f.sp. *lycopersici* (1 and 2); N, Galligen Nematoda (*Meloidogyne incognita*, *arenaria*, *javanica*); Pto, *Pseudomonas syringae* pv. *tomato*; TSWV, Tomato Spotted Wilt Virus.
[a] Partial resistance.

2. Materials and methods

2.1. Plant material

Six elite commercial cultivars (Auspicio, Regent, Sibari, Augurio, Wally Red, Alican), were selected after an initial survey on a larger set. The six cultivars were selected as a representative sample of the genetic variability of processing tomato cultivated in conventional management in Southern Italy in recent years. Seed companies were also asked to suggest cultivars that, in their opinion, were probably suited also for organic management in Southern Italy. The characteristics of the processing tomato F1 hybrids used for this study are listed in Table 1.

2.2. Field trial and growth conditions

The study started in the Spring–Summer 2010 at Battipaglia, in the Sele Plain, Campania Region, Southern Italy, in two farms with different managements: organic and conventional (Table 2); the study was repeated during the Spring–Summer 2011. The site has a Mediterranean climate with mild winters and dry-and-warm summers. The weather conditions of the two growing seasons are reported in the supplementary material (Fig. S1). In the two growing season periods (2010 and 2011), the average minimum and maximum temperatures were 16.9 ± 1.0 and 29.0 ± 1.0 °C, respectively and the ten-days rainfall averaged through the cropping season was 9.3 ± 1.0 mm. The organic field trials took place at a privately-owned organic farm named Morella, which adopted organic management over 10 years, while the conventional system was managed in fields of the CRA-ORT experimental farm (Table 2). A four-years rotation was used as fallow-pumpkin-spinach-processing tomato and fallow-cauliflower-winter wheat-processing tomato at Morella farm and CRA-ORT, respectively. Crop rotation was selected to minimize the possible adverse effects on the plant health status. Different plots were used in 2010 and 2011. The organic and conventional fields had very similar soil types, classified as Typic Haploxerepts (Soil Taxonomy, USDA). Notwithstanding the common soil

Table 2
Field trial sites of processing tomato in the two systems for the 2010 and 2011 harvests.

Site	Year	Location (Lat Long)	Sowing date	Harvest date	Average *T* min (°C)	Average *T* max (°C)	Average rainfall[a] (mm)
ORG	2010	Morella 40°36′ N; 14°56′ E	30/04/2010	02/08/2010	14.4	30.3	14.2
ORG	2011	Morella 40°36′ N; 14°56′ E	06/05/2011	17/08/2011	16.9	28.0	4.1
Average					**15.7**	**29.2**	**9.2**
CONV	2010	CRA-ORT 40°35′ N; 14°58′ E	30/04/2010	09/08/2010	18.6	29.2	11.3
CONV	2011	CRA-ORT 40°35′ N; 14°58′ E	07/05/2011	11/08/2011	17.3	28.2	7.5
Average					**18.0**	**28.7**	**9.4**

Lat, latitude; Long, longitude; *T*, temperature; min, minimum; max, maximum; ORG, organic system; CONV, conventional system.
[a] Ten-days rainfall averaged through the cropping season.