Influence of salinity and water regime on tomato for processing

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Abstract

The effects of salinity and watering regime on tomato crop are reported. The trials have been carried out over two years in southern Italy on a deep loam soil. Three saline levels of irrigation water (with electrical conductivity of 0.5, 5 and 10 dS m^{-1}), three watering regimes (at 20%, 40% and 60% of available water depletion), and two cultivars (*HLY19* and *Perfectpeel*) were compared. The overall results related to the salinity tolerance are in agreement with those from the literature indicating that water salinity reduced marketable yield by 55% in respect to the control treatments. The irrigation regimes that provided higher total and marketable yield were at 40% and 60% of available water depletion (on average, 90.5 and 58.1 Mg ha^{-1} against 85.3 and 55.5 Mg ha^{-1} of the 20% available water depletion). Saline and irrigation treatments did not affect sunburned fruits, while affected incidence of fruits with blossom-end rot. The former disease appeared more dramatically in saline treatments (+28% in respect to the control), and occurred mainly in *HLY19*. The disease incidence was by 52% lower in W2 respect to the W1 and W3. Fruit firmness was higher in S0, whereas it was not affected by irrigation regimes. Total soluble solids and dry matter content of tomato fruits were increased by salinity, whereas it was not affected by irrigation regimes and cultivars. The pH and the titratable acidity remained unchanged between the years, the cultivar and the saline and irrigation treatments. Similarly to the last parameters, the fruit ascorbic acid content remained unchanged in relation to the treatments, but it was higher in *HLY19*.

The recommended thresholds of easily available water to preserve total and marketable yield were at 40% and 60%, respectively. Watering more frequently, instead, on the soil type of the trial, probably caused water-logging and root hypoxia affecting negatively yield.

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Introduction

Irrigated agriculture is dependent on adequate water supply and its quality. Water used for irrigation can vary greatly in quality, depending upon type and quantity of dissolved salts. They originate from dissolution or weathering of the rocks and soils, and by intrusion of seawater into the river and underground water resources (Selvaggi *et al*., 2010).

The European Environment Agency has recognized that the problem of saltwater intrusion due to groundwater over-exploitation is one of the major threats to coastal area freshwater resources in Europe (Scheidleger *et al*., 2004; Rapti-Caputo, 2010). Italy has been indicated as one of the countries where the problem is felt most severely (Cau *et al*., 2002; Barrocu, 2003; Scheidleger *et al*., 2004; Capaccioni *et al*., 2005) with several hot-spot areas in Apulia region (Cotecchia and Polemio, 1997; Polemio and Limoni, 2001; Ancona *et al*., 2010).

In many irrigated areas, especially in the zones characterized by intensive agricultural activities, dwindling supplies of quality water for irrigation and increasing demand from other users are forcing farmers to use saline irrigation waters (Rhoades, 1987; Rhoades *et al*., 1992; Shani and Dudley, 2001). In the case of irrigation, the salts are applied with the water and remain behind in the soil, as water evaporates or it is used by the crop, contributing to soil salinization. This can lead to the acceleration of desertification process with increasing salt concentration in the top soil layers and negative effect on plant growth and productivity.

Saline soil water inhibits plant growth for an osmotic effect, which reduces the ability of the plant to take up water, and by ion excess which affects the plant cells (Yeo *et al*., 1991; Munns, 2002; 2005). Soil salinity also induces reduced plant growth due to specific ion toxicities (e.g., Na^+ and Cl^-) and ionic imbalances acting on biophysical and/or metabolic components of plant growth (Grattan and Grieve, 1999). When salinity is due to sodium salts, it can lead to the formation of sodic soils where salts are leached from the soil profile.

In many cases, salinity can lead to waterlogged soils and these two negative interactions between hypoxia and salts have a powerful depressive effect on plant growth (Barrett-Lennard, 2003). Under saline conditions, many plants are able to compensate partially low osmotic potential of soil water by building up higher internal solute contents. This is done by absorbing ions from the soil solution and by synthesizing organic osmolytes. Both of these reactions reduce the impact of osmotic potential on water availability (Allen *et al*., 1998).

When saline waters are used for irrigation, attention should be given to minimize root-zone salinity (Shani and Dudley, 2001; Gideon *et al*., 2002; Katerji *et al*., 2003), using appropriate irrigation systems and practices that will supply just sufficient quantity of water to the root-zone to meet the evaporative demand and minimize salt accumulation in the root-zone (Fisher, 1980; Munns, 2002). Irrigation frequency has stated the most important factor in crop management using saline irrigation (Pereira *et al*., 2009). In fact, generally saline water requires more frequent irrigation than fresh water because salts in the water and in the soil increase the osmotic potential of soil water, which makes water uptake by the crop roots more difficult.

The threshold value above which deleterious effects occur can vary depending on several factors including plant type, soil water regime and climatic condition (Maas, 1986). In rainfed agriculture soil water can be far below field capacity and the salt concentration several-fold higher than measured at soil saturation water content (Rengasamy, 2002). Tomato for processing industry is among common open field crops cultivated in Southern Italy with a high economical impact. This species is often cultivated in soils affected by salinity problems and/or irrigated with saline water.

Experimental results indicate tomato as a salt moderately sensitive crop (Flagella *et al*., 2002) according to Mass and Hoffman (1977) model, and stressed also negative effects of salinity on absorption and translocation of Ca^{++} (Grattan and Grieve, 1999) that is easily connected to the blossom-end rot (Adams and Ho, 1992; Belda and Ho, 1993; Max and Horst, 2009).

The soil water regime is a remarkable factor that affect tomato yield in saline conditions. As known, the water depletion fraction threshold is a specific characteristic and for tomato crop this parameter is equivalent to 40% (Allen *et al*., 1998). However, to compensate the higher osmotic pressure that happened in saline conditions, it is necessary to increase soil water potential; for this reason, the threshold of water depletion fraction can change.

For tomato crop, literature data showing the optimal water depletion fraction in saline conditions are not available. Therefore, the aim of this work is to evaluate the best watering regime in relation to the salinity.

Materials and methods

Experimental site and climate

The research was carried out during 2007 and 2009 summer period at the experimental farm *Enrico Pantanelli* of Bari's University and located in Policoro (MT, southern Italy; 40°10'20'' N, 16°39'04'' E). This site is 15 m above sea level and is characterized by sub-humid climate according to De Martonne classification (Cantore *et al*., 1987), with average annual rainfall of 560 mm distributed mainly during autumn and winter, and with maximum temperature reaching 40-42°C in the summer.

The soil, more than 1.2 m deep, was a loam. Physical and chemical characteristics of the soil were: sand (2>Ø>0.02 mm) 40%, silt 37.1%, clay (Ø<2 µ) 22.9%; pH 7.7; total N (Kjeldahl method) 1.67 g kg^{-1}, available P_2O_5 (Olsen method) 26.7 mg kg^{-1}, exchangeable K_2O (ammonium acetate method) 227 mg kg^{-1}, organic matter (Walkley-Black method) 36.4 g kg^{-1}, total limestone 15.0 g kg^{-1}, active limestone 5.0 g kg^{-1}; saturated paste extract electrical conductivity (ECe) 0.95 dS m^{-1}, ESP 1.9%; bulk density 1.25 kg dm^{-3}; soil moisture at field capacity (measured *in situ*) 31.5% and at wilting point (-1.5 MPa) 15% of soil dry weight.

Treatments and cultural practices

Two tomato (*Solanum lycopersicum* L.) cultivars, HLY 19 (Hazera Genetics Ltd, Brurim Israel, for Italy COIS'94® S.p.A., Catania) and *Perfectpeel* (Seminis Vegetable Seeds, Parma, Italy) were irrigated with water having three salinity levels (S0, S1 and S2) of electrical conductivity (EC_w) corresponding to 0.5 (i.e. control), 5 and 10 dS m-1, respectively, and applying three irrigation regimes (W1, W2 and W3) with management allowable depletion 20, 40 and 60% of available water depletion, respectively. The two saline waters (S1 and S2) were obtained by adding sea salt to the fresh water. A split plot experimental design with three replicates was established with salinity levels as main factor and the cultivars in the sub-sub plots 15 m^2 large. Tomato seedlings were transplanted at three true leaves stage on June 5th and May 12th in 2007 and 2008, respectively. Plant density was 2.7 plants m^{-2} in single rows spaced, 1.50 m between rows and 0.25 m between the plants along the row. Along the rows a black PVC mulching was applied. The soil was fertilized before transplanting with 80 and 100 kg ha^{-1} of N and P_2O_5, respectively. The irrigation was performed by polyethylene drip tubing method, placing one pipeline for each row under the mulching, when water lost by evapotranspiration (ETc) reached the 20 (W1), 40 (W2) and 60% (W3) of available water depletion in the soil layer explored by roots, with a watering volume able to restore 100% of water lost. The ETc was calculated by evopotranspirometric method, utilizing daily values of class A pan evaporation, pan coefficient equal to 0.8 (Castrignanò *et al*., 1985), and the crop coefficients reported by Tarantino and Caliandro (1984), adjusted for saline treatments (Allen *et al*., 1998). The irrigation was cut off 22-24 days before harvest (on August 29th 2007 and on August 4th 2008), according to farmers practice to improve fruits quality in terms of total soluble solids and dry matter content of fruits.

Phytosanitary control was performed by integrated pest management strategies. Moreover, weed control was performed by a mechanical hoeing in the inter-row and by hand the weeds emerged from the hole of the plastic mulch.

Climatic parameters

The main climatic parameters, including solar radiation, air temperature, relative humidity, wind speed, *class A* pan evaporation and rainfall, were provided by a standard weather station located about 50 m from the experimental field and equipped with a pyranometer (model CM 4, Kipp and Zonen, Delft, The Netherlands), thermistor (model E001, Tecno.El, Roma, Italy), hygrometer (C-83_N Rotronic, Zurich, Switzerland), anemometer (model VT 0805B, SIAP Bologna, Villanova di Castelnaso, BO, Italy), *class A* pan (NovaLynx Corporation Grass Valley, Auburn, CA, USA), and tipping bucket rain gauge (Tecno.El). The weather data were collected by the electronic system operated through a data-logger (model Kampus, Tecno.El) connected via modem to a PC.

Soil moisture and salinity

Monthly, in the S1 salinity treatment of each irrigation treatment, the moisture of 0-0.6 m deep soil layer was measured by gravimetric method in three places per plot, crosswise to the row at 0 - 0.25 - 0.5 m from the emitters.

The ECe was measured in the laboratory, on the soil samples collected through a cylindrical probe (∅ 2.5 cm) from 0-0.6 m soil layer in three places per plot, crosswise to the row at 0 - 0.25 - 0.50 m from the emitters. The measures were made at beginning, in the middle and at the end of crop cycle in S0 and S2 salinity levels and in W1 and W3 irrigation regimes.

Yield and quality

Harvest took place by hand on September 20th 2007 and on August 28th-30th 2008. The total, marketable and unmarketable (including green, blossom-end rot, cracked, green shoulder, and fruits damaged by viruses and/or pests) yields were determined.

A sample of 2-3 kg of product was taken to assess the percentage of fruits with blossom-end rot, sunburn, pest and virus attacks. On the marketable fruits, firmness, dry biomass, total soluble solids, titratable acidity, pH,

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ascorbic acid content and the morphological parameters including the mean weigh and the shape index were measured. The mean weight was calculated on a sample of 4-5 kg of fruits. The dry matter content was assessed by splitting a sample of 5-6 fruits and placing it in a ventilated oven at the temperature of 55°C till a constant weight was reached (about 48 hrs). The total soluble solids, the titratable acidity and the ascorbic acid content were determined on the sauce (using about 2 kg of fruits) obtained by liquefying fruit in a blender (1 min; 14,000 rev. min^{-1}) and then filtering all mesocarp; from a well-homogenised sauce three samples were taken for each parameter to test. Total soluble solid (TSS) content in juice was determined using a refractometer (model DBR35, XS Instruments, Poncarale, BS, Italy) and expressed as °Brix at 20ºC. Acidity was determined by titrating NaOH 0.1 M in the presence of phenolphthalein with an automatic titrating machine (Technotrate, Kartell, Noviglio, MI, Italy) until color change with the result expressed in terms of monohydrate acid. Fruit juice pH was measured using a pH meter (Acorn pH 6 Meter, Oakton Instruments, Vernon Hills, IL, USA). Ascorbic acid content was assessed with a RQflex 2 Reflectoquant® system (Merck KGaA, Darmstadt, Germany). Fruit firmness was measured on a sample of ten fruits after the skin peeling (1 mm thick); in particular, two measures were carried out at equatorial level utilizing a digital fruit firmness tester (model 53205 TR, Turoni, Forlì, FC, Italy) with a point of 3 mm of diameter.

Statistical analysis

Analysis of variance of the treatment effects on measured traits was performed using the SPSS Software package; the differences between means were analyzed with the Student-Newman-Keuls test.

Results and discussion

Climatic trend

In 2007, the climatic conditions during the growing season were very dry (Figure 1). The total amount of rainfall (20 mm) occurred almost all in the first week after planting. Daily minimum temperature (Tmin) ranged between 9.5 and 29.5°C: the lower value occurred at the end of crop cycle and the higher on August 9th, during the fruit enlargement stage. Tmin was lower than 20°C until June 20th; after this date it was almost always higher than 20°C until the end of August.

Daily maximum temperature (Tmax) ranged between 21.5 and 41.5°C. In the period between the middle of June and the end of August it was almost always higher than 30°C. Very hot days (Tmax>40°C) occurred on June 24th and 25, July 24th and August 26th (Figure 1).

Also in 2008, the growing season of tomato was characterized by very dry climate. The total rainfall was 54 mm, the 80 % of which occurred in the 1st decade of June. Tmin ranged between 12 and 29°C. The lower value occurred at beginning of crop cycle and the higher one on July 3rd, at fruit enlargement stage. Until June 10th, Tmin was lower than 20°C, afterwards it was almost always higher than 20°C. Tmax ranged between 20 and 40°C. After the middle of June it exceeded 32°C with the hottest days (38-40°C) occurring on July 8th and 15th (Figure 1).

Soil salinity

In both years, ECe in the control treatment (S0) remained stationary with values ranging around 1.2 dS m^{-1}, whereas it increased in S2 treatment as a consequence of salts distributed by irrigation (Figure 2). In the former salinity treatment, ECe increased from 1.7 to 10.6 dS m^{-1} and from 1.7 to 12.3 dS m^{-1} of S2W1, from 1.7 to 13.4 dS m^{-1} and from 1.8 to 12.1 dS m^{-1} of S2W3, in the 1st and 2nd year, respectively. The ECe mean of the whole crop cycle ranged from 1.6 to 7.9 and from 1.7 to 8.5 dS m^{-1}, in the 1st and 2nd year, respectively (Table 1).

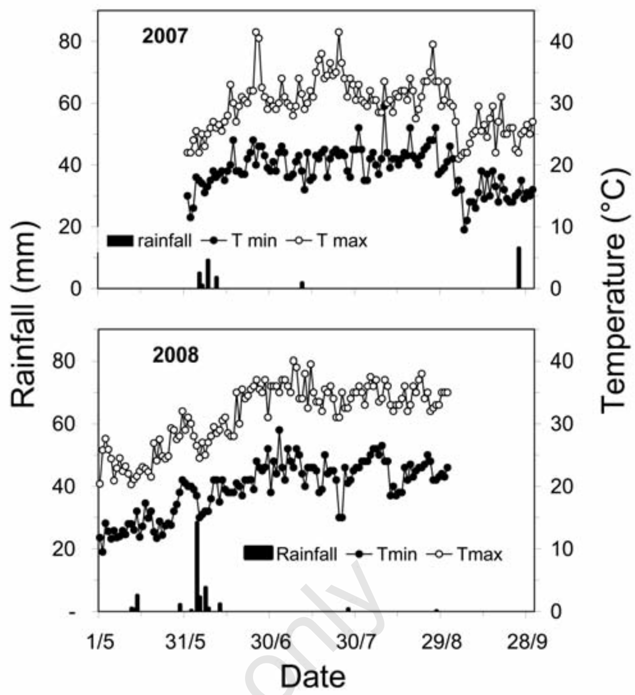

Figure 1. Daily rainfall, minimum (Tmin) and maximum (Tmax) temperature during the two crop cycles of tomato.

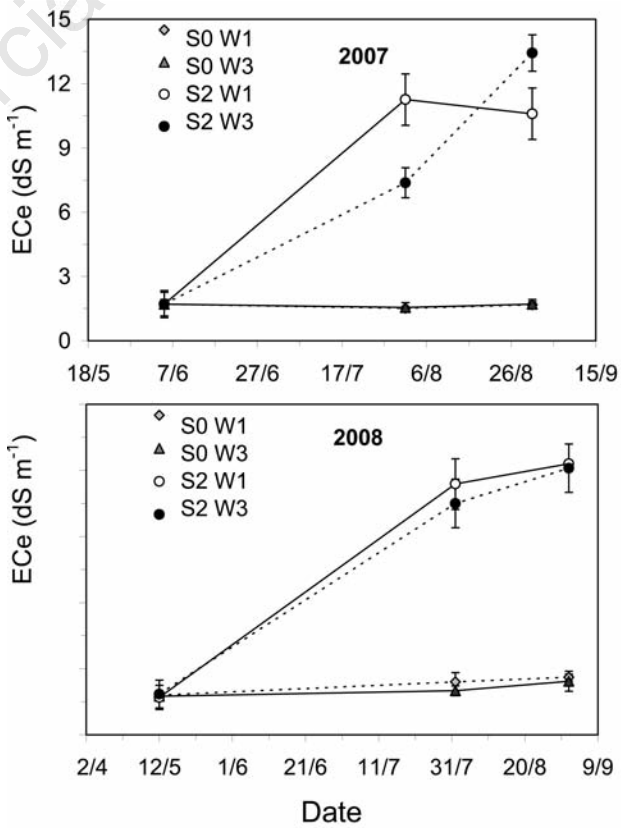

Figure 2. Soil ECe in the two salinity treatments (S0 and S2) and two irrigation regimes (W1 and W3) of the layer 0-0.6 m deep, during the tomato crop cycle. Each value represents the average between three distances from the emitter (0, 0.25 and 0.5 m) and three replicates. Vertical bars shown ± SD.

Yield and quality

Marketable yield was 24% higher in 2008 in respect to 2007 whereas total yield remained unchanged (Table 2). Salinity and irrigation regimes treatments affected tomato yield. Total and marketable yield decreased respectively by 49 and 55% between S0 and S2. The irrigation regimes that provided higher total and marketable yield were W2 and W3 (on average, 90.5 and 58.1 Mg ha^{-1} against 85.3 and 55.5 Mg ha^{-1} of W1).

Saline and irrigation treatments did not affect sunburned fruits, while affected incidence of fruits with blossom-end rot (BER) (Table 2). The former disease appeared more dramatically in saline treatments (+28%) respect to the control, mainly in *HLY19* that is a cultivar with elongated fruits. Moreover, the disease incidence was by 52% lower in W2 in respect to W1 and W3. These results are in agreement with the literature data. The blossom-end rot is related to the ionic imbalances caused by Na^{+}/Ca^{2+} competition (Grattan and Grieve, 1999). This disease, occurring more frequently in the tomato cultivar with elongated fruits (Adams and Ho, 1992; 1995; Belda and Ho, 1993; Cantore *et al*., 2008), apart from the high environmental evaporative demand (Adams and Ho, 1993; Ho and White, 2005), is favoured by water and/or saline stress (Adams and Ho, 1992; Max and Horst, 2009). Higher incidence of BER, happened in W1 and W3, is ascribed to i) temporary conditions of root asphyxia for W1, that occurred because of frequent watering and consequent water and nutritional imbalance; ii) short periods of water stress because of less frequent watering and greater allowable depletion for W3.

Yield decrease caused by salinity is ascribed mainly by the fruit weight decrease. In fact, the salt stressed tomato reduces yield initially through the lowering of fruit size and then decreasing their number (van Ieperen, 1996; Cuartero and Soria, 1997).

Moreover, reporting the relative marketable yield values vs the soil ECe mean for the whole crop cycle, we can conclude that these values are in agreement with the Maas and Hoffman (1977) model of tomato as reported by Francois and Maas (1994). In fact, tomato crop is moderately sensitive to salinity with the ECe threshold equal to 2.5 dS m^{-1} and slope of 9.9 % dS^{-1} m (Maas, 1986). Instead, salinity tolerance can change related to the plant intrinsic factors (cultivar), or external factors (soil and climatic conditions) related to phenological stage and the length of salt stress (Ehret and Ho, 1986; Adams, 1986; van Ieperen, 1996).

Shape index was different for two cultivars (2.1 for *HLY19* and 1.2 for *Perfectpeel*) as expected and lasted unchanged in relation to the saline and irrigation treatments. Fruit firmness was higher in 2008, in *HLY19* and in S0, whereas it was not affected by irrigation regimes (Table 3). Total soluble solids and dry matter content of tomato fruits were higher in 2007 and were enhanced by increasing salinity level, whereas they were not affected by irrigation regimes and cultivar (Table 4).

The results confirmed that the use of brackish water improve tomato quality traits as total soluble solids and dry matter (Mizrahi and Pasternak, 1985; Plaut, 1997; Cucci *et al*., 2000; Cantore *et al*. 2001; Incerti *et al*., 2007; Magàn *et al*., 2008; Wu and Kubota, 2008; Segura *et al*., 2009) and reduce firmness (Sharaf and Hobson, 1986). The pH and the titratable acidity remained unchanged in two experimental years, for different cultivars and saline and irrigation treatments. Similarly to the last parameters, fruit ascorbic acid content remained unchanged in relation to the treatments, but it was higher in *HLY19*.

Table 1. ECe ±SD, mean of crop cycle of different salinity and water regime treatments, in two experimental years.

Treatments	Years 2007	2008
S0 W1	1.64±0.12	2.27±0.15
S0 W3	1.66±0.84	2.06±0.68
S2 W1	7.85±1.00	8.46±1.15
S2 W3	7.50±1.36	8.15±0.99

Table 2. Yield and damaged tomato fruits by blossom-end rot and sunscald for different years, salinity levels, irrigation regimes and cultivars.

Treatments	Yield Total (Mg ha^{-1})	Marketable (Mg ha^{-1})	Blossom end rot (%)	Sunscald (%)
Years				
2007	87.8	51.0 ^{b}	2.3 ^{b}	3.0 ^{a}
2008	89.6	63.5 ^{a}	3.6 ^{a}	2.3 ^{b}
Salinity				
S0	121.5 ^{a}	82.2 ^{a}	2.5 ^{b}	2.7
S1	82.5 ^{b}	52.4 ^{b}	3.2 ^{a}	2.9
S2	62.1 ^{c}	37.1 ^{c}	3.2 ^{a}	2.4
Irrigation regime				
W1	85.3 ^{b}	55.5 ^{b}	3.2 ^{a}	2.6
W2	91.7 ^{a}	59.0 ^{a}	1.7 ^{b}	2.5
W3	89.2 ^{a}	57.2 ^{a}	3.9 ^{a}	2.8
Cultivar				
HLY19	81.1 ^{b}	51.0 ^{b}	4.9 ^{a}	2.2 ^{b}
Perfectpeel	96.4 ^{a}	63.4 ^{a}	1.1 ^{b}	3.1 ^{a}
Significance				
Y	ns	*	*	*
S	**	**	*	ns
IR	*	*	*	ns
C	**	**	**	*
Interactions (Y·S; Y·IR; Y·C; S·IR; S·C; IR·C; Y·S·IR·C)	ns	ns	ns	ns

Y, year; S, salinity; IR, irrigation regime; C, cultivar; ^{a,b,c}values followed by different letters within columns are significantly different by SNK test, P<0.05; ns, F test not significant; *F test significant at P<0.05 and **P<0.01.

Table 3. Morphological characteristics of tomato fruits for different years, salinity levels, irrigation regimes and cultivars.

Treatments	Mean weight (g)	Length (a) (mm)	Width (b) (mm)	Shape index ($a\ b^{-1}$)	Firmness ($kg\ cm^{-2}$)
Years					
2007	54.2	62.3 [a]	44.7 [a]	1.4 b	4.4 [b]
2008	52.9	45.0 [b]	25.4 [b]	1.8 a	5.1 [a]
Salinity					
S0	65.9 [a]	58.5 [a]	38.4 [a]	1.6	5.2 [a]
S1	53.8 [b]	54.2 [b]	35.5 [ab]	1.6	4.7 [ab]
S2	41.1 [c]	48.3 [c]	31.3 [b]	1.7	4.4 [b]
Irrigation regime					
W1	52.7 [b]	52.9 [b]	35.3	1.6	4.9
W2	57.0 [a]	56.2 [a]	35.3	1.7	4.7
W3	51.1 [b]	51.9 [b]	34.5	1.6	4.7
Cultivar					
HLY19	51.0 [b]	61.1 [a]	30.5 [b]	2.1 [a]	5.4 [a]
Perfectpeel	56.2 [a]	46.2 [b]	39.6 [a]	1.2 [b]	4.2 [b]
Significance					
Y	ns	*	*	*	*
S	**	*	*	ns	*
IR	*	*	ns	ns	ns
C	*	**	*	**	*
Interactions (Y·S; Y·IR; Y·C; S·IR; S·C; IR·C; Y·S·IR·C)	ns	ns	ns	ns	ns

Y, year; S, salinity; IR, irrigation regime; C, cultivar; [a,b,c]values followed by different letters within columns are significantly different by SNK test, P<0.05; ns, F test not significant; *F test significant at P<0.05 and **P<0.01.

Table 4. Quality characteristics of tomato fruits for different years, salinity levels, irrigation regimes and cultivars.

Treatments	Total soluble solids (°Brix)	Ascorbic acid ($mg\ 100\ mL^{-1}$ juice)	Titratable acidity (g citric acid $100\ mL^{-1}$ juice)	pH	Dry matter ($g\ 100\ g^{-1}$ fw)
Years					
2007	7.0 [a]	28.3	0.3	4.4	8.0 [a]
2008	5.4 [b]	29.5	0.3	4.6	6.4 [b]
Salinity					
S0	5.7 [b]	29.4	0.3	4.5	6.6 [b]
S1	6.2 [a]	29.0	0.3	4.5	7.3 [a]
S2	6.7 [a]	28.4	0.3	4.5	7.7 [a]
Irrigation regime					
W1	6.2	30.2	0.3	4.5	7.2
W2	6.3	28.0	0.3	4.4	7.2
W3	6.2	28.6	0.3	4.5	7.1
Cultivar					
HLY19	6.4	34.0 [a]	0.3	4.5	7.3
Perfectpeel	6.0	23.8 [b]	0.3	4.4	7.1
Significance					
Y	*	ns	ns	ns	*
S	**	ns	ns	ns	**
IR	ns	ns	ns	ns	ns
C	ns	*	ns	ns	ns
Interactions (Y·S; Y·IR; Y·C; S·IR; S·C; IR·C; Y·S·IR·C)	ns	ns	ns	ns	ns

Y, year; S, salinity; IR, irrigation regime; C, cultivar; [a,b]values followed by different letters within columns are significantly different by SNK test, P<0.05; ns, F test not significant; *F test significant at P<0.05 and **P<0.01.

The results of this research did not show any variation of optimal water depletion fraction in saline condition contrary to the literature information. In fact, the literature reported that the osmotic stress, due to the soil salinity, interferes with water availability and that optimal water depletion fraction in saline condition decreases and depends also on the crop yield characteristics (Allen *et al*., 1998) which is in agreement with the results obtained on artichoke crop at the same experimental site (Boari *et al*., 2012). The results of this trial demonstrate that tomato irrigated with saline water needs watering less frequently. Maximum water depletion fractions were 40% and 60% of total soil available water to preserve total and marketable yield, respectively.

Conclusions

The salt tolerance of tomato cultivar utilized in this trial resulted in agreement with that reported by Francois and Maas (1994). Salinity improved fruit quality, but caused blossom-end rot, and the cultivar mostly susceptible was *HLY19* with elongated fruits.

The results of this work demonstrated that the thresholds of easily available water to preserve total and marketable yield of tomato crop were 40 and 60 %, respectively. These results are in disagreement with Allen *et al*. (1998) that stated a lower value of soil water depletion by increasing soil salinity, as a consequence of higher osmotic stress. Watering more frequently, instead, on the soil type of the trial, probably causes waterlogging and root hypoxia affecting negatively tomato yield. In fact, tomato is a species very sensitive to the soil hypoxia (Bray *et al*., 2001; Jackson *et al*., 2003; Ahsan *et al*., 2007; Vidoz *et al*., 2010). Therefore, the non-interaction between the salinity level and the watering regime can be attributed to the soil structure deterioration that happened by increasing salinity, that worsened further by watering more frequently. In fact, the most appropriate irrigation scheduling should be decided after the testing several solution with respect to the soil type, cultivar and environmental conditions.

Finally, it is worthwhile to point out that in W1 and W3 happened higher incidence of blossom-end rot that could be explained by i) temporary conditions of root asphyxia for W1, occurred because of frequent watering and water and nutritional imbalance; and ii) short periods of water stress due to greater allowable depletion and less frequent irrigation for W3.

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