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Effect of Drip or Subirrigation on Growth and Yield of *Solanum melongena* L. in Closed Systems with Salty Water

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Abstract: The study was aimed at evaluating the response of eggplant (*Solanum melongena* L.) to drip or subirrigation in the spring-summer typical growing conditions of the Mediterranean area, where salty water is often used. Four F_1-hybrids (Talina, Nilo, Birgah and Black Bell) were grown into pots in trough benches in a recirculating water system. The EC value of the nutrient solution, prepared using NaCl-enriched water (10 mM), was 3.2-3.5 dS m^{-1} until the first fruit harvest and reduced to 2.3-2.5 dS m^{-1}afterwards; the salinisation induced a nutrient solution turnover whenever the EC value exceeded 7.0 dS m^{-1}. Nutrient solution supply with drip irrigation was 32% more than with subirrigation, due to runoff and the need of a more frequent complete renewal. As a consequence, subirrigation allowed a higher fertigation efficiency (91 vs 79%) and an easier and cheaper management of the nutrient solution; nevertheless, the water use efficiency referred to the fruit yield was similar with both the irrigation methods, since the higher water supply with drip irrigation was counterbalanced by the significant higher yield (roughly +50%) compared with subirrigation, which caused a very high accumulation of salts in the upper layer of the substrate. These results suggest that subirrigation of eggplant may be problematic with high water EC, due to high water requirements of this species.

Key words: Aubergine, eggplant, greenhouse, nutrient solution, soilless culture

INTRODUCTION

In the recent years, an increasing interest in the soilless culture for eggplant (*Solanum melongena* L.) occurred (Savvas and Lenz, 2000; Venezia *et al.*, 1999). Closed loop systems allow more efficient and environmental friendly production, limiting water and nutrient losses, in comparison with open growing systems (Van Os, 1994) nevertheless, with salty water the recirculating nutrient solution must be periodically replaced, due to the excessive accumulation of salts, potentially toxic, with consequent waste of water and nutrients (Van Os and Stanghellini, 2001). In the Mediterranean regions, water is limited and often with a high salt content, especially NaCl. According to some authors, there is no advantage to the growers in maintaining a closed loop whenever the quality of irrigation water is poor (Stanghellini *et al.*, 2004). Nevertheless, irrigation with saline water is successfully practiced in many countries, being sustainable if the salt concentration in the soil is kept below a threshold value specific for each species. Among the closed loop systems, different subirrigation methods (ebb-and-flow, capillary mat, trough benches, flooded floors, wick culture) have been proposed for containerized crops instead of the more widely used drip irrigation, since they result in a substantial water, fertilizer and labour saving, water is applied uniformly and do not require disinfection (Molitor, 1990; Son *et al.*, 2006; Uva *et al.*, 1998). Furthermore, drip and subirrigation have a different impact on the environment, due to the various needs of the substitution of the nutrient solution and the incidence of runoff. In the subirrigated plants accumulation of excess fertiliser can occur if the nutrient solution is too concentrated, because the growing medium is not leached during the production. Thus, subirrigation systems commonly use lower fertiliser concentrations than overhead irrigation systems (Kent and Reed, 1996; Iersel, 1999). Drip irrigation and subirrigation determine different stratification of salts in the growing medium, that are concentrated at the bottom with the first method and at the top with the second (Morvant *et al.*, 1997; Santamaria *et al.*, 2003). Some authors pointed out the suitability of subirrigation in a closed soilless system when available water is salty, for the concentration of the salts in the upper layer of the medium does not affect the

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growth of the plant, being roots in this layer much less than in the lower portion (Elia *et al.*, 2003). Other authors, on the contrary, suggest that drip irrigation should be preferred when using saline water, since evaporation can cause salt accumulation to toxic levels into the substrate (Colla *et al.*, 2003; Rouphael *et al.*, 2006). Satisfactory results were obtained with many subirrigated ornamental and vegetable crops characterised by short growing cycle and/or low salinity of the nutrient solution (Cox, 2001; Dole *et al.*, 1994; Incrocci *et al.*, 2006; Kang and Iersel, 2002; Todd and Reed, 1998) whereas reduction in plant growth and yield was observed on vegetable crops with long cycle and in hot dry conditions, due to the high evaporative demand and the high salt accumulation in the upper portion of the root zone (Rouphael and Colla, 2005; Venezia *et al.*, 2003).

Eggplant is an important vegetable crop in the Mediterranean area, considered moderately sensitive to salinity by some authors (Maas and Hoffman, 1977), moderately tolerant or tolerant by others, who found that the threshold of water EC ranged from 1.4 dS m^{-1} to 4.9 dS m^{-1} increasing the irrigation frequency (Barbieri *et al.*, 1994). Such different findings are due to different environmental, pedological and biological conditions, interacting with salinity in the growth response of the crop. Variable salt tolerance among cultivars was also observed (Yasar *et al.*, 2006). In field experiments, eggplant fruit yield was reduced at the rate of 6.9% per unit increase of the EC of the soil saturation extract over 1.1 dS m^{-1} (Heuer *et al.*, 1986); in other trials a 50% reduction in yield was obtained at 8.5 dS m^{-1} of the soil saturation extract (Shalhevet *et al.*, 1983). Savvas and Lenz (2000) observed a significant reduction (22-23%) of the fresh fruit yield of hydroponically grown eggplants raising the nutrient solution EC from 2.1 up to 4.7 dS m^{-1}, irrespective of the kind of salts in excess; this suggested that the detrimental effects of salinity were osmotic in origin, not ion specific (Shannon and Grieve, 1999; Munns, 2002).

Other trials pointed out that salty water with EC 6.0 dS m^{-1} can be successfully applied for eggplant in soilless culture, if the salt accumulation in the medium is kept under 4 dS m^{-1}, eventually by leaching, especially at flowering and fruit setting growth stages, that are the most sensible (Hamdy *et al.*, 2004). Some experiments pointed out the suitability of eggplant to subirrigation by using good quality water (Venezia *et al.*, 1999, 2001). This research, on the contrary, was aimed at comparing subirrigation with drip irrigation on different cultivars of eggplant in a closed soilless culture with saline water, typical of the Mediterranean area.

MATERIALS AND METHODS

Plant material and growing conditions: Four F_1-hybrids of *Solanum melongena* L. (Talina and Nilo with elongated fruits, Birgah and Black Bell round fruited) were grown in a recirculating water system in a heated PMMA covered greenhouse at the Centre for Advanced Technologies in Greenhouse (Ce.T.A.S.), University of Milan (North Italy). Seedlings at the four leaf stage (55 days old) were potted at the beginning of April 2004 into 12 L-plastic pots (26 cm diameter), containing sphagnum peat adjusted with $CaCO_3$ (3 kg m^{-2}) and spaced 75 cm apart (2.2 plants m^{-2}) in troughs 12×0.25×0.07 m, slope 1%, covered with a black-white polyethylene film in order to prevent the exposure to the light and the evaporation of the nutrient solution. The plants were vertically trained into three stems by means of nylon supporters.

Drip irrigation was compared with subirrigation, according to a split-plot experimental design, irrigation systems being in the whole plots and cultivars in the plots; there were four blocks and 8 replicates, 256 plants in all.

The minimum and ventilation air temperatures were set at 18 and 24°C, respectively and cooling system was activated at 28°C. Automatically shading 50% at 700 Watt m^{-2} and additional shading up to 75% at 900 Watt m^{-2} occurred.

Drip irrigation was applied indistinctly to all the plants for three weeks after potting, in order to stimulate the deep root growth; afterwards, different irrigation systems were performed. Drip irrigation was realized through three emitters per pot (flow rate of 6 L h^{-1}). Watering timing (2-9 times/day) and dose (0.5-5.0 L m^{-2}) varied on the basis of solar radiation: each irrigation occurred when cumulated global radiation exceeded 50 J cm^{-2}, being 90 min the minimal interval between two applications and lasted 30 min on average. In the subirrigation treatment, the pots were flooded and allowed to absorb the nutrient solution (flow rate of 3 L min^{-1}) before the excess was discarded. Supply timing was the same as in the drip irrigation treatment, but duration was variable and gradually reduced from 30-5 min during the growing cycle. In both the irrigation methods, the exceeding solution was drained back to indipendent tanks, refilled with newly prepared nutrient solution if needed and recirculated. The solution was discharged and completely renewed whenever the EC value exceeded 7.0 dS m^{-1}.

The nutrient solution, prepared using NaCl-enriched water (10 mM), had the following macronutrient (mM) and micronutrient (μM) concentration until the first harvest: N-NO_3(8.21), N-NH_4 (1.37), P (1.33), K (4.07), Ca (4.26), Mg

(0.93), S (2.04), Fe-EDTA (44.0), Mn (22.38), Cu (4.72), Zn (14.0), B (16.45), Mo (0.19), Co (0.1). The pH of the solution was maintained between 5.5 and 6.0 and EC was 3.2-3.5 dS m^{-1}, that is a common value in many Mediterranean cultivations as a consequence of the high salinity of the available water. During the harvesting period, the nutrient solution was diluted and EC value was reduced to 2.3-2.5 dS m^{-1}. The micronutrient concentration of this second nutrient solution, still enriched by NaCl (10 mM), was the same of the first one, whereas the macronutrient concentration was modified as follows (mM): N-NO_3 (3.64), P (1.15), K (1.15), Ca (2.2), Mg (0.7), S (0.5).

At flowering, plants were daily shaked in order to improve fruit set. Fruit harvest started at the end of June and was repeated weekly until the beginning of August (six harvests).

Measurements: At every harvest we measured: number, length, diameter (maximum diameter of the equatorial section on the longitudinal axis) and weight of fruits, graded as marketable or not and incidence of blossom-end rot. Fruits were considered marketable when they were health, without cracks and weighing more than 150 g. Harvest index was calculated both as marketable yield/shoot vegetative fresh weight and total yield/shoot vegetative fresh weight ratios. At the end of the trial, the plant height (from the medium surface to the top of the plant), number and size (length and width) of the leaves, fresh and dry weight of leaves and stems were measured on two plants per plot.

As regards the nutrient solution, the volume, pH, EC and ion concentration of the refill water, of the discharged solution and the recirculating solution were systematically measured. Furthermore, at the end of the trial, pH, EC and mineral content of the aqueous extracts of the growing medium (substrate:deionized water 1:1.5, v/v) sampled at three different depths (upper, medium and lower layer), from which major roots were removed, were detected (Sonneveld *et al.*, 1974). N was determined by a flow analyser Foss Tecator Fiastar 5000; P was estimate colorimetrically as phosphomolybdate blue complex at 650 nm; Ca, Mg, K and Na were determined by atomic absorption spectrophotometry at 422.7, 285.2, 766.5 and 589 nm, respectively.

Statistical analysis: The collected data were subjected to analysis of variance based on a split-plot design model and when a significant F-test was obtained, means were separated according to Duncan's Multiple Range Test. All statistical analysis were carried out using MSTAT-C software (Michigan State University).

RESULTS AND DISCUSSION

Plant growth and yield: All the plants showed a high growth rate, as observed in other similar experimental conditions (Venezia *et al.*, 1999) nevertheless, significant differences among cultivars and between irrigation systems were observed (Table 1). Plants of 'Black bell' showed the highest leaf number and size. Regarding plant height, higher values were observed in 'Nilo' and 'Black bell'; 'Birgah', on the contrary, showed the lowest growth. Plants of all cultivars presented higher growth with the drip irrigation system in comparison with subirrigation. In fact, plants grown with drip irrigation were taller (on the average, +15%) and with a higher number of leaves (+27, 20 and 10%, respectively, in Birgah, Black bell and Talina, Nilo, on the contrary, presented the same number of leaves in both the irrigation treatments). Moreover, leaves were wider (about +50% in Black bell, +30% in other cultivars), longer (on the average, +21%) and weightier, both as fresh and dry matter; also fresh and dry stem weight was significantly higher in drip irrigated plants, with some differences among cultivars. Differences among genotypes might be due to a variable sensitivity to the high salinity of the medium with subirrigation, being the reduction in leaf and plant growth the first phase of plant response to salinity (Munns, 2002).

Fruit yield parameters were also affected by genotypes and irrigation treatments (Table 2). Birgah, followed by Talina, gave the highest yield, both in marketable and small fruits. It is remarkable that, except in 'Nilo' subirrigated, the mean weight of small fruits was always above 100 g, that is the minimum standard value accepted by markets (UNECE, 2000) so, most of such fruits, albeit small, would have been considered marketable if our criteria for selection had been less severe. The mean weight of marketable fruits was significantly separated between the globus and elongated types. The same remark applies to fruit size nevertheless, differences within each type arose, being the fruits of the oblong fruited Nilo longer and narrow than in Talina and the fruits of the round fruited Birgah shorter and larger than in Black bell. Number of fruits was significantly lower in Black bell in comparison with other genotypes.

Drip irrigation promoted fruit setting and growing in all the cultivars, confirming analogous results obtained by other authors on tomato, snap bean and zucchini squash (Rouphael and Colla, 2005; Santamaria *et al.*, 2003; Scholberg and Locascio, 1999; Venezia *et al.*, 2003). In fact, with drip irrigation the marketable yield was roughly 50% more than with subirrigation, while total fruit yield was only about 35% more; this means that the proportion of marketable fruits on the total yield was significantly

Table 1: Growth parameters obtained at the end of the trial (mean separation within column by Duncan's test: $p<0.05$, small letters; $p<0.01$: capital letters)

Cultivar	Treatment	Plant height (cm)	N° leaves per plant	Leaf width (cm)	Leaf length (cm)	Leaf fresh weight (g/plant)	Leaf dry weight (g/plant)	Stem fresh weight (g/plant)	Stem dry weight (g/plant)
Birgah	Subirrigation	115 gE	108 deDE	20.6 D	27.8 d	342.5 fE	46.2 D	475.8 F	85.2 C
	Drip irrigation	130 fD	137 bB	27.0 B	34.2 bc	556.0 bcBC	68.1 BC	720.6 C	115.3 B
Black bell	Subirrigation	163 dB	138 bB	21.8 C	32.8 bc	541.3 cC	66.3 BC	650.5 D	96.3 C
	Drip irrigation	187 bA	166 aA	32.4 A	39.6 a	772.4 aA	92.7 A	995.8 A	136.4 A
Talina	Subirrigation	143 eC	97 fE	20.9 D	29.3 cd	368.2 eE	42.3 D	560.3 E	93.6 C
	Drip irrigation	170 cB	107 eDE	26.8 B	36.0 ab	570.4 bB	64.0 BC	710.2 C	117.9 B
Nilo	Subirrigation	172 cB	117 cdCD	20.6 D	30.4 cd	452.5 dD	57.2 CD	565.4 E	101.2 BC
	Drip irrigation	193 aA	125 cC	27.0 B	36.0 ab	568.8 bB	73.4 B	785.5 B	136.7 A

Table 2: Yield parameters (mean separation within column by Duncan's test: $p<0.05$, small letters; $p<0.01$: capital letters)

		Marketable fruits (>150 g)				Small health fruits		Total yield			
Cultivar	Irrigation	Yield ($kg\ m^{-2}$)*	N° m^{-2} *	Weight (g)	Length (cm)	Diameter (cm)	Yield ($kg\ m^{-2}$)*	N° m^{-2} *	°Weight (g)	Weight ($kg\ m^{-2}$)*	N° m^{-2} *
Birgah	Sub	4.20 B	16.0 B	262.5 A	7.2 hG	9.5 A	3.14 C	28.2 A	111.3 B	7.34 B	44.2 B
	Drip	6.30 A	22.4 A	281.3 A	7.9 gF	9.7 A	3.67 A	25.0 BC	146.8 A	9.97 A	47.4 A
Black bell	Sub	2.63 C	10.5 C	250.5 A	11.6 fE	8.0 B	0.99 H	8.6 E	115.1 B	3.62 F	19.1 F
	Drip	3.94 B	14.7 B	268.0 A	12.2 eDE	8.3 B	1.15 G	10.2 E	112.8 B	5.09 DE	24.9 E
Talina	Sub	2.92 C	15.5 B	188.4 B	12.8 dD	7.0 C	2.89 D	26.6 AB	108.6 B	5.81 D	42.1 BC
	Drip	4.38 B	21.7 A	201.8 B	14.3 bB	6.4 D	3.37 B	23.1 C	146.5 A	7.75 B	44.8 AB
Nilo	Sub	2.56 C	15.0 B	170.7 B	13.6 cC	6.1 DE	1.90 F	22.3 C	85.2 C	4.46 EF	37.3 D
	Drip	3.84 B	21.0 A	182.9 B	16.2 aA	5.9 E	2.22 E	18.7 D	118.7 B	6.06 CD	39.7 CD

* Total yield of six harvests

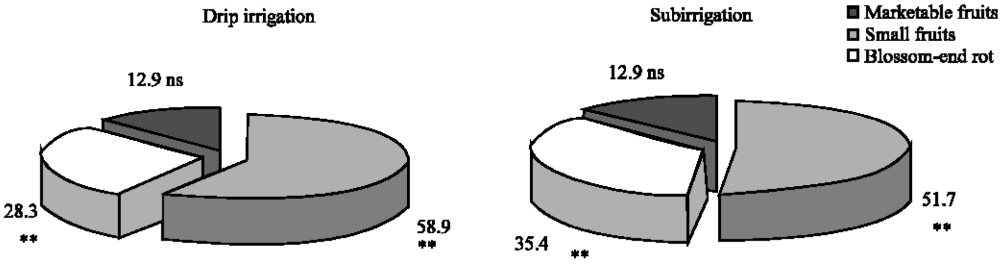

Fig. 1: Percentage (fresh weight) of marketable fruits, small fruits and fruits with blossom-end rot in relation to the irrigation system (mean separation within sector between irrigation systems by Duncan's test, $p<0.01$)

higher with drip irrigation in comparison with subirrigation, as shown on Fig. 1. The occurrence of blossom-end rot (Fig. 1), on the contrary, was unaffected by the irrigation method and was rather high, probably stimulated by the unfavourable environmental conditions and by salinity, that evoke oxidative stresses (Aktas *et al.*, 2003; Saure, 2001). On the whole, harvest index, both as marketable yield/shoot vegetative fresh weight and as total yield/shoot vegetative fresh weight ratios, was unaffected by irrigation method; Birgah presented the highest values (Table 3).

The number of marketable fruits was enhanced by drip irrigation (on average, by 40%), whereas small fruits were reduced (about -13%), except in Black bell, that produced few small fruits regardless of the irrigation system (Table 2). Total fruit number was enhanced by drip irrigation by about 6.5% in all the varieties, with exception of Black bell, in which the increasing was about 30%.

The weight of marketable fruits was not influenced by the irrigation system, the weight of small fruits, on the contrary, was increased by drip irrigation, except in Black bell (Table 2). As regards fruit size, drip irrigation reduced diameter only in Talina; length was generally reduced by subirrigation. This tendency to round form was observed in eggplant by other authors when using salty water (Barbieri *et al.*, 1994), in our experiment these findings might be due to the different salinity of the medium with drip or subirrigation.

The harvesting period was short (6 weeks), because fruit setting and yield soon declined, as a consequence of the unfavourable climatic conditions, being eggplant very sensitive to temperature, humidity and radiation stresses (Nothmann, 1986; Sun *et al.*, 1990). In fact, in spite of the microclimatic parameter control, maximum temperature often reached up to 32-35°C and relative humidity reached up to 85-90% for long periods; moreover, although the global radiation was rather high, the abundant growth of the above-ground portion caused shading of the lower part of the plant. Especially in the latest two harvests, in the hottest period of summer, fruit set was drastically reduced, albeit the plants were still full growing and both irrigation systems were equally unsatisfactory (Fig. 2). On the other hand, similar short cycle was observed in other trials carried out in the Mediterranean regions (Hamdy *et al.*, 2004). Furthermore, the high salinity of the nutrient solution can explain the low marketable fruit yield, in spite of the high vegetative growth, regardless of the irrigation system. In fact, the fresh fruit yield of eggplant is affected by the salt concentration of the nutrient solution more than the vegetative growth, in consequence of a restriction of water accumulation in the fruit; moreover, salinity increases the proportion of undersized fruit yield, being the fresh fruit weight the more sensitive parameter (Savvas and Lenz, 2000).

Use and analysis of recycling solution: The managing of the nutrient solution in the closed-loop systems considered in this study is synthesized in Table 4. Nutrient solution supplied with drip irrigation was 32% more than with subirrigation, due to runoff and frequent substitutions. In fact, with drip irrigation EC of the nutrient solution raised up to the threshold value (7 dS m^{-1}) starting from one month after preparation and it was replaced with freshly solution 5 times during the growing cycle (every 2-3 weeks during the fruit set period), whereas with subirrigation only one solution renewal was necessary three months after the preparation. As a consequence, subirrigation allowed a bigger fertigation efficiency (91% of the solution distributed was uptaken by the plants with subirrigation, vs 79% with drip irrigation) and a minor environment pollution. In an analogous experiment, using a low salinity nutrient solution with EC 2.0 dS m^{-1} in the first period and EC 0.9 dS m^{-1} subsequently, eggplant was grown in a closed subirrigation system for 280 days without any discharge of the nutrient solution (Venezia *et al.*, 2001).

Despite the greater water consumption with drip irrigation, the water use efficiency referred to the fruit yield (weight of all health fruits above 100 g per solution liter) was similar with both the irrigation methods. This means that the higher water supply with drip irrigation was counterbalanced by the significant higher yield compared to subirrigation. These results agree with the findings of Colla *et al.* (2003) on zucchini squash irrigated with saline water; on the contrary, the same authors reported a better water use efficiency with subirrigation than with drip irrigation when good quality water was used (Rouphael and Colla, 2005). On average, 65 L and 63 L of nutrient solution were necessary to produce 1 kg of fruits with sub and drip irrigation, respectively; the high plant growth and the wide leaf surface justify this high water consumption, in agreement with the findings of other authors (Sarker *et al.*, 2005).

The pollutant aspects associated with the two irrigation methods must be taken into consideration. At the end of the growing cycle, with the exception of N and P, the ion concentration of the recirculating solution increased compared with the initial value of mineral elements in the solution, probably as a consequence of the reduced nutrient uptake by the crop (Table 4). Ion concentration in the drainage or residue solution was significantly higher with drip irrigation than with subirrigation; especially, the highest differences concerned Na^+, Ca^{2+} and Mg^{2+}.

Table 3: Harvest index of cultivars drip- or subirrigated (mean separation by Duncan's test, p=0.05)

	Marketable yield/shoot f.w.		Total yield/shoot f.w.	
Cultivar	Sub	Drip	Sub	Drip
Birgah	2.33 a	2.24 a	4.08 a	3.55 a
Black bell	1.00 b	1.01 b	1.38 c	1.31 c
Talina	1.43 b	1.56 b	2.84 b	2.75 b
Nilo	1.14 b	1.29 b	1.99 c	2.03 c

Table 4: Nutrient solution use and mean value of ion concentration in the drainage solution (drip irrigation) or residue (subirrigation)

	Subirrigation	Drip irrigation	Significance
Solution supply (L m^{-2})	◂ 342	◂ 450	p<0.01
Solution discarded (L m^{-2})	◂ 31	◂ 95	p<0.01
Solution uptake (%)	◂ 91	◂ 79	p<0.01
Yield solution use efficiency (g L^{-1})	◂ 15.5	◂ 16.0	n.s.
°Mean ion concentration in the drainage solution (drip) or residue (sub) (mmol L^{-1}):			
Na+	◂ 13.53	◂ 20.67	p<0.01
K+	◂ 7.44	◂ 7.62	n.s.
Ca^2+	◂ 5.28	◂ 7.65	p<0.01
Mg ^{2}+	◂ 1.41	◂ 2.14	p<0.01
N-NO_3^-	◂ 3.00	◂ 3.36	n.s.
P-$H_2PO_4^-$	◂ 0.26	◂ 0.42	n.s.

Table 5: Analysis of the aqueous extract (1:1.5, v/v) of three substrate layers at the last harvest (mean separation within column by Duncan's test, p = 0.05: Small letters; p = 0.01: Capital letters)

Treatment	Substrate layer	EC (mS cm^{-1})	pH	N-NO$_3^-$ (mmol L^{-1})	P-H$_2$PO$_4^-$ (mmol L^{-1})	K+ (mmol L^{-1})	Na+ (mmol L^{-1})	Ca^2+ (mmol L^{-1})	Mg^{2}+ (mmol L^{-1})
Subirrigation	Upper	15.09 A	5.22 dE	14.21 A	0.90 A	22.54 A	80.75 aA	25.50 A	10.00 A
	Medium	6.37 B	6.03 cD	5.19 B	0.25 B	11.39 B	33.39 bB	6.90 B	2.38 B
	Lower	2.35 D	7.25 aA	1.68 C	0.07 C	4.92 C	11.34 dC	1.70 C	0.62 C
Drip irrigation	Upper	3.14 C	7.08 aAB	1.78 C	0.28 B	5.75 C	17.90 cC	1.89 C	0.70 C
	Medium	3.10 C	6.83 bBC	1.69 C	0.25 B	5.50 C	16.69 cdC	1.70 C	0.69 C
	Lower	3.10 C	6.73 bC	1.75 C	0.25 B	5.20 C	18.01 cC	1.74 C	0.69 C

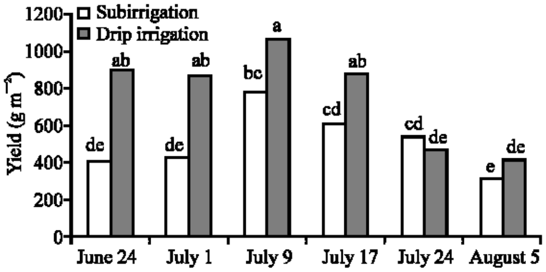

Fig. 2: Marketable fruits (g m^{-2}) harvested during the growing cycle with the two irrigation systems (mean sepration by Duncan,s test, $p<0.05$)

The analysis of the aqueous extracts of the substrate sampled at three depths at the end of the trial showed a different distribution of salinity in relation to the irrigation methods (Table 5). With drip irrigation, in all the cultivars ion concentration and EC were similar and relatively low, in all the volume of the substrate; only pH was a little higher in the near-surface depth in comparison with the underlying layers. With subirrigation, on the contrary, ion concentration and EC increased from the bottom to the top of pots, in consequence of the upward flow of the water; in the deeper layer, salinity with subirrigation was similar to the salinity of the substrate drip irrigated, whereas in the middle and upper layers the values were very higher. As a matter of fact, EC in the middle layer almost reached the threshold value, whereas in the upper layer it was so excessive, to be completely inadequate to allow the root growth. In the pots subirrigated roots were concentrated at the bottom, whereas with drip irrigation they were uniformly distributed in all the volume of the substrate; this fact can justify the better performance of drip irrigated plants.

CONCLUSION

Subirrigation is a very interesting method for its low environmental impact: In fact, it significantly reduced the water supply and the recirculating solution salinisation and resulted in an easier and cheaper management of the nutrient solution compared with drip irrigation, as reported by other studies (Incrocci *et al.*, 2006; Rouphael and Colla, 2005). This is a very important aspect, for in the near future it will be necessary to increase irrigation efficiency and minimize leaching of nutrients to realize profitable crop productions (Locascio, 2005). Nevertheless, the continuous upward flow of the nutrient saline solution caused a very high accumulation of salts in the upper depth of the substrate (EC was roughly 2.5 and 6.5 times higher than in the medium and lower layers, respectively), that inhibited root growth and reduced plant growth and fruit yield. Therefore, in the usual conditions of the Mediterranean Basin area, where poor quality water is very common, subirrigation of eggplant may be problematic, due to its high water requirements. It is worth of studying the suitability of different cultivars to this irrigation method as a consequence of their different tolerances to salinity; in our trial the different cultivar responses concerned only vegetative parameters, whereas fruit yield was equally reduced in all the genotypes.

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