

Suaeda salsa, A Desalinating Companion Plant for Greenhouse Tomato

Mohammed S. Albaho¹ and James L. Green²

Department of Horticulture, Oregon State University, Corvallis, OR 97331-7304

Additional index words. salinity, desalination, halophyte, closed insulated pallet system, blossom end rot, *Lycopersicon esculentum*, seepweed

Abstract. To determine its effect on salinity of the growth medium and on tomato (*Lycopersicon esculentum* Mill.) growth and yield, the halophyte *Suaeda salsa* (L.) Pallas, or seepweed, was planted as a companion plant in the closed insulated pallet system (CIPS). In this production system, water moves from a bottom reservoir through capillary wicks to the medium in the root pouch in response to plant uptake. Fertilizers are placed at the top surface of the root matrix, so nutrient ions move downward to the roots by chemical ion diffusion to establish relatively stable chemical gradients within the matrix. Plants were subjected to capillary subirrigation water containing 0 or 4 g·L⁻¹ NaCl. Sodium (Na⁺) concentration of the root medium at termination was 50% lower when *S. salsa* was grown in the same pouch with tomato. Sodium concentration was also significantly less in the tomato foliage, but *S. salsa* did not prevent suppression of growth of tomato plants by NaCl. *Suaeda salsa* plants reduced blossom end rot of tomato fruit but did not significantly affect fruit weight, number or yield.

In the closed insulated pallet system (CIPS), salinity in the root medium may increase during tomato production, especially when the irrigation water is high in NaCl. High salinity in the plant rootzone either retards the plant's ability to take up water from the soil solution or is toxic, thereby limiting growth and fruit yield. Tomato has been classified as a moderately salt-tolerant crop (Bernstein, 1964). Tomato yield was reduced by 50% when the electrical conductivity (EC) of the soil solution was increased to 7.6 dS·m⁻¹ or ≈4.86 g·L⁻¹ (Sanchez and Silvertooth, 1996). However, solute ions may accumulate in the growth medium of CIPS and can lead to an EC much higher than 7.6 dS·m⁻¹. Jones (1986) reported that tomato selectively excluded sodium (Na⁺) ions from its roots. Halophytic plant species that desalinize saline soils have been used to increase crop yields on soils with marginal salinity. Major plant species used to improve arid pastures around the world include *Atriplex* sp., *Distichlis* sp., *Jouvea* sp., *Allenrofla* sp., *Salicornia*

europaea L., and *Suaeda fruticosa* Forssk. ex Gmelin (Kovalev and Krylova, 1992). Important properties of halophytes are the use of NaCl as an osmoticum and the compartmentalization of Na⁺ and Cl⁻ in leaf vacuoles. This is achieved through extremely low permeability of the tonoplast to these toxic ions (Maathuis et al., 1992). *Suaeda salsa* is a halophyte that removes Na⁺ and Cl⁻ from the root medium and compartmentalizes these ions in the leaf vacuoles (Maathuis et al., 1992). *Suaeda salsa* decreased Na⁺ in field soils by 4.5% with plant density of 15 plants/m² and by 6.7% at 30 plants/m² (Zhao, 1991). In container experiments, *S. salsa* reduced Na⁺ content from 20.6 to 10.0 g per 9-L pot (Zhao, 1991). In the current study, we hypothesized that the *S. salsa* might remove sufficient ions from the medium to affect tomato performance when grown in CIPS. This is important, particularly in areas where poor quality water is the only source for irrigation. *Suaeda salsa* foliage can be used in animal feed as a by-product when grown with high cash crops to enhance growers' incomes. The objective of our study was to evaluate the effect of *S. salsa* on salinity of the growth medium, and on tomato growth and yield when planted as a companion plant in the same CIPS pouch with tomato.

Materials and Methods

Production system. The CIPS (Fig. 1) has been described by Albaho (1998), Blackburn (1992), Briggs and Green (1991), Green et al. (1993a, 1993b), Green and Schneckeburger (1992), and Kelly et al. (1997). It is a continuous subirrigation-capillary system in which water movement is plant-driven in response to uptake to support transpiration and growth. In CIPS, fertilizers are placed at the top of the

growth medium. Nutrient ions move downward slowly by chemical diffusion to establish relatively stable chemical gradients.

The bottom, top, and sidewalls enclosing the root environment were impermeable to water. They were opaque, reflective, and insulated to prevent transfer of light, heat, and moisture. Each pallet base reservoir had a volume of 262 L. Pallet tops were covered with reflective, heavy-duty aluminum foil. A collar was fitted around the plant stem, extending and sealing to the surrounding lid. Water-impermeable, nonphytotoxic, triple-expanding polyurethane foam completed the seal between the plant stem and collar without restricting growth. Water- and air-permeable root pouches were constructed of spunbonded polypropylene [e.g., Agro fabric PRO70, 47.4 g·m⁻² (American Agrifabrics PCK, Alpharetta, Ga.) or Kimberly Clark 11564-00, 63.8 g·m⁻² SMS filter fabric (Kimberly-Clark, Rosewell, Ga.)] and sewn with polyester thread. To regulate root growth and confine the roots within the pouch, the pouches were treated with a copper-latex solution {100 g·L⁻¹ Kocide (Griffen Corp., Valdosta, Ga.) 101 WP [77% Cu(OH)₂, 60 µg·L⁻¹ soluble copper] in latex paint diluted 1:1 (v/v) with water}.

Baskets were constructed from 15-cm-diameter × 17-cm-deep polyethylene nursery containers, with rectangular openings cut from four sides. The pouches were suspended from the CIPS lid within the containers placed in the precut holes; the suspended container was supported by the container-lip/lid overlap. Capillary strips (spunbonded polyester fabric 10.2-cm wide × 46-cm long; Troy Mills, Troy, N.H.) were placed across the bottom of the basket. The bottom of the pouch was in direct contact with the capillary mat and the ends of the capillary strip extended downward 15 cm to the bottom of the water reservoir in the base of the CIPS pallet. Water moved by capillary and adsorptive forces. The Troy capillary material has a vertical water capillary rise of ≈13 to 15 cm. Water moved upward against gravity in response to surface adsorption, capillary, diffusive, and hygroscopic forces ranging from >1 to ≈300,000 times the force of gravity.

The rooting medium used was 1 peatmoss (Canadian sphagnum) : 1 horticultural grade vermiculite (v/v) that was sufficiently fine to provide capillary movement of water. In the medium, 3.0 kg·m⁻³ dolomite (CaCO₃ and MgCO₃) and 1.8 kg·m⁻³ gypsum (CaSO₄·H₂O) were uniformly incorporated to provide Ca²⁺, Mg²⁺, and S, and to adjust pH. The volume of each pouch was 2 L; planting density was 7.5 plants/m².

After planting, the medium was initially moistened to field capacity to establish capillarity. Prior to addition of fertilizer, the base level total dissolved solutes (TDS) of the growth medium was 1 g·L⁻¹. After draining gravitational water, fertilizer was applied to the perimeter of the top surface away from the young plant roots. Plants were fertilized with 20 g controlled-release 17N-2.6P-10K plus micronutrients (Scotts-Sierra Horticultural Products Co., Marysville, Ohio) and 20 g soluble Ca(NO₃)₂·4H₂O. Fertilizers were

Received for publication on 24 Mar. 1999. Accepted for publication 30 Aug. 1999. Part of a dissertation submitted by Mohammed Albaho in partial fulfillment of the requirements for the PhD degree. Mention of a trade names does not constitute a guarantee or warranty of the products by Oregon State Univ. and does not imply its approval to the exclusion of other products or vendors that also may be suitable. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Current address: Kuwait Inst. for Scientific Research/ A.A.D., P.O. Box 24885, Safat 13109, Kuwait. E-mail address: mbahouh@kisir.edu.kw

²Professor of Horticulture.

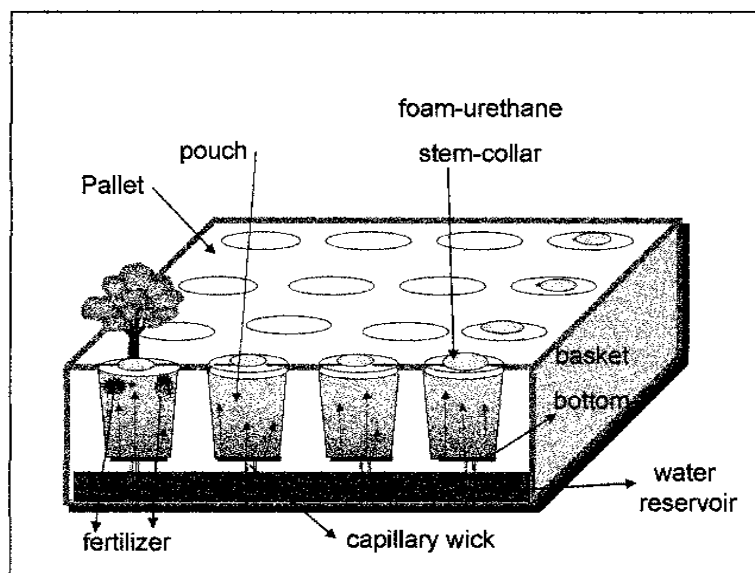


Fig. 1. The closed insulated pallet system (CIPS) unit. Each pallet can hold 16 plants (pouches) with a reservoir capacity of 262 L of water. In each pouch, either one or two plants are placed. (Modified from Green et al., 1999).

placed on the surface at the perimeter of the pouched growth medium. The plant collar was then installed, and the stem sealant applied so that the fertilizer was shielded from surface-applied water and from gravitational and evaporative water-flow pathways. Solubilized fertilizer ions moved by diffusion in accordance with Fick's laws from the top-placed fertilizer reserve and established ion concentration gradients to the plant roots and other areas of lower solute concentration (Blackburn, 1992; Kelly et al., 1997).

Plant materials. Seeds of *S. salsa* were obtained from Dr. Kefu Zhao, Dept. of Biology, Shandong Teachers Univ., Jinan, China. Because of slower growth, seeds were sown 30 d before the tomato seeds. *Suaeda* seeds for the spring trial were sown in 5-cm plastic cubes containing 1 peat: 1 vermiculite (v/v) on 24 Jan. 1996 and transplanted into CIPS pouches on 24 Feb. 1996. Seeds for the autumn trial were sown on 20 July 1996 and transplanted on 20 Aug. 1996. Nutrients were supplied in a Long Ashton mineral solution (Hewitt, 1966) from seedling emergence until the date of transplanting.

Three seeds each of an early hybrid tomato (cv. Pik Red) were sown directly into CIPS pouches on 24 Feb. 1996 (spring trial), and on 20 Aug. 1996 (autumn trial). Seedlings were selected for uniformity of size and thinned to one per pouch immediately after second true-leaf expansion. There were three combinations of plants per pouch: tomato alone, *Suaeda* alone, and both species together. Flowers were pollinated with a battery-powered tomato pollinator for a few seconds each plant around midday, three or four times per week.

Plants were grown in a glass greenhouse with perimeter and under-bench hot-water pipe heating with a minimum temperature setting of 18 °C. Cooling by roof vents, fans, and

evaporative-cooling pads was activated at 24 °C. Plants were exposed to ambient CO₂ and humidity. Plants received 16 h (0700 to 2300) daily supplementary irradiation with 400-watt high-pressure sodium lamps centered 182 cm above each CIPS unit (200 μmol·m⁻²·s⁻¹). In the autumn trial, light supplementation began on 13 Sept. 1996. The spring and autumn trials were terminated on 22 June 1996 and 2 Dec. 1996, respectively. Average solar irradiance was 352.9 langley (14995.8 KJ·m⁻²) per day for the spring trial and 228.7 langley (9567.8 KJ·m⁻²) per day for the autumn trial.

Data measurements. Sodium (Na⁺) and Cl⁻ concentrations in plant foliage and root media were determined at termination of each trial. Sodium was analyzed by ICP Spectrometer (Perkin-Elmer Optima 3000 DV; Perkin-Elmer Corp., Norwalk, Conn.) and Cl⁻ was analyzed by Dionex Ion Chromatography (Dionex 2000I; Dionex Corp., Sunnyvale, Calif.). EC of the root media was also determined using the saturated paste method. Fresh weight of shoots (leaves, petioles, and stems) of tomato and *S. salsa* and fruit yield per tomato plant were recorded. Dry weight of shoots (leaves, petioles, and stems) was determined after oven-drying at 60 °C for 48 h. Concentrations of P, K⁺, Ca²⁺, Mg²⁺, and Mn²⁺ were determined in both the plant foliage (ICP Spectrometer) and growth medium, after extraction with ammonium acetate (Horneck et al. 1989), and analyzed by atomic absorption (Perkin-Elmer Atomic Absorption Spectrometer 372; Perkin-Elmer Corp.). Measurements of the Cu²⁺ concentration in the growth media in CIPS revealed that it was not influenced by the pouch treatment with cupric hydroxide and therefore Cu²⁺ concentrations were not measured in this experiment.

Experimental design. The experiment was a two-factor, split-plot design, with three plant

combinations (tomato alone, tomato with *S. salsa* in the same root pouch, and *S. salsa* alone) and two subirrigation water salinities (0 and 4 g·L⁻¹ NaCl). Four replicates per plant combination were randomized within each salinity treatment. Salinity was the main plot factor and plant combination was the subplot factor.

Statistical analyses. Analysis of variance (ANOVA) was performed by SAS Institute procedures (SAS Inst., 1996). Fisher's protected least significant difference (LSD) test was used to separate means. Shoot weight and elemental concentrations in the foliage were analyzed for each species separately.

In pouches where both species were placed together, tomato will be referred to as (T+), *S. salsa* as (S+), and their growth medium as (T+S). Tomato-alone (T) was the control for tomato plants grown with *Suaeda* (T+). *Suaeda* alone (S) was the control for *Suaeda* plants grown with tomato (S+). Analyses of Na⁺ or Cl⁻ were performed on the 4 g·L⁻¹ water treatment only.

Results

Effect of *S. salsa* on salinity of growth medium. *S. salsa* reduced the Na⁺ concentration 50.8% and the EC of the growth medium 45.2%, when capillary-irrigated with 4 g·L⁻¹ NaCl water in the spring trial (Table 1). Reduction in Cl⁻ concentration in the medium was not significant in either trial. With *S. salsa*, the growth medium was slightly acidified (pH 5.16 and 5.08 with *S. salsa* compared with pH 5.40 and 5.46 without *S. salsa* in 0 and 4 g·L⁻¹ NaCl water treatment, respectively); the pH was lower with *S. salsa* regardless of salinity treatment or plant combination. Results were similar in the autumn trial.

With high-salinity subirrigation water, the concentration of Mg²⁺ was significantly lower in the root medium with S than with T (Fig. 2). No other elements were significantly influenced by salinity. The Mg²⁺:Ca²⁺ in the solution were 0.26, 0.19, and 0.12 (LSD_{0.05} = 0.06) for T, T+S, and S, respectively, and 0.25 and 0.13 (LSD_{0.05} = 0.09) in the control and saline treatment, respectively.

Effect of *S. salsa* on ion concentration in tomato foliage. Adding 4 g·L⁻¹ NaCl to the subirrigation water reduced Na⁺ concentration in tomato foliage in the presence of *S. salsa* (T+) 37.6% in the spring trial (Table 1), but had no significant affect in the autumn trial (data not shown). Concentration of P in tomato foliage was significantly higher with 0 g·L⁻¹ than with 4 g·L⁻¹ NaCl irrigation water whether accompanied by *S. salsa* or not (Table 2). However, concentration of Mn²⁺ was much higher in the foliage of tomato plants irrigated with saline water. Magnesium was greater in tomato foliage grown alone (T) than when grown with *S. salsa* (T+S). Concentrations of NO₃⁻, K⁺, and Ca²⁺ in the foliage were not influenced by salinity level whether grown alone or with *S. salsa*.

Effect of *S. salsa* on tomato growth and yield. The dry weights of tomato plants and fruits were significantly less with 4 g·L⁻¹ than with 0 g·L⁻¹ NaCl irrigation water in the

Table 1. Influence of *Suaeda salsa* on sodium (Na⁺) concentration in 'Pik Red' tomato foliage and on sodium concentration and electrical conductivity (EC) of the growth medium measured at termination of experiment subirrigated with 4 g·L⁻¹ NaCl (spring).

Plant combination	Na ⁺ concentration in growth medium (meq/100 g)	EC of growth medium (dS·m ⁻¹)	Na concentration in tomato foliage (g·kg ⁻¹ dwt)
Tomato alone	186.8	43.4	4.65
Tomato + <i>S. salsa</i>	91.8	29.9	2.90
Significance	**	**	**

**Significant at $P \leq 0.01$.

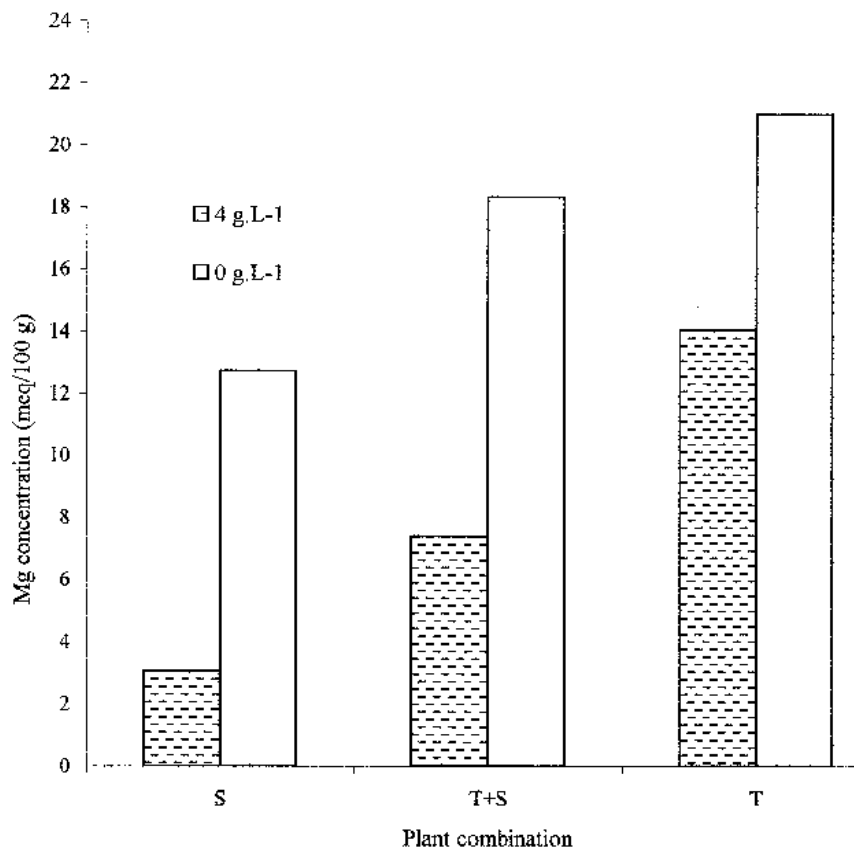


Fig. 2. Magnesium (Mg²⁺) concentration of growth medium for plant combinations [tomato (T), *Suaeda* (S), or T+S irrigated at two salinity levels (SE = 2.67; spring)].

Table 2. Main effects of salinity and of *Suaeda salsa* as a companion plant on ion concentration in 'Pik Red' tomato foliage (autumn).

Treatment	P (%)	Mn ²⁺ (mg·L ⁻¹)	Mg ²⁺ (%)
Water salinity (g·L ⁻¹ NaCl)			
0	0.78	164.9	0.70
4	0.56	251.9	0.80
Significance	*	*	NS
Plant combination			
T ^z	0.73	231.9	0.84
T+	0.61	184.9	0.66
Significance	NS	NS	*

^zTomato alone (T), or with *S. salsa* in same pouch (T+).

NS, *Nonsignificant or significant at $P \leq 0.05$.

spring trial (Table 3). The *S. salsa* companion plant had no significant effect on tomato growth (e.g., dry weight of shoot), fruit weight per plant or weight per fruit. However, presence of *S. salsa* reduced blossom-end rot (BER) from 17.5% to 9.2%. Furthermore, addition of NaCl to the subirrigation water reduced BER in spring (Table 3). In the autumn trial, BER was not affected but was generally much lower than in spring (Table 3), probably because of the lower growth rate

in autumn. BER is a widespread physiological disorder caused by local Ca²⁺ deficiency and loss of selective permeability of the cell membranes in developing fruit (Simon, 1978; Van Goor, 1968).

In the autumn trial, similar results were obtained for growth and fruit weight parameters. However, incidence of BER was generally extremely low and was not significantly affected by the presence of *S. salsa* or by NaCl concentration (Table 3).

Growth of *S. salsa*. *Suaeda salsa* alone (S) grew more in the saline than in nonsaline water (Table 4), an indication that *S. salsa* has an obligate requirement for Na⁺ for optimal growth and development. When *S. salsa* was grown with tomato in the same root pouch (S+), its dry shoot weight was reduced by 38.7%.

Concentrations of Na⁺ and Cl⁻ in *S. salsa* foliage were not affected by the presence of tomato plants (data not shown). Phosphorus (P) and Ca²⁺ concentration in the foliage were much greater in 0 g·L⁻¹ than in the 4 g·L⁻¹ NaCl water treatment (Table 4). However, concentrations of these elements were similar in S and S+. *Suaeda salsa* alone (S) at either salinity level had greater foliar concentrations of Mn²⁺ ($P \leq 0.05$) and NO₃⁻ ($P \leq 0.01$) than did S+. Potassium (K⁺) and Mg²⁺ concentrations in S and S+ were similar regardless of water salinity for S or S+.

Discussion

Although *S. salsa* considerably reduced EC and Na⁺ concentration of the medium (Table 1), the reduction may have been insufficient to improve tomato plant growth and fruit yield (Tables 3 and 4) because of the high NaCl concentration in the capillary irrigation water (4 g·L⁻¹). The poorer growth of *S. salsa* in 0 g·L⁻¹ NaCl than in 4 g·L⁻¹ NaCl was attributed to its obligate sodium requirement.

The Mg²⁺ to Ca²⁺ ratio of the medium was greater in the control than in the saline treatment and percentage BER was lower in the saline treatment than in the control (Table 3). Furthermore, the lower Mg²⁺ concentration in both growth media (Fig. 2) and in tomato foliage (T+, Table 2) in the presence of *S. salsa* than in its absence may indicate that *S. salsa* has a high demand for Mg²⁺ as well. Moreover, the significantly lower Mg²⁺ to Ca²⁺ ratio in the medium when *S. salsa* was present may have reduced BER in tomato fruit. This is supported by the substantially lower Mg²⁺ to Ca²⁺ ratio in the saline than in the control medium where BER was much more severe. Incidence of BER may be more related to ion balance (ionic ratio) than to intensity. For instance, high K⁺ or Mg²⁺ in relation to the Ca²⁺ in solution may increase BER (Adams, 1991; Ehret and Ho, 1986; Willumsen et al., 1996). Any factor that reduces incidence of BER is noteworthy, as this physiological disorder causes serious economic losses annually.

In the autumn trial, the very low % BER (Table 3) was probably a result of the low solar irradiance in this season, as increasing irradiance would increase photosynthesis and thus increase import of carbohydrates for fruit growth (Ho et al., 1993). Higher irradiance also tends to increase ambient temperature, which in turn stimulates fruit enlargement.

Data for foliage NO₃⁻ concentrations (Table 4) indicate that the tomato plant was more competitive for NO₃⁻ than was *S. salsa*, especially in nonsaline water. As for the remaining elements (K⁺, Ca²⁺, Mn²⁺, and P), their concentrations were not affected. Nutri-

Table 3. Main effects of salinity and of *Suaeda salsa* as a companion plant on dry shoot weight, fruit weight per plant, fresh weight per fruit, and incidence of blossom-end rot (BER) in 'Pik Red' tomato.

Treatment ^a		Dry shoot mass(g)	Fruit wt/ plant (g)	Fresh wt/ fruit (g)	BER (% of fruits)
<i>Expt. 1. Spring</i>					
Water salinity (g·L ⁻¹ NaCl)	0	61.9	1008.4	91.9	19.0
	4	33.9	416.6	61.8	7.7
	Significance	**	*	*	*
Plant combination	T ²	52.4	675.8	74.1	17.5
	T+	43.4	749.2	79.6	9.2
	Significance	NS	NS	NS	*
<i>Expt. 2. Autumn</i>					
Water salinity (g·L ⁻¹ NaCl)	0	47.6	981.2	136.0	3.2
	4	28.5	589.2	111.9	1.3
	Significance	*	*	*	NS
Plant combination	T	42.5	789.2	132.6	3.2
	T+	33.6	761.2	115.3	1.3
	Significance	NS	NS	NS	NS

^aTomato alone (T), or with *S. salsa* in same pouch (T+).

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01.

Table 4. Main effects of salinity and of tomato as a companion plant on shoot dry weight and of ion concentration at harvest in *Suaeda salsa* foliage when grown alone (S) or with the tomato cv. Pik Red (S+) in a single root pouch (autumn).

Treatment	Dry shoot wt (g)	P (%)	Ca ²⁺ (%)	NO ₃ ⁻ (%)	Mn ²⁺ (mg·L ⁻¹)
Water salinity	0	12.8	1.32	2.33	1.06
	4	27.8	0.68	1.57	0.98
	Significance	**	***	*	NS
Plant combination	S	24.3	1.02	2.23	1.43
	S+	16.3	1.98	1.67	0.61
	Significance	*	NS	NS	**

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001.

ent concentrations in tomato foliage were within the range for a healthy tomato crop (Winsor et al., 1980).

Competition for light between tomato and *S. salsa* companion plantings may have reduced growth of *S. salsa*; its shoot dry weight was significantly reduced when it shared a root pouch with tomato (Table 4). Light was probably not limiting for the taller tomato plant; its growth was unaffected by the presence of *S. salsa* (Table 3).

A wide range of irrigation water salinity concentrations, including those lower than 4 g·L⁻¹ NaCl, needs to be evaluated. A NaCl concentration of only 0.2 g·L⁻¹ was used by Zhao (1991) for testing *Suaeda* as a desalinator for *Medicago sativa* L. This was considerably less than the 4 g·L⁻¹ employed in our investigation. Salinity alleviation is an important issue, as salt accumulation is a major concern in CIPS when available irrigation water is of poor quality.

Tomato cultivars that are more salt-tolerant should be evaluated with the companion *S. salsa*. Also, other salt-loving plant species, such as *Atriplex* and *Salicornia*, and other *Suaeda* sp. should be tested as salt absorbers when planted

with tomato or other important vegetable crops in CIPS.

Literature Cited

- Adams, P. 1991. Effects of increasing the salinity of the nutrient solution with major nutrients or sodium chloride on the yield, quality, and composition of tomatoes grown in rockwool. *J. Hort. Sci.* 66:201–207.
- Albahou, M. 1998. Alternative greenhouse tomato production system. PhD Diss., Oregon State Univ., Corvallis.
- Blackburn, B. 1992. A closed root environment for plant production. MS Thesis, Oregon State Univ., Corvallis.
- Bernstein, L. 1964. Salt tolerance of plants. U.S. Dept. of Agr. Info. Bul. 283.
- Briggs, B.A. and J.L. Green. 1991. Environment-friendly plant production system: The closed insulated pallet. *Combined Proc. Intl. Plant Prop. Soc.* 41:304–307.
- Ehret, D.L. and L.C. Ho. 1986. Translocation of calcium in relation to tomato fruit growth. *Ann. Bot.* 58: 679–688.
- Green, J.L., B. Blackburn, S. Kelly, and M. Albahou. 2000. Efficient fertilization of nursery crops—Plant controlled uptake.

- Acta Hort. 511:59–64.
- Green, J.L., B. Briggs, and D. Briggs. 1993a. Fertilizing apparatus. U.S. Patent No. 5,212,904 assigned to the State of Oregon, acting by and through the State Board of Higher Educ. on behalf of Oregon State Univ. Issued by the U.S. Patent Office, 25 May 1993.
- Green, J.L., S. F. Kelly, B. Blackburn, J. Robbins, B.A. Briggs, and D.L. Briggs. 1993b. A protected diffusion zone (PDZ) to conserve soluble production chemicals. *Combined Proc. Intl. Plant Prop. Soc.* 43:40–44.
- Green, J.L. and R. Schneckenburger. 1992. Pallet system for container-grown plants. U.S. Patent 5,170,581. Assigned to the State of Oregon, acting by and through the State Board of Higher Educ. on behalf of Oregon State Univ. 2 June 1992.
- Hewitt, E.J. 1966. Sand and water culture methods used in the study of plant nutrition. *Tech. Comm. No. 22* (2nd ed., revised), Cmnwlth. Agr. Bur., Maidstone, Kent, England.
- Ho, L.C., R. Belda, M. Brown, J. Andrews, and P. Adams. 1993. Uptake and transport of Ca and the possible causes of blossom-end rot in tomato. *J. Expt. Bot.* 44:509–518.
- Horneck, D.A., J.M. Hart, K. Topper, and B. Koepsell. 1989. Methods of soil analysis used in the soil testing laboratory at Oregon State Univ. Oregon State Univ. Agr. Expt. Sta. SM 89:4.
- Jones, R.A. 1986. The development of salt tolerant tomatoes: breeding strategies. *Acta Hort.* 190:101–114.
- Kelly, S.F., J.L. Green, and J.S. Selker. 1997. Fertilizer diffusion in container medium. *J. Amer. Soc. Hort. Sci.* 122:122–128.
- Kovalev, V.M. and N.P. Krylova. 1992. Use of halophytes to improve arid pastures. (Russian) *Sel'skokhozyaistvennaya Biol.* No. 4, 135–141.
- Maathius, F.J.M., T.J. Flowers, and A.R. Yeo. 1992. Sodium chloride compartmentation in leaf vacuoles of the halophyte *Suaeda maritima* (L.) Dum. and its relation to tonoplast permeability. *J. Expt. Bot.* 43:1219–1223.
- SAS Institute. 1996. SAS/STAT user's guide, vers. 6.12, SAS Inst., Cary, N.C.
- Sanchez, C.A. and J.C. Silvertooth. 1996. Managing saline and sodic soils for producing horticultural crops. *HortTechnology* 6:99–107.
- Simon, F.W. 1978. The symptoms of calcium deficiency in plants. *New Phytol.* 80:1–15.
- Van Goor, B.J. 1968. The role of calcium and cell permeability in the disease blossom-end rot of tomatoes. *Physiol. Plant.* 21:1110–1121.
- Willumsen, J., K.K. Peterson, and K. Kaack. 1996. Yield and blossom-end rot of tomato as affected by salinity and cation activity ratios in the root zone. *J. Hort. Sci.* 71:81–98.
- Winsor, G.W., P. Adams, and D. Massey. 1980. New light on nutrition. *Suppl. Grower* 93(8):99, 103.
- Zhao, K.F. 1991. Desalination of saline soils by *Suaeda salsa*. *Plant Soil* 135:303–305.