SHORT COMMUNICATION

Purslane (*Portulaca oleracea* L.) has potential for desalinizing greenhouse recirculation water

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Ngosong, C., Halpern, M. T., Whalen, J. K. and Smith, D. L. 2013. **Purslane (*Portulaca oleracea* L.) has potential for desalinizing greenhouse recirculation water.** Can. J. Plant Sci. **93**: xxx–xxx. Recirculating fertigation solutions improves the environmental sustainability of hydroponics-based vegetable production in Canada. Purslane is an edible halophyte with proported medicinal benefits that could absorb excess salts from recirculation water. It grew well in hydroponic solutions with up to 1000 mg NaCl L^{-1}. Greatest Na absorption occurred during earlier vegetative growth.

Key words: Greenhouse, hydroponics, purslane, recirculating system, salinity, salts

Ngosong, C., Halpern, M. T., Whalen, J. K. et Smith, D. L. 2013. **Le pourpier potager (*Portulaca oleracea* L.) pourrait dessaler l'eau de recirculation dans les serres**. Can. J. Plant Sci. **93**: xxx–xxx. Réutiliser les solutions employées comme irrigations fertilisantes concourt à la pérennité de l'environnement dans les systèmes de production maraîchère recourant à l'hydroponique au Canada. Halophyte comestible aux propriétés médicinales, le pourpier potager pourrait absorber les sels en excédents dans l'eau lors de sa recirculation. Cette plante pousse bien dans des solutions hydroponiques contenant jusqu'à 1 000 mg de NaCl par litre. Le sodium est particulièrement bien absorbé au début de la période végétative.

Mots clés: Serre, hydroponique, pourpier, système de recirculation, salinité, sels

Recirculating water and nutrient solutions in a closed-loop hydroponic system saves water and fertilizers, and mitigates environmental pollution (Savvas 2002). About 80% of greenhouse vegetables in Ontario, Canada, are now grown in raised troughs that permit recirculation (Ontario Greenhouse Vegetable Growers 2012); however, greenhouse operators identify several problems with recirculating water, such as disease control, nutrient ion imbalances and salt accumulation (Richard et al. 2006). Salt accumulation occurs because water sources contain ions that are not required for crop nutrition (e.g., Na^+). Salt removal from recirculating solutions is a particular challenge because there is no physical matrix with sufficient exchange capacity (e.g., soil or growth media) to adsorb and retain salts from the solution. While salinity levels can be reduced by diluting the solution with fresh water, another option is to add salt-absorbing companion plants to the system.

Purslane (*Portulaca oleracea* L.) is an excellent candidate to mitigate salinity by absorbing excess salts from saline irrigation water. This halophyte preferentially absorbs Na over other cations (e.g., K, Ca and Mg), with a five- to six-fold increase in shoot Na concentration when water salinity increased from 2.1 to 28.5 dS m^{-1} (Grieve and Suarez 1997). Sequestration of Na^+ and Cl^- in vacuoles is accompanied by greater synthesis of proline in the cytosol, to adjust the osmotic balance between vacuole and cytosol, as well as more water storage in leaves and the production of antioxidants (e.g., α-tocopherol, glutathione and ascorbate) to scavenge superoxide radicals resulting from salinity-induced oxidative stress (Yazici et al. 2007). Purslane growth is stimulated by repeated harvesting and it can complete its life cycle when grown in sand culture with salinity levels of 2988 mg Na L^{-1} and 6322 mg Na L^{-1}, although higher salinity reduced dry matter yields by up to five times (Grieve and Suarez 1997). Similarly, Uddin et al. (2012) reported that purslane growth and protein content were reduced when grown in soils irrigated with water containing 6000 mg Na L^{-1} compared with water with lower salinity (1500 mg Na L^{-1} and 3000 mg Na L^{-1}). Purslane can be harvested and sold as a high-value salad green, as it is rich in omega-3 fatty acids (Simopoulos 2004), or for medicinal purposes to relieve pain and inflammation through topical application or intraperitoneal injection (Chan et al. 2000). Thus, purslane has potential to adsorb excess salts in recirculation water and provide extra income for the greenhouse operator.

The objective was to assess the extent of Na absorption by purslane in saline hydroponic systems.

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We hypothesized that purslane growth and biomass production would decline at higher salinity levels, and for plants grown to maturity without repeated harvesting or clipping, that Na absorption would be highest during early vegetative growth and decline with age.

Experimental Setup

Purslane seeds were germinated and grown in perlite/peat medium in the greenhouse for 5 wk. Plants were at the vegetative growth stage (20 to 35 cm long from base to end of stem, erect growth habit, on average 15 leaf clusters per plant) when they were transferred to 1-L Mason jars (one plant per jar) containing passively aerated hydroponic solution. Greenhouse conditions during the hydroponic experiment (February to March, 2008) gave, on average, 14.5 h of sunlight per day and daily temperatures of 20 to 27°C. The hydroponic experiment was a completely randomized design with five concentrations of sodium chloride salt (0, 10, 100, 1000 and 35 000 mg Na L^{-1}), each prepared in half-strength Hoagland solution, with slight adjustment to ensure that nutrient concentrations (N, P, K, etc.) were the same across treatments (Johnson 1977). Salinity in the 35 000 mg Na L^{-1} treatment was equivalent to sea water (electrical conductivity = 48 dS m^{-1}), with treatments of 10, 100 and 1000 mg Na L^{-1} having electrical conductivity of 0.7, 0.9 and 2.4 dS m^{-1}, respectively. Mason jars were filled with 800 mL of the Na-enriched half-Hoagland solution (five replicates per treatment, for a total of 25 plants), which was replaced with fresh solution every week for 4 wk. After measuring the volume of hydroponic solution remaining in the jar at the end of the week, a subsample of the week-old solution was saved for analysis of the Na concentration by atomic absorption spectroscopy.

Sodium Absorption and Purslane Growth Response

Sodium absorption by purslane was the difference between the initial Na content (mg, measured in fresh mixtures of Na-enriched half-strength Hogland solution) and the measured Na content (mg) in jars at the end of the week, accounting for the volume of hydroponic solution lost through plant uptake and evapotranspiration (by measuring the volume of solution remaining in a graduated cylinder). After 4 wk, purslane plants were removed from the Mason jars, rinsed and analyzed for biomass accumulation, root length and leaf chlorophyll content. Shoots (leaves and stems) were separated from roots, the root length was measured with a ruler (from the base of the stem to the longest extended root), both components were oven-dried at 65°C for 48 h and then weighed. The relative chlorophyll content of purslane leaves (20 measurements taken at random from fully formed leaves at least 1.5 cm diameter in size) was measured with a SPAD 502 chlorophyll meter (Konica Minolta Optics Inc., Tokyo, Japan).

Statistical Analysis

The effect of Na-enriched hydroponic solution on biomass, root length and relative chlorophyll content was assessed by analysis of variance, while Na absorption and water uptake by purslane was assessed by repeated-measures analysis of variance using STATISTICA, version 9.1 for Windows (StatSoft Inc., Tulsa, OK). A post-hoc Tukey's HSD test was used for means comparison.

Purslane Growth and Biomass Accumulation

Purslane growth was normal, and plants appeared healthy in hydroponic solutions containing up to 1000 mg Na L^{-1}. Shoot morphology changed from erect to prostate during the hydroponics experiment, which is typical for purslane as it ages. Leaves were succulent and most appeared healthy; although chlorosis and wilting was occasionally observed, this was corrected when fresh hydroponic solution was added to the jars. Purslane grown in the 35 000 mg Na L^{-1} treatment had small, folded leaves that maintained their turgor, although they did not grow visibly during the 4-wk hydroponics experiment. Floral initiation occurred between weeks 2 and 3 of the experiment and all plants produced capsules containing seeds by the end of the 4-wk study.

Shoot biomass after 4 wk was 2.2 to 11.2 g dry weight (DW), with less shoot biomass ($P < 0.05$) in the 35 000 mg Na L^{-1} treatment than other salt-amended treatments and the control (Table 1). Root biomass and root

Table 1. Growth attributes and chlorophyll content of purslane (*P. oleracea*) after 4 wk growing in Na-enriched half-strength Hoagland's hydroponic solution

	Concentration of Na-enriched hydroponic solution (mg Na L^{-1})				
	0	10	100	1000	35 000
Shoot biomass (g DW)[z]	8.30 ± 1.86*a*	10.4 ± 5.51*a*	10.2 ± 4.67*a*	11.22 ± 4.53*a*	2.20 ± 0.54*b*
Root biomass (g DW)	1.95 ± 1.50*b*	4.07 ± 1.44*ab*	1.62 ± 0.54*b*	4.58 ± 2.29*a*	0.90 ± 0.11*b*
Root length (cm)	4.85 ± 1.93*ab*	5.61 ± 0.40*a*	5.95 ± 0.97*a*	4.65 ± 1.28*ab*	2.87 ± 0.00*b*
Chlorophyll content (SPAD reading)	34.7 ± 1.75	31.1 ± 5.00	29.3 ± 3.91	33.2 ± 4.12	38.2 ± 22.8

[z]DW = dry weight.
a, *b* Values (mean ± standard deviation) within a row followed by different letters are significantly different according to Tukey's HSD test ($P < 0.05$).

Table 2. Weekly and cumulative sodium (Na) absorption and water uptake by purslane (*P. oleracea*) grown in Na-enriched half-strength Hoagland's hydroponic solution

	Na absorbed (mg)				Water absorbed (L)				
Week	0 mg Na L^{-1}	10 mg Na L^{-1}	100 mg Na L^{-1}	1000 mg Na L^{-1}	0 mg Na L^{-1}	10 mg Na L^{-1}	100 mg Na L^{-1}	1000 mg Na L^{-1}	35 000 mg Na L^{-1}
1	2.1 ± 0.5	6.5 ± 6.3	14.1 ± 10.8	131.6 ± 82.3	0.26 ± 0.14	0.34 ± 0.20	0.27 ± 0.18	0.35 ± 0.25	0.05 ± 0.01
2	9.9 ± 6.8	13.5 ± 7.8	33.9 ± 26.7	127.0 ± 109.7	0.50 ± 0.25	0.54 ± 0.29	0.52 ± 0.32	0.55 ± 0.18	0.18 ± 0.35
3	4.9 ± 3.3	16.4 ± 0.3	25.5 ± 13.3	148.8 ± 105.5	0.51 ± 0.23	0.46 ± 0.27	0.51 ± 0.32	0.69 ± 0.10	0.03 ± 0.03
4	4.5 ± 2.6	7.0 ± 4.5	3.8 ± 1.7	37.2 ± 0.0	0.54 ± 0.07	0.40 ± 0.21	0.35 ± 0.19	0.50 ± 0.15	0.01 ± 0.00
Sum, 4 wk	21.4 ± 4.5*b*	43.4 ± 5.9*b*	77.6 ± 19.7*b*	444.6 ± 83.1*a*	1.82 ± 0.35*a*	1.74 ± 0.73*a*	1.64 ± 0.94*a*	2.09 ± 0.44*a*	0.26 ± 0.35*b*

a, *b* Values are the mean (± standard deviation) and cumulative Na absorption and water uptake within a row followed by different letters are significantly different according to Tukey's HSD test ($P < 0.05$).

length were also lower ($P < 0.05$) when purslane was grown in 35 000 mg Na L^{-1} than other treatments, but there was no difference in the chlorophyll content among treatments (Table 1). A chlorophyll meter may not detect purslane response to salt stress, which is expected to be modest since salinity does not affect chlorophyll *a* content of purslane, but stimulates the production of chlorophyll *b* by 10–15% (Rahdari et al. 2012). Overall, the purslane growth and biomass accumulation in hydroponic solutions containing up to 1000 mg Na L^{-1} was consistent with other reports indicating that purslane grows well in non-saline to moderately saline conditions (Grieve and Suarez 1997). The 1000 mg Na L^{-1} treatment had an electrical conductivity of 2.4 dS m^{-1}, which was in the same range as tap water and recirculation water (2.1 to 3.2 dS m^{-1}) reported for a greenhouse in semi-arid Israel (Raviv et al. 1995) but exceeds the recommended salinity level (1.0 to 2.0 dS m^{-1}) in water applied to greenhouse vegetable transplants in Ontario (Ontario Ministry of Agriculture Food and Rural Affairs 1996).

Sodium Absorption and Water Uptake by Purslane

Salt absorption of purslane in the 35 000 mg Na L^{-1} treatment was excluded due to uncertainty in the analytical results (negative values reported). Plants grown in hydroponics solutions containing 0 to 1000 mg Na L^{-1} absorbed between 21.4 and 444.6 mg Na after 4 wk, with greater ($P < 0.05$) Na absorption from the 1000 mg Na L^{-1} solution than other treatments and the control (Table 2). In all treatments, there was more Na absorption in weeks 2 and 3 of the study than in the first and last week (Table 2). Cumulative water uptake was 0.26 to 2.1 L during the study, similar in treatments that received 0 to 1000 mg Na L^{-1} but less ($P < 0.05$) in jars with 35 000 mg Na L^{-1} (Table 2). Water uptake tended to increase between week 1 and subsequent weeks of the experiment, but did not match the same pattern as Na absorption, suggesting that purslane has a finite ability to absorb and store Na from hydroponic solutions. We attribute this observation to changes in purslane metabolism and physiology as it entered the reproductive growth stage between weeks 2 and 3 of the experiment. To maximize Na absorption, it may be preferable to introduce purslane into the recirculation system at an earlier vegetative growth stage, but this needs to be confirmed. The Na absorption by purslane plants represented 1 to 14% of the Na contained in the hydroponic solutions tested in this study, indicating that purslane has the potential to desalinize recirculation water in greenhouses. It may be cost-effective to transplant purslane into the recirculation water system and allow it to grow hydroponically until the end of the vegetative growth stage, when most of the Na adsorption occurs, then harvest the crop and transplant a new batch of young purslane. This approach differs from other studies where purslane was grown in sand-based culture (Grieve and Suarez 1997; Uddin et al. 2012) and harvested repeatedly during its growth (Grieve and Suarez 1997), thus the feasibility and cost of our proposed method to remediate recirculation water in greenhouses remains to be determined.

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