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The Pepino (*Solanum muricatum* Ait.): An Alternative Crop for Areas Affected by Moderate Salinity

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Abstract. **Three clonal hybrids of pepino and their six parental clones were grown in a greenhouse at two salinity levels, 3 and 8 dS·m^{-1}, and two K levels, 246 and 492 mg·L^{-1}. Nearly all the clones maintained high yields even at 8 dS·m^{-1}. Hybrids were highly productive and were more salt-tolerant than their parental clones. In the majority of clones, salinity shortened mean time to harvest by more than 10 days. Salinity also increased organoleptic quality of pepino fruit, mainly due to the increase in soluble solids concentration (SSC). Potassium had little effect on yield and on organoleptic characteristics, although the yield of the less-productive clones appears to be affected by the high level of K (492 mg·L^{-1}). Our results suggest that the pepino could be an alternative crop in areas where only moderately saline water is available, since it is possible to maintain crop productivity while improving its organoleptic quality—the latter being a key issue for its acceptability in European and U.S. markets.**

The pepino is an aromatic fruit, normally grown as an annual and vegetatively propagated through small cuttings. It is a traditional crop in South America and is also grown commercially in Chile, New Zealand, and Australia. In addition, the pepino is being cultivated experimentally at several points in Europe (Daunay et al., 1995), and markets are being developed in California, Europe, and Israel (Heiser, 1985; National Research Council, 1989; Pluda et al., 1993a).

Increasing salinity of soils and water constitutes the principal problem for agriculture in arid and semiarid regions of the world (Epstein et al., 1980). Southeastern Spain is an area of great agricultural importance where most of the country's intensive horticultural activity is concentrated. In this area, as in numerous zones of the coastal Mediterranean basin, agriculture is seriously threatened by the increasing salinity of the groundwater and by the shortage of good quality surface water. Irrigation waters are very often saline, with an electrical conductivity (EC) ranging between 2.5 and 5 dS·m^{-1}, occasionally exceeding the latter value. This situation is leading to the increasing use of soilless culture techniques (Rincón and Pérez, 1995), mainly sand culture with high-frequency irrigation. However, agricultural production in this area is based on few crops, mainly on tomato (*Lycopersicon esculentum* Mill.) and muskmelon (*Cucumis melo* L.), two moderately salt-sensitive plants (Maas, 1986; Mendlinger and Pasternak, 1992).

Solanum muricatum is a high-yield-potential species, and there are some reports of it being grown in saline soils in Chile, with apparently satisfactory yields (Bravo and Arias, 1983). The pepino could be an alternative crop in moderately saline areas, contributing to the diversification of agricultural production. It is also necessary to take into account that current requirements of horticultural markets are increasingly focusing on fruit quality. In this respect, salinity could have advantageous points, given that, as in tomato (Mitchell et al., 1991; Mizrahi and Pasternak, 1985; Niedziela et al., 1993) and in melon (Levitt, 1980; Mendlinger and Pasternak, 1992), salinity appears to improve some quality characteristics of the pepino fruit (Pluda et al., 1993a).

The adequate use of K fertilization is another important factor that could contribute to improved pepino fruit quality and its acceptability in the markets, as is the case with tomato (Adams et al., 1978; Picha and Hall, 1982). Moreover, high Na^+ concentrations due to salinity may disrupt K^+ transport and interfere with growth of many plant species (Cramer et al., 1987). Some authors have recently suggested that high levels of K fertilization can reduce the salinity effects in diverse crops (Bohra and Doerffling, 1993; Chow et al., 1990; Ella and Shalaby, 1993; Haddad and Coudret, 1991; Satti and López, 1994; Saxena and Rewari, 1993).

We determined the potential of the pepino as a crop that would diversify agricultural production in areas affected by moderate salinity, and we studied whether K fertilization could contribute to this objective.

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Material and Methods

Plant material. Six clones of pepino, two clonal hybrids (UPV-107 and UPV-641), and their four parental clones were grown in 1993. The parents of hybrid UPV-107 were a seedling selection made by the Polytechnic Univ. of Valencia (UPV) from New Zealand seeds (clone 9-2), and a Chilean cultivar (clone 0-8) originating at Ovalle, in the center of Chile. Parents of hybrid UPV-641 were two seedling selections developed by the UPV from New Zealand seeds (clone 9-1), and from Chilean seeds (clone 6-10). In 1994, the plant material was the same, adding a third high yielding hybrid (UPV-927) and one of its parental clones (clone 6-21), developed by selection from seeds originating from Chile. Its other parent was the clone 9-2, in common with that of hybrid UPV-107.

Experimental design and nutritional treatments. A factorial design for genotype and treatment effects, with five plants per clone and treatment, was used in two experiments over 2 years. The four treatments resulted from combining two salinity levels (S1 ≈3 dS·m^{-1} and S2 = 8 dS·m^{-1}) with two K levels (K1 = 246 mg·L^{-1} and K2 = 492 mg·L^{-1}). The treatments were T1 (S1K1): control (nutrient solution with an electrical conductivity (EC) equal to 2.7 dS·m^{-1}, with (mg·L^{-1}) 172 N, 76 P, and 246 K). T2 (S1K2): nutrient solution with double K concentration (492 mg·L^{-1}) supplied as K_2SO_4 and EC = 3.1 dS·m^{-1}. T3 (S2K1): nutrient solution adjusted to 8 dS·m^{-1} using NaCl. Molar ratio Na : K ≈7:1, molar ratio Na : Ca = 3.9:1. T4 (S2K2): nutrient solution with double K concentration (492 mg·L^{-1}) adjusted to 8 dS·m^{-1} using NaCl, molar ratio Na : K = 3:1. Molar ratio Na : Ca = 3.5:1.

Growing conditions. The plants were grown in a temperature-regulated greenhouse. During the period of flowering and fruit set, from May to mid June, maximum temperatures did not exceed 30 °C, with a minimum of 14 °C. In both experiments, 15-day-old rooted cuttings were transplanted to benches filled with quartz sand by the end of February. Plants were spaced 33 cm apart in the bench, with 110 cm between bench centers. Treatment solutions from independent holding tanks were applied by frequent drip irrigations (seven to nine times a day, 5 min each), thus avoiding salt build up in the benches. Electrical conductivity of the nutrient solutions and of the leachates was monitored weekly with a conductivity meter at 25 °C. Plants were thinned to three stems supported by vertical strings. All sideshoots were nipped. Apical shoots were removed five leaves above the third truss. Flowers were mechanically pollinated at full anthesis and tagged. Harvest began by mid-June. All fruits were harvested daily when ripe (yellow skin) and the date recorded, they were all weighed and analyzed for soluble solids concentration (SSC) using a hand refractometer. Every plant was measured for internode length and the length and width of the first leaf above the first truss.

Organoleptic test. In both years, organoleptic quality of the two best flavored clones (0-8 and 6-10) was evaluated through the panel difference method. The tests were conducted according to the ranking method (Gould, 1983). An incomplete-block design was used

(Cochran and Cox, 1957) with 24 blocks of three samples per block. Using an index of 1 (bad) to 3 (good), 18 untrained tasters ranked the three fruit samples from the four treatments, according to aroma, texture, and general flavor. Significant differences between treatments were determined by comparing the Durbin statistic to the X^2 value at t-1 degrees of freedom, with t = 4.

Results and Discussion

There were no significant interactions between the effect of salinity and K. In tomato, Satti and López (1994) reported that the addition of K (160-320 mg·L^{-1}) to the saline nutrient solution could alleviate the detrimental effects of salt-stress. In our experiments, doubling K levels had no effect on salt-stress tolerance of pepino. However, the Na : K ratio at the lower K level (K1 = 246 mg·L^{-1}) was 7:1, and it is likely that this ratio was already somewhat low, thus making the effect of further increases in K concentration undetectable.

Yield. Yields from the low saline treatments (EC = 3 dS·m^{-1}) were high for this crop (Table 1). The hybrid clones were always more productive than their respective parents, two of them (UPV-107 and UPV-927) yielding more than 5 kg/plant, i.e., more than 150 t·ha^{-1}. Overall, yield depressions due to salinity at 8 dS·m^{-1} were relatively small, since all the clones (except clone 9-1) achieved acceptable productions with these treatments. High-yielding genotypes generally show a sharper relative decrease in yield in response to salinity than low-yielding genotypes (Shannon, 1984). In our experiments, the pepino clonal hybrids were high-yielding genotypes at the low salinity levels, and they exhibited a lower relative yield decrease due to salinity than their parents. At 8 dS·m^{-1}, parental clone yield decreased by 31% and 35%, in the first and second year, respectively, as compared to the decreases of 15% and 20% exhibited by clonal hybrids (Table 1). Yield reduction caused by salinity was mainly the result of the decrease in mean fruit mass, since salinity had a quantitatively small effect on the number of fruits per plant (Table 1). Mean fruit mass decreased to the same extent in most clones, and the greater yield stability of the hybrids as compared to that of the parents is explained by their different response in fruit count per plant. In both years, the number of fruit was slightly reduced in all parental clones, while with UPV-107 and UPV-641 the response to saline treatments was a slight increase in the number of fruit per plant. The inverse relationship between vegetative and reproductive growth that is found in many crops also exists in *S. muricatum* (Hermann, 1988). Based on this concept, Pluda et al. (1993b) added salt (≈3 g·L^{-1}) to the growth medium as a means of restricting vegetative growth with the idea of improving pepino fruit set and yield. However, they reported a concomitant decrease in fruit count and mean fruit mass. In contrast, increases in number of fruit per plant in response to salinity have been reported in melon (Mendlinger, 1994; Nerson, 1992) and also in tomato (Satti and López, 1994). This effect also appears to be present in our experiments, but only in the vigorous and high-yielding clonal hybrids, in which fruit set was slightly increased by salinity. Further examination of the yield data in each truss revealed a similar response to salinity in the parental clones, but only in the first truss (data not shown). In this truss, the saline treatments also increased fruit count, but fruit set of the second and third trusses was considerably reduced, likely due to competition between trusses (Burge, 1989; Ruiz and Nuez, 1993). Thus, total number of fruits of the parental clones decreased due to salinity.

Hybrid UPV-927 was only examined in the second year, and it was also more salt-tolerant than its parental clones. In fact, UPV-927 was the highest yielding and the most salt-tolerant clone in the second trial. Its yield at the 8-dS·m^{-1} treatments (equivalent to 127 t·ha^{-1}) was higher than the yield of any one of the parental clones, even at 3 dS·m^{-1}. Salinity did not affect the number of fruits of UPV-927, and its yield decrease was only the result of the mean fruit mass reduction.

The effect of K was relatively small. Increasing K level did not statistically affect yield components, although, in both years, there was a consistent trend of increasing productivity in the high-yielding clones (9-2, UPV-641, UPV-107, and UPV-927) and decreasing productivity in the low-yielding clones (0-8, 9-1, 6-10 and 6-21) with doubling the K level (data not shown). In New Zealand (Dennis et al., 1985) and Australia (Goubran, 1985), the K fertilization levels used in tomato production also are recommended for the pepino. The K levels we used in our experiments with pepino can be considered medium-high for tomato hydroponic culture (Adams et al., 1973, 1978; Cadahía, 1988). However, it is likely that the low level (K1 = 246 mg·L^{-1}) was already high for our clones of *S. muricatum*, a species with low nutritional requirements, as reported by some Chilean authors (Bravo and Arias, 1983; Torelli, 1984), since the high K level (K2 = 492 mg·L^{-1}) appeared to have

Table 1. Yield, mean fruit mass and number of fruits of pepino clones grown at two saline levels, S1 = 3 dS·m^{-1} and S2 = 8 dS·m^{-1} (S2 as % of S1).

Clone	Yield (g/plant) S1	Yield (g/plant) S2	Mean fruit mass (g) S1	Mean fruit mass (g) S2	Fruit per plant (no.) S1	Fruit per plant (no.) S2
1993						
0-8	2448	1846(75)*	245	210(85)*	10.0	8.9(89)^{NS}
9-2	4034	2564(64)**	329	205(62)**	12.5	12.6(100)^{NS}
UPV-107	5390	4188(78)**	391	277(71)**	14.0	15.3(109)^{NS}
6-10	2186	1552(71)**	257	221(86)*	8.6	7.2(84)^{NS}
9-1	1793	1213(68)**	195	151(78)*	9.4	8.7(93)^{NS}
UPV-641	3775	3472(92)^{NS}	383	289(75)**	9.9	12.0(121)*
Mean change (%)						
Parents	−31		−22		−8.8	
Hybrids	−15		−27		+15.2	
1994						
0-8	2469	1611(65)**	282	204(72)**	8.7	7.9(89)^{NS}
9-2	4113	2297(56)**	314	207(66)**	13.5	11.1(82)*
UPV-107	5351	4091(76)**	422	308(73)**	12.8	13.5(106)^{NS}
6-10	2374	1537(65)**	296	209(70)**	8.1	7.4(91)^{NS}
9-1	1651	1224(74)*	180	133(74)**	9.4	9.5(100)^{NS}
UPV-641	3852	3157(82)*	388	301(77)**	10.0	10.6(106)^{NS}
6-21	2410	1752(62)**	238	174(73)**	9.8	8.4(86)^{NS}
UPV-927	5473	4605(84)**	378	325(86)**	14.5	14.3(99)^{NS}
Mean change^{z} (%)						
Parents	−35		−29		−9.7	
Hybrids	−20		−25		+5.8	

^{z}Mean of the clones grown over both years.
$^{NS, *, **}$Nonsignificant or significant at $P \le 0.05$ or 0.01, respectively.

Table 2. Internode length and mean days to harvest in pepino clones grown at two saline levels, S1 = 3 dS·m⁻¹ and S2 = 8 dS·m⁻¹ and two K levels, K1 = 246 mg·L⁻¹ and K2 = 492 mg·L⁻¹.

	Internode length (cm)				Mean days to harvest			
	Salinity		Potassium		Salinity		Potassium	
Clone	S1	S2	K1	K2	S1	S2	K1	K2
				1993				
0-8	6.9	7.3[NS]	6.8	7.4	182	181[NS]	179	182[NS]
9-2	7.6	7.4[NS]	7.0	7.7*	187	171*	173	184*
UPV-107	7.4	7.4[NS]	7.9	7.0*	159	151*	157	153[NS]
6-10	6.9	6.2*	6.5	6.6[NS]	174	159**	169	164[NS]
9-1	4.6	4.3[NS]	4.5	4.5[NS]	183	164**	175	173[NS]
UPV-641	7.4	6.2**	6.7	6.8[NS]	177	170[NS]	176	172[NS]
Mean	6.8	6.5	6.6	6.7	177	166	172	171
				1994				
0-8	7.3	6.7[NS]	7.2	6.8[NS]	170	169[NS]	168	172[NS]
9-2	7.5	5.8**	6.7	6.7[NS]	186	164**	178	172[NS]
UPV-107	7.3	6.0**	6.5	6.9[NS]	165	146**	154	156[NS]
6-10	7.0	5.5**	6.1	6.4[NS]	161	152*	159	151[NS]
9-1	5.0	3.8**	4.7	4.2*	180	169*	179	170*
UPV-641	7.6	6.7*	7.3	7.0[NS]	171	163[NS]	164	171[NS]
6-21	8.1	6.5**	7.1	7.5[NS]	166	154*	162	157[NS]
UPV-927	9.4	8.8*	9.1	9.1[NS]	179	165**	170	174[NS]
Mean[z]	7.0	5.8	6.4	6.3	172	160	167	166

[z]Mean of the clones grown over both years.
[NS, *, **]Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

negative effects on the yield of the low-yielding clones.

Vegetative growth. A salinity level about 7.4 dS·m⁻¹ has been reported to be toxic to plant and fruit development in pepino pot culture (Pluda et al., 1993a). In our experiments, vegetative growth appeared healthy and vigorous in all clones, and at low (3 dS·m⁻¹) and high (8 dS·m⁻¹) salinity. The length of the internodes between the first and the third truss was reduced by salinity (Table 2); this reduction was very slight in the first year and moderate in the second year. The same trend was observed in leaf size, although less markedly. Salinity shortened leaf length in all clones, by 10% on average in the first year and by 13% in the second year. Vegetative growth of the hybrids was highly vigorous, and their leaves were larger (25% to 45%) than those of their parental clones.

There were no consistent effects of K on vegetative characters over the 2 years.

Earliness. High salinity shortened mean time to harvest by more than 10 days in most clones (Table 2). In both trials, hybrid UPV-107 was earlier than either of its parental clones. However, in both years, hybrid UPV-641 showed a mean time to harvest between those of their respective parents. The same was true for hybrid UPV-927, examined only in the second year.

The effect of K on mean time to harvest was slight. A significant, but inconsistent response was only found in clone 9-2 in the first year and in clone 9-1 in the second year (Table 2).

Salinity also had little effect on mean time to anthesis, although statistical analysis showed no correlations between mean time to anthesis and mean time to harvest (data not shown). Thus, time to anthesis did not seem to be an important agronomic trait under the conditions of our trials.

Soluble solids concentration. As with tomato (Mizrahi et al., 1988) and melon

Table 3. Soluble solids concentration of pepino fruit grown at two saline levels, S1 = 3 dS·m⁻¹ and S2 = 8 dS·m⁻¹ and two levels of K, K1 = 246 mg·L⁻¹ and K2 = 492 mg·L⁻¹.

	Soluble solids concn (%)			
	Salinity		Potassium	
Clone	S1	S2	K1	K2
		1993		
0-8	7.2	8.7*	7.9	8.0[NS]
9-2	7.2	9.1**	8.1	8.3[NS]
UPV-107	7.8	10.2**	9.2	8.8[NS]
6-10	7.8	10.3**	9.0	9.1[NS]
9-1	7.9	10.1**	8.8	9.2[NS]
UPV-641	8.1	10.1**	9.0	9.2[NS]
Mean	7.7	9.8	8.7	8.8
		1994		
0-8	7.7	9.2*	8.4	8.5[NS]
9-2	7.6	9.3*	8.3	8.6[NS]
UPV-107	8.2	10.5**	9.2	9.4[NS]
6-10	8.2	10.6**	9.4	9.4[NS]
9-1	7.9	10.7**	9.2	9.5[NS]
UPV-641	8.3	10.6**	9.6	9.3[NS]
6-21	7.8	10.7**	9.2	9.5[NS]
UPV-927	7.3	8.3*	7.8	7.8[NS]
Mean[z]	8.0	10.2	9.0	9.2

[z]Mean of the clones grown over both years.
[NS, *, **]Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

(Mendlinger and Pasternak, 1992), salinity increased SSC of pepino fruits (Table 3). The increase, ≈2%, was the same in all clones and in both years. Pluda et al. (1993a), reported a much greater increase in SSC of pepino fruit caused by 7.4-dS·m⁻¹ saline treatments. Differences in genetic material used, and the higher frequency of fertigation we used, may explain the contradictory results with respect to SSC and vegetative growth.

Organoleptic test. Treatments had no significant effects on the aroma and texture of the fruits. However, at each level of K, scores were highest at the 8-dS·m⁻¹ salinity level (Table 4); this response was consistent over the 2 years and the two examined clones (0-8 and 6-10).

Salinity significantly improved pepino fruit flavor ($P < 0.01$). In tomato, sugar increase contributes to a better flavor (Adams and Ho, 1989; Stevens et al., 1979), and the higher scores of pepino fruit at 8 dS·m⁻¹ may be partially explained by the increase in SSC due to salinity, since sugars also contribute to improve flavor of pepino (El-Zeftawi et al., 1988). The effect of K level on fruit flavor was not significant.

Conclusion

In this study, *S. muricatum* has proved to be a high-yielding crop species. We suggest that the pepino could be an alternative crop in areas affected by slight to moderate salinity, since in our experiments the 8-dS·m⁻¹ saline solutions produced relatively little loss of yield and only a slight reduction in vegetative growth. Salinity also had the advantage of shortening the mean time to harvest and improving organoleptic fruit quality. Since little breeding work

Table 4 . Effect of salt and K concentrations in the nutrient solution on aroma, texture, and general flavor of fruits of two pepino clones (1993).[z]

	Clone 6-10			Clone 0-8		
Treatment[y]	Aroma	Texture	Flavor	Aroma	Texture	Flavor
S1K1	37	34	31	32	33	31
S1K2	34	36	32	39	31	34
S2K1	41	41	49	40	41	43
S2K2	40	38	40	42	39	45
T value	2.9[NS]	2.1[NS]	14.1[**]	4.8[NS]	3.69[NS]	9.9[**]

[z]Each value is the sum of scores of 18 tasters, on a 1 (bad) to 3 (good) scale. Maximum = 54
[y]The four treatments resulted from combining two salinity levels (S1 + 3 $dS\cdot m^{-1}$ and S2 = 8 $dS\cdot m^{-1}$) with two K levels (K1 = 246 $mg\cdot L^{-1}$ and K2 = 492 $mg\cdot L^{-1}$)
[NS, **]Nonsignificant or significant at $P \leq 0.01$; T = Durbin statistic.

has been done on this crop, positive results probably could be obtained with little effort. In this respect, and more specifically for pepino production under saline conditions, the development of clonal hybrids presents an interesting breeding approach, since they have proved to be high-yielding genotypes and more salt tolerant than their parents.

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