Salinity Influences Cucumber Growth and Yield

R.W. Jones, Jr., L.M. Pike, and L.F. Yourman
Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843

Abstract. Germination and radicle elongation experiments were performed with six cultivars of cucumber (Cucumis sativus L.) at seven salinity concentrations (0, 0.8, 4.0, 6.0, 9.0, 12.0, and 15 dS m⁻¹). Increasing salinity has no effect on final germination percentage after 5 days, but did decrease radicle elongation. In seedling growth studies with salinity levels ranging from 0.8 to 12 dS m⁻¹, increasing salt levels decreased shoot length and shoot dry weight. Analysis of shoot tissue from these seedlings indicated that higher salinity levels increased concentrations of Ca and Na, while Mg and K concentrations decreased. Yield and fruit quality were measured in a greenhouse study at two salinity levels (1.6 and 4.0 dS m⁻¹). Salinity significantly decreased fruit yield in five of six cultivars, but had no effect on fruit quality. Seedling shoot length of a cultivar grown at 9.0 dS m⁻¹ was correlated with relative yield at 4.0 dS m⁻¹. A salinity screening technique based on this relationship is proposed.

Growers in the western United States historically have used advances in production technology such as soil amendments, tile drainage, and leaching to ameliorate salinity problems. These traditional methods were designed to minimize exposure of the crop to salinity stress (5). However, many of these technological solutions create saline waste water that nearby residents and other growers may find undesirable. As the population of these states increases, growing competition for high-quality water may prohibit some of these technological solutions to crop production in saline environments (16).

An alternative solution to improving crop yield under salinity is to increase the crop’s ability to tolerate saline conditions through genetic improvement (5). Efficient screening techniques are necessary to uncover the variability in salt tolerance among genotypes within a crop species (14, 18). However, development of rapid screening techniques to identify salt-tolerant individuals has been difficult due to lack of fundamental understanding of the physiology of the growth reduction due to high salinity and because of the complexity of the interactions between salinity and environmental factors (7, 12). Some of the methods that have been used to screen plants for salt tolerance were: visual symptoms (e.g., leaf burn) (4), K content of shoots (15), plasmolysis (17), and growth and yield (2, 4). Cucumbers have been classified as moderately susceptible to salinity stress (11). However, no detailed study of the effects of salinity on cucumber growth and yield has been reported. In order to explore salinity tolerance in cucumbers, we examined germination, radicle elongation, early plant growth, and yield of six cultivars under various salinity levels.

Materials and Methods

Six genetically diverse cultivars of cucumbers were included in these studies: ‘Beth-Aleph’, PI 211117; ‘Expo’, F₁, cultivar; ‘Khîar’, PI 222985; ‘Poinsett’, open-pollinated cultivar; ‘SMR-58’, open-pollinated cultivar; ‘Super Slice’, open-pollinated cultivar.

Germination and radicle elongation. These tests were designed to determine if differences in germination rate, final germination percentage, radicle elongation rate, or final radicle length could be detected among the cultivars under a wide range of salinity levels. Seven levels of salinity were used. Electrical conductivities (EC) of the treatments were: 0.0, 0.8, 4.0, 6.0, 9.0, 12.0, and 15.0 dS m⁻¹. Distilled water (0.0 dS m⁻¹) and tap water (0.8 dS m⁻¹) were used as the two lowest salinity levels. The remaining solutions were prepared by salinizing distilled water with equal weights of NaCl and CaCl₂ to the desired EC. In order to increase the electrical conductivity of the solution by 1.0 dS m⁻¹, 0.341 g liter⁻¹ of each salt was added to the solution. Twenty-five seeds of each cultivar were placed in petri dishes on filter paper. The desired solution was poured in and the excess was drained. The seeds were placed in a germination chamber at 35°C for 5 days. Daily, appropriate solutions were added and drained in each dish and observations on germination rate and radicle elongation were made. A seed was considered to have germinated when the radicle could clearly be seen emerging from the seed coat. Three replications of these treatments were included. The data were analyzed by multivariate analysis of variance. Regression analyses were performed on the pooled cultivar data.

Laboratory plant growth. This experiment was designed to determine if salt tolerance among cultivars could be detected by examining seedling growth. The six salinity treatments used in this study were: 0.8, 1.6, 4.0, 6.0, 9.0, and 12.0 dS m⁻¹. The 8.0-dS·m⁻¹ level was prepared using the complete nutrient solution recommended by the U.S. Salinity Laboratory (20) in distilled water. The 1.6-dS·m⁻¹ concentration contained the complete nutrient solution prepared using tap water. The remaining salinity levels were composed of the complete nutrient solution in tap water salinized to the appropriate level by the addition of a 1:1 mixture by weight of NaCl and CaCl₂. The experimental setup was identical to one described by Wannamaker and Pike (20). Plants were grown in the laboratory in stainless steel pans (50 × 28 × 18 cm) filled with sterile medium-grade vermiculite. The pans rested on a wooden support and were suspended into an insulated fiberglass tank filled with water. Controlled heating and circulation of the water in the tank maintained the water temperature, and therefore the vermiculite growth medium, at 35°C. Drainage of excess irrigation solution was achieved through a drainage hole in the bottom of each pan that was connected by tubing to an effluent drain in the bottom of the tank. Through this system, drainage was unimpeded and yet the pans were completely sealed from the water in which they rested. Relative humidity ranged from 38% to 45%. Aerial temperatures during the day were 33 ± 3°C, and 25 ± 2°C during the night, with a 12-hr photoperiod at 240 μmol·s⁻¹·m⁻² provided by a combination of fluorescent and incandescent bulbs.

Twelve seeds of each cultivar were planted 4 cm deep in the...
Results and Discussion

Germination and radicle elongation study. Previous research on other crop species indicated that germination tests were usually not good indicators of differences in salt tolerance among cultivars (1, 4). However, since most crops are more salt-susceptible at a particular stage than at another in their ontogeny, differences in salt tolerance at germination or early seedling growth might be important if that is the period of greatest exposure to salt or physiological susceptibility (12, 14). Our results (Fig. 1) indicated that, although the germination rate of cucumber was decreased by increasing EC, the final germination percentages of five of the six cultivars were not affected by salinity. No differences in rate or final germination percentages were detected between the 0.0 dS·m⁻¹ and the 0.8 dS·m⁻¹ treatments and the linear models were similar; thus, only the latter is displayed. The only cultivar significantly affected by salinity during germination was ‘Poinsett’, with a final germination percentage of 76% at an EC of 15 dS·m⁻¹ compared with the control (0.0 dS·m⁻¹) germination percentage of 100%.

Radicle elongation decreased in all cultivars as salinity increased (Fig. 2). The model representing the pooled 0.0 dS·m⁻¹ treatments is not shown, but was similar to the linear model representing the pooled 0.8-dS·m⁻¹ treatments. Multivariate analysis showed no significant differences in final radicle length among any cultivar at either the 0.0 or 0.8 dS·m⁻¹ levels. Both salinity levels had pooled mean radicle lengths of 81 mm. However, radicles elongated significantly less when subjected to an EC of 4.0 dS·m⁻¹ (pooled mean, 62 mm) and significantly decreased with each increase in EC for all cultivars. At the two highest EC, 12.0 and 15.0 dS·m⁻¹ (pooled means, 9 and 6 mm, respectively), the radicles were thickened and appeared abnormal. No differences among cultivars were found within any salinity treatment. No significant interactions between cultivar and salinity were detected in germination or radicle elongation. This lack of difference among cultivars in germination or radicle
elongation indicates that these tests will probably be of little use in screening for salt tolerance in cucumbers.

Laboratory plant growth study. Multivariate analysis of shoot length and shoot dry weight resulted in differences between the cultivars at all salt levels. The interaction of EC and cultivar was complex, and no one cultivar appeared to be significantly more salt-tolerant than the others across any two consecutive salt levels.

Figure 3 displays the main effect of increasing salinization on the shoot length when the cultivars were pooled. An increase in EC from 0.8 to 1.6 dS·m⁻¹ reduced shoot length by 40%. The percentage reduction in shoot length from each successive increase in EC ranged from 30% to 50% and averaged 40%.

Shoot dry weight was also reduced by increasing EC (Fig. 4). Examination of the pooled cultivar values for dry weight indicates that the initial increase in EC from 0.8 to 1.6 dS·m⁻¹ reduced dry weight by 30%. The successive increases in salinity did not reduce dry weight as severely as shoot length, with percentage reductions ranging from 10% to 40%, with an average reduction of 30%.

No consistent cultivar differences in shoot tissue cation concentrations were found. Although some glycophytes have been shown to exclude Na from shoots to avoid injury from salinity (9), elemental analysis of the shoot tissue of the pooled cultivars revealed that increases in salinity resulted in increased tissue concentrations of Na and reduced concentrations of K (Fig. 5). Francois (6) found that another moderately salt-sensitive member of the Cucurbitaceae, Cucurbita pepo L. 'White Bush Scallop', displayed similar linear effects of salinity on leaf K and Na concentrations. A plausible hypothesis for these changes could be that the higher salinities reduced the relative growth rate, and, therefore (3), resulted in a decline in the K flux into the roots. Rains (16) discussed the dual mechanism concept of K uptake, featuring a mechanism of uptake at low concentrations (1 mM) that is specific for K over Na. The second mechanism, characterized by little specificity for K over Na and operating at higher concentrations, would be responsible for the increase in Na tissue concentrations in these cucumber plants as the salinity increased (16).

The increase in Ca and the decrease in Mg due to salinity found in this study (Fig. 6) has not been reported in tissue analysis of mature leaves in either squash or muskmelon (6, 19). Cucumbers have been shown to take up and store high concentrations of Ca in the older leaves when the levels were high (8, 21). This Ca uptake, hypothesized to be an adaptation to calcareous soils, could have interfered with Mg uptake by these young plants at the higher EC levels (13).

Yield in greenhouse. Observations of the plants irrigated with the saline solution (4.0 dS·m⁻¹) indicated that these had reduced leaf size, and the shoots elongated more slowly than the control treatments (1.6 dS·m⁻¹). The plants in these saline treatments also began flowering several days later than the controls. Salinity had no effect on fruit shape or the percentage of marketable fruit within any cultivar. Differences in yield between the control and saline treatments for a cultivar were due to decreased fruit number (Table 1). Significant interactions between salinity and cultivar indicate that genetic variability for salt tolerance probably exists within these populations. Examination of fruit number also allowed us to compare the yields of the slicing and pickling types of cucumbers. The higher EC significantly de-
Fig. 4. Effect of salinity on cucumber shoot dry weight after 25 days in laboratory growth study. Relationship from regression model: \( y = 1330 - 360x + 39x^2 - 1.4x^3, r^2 = 0.80 \). Diamonds are pooled cultivar means. Vertical lines represent SE.

Fig. 5. Effect of salinity on cucumber tissue concentrations of monovalent cations after 25 days in laboratory growth study. Regression models: Na, \( y = 33.9 + 13.7x, r^2 = 0.77 \); K, \( y = 163 - 8.0x, r^2 = 0.78 \). Symbols are pooled cultivar means. Vertical lines represent SE.

Table 1. Mean number of fruit (4.4 cm in diameter) harvested per plant of control and salt treatments from the greenhouse yield trial.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fruit number(^a)</th>
<th>Salinity level (dS-m(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMR 58</td>
<td>7.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Beth-Aleph</td>
<td>7.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Khiar</td>
<td>7.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Super Slice</td>
<td>7.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Expo</td>
<td>7.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Poinsett</td>
<td>7.7</td>
<td>4.0</td>
</tr>
</tbody>
</table>

\(^a\)Means of six replications.

Table 2. Relative yield of cucumber cultivars (mean fruit number at EC = 4.0 dS-m\(^{-1}\)/mean fruit number at EC = 1.6 dS-m\(^{-1}\)) grown in the greenhouse compared to shoot length at 9 dS-m\(^{-1}\) after 25 days of growth in the laboratory.

<table>
<thead>
<tr>
<th>Cultivar(^a)</th>
<th>Relative yield</th>
<th>Shoot length(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beth-Aleph (P)</td>
<td>0.66(^*)</td>
<td>43a</td>
</tr>
<tr>
<td>SMR 58 (P)</td>
<td>0.80</td>
<td>37b</td>
</tr>
<tr>
<td>Khiar (P)</td>
<td>0.60(^*)</td>
<td>30c</td>
</tr>
<tr>
<td>Super Slice (S)</td>
<td>0.52(^*)</td>
<td>21d</td>
</tr>
<tr>
<td>Expo (P)</td>
<td>0.48(^*)</td>
<td>19d</td>
</tr>
<tr>
<td>Poinsett (S)</td>
<td>0.32(^*)</td>
<td>15d</td>
</tr>
</tbody>
</table>

\(^a\)S = slicing, P = pickling cultivar.

\(^b\)Means from multivariate analysis separated by Duncan’s multiple range test \(P = 0.05\).

The relative yield of a cultivar is a measure of the cultivar’s salt tolerance. In order to determine if there was a relationship between the relative yield and the seedling shoot length after 25 days of growth, we compared the results of the laboratory at this EC. The most salt-tolerant of the cultivars tested (‘SMR 58’) had a relative yield of 0.80. Unknown environmental factors, selection of cultivars for testing, or duration of harvest could have contributed to our finding the cucumber to be less salt-tolerant in this study than previously reported.
growth study to the yield study. Table 2 displays the relative yields of the cultivars ranked by shoot length at an EC of 9 dS/m from the laboratory growth results. With the exception of 'SMR 58' and 'Beth-Aleph', the ranking of relative yield corresponds well with shoot length ranking, and these two measures of salt tolerance were significantly correlated ($r^2 = 0.75$). The cultivar Poinsett manifest the greatest reduction in fruit number and shortest shoots from the laboratory growth study and was also the only cultivar to display a significant germination percentage reduction due to salinity. This correlation of shoot length with yield, coupled with the evidence from the yield study that genetic variability for salt tolerance exists within this species, indicates a potential for selecting salt-tolerant individuals using the laboratory seedling growth technique described above.

Literature Cited