Vegetative growth. The effect of salinity on vegetative growth of the 2 cultivars was not too different from the effects on fruit yield. The threshold for 'Scallop' occurred at 4.6 dS/m and for 'Zucchini' at 5.7 dS/m. The \( k_e \) at which a 50% reduction in vegetative growth occurred was 7.9 and 13.0 dS/m for 'Scallop' and 'Zucchini', respectively. The salt tolerance categories (5) for vegetative growth were identical to those for fruit yield.

Mineral composition. Mineral analyses of leaves sampled from the 2 cultivars are presented in Table 2. Both cultivars showed a significant increase in leaf Na and Cl concentration and significant decrease in K concentration with increased soil salinity levels. In comparison to muskmelon grown under similar soil salinity conditions (7), the K and Cl concentrations were significantly higher and Na significantly lower in both 'Scallop' and 'Zucchini'.

Calcium and Mg concentrations in 'Zucchini' leaves also showed a significant increase with increased soil salinity. In 'Scallop' leaves, however, the Ca and Mg levels were unaffected by salinity.

Phosphorus concentrations in both cultivars, although not significantly affected, tended to decrease as salinity increased.

Germination. Soil water salinities up to 14.4 dS/m delayed germination of both cultivars but did not reduce final germination percentage significantly (Fig. 2). At \( k_{sw} \) values of 16.1 and 17.8 dS/m, 'Zucchini' showed an additional delay in germination, but final germination percentage was unaffected. However, both 16.1 and 17.8 dS/m significantly reduced the final germination percentage of 'Scallop'.

Both cultivars were considerably more salt tolerant during germination than at the mature stage of growth. The soil water salinity of 14.4 dS/m had no effect on final germination percentage. Since the soluble salt concentration of the soil solution at field capacity is about twice that at saturation (8), i.e., \( k_{sw} = 2 k_e \), the data in Fig. 1 indicate that fruit yield of 'Scallop' would be reduced 64% and 'Zucchini' 18% at a \( k_{sw} \) of 14.4 dS/m.

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Relationship among Nitrogen, Phosphorus, and Potassium Fertility Regimes on Celery Transplant Growth

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Abstract. ‘Utah 52-70R’ celery (Apium graveolens L.) seedlings were fertilized weekly with solutions containing N, P, and K to determine the nutrient needs required to produce high quality transplants. As N rate increased from 10 to 250 ppm, shoot number, seedling diameter and height, leaf area/seedling, shoot and root dry weight/seedling, and dry weight/seedling increased in 52-day-old seedlings. As P rate increased from 5 to 125 ppm, seedling diameter, height, shoot dry weight/seedling, and leaf area increased, but root dry weight and shoot number were not affected. Nitrogen interacted with P for all growth variables measured. Increasing P rates from 5 to 125 ppm significantly increased shoot number, diameter, height, and shoot and root dry weights only in combination with N rates of at least 250 ppm; however, dry weight/seedling, leaf area, and root to shoot dry weight ratios increased with P rates used in combination with at least 50 ppm N. Potassium rates from 10 to 250 ppm affected neither the growth variables nor did they interact with P or N. Therefore, to grow high-quality celery transplants, nutrient solutions should contain at least 250N–125P–10K ppm if a vermiculite-perlite medium low in N, P, and K is used.

Traditionally, celery production fields are established using bareroot transplants originally grown on organic soils in field nurseries. The use of greenhouse-grown, containerized transplants, however, is becoming increasingly popular in geographical areas where bareroot transplant production is not practical or feasible. The nutritional requirements needed to produce quality containerized transplants are not understood fully, and research describing the nutritional needs of seedling transplants is lacking. Some fertilizer recommendations for celery seedlings are available in celery production guides. Zandstra et al. (8) mentioned that containerized transplants should be fertilized with a solution containing 14N–OP–44K(%). Guzman et al. (4) recommended applying ON–89P–214K kg/ha to organic soil seedbeds used for bareroot transplant production in Florida. In relation to fresh market celery production, 333N–97P–184K kg/ha are recommended in California to produce optimal yields on mineral soils (6). The role of N, P, and K fertility on the growth of seedling celery has not been investigated, but celery grown to maturity on sphagnum peat indicated a nutrient requirement of 180N–80P–225K kg/ha (2). If these data are used to derive the general nutrient needs of celery seedlings, nutrient regimes combining high K rates seem appropriate. The objective of this study was

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to determine the N, P, and K nutrient requirements for producing high quality celery transplants using an artificial soil medium low in N, P, and K.

'Utah 52-70R' celery seeds were planted into plastic containers (130 cm³) filled with about 15 g of a 1.5 vermiculite:1.5 perlite:7 peat (by volume) medium (Sunshine Mix Basic Blend No. 2, Western Peat Moss Ltd., Vancouver, B.C.). This medium was chosen since it was found to be very low in N, P, and K. An analysis of the medium indicated 4N–16P–40K (ppm) and a pH of 6.3. An ammonium acetate, EDTA, and hydrochloric acid extraction solution was used for P and K, and a salicylic acid–sulfuric acid extraction solution was used for N. The seeded containers were placed on individual plastic-drip saucers and watered with distilled water. The treatments were factorial combinations of aqueous solutions of N from urea at 10, 50, or 250 ppm, and K from KCl at 10, 50, or 250 ppm. Each of the nutrient solutions was adjusted to pH 6.5. Twenty ml of the N, P, and K treatment solutions were applied to the medium in each container. Applications of the solutions were made weekly. The first application was made 21 days after seeding and coincided with the first expanded true leaf stage. A total of 5 applications were made during the experimental period. Each saucer held 9 plants, and the 27 treatments were replicated 4 times and arranged in a randomized complete block design.

Plants were watered when necessary with distilled water placed into the saucer; after several hours, water not absorbed was discarded. The plants were grown in a shade house covered with 51% shade cloth from 8 Oct. to 1 Dec. 1984. A plastic tent was placed over the area to exclude rainfall, but it did not restrict air flow. Temperature data were recorded continuously in the shadehouse with a recording hygrothermograph. The temperatures during the experimental period are presented in Fig. 1. The experiment was terminated 52 days after seeding when at least 1 treatment was considered to be at the appropriate growth stage for transplanting. The following plant growth variables were measured: leaf area/seeding (including petioles) with a LI-COR LI-3000 leaf area meter (LI-COR, Lincoln, Neb.), stalk diameter of the entire seeding (measured at the widest part of the plant nearest the media); seedling height (measured from the media surface to the approximate apical meristem tip); shoot and root dry weights/seeding (dried for 24 hr at 65°C); and shoot number. Dry weight/shoot and root to shoot dry weight ratios were calculated from these data. Orthogonal contrasts were performed if significant interactions were detected by analysis of variance (ANOVA). Linear or quadratic equations were tested for goodness of fit using the RSREG procedure of SAS software (SAS Institute, Inc., Cary, N.C.).

Any beneficial growth response induced by N, P, and K fertility regimes must be judged according to a predetermined standard of quality. In this study, a "quality" celery transplant was defined as having 5 to 6 shoots with large leaf area and weight. Also, quality transplants should have large root systems to maximize water and nutrient absorption, thereby decreasing the possibility of transplant shock. Seeding stalk di-

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### Table 1. Main and interaction effects of N and P on the growth of 52-day-old celery seedlings.

<table>
<thead>
<tr>
<th>N (ppm)</th>
<th>P (ppm)</th>
<th>No. of Shoots</th>
<th>Significance</th>
<th>Dry wt/shoot (mg)</th>
<th>Root dry wt/shoot (mg)</th>
<th>Leaf area/seeding (cm²)</th>
<th>Root dry wt ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5</td>
<td>6</td>
<td>L***</td>
<td>116</td>
<td>54</td>
<td>136</td>
<td>0.73</td>
</tr>
<tr>
<td>25</td>
<td>5</td>
<td>5</td>
<td>Q***</td>
<td>115</td>
<td>50</td>
<td>135</td>
<td>0.73</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
<td>4</td>
<td>L***</td>
<td>113</td>
<td>49</td>
<td>134</td>
<td>0.71</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>5</td>
<td>L***</td>
<td>114</td>
<td>51</td>
<td>135</td>
<td>0.71</td>
</tr>
</tbody>
</table>

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*Interaction of N × P significant for all variables at the 0.1% level.

**F test significant at 5% (*), 1% (**), and 0.1% (***+) level or nonsignificant (NS); L = linear effect, and Q = quadratic effect.

*Indicates significance of increasing P rate with N rate held constant; row mean not included.

**Significance of P main effect.

*Indicates significance of increasing N rate with P rate held constant; column mean not included.

*Significance of N main effect.
crease shoot production and root dry weight accumulation. At N rates of 10 or 50 ppm, effects were not significant for root dry weight, shoot and root dry weights, dry weight/area/seedling, shoot dry weight/seedling, and root dry weight/shoot and seedling, leaf area, root dry weight, and root to shoot ratios. In this study, celery seedlings have a low K requirement containing at least 10 ppm were adequate for quality transplant production. The K requirements of celery may increase at later developmental stages, since previous work emphasized the need for high K fertility to obtain satisfactory yields (2, 4, 6, 8).

The main effects of increasing N were significant for all the variables measured (Table 1). Generally, as N increased at any constant P rate, root and shoot growth increased. This response was linear for seedling diameter and height, but curvilinear for shoot number, dry weight/shoot and seedling, leaf area, root dry weight, and root to shoot ratios. This curvilinear response is best illustrated by leaf area/seedling, shoot dry weight/seedling, and dry weight/shoot which more than doubled as N rate increased from 50 to 250 ppm. Visually, as N increased, the color of the foliage increased from a pale, lime green to a dark, emerald green.

The main effects of P also were significant. Increasing P rate, root and shoot growth increased. This shift was strongest at 250 ppm N. Significant N × P interactions have been reported with other crops. Nitrogen supplied below the optimal level shifted biomass accumulation more into roots of Phaseolus vulgaris than into shoots (3). Increasing amounts of N and P decreased root to shoot ratios in corn (5). Lack of optimal N and P fertilizer inputs is considered a stress situation, and Arkin and Taylor (1) generalized that any reduction in root stress usually decreases root to shoot ratios. In this study, celery seedlings grown under low N and P status were stunted, spindly, and of poor quality for commercial use.

Identifying and understanding the differential growth responses of celery to N and P provides new guidelines for the use of appropriate fertility practices for transplant production. The evidence suggests that the fertility regimes needed to produce high quality celery transplants under the conditions similar to those described in this study should include at least 250 ppm N and 125 ppm P. Although K at the rates evaluated did not contribute significantly to plant growth using this medium, it is recommended that at least 10 ppm be included in nutrient solutions to sustain growth at the levels reported. These data indicated that using fertility guidelines suggested for field grown celery may not be appropriate for transplant production.

References