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Use of Slow-release Nitrogen and Phosphorus Fertilizers in Celery Transplant Production

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Abstract. **'Utah 52-70R' celery (*Apium graveolens* L.) seedlings were grown in a N- and P-deficient soilless medium amended with N and P slow-release fertilizers (Osmocote) in greenhouses maintained at either 21° to 32°C (warm house) or 14° to 24° (cool house). Generally, as N rate increased from 1.25 to 10 g N/kg of medium, plant stands, chlorophyll, shoot number, plant height, leaf area, and shoot and root dry weights increased; but, from 10 to 20 g N/kg of medium, these variables decreased. As P rates increased from 2.5 to 10.0 g·kg^{-1} of medium, only chlorophyll content decreased linearly. Temperatures in the warm house generally reduced celery growth compared to the cool house. At the experiment's termination, it was determined that as N and P rates increased, media conductivity, nitrate-N, and phosphorus levels increased, but pH decreased. A N rate of 1.25 and 2.5 g P/kg of medium was adequate to produce quality celery transplants in a cool house.**

Celery production is increasing in the Lower Rio Grande Valley of Texas. Virtually all celery production fields are established using either bareroot or greenhouse-grown containerized transplants. Many of these transplants are shipped to Texas from Florida, but local transplant production is increasing. Success, however, depends on careful N, P, and K fertility practices. Lack of information about N:P:K ratios, concentrations, and application timing makes fertilization scheduling difficult. Usually, nutrient solutions are applied at every other irrigation, but excessive salt buildup from nutrient solutions and the naturally saline irrigation water may increase media salinity and pH and reduce growth.

The role of N, P, and K fertility in celery seedling growth has received some attention. In a recent study, solutions of 250N–125P–10K mg·liter^{-1} enhanced celery transplant growth in a soilless medium (1); however, timing of application was not studied. Slow-release fertilizers may be useful by providing a steady prolonged nutrient supply and reduction of nutrient leaching (4). Nutrient release by Osmocote is temperature-regulated (4). Identification of the optimal N:P:K ratio and application rate of Osmocote and appropriate temperature regime to optimize plant growth would greatly simplify transplant production. The objective of this study was to determine the N and P nutrient requirements of celery seedlings grown in "cool" and "warm" greenhouses using Osmocote fertilizers.

Two experiments were conducted from 20 Jan. to 17 Mar. and from 28 Feb. to 14 Apr. 1986. Single N, P, and K sources of slow-release fertilizers were derived from Osmocote (Sierra Chemical Co., Milpitas, Calif.). In the first experiment, N at 5, 10, 15, and 20 g·kg^{-1} of medium were factorially combined with P at 2.5, 5.0, 7.5, and 10.0 g·kg^{-1} of medium. In the second experiment, N rates were 1.25, 2.5, 5.0, and 10.0 g·kg^{-1} of medium, and P rates remained the same. K at 10.3 g·kg^{-1} of medium was included in all treatments in both experiments. The nutrients were mechanically mixed into each medium prior to filling the containers. Generally, temperatures in cool house ranged from 14° to 24°C and in the warm house from 18° to 31° and 23° to 33° in Expts. 1 and 2, respectively.

In the first experiment, 'Utah 52-70R' celery seeds were planted in plastic containers (161 cm^3) filled with ≈18 g of a 1.5 vermiculite : 1.5 perlite : 7 peat (by volume) medium (Sunshine Mix Basic Blend No. 2, Fisons Western Corporation, Vancouver, B.C.). In the second experiment, 83-cm^3 containers were filled with ≈13 g of the same medium. This medium was chosen because of its low N and P content. An analysis of the medium indicated 1 mg·liter^{-1} N and P and a pH and conductivity, respectively, of 7.1 and 1.5 dS·m^{-1} (Expt. 1) and 6.9 and 1.0 dS·m^{-1} (Expt. 2). In Expts. 1 and 2, each treatment plot consisted of eight and 12 plants, respectively. The 32 treatments were replicated four times and arranged in a randomized complete block design within each greenhouse.

Plants were watered with distilled water to reduce any salinity. Temperature data were recorded continuously with a recording hygrothermograph. Plant stands within each treatment plot were counted 35 days after seeding in both experiments. The first and second experiments were terminated 56 and 49 days after seeding, respectively, when one treatment across all replications was considered to be at the appropriate growth stage for transplanting. The following plant growth variables were measured: leaf area per seedling, including petiole, with a LI-COR LI-3000 leaf area meter; stalk diameter of the widest part of the plant nearest the medium; seedling height measured from the medium surface to the tip of the longest leaf; shoot number; and shoot and root dry weights per seedling (dried for 24 hr at 65°C). Leaf disks (0.31 cm^2) were removed and composited from the fifth true leaf from five random plants per treatment, and total chlorophyll was determined (3). Growth data were analyzed by analysis of variance (ANOVA) and polynomial regression (SAS Institute, Cary, N.C.) To evaluate growth response to fertility regimes, a predetermined standard for quality was used (1). The relative importance of N, P, and greenhouse temperatures on transplant growth was determined by partitioning the total sum of squares for treatments into main and interaction effects and expressing these individual contributions to variation as a percentage of the sum of squares for the model (composed of only those sources of variation in the ANOVA).

The fertility status of the media of each treatment was determined at the termination of the first experiment. Medium was removed from one container in each replication, composited, and analyzed for conductivity (1 soil : 2 water ratio), pH, nitrate-N (salicylic acid-sulfuric acid extraction), and P (hydrochloric acid extraction) by the Texas A&M Univ. Soil Testing Service, College Station. (5). Statistical analysis was not performed on soil test results.

Although the seedling response to fertility and temperature treatments differed in each experiment, the major factors affecting growth

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Table 1. Percentages of treatment sum of squares of the model[z] partitioned into main and interaction effects for celery transplant growth variables in response to N and P slow-release fertilizers and greenhouse temperatures.

Source of variation	df	Percentages of treatment sums of squares															
		Stand		Total chlorophyll		No. shoots		Plant ht		Leaf area		Stem diam		Dry wt			
														Shoot		Root	
		1[y]	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Treatment	34																
Rep	3	2.9*	2.8	0.4	2.8	6.8**	2.0	11.5	4.4**	9.5**	1.1*	70.2**	47.9**	8.2*	4.9	5.6	58.4**
N	3	91.8**	20.9**	8.0**	35.0**	22.5**	24.8	39.8**	19.7**	46.4**	29.8**	2.1	2.8	56.7**	35.8*	65.6**	2.1
P	3	0.7	3.0	4.3**	11.1**	0.9	8.0**	1.8	2.4**	0.9	3.1**	2.1	2.7	6.4	1.8	4.4	3.8
NP	9	1.4	7.3	8.1	12.8*	3.5	6.7**	2.5	3.0**	1.0	4.2**	13.2**	5.3	1.3	8.0	3.3	8.1
Temp	1	0.1	51.0**	62.5**	1.9	50.4**	44.4**	20.2**	63.1**	13.8**	51.0**	0.4	24.6**	7.9**	21.7*	14.6**	8.0**
Temp × N	3	0.0	3.8	4.3	4.2	8.8**	7.3**	9.8**	4.7**	8.2**	7.8**	1.3	4.9*	4.1*	21.8	2.2*	3.3
Temp × P	3	1.1	3.7	4.8	13.5**	2.3	3.7**	6.2	1.1**	10.4	1.1**	4.1*	0.0	6.5	1.6	2.0	0.0
Temp × N × P	9	1.9	9.3	7.5**	18.7**	4.8	3.1	8.2*	1.5**	9.8*	1.8**	6.5*	11.6*	8.8	4.4	2.2	16.3**
Model R^2		0.83	0.63	0.67	0.60	0.29	0.21	0.26	0.66	0.20	0.50	0.27	0.12	0.20	0.01	0.38	0.10

[z]Composed on only those sources of variation given in this analysis of variance table.
[y]1 = first experiment (20 Jan–17 Mar. 1986): 2 = second experiment (28 Feb.–14 Apr. 1986).
*,**F value significant at the 5% or 1% levels, respectively. Values not followed by asterisks are not significant at the 5% level.

Table 2. Main effects of N and P slow-release fertilizers and greenhouses temperatures on celery seedling growth.

Main effect	Stand (%)		Total chlorophyll (μg/cm²)		No. shoots		Plant ht (cm)		Leaf area (cm²)		Stem diam. (mm)		Dry wt (g)			
													Shoot		Root	
	1[z]	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
N (g N/kg media)																
1.25	---	96	---	111	---	5.8	---	9.0	---	20.0	---	4.5	---	0.46	---	0.06
2.5	---	95	---	122	---	6.1	---	11.2	---	30.0	---	4.7	---	0.54	---	0.07
5.0	100	94	134	133	8.3	6.3	15.9	12.2	121.8	35.3	6.4	4.6	0.90	0.55	0.25	0.06
10.0	98	86	135	123	8.2	6.3	15.7	12.5	119.6	36.6	6.3	4.5	0.84	0.65	0.17	0.06
15.0	78	---	125	---	7.7	---	14.1	---	96.6	---	6.1	---	0.64	---	0.11	---
20.0	31	---	121	---	7.3	---	12.5	---	82.4	---	6.6	---	0.56	---	0.10	---
P (g P/kg media)																
2.5	78	91	136	129	8.0	6.3	15.0	11.9	110.8	33.9	6.4	4.5	0.82	0.52	0.18	0.07
5.0	72	91	128	120	8.1	6.0	15.5	10.6	115.0	28.2	6.4	4.6	0.83	0.55	0.19	0.07
7.5	77	94	128	122	7.9	6.1	14.8	10.8	109.9	28.6	6.0	4.7	0.74	0.54	0.16	0.06
10.0	79	95	124	118	8.0	6.2	15.1	11.2	109.7	29.4	6.4	4.4	0.75	0.56	0.17	0.07
Temperature																
Cool	77	98	113	120	8.5	6.4	15.8	13.4	118.1	38.1	6.2	4.3	0.83	0.50	0.20	0.07
Warm	77	88	146	124	7.5	5.8	14.4	8.2	104.2	19.9	6.4	4.9	0.74	0.60	0.15	0.06
Significance																
N rates	Q**	L**	L*	Q**	L**	Q**	Q**	Q**	Q**	Q**	NS	NS	L**	L*	Q**	NS
P rates	NS	NS	L**	L**	NS	Q**	NS	Q**	NS	Q**	NS	NS	NS	NS	NS	NS
Temperature	NS	**	**	NS	**	**	**	**	**	**	NS	**	**	*	**	**

[z]1 = first experiment (20 Jan.–17 Mar. 1986); 2 = second experiment (28 Feb.–14 Apr. 1986).
*,**,NSF test significant at the 5% or 1% level or not significant, respectively. L = linear, Q = quadratic.

were N and temperature. In the first experiment, N fertility and temperature affected seedling growth more than P or any fertility and temperature interaction. The major portion of variation in stands, plant height, leaf area, and shoot and root dry weights was attributable to the main effect of N (Table 1). In contrast, temperature accounted for most of the variation in chlorophyll content and shoot number, whereas P and N × P × temperature interactions accounted for much lower amounts of variation. In the second experiment, the major portion of variation in stands, shoot number, plant height, and leaf area was attributed to temperature; N accounted for the major portion of variation in chlorophyll content and shoot dry weight. To a lesser degree, P and interactions among N, P, and temperature accounted for smaller amounts of the variation.

Effect of nitrogen. As N rate increased from 5 to 20 g·kg^{-1} of medium in the first experiment, there was a curvilinear decrease in stands, plant height, leaf area, and root dry weight, with the greatest reductions occurring at N rates >10 g·kg^{-1} (Table 2). Shoot dry weight, chlorophyll content, and shoot number decreased linearly with N rates. Although growth and quality of surviving plants were considered acceptable at the 20-g rate, stands were reduced by 69%. Stand reductions >10% were considered unacceptable; consequently, N rates >10 g·kg^{-1} were considered excessive.

In the second experiment, N rate increased from 1.25 to 10 g·kg^{-1} of medium, shoot dry weight increased linearly, but stands decreased linearly from 96% to 86%. Shoot number, plant height, leaf area, and chlorophyll content increased curvilinearly with negligible increases with >5 g·kg^{-1} of medium. Both root dry weight and stem diameter were not affected by N rate. The higher average greenhouse temperatures in the second experiment may have increased nutrient release and salinity and thereby reduced growth. Growth and stands were acceptable within the 1.25 to 5 g N/kg of medium range. The lowest N rate has the best potential for seedling production, since it will produce similar growth responses as in the 5-g rate, but, in a practical sense, if greenhouse temperatures were to increase unexpectedly, excessive nutrient release is less likely to occur. N rates >5 g were considered excessive because of stand reductions.

Effect of phosphorus. Increasing the P rate in the first experiment decreased chlorophyll content linearly, but none of the other growth variables were affected (Table 2). In the second experiment, as the P rate increased, chlorophyll content decreased but stand and shoot and root dry weights were not affected.

Table 3. Nitrate-N and P content of medium amended with slow-release N and P fertilizers at termination of the first experiment conducted in cool and warm greenhouses.

Nutrient ($g \cdot kg^{-1}$ medium)	Cool	Warm
N[z]	*Nitrate-N ($mg \cdot liter^{-1}$)*	
5	80	92
10	294	302
15	415	421
20	384	465
Mean	293	320
P[y]	*Phosphorus ($mg \cdot liter^{-1}$)*	
2.5	13	14
5.0	21	43
7.5	68	91
10.0	85	132
Mean	47	70

[z]Mean of the N treatments with all P treatments pooled.
[y]Mean of the P treatments with all N treatments pooled.

Shoot number, height, and leaf area tended to be highest at 2.5 g P/kg. Higher rates, therefore, were considered unnecessary. The 2.5 $g \cdot kg^{-1}$ rate of P had negligible effect on stands and transplant growth was acceptable.

Effect of greenhouse temperature. In the first experiment, shoot number, plant height, leaf area, and shoot and root dry weights generally were lower in the warm house compared to the cool house (Table 2). Chlorophyll content, however, increased in the warm house. In the second experiment, shoot number, plant height, leaf area, and root dry weight were lower in the warm house compared to the cool house. In contrast, stem diameter and shoot dry weight were greater in the warm house, but stands were reduced >10%.

Media analysis. Since nutrients in Osmocote are released solely in response to increasing temperatures (4), the media pH and conductivity may vary according to fertilizer source and rate and greenhouse temperature. In the first experiment, medium pH, conductivity, and nitrate-N and phosphorus were determined at termination to indicate associations between growth and these medium characteristics. Nitrate-N and phosphorus levels were within an acceptable range for transplant growth at the 5 g N/kg and 2.5 g P/kg rates (6) (Table 3), but, as N and P Osmocote rates increased, the nitrate-N and P increased to levels that reduced celery growth. Generally, the nitrate-N and P levels were higher in the warm house than the cool house.

Media nitrate-N and P levels affected media pH and conductivity. The pH of the medium before Osmocote amendment was 7.1. After Osmocote amendment, the pH and conductivity increased with N rate (Table 4). Conductivity increased, but pH decreased with increasing P rate. These initial pH and conductivity levels were considered within acceptable ranges suitable for greenhouse media (6). At termination of the experiment, media conductivity increased, but pH decreased with N rate. Conductivity of the media amended with P ranged from an EC of 3.0 to 3.5 $dS \cdot m^{-1}$ in the cool house and 2.5 to 3.9 $dS \cdot m^{-1}$ in the warm house. The pH in both houses tended to decrease as P rate increased. Media conductivity increased from 3.0 to 4.7 $dS \cdot m^{-1}$ at N rates of ≥ 10 $g \cdot kg^{-1}$. Celery seedlings may not tolerate this level of salinity. Francois and West (2) found celery moderately sensitive to salinity and that fresh-market yields were reduced at levels >1.8 $dS \cdot m^{-1}$. In the first experiment, stands were reduced by >22% with N rates of ≥ 15 $g \cdot kg^{-1}$; however, in the second experiment, stands were reduced 14% at the 10 $g \cdot kg^{-1}$ rate. Rates >5 g N/kg in our study were considered toxic to celery growth.

This study indicates that slow-release fertilizers have potential for use in celery transplant production, but greenhouse temperatures must be controlled. Temperatures of 14° to 24°C proved effective, whereas a regime of 21° to 32° was too high. Fertilization with Osmocote at 1.25N–2.5P–10.3K $g \cdot kg$ medium, the lowest rates used in this study, showed the best potential for quality celery transplant production.

Table 4. Conductivity and pH of media amended with slow release N and P fertilizers at commencement and termination of the first experiment conducted in cool and warm greenhouses.

Nutrient ($g \cdot kg^{-1}$ medium)	Conductivity ($dS \cdot m^{-1}$)			pH		
		Termination			Termination	
	Initial	Cool	Warm	Initial	Cool	Warm
N[z]						
5	1.3	1.5	1.5	5.7	6.5	6.5
10	1.4	3.3	3.0	5.8	6.2	6.1
15	1.3	4.2	4.0	6.2	6.1	6.1
20	1.5	3.6	4.7	6.6	5.9	5.3
Mean	1.4	3.1	3.3	6.1	6.2	6.0
P[y]						
2.5	1.0	3.0	2.5	6.6	6.3	6.5
5.0	1.3	3.0	3.6	6.1	6.5	6.2
7.5	1.3	3.1	3.9	5.9	5.6	5.6
10.0	1.9	3.5	3.2	5.5	5.8	5.8
Mean	1.4	3.1	3.3	6.0	6.1	6.0

[z]Mean of the N treatments with all P treatments pooled.
[y]Mean of the P treatments with all N treatments pooled.

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