HORTSCIENCE 37(4):651–655. 2002.

Evaluation of Transplant Fertility of Short-day Onions in Southeast Georgia

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Additional index words. Vidalia®, plantbed onions, fertilizer, nitrogen, phosphorus, potassium, calcium, sulfur

Abstract. **Preplant levels of 5N–4.4P–12.4K (–5S or –9S) and sidedress applications of $CaNO_3$ were evaluated in onion (*Allium cepa* L.). In addition, high phosphorus fertilizers 18N–20.1P–0K (diammonium phosphate) and liquid 10N–14.8P–0K were evaluated on sites with and without high residual phosphorus levels as well as their interaction with onion cultivars. Sidedress applications of $CaNO_3$ had a significant effect on plant height and an interaction with preplant 5N–4.4P–12.4K fertilizer. There was a linear increase in plant height with increasing applications of 5N–4.4P–12.4K from 0 to 1569 kg·ha^{-1} with the $CaNO_3$ applications. Neither 5N–4.4P–12.4K nor $CaNO_3$ applications affected stand count. 5N–4.4P–12.4K fertilizer had significant linear effects on tissue potassium and sulfur. Tissue nitrogen and calcium increased with $CaNO_3$ applications while phosphorus, potassium, and sulfur decreased. $CaNO_3$ also had a positive effect on suitability for transplanting. There was an interaction effect between 5N–4.4P–12.4K and $CaNO_3$ for tissue phosphorus levels. There was a linear decrease in tissue phosphorus levels with increasing amounts of 5N–4.4P–12.4K fertilizer with the sidedress $CaNO_3$ treatments. High phosphorus fertilizers applied directly after seeding had no effect on plant stand or plant height either on soils with or without high residual phosphorus in 1998. In 1999, 10N–14.8P–0K fertilizer had a significant effect on plant height while 18N–20.1P–0K did not. Based on this study, we conclude that additional applications of high phosphorus fertilizers applied post seeding are not required due to the relatively warm conditions found in southeast Georgia in September. There were differences between cultivars, but cultivar × high phosphorus fertilizer interactions were nonsignificant.**

Both field and greenhouse transplant production are used for onion (*Allium cepa* L.) production depending on world location and specific requirements. In northern climates, onions may be seeded under glass to produce transplants because weather conditions are not suitable for outdoor production (Brewster, 1994). Onion transplants are used in many production areas such as the high plains of west Texas and western New York; however, in most cases the transplants are produced elsewhere and brought to the production area in order to gain time in production (Ellen Peffley, Texas and Dale Shuknecht, personal communications). Short-day onion production in southeast Georgia, however, relies on transplant production within the production region. This is done because the currently used irrigation systems (center-pivot or cable tow) are not able to irrigate whole fields sufficiently during the high temperatures of September to insure stand establishment for direct seeded crops. High-density seedling production can be more efficiently irrigated with these systems. In addition, transplanted onions are believed better protected during cold weather since they are set 2.5–5.1 cm deep, conversely, direct seeded onions are seeded very shallow (0.6–1.3 cm), consequently meristematic tissue is more exposed and susceptible to cold injury. Finally, transplant onions don't form seedstems in the spring as readily as direct seeded onions.

Work on onion transplant production and growth has included fertilization, cultural practices, watering regimens, and disease control. Fertilizer application efficiency, particularly the use of liquid starter fertilizers, has been investigated with the result that use of these fertilizers are comparable to additional topdressing nitrogen in onion production with a concomitant reduction in off-site losses of fertilizer (Stone, 2000). Phosphorus alone at high rates (31 kg·ha^{-1} P) did not result in bulb dry matter yields comparable to nitrogen alone at 90 kg·ha^{-1} or to combinations of nitrogen and phosphorus (Halder et al., 1998). Increasing nitrogen fertilizer rates from 0 to 160 kg·ha^{-1} increased onion bulb nitrate levels, but decreased tissue phosphorus levels and had no effect on tissue potassium (Rostamfrodi et al., 1999). Use of muriate of potash or farm yard manure increased onion dry matter and potassium uptake with a significant interaction between these two fertilizer sources (Geetha et al., 1999). Onions generally performed better with fertilizers that include sulfur on soils with low residual sulfur. Sumantra and Tiwari (1997) found cultivar Pusa Red performed best with $CaSO_4$ at 24 kg·ha^{-1} compared to $CaSO_4$ at 8 and 16 kg·ha^{-1}, single superphosphate at three rates, or $(NH_4)_2SO_4$ at three rates.

Cultural practices such as planting date and use of transplants can play a significant role in onion production. Movalia et al. (1999) found that earlier sowing, use of transplants, and higher nitrogen fertilizer (100 kg·ha^{-1}) resulted in higher onion bulb yields. Onion seedling dry weight was increased when fluid drilled in a guar gel that contained N–P–K at the first harvest but not at the second harvest (Finch-Savage and Cox, 1983). Onion set production, and presumably onion transplant production, is feasible in Styrofoam trays. Cardoso and Costa (1999) found that sets of 1.5 cm (2 g) could be obtained in a 128-cell tray with five plants per cell if good fertility was maintained. Singh and Chaure (1999) found that the optimum transplant age and nitrogen fertilizer for 'Pusa Red' onions was 6 weeks at 150 kg·ha^{-1}, which maximized overall yield while minimizing fertilizer costs. It was found that nitrogen rate (40, 60, or 80 kg·ha^{-1}) had no effect on yield of 1–2 cm sets while seeding density increased set production up to 8 g·m^2 (Bhattarai, 1998).

Short-day onion production in southeast Georgia begins with the production of onion transplants. Onion transplants are field produced in high-density plantings. Typically

Received for publication 13 Mar. 2001. Accepted for publication 23 Sept. 2001.
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onions are seeded in September with 50–70 seed per 30.5 cm of row and are grown for 8–10 weeks at which time they are transplanted to their final spacing. Growers will typically apply 897–1121 kg·ha^{-1} of 5N–4.4P–12.4K fertilizer with 5% to 9% sulfur and preplant incorporate, plant the seed, and then broadcast 168 to 224 kg·ha^{-1} of 18N–20.1P–0K or 10N–14.8P–0K. This is usually followed by two broadcast applications of 224 kg·ha^{-1} of $CaNO_3$ at 4 and 6 weeks.

The objective of this study was to evaluate current transplant production practices with short-day onions in southeast Georgia. The ultimate goal of this study was to develop soil test recommendations for transplant production in this region.

Materials and Methods

Preplant fertilizer and $CaNO_3$ top-dress experiments. In 1997, a 5 × 2 factorial experiment was initiated with five rates of preplant 5N–4.4P–12.4K–5S (0, 224, 673, 1121, and 1569 kg·ha^{-1}) as one factor and top-dress applications of $CaNO_3$ (0 and 224 kg·ha^{-1}) as the second factor. Preplant fertilizer treatments were broadcast over the plot and incorporated to 15–20 cm. $CaNO_3$ was applied at 4 and 6 weeks after seeding by broadcasting over the plots. The experiment was arranged in a randomized complete-block design (RCBD) with four replications. Cultivar Southern Belle was seeded on an Ocilla-Pelham-Albany association (loamy, siliceous, thermic Aquic Arenic Grossarenic Paleudults) at the Bamboo Farm and Coastal Garden (BFCG) in Savannah, Ga. Seed were planted with an Earthway Precision Push Planter (Bristol, Ind.) using seed plate 1002–5 radish medium. Each experimental plot consisted of two 1.5-m-long rows with a between row spacing of 36 cm. Seed were planted on 28 Oct. 1997. Top-dress applications of $CaNO_3$ were applied on 2 Dec. 1997 and 12 Dec. 1997. Plant stand was determined by counting a 30.5 cm length of row in each plot on 28 Jan. 1998. In addition, leaf tissue samples were collected at this time and analyzed for nitrogen, phosphorus, potassium, calcium, and sulfur (Isaac and Johnson, 1985). Plant height was determined by measuring three randomly chosen plants in each plot.

In 1998, this 5×2 experiment was repeated at the BFCG with cultivar Granex 33. Seed were planted on 8 Sept. 1998 and the $CaNO_3$ top-dressings were applied on 2 Oct. 1998 and 30 Oct. 1998. Oxyfluorfen herbicide was applied 30 Oct. 1998 at 292 mL·ha^{-1} to control weeds. Plant stand was determined on 13 Nov. 1998. Plant height was measured on 10 Nov. 1998 by measuring five randomly chosen plants per plot. In addition, plant tissue samples were collected at this time.

In 1999, this 5 × 2 factorial design was repeated at the Vidalia Onion and Vegetable Research Center (VOVRC) in Lyons, Ga., on a Tifton soil (fine-loamy, siliceous, thermic Plinthic Paleudults). The experiment was arranged in a RCBD. Each plot consisted of 4 rows seeded on beds with a center-to-center spacing of 1.8 m and a between row spacing of 30.5 cm. The plot length was 3.0 m long. The plot soil was treated with 42% metam-sodium on 13 Aug. 1999 at a rate of 467.6 L·ha^{-1}. The 5N–4.4P–12.4K–9S treatments were applied preplant on 22 Sept. 1999. 'Sweet Vidalia' was seeded on 23 Sept. 1999 with a Stanhay Precision Planter model S870 (Newmarket, U.K). On 23 Sept. 1999, 168 kg·ha^{-1} diammonium phosphate was applied to all treatments. $CaNO_3$ was sidedressed on 21 Oct. 1999 and 8 Nov. 1999. Stand count was measured on 15 Oct. 1999 by measuring a 30.5 cm section of row in each plot. In addition, plant height was measured on 9 Nov. 1999 by measuring the height of five randomly chosen plants in each plot. In addition, tissue nitrogen (Isaac and Johnson, 1985) was determined on samples collected on 29 Oct. 1999 and 17 Nov. 1999 and the results averaged for ease of analysis. Finally, the transplants within each plot were visually evaluated for suitability for transplanting on a 1–3 scale with 1 = acceptable, 2 = intermediate acceptability, and 3 = unacceptable. An acceptable transplant should be ≈0.6 cm in diameter and 15 cm tall.

High phosphorus fertilizer experiments. High phosphorus fertilizers were evaluated in 1998 at the BFCG. Four separate experiments were set up to evaluate 18N–20.1P–0K (diammonium phosphate) and liquid 10N–14.8P–0K. The experiments were arranged in a RCBD. A new site was cleared at the farm that had previously been in bamboo, had not been previously fertilized, and had a relatively low level of residual extractable phosphorus (56 kg·ha^{-1}). Current plot land had a residual extractable phosphorus level of 271 kg·ha^{-1} by the Mehlich method (Jean Dawson, personal communication). On the low phosphorus site two experiments were established to evaluate 10N–14.8P–0K and 18N–20.1P–0K. The site was prepared by incorporating 1121 kg·ha^{-1} of 5N–4.4P–12.4K–5S before seeding. Cultivar Sweet Success was seeded on these plots with an Earthway push planter with plate 1002-5 radish medium. Plots were two rows, 1.5 m long with a between row spacing of 36 cm. These two experiments were duplicated on the high phosphorus sites.

Treatments for the liquid 10N–14.8P–0K were rates of 0, 112, 224, and 448 kg·ha^{-1} for both the low and high phosphorus sites, applied directly after seeding in 1.9 L of water, with a sprinkler can over the entire plot. Treatments for 18N–20.1P–0K were 0, 112, 168, and 224 kg·ha^{-1} for both the low and high phosphorus sites, which was broadcast applied directly after seeding. Treatments were applied on 4 Nov. 1998. On 17 Dec. 1998, 224 kg·ha^{-1} of $CaNO_3$ was broadcast applied to each plot. Plant height was measured on 21 Dec. 1998 by randomly measuring three plants in each plot. Plant stand was also determined on this date on a 30.5 cm section of row in each plot.

In 1999, two additional experiments were conducted at the VOVRC to evaluate 10N–14.8P–0K and 18N–20.1P–0K fertilizers. The residual extractable phosphorus level at this site was 272 kg·ha^{-1}. Both experiments were split-block designs with the strip plot effect being different onion cultivars. A single row of each; 'Pegasus', 'WI-609', 'Savannah Sweet', and 'Granex 33', was seeded as described above with a Stanhay planter. 5N–4.4P–12.4K–9S fertilizer was applied preplant incorporated to all treatments at a rate of 1121 kg·ha^{-1}. The main plot effects were superimposed over the strip plot in a RCBD with each plot 3.0 m long. The main plot treatments for the 10N–14.8P–0K were rates of 0, 112, 224, and 448 kg·ha^{-1} with treatments applied in 3.8 L of water as described above directly after seeding. $CaNO_3$ was applied at a rate of 224 kg·ha^{-1} on 21 Oct. 1999 and 8 Nov. 1999 to all treatments. The main plot treatments for 18N–20.1P–0K was 0, 112, 168, and 224 kg·ha^{-1} broadcast applied directly after seeding. Stand count was measured on 1 Oct. 1999 for each cultivar within the main plot treatment by measuring a randomly chosen 30.5 cm section of each row. Plant height was measured on 9 Nov. 1999 by measuring the height of three randomly chosen plants for each cultivar within a plot.

All plots were irrigated, beginning immediately after seeding and initial fertilizer application. Plots were irrigated from an overhead portable pipe irrigation system as much as 2–3 times per day with 0.25 cm of water at each irrigation until seedling emergence. After seedling emergence plots were irrigated as needed to insure 2.5–3.8 cm of water per week. All data were analyzed with Systat 5.2.1 and Microsoft Excel 98.

Results

Preplant fertilizer and $CaNO_3$ top-dress experiments. $CaNO_3$ had a positive effect on plant height while preplant application of 5N–4.4P–12.4K did not (Table 1). There was an interaction effect between 5N–4.4P–12.4K and $CaNO_3$. The effect of preplant 5N–4.4P–12.4K was a linear increase in plant height with the $CaNO_3$ applications, however, without $CaNO_3$ application there was no significant effect (Table 2).

Stand count was unaffected by either preplant 5N–4.4P–12.4K or sidedress $CaNO_3$ application over the 3 years of the study (Table 1). There was, however, a $CaNO_3$ × experiment interaction for stand count. In the second year of the study (1998) stand count was significantly increased by 50% with applications of $CaNO_3$.

Tissue nitrogen levels were higher with $CaNO_3$ sidedress applications but were unaffected by preplant 5N–4.4P–12.4K application. In addition, there was a $CaNO_3$ × experiment interaction for tissue nitrogen (Table 1). In 1997, there was no difference in tissue N with or without sidedress applications of $CaNO_3$, but there were differences in 1998 and 1999. In 1997, the tissue nitrogen level was 12 g·kg^{-1} with or without $CaNO_3$ sidedress application. In 1998, with $CaNO_3$ sidedress application the tissue N level was 36 g·kg^{-1}, whereas without $CaNO_3$ application the tissue N level was 16 g·kg^{-1}. The results in 1999 were similar with 35 g·kg^{-1} tissue N with $CaNO_3$ and 18 g·kg^{-1} without.

Table 1. Growth, leaf tissue analysis, and transplant evaluation of short-day onions as affected by 5N–4.4P–12.4K and sidedress $CaNO_3$ fertilizer (1997–99).

Preplant 5N–4.4P–12.4K ($kg\cdot ha^{-1}$)	1997–99 Plant height (cm)	1997–99 Stand count	1997–99 Nitrogen ($g\cdot kg^{-1}$)	1997–98 Phosphorus ($g\cdot kg^{-1}$)	1997–98 Potassium ($g\cdot kg^{-1}$)	1997–98 Sulfur ($g\cdot kg^{-1}$)	1997–98 Calcium ($g\cdot kg^{-1}$)	Evaluation[z] 1999
0	12.2	14	24	4.5	18	2.8	12	2.6
224	13.2	16	21	4.2	19	3.0	12	2.1
673	14.7	16	22	4.4	23	3.4	11	2.0
1121	14.7	17	21	5.1	26	3.8	11	1.8
1569	15.2	16	21	4.8	25	4.1	10	1.6
Top-dress $CaNO_3$								
Yes	15.5	16	28	3.6	20	2.7	14	1.7
No	12.7	15	16	5.6	24	4.2	8	2.4
P >F								
5N–4.4P–12.4K	0.062	0.791	0.053	0.095	0.001	0.001	0.053	0.009
$CaNO_3$	0.037	0.203	0.000	0.008	0.003	0.000	0.003	0.001
5N–4.4P–12.4K × $CaNO_3$	0.005	0.085	0.145	0.009	0.392	0.620	0.059	0.250
5N–4.4P–12.4K × experiment	0.058	0.474	0.196	0.401	0.636	0.001	0.051	
$CaNO_3$ × experiment	0.281	0.003	0.000	0.001	0.314	0.220	0.000	
5N–4.4P–12.4K linear					0.000	0.000	0.001	

[z]Evaluation: 1 = acceptable, 2 = intermediate, 3 = unacceptable.

Table 2. Interaction of $CaNO_3$ on plant height at different levels of 5N–4.4P–12.4K fertilizer.

Preplant 5N–4.4P–12.4K ($kg\cdot ha^{-1}$)	Plant height With $CaNO_3$ (cm)	Plant height Without $CaNO_3$ (cm)
0	11.7	13.0
224	13.0	13.5
673	17.0	12.7
1121	17.8	11.9
1569	18.0	12.7
P >F		
5N–4.4P–12.4K	0.004	0.804
Linear	0.000	

In 1999, onion leaf tissue was sampled twice to see if there were any differences in nitrogen levels between the two sample dates. A paired *t* test indicated there were no differences between the 29 Oct. and 17 Nov. 1999 sample dates so for ease of analysis these treatment samples were averaged before the final analysis.

Tissue phosphorus levels were unaffected by preplant 5N–4.4P–12.4K, but were affected by $CaNO_3$ applications. With $CaNO_3$ the tissue phosphorus level was lower than without $CaNO_3$ applications. In addition, there was a preplant 5N–4.4P–12.4K × $CaNO_3$ interaction. Tissue phosphorus levels decreased linearly with increasing levels of preplant 5N–4.4P–12.4K with sidedress $CaNO_3$ applications (Table 3). Finally, there was a $CaNO_3$ × experiment interaction for tissue phosphorus. Tissue phosphorus with and without $CaNO_3$ was 3.6 $g\cdot kg^{-1}$ and 4.9 $g\cdot kg^{-1}$, respectively in 1997. In 1998, tissue phosphorus was 3.5 $g\cdot kg^{-1}$ and 6.6 $g\cdot kg^{-1}$ with and without $CaNO_3$, respectively. The magnitude of the tissue phosphorus levels between 1997 and 1998 were different, however, the level of tissue phosphorus in both cases was higher without the $CaNO_3$ sidedress applications.

There was a significant linear increase in tissue potassium with increasing levels of 5N–4.4P–12.4K. In addition, tissue potassium was less with sidedress applications of $CaNO_3$. There were no interaction affects between 5N–4.4P–12.4K and $CaNO_3$.

Tissue sulfur increased linearly with increasing preplant applications of 5N–4.4P–12.4K as well as lower tissue levels of sulfur with sidedress applications of $CaNO_3$. There was also a 5N–4.4P–12.4K × experiment interaction for sulfur. In 1997 there was no difference in tissue sulfur based on level of preplant 5N–4.4P–12.4K, however, in 1998 there was a linear increase in tissue sulfur with increase applications of preplant 5N–4.4P–12.4K (Table 4).

Tissue calcium levels were unaffected by applications of 5N–4.4P–12.4K (Table 1). Sidedress $CaNO_3$ applications however, increased tissue calcium from 8.0 to 14.0 $g\cdot kg^{-1}$. In addition, there was a $CaNO_3$ × experiment interaction, which represents a difference in magnitude for tissue calcium levels from one year to the next. Tissue calcium in 1997 was 7 $g\cdot kg^{-1}$ with $CaNO_3$ applications and 4.9 $g\cdot kg^{-1}$ without $CaNO_3$ applications. In 1998, the tissue calcium levels were 21.0 $g\cdot kg^{-1}$ for treatments with $CaNO_3$ applications and 10.8 $g\cdot kg^{-1}$ without $CaNO_3$ applications.

In the visual evaluations in 1999, there was a linear improvement of transplants with increasing amounts of 5N–4.4P–12.4K as well as with sidedress applications of $CaNO_3$. There was no interaction effect.

High phosphorus fertilizer experiments. High phosphorus fertilizers (10N–14.8P–0K and 18N–20.1P–0K) were evaluated on land with either low or high residual phosphorus for plant stand or plant height. There were no differences among the four experiments for plant stand or plant height on either the site with high residual phosphorus or low residual phosphorus (Table 5). In 1999, high phosphorus fertilizers were evaluated in conjunction with onion cultivars. There was a linear increase in plant height with increasing amounts of 10N–14.8P–0K, however, there was no difference in plant height with applications of 18N–20.1P–0K (Table 6). Plant height was significantly different based on cultivar with 'WI-609' and 'Savannah Sweet' growing more than 'Pegasus' or 'Granex 33' in both the 10N–14.8P–0K and 18N–20.1P–0K experiments. In addition, plant stand was greater with 'Pegasus' in the 18N–20.1P–0K fertilizer experiment compared to 'WI-609', 'Savannah Sweet', and 'Granex 33'. There were no differences in plant stand in the 10N–14.8P–0K experiment. There were no treatments × cultivar interactions for plant stand or plant height in either the 10N–14.8P–0K or 18N–20.1P–0K experiments.

Discussion

Overall, increasing amounts of 5N–4.4P–12.4K resulted in better transplants, particularly with sidedress applications of $CaNO_3$ (Table 2). Nitrogen levels were in the sufficiency range of 20–30 $g\cdot kg^{-1}$ for all treatments 0–1569 $kg\cdot ha^{-1}$ of 5N–4.4P–12.4K (Maynard and Hochmuth, 1997). In addition, treatments with $CaNO_3$ also were in this sufficiency range, however, without $CaNO_3$ applications, tissue

Table 3. Interaction effect of $CaNO_3$ on tissue phosphorus levels with increasing levels of 5N–4.4P–12.4K fertilizer (1997–98).

Preplant 5N–4.4P–12.4K ($kg\cdot ha^{-1}$)	Phosphorus With $CaNO_3$ ($g\cdot kg^{-1}$)	Phosphorus Without $CaNO_3$ ($g\cdot kg^{-1}$)
0	4.0	5.4
224	3.7	4.8
673	3.6	5.1
1121	3.4	6.8
1569	3.1	6.4
P > F		
5N–4.4P–12.4K	0.040	0.141
Linear	0.003	

Table 4. Interaction effect of 1997–98 experiments on tissue sulfur levels with increasing levels of 5N–4.4P–12.4K fertilizer.

Preplant 5N–4.4P–2.4K (lbs./acre)	Tissue sulfur 1997 ($g\cdot kg^{-1}$)	Tissue sulfur 1998 ($g\cdot kg^{-1}$)
0	2.8	2.9
224	3.0	3.0
673	3.1	3.6
1121	3.0	4.7
1569	3.4	4.7
Prob.>F		
5N–4.4P–12.4K	0.688	0.007
Linear	0.000	

nitrogen was 16 g·kg^{-1}. It should be noted that the published sufficiency range is based on most recently mature leaf on sweet onion plants just prior to bulbing. However, bulbing does not occur in southeast Georgia until after transplanting.

Reduced levels of tissue phosphorus, potassium, and sulfur concentration with applications of $CaNO_3$ are probably the result of increased plant growth that diluted these nutrients in the tissue. This agrees with the work of Rostamfrodi et al. (1999) at least for tissue phosphorus. Preplant 5N–4.4P–12.4K × $CaNO_3$ interaction for tissue phosphorus may also be due to a dilution effect related to increased growth with increasing amounts of 5N–4.4P–12.4K in the presence of $CaNO_3$ top-dress applications resulting in reduced levels of tissue phosphorus (Table 3). All tissue phosphorus levels were within or above the reported sufficiency range of 2.0–5.0 g·kg^{-1}.

Potassium also was within the sufficiency range of 15–30 g·kg^{-1}. Potassium has been reported to have increased bulb dry matter and may be an important reason the transplants did well at higher rates of the preplant 5N–4.4P–12.4K fertilizer (Geetha et al., 1999). Geetha et al. (1999) also reported an interaction for bulb dry weight between potassium applications and farmyard manure applications, which would have small but significant amounts of nitrogen, phosphorus, and potassium as well as other nutrients. This is somewhat analogous to our results for plant height with increasing rates of 5N–4.4P–12.4K and top-dress applications of $CaNO_3$.

Tissue sulfur did not respond in 1997 as it did in 1998. Published results indicate the importance of sulfur in onion production in some areas (Sumantra and Tiwari, 1997), which is generally the case in southeast Georgia where the soils are very low in sulfur. The importance of sulfur is particularly evident during seasons of high rainfall when sulfur leaching can result in sulfur deficiency symptoms. The lack of response in 1997 was probably due to the later planting date, which resulted in less growth than in 1998. It should be noted that all of the results were within the published sufficiency range for sulfur of 2.0–6.0 g·kg^{-1}.

Calcium levels were all much higher than the published sufficiency range of 6.0–8.0 g·kg^{-1} with the exception of treatments without $CaNO_3$, which had a level of 8.0 g·kg^{-1}. As mentioned earlier, the sufficiency ranges are with the most recently mature leaf just prior to bulb initiation and these results may herald the need for the establishment of sufficiency ranges earlier in the crop. Further study under more controlled conditions would be needed.

There were several $CaNO_3$ × experiment interactions. In the case of the stand count, in 1998 there was a higher stand count with $CaNO_3$ applications. This was not the case in 1997 or 1999 and may represent just an anomaly of the data since there is no obvious reason for this difference. It should be noted, however, that different cultivars were used each year and this may represent a differential response to $CaNO_3$ applications by cultivar. Differences in tissue nitrogen for treatments with and without applications of $CaNO_3$ by experiment may have been the result of planting date. In 1997, onion seed was not planted until 28 Oct., while in 1998 and 1999 they were planted on 8 Sept. and 23 Sept., respectively. Earlier seeding gave the plants more time to grow and develop. In the case of tissue phosphorus and calcium the magnitude of the difference between the experiments differed but the effect was the same.

Since there were different varieties each year and experiments were conducted at 2 different locations the 5N–4.4P–12.4K by experiment and $CaNO_3$ × experiment interactions are difficult to interpret (Table 1). Interestingly, however, there is only one 5N–4.4P–12.4K × experiment interaction for tissue sulfur and two of the four $CaNO_3$ × experiment interactions represent changes in magnitude only not in the overall results. This suggests that the robustness of the experiment and applicability of the results to a wide range of situations.

This work uses fertilizer blends, which represent the most common practices in the Vidalia onion growing region. This does confound to a certain extent interpretation of which fertilizer element is most important in affecting transplant growth.

The most interesting result of these experiments is the lack of effect with high phosphorus, so called 'pop-up', fertilizers immediately after seeding. Even on sites with low residual phosphorus, high phosphorus fertilizers did not have an effect on plant height or plant stand. There was only a single year affect of 10N–14.8P–0K on plant height. This lack of effect with high phosphorus fertilizers may be due to the time of seeding onions in southeast Georgia. Typically onions are seeded for transplant production in September when temperatures can still be extremely high. High phosphorus fertilizers are recommended during spring seeding and transplanting because cool temperatures limit phosphorus availability. This is not the case in the fall in southeast Georgia where the 50-year temperature minimum and maximum in Toombs County, Ga. for September was 18 °C and 31 °C, respectively. In March, by contrast, this range was 7 to 22 °C. Based on these results, we are recommending that growers forgo applications of high phosphorus fertilizers and increase their preplant application of 5N–4.4P–12.4K. Although they are still applying a large amount of phosphorus with this formulation, it precludes the need for an additional trip across the field to apply the high phosphorus fertilizer while still maintaining the necessary nitrogen levels. In addition, 5N–4.4P–12.4K fertilizer is a common formulation in southeast Georgia, but it may be time for fertilizer companies to consider reformulating their fertilizers and reduce the amount of phosphorus for trans-

Table 5. Onion plant stand and height as affected by high phosphorus fertilizers on sites with low and high residual phosphorus levels.

	Fertilizer: 10N–14.8P–0K			
	Expt. 1. High residual P		Expt. 2. Low residual P	
Treatment (kg·ha^{-1})	Plant stand	Height (cm)	Plant stand	Height (cm)
0	23	10.9	19	8.6
112	21	9.9	18	8.9
224	24	9.4	16	10.4
448	19	9.7	11	10.7
P > F	0.632	0.345	0.404	0.148
	Fertilizer: 18N–20.1P–0K (diammonium phosphate)			
	Expt. 3. High residual P		Expt. 4. Low residual P	
Treatment (kg·ha^{-1})	Plant stand	Height (cm)	Plant stand	Height (cm)
0	16	9.7	21	8.6
112	14	10.9	15	9.7
168	15	11.9	17	9.9
224	20	8.9	11	9.7
P > F	0.593	0.262	0.262	0.586

Table 6. Onion plant stand and height as affected by high phosphorus fertilizers and cultivars.

10N–14.8P–0K (Expt. 1)			18N–20.1P–0K (Expt. 2)		
Treatment (kg·ha^{-1})	Plant stand	Height (cm)	Treatment (kg·ha^{-1})	Plant stand	Height (cm)
0	21	25.4	0	28	9.9
112	20	26.4	112	24	10.7
224	17	28.4	168	23	11.2
448	18	28.4	224	24	10.4
Cultivar					
Pegasus	23	24.1b[z]		28a[z]	23.1c[z]
WI-609	19	30.2a		22b	28.4a
Savannah Sweet	20	29.7a		24b	28.9a
Granex 33	15	24.9b		22b	26.4b
P > F					
Treatment	0.727	0.004		0.618	0.170
Linear	0.001				
Cultivar	0.070	0.000		0.008	0.000
Treatment × cultivar	0.969	0.165		0.180	0.051

[z]Means followed by the same letter within a column are not different by Fisher's protected LSD ($P \le 0.05$)

plant onions since soil tests are generally at very high levels in cultivated fields.

This study's ultimate goal was to develop soil test recommendations for producing transplant onions. Current soil testing by the Univ. of Georgia tests for phosphorus and potassium only. Extractable phosphorus and potassium are reported in a range 0–112+ and 0–308+ kg·ha^{-1}, respectively on the Coastal Plain soils of South Georgia. For phosphorus, results are placed in four categories; low (0–34 kg·ha^{-1}), medium (35–67 kg·ha^{-1}), high (68–112 kg·ha^{-1}) and very high (112+ kg·ha^{-1}). For potassium the four categories are; low (0–78 kg·ha^{-1}), medium (79–191 kg·ha^{-1}), high (192–308 kg·ha^{-1}), and very high (308+ kg·ha^{-1}). This range is used to determine the level of phosphorus and potassium to apply. Based on this study and soil test recommendations for salad onions, it is recommended that for the low range 59 and 112 kg·ha^{-1} of phosphorus and potassium be used, respectively. For the medium range, 40 and 84 kg·ha^{-1} of phosphorus and potassium are recommended, respectively. For the high range 20 and 56 kg·ha^{-1} of phosphorus and potassium are recommended, respectively. Finally, for the very high range 0 and 28 kg·ha^{-1} are recommended for phosphorus and potassium, respectively. For nitrogen we recommend 112–146 kg·ha^{-1}.

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