

Controlled Release Fertilizer Improves Quality of Container Longleaf Pine Seedlings

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Abstract: In an operational trial, increasing the amount of nitrogen (N) applied to container longleaf pine seedlings by incorporating controlled release fertilizer (CRF) into the media improved seedling growth and quality. Compared with control seedlings that received 40 mg N, seedlings receiving 66 mg N through CRF supplemented with liquid fertilizer had needles that were 4 in (10 cm) longer as well as 42%, 84%, and 47% greater root collar diameter, shoot biomass, and root biomass, respectively. We use data from this study and other published sources to make general, practical guidelines concerning appropriate levels of fertilization for longleaf pine seedlings in containers.

Keywords: nitrogen, seedling quality, seedling viability, nursery production

Introduction

Longleaf pine (*Pinus palustris*) is an important reforestation species in the South. Longleaf pine's fire tolerance, resistance to bark beetles, better growth on sand ridges, and higher value as sawtimber makes it, for some landowners, a more secure investment than other southern pines (Hains 2002). Secondary products like pine straw for landscaping and the fact that longleaf stands can be managed in a variety of ways also favor its use (Outcalt 2000). As a result, production of longleaf pine in containers surged during the past decade to meet demand caused by changes in United States farm policy, seed scarcity, longer planting windows afforded by container stock, and better performance of container seedlings over bareroot seedlings on outplanting sites (see Dumroese and Barnett 2004).

The only guidelines available for growing container longleaf pine are the interim guidelines suggested by Barnett and others (2002a,b). Their guidelines encourage seedlings with root collar diameters (measured on the hypocotyl directly below the base of the needles) >3/16 in (4.8 mm) and nonclipped needle length of 8 to 12 in (20 to 31 cm). Root collar diameter is important; South and others (1993) found that seedlings with larger diameters survived better and grew more vigorously after outplanting than seedlings with smaller diameters.

Generally, to obtain root collar diameter, growers must apply sufficient nutrients to stimulate growth (Montville and others 1996). Too much nitrogen (N) can result in lush, excessively long needle growth. Long needles can lodge and cover seedlings, disrupting irrigation and fertilization applications and promoting disease (Barnett and McGilvray 1997, 2000). To prevent lodging, needles can be clipped; with high doses of N, seedlings are often clipped several times. Excessive clipping (trimming needles to less than 15 cm [6 in]) can reduce growth (Barnett and McGilvray 1997, 2000). Usually, clipping is done by hand. Ideally, growers would like techniques to increase root collar diameter while controlling needle growth without clipping, thus avoiding the high labor costs associated with this practice.

The staff at Claridge State Forest Nursery in Goldsboro, North Carolina, asked for assistance in improving the root collar diameter of their longleaf pine seedlings. In reviewing their cultural regime, we noted that seedlings were given fairly low doses of fertilizer early in the growing season, a time when seedlings can begin developing significant root collar diameter. Our objective was to see if addition of a controlled release fertilizer (CRF) to the crop might improve early season growth, result in seedlings with larger root collars by the end of the growing season, and produce acceptable seedlings without resorting to needle clipping.

Methods and Materials

Our operational trial was conducted at the Claridge State Forest Nursery in Goldsboro, North Carolina. Previous to this study, longleaf pine seedlings were grown outdoors on tables in Ropak[®] Multi-Pot #6-45 containers (Table 1) filled with 2:2:1 (v:v:v) peat moss:vermiculite:perlite custom mixed at the nursery, and fertilized via a tractor-pulled spray tank.

For this experiment, we had 2 treatments: (1) seedlings grown in medium with CRF, and (2) seedlings grown in medium without CRF (control). For the CRF treatment, the nursery staff used a mixer to incorporate 4 lbs 18N:6P₂O₅:12K₂O Polyon[®] controlled release fertilizer (9 month release rate; Pursell Technologies, Inc., Sylacauga, Alabama) per cubic yard of medium (2.37 kg/m³). Since each container cavity had a volume of 98 cm³ (Table 1), the medium in each cavity contained about 42 mg N via the polyurethane-coated prills. For the control treatment (no CRF), 3 lbs dry 10N:10P₂O₅:10K₂O were incorporated per cubic yard (1.78 kg/m³) to the medium described above—the medium in each cavity contained about 17 mg N.

In early May, randomly selected Ropak[®] containers were machine filled with the media described above and sown with seeds from the orchard at Bladen Lakes State Forest in North Carolina. Filled containers were transferred to an outdoor growing area. This area had been historically divided into 2 sections, so we installed a block in each section with 3 replications of each treatment per block (we had about 5,000 seedlings per replication).

Liquid fertilizer (Peter's 20N:20P₂O₅:20K₂O; The Scotts Company, Marysville, Ohio) was applied to both treated and control seedlings 8 times during the growing season as per the discretion of the nursery manager to maintain adequate growth of control seedlings. Of these eight applications, five were made at 10 lbs N/ac, one at 15 lbs N/ac, and two at 30 lbs N/ac (11.2, 16.8, and 33.6 kg N/ha, respectively)—based on cavity density of the Ropak[®] container (Table 1), we estimate that each seedling received about 24 mg N via these 8 applications. Therefore, control seedlings received about 41 mg N (17 from incorporated + 24 from liquid) over the

course of the growing season whereas treated seedlings received 66 mg N (42 from CRF + 24 from liquid).

One month after planting (mid-June), and then once every month throughout the growing season (mid-July, mid-August, mid-September), we collected a random sample of 25 seedlings from each replicate for morphological evaluation. Length of the longest needle and root collar diameter were recorded. Shoots and roots were separated, dried at 150 °F (65 °C) until constant weight (about 48 hours), and weighed for biomass. Dried tissues were ground to pass a 0.04 mm mesh, and analyzed for total N and C content with a LECO-600 analyzer (LECO Corp., St. Joseph, Michigan).

For each dependent variable, data were analyzed using analysis of variance procedures in Statistical Analysis Software (SAS 1998). The stepdown bootstrap method was used to adjust p-values for family-wise error (Westfall and Young 1993).

Results and Discussion

Morphology

Seedlings provided an additional 42 mg N via controlled release fertilizer had longer needles, thicker root collars, and more biomass than control seedlings (Figure 1). By mid September, needles on CRF-treated seedlings were about 4 in (10 cm) longer than those of control seedlings. Needle length for control seedlings was, however, within the interim guidelines of Barnett and others (2002a,b) and although needles of the treated seedlings were 1.5 inches longer (3.5 cm) than the guideline, we did not encounter problems with lodging. As with height, root collar diameter of control seedlings met the minimum guideline of 3/16 in (4.8 mm), but root collar diameter of treated seedlings was 42% greater, averaging 1/4 in (6.8 mm). Shoot and root biomass were also increased by controlled release fertilizer, 84% and 47% respectively. For all of these seedling characteristics, the magnitude of the effects of controlled release fertilizer became most apparent 2 to 3 months following sowing. Over the course of the growing season, the relationships between the N content of seedlings and resulting seedling biomass, root collar diameter, and needle length were similar (Figure 2).

Nitrogen

On the last sample date, about 41% (17 mg) of the 41 mg of N applied to the control seedlings resided in the seedlings, whereas about 59% (39 mg) of the 66 mg N applied to the treated seedlings resided within them.

For treated and control seedlings, N concentration in shoots and roots was high 1 month after sowing (Figure 3), and decreased precipitously from values of 3% to 4% to values around 1% after 3 additional months of growth. Nitrogen concentration and content in treated seedlings was significantly higher than the control at the end of the growing season ($P < 0.0001$). Although seedling N concentrations dropped, seedling total N content continued to increase for treated and control seedlings. In the control seedlings late in the growing season, however, the increase in total N content occurred concurrently with a slight decrease in

Table 1—Characteristics of Ropak[®] Multi-Pot #6–45 used at Claridge State Forest Nursery, Goldsboro, North Carolina.

Cavity characteristics	English	Metric
Volume	6 in ³	98 ml
Diameter	1.5 in	3.8 cm
Density	54 per ft ²	581 per m ²

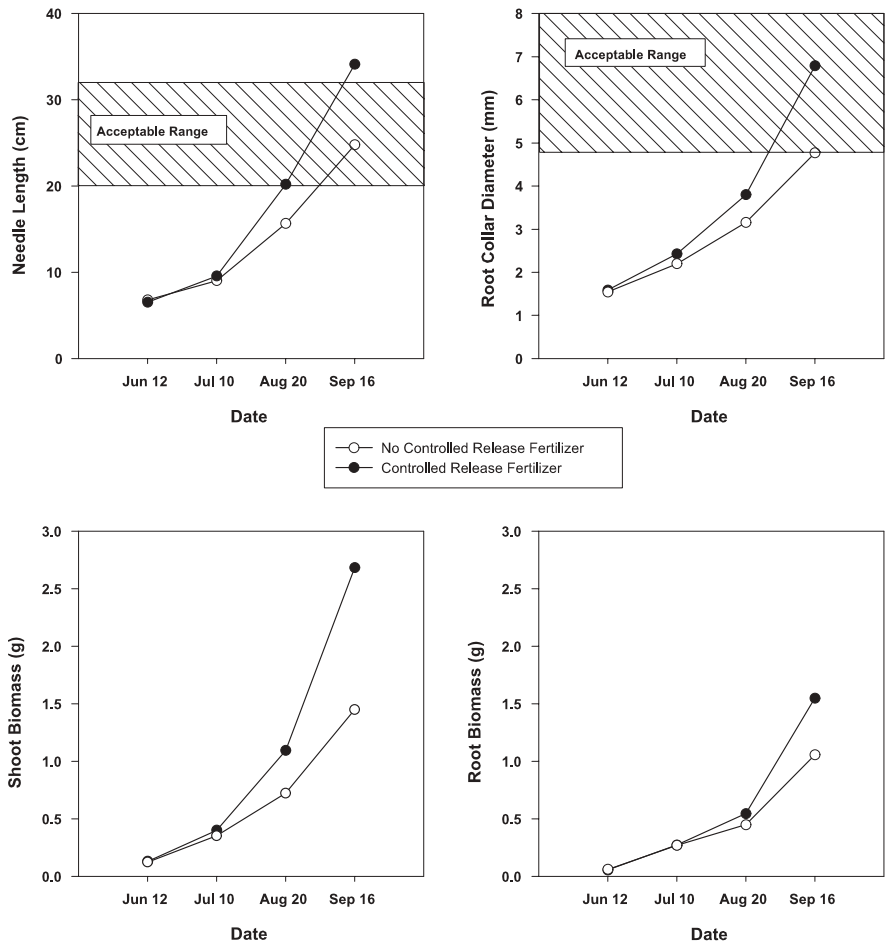


Figure 1—Mean morphological characteristics of control seedlings and seedlings provided an extra 42 mg N via controlled release fertilizer. Seeds were sown in mid May. For needle length and root collar diameter, the acceptable ranges are based on interim guidelines suggested by Barnett and others (2002a,b).

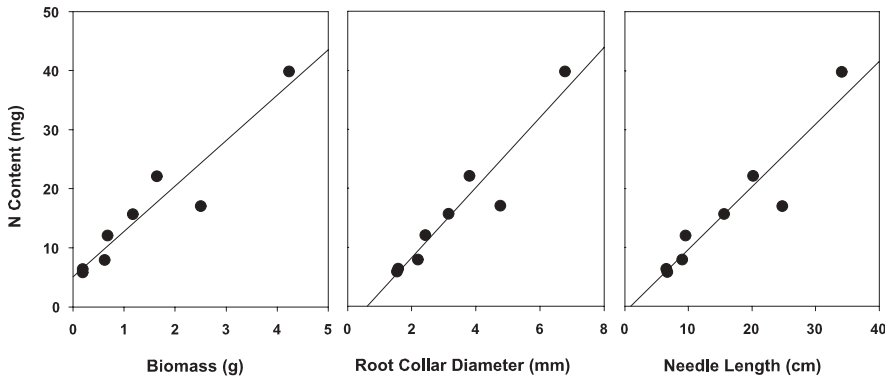


Figure 2—The relationships between longleaf pine seedling N content and biomass, root collar diameter, and needle length were linear and well correlated ($R^2 > 0.9$). This similar relationship makes it unlikely that fertilization can be manipulated to favor one characteristic without favoring the others.

shoot N content, perhaps a reflection of preferential translocation of N by the seedling to roots or variation in seedling samples.

Discussion

We used a polymer-coated controlled release fertilizer, considered to be the most technically advanced because it provides efficient (gradual and consistent) nutrient delivery. The desired nutrients, surrounded by the polymer, are

known as prills. Nutrients are released as water diffuses through the polymer coat (Goertz 1993). Diffusion is accelerated by warmer soil temperatures (Kochba and others 1990), and manufacturers generally provide estimates of how long it takes for 90% of the nutrient to be released at an average temperature of 70 °F (21 °C) (Goertz 1993). The product in this study had a 9-month release rate, so, presumably, not all of the N in the prills had been made available to the seedlings. Unfortunately, without tests of the medium, we do not know for sure how much N was released from the prills and made available to seedlings. In addition, different

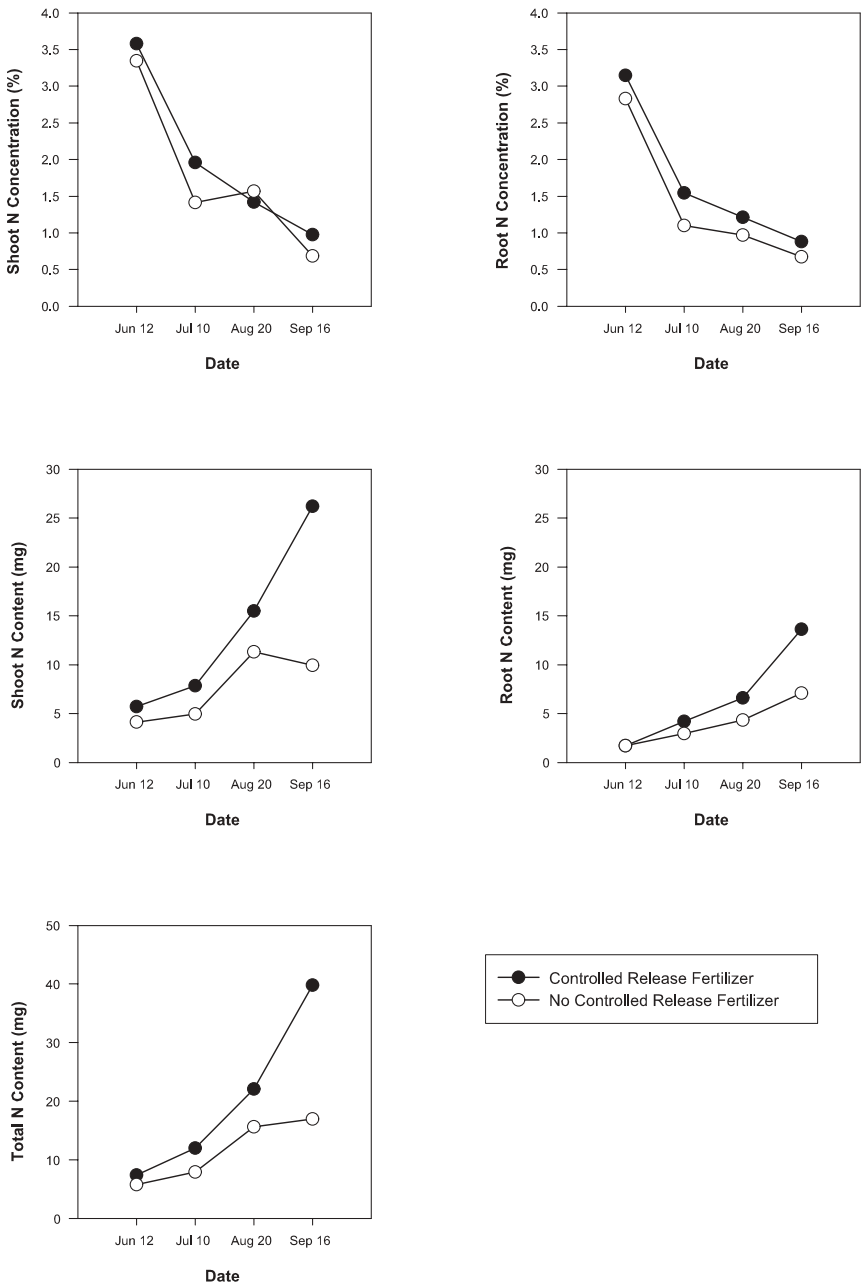


Figure 3—Mean nitrogen concentrations and contents in shoots and roots of controlled release fertilizer. Seeds were sown mid May.

controlled release fertilizers with different polymers release nutrients at varying rates.

The decrease in shoot and root N concentrations throughout the growing season, concurrent with increases in total N content within treated and control seedlings and sustained seedling growth, indicates that N was probably available in the optimum range even when shoot N concentrations were <1%. If so, then this particular seed source was likely in luxury consumption of N for most of the growing season, even when N concentrations were <2%. This value is much lower than the luxury consumption value proposed for most conifers (Dumroese 2003).

Over the course of the growing season, the similar relationships between the N content of seedlings and resulting seedling biomass, root collar diameter, and needle length make it

appear unlikely that seedling N fertilization can be manipulated in favor of one of these variables without favoring the others. Therefore, nursery managers are forced into a give-and-take situation between maximizing root collar diameters and minimizing frequency of needle clipping.

Our initial objective was to find a N rate that yielded longleaf seedlings with: (1) root collar diameters within the range proposed by Barnett and others (2002a,b), and (2) needle lengths that did not require clipping. Our results seemed to indicate that the CRF rate used in this study met that objective. Safe and steady nutrient release by the controlled release fertilizer successfully augmented liquid fertilization and the result was seedlings of higher quality. We were curious as to how our rates compared to other growing regimes. Very little information is available

concerning fertilization regimes for container longleaf pine, but 2 papers that we found provide similar recommendations. Barnett and McGilvray (1997) suggest applications of 350 ppm N of 15N:16P₂O₅:17K₂O but with this caveat: weekly applications will provide maximum root collar diameter but necessitate clipping, perhaps several clippings, to prevent needle lodging whereas less frequent applications of this rate can reduce or eliminate clipping at the expense of smaller root collar diameters. Starkey (2002) recommends fertigation 3 times per week using a balanced fertilizer as well, either 20N:20P₂O₅:20K₂O or 15N:15P₂O₅:15K₂O. Starkey advocates using 50 ppm N for 2 weeks during the establishment phase, increasing up to 200 ppm N during the exponential phase that lasts about 15 weeks, followed by 25 to 50 ppm N for a 5-week hardening phase.

On the other hand, Pittman (2002; 2004) uses 4 lbs 17N:6P₂O₅:10K₂O Miester[®] controlled release fertilizer (9-month release rate; Helena Chemical Company, Collierville, Tennessee) per 24 ft³ of medium (2.67 kg/m³). Miester uses a synthetic thermoplastic resin as a coating. Ten weeks after sowing, Pittman adds 9N:45P₂O₅:15K₂O at 11 lbs/ac (12.3 kg/ha), making a single application each week for 6 to 8 weeks. About 12 applications from week 10 through early November of 20N:20P₂O₅:20K₂O are made at 11 lbs/ac (12.3 kg/ha) to give the seedlings a healthy green color.

To compare these regimes, we assumed that seedlings were grown in Ropak[®] Multi-Pot #6–45 (see Table 1), received 0.5 in (15 ml) of fertilizer solution per fertigation,

and were fertigated once per week for 20 weeks. On this basis, 101 mg N would be applied per seedling using Barnett and McGilvray (1997), 110 mg N using Starkey (2002), and 44 mg N using Pittman (2002, 2004). Our control seedlings received 41 mg N and our CRF-treated seedlings 66 mg N. Our seedlings receiving 66 mg N were borderline for requiring clipping but achieved acceptable root collar diameter growth.

Based on this preliminary data, we feel that some general fertilizer guidelines can be drafted to accompany the interim seedling quality guidelines. The fertilizer guidelines are still broad (Table 2). The actual fertilizer needed to meet target seedling specifications depends on the intrinsic characteristics of nursery, including variables like seed source and weather, the fertilizer type, and the philosophy and budget of the nursery manager (Dumroese and Wenny 1997; Starkey 2002). If additional costs associated with clipping can be justified by increased value of the crop to customers (through enhanced root collar diameters), then a heavier fertilizer regime may be satisfactory. Barnett and McGilvray (1997) caution, however, that clipping needles to a length less than 6 in (15 cm) can reduce stock quality.

Conclusions

Container longleaf pine seedlings given between 40 and 100 mg N over the course of a growing season, either through liquid fertilization, controlled release fertilizer, or some

Table 2—Fertilizer recommendations for container longleaf pine seedlings grown outdoors in Ropak[®] Multi-Pot #6–45. The target levels, expressed in mg N per seedling, are provided in common application rates for southern nurseries.

Fertilization method	Comments on application rate	mg N per seedling			
		< 40	40 to 70	70 to 100	> 100
		<i>Too low</i>	<i>Yields satisfactory root collar diameter; no needle clipping</i>	<i>Yields enhanced root collar diameter; one or more needle clippings necessary</i>	<i>Probably excessive</i>
Fertigation using ppm	Assumes 1 application per week for 20 weeks; 0.5 in (15 ml) of solution per application		135 to 240 ppm N	240 to 345 ppm N	
or					
Fertigation using lb/ac (kg/ha)	Assumes 54 seedlings per ft ² (581/m ²); applied as liquid fertilizer in equal increments over 20 weeks		207 to 363 lb N/ac (232 to 407 kg N/ha)	363 to 519 lb N/ac (407 to 582 kg N/ha)	
or					
Incorporation into media before sowing	Assumes 6 in ³ (98 ml) volume cavity in the container		0.7 to 1.2 N/yard ³ (0.4 to 0.7 kg/m ³)	1.2 to 1.7 N/yard ³ (0.7 to 1.0 kg/m ³)	
or					
Fertigation plus incorporation	A combination of the above		Application rates will depend on proportion of each fertilization method used		

combination of both, should meet the interim seedling quality guidelines. At a rate of 40 to 70 mg N, it appears likely that growers can produce seedlings of acceptable quality without having to clip needles. Higher rates of fertilization will increase root collar diameter but probably necessitate the need for one or more clippings during the season. As suggested by Dumroese (2002), we still need some data showing the optimum nitrogen levels to have in container seedlings to yield optimum outplanting performance.

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References

- Barnett JP, Hains MJ, Hernandez GA. 2002a. Interim guidelines for growing longleaf seedlings in containers. In: Barnett JP, Dumroese RK, Moorhead DJ, editors. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Asheville (NC): USDA Forest Service Southern Research Station. General Technical Report SRS-56. p 27-29.
- Barnett JP, Hains MJ, Hernandez GA. 2002b. Interim guidelines for growing longleaf seedlings in containers. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SO-60. 28 p.
- Barnett JP, McGilvray JM. 1997. Practical guidelines for producing longleaf pine seedlings in containers. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SO-14. 28 p.
- Barnett JP, McGilvray JM. 2000. Growing longleaf pine seedlings in containers. *Native Plants Journal* 1:54-58.
- Dumroese RK. 2002. An outsiders perspective on growing longleaf pine—thoughts from a nursery manager in the Pacific Northwest. In: Barnett JP, Dumroese RK, Moorhead DJ, editors. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-56. p 35-42.
- Dumroese RK. 2003. Hardening fertilization and nutrient loading of conifer seedlings. In: Riley LE, Dumroese RK, Landis TD, technical coordinators. National proceedings: forest and conservation nursery associations—2002. Ogden (UT): USDA Forest Service, Rocky Mountain Research Station. Proceedings. RMRS-P-28. p 31-36.
- Dumroese RK, Barnett JP. 2004. Container seedling handling and storage in the Southeastern States. In: Riley LE, Dumroese RK, Landis TD, technical coordinators. National proceedings: forest and conservation nursery associations—2003. Ogden (UT): USDA Forest Service, Rocky Mountain Research Station. Proceedings. RMRS-P-33. p 22-25.
- Dumroese RK, Wenny DL. 1997. Fertilizer regimes for container-grown conifers of the Intermountain West. In: Haase DL, Rose R, coordinators and editors. Symposium proceedings, forest seedling nutrition from the nursery to the field; 1997 Oct 28-29; Corvallis, OR. Corvallis (OR): Oregon State University, Nursery Technology Cooperative. p 17-26.
- Goertz HM. 1993. Controlled release technology. In: Howe-Grant M, editor. Encyclopedia of chemical technology. 4th ed. New York (NY): John Wiley & Sons Inc. p. 254-274.
- Hains MJ. 2002. Longleaf seedling trends. In: Barnett JP, Dumroese RK, Moorhead DJ, editors. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Asheville (NC): USDA Forest Service Southern Research Station. General Technical Report SRS-56. p 3-4.
- Kochba M, Gambash S, Avnimelech Y. 1990. Studies on slow release fertilizers. 1. Effects of temperature, moisture, and water vapour pressure. *Soil Science* 149:339-343.
- Montville ME, Wenny DL, Dumroese RK. 1996. Impact of foliar fertilization on container-grown ponderosa pine seedling viability. *Western Journal of Applied Forestry* 11:114-119.
- Outcalt KW. 2000. The longleaf pine ecosystem of the South. *Native Plants Journal* 1:42-44, 47-53.
- Pittman T. 2002. Growing large quantities of containerized seedlings. In: Barnett JP, Dumroese RK, Moorhead DJ, editors. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Asheville (NC): USDA Forest Service Southern Research Station. General Technical Report SRS-56. p 60-61.
- Pittman T. 2004. Personal communication. Chiefland (FL): Florida Division of Forestry, Andrews Nursery. Forestry Supervisor.
- SAS. 1998. Statistical software. Release 6.12. SAS Institute Inc, Cary, North Carolina.
- South DB, Mitchell RJ, Zutter BR, and others. 1993. Integration of nursery practices and vegetation management: economic and biological potential for improving regeneration. *Canadian Journal of Forest Research* 23:2083-2092.
- Starkey TE. 2002. Irrigation and fertilization type, rate, and frequency of application. In: Barnett JP, Dumroese RK, Moorhead DJ, editors. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-56. p 30-34.
- Westfall PH, Young SS. 1993. Resampling-based multiple testing: examples and methods for p-value adjustment. New York (NY): John Wiley & Sons Inc.