Auburn University
Southern Forest Nursery
Management Cooperative

RESEARCH REPORT 12-02

FOLIAR NUTRIENT SURVEY OF LOBLOLLY AND LONGLEAF PINE SEEDLINGS

by
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INTRODUCTION

Nursery managers routinely inspect their crop for seedling abnormalities throughout the growing season. Often, experienced managers can determine the causal agents associated with diseases, insects or nematodes, however, the diagnosis of nutrient-related problems can sometimes be challenging. Specific nutrient problems can be identified if diagnosis is made early in symptom development (Baker and Pilbeam 2007). However, as the symptoms intensify, precise diagnosis becomes more difficult.

Analysis of plant tissue for nutrients dates back as far as 1804 (Baker and Pilbeam 2007) and still provides the best tool in identifying plant nutritional problems. Although a single nutrient analysis may not be definitive, it can provide information about either a nutrient excess or deficiency and allow growers to take steps to correct seedling nutrition. Often, there is an interaction of one or more nutrients that may be causing the problem. These interactions can only be solved using a nutrient analysis. Nursery managers are strongly encouraged to monitor their seedling crop with foliar analysis throughout the growing season. A key point in identifying a nutrient problem is to know what is normal. For example, if a nursery manager only obtained a tissue analysis when there was an issue with seedling health, there would not be a benchmark from which to compare. Tissue analysis of healthy seedlings will provide this comparison.

In 1985, Boyer and South reported results of a survey of loblolly pine (Pinus taeda) from forest-tree nurseries in 10 southern states. Seedling samples were separated into foliage, stems and roots and analyzed by A&L Laboratories in Memphis, TN. Two sample periods were used in their studies. The first included 21 nurseries sampled between late November 1981 and late January 1982. The second sample included 20 nurseries sampled the following December (Boyer and South 1985). Since their study, there has not been another region-wide nutrient survey of southern pine seedlings.

One of the responsibilities of the Southern Forest Nursery Management Cooperative is to diagnose seedling health problems that occur in the nursery. Seedlings with potential nutrient problems are regularly sent to the Nursery Cooperative laboratory for diagnosis. Since these seedlings are received throughout the growing season, our only source of comparative data reflecting the range of normal nutrient values has been the 1985 Boyer and South study. Most plant nutrients decrease in concentration within the seedling over the growing season, and as a result, the Boyer and South data underestimates the range of values that can be expected earlier in the growing season.

The purpose of this survey was to obtain a foliar nutrient analysis from nurseries at three times in the same growing season. The data obtained from this survey should provide a better indication of the ranges of nutrient levels and how they vary over time within nurseries in the southern region.

METHODOLOGY

During the 2009-2010 growing season, 20 bareroot and 7 container nurseries from 9 southern states participated in the seedling nutrient survey. Each bareroot and container nursery provided foliage samples from a coastal plain loblolly pine family in July 2009, October 2009 and again in January 2010. At each nursery, the same seedling family was used during the sampling period. In addition, for those container nurseries that produced longleaf pine *(P. palustris*), a southern coastal plain longleaf pine family was provided during these same periods.

The nurseries were instructed to randomly choose 15-20 seedlings within the designated pine family, cut the central stem off each seedling and send only the upper portion of the seedling for analysis. To facilitate and increase participation, prepaid mailing envelopes for A&L Laboratories in Memphis, TN were supplied to each nursery for all three sampling periods.

Nutrient analysis results were returned to the Nursery Cooperative laboratory where the data was analyzed and tabulated. Each nursery manager received a summary copy of all participating nurseries with the nursery name coded to maintain anonymity. The median, minimum and maximum nutrient value along with the coefficient of variation was calculated for each nutrient by tree species and stock type.

RESULTS AND DISCUSSION

Since good quality seedlings can be produced at various soil fertility levels, this survey did not determine optimum or critical seedling nutrient levels (May 1985). However, there is an accepted general relationship between seedling growth and nutrient concentration as shown in Figure 1a and 1b. That healthy seedlings can be produced over a large range of tissue concentrations is evident in Figure 1a which gives an “adequate zone” as opposed to an optimum range as shown in Figure 1b. Also, Figure 1a allows a greater range from a diagnostic standpoint to identify the range of nutrient values that can be expected at specific times during the growing season.

Foliar nutrient concentrations will differ based upon the time of growing season from which the foliage sample is analyzed. For example, actively growing seedlings are expected to be different from dormant seedlings (Boyer and South 1985). In this survey, the nutrient values of bareroot loblolly pine for all the macronutrients plus the micronutrients boron and zinc either decreased or remained unchanged from actively growing tissue to dormancy in January 2010 (Table 1, 2, 3). This same trend of decreasing nutrient levels was also observed in the loblolly pine container-grown seedlings (Table 4, 5, 6).

When comparing the current nutrient results for bareroot loblolly pine to Boyer and South's January results (Boyer and South 1985), all macronutrients were of the same relative magnitude with one exception. The concentration of potassium from the 1985 survey was about 25% higher than this survey. It was common practice in the 1980s to apply potassium to harden-off seedlings in preparation for lifting. The addition of potassium in the fall to harden-off seedlings is not widely followed today and is reflected in the lower potassium levels observed in 2010 compared to 1981 (Boyer and South 1985).

In general, the smallest variation in the nutrient values for both species and stock, as measured by the coefficient of variation, was observed in the macronutrients. The greatest variation in nutrient levels was observed in the micronutrients. This is not unexpected as macronutrients are required for plant growth at much higher concentrations than micronutrients. Of the micronutrients, iron frequently had the greatest variation among nurseries. The large range of iron concentration is due to the application of foliar iron by some nurseries that is not practiced at other nurseries. When comparing loblolly pine seedling stock type, the bareroot loblolly pine had the greatest range between the macro- and micronutrients (Table 1, 2, 3). This is in stark contrast between the macro- and micronutrients in container-grown loblolly pine that had similar coefficient of variations (Table 4, 5, 6). The smaller ranges observed in the container-grown loblolly pine is due to the use of artificial growing media which tends to be more uniform among container nurseries as opposed to the wide variation in soil types found among bareroot nurseries.

When comparing stock type, the nitrogen content was consistently greater in bareroot loblolly pine (Table 1, 2, 3,) than container-grown loblolly pine (Table 4, 5, 6), especially in the July and October seedling samples. The other nutrients were similar in magnitude and change between bareroot and container. The greater nitrogen content in bareroot loblolly pine when compared to container-grown loblolly pine may be attributed to the inability of some container nursery managers to apply water-soluble fertilizer to the seedlings through their irrigation system over the growing season. Four of the seven container nurseries in this survey did not have the ability to inject fertilizer through their irrigation system and relied primarily on slow release fertilizer premixed in the media for seedling fertilization. Container nursery managers with the ability to apply water-soluble fertilizer through their irrigation systems are better able to respond to seedling needs as dictated by either chlorosis or nutrient analysis.

The decrease of nutrient concentration over the growing season was also observed in the container-grown longleaf pine seedlings (Table 7, 8, 9). This downward trend was similar to that observed in the container-grown loblolly pine seedlings (Table 4, 5, 6). However, the micronutrients boron and zinc remained constant in container-grown longleaf pine when compared to container-grown loblolly pine.

Although nursery growth and outplanting performance is a function of the proper balance of all nutrients, nitrogen is the single nutrient that is routinely monitored and reported in nearly all studies. Several interesting trends for nitrogen concentration can be seen in Figure 2. Each line represents the range of nitrogen concentrations of the 27 nurseries surveyed. First, the greatest variation in nitrogen content was in the container-grown longleaf pine in the July sample. The four lowest nitrogen levels in the July sample came from nurseries that primarily relied on slow-release fertilizer for seedling fertilization. Slow-release fertilizers do not release nutrients based upon seedling demand, but rather based upon environmental cues such as temperature and moisture. Second, bareroot loblolly pine seedlings had greater nitrogen concentration in July and October than container-grown loblolly pine. Third, in the January sample, nitrogen levels were lower in more container nurseries than bareroot nurseries. Also, the four lowest nitrogen levels in the January sample came from nurseries that primarily relied on slow-release fertilizer for seedling fertilization. This decrease in foliar nitrogen concentration especially in container stock has been observed in previous studies (Dumroese et al. 2005, Jackson et al. 2007) and was appropriately described by Dumroese as a "precipitous" decline.

This precipitous decline in nitrogen can be reflected in negative outplanting performance, i.e. time in the grass stage, initial seedling growth or even seedling death. The level of current photosynthate in a seedling following outplanting directly effects root growth potential (Feret, P et al. 1984, Larsen, H et al. 1989, Tinus, R 2000, van den Driesschie, 1987). The faster a seedling is able to become established following outplanting, the greater the chance of seedling survival, especially in times of environmental stress. Unfortunately, scientists have yet to determine what an acceptable foliage nitrogen level should be for outplanting success. Nitrogen levels for container-grown longleaf pine in the January sample were less than 1% which may be too low for optimum outplanting performance.

The low nitrogen levels in container-grown seedlings can be attributed to one of two reasons. First, it is common practice among container seedling nurseries that apply water-soluble fertilizer to stop all fertilization once seedling target size has been reached in September or October. This would be acceptable if the seedlings were outplanted at that time. However, if the seedlings remain in the nursery for several months more, all nutrients in the plug are leached out either during irrigation or precipitation. Second, container seedling nurseries that only use slow release fertilizer may find that the available nutrients have been depleted in the media by fall. With no ability to supplement with water-soluble fertilizer, the nutrient content of the media plug and seedling decrease as the seedling remains in the container before outplanting.

In another container longleaf study, seedlings were fertilized at 5 levels of nitrogen: 0.5, 1.0, 2.0, 3.0 and 4.0 mg nitrogen per week for 20 weeks (Jackson et al. 2007). The foliar nitrogen concentration at their mid-November sample for the five nitrogen levels were approximately 0.7, 0.9, 1.2, 1.5 and 1.8%. In our October sample, container longleaf pine nitrogen levels ranged from 0.62 to 1.45%. The nitrogen range in our study best corresponds to the 1.2% and 1.5% nitrogen levels obtained using 2.0 and 3.0 mg of nitrogen fertilization by Jackson et al. In a paper examining outplanting performance, the 3.0 mg of nitrogen per seedling yielded the best growth during the nursery phase and 3 years after outplanting in the field when compared to seedlings that received lower rates of nitrogen fertilization (Jackson et al. 2012). Outplanting performance was determined by time in the grass stage, ground-line diameter and seedling height. In our study, the nitrogen content in January ranged from 0.52% to 1.07%. When we compare the results of these two studies, we can speculate that the container longleaf pine in the October sample might have better outplanting performance than those in our January sample when the foliar nitrogen content was much lower.

MANAGEMENT IMPLICATIONS

1. This study provides information for evaluating nutrient problems throughout the growing season. Tables 1-9 can also be found online on the "Members Only" section of the Nursery Cooperative web site under the tab "Nutrient Survey".
2. Nursery managers should use the nutrient range information in these tables as a guideline for evaluating their crop with respect to nutrient levels at a particular time. Nutrient levels which do not fall within the range of the data presented should be critically evaluated.
3. Container nurseries with the ability to inject fertilizer through their irrigation system tended to have the highest foliar nutrient levels.
4. Fertility levels for most container and some bareroot seedlings between October and January may be too low to ensure outplanting success.
5. Although not without risks, nurseries should consider fall fertilization (after dormancy has initiated) to increase base-line seedling nutrient levels.

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Table 1. Bareroot loblolly pine foliar nutrient content for July 2009.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	2.08[a]	0.16	0.2	1.11	0.11	0.28	0.02
Median	**2.56**	**0.19**	**0.28**	**1.42**	**0.145**	**0.37**	**0.03**
Maximum	3.22	0.25	0.38	1.72	0.17	0.55	0.05
Coeff var.	11.8	10.0	15.2	12.3	13.0	17.8	32.8

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	6 [a]	44	145	112	11	81
Median	**22.5**	**76.5**	**378**	**270.5**	**16**	**337**
Maximum	103	98	1227	1098	20	1027
Coeff var.	77.0	23.4	58.7	69.3	15.5	58.6

[a]Numbers are an average of 15-20 seedlings collected at each of 20 bareroot nurseries from 9 southern states.

Table 2. Bareroot loblolly pine foliar nutrient content for October 2009.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	1.15[a]	0.1	0.14	0.66	0.07	0.21	0.01
Median	**1.61**	**0.13**	**0.19**	**0.9**	**0.11**	**0.35**	**0.02**
Maximum	2.27	0.14	0.26	1.31	0.16	0.48	0.07
Coeff var.	18.2	8.9	18.0	19.5	17.0	19.3	52.9

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	7 [a]	31	132	103	8	154
Median	**16**	**56**	**549**	**163**	**11**	**334**
Maximum	42	89	1362	748	36	576
Coeff var.	48.1	30.4	53.9	77.4	51.7	35.2

[a]Numbers are an average of 15-20 seedlings collected at each of 20 bareroot nurseries from 9 southern states.

Table 3. Bareroot loblolly pine foliar nutrient content for January 2010.

Nutrient	N	S	P	K	MG	CA	NA
Unit	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Minimum	0.61[a]	0.07	0.07	0.31	0.06	0.25	0.01
Median	**1.26**	**0.10**	**0.15**	**0.76**	**0.11**	**0.33**	**0.03**
Maximum	1.38	0.15	0.21	1.19	0.15	0.59	0.06
Coeff var.	15.5	18.1	20.2	28.5	25.3	28.2	50.1

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	*PPM*	*PPM*	*PPM*	*PPM*	*PPM*	*PPM*
Minimum	6 [a]	31	135	85	6	185
Median	**13**	**55.5**	**485.5**	**219.5**	**13.5**	**418.5**
Maximum	25	115	1677	1161	52	2097
Coeff var.	35.3	32.9	74.1	86.4	68.2	84.8

[a]Numbers are an average of 15-20 seedlings collected at each of 20 bareroot nurseries from 9 southern states.

Table 4. Container loblolly pine foliar nutrient content for July 2009.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	1.72[a]	0.17	0.21	1.21	0.15	0.3	0.02
Median	**2.07**	**0.19**	**0.28**	**1.51**	**0.18**	**0.34**	**0.05**
Maximum	2.87	0.27	0.39	1.8	0.21	0.6	0.06
Coeff Var.	18.2	18.7	21.8	14.5	12.9	32.4	33.7

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	14[a]	38	100	92	11	37
Median	**17**	**56**	**163.5**	**171**	**13.5**	**134**
Maximum	27	70	368	212	20	222
Coeff Var.	29.8	19.3	50.5	28.9	27.8	49.4

[a]Numbers are an average of 15-20 seedlings collected at each of 7 container nurseries from 5 southern states.

Table 5. Container loblolly pine foliar nutrient content for October 2009.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	0.93[a]	0.09	0.12	0.74	0.13	0.32	0.02
Median	**1.35**	**0.12**	**0.17**	**1.05**	**0.15**	**0.45**	**0.04**
Maximum	1.47	0.15	0.22	1.38	0.22	0.77	0.06
Coeff Var.	14.7	18.3	22.7	22.2	21.1	34.5	41.1

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	12[a]	24	84	123	10	64
Median	**17.5**	**39.5**	**108.5**	**158**	**13**	**119**
Maximum	27	75	171	317	29	202
Coeff Var.	31.5	41.1	30.6	38.7	49.3	43.0

[a]Numbers are an average of 15-20 seedlings collected at each of 7 container nurseries from 5 southern states.

Table 6. Container loblolly pine foliar nutrient content for January 2010.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	0.64[a]	0.09	0.07	0.52	0.11	0.33	0.02
Median	**1.03**	**0.11**	**0.13**	**0.90**	**0.15**	**0.39**	**0.05**
Maximum	1.47	0.16	0.14	1.11	0.25	0.59	0.06
Coeff Var.	31.0	23.7	21.7	26.2	29.9	28.5	49.0

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	10[a]	18	70	134	7	92
Median	**13.5**	**38.5**	**123.5**	**238.5**	**13.5**	**215**
Maximum	20	69	239	303	23	483
Coeff Var.	24.3	41.6	41.5	27.6	37.7	55.2

[a]Numbers are an average of 15-20 seedlings collected at each of 7 container nurseries from 5 southern states.

Table 7. Container longleaf pine foliar nutrient content for July 2009.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	1.23 [a]	0.1	0.08	0.88	0.1	0.19	0.02
Median	**1.46**	**0.17**	**0.15**	**1.06**	**0.14**	**0.35**	**0.09**
Maximum	2.87	0.26	0.34	1.4	0.17	0.63	0.09
Coeff Var.	34.9	29.8	48.4	17.0	19.2	40.8	44.4

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	6 [a]	20	41	80	4	33
Median	**14**	**40**	**89**	**141**	**10**	**120**
Maximum	35	63	391	409	23	379
Coeff Var.	60.7	43.6	84.0	58.6	59.0	77.3

[a]Numbers are an average of 15-20 seedlings collected at each of 7 container nurseries from 5 southern states.

Table 8. Container longleaf pine foliar nutrient content for October 2009.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	0.62 [a]	0.08	0.08	0.61	0.1	0.23	0.03
Median	**1.21**	**0.14**	**0.13**	**1.07**	**0.13**	**0.33**	**0.05**
Maximum	1.45	0.17	0.18	1.31	0.19	0.55	0.08
Coeff Var.	31.1	24.5	27.0	21.3	23.1	30.7	41.9

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	11 [a]	17	54	89	8	58
Median	**16**	**36**	**115**	**197**	**14**	**126**
Maximum	20	78	266	366	27	362
Coeff Var.	25.1	49.3	59.2	45.7	41.8	70.6

[a]Numbers are an average of 15-20 seedlings collected at each of 7 container nurseries from 5 southern states.

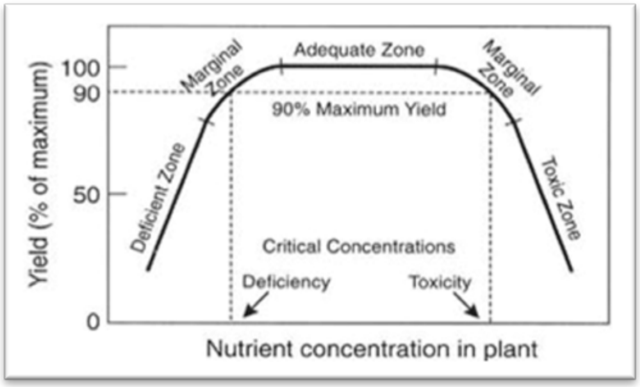
Table 9. Container longleaf pine foliar nutrient content for January 2010.

Nutrient	N	S	P	K	MG	CA	NA
Unit	%	%	%	%	%	%	%
Minimum	0.52 [a]	0.08	0.06	0.59	0.1	0.23	0.02
Median	**0.83**	**0.1**	**0.1**	**0.94**	**0.13**	**0.33**	**0.04**
Maximum	1.07	0.12	0.22	1.32	0.31	0.46	0.09
Coeff Var.	21.8	15.5	46.9	30.9	47.1	29.3	53.4

Nutrient	B	ZN	MN	Fe	Cu	Al
Unit	PPM	PPM	PPM	PPM	PPM	PPM
Minimum	8 [a]	19	67	97	8	76
Median	**14**	**44**	**92**	**178**	**13**	**191**
Maximum	15	79	186	843	26	702
Coeff Var.	19.3	45.4	39.3	107.5	43.1	93.8

[a]Numbers are an average of 15-20 seedlings collected at each of 7 container nurseries from 5 southern states.

1a



1b

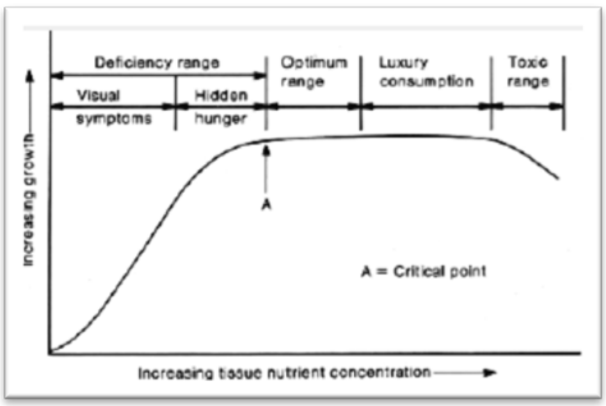


Figure 1. The relationship between seedling growth and seedling nutrient concentration. Figure 1a. . Plank, CO and RN Carrow. Figure 1b. Landis et.al. 1989

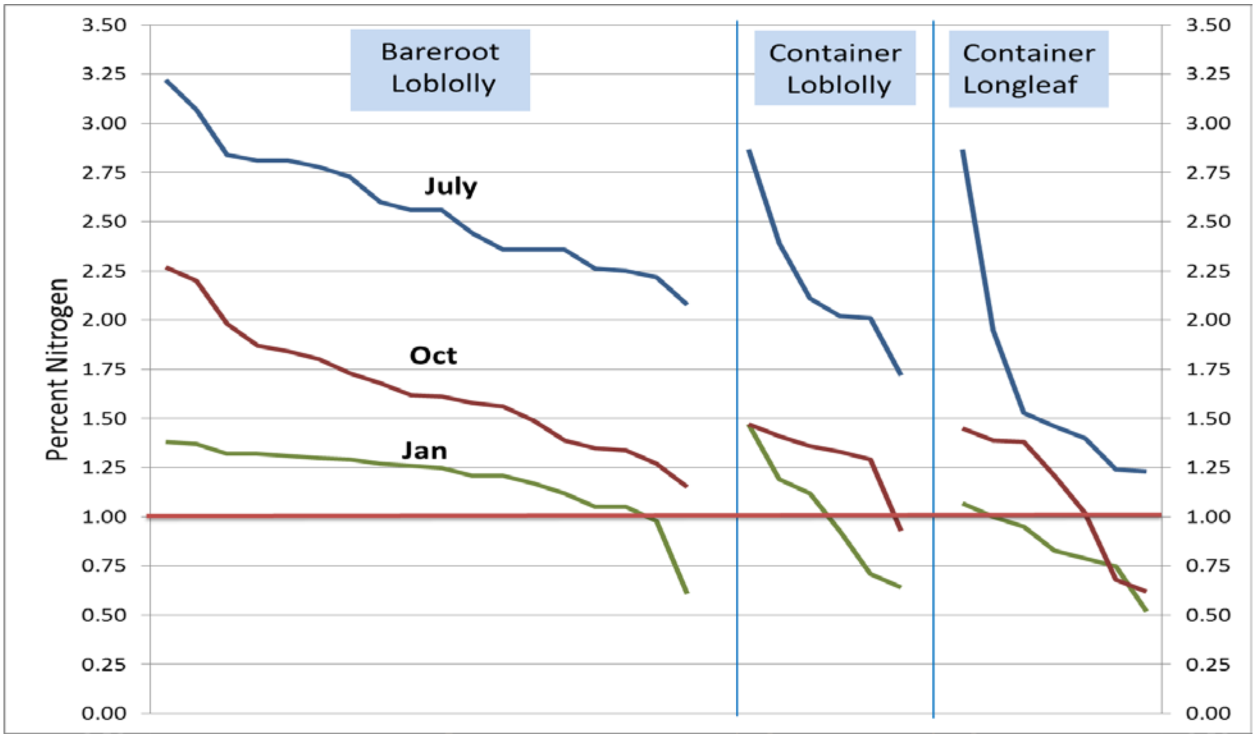


Figure 2. Comparison of species by stock type and foliar nitrogen concentration across the 27 nurseries sampled. Each line for each species and collection period represents the range of values from the nurseries sampled within that stock type. For example, July bareroot nitrogen ranged from 3.22 to 2.08 percent.