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Nursery Seedling Quality Affects Growth And Survival In Outplantings

By:
S. J. Rowan

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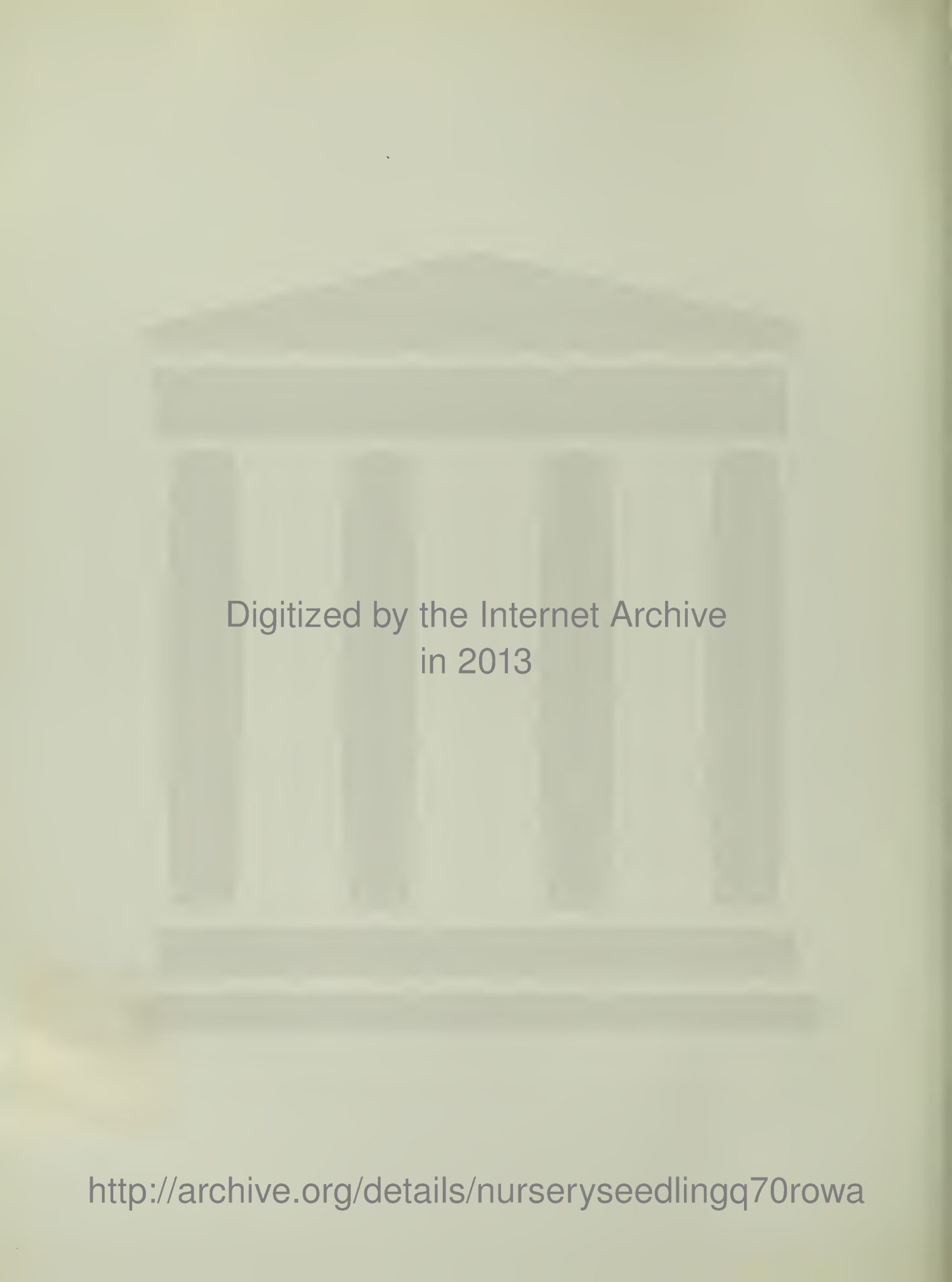

About The Author

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Hand lifting at state nursery.

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Survival and growth of loblolly pine seedlings from nine Georgia nurseries were monitored in several plantations established during three consecutive years. Outplanted seedlings were lifted both operationally and with tender loving care (TLC). Rates of survival and growth were correlated with 71 X-variables generated from seedling measurements made at lifting. Incidence of fusiform rust, root rot severity, root and shoot biomass, and other variables were included among the measurements. Anthrone reactive soluble sugars, soluble glucose, and starch concentrations were measured in both small and large roots of seedlings lifted operationally and with TLC from the nine Georgia nurseries. Root starch concentrations (mg/g) in small roots were best correlated with increased growth in outplantings but the total quantity (mg/tree) of anthrone reactive soluble sugars, soluble glucose, and starch in entire root systems (both large and small roots combined) were also significantly correlated with increased growth. Poor handling and planting techniques by landowners or planting contractors caused more mortality than all other measured causes. Shoot/root ratio was the best predictor of increased survival. Improved survival was correlated with increased growth.

INTRODUCTION

Forest land managers are becoming more aware of the financial impact of regeneration practices on the yield of plantations of southern pines. Plantations established on unprepared or poorly prepared sites may have significant numbers of planting spaces that were never planted. The number of such spaces (missed) increases with roughness of the terrain, planting crews, and planting machinery. Certain planting crews--regardless of planting method--and certain planting machines--regardless of planting crew--improperly plant seedlings in rough terrain, resulting in substantial mortality rates. Initial stocking is important to the final yield of a plantation and careful supervision of crews that prepare sites and outplant seedlings can add significant profit to each rotation crop (Godbee et al. 1983).

Poor seedling quality (size, disease incidence, genotype, physiology, etc.) is often pointed to in explanation for poor growth and survival of plantations but little information is available correlating measures of quality and performance. Godbee and coworkers (1983) indicated that improper planting accounted for the majority of mortality in their plantings. The work reported in this paper was begun in 1979 in an attempt to determine if the rates of survival and growth of seedlings differed among the nine Georgia nurseries, by methods of lifting, by methods of transportation, handling and planting by landowners, lifting and planting dates, root starch, root glucose, root soluble sugars, and by outplanting sites.

MATERIALS AND METHODS

Rates of seedling survival obtained by the average landowner were determined among 49 random landowners in 1979-1980 (Table 1) and among 35 random landowners in 1980-1981 (Table 2). Dates of lifting, storage at nursery, storage at Georgia Forestry Commission county offices, storage on landowner's property, outplanting, and quality of the outplanting job were recorded. Weather records during the time intervals were obtained from weather bureau records nearest the site or sites involved.

Effects of lifting methods (operational versus TLC), method of shipping (operational versus hand delivered), and outplanting crew (author's careful hand planting versus random landowners' machine planting) on outplanting survival were tested on six random sites in 1979-1980 and on five random sites in 1980-1981 (Tables 3 and 4). Seedlings were hand planted in randomized complete block design with four blocks and 25 seedlings per treatment row.

Survival and growth were monitored in plantations established with loblolly pine seedlings lifted operationally and with TLC from each nursery in Georgia during 1980, 1981, 1982. The seedlings were lifted and outplanted during January, February, and March in 1980 and 1981 and during February of 1982. The outplantings were machine planted (Whitfield chain driven finger planter) in randomized complete block design with 4 blocks and 50 seedlings per treatment row. Seedlings were lifted, refrigerator-stored, and outplanted during a two to three week period.

Quantities of root starch, anthrone reactive soluble sugars, and soluble glucose were determined in small and large roots from 25 random seedlings lifted from each nursery in Georgia in February 1982. The root samples were collected on the day before the seedlings were outplanted, placed in a forced draft oven at 65 degrees C. for 48 hours to stop enzyme activity and carbohydrate conversions (Ebell, 1969). Large and small roots were separated after drying by gentle hand stripping followed by sieving through a 5 m.m sieve. Large and small roots were easily separated from each other in this fashion, ground in a Wiley mill to pass a 40 mesh sieve, and placed in a freezer until carbohydrates were extracted and measured.

Table 1. First-year survival of pine seedlings produced in Georgia Forestry Commission nurseries and planted by landowners or contractors on 49 random sites in 46 Georgia counties during 1979-1980 planting season.

County	Percent	County	Percent
Appling	46.2	Morgan	5.0
Baldwin	60.7	Muscogee	79.0
Bartow	82.0	Putnam	79.7
Brantley	53.0	Randolph	62.0
Bulloch	55.0	Richmond	70.4
Burke	17.3	Schley	76.9
Butts	77.3	Screven	68.0
Clarke	62.0	Stewart	91.1
Clayton	54.0	Sumter	30.4
Columbia	0.0	Talbot	77.3
Coweta	77.0	Taliaferro	71.6
Dooly	71.0	Tattnall	58.9
Emanuel	67.0	Taylor	78.3
Evans	56.5	Toombs	37.0
Fayette	76.0	Twiggs	28.8
Glascock	88.6	Warren	6.0
Gordon	76.0	Warren	68.3
Hancock	88.5	Washington	16.0
Harris	81.9	Washington	66.0
Jeff Davis	86.2	Washington	0.0
Jefferson	42.0	Wayne	87.3
Jenkins	69.0	Webster	74.9
Johnson	71.0	Wilkes	47.0
Lincoln	44.5	Wilkinson	0.0
Macon	0.0		

Table 2. First-year survival of pine seedlings produced in Georgia Forestry Commission nurseries and planted by landowners or contractors on 35 random sites in 30 Georgia counties during 1980-1981 planting season.

County	Percent	County	Percent
Baker	53.4	Irwin	59.5
Baldwin	77.0	Madison	39.9
Ben Hill	73.0	Mitchell	73.9
Brooks	65.7	Oconee	46.3
Calhoun	43.5	Oglethorpe	37.8
Chattooga	99.0	Paulding	49.0
Chattooga	75.0	Paulding	39.0
Clay	28.2	Polk	47.0
Clinch	66.0	Polk	40.0
Colquitt	60.3	Pierce	54.0
Coweta	86.7	Seminole	68.0
Decatur	95.0	Tift	91.8
Early	90.0	Walker	68.0
Elbert	65.9	Walton	85.9
Grady	71.0	Warren	27.0
Greene	38.5	Worth	88.1
Haralson	31.0	Worth	52.4
Haralson	95.0		

Table 3. First-year survival of pine seedlings produced in Georgia Forestry Commission nurseries lifted operationally by nursery personnel (Reg) and by the author with tender loving care (TLC), transported to the landowner by state truck delivery (State) and by the author (Hand), and outplanted on the landowner's site by landowner (LO) or by the author in randomized complete block design during 1979-1980.

Lift method	Transport method	Site 1 (Morgan)	Site 2 (Warren)	Site 3 (Clarke)	Site 4 (Washington)	Site 5 (Washington)	Site 6 (Brantley)	Avg.
				Percent				
Reg	Hand	85.0 a	12.1 b	62.6 b	82.1 b	1.0 a	82.0 b	54.1
Reg	State	74.0 b	11.2 b	57.5 b	83.0 b	0.0 a	51.0 c	46.1 a
TLC	Hand	83.0 a	24.0 a	76.3 a	92.7 a	0.0 a	99.0 a	62.5
TLC	State	82.0 a	28.6 a	64.0 b	92.0 a	1.0 a	91.2 a	59.8
Reg	State (LO)	5.0 c	6.0 b	62.0 b	66.0 c	0.0 a	53.0 c	32.0 b
Avg Reg lift		79.5 a	11.6 b	60.0 b	82.5 a	0.5 a	66.5 b	50.1 b
Avg TLC lift		82.5 a	26.3 a	70.1 a	92.3 a	0.5 a	95.1 a	61.1 a
Avg Hand transport		84.0 a	18.0 a	69.4 a	87.4 a	0.5 a	90.5 a	58.3 a
Avg State transport		78.0 a	19.9 a	60.7 b	87.5 a	0.5 a	71.1 b	52.9 b

Column means followed by a common letter do not differ significantly (P=0.05) according to Duncan's multiple range test. Paired mean averages should not be compared with other means.

Table 4. First-year survival of pine seedlings produced in Georgia Forestry Commission nurseries lifted operationally by nursery personnel (Reg) and by the author with tender loving care (TLC), transported to the landowner by state truck delivery (State) and by the author (Hand), and outplanted on the landowner's site by landowner (LO) or by the author in randomized complete block design during 1980-1981.

Lift method	Transport method	Site 1 (Baldwin)	Site 2 (Warren)	Site 3 (Greene)	Site 4 (Clinch)	Site 5 (Pierce)	Avg.
				Percent			
Reg	Hand	99.1 a	98.0 a	93.2 a	84.0 b	88.0 c	92.5
Reg	State	98.0 a	97.0 a	74.2 a	88.0 b	79.0 d	87.2 a
TLC	Hand	95.0 a	95.0 a	93.0 a	98.0 a	100.0 a	96.2
TLC	State	99.1 a	99.0 a	92.1 a	97.0 a	91.2 b	95.7
Reg	State (LO)	77.0 b	27.0 b	38.5 b	66.0 c	54.0 e	52.5 b
Avg Reg lift		98.6 a	97.5 a	83.7 a	86.0 b	83.5 b	89.9 b
Avg TLC lift		97.1 a	97.0 a	92.6 a	97.5 a	95.6 a	96.0 a
Avg Hand transport		97.1 a	96.5 a	93.1 a	91.0 a	94.0 a	94.3 a
Avg State transport		98.6 a	98.0 a	83.2 a	92.5 a	85.1 b	91.5 a

Column means followed by a common letter do not differ significantly (P=0.05) according to Duncan's multiple range test. Paired mean averages should not be compared with other means.

Table 5. Morphological characteristics of loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia during January, February, and March of 1981.

Nursery source	Seedling ht. at lift (cm)	Shoot Wt. (g/25 trees)	Shoot/ root ratio (g/g)	Sturdiness Indices (mm ht/ g shoot)	(mm ht/ g root)	(mm ht/ g tree)	Root Wt. (g/25 trees)	Large roots (g/25 trees)	Small roots (g/25 trees)	1st-order roots (No.)	Mycorrhizal index (%)	Small roots lost at lift (%)	Root rot index
Morgan	15.7	173.8	1.968	22.6	44.5	15.0	88.3	71.3	17.0	16.6	52.7	0.5	5.4
Page-Walker	18.5	219.8	1.823	21.0	38.3	13.6	120.6	92.8	27.8	17.9	43.9	40.8	10.1
Hiwassee	24.3	208.8	1.939	29.1	56.4	19.2	107.7	71.0	36.7	17.5	51.5	36.4	5.6
Great Southern	20.5	185.8	2.464	27.6	68.0	19.6	75.4	63.6	11.8	15.5	37.8	85.9	4.9
Cont. For. Ind.	20.7	156.0	2.626	33.2	87.1	24.0	59.4	50.6	8.8	15.6	43.8	61.0	3.9
Union Camp	16.3	109.8	1.794	37.1	66.6	23.8	61.2	50.6	10.6	14.3	41.2	66.0	5.9
Rayonier	23.2	172.3	2.591	31.9	87.2	24.3	66.5	52.8	13.7	14.6	34.9	76.9	10.9
Brunswick P&P	23.6	176.3	2.064	33.5	69.1	22.5	85.4	69.0	16.4	16.9	47.4	59.5	16.3
Ga. Kraft	19.1	182.7	1.874	26.1	49.0	17.0	97.5	79.8	17.7	17.1	56.3	35.2	5.0
Average:													
Operational	19.9	164.2	2.271	30.3	68.8	21.0	72.3	61.0	11.3	15.1	32.8	44.0	7.2
TLC	20.7	188.1	1.939	27.5	53.4	18.2	97.0	75.9	21.1	17.4	57.8	0.0	7.1
Average:													
January	19.9	166.5	1.945	29.9	58.1	19.7	85.6	71.1	14.5	17.0	53.0	—	6.2
February	19.4	176.9	2.089	27.4	57.3	18.5	84.7	68.9	15.8	14.9	40.8	—	9.2
March	21.6	185.0	2.210	29.2	64.5	20.1	83.7	65.4	18.3	16.8	42.3	—	6.2

Carbohydrates were extracted in soxyhlets with 80% ethanol and the quantity of soluble anthrone reactive sugars was measured (Ebell, 1969). Soluble glucose was measured by use of both ASTRA and KDA instrumentation (Anony. 1979a and 1979b). Both instruments utilize the glucose oxidase enzyme reaction but the KDA uses a chromogen reaction to indicate glucose concentration and the ASTRA uses an oxygen electrode to measure oxygen depletion and, consequently, glucose concentration. Starch was extracted in perchloric acid and iodine-potassium-iodine reagent (Ebell, 1969). The extracted starch was hydrolyzed in boiling hydrochloric acid (Hassid and Neufeld, 1964; Pulcher et. al., 1948) and the resultant glucose concentrations measured with both the KDA and ASTRA.

Because the dry weights of small and large roots of 25 random seedlings were known, starch, glucose, and anthrone reactive soluble sugars were calculated as concentration per gram of root tissue and concentration per root system (per tree).

At each lifting date and before seedlings were outplanted during the three-year period, 25 random seedlings were collected from each nursery source and each lifting method for measurements. The following were recorded: shoot height; shoot diameter; shoot fresh weight; shoot dry weight; root rot index (percent root length with lesions); fusiform rust incidence (based on 500 seedling count); number of first order roots; root fresh weight; root dry weight; mycorrhizal index (percent feeder roots mychorrhizal); weight and percentage of small roots lost at lifting (TLC root weight less operational root weight); dry weights of roots after stripping and separation by sieving and resieving into size classes $\geq$5.6mm, $<5.6 - \geq 4.0$ mm, $<4.0 - \geq 2.0$ mm; and <2.0 mm, shoot/root ratio (based on fresh weights); sturdiness index (shoot height/shoot dry weight); sturdiness index (shoot height/root fresh weight); sturdiness index (shoot height/root dry weight); sturdiness index (shoot height/total seedling fresh weight); sturdiness index (shoot height/total seedling dry weight); shoot/root ratio (based on dry weights of each root size class and in all possible combinations of shoot weight and root size classes); and the reciprocals (1/X) of root fresh and dry weights in each size class and in all possible combinations. After including survival and growth in regression equations a total of 71 X-variables were used for growth and survival predictions. The MAX-R procedure was used in order to determine which X-variables were contributing most to the prediction of survival and growth (anomy. 1952).

RESULTS AND DISCUSSION

Rates of seedling survival obtained by the average landowner were determined among 49 random landowners in 1979-1980 (Table 1) and among 35 landowners in 1980-1981 (Table 2). Survival ranged from 0 to 89 percent (average 60%) in 1979-1980 plantings and ranged from 27 to 99 percent (average 62%) in 1980-1981 illustrating large variation in rates of survival of seedlings from Georgia Forestry Commission nurseries.

Method of lifting was shown to significantly affect rates of survival (Tables 3 and 4) but lifting seedlings with tender loving care (TLC) only improved survival by 11.0% in 1979-1980 and 6.1% in 1980-1981 (average 8.6%). Method of transport affected the rate of survival in only 1 of 2 years (Tables 3 and 4) and average improvement for the 2 years was 4.1% if extra care was taken during transport of seedlings from nursery to planting site.

Although seedlings from the nine Georgia nurseries differed in size, weight, disease incidence, and other measurements at lifting (Table 5), their rates of survival did not differ significantly due to nursery source (Tables 6,7, and 8). Outplanting site did significantly affect rates of survival (Tables 6 and 7).

Although lifting seedlings with TLC was shown to improve survival by 8.6 percent during the 2-year period (Tables 3 and 4), only 2200 TLC seedlings were outplanted. Survival was also shown to be improved by TLC lifting from all nurseries and outplanted on five sites during the same 2-year period (Table 9). The average improvement due to TLC lifting was 7.3 percent among these 25,200 outplanted seedlings. Outplanting date also affected survival on some but not all sites in each of the two years (Table 9).

The greatest improvement in rate of survival resulted from extra care during outplanting on 11 random Georgia sites (Tables 3 and 4). Survival was improved by 14 percent in 1979-1980 and by 35 percent in 1980-1981---an average of 24 percent improvement for both years.

It can, therefore, be concluded that some improvement in seedling quality can be realized from greater care during transportation of seedlings from nursery to outplanting site, during lifting of seedlings from nursery beds and during packing of seedlings in the nursery shed, but care during transplanting by outplanting crews can provide more improvement in seedling survival than can improved lifting and packing methods or improved care during transportation. Disease incidence (fusiform rust, root rot) and other differences in seedling quality (71 X-variables measured and listed above) among seedlings lifted from the nine Georgia nurseries during the 3 years of this study did not cause survival rates to differ significantly among nurseries. Top/root ratio was the best predictor of survival, and those seedlings that survived best also grew best. Weight of large roots was more important to seedling growth than was the weight of small roots (including feeder roots and mycorrhizae). Larger lateral and larger feeder roots were more important to seedling survival than were smaller feeder roots. The following prediction equations generated by use of the MAX-R statistical procedure illustrate the importance of shoot/root ratio and large roots to seedling survival. Weather was not one of the measured variables.

SURVIVAL= TOP/ROOT RATIO + ROOT/TREE RATIO + 4mm ROOT WEIGHT + 5.6 mm ROOT WEIGHT.

R^2 = Y (.272) = .429 + .351 + .332 + .328

GROWTH= SURVIVAL + INVERSE ROOT WEIGHT + INVERSE LARGE ROOT WEIGHT + FEEDER ROOT BIOMASS

R^2 = Y (.409) = .579 + .317 + .322 + .319

Root carbohydrate concentrations varied significantly by method of lifting and by nursery source (Tables 10, 11 and 12). Starch concentrations in small roots expressed as mg/g of root tissue was best correlated with seedling growth in outplantings (Table 13). Survival in the plantation was too good to allow calculating correlation coefficients between root carbohydrates and survival. Root starch concentrations in large roots were correlated with growth when expressed as mg/tree but not significant when expressed as mg/g of root tissue (Table 13). Root starch concentrations in large and small roots combined (total root system) were correlated with growth whether expressed as mg/g or mg/tree (Table 13). Soluble glucose in large roots and in both large and small roots combined (total root system) was significantly correlated with growth when expressed as mg/tree but not when expressed as mg/g of root tissue (Table 13). Soluble sugars (total) in total root system were significantly correlated with growth only when expressed as mg/tree but their concentrations in small or large roots were not correlated with growth (Table 13).

Second year heights of seedlings were significantly affected by method of lifting, dates of planting, site, and nursery source (Tables 14, 15 and 16). The earlier the outplanting date, the larger were seedlings two years later. The TLC lifted trees were also taller than operationally lifted ones after the second year. The obvious conclusion from this data is that the better the quality of seedlings outplanted and the better the handling and care, the higher the yield and profits by rotations end.

Table 6. First-year survival of loblolly pine seedlings lifted from each nursery in Georgia and outplanted on each of three sites during 1979-1980 planting season.

Nursery source	Oglethorpe	Baldwin	Ware	Average
		Percent		
Morgan	64.6	37.5	92.7	64.9 a
Page-Walker	55.2	38.5	95.8	63.2 a
Hiwassee	39.2	39.1	92.1	56.8 a
Great Southern	58.2	37.8	96.2	64.1 a
Cont. For. Ind.	49.9	29.4	91.0	56.8 a
Union-Camp	64.6	30.0	92.2	62.3 a
Rayonier	57.1	26.2	93.7	59.0 a
Brunswick P&P	48.4	34.2	94.6	59.1 a
Average	54.7 B	34.1 A	93.5 C	

Column means followed by a common lowercase letter or row means followed by a common uppercase letter do not differ significantly (P=0.05) according to Duncan's multiple range test.

Table 7. First-year survival of loblolly pine seedlings lifted from each nursery in Georgia and outplanted on each of two sites during 1980-1981 planting season.

Nursery source	Baldwin	Ware	Average
	Percent		
Morgan	71.5 ab	88.8 b	80.1 bc
Page-Walker	73.1 b	88.6 ab	80.9 c
Hiwassee	62.4 a	86.0 ab	74.2 abc
Great Southern	65.7 ab	82.9 ab	74.3 abc
Cont. For. Ind.	62.1 a	84.5 ab	73.3 ab
Union-Camp	67.4 ab	91.9 b	79.7 bc
Rayonier	65.1 ab	83.2 ab	74.2 abc
Brunswick P&P	62.1 a	79.0 a	70.5 a
Ga. Kraft	66.5 a	90.0 b	78.3 bc
Average	66.2 A	86.1 B	

Column means followed by a common lowercase letter or row means followed by a common uppercase letter do not differ significantly (P=0.05) according to Duncan's multiple range test.

Table 8. First-year survival of loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia and outplanted during February 1982.

Nursery source	Lifting method		
	Operational	TLC	Average
	Percent		
Morgan	92.0	98.5	95.3a
Page-Walker	98.0	99.0	98.5a
Hiwassee	100.0	97.2	98.6a
Great Southern	96.4	98.6	97.5a
Cont. For. Ind.	96.0	99.5	97.8a
Union-Camp	99.5	99.0	99.3a
Rayonier	97.5	99.0	98.3a
Brunswick P&P	99.1	97.7	98.4a
Ga. Kraft	98.5	99.0	98.8a
Average	97.4	98.6	98.0

Means followed by a common letter do not differ significantly (P=0.05) according to Duncan's multiple range test.

The rate of survival did not differ significantly due to nursery source.

Table 9. First-year survival of loblolly pine seedlings lifted operationally (Reg) by nursery personnel and with tender loving care (TLC) by the author and outplanted during January, February, and March on three sites in 1979-1980 and on two sites in 1980-1981.

	Oglethorpe	Baldwin	Ware	Avg.
		Percent		
1979-1980 lifting				
Reg.	50.9 a	32.2 a	91.5 a	58.0 a
TLC	58.5 b	35.9 a	95.6 b	63.3 b
1980-1981 lifting				
Reg.	—	62;0 a	81.1 a	71.6 a
TLC	—	70.5 b	91.1 b	80.8 b
1979-1980 lifting				
Jan.	44.2 a	31.9 a	87.7 a	54.6 a
Feb.	58.1 b	29.3 a	96.2 a	61.2 a
Mar.	61.7 c	41.0 b	96.7 a	66.5 a
1980-1981 lifting				
Jan.	—	63.6 a	90.6 b	77.1 b
Feb.	—	72.0 b	87.2 b	79.6 b
Mar.	—	63.0 a	80.6 a	71.8 a

Column means within each year and lifting method or planting date followed by a common letter do not differ significantly (P=0.05) according to Duncan's multiple range test.

Care during transplanting by outplanting crews can provide more improvement in seedling survival than can improved lifting, packing or transportation methods.

Table 10. Root starch in random loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia. Seedlings were lifted and outplanted in Ware County Georgia during February 1982.

Nursery source	Lift method	Small root (mg/g)	Small root (mg/tree)	Large roots (mg/g)	Large roots (mg/tree)	Total roots (mg/g)	Total roots (mg/tree)
Morgan	Operational	43.2	8.9	95.9	72.9	84.8	81.8
	TLC	61.7	34.2	99.5	204.0	91.3	238.2
Page-Walker	Operational	21.6	2.4	32.4	19.9	30.8	22.3
	TLC	32.4	11.3	58.1	59.6	51.6	70.9
Hiwassee	Operational	58.1	15.1	82.5	117.6	78.7	132.7
	TLC	47.8	16.7	68.4	75.2	63.4	91.9
Great Southern	Operational	40.1	6.2	60.3	110.7	58.7	116.9
	TLC	35.1	30.2	81.5	56.6	55.8	86.8
Cont. For. Ind.	Operational	52.7	7.1	40.5	39.9	42.0	47.0
	TLC	48.0	23.5	35.1	38.6	39.1	62.1
Union Camp	Operational	58.7	13.8	57.6	25.3	57.9	39.1
	TLC	29.7	8.6	55.8	34.6	47.5	43.2
Rayonier	Operational	45.0	7.9	78.0	149.8	75.3	157.7
	TLC	59.0	46.9	103.5	147.0	87.5	193.9
Brunswick P&P	Operational	58.0	7.5	97.3	73.0	91.5	80.5
	TLC	74.2	30.4	99.0	70.8	90.0	101.2
Ga. Kraft	Operational	76.1	43.2	91.2	179.7	92.1	222.9
	TLC	56.3	39.1	95.9	165.4	84.5	204.5
Average	Operational	50.4	12.5	70.6	87.6	68.0	100.1
	TLC	49.4	26.8	77.4	94.6	67.9	121.4

Table 11. Ethanol-soluble, anthrone-reactive sugars in roots of random loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia. Seedlings were lifted and outplanted in Ware County Georgia during February 1982.

Nursery source	Lift method	Small roots (mg/g)	Small roots (mg/tree)	Large roots (mg/g)	Large roots (mg/tree)	Total roots (mg/g)	Total roots (mg/tree)
Morgan	Operational	40.4	8.3	36.4	27.7	37.3	36.0
	TLC	48.4	26.9	39.0	80.0	41.0	106.9
Page-Walker	Operational	68.0	7.5	22.9	14.1	29.8	21.6
	TLC	23.0	8.1	18.4	18.9	19.6	27.0
Hiwassee	Operational	65.0	16.9	22.8	32.5	35.9	49.4
	TLC	36.0	12.6	26.6	29.3	28.9	41.9
Great Southern	Operational	37.6	5.8	22.3	40.9	23.5	46.7
	TLC	24.0	20.6	16.8	11.7	20.8	32.3
Cont. For. Ind.	Operational	42.0	5.7	23.3	23.0	25.6	28.7
	TLC	27.0	13.2	22.4	24.6	23.8	37.8
Union Camp	Operational	36.0	8.5	23.4	10.3	27.9	18.8
	TLC	33.2	9.6	22.8	14.1	26.0	23.7
Rayonier	Operational	77.0	13.5	26.8	51.5	31.0	65.0
	TLC	24.0	19.1	25.2	35.8	24.8	54.9
Brunswick P&P	Operational	41.0	5.3	27.0	20.3	29.1	25.6
	TLC	25.5	10.5	19.3	13.8	21.6	24.3
Ga. Kraft	Operational	33.8	15.2	22.0	43.3	24.2	58.5
	TLC	35.0	24.3	21.8	37.6	25.6	61.9
Average	Operational	49.0	9.6	25.2	29.3	29.4	38.9
	TLC	30.7	16.1	23.6	29.5	25.8	45.6

Table 12. Ethanol-soluble glucose in roots of random loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia. Seedlings were lifted and outplanted in Ware County Georgia during February 1982.

Nursery source	Lift method	Small roots (mg/g)	Small roots (mg/tree)	Large roots (mg/g)	Large roots (mg/tree)	Total roots (mg/g)	Total roots (mg/tree)
Morgan	Operational	12.2	2.5	7.0	5.3	8.1	7.8
	TLC	14.1	7.8	12.0	24.6	12.4	32.4
Page-Walker	Operational	13.6	1.5	10.1	6.2	10.6	7.7
	TLC	14.0	4.9	8.0	8.2	9.5	13.1
Hiwassee	Operational	11.2	2.9	10.0	14.3	10.2	17.2
	TLC	11.1	3.9	10.0	11.0	10.3	14.9
Great Southern	Operational	12.3	1.9	10.0	18.4	10.2	20.3
	TLC	8.0	6.9	7.1	4.9	7.6	11.8
Cont. For. Ind.	Operational	14.8	2.0	6.0	5.9	7.1	7.9
	TLC	14.1	6.9	10.5	11.6	11.6	18.5
Union Camp	Operational	11.9	2.8	5.0	2.2	7.4	5.0
	TLC	9.0	2.6	6.0	3.7	6.9	6.3
Rayonier	Operational	17.7	3.1	7.5	14.4	8.4	17.5
	TLC	7.0	5.6	6.0	8.5	6.4	14.1
Brunswick P&P	Operational	8.5	1.1	7.1	5.3	7.3	6.4
	TLC	8.5	3.5	5.0	3.6	6.3	7.1
Ga. Kraft	Operational	10.0	4.5	6.5	12.8	7.1	17.3
	TLC	10.9	7.6	7.0	12.1	8.1	19.7
Average	Operational	11.2	2.5	7.7	9.4	8.5	11.9
	TLC	10.7	5.5	8.0	9.8	8.8	15.3

Table 13. Correlation coefficients (r) between root carbohydrates and first-year heights of loblolly pine seedlings lifted operationally and with tender-loving-care from each of the nine nurseries in Georgia. Seedlings were lifted and outplanted in February 1982.

Root class	Quantity	Anthrone-soluble sugars	Soluble glucose	Starch
Small roots	(mg/g)	0.037	-0.126	0.610**
Small roots	(mg/tree)	0.422	0.264	0.390
Large roots	(mg/g)	0.272	0.366	0.449
Large roots	(mg/tree)	0.113	0.472*	0.487*
Total roots	(mg/g)	0.250	0.259	0.525*
Total roots	(mg/tree)	0.504*	0.477*	0.499*

Carbohydrates are significantly correlated with tree heights when coefficients are followed by one (P=.05) or two (P=.01) asterisks.

Table 15. Second year heights of loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia and outplanted on each of two sites during January, February and March 1981.

Nursery source	Ware (cm)	Baldwin (cm)	Average
Morgan	81.6	85.4	83.5 d
Page-Walker	79.7	85.1	82.4 cd
Hiwassee	69.2	77.9	73.6 a
Great Southern	72.7	82.3	77.5 b
Cont. For. Ind.	82.4	82.3	82.4 cd
Union Camp	80.2	84.8	82.5 cd
Rayonier	76.3	88.5	82.4 cd
Brunswick P&P	77.3	84.8	81.1 c
Ga. Kraft	79.7	87.3	83.5 d
Average:			
Operational	74.1 a	82.4 a	78.3 a
TLC	81.2 b	86.2 b	83.7 b
Average:			
January	78.4 b	86.9 b	82.7 b
February	78.3 b	87.9 b	83.1 b
March	76.4 a	78.0 a	77.2 a

Means among nursery source comparisons, lifting method comparisons, or outplanting date comparisons followed by a common letter do not differ (P=0.05) according to Duncan's multiple range test (nursery sources and planting dates) or Fishers F test (lift methods).

Table 14. Second year heights of loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia and outplanted on each of three sites during January, February, and March 1980.

Nursery source	Oglethorpe (cm)	Baldwin (cm)	Ware (cm)	Average
Morgan	107.6	101.6	119.5	109.6 cde
Page-Walker	114.8	108.4	127.5	116.9 e
Hiwassee	97.3	91.9	108.1	99.1 ab
Great Southern	105.1	99.3	116.8	107.1 cd
Cont. For. Ind.	92.6	87.6	102.9	94.4 a
Union Camp	100.5	94.9	111.7	102.4 bc
Rayonier	101.1	95.0	111.7	102.6 bc
Brunswick P&P	111.9	105.7	124.3	114.0 de
Average:				
Operational	100.4 a	94.8 a	111.5 a	102.2 a
TLC	107.2 b	101.2 b	119.1 b	109.2 b
Average:				
January	101.8 a	96.1 a	113.1 a	103.7 a
February	109.2 b	103.1 b	121.3 b	111.2 b
March	100.3 a	94.7 a	111.4 a	102.1 a

Means among nursery source comparisons, lifting method comparisons, or outplanting date comparisons followed by a common letter do not differ (P=0.05) according to Duncan's multiple range test (nursery sources and planting dates) or Fishers F test (lift methods).

Table 16. Second year heights of loblolly pine seedlings lifted operationally and with tender loving care (TLC) from each nursery in Georgia and outplanted on one Georgia site during February 1982.

Nursery source	Ware (cm)
Morgan	80.9 c
Page-Walker	69.4 a
Hiwassee	94.1 d
Great Southern	72.2 b
Cont. For. Ind.	81.5 c
Union Camp	72.4 b
Rayonier	81.3 c
Brunswick P&P	92.3 d
Georgia Kraft	80.6 c
Average:	
Operational	78.6 a
TLC	82.5 b

Means among comparisons of nursery sources or lifting methods followed by a common letter do not differ (P=0.05) according to Duncan's multiple range test (nursery source) or Fisher's F test (lift method).

Packing seedlings at nursery.

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