A COMPARATIVE EVALUATION OF SEEDLING QUALITY IN COMMERCIAL FOREST NURSERIES IN FLORIDA

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Abstract.--A variety of morphological and physiological parameters are being evaluated on sample slash pine seedlings from five commercial forest nurseries in Florida. Seedbed soil characteristics and nursery cultural/handling practices are also being considered in an effort to identify the cause(s) of "unexplained" outplant failures. Under some conditions, reduced survival can be attributed to root loss and/or damage resulting from machine lifting of seedlings. Also, seedling root starch reserves have, to date, exhibited a consistent relationship to first-year field survival of outplanted nursery stock. Methodology employed and the significance of preliminary results are discussed.

Additional key words: slash pine, *Pinus elliottii*, carbohydrates, root starch, seedling survival.

In recent years, foresters in Florida have been plagued by repeated and sometimes extensive regeneration "failures"; i.e., inadequate field performance (survival and growth) of bare-root nursery stock. Through 1976 a significant component of these failures could be attributed to damage sustained by seedling root systems as a result of infection by *Macrophomina phaseolina* (Tassi) Goid. (*Sclerotium bataticola* Taub.), the charcoal root rot fungus (Barnard 1979, Hodges 1962, Seymour 1969, and Seymour and Cordell 1979). More recently, however, seedbed fumigations with appropriate formulations and rates of methyl bromide and chloropicrin have held charcoal root rot infections to a minimum in Florida tree nurseries, and many outplant failures have been relegated to the "unexplained".

In 1978, we initiated a cooperative study in an attempt to identify the major cause or causes of "unexplained" outplant failures. In this paper, we present our approach to the problem, and some of our preliminary results.

METHODS

Sampling: 1978-79 Lifting Season. In the first year of our study we designed our work to evaluate seedling outplant performance as related to

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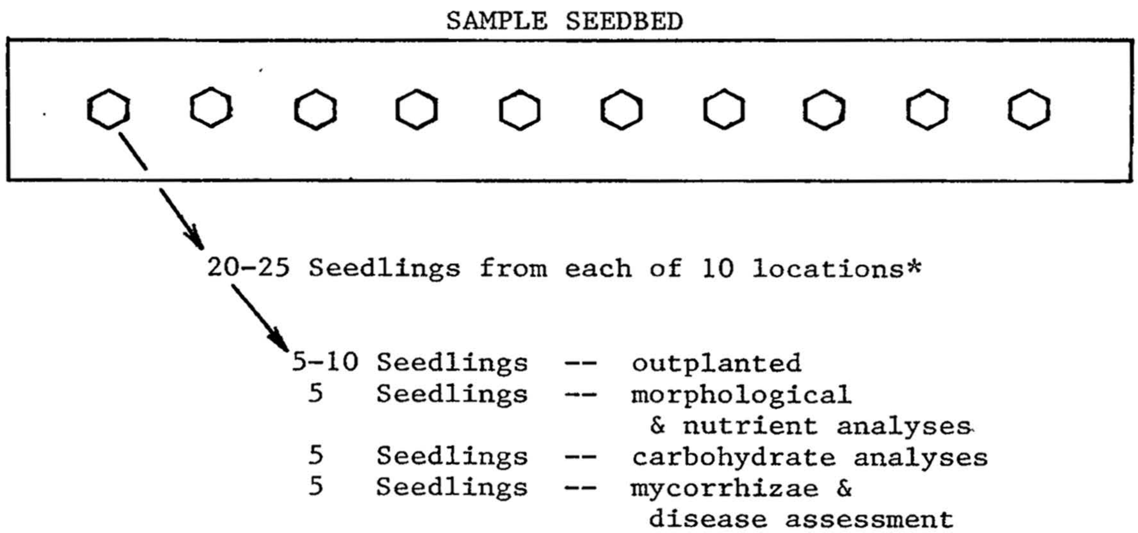
a) seedbed soil fertility, b) seedling morphology, c) seedling physiology, and d) methods of seedling lifting/handling. Sample seedlings (1-0 slash pine = *Pinus elliottii* Engelm.) were collected systematically from a representative seedbed in each of four commercial forest nurseries in Florida. Sampling was conducted twice; for logistical reasons from one seedbed in early December 1978 ("early-season") and from another seedbed in early February 1979 ("late-season"). Three primary lifting/handling treatments were identified; i.e., I - "hand lifted" by investigators, II - "machine lifted", seedlings taken from the lifting machine in the field, and III - "end-line packed", seedlings machine lifted, transported to packing shed, sorted or weighed according to routine procedures of the individual cooperating nurseries, and sampled just prior to placing bags or bales in cold storage. (Two nurseries bagged seedlings on their lifting machines in the field. Treatment III seedlings in such cases were obtained by opening bags after transport from the field, just prior to cold storage.) Twenty sample seedlings were taken from the middle four rows of each selected seedbed at each of ten locations throughout the length of the seedbed and distributed according to the schematic shown in Figure 1. All sample seedlings were immediately placed in appropriately labelled plastic bags with small amounts of moist pulp fiber mulch and transported on ice in insulated coolers to their respective destinations (i.e., lab, field, etc.).



*Soil sample collected from rhizosphere soil at each location and composited for seedbed soil analysis.

Fig. 1. Schematic representation of seedling sampling and sample distribution systems employed.

Sampling: 1979-80 Lifting Season. In year two of our study we decided to concentrate efforts on evaluation of the seedlings *per se* as compared to lifting/handling variables. This decision was based largely on preliminary results from our first year's work. Accordingly, only hand lifted seedlings were evaluated. As in year one, tests were again designed to examine relationships between outplant performance of early- and late-season seedlings and a) seedbed soil fertility, b) seedling morphology, and c) seedling physiology. Seedlings were sampled from each of five commercial forest nurseries during the second year. Sampling and sample handling was conducted as described above, except that this time three seedbeds were sampled in each nursery and samples were taken from the same seedbeds on both the early- and late-season sampling dates.

Seedling and seedbed soil analyses. The following factors were targeted for evaluation and are currently under investigation in our study:

1) seedling weight (green and dry),
2) seedling stem diameters,
3) top to root ratios (green and dry weight bases),
4) disease influences,
5) seedling mineral status,
6) seedling carbohydrate status,
7) seedbed soil nutrient levels,
8) seedbed soil pH,
9) root system mycorrhizae
10) nursery cultural practices.

Establishment of Test Plantings. Experimental plots were established with seedlings representing each specified treatment, nursery, sampling date, and/or seedbed. All seedlings were hand planted within 24 hours following lifting on prepared (chopped-burned-bedded) sites located on well-drained sandy soils (site index = 70+) in central Florida.

In the first year of our study, a randomized complete block design was employed. Four 25-tree square plots were established for each treatment (I, II, III) from each of the four nurseries and each of the two sampling dates. Logistical constraints necessitated a reduction in replication of field plots during our second year's work. Accordingly, we established two randomly located 25-tree square plots with seedlings from each of the three seedbeds from each of the five cooperating nurseries and both early- and late-season sampling dates (thus: 6 plots per nursery; 2 each from each of three seedbeds - repeated in early- and late-season). In all, a total of 156 test plots (3900 seedlings) were established over the two-year period. Survival data were collected at the end of the first growing season (year two data not yet finalized) and growth measurements are being taken annually for a period of three years.

RESULTS AND DISCUSSION

Not all analyses are complete at this time, nor have thorough statistical analyses been conducted. As a result, we are reporting preliminary observations and relationships which are readily apparent. We anticipate a formal and more complete report following the termination of our study.

I. Performance Related to Lifting/Handling Methods. With only one exception, seedlings lifted by hand survived better than those lifted by machine (Table 1). The greatest differences in survival between hand and

Table 1. Survival (%)[a] of hand and machine lifted 1-0 slash pine nursery stock at the end of the first growing season following outplanting in central Florida.

Nursery	Treatment[b]	Date Seedlings Lifted & Outplanted December '78	February '79
A	I-Hand lifted	88	85
	II-Machine	71	34
	III-"End-Line"	68	51
B	I-Hand lifted	52	73
	II-Machine	45	53
	III-"End-Line"	31	58
C	I-Hand lifted	91	82
	II-Machine	83	59
	III-"End-Line"	75	64
D	I-Hand lifted	73	32
	II-Machine	71	42
	III-"End-Line"	62	64

[a]Figures represent means of four replicate 25-tree plots.

[b]Method of seedling lifting/handling at the nurseries.

machine lifted seedlings, not unexpectedly, were recorded for nursery "A". Nursery "A" is located on relatively fine textured soil with a high component of clay, whereas nurseries "B", "C", and "D" are located on predominantly sandy soils, typical of central Florida. Why machine lifted seedlings from nursery "D" survived better than hand lifted seedlings (February sample) is unknown. However, two possibilities should be kept in mind: a) experimental error, and b) nursery "D" employs a slightly different type of mechanical lifter than the other three nurseries. In general, our data reflecting detrimental effects of machine lifting agree with data now being accumulated by C. E. Cordell (personal communication). We attribute this phenomenon to root loss and/or damage sustained by seedlings during the lifting process, and our data suggest that this problem is potentially worse in heavier soils. It must be pointed out, however, that the degree of root loss/damage will vary not only with soil conditions, but with lifter type and care used in its operation as well. Also, survival losses may be greater or less than those we observed, depending upon such factors as subsequent handling of seedlings, outplant site conditions, and weather patterns. The bottom line might simply be stated thus: "It will do you no good to grow a quality seedling if you beat it to death in lifting and handling" (ref. Table 1: Nursery "A" - February sample).

II. Performance Related to Other Factors. Noteworthy differences between individual cooperating nurseries, sampling dates, and/or seedbeds included variations in seedbed soil pH and nutrient levels, seedling size and/or top to root ratios, seedling nutrient status (inorganic), and seedling carbohydrate status (especially root starch). For example, seedbed soil pH values ranged from ca. 5.1 to 6.2, seedling top to root ratios (biomass - oven dry weight basis) varied from a low of 2.8 to a high of 7.5, stem diameters ranged from 3.6 mm to 5.7 mm, and root starch content varied from ca. 34 mg/g root tissue (o.d.wt.) to 145 mg/g. Seedbed soils as well as seedling tissues showed considerable variation in the amounts of inorganic nutrients present; particularly soil P, Mg, K, and tissue Ca and Mg. In many cases, these differences could be related to nursery cultural practices; e.g., greater seedbed densities usually resulted in smaller stem diameters, mineral nutrient analyses reflected fertilization programs, etc. Not surprisingly, seasonal trends were evident in many measurements, with late season samples having larger stem diameters, lower top to root ratios, and higher levels of root starch. Finally, both qualitative and quantitative differences in mycorrhizae were evident between individual nurseries. While Thelephora terrestris Ehrh. ex Fr. and Rhizopogon nigrescens Coker and Couch were the predominant fungal symbionts in most cases, a major component of the mycorrhizal symbioses in one of the cooperating nurseries was a result of natural colonization by Pisolithus tinctorius Coker and Couch. In no case were diseases (e.g., fusiform rust, root disease, etc.) considered a significant factor in our study.

To date, we have been unable to consistently relate field performance (survival only - growth data incomplete at present) of test seedlings to any of the observed morphological or physiological differences cited above with one apparent exception. While in certain cases outplant survival appeared related to stem diameters and/or top to root ratios, etc., root system starch content has shown the best and most consistent relationship to survival among all factors under consideration. In the first year of our study, two sets of sample seedlings performed miserably in the field relative to their peers. In both cases these seedlings contained significantly less root starch (per gram of dry weight) than did the "relatively good performers" collected on the same sample dates (Fig. 2). Although we have not tabulated all data for our second year's work as yet, there are substantive indications that this root starch - survival relationship is holding up.

III. Significance of Root Starch - Survival Relationships. Wakeley (1954) recognized the "unreliability" of morphological grades as measures of seedling quality (i.e., the ability of seedlings to survive and grow). He pointed out that "morphological grades and physiological qualities may or may not coincide" and stated that "physiological qualities of seedlings can overbalance the effects of their morphological grades upon survival and growth." Stone and his colleagues (Stone 1955, Stone and Schubert 1959, Stone et al. 1963) also recognized these phenomena and proposed methods other than morphological grades for assessing the fitness of seedlings for withstanding the trauma of lifting and outplanting. They proposed "root regenerating potential" (i.e., the ability of seedlings to generate new roots following lifting and outplanting) as a key measure of such "fitness" or "physiological quality".

We believe that root starch reserves may be a valid (and hopefully usable) parameter for assessing the physiological readiness of seedlings for withstanding "transplant shock". When lifted as bare-root stock, seedlings inevitably sustain some degree of root loss or damage. In order to survive

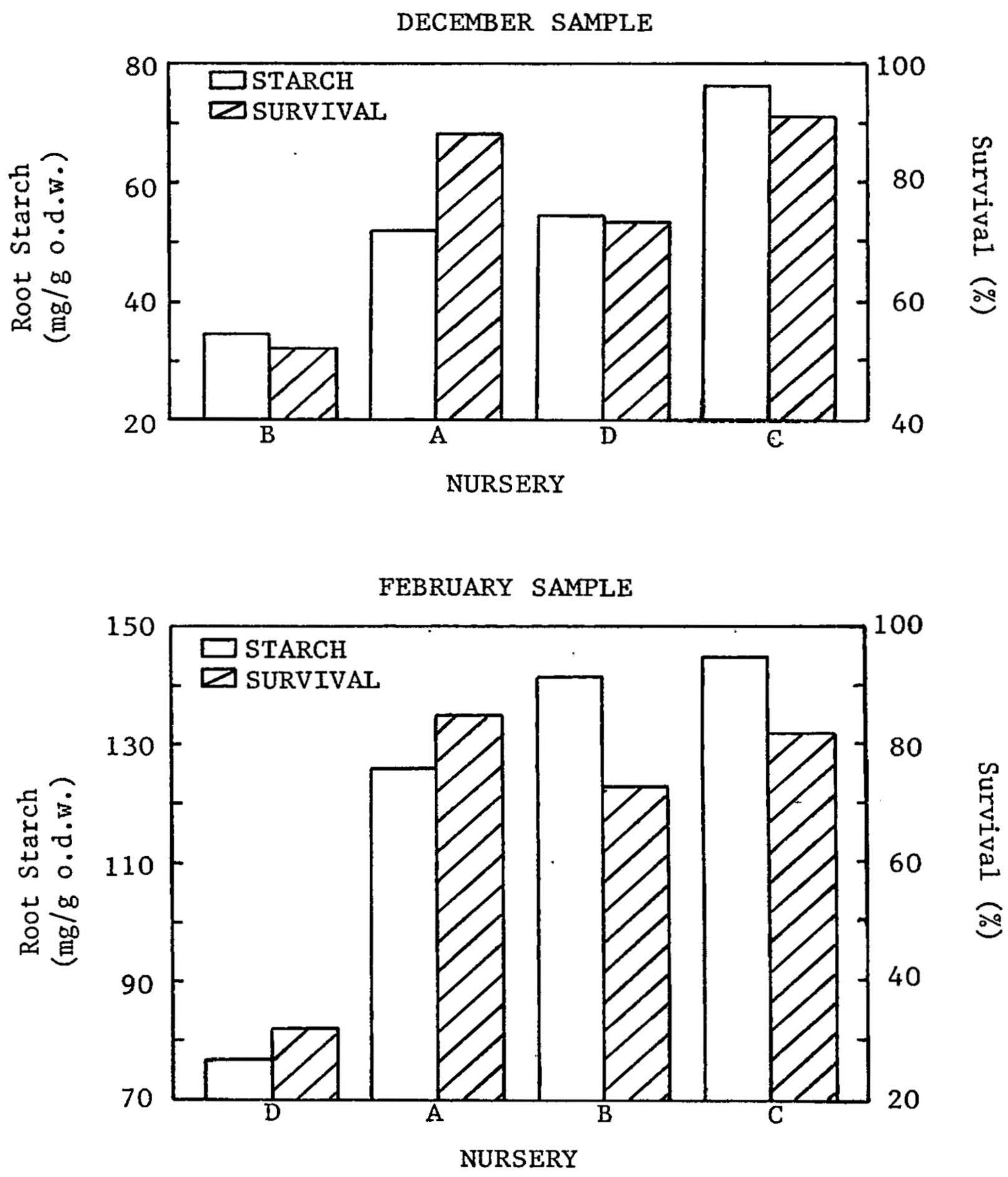


Fig. 2. Relationships between root starch (mg/g o.d.wt. of root tissue) and first year outplant survival of hand lifted 1-0 slash pine nursery stock in Florida. (Root starch content determined at the time sample seedlings were lifted from their respective nurseries' seedbeds.)

following outplanting, especially through periods of drought, etc., it is important that seedlings be capable of rapidly replacing lost roots and establishing adequate contact with their new soil environment by generating new roots. By and large this ability to regenerate roots (i.e., "root regenerating potential" sensu Stone et al.) is a function of reserve carbohydrates, particularly starch (Farmer 1978, Kozlowski 1971, Kramer and Kozlowski 1960, Larson 1975, Smith 1962, Wakeley 1954) which are accumulated in the seedlings during the growing season.

Assuming that reserve root starch does represent a meaningful measure of "seedling quality", there are several critical needs on which the successful use of this parameter depends. First, "optimum" or "adequate" starch reserve levels must be defined. These are apt to vary with tree species, season of lifting, and post outplant conditions (site, weather extremes, etc.). Secondly, a rapid and reliable method of determining whether or not seedlings have acquired sufficient levels of reserve starch is a must; such a method should be adaptable to field use. And thirdly, the effects of cultural practices (irrigation, fertilization, seedbed density, etc.) and climatic factors on starch metabolism must be determined so that nurserymen can employ management practices which encourage the synthesis and accumulation of this reserve carbohydrate. These and other factors related to "seedling quality" are currently under investigation at the University of Florida.

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