COMPARING ROOT GROWTH POTENTIAL OF LOBLOLLY PINE SEEDLINGS IN HYDROPONIC CULTURE AND PEAT-VERMICULITE MEDIUM

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Abstract.--Root growth potential is the ability of seedlings to initiate and elongate roots when placed in a favorable environment. It is a valuable measure of physiological quality and is a good predictor of field performance. A simple apparatus using aerated water for the root growing medium can be inexpensively built for conducting evaluations at a nursery. However, this study shows that both the number and total length of new root production are less in hydroponic culture than in similar tests conducted in peat-vermiculite potting medium. Even so, the differences between the test methods are consistent enough that the hydroponic system gives meaningful results.

Additional keywords: (Pinus taeda).

INTRODUCTION

The morphological grades for southern pine nursery stock (Wakeley 1954) were developed after years of measuring the survival and growth of seedlings which had various morphological characteristics when they were planted. In general, the distinction between plantable and cull seedlings is substantiated by outplanting success. However, there are enough exceptions that Wakeley (1949) recommended the development and adoption of physiological grades which better reflect survival and growth potential. Since Wakeley's time, several methods have been developed to measure such physiological attributes as stress resistance, frost hardiness, and potential for new root growth. While no "black box" approach to assessing seedling quality is likely, measuring root growth potential (RGP) may be the single best test (Ritchie 1985). RGP is a measure of a seedling's readiness to produce new roots; relatively high RGP indicates better seedling quality than lower RGP.

The literature on RGP was thoroughly reviewed by Ritchie and Dunlap (1980). Their review highlighted several important aspects of RGP: a) it is seasonally cyclic and apparently dependent upon the dormancy status of the terminal bud; b) because it is related to dormancy, it indicates tolerance to desiccation and physical damage; and c) in tests with numerous species, including loblolly pine (Pinus taeda L.), **it** has shown good to strong correlations with field survival.

RGP is affected by many factors besides the dormancy cycle. RGP of loblolly pine varies between years and nurseries (Brissette and Ballenger 1984, Larsen and Boyer 1985), and with cultural practices and storage (Feret et al. 1984, 1985; Carlson 1985). RGP also varies with geographic seed

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source and family (Carlson 1985), and with seedling morphology (Brissette and Roberts 1984, Larsen and Boyer 1985, Carlson 1986). Because new root growth can he markedly affected by so many factors, it means that RGP testing is a reliable method of evaluating the effects of cultural practices, and for comparing seedling lots, or the same lot grown in different locations or in different years. This is important to the nursery manager because many of these factors--storage, for example--do not always result in apparent morphological differences.

In their review Ritchie and Dunlap (1980) point out that no standard method of conducting RGP tests, or of measuring the root growth response, has been adopted. This is because of the variety of facilities available to workers using RGP evaluations, the length of time needed for testing and the tediousness of measuring new root growth. Because tests are conducted differently and the results are measured differently, RGP is a relative value and should only be compared with other results obtained from the same procedure and facility.

In a subsequent paper, Ritchie (1985) described a soil-based RGP test useful for Pacific Northwest conifers and outlined several alternatives to reduce the time needed for the test or to simplify the techniques used and measurements taken. One alternative discussed is an aerated water system. The hydroponic system described has the advantages of: 1) avoiding potting, unpotting, and washing seedling root systems, 2) RGP is easier to measure because roots are clean, and 3) new root growth can be monitored during the test.

Although the hydroponic system has advantages over potting seedlings in sand or potting soil, water is not a natural medium for pine seedling root growth. Therefore, it is important to know how RGP compares in tests using both methods. The remainder of this paper has two purposes: 1) to describe a simple, inexpensive hydroponic apparatus for conducting RGP tests at a nursery, and 2) to compare the results of RGP tests conducted in both hydroponic culture and in peat-vermiculite potting medium.

MATERIALS AND METHODS

The hydroponic RGP apparatus

The use of aerated water for RGP testing is well documented (DeWald et al. 1985, Rose and Whiles 1985, Ritchie 1985). The system is simply a darkened container with seedlings suspended in an aerated water bath. Most such systems use tropical fish aquariums for the container. Because roots will not grow in the light, the glass sides of aquariums must be painted or covered with an opaque material.

The system described in this paper uses a much less expensive and unbreakable plastic utility pot for the container., The pots, costing less than $2.00 at a discount department store, are 30 cm (12 in) in diameter and 20 cm (8 in) deep. They come in various colors; the dark colors do not let light through. The top for the pot is 6.4 mm (1/4 in) thick plywood. Sheet fiberglass was laminated to the plywood to make it waterproof but polyurethane varnish would also be an effective sealer. Eighteen holes each 4.4 cm (1 3/4 in) are evenly spaced in the pot's top for the seedlings. The exposed plywood edges were sealed with silicone caulk. Styrofoam packing, 2.5 cm (1 in) thick, was cut with a 4.4 cm (1 3/4 in) hole saw to serve as the seedling holders. When cut in half across the diameter, the plugs firmly hold the seedling stem while fitting snuggly into the holes in the top. Two fish aquarium bubble stones are suspended in each pot to aerate the water. The bubble stones are connected to an air supply with plastic tubing. Holes are drilled to allow the tubing to pass through the top. Several such pots were made and for experiments each pot can serve as a replication.

The Seedlings

Loblolly pine seedlings of a bulked seed orchard lot of a Louisiana seed source were lifted from the W. W. Ashe Nursery in Southern Mississippi on December 17, 1984. Prior to the day they were lifted, the seedlings had received about 297 hours of chilling between 0 and 8°C (32-46°F). They were packed in K-P bags and kept in cold storage until the RGP tests were started on December 21.

Seedlings were assigned at random to either the hydroponic or media based tests. Seedling height, root collar diameter, and fresh weights were measured at the beginning of the RGP tests. Four hydroponic pots, each with 18 seedlings were used. The potting medium comparison consisted of 8 pots, each with 9 seedlings.

RGP Tests Conditions and Measurements

Some water splashed out of each hydroponic pot due to vigorous bubbling action. More water was added as needed to keep the level above the root system. The comparison test was conducted in 8 liter (2 gal) pots filled with a peat-vermiculite potting medium. Although not compared in this study, washed sand is also an excellent medium for RGP testing. The peat-vermiculite pots were watered during the test to maintain field capacity. No nutrients were added in either system. The test was conducted in a growth chamber with the temperature held constant at 20°C (68°F). A 16-hour photoperiod under fluorescent lights was used. The test period was 28 days. The chamber floor was flooded to keep the relative humidity above 60 percent. In this study, new roots greater than 1 cm in length were counted and their total lengths were measured.

Several statistical analyses were performed. The two RGP test methods were compared with t tests. Separate t tests were done for number and length of new roots based on pot averages. Linear regressions were run to determine the relationship between number and length of new roots after the RGP test period. The regressions used individual seedling data and were done separately for the hydroponic and peat-vermiculite RGP tests. Finally, simple correlation coefficients were determined to relate seedling morphology and RGP on an individual seedling basis.

RESULTS AND DISCUSSION

Both the average number of new roots and the average total length of new roots were significantly ($p=0.01$) greater in the peat-vermiculite medium than they were in the hydroponic system (table 1). The average number of new roots greater than 1 cm in length was 16.5 in peat-vermiculite, while in hydroponics it was 11.7. Average total length of those roots was 63.5 cm in potting medium and 42.9 cm in hydroponic culture. Comparing the two systems, hydroponics yielded 71% of the number of new roots in peat-vermiculite and 68% of the total length. RGP is quite variable among seedlings but test method had little effect on the coefficients of variation (CV). In hydroponics the number of new roots ranged from 2 to 32 with a CV of 51%. The total length of new roots ranged from 4 to 114 cm with a CV of 59%. In the potting medium, number ranged from 0 to 53 with a CV of 56%; length ranged from 0 to 197 cm with a CV of 58%.

Table 1.--Comparison of RGP of loblolly pine seedlings tested in hydroponic culture and peat-vermiculite potting medium

Test method	RGP: Number of new roots > 1 cm				RGP: Total Length of new roots > 1 cm			
	Max.	Min.	Mean	CV	Max.	Min.	Mean	CV
				-%-	--------cm--------			-%-
Hydroponic	32	2	11.7	51	114	4	42.9	59
Peat-vermiculite	53	0	16.5	56	197	0	63.5	58

RGP is a robust test and precise control of air temperature is not necessary for comparing relative differences in new root production or growth. The temperature of the rooting medium should be fairly constant, which could be achieved in a heated greenhouse or lighted room. A constant photoperiod is important if tests conducted in different times of the year are to be compared.

Counting the number of new roots and measuring their total length quantify both initiation and elongation of dormant root tips and thus provide the most complete picture of RGP. However, RGP can be quantified in a number of other faster, or simpler, ways. Root weight and volume increase have been used, and with electronic area-measuring equipment the increase in root surface area can be estimated. To speed the evaluation process an index based on a visual estimate can be used to describe RGP.

Root volume before and after RGP testing can be easily measured to determine the increase. Volume is measured by applying the Archimedes principle that an object's volume is equal to the weight of water it displaces. By dipping the root system into a vessel of water standing on a top-loading balance, its volume (in milliliters or cubic centimeters) is indicated by the increase in weight measured in grams. The slight error in this volume to weight relationship that may be caused by differences due to variation in room temperature is negligible and can be ignored. Burdett (1979b) tested this method using lodgepole pine (P. contorta Dougl. ex Loud.) and found it to be highly reproducible. He cautioned, however, that accuracy depends on dipping to the same point (root collar) each time and that the surface must not have free water clinging to it. Also, since this method requires measurement before and after the RGP growth period, it may require more time than one measurement at the end of the test period. Burdett (1979a) also evaluated an index of RGP where 0 = no new roots and 5 = more than 30 new roots over 1 cm in length with corresponding levels in between. The index method is faster but is not as reproducible as more precise methods that count number or measure length or volume increase of new roots.

The seedlings used in this study averaged 23 cm (9.1 in) tall (they were top pruned), 4.6 mm (3/16 in) in diameter, and had a fresh weight of 11.9 g (.42 oz). There were small but significant (p=0.05) correlation coefficients between seedling morphological characteristics and RGP (table 2). In the hydroponic system, the number of new roots was correlated (r=0.24) with seedling fresh weight. In the potting medium, there were significant correlations between the number of new roots and both fresh weight (r=0.27) and diameter (r=0.29). There were no significant correlations between the total length of new roots and the characteristics measured.

Table 2.--Correlation coefficients between RGP and morphological characteristics of loblolly pine seedlings tested by 2 methods

	Hydroponic (n=72)		Peat-vermiculite (n=72)	
	number	length (cm)	number	length (cm)
Height	.15	.10	.12	.15
Diameter	.20	.10	.29*	.12
Fresh weight	.24* [a]	.22	.27*	.19

[a] Critical value (p=0.05, df=70) = 0.232.

A very strong, highly significant (p=0.01) relationship was found between the number of new roots and the length of new roots under either RGP test method (figure 1). With 72 seedlings evaluated by each method, linear regressions had r^2 values of 0.76 and 0.80 for the hydroponic and peat-vermiculite test methods respectively. This relationship is important because it shows that the number of new roots alone is probably a very good predictor of RGP. Counting roots is easier, faster, and less error-prone than measuring root lengths. Also, it is better related to seedling morphology, which should be of great interest to the nursery manager.

In this study, hydroponic culture yielded lower RGP than did the peat-vermiculite medium. However, the difference was consistent among the replications and the relationship between root number and length was almost identical for both test methods (figure 1). Therefore, this study indicates that under the conditions imposed, the hydroponic method of RGP testing had a consistent comparability to soil-based testing. Therefore, for the nursery manager, the hydroponic system represents a less labor-intensive alternative of conducting meaningful physiological tests of seedlings.

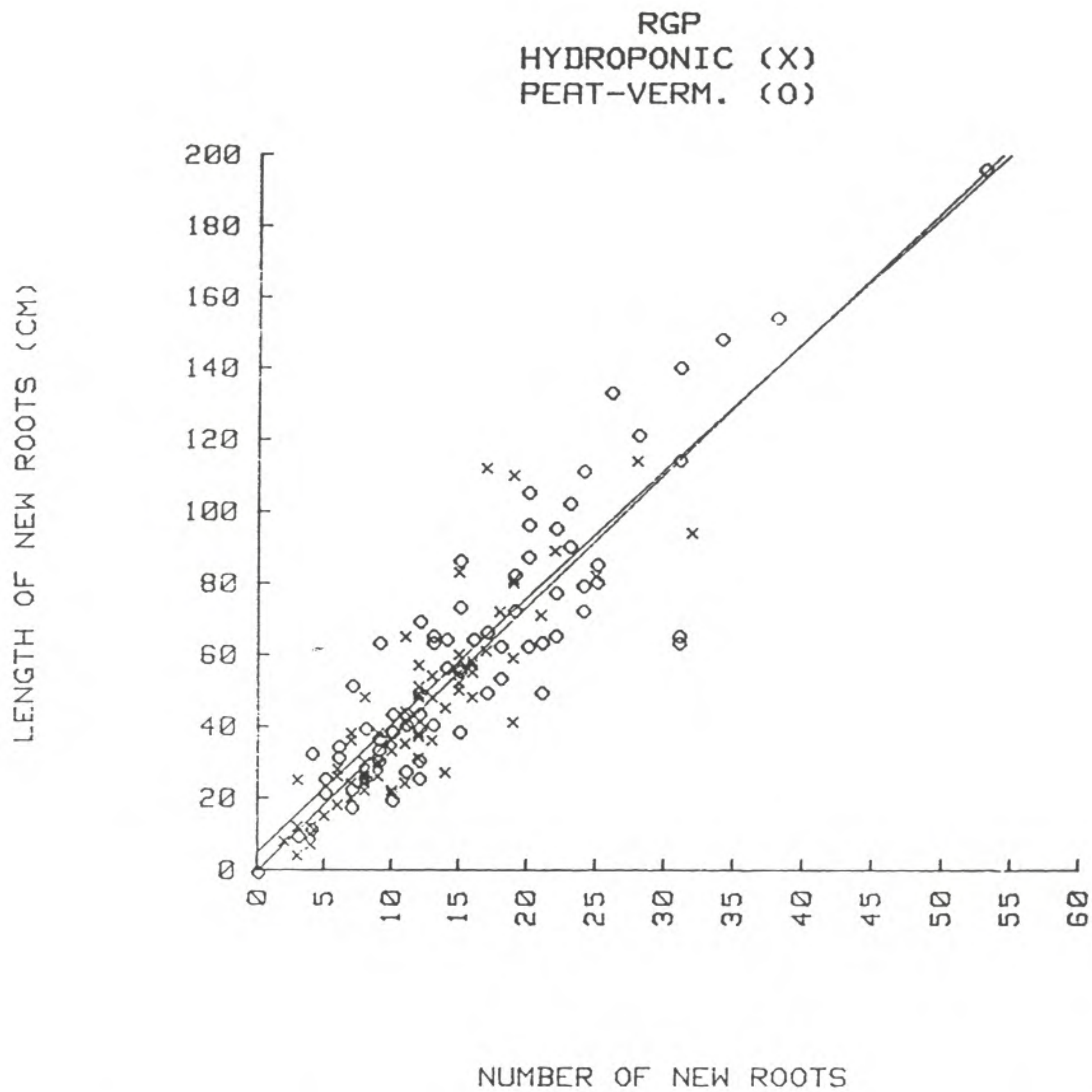

Figure 1.--Relationship between the number of new roots greater than 1 cm and total length of new roots greater than 1 cm under both hydroponic and potting medium RGP tests. Hydroponic culture $r^2 = 0.76$, peat-vermiculite $r^2 = 0.80$.

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