ROOT GROWTH POTENTIAL - ONE TOOL FOR MEASURING LOBLOLLY PINE SEEDLING QUALITY

Peter P. Feret, Richard E. Kreh and Laura E. DeWald 1/

INTRODUCTION

Root growth potential (RGP) of West Coast species has been extensively studied for several decades and appears to be a very useful tool for measuring seedling quality in ponderosa pine (*Pinus ponderosa* Laws), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.), and other species (Jenkinson and Nelson 1983, Ritchie and Dunlap 1980, Brissette and Roberts 1984). At Virginia Tech we have been studying RGP of loblolly pine (*Pinus taeda* L.) since 1981 to determine the efficacy of RGP measurements as:

1. a way of measuring seedling physiological condition and

2. a predictor of field performance.

As we continue to gather data on RGP of loblolly pine seedlings we are finding that seedling RGP is sensitive to factors known to affect seedling growth and development and that RGP varies directly with the apparent physiological condition of the seedling at the time of assessment. With considerable research effort, seedling RGP could become a dependable measure of the effectiveness of nursery management and seedling handling practices which produce the physiological condition in a seedling needed for good early field performance.

PREVIOUS WORK AND PRESENT OUTLOOK

RGP has been defined as the physiological readiness of a seedling to rapidly produce new roots and thereby re-establish intimate contact with the soil. RGP may be measured by determining the number or length of new roots produced by a seedling in a controlled environment after a specified period of growth. We use two greenhouse systems for measuring RGP. One system consists of water baths maintained at 20° C into which are placed acrylic trays, each containing 15 seedlings planted in Promix®. Seedlings are allowed to grow for 24 days (16-hour photoperiod), then excavated and new roots counted and measured. The second system is similar to the above but seedlings are grown hydroponically in the greenhouse for 15 or 24 days.

Since 1981 we have conducted RGP analysis on several thousand seedlings and continue to monitor the field performance of many samples for which we have RGP data. From these data (Feret, unpublished data) we have begun formulating hypotheses about how RGP is affected by various factors and how RGP correlates with field performance. The data collected to date supports the following statements about RGP as an indicator of physiological condition of seedlings:

Associate Professor, Research Associate, and Graduate Research Assistant, respectively, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. We gratefully acknowledge the cooperation of T. A. Dierauf and his colleagues for providing seedlings used in this study. Without their support much of our research would not have been possible.

1. RGP is significantly diminished in seedlings which have been intentionally desiccated or improperly stored.

2. RGP is significantly affected by several nursery practices including nitrogen fertilization, top clipping, organic matter, soil amendments, and undercutting during the growing season.

3. RGP varies significantly between nurseries and between nursery beds within nurseries.

4. RGP varies over the lifting season within any one nursery.

5. Storage of seedlings can significantly alter RGP, both positively and negatively.

6. RGP is under relatively strong genetic control.

7. Seedling size may or may not affect RGP; correlations between seedling size and RGP may be treatment specific or spurious, if they exist at all.

Perhaps the most important conclusion to be drawn from our data is that nearly everything we have investigated has produced significant variation in RGP with the exception of a study showing no differences between hand and machine lifting at the VDF nursery. That there is exceptional variation in RGP may cause some to dismiss RGP as too unpredictable to be of any use. However, the fact that so many factors affect RGP underlines its potential as a general tool for measuring the physiological condition of seedlings.

In summary, our data suggests RGP is very sensitive to factors which are known to affect the physiological condition of a seedling. Relative RGP differences among various treatments remain the same over a range of greenhouse and laboratory environments. But because absolute measures of RGP are sensitive to many factors, RGP can be compared over time only if a consistent, tightly controlled RGP analysis system is used.

From data collected to date we have formulated the following working hypotheses regarding RGP and field performance in Virginia:

Ho 1: RGP of <u>spring planted</u> seedlings is correlated with first- and second-year field performance as measured by: spring vigor, seedling survival, and seedling height growth increment.

Ho 2: RGP at planting time of <u>fall and winter planted seedlings</u> is not correlated with early field performance.

Ho 3: For <u>fall and winter planted seedlings</u> RGP at the start of the (root) growing season is correlated with field performance.

Ho 4: Spring planted seedlings with no root growth potential can survive but their probability of surviving and growing well in any given year on any given site is less than that for seedlings with an RGP >0.

Ho 5: Field performance and RGP relationships are most likely found under high-stress field conditions.

These hypotheses are all supported by data currently being prepared by us for publication. However, we have no data sufficiently replicated over time allowing us to accept these hypotheses without condition. Our assessment of the present outlook for RGP as a research tool is extremely optimistic, but because of the many factors and interactions affecting RGP, a major research effort is needed before a holestic model can be developed to use RGP to predict field performance.

AN EXAMPLE OF RGP AS AFFECTED BY NURSERY CULTURAL TREATMENTS

To illustrate how RGP can be modified by nursery techniques, presented here are the results of RGP tests on seedlings from an experiment conducted by T. A. Dierauf and his colleagues at the Virginia Division of Forestry New Kent nursery.

Materials and Methods

Seedlings were hand lifted December 15, 1983, stored at 4° C until analyzed for RGP. On December 20, seedlings were placed into the hydroponic system and left to grow for 24 days. RGP was measured by counting the number of new roots >0.5 cm in length. Dry weights of seedling roots and shoots were also measured.

Treatments analyzed included three organic matter (OM) supplements [0.5" (1.27 cm), 1" (2.54 cm), 1.5" (3.81 cm) sawdust rotovated into the beds prior to seeding], nitrogen (N) applied at operational and 2X operational levels (ca. 185 kg/ha and ca. 370 kg/ha, respectively), and topclipping (Level 1) and no topclipping (Level 2). The study included five replicate beds and within each replicate each treatment combination was analyzed using six seedlings. Thus, a total of 30 seedlings/treatment combination was used.

Data analysis was accomplished using chi square analysis and Duncan's multiple range test to separate treatment differences. Chi square analysis was made of seedlings grouped into three categories according to the number of new roots recorded. Seedlings with 0-5 new roots were classed as "poor" (P), 6-10 new roots as "good" (G), and ≥11 new roots "excellent" (E).

Results

Chi square analysis (Table 1) of categorized seedlings showed significant main effects and no treatment interactions (confirmed with ANOVA). Therefore, results are presented by considering main effects only.

Table 1. Results of chi square independence test, by treatment and treatment combination, for seedling root growth potential (number of new roots/seedling). Analysis conducted on seedlings categorized into three groups: P = 0-5, G = 6-10, E ≥11 new roots/seedling.

Source	df	λ^2	P
Intercept	2	8.04	0.02
Organic matter (OM)	4	11.28	0.02
Nitrogen (N)	2	12.73	0.01
Clipping (P)	2	14.02	0.01
OM x N	4	3.24	0.52
OM x P	4	2.97	0.56
N x P	2	0.27	0.87
Residual	4	0.42	0.98

Organic Matter. Figure 1 illustrates the changes in frequency distribution for RGP at the three OM levels. In this case, increasing OM increased the relative frequency of "poor" seedlings. As shown in Figure 2, OM level] (operational levels of sawdust at 0.5") produced seedlings with the largest number of new roots, with levels 2 and 3 showing progressively smaller numbers of new roots. Expressed as number of new roots/gm shoot (a measure of the ability of new roots to support the shoot), no significant differences were found among treatments but the same trend was observed: OM supplements diminished RGP.

Nitrogen. 2X operational levels of nitrogen enhanced RGP. The distribution of seedlings changed significantly (Figure 3), from one with approximately 50% seedlings "good" and "excellent" to one with approximately 67% "good" and "excellent." When RGP was expressed in absolute number of new roots and as number of new roots/gm top dry weight, RGP was enhanced approximately 35% and 30%, respectively, by 2X N applications (Figure 4).

Top Clipping. Top clipping had a significant negatve impact on RGP when RGP was expressed as categorized seedlings (Figure 5) and as number of new roots/seedling (Figure 6). Top clipping significantly increased the relative number of "poor" seedlings (Figure 5). However, because of diminished top (try weight of top clipped seedlings, no difference in number of new roots/gm top (try weight was observed (Figure 6).

Discussion

Results of RGP analysis on these December-lifted seedlings show significant physiological effects of treatments on ability of seedlings to regenerate new roots at lifting. Because increasing OM levels depressed RGP, and increasing N levels enhanced RGP, it may be that all treatments in this study received insufficient nitrogen (insufficient in terms of maximizing RGP). Our unpublished data of a prior experiment indicated RGP is enhanced by increased OM levels and N levels, but that an interaction between N and OM was present, making excessive application of N detrimental to RGP at low OM levels. Clearly, more research is needed to understand how OM and N affect RGP.

RGP was modified by top clipping, but since roots/gm top dry weight was not significantly altered, top clipping does not seem to alter the ability of new roots to support the shoot. In Virginia, top clipping is known to have significant and advantageous, or neutral, effects on subsequent loblolly pine seedling survival (Dierauf, personal communication; Dierauf and Garner 1980). RGP measured in December does riot seem to be reflecting an effect, suggesting if top clipping is significantly advantageous it is affecting seedlings in a way independent of RGP. But, again, more research is needed to understand these interrelationships.

These data may or may not reflect the ability of seedlings from the various treatments to survive and grow when field planted. These seedlings were lifted and planted in mid-December. Subsequent intervening effects of winter moisture availability, soil and air temperature after planting, etc. and nursery treatment x site interactions effective prior to the start of the growing season, may be relatively more important than RGP at the time of planting (December). Thus, from these data we can conclude that nursery treatments significantly altered seedling physiology (as measured by RGP) but at the present time how winter RGP alterations relate to spring and summer field performance is not known.

We propose the model depicted in Figure 7. The model shows the factors affecting root growth potential in the nursery beds, factors which may impact RGP between lifting and the planting site, and factors expected to impact RGP of seedlings between the time of planting and the start of the growing season. All factors affecting RGP can be considered as having both positive and negative effects.

We propose that if seedlings are lifted when planting site soil is sufficiently warm to allow new root growth, and none of the proposed factors between A and C come into play (i.e., immediate planting), then RGP will be correlated with performance (A with D); correlations should be enhanced by stressful site conditions after planting. When factors depicted in the model between A and C come into play, the correlation between RGP at lifting and field performance may be modified in ways not predictable at the current state of knowledge. In any case, correlations between C and D should be positive at all times as long as the minimum RGP values represented in C fall below the minimum RGP required for a seedling sample lot to reach 100% survival and 100% of its potential height growth increment.

We are currently in a research phase of developing RGP tests as a way of quantifying seedling quality. With additional research, the potential of RGP as a tool for the nurseryman and regeneration forester should be great.

LITERATURE CITED

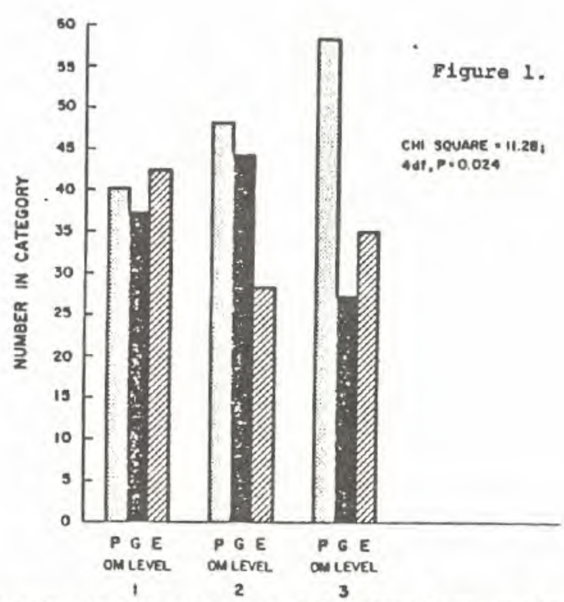
Brissette, J. C. and T. C. Roberts. 1984. Seedling size and lifting date effects on root growth potential of loblolly pine from two Arkansas nurseries. Tree Planters Notes 35:34-38.

Dierauf, T. A. and J. W. Garner. 1980. Results of root wrenching in a sandy nursery soil. Occ. Rpt. 55, Virginia Div. of Forestry. 3 pp.

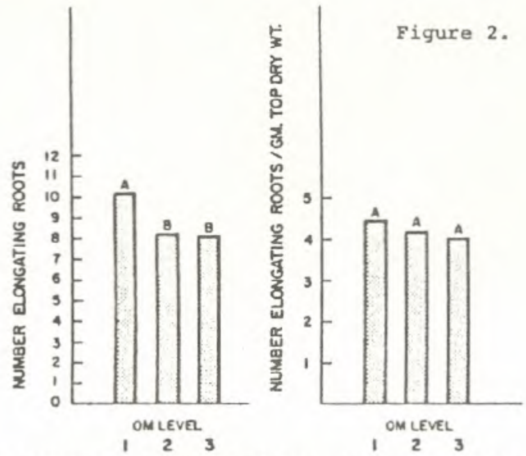
Jenkinson, J. L. and J. A. Nelson. 1983. 1-0 Douglas-fir: a bare-root planting option. In: Proc. Western Forest Nursery Council Western Nurserymen's Conference. p. 63-76. Southern Oreg. Regional Services Inst., Southern Oreg. State College, Ashland.

__________. 1978. Seed source lifting windows for Douglas-fir in the Humbolt Nursery. In: Proc. Western Forest Nursery Council and Seed Processing Workshop. p. B77-95. Pac. S. W. Reg., Forest Service, U.S.D.A. San Francisco, CA.

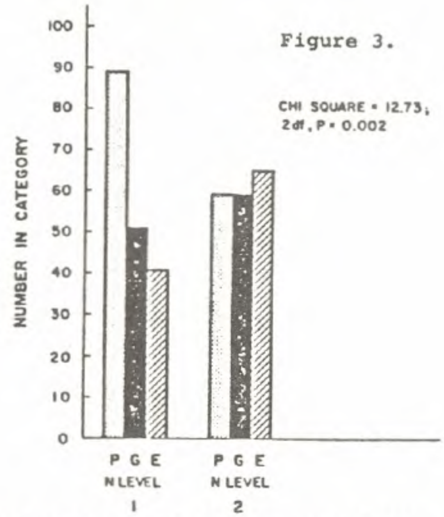
Ritchie, G. A. and J. R. Dunlap. 1980. Root growth potential: its development and expression in forest tree seedlings. N. Z. J. For. Sci. 10:18-248.



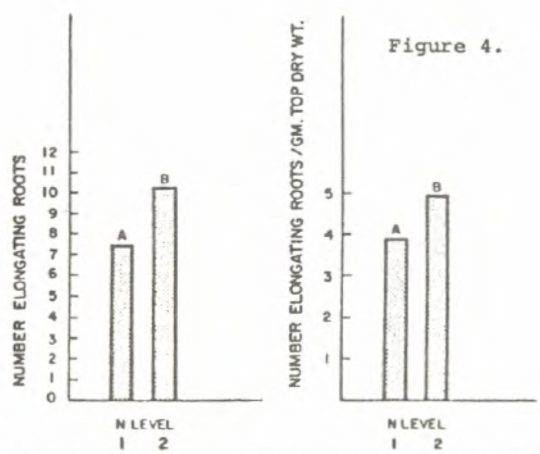
Number of seedlings in each category as a function of organic matter (sawdust) supplements (OM level 1 = 0.5", 2 = 1", 3 = 1.5"). P = poor, number of new roots 0-5; G = good, number of new roots 6-10; E = excellent, number of new roots ≥11. Sample size for each OM level = 120 seedlings.



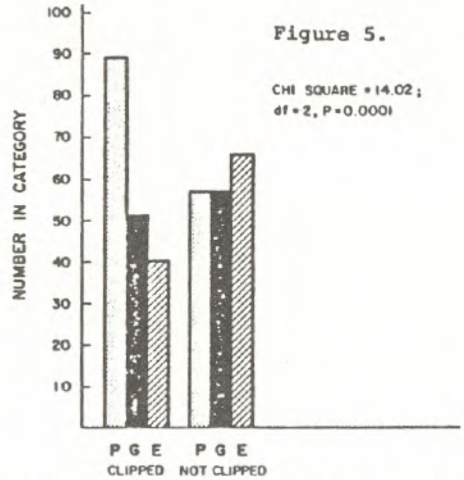
Number of elongating roots and number of elongating roots/gm top dry weight for each organic matter (OM) treatment. OM level 1 = 0.5", 2 = 1", 3 = 1.5". Sample size for each OM level = 120 seedlings.



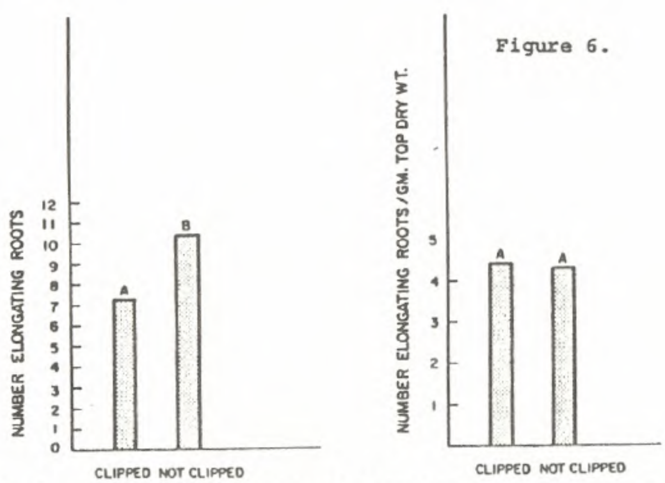
Number of seedlings in each category as a function of nitrogen fertilization. N = 1 = 185 kg/ha; 2 = 370 kg/ha. P = poor, number of new roots 0-5; G = good, number new roots 6-10; E = excellent, number of new roots ≥11. Sample size for each N level = 180 seedlings.



Number of elongating roots and number of elongating roots/gm top dry weight for each nitrogen level. N = 1 = 185 kg/ha; 2 = 370 kg/ha. Sample size for each N level = 180 seedlings.



Number of seedlings in each category as a function of top clipping. P = poor, number of new roots 0-5; G = good, number of new roots 6-10; E = excellent, number of new roots ≥11. Sample size for each treatment = 180 seedlings.



Number of elongating roots and number of elongating roots/gm top dry weight for top clipped and unclipped seedlings. Sample size for each treatment = 180 seedlings.

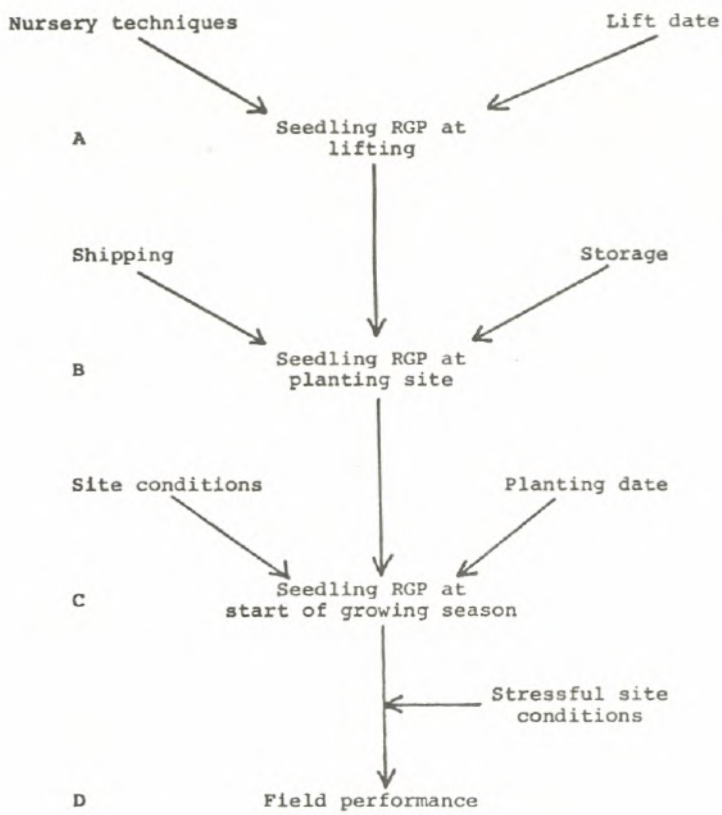


Figure 7. Simplified model depicting the relationship between RGP at the nursery when seedlings are lifted and factors of potential importance affecting RGP from the nursery to the start of the growing season.