Seedling height growth: a monitoring technique in nursery soil management

Keith M. McClain *Research scientist. Ministry of Natural Resources. Thunder Bay. Ontario. Canada.*

Introduction

During the past two decades nursery soil management in Ontario's forest tree nurseries has become more sophisticated. To date, however, a convenient, nondestructive and practical technique has not been available that would enable nurserymen to monitor the growth and development of their stock. The purpose of such a technique would be twofold: first, to ensure that seedlings in production are developing to the desired size and quality when shipped; and second, to assess the relative effectiveness of current amendment programs such as irrigation and fertilization.

Height is a parameter of seedling growth which is one of the easiest to measure nondestructively. It can be measured accurately and with simple equipment. Also, conifer seedlings of most species show a more or less continuous ability to increase in height during their first growing season if temperature. moisture supply, and fertility are not limiting. Further, although by no means the only measure of seedling size, height is nevertheless a prime attribute in any nurseryman's evaluation of stock.

It is generally known that variations in certain environmental factors may be reflected in seedling size. Armson *(1)* states that the ultimate size of a seedling depends on two things: the rate of growth, and the duration of the growing period. This relationship has been utilized in developing a quantitative expression for monitoring height.

Two basic assumptions are made. First, the nurserymen must decide on the ultimate height that he desires his seedlings at the end of the growing season. Realistically, this must he based on his previous experience. but it does not mean that it need be uniform for a species or age class. For example, it is usual to have smaller stock to be used for transplanting at the end of a growing period than would be desirable for field outplanting. The second assumption is that once the ultimate height at the end of the growing season is established, an estimate (in weeks) must be made of the total length of the growing period. A mean weekly rate of height growth (h_m) can then be calculated. It is this value against which the current weekly means are compared. This assumed linearity, although not representative of height growth progression, does not necessarily invalidate its use.

The Relative Weekly Growth Percentage can then be expressed as:

$$\mathrm{RWGP} = \frac{(H_t - H_{t-1}) - h_m}{h_m} \times 100$$

$$\text{or} \quad = \frac{h_c - h_m}{h_m} \times 100$$

where (H_t - H_t-1) = h_c (current weekly height increment), h_t and ^{h}t-1 represent total seedling height at weeks t and t-1 respectively and h_m is the mean weekly height increment calculated as h(m) = H/N f where H(f) the total (assumed) desired final height, and N is the total growing period in weeks.

General Case

The practicality of the RWGP can be demonstrated by the following example: It has been stated that two parameters must be quantified with some degree of accuracy before its (RWGP) calculation; that is, the desired height of seedlings, and the length of the effective growing period. If, for example. the growth period for height is normally 9 weeks and the desired seedling height is 7.2 cm, the mean weekly height growth rate should be 0.8 cm per week for 9 weeks to produce such a seedling.

This assumed and idealized pattern of growth would be represented by a straight line cumulative growth curve and relative weekly growth percentages of zero for each weekly interval throughout the growing period (fig. 1). However, height growth rarely occurs at a constant rate, it fluctuates. For illustrative purposes only, figure 1 shows three artificial cumulative height growth curves and their corresponding relative weekly growth percentage charts. Each curve in-

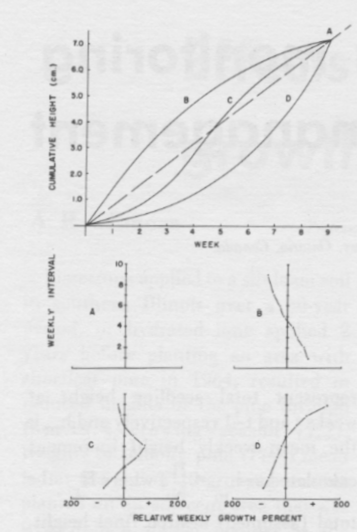

Figure 1.—Hypothetical cumulative height growth curves and corresponding relative weekly growth percentage charts.

itiates at 0 and converges at a seedling height of 7.2 cm at 9 weeks. Despite pattern differences, mean weekly growth rates are similar; that is, 0.8 cm per week (table 1). When the RWGP's are calculated for each curve, distinctly different patterns arise, but yet the final size of the seedlings are graphically identical.

Specific Example

To further illustrate the usefulness of relative weekly growth percentages in monitoring the growth of nursery seedlings, weekly growth percentage charts were constructed for three conifer seedling species grown under greenhouse conditions (2). This experiment lent itself very well for illustrative purposes in that the three species, jack pine *(Pines banksiana* Lamb.), black spruce *(Picea mariana* (Mill.) B.S.P.), and white spruce *(Picea glauca* (Moench) Voss.) were grown subject to twelve treatment combinations of moisture and fertility (three regimes of moisture and four levels of fertility), replicated twice. The experiment ran for 15 weeks with height increments of each seedling per species (720 in total) recorded on a weekly basis for 12 weeks beginning at week three, the termination of the initial germination and establishment phase.

The raw height data, that is, the mean weekly values for each treatment combination were fitted into the RWGP formula and charts constructed for jack pine. black spruce, and white spruce (figs. 2, 3 and 4).

It should be noted here that one difference exists between the propos

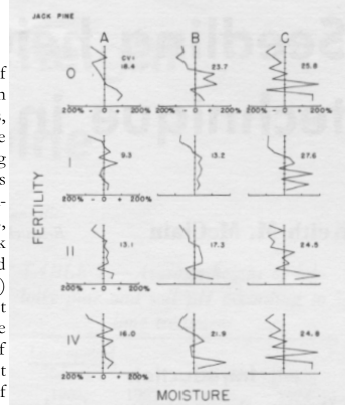

Figure 2.—Relative weekly growth percentage charts for jack pine at twelve treatment combinations of moisture (A>B>C) and fertility (O<I<II<IV). Note: Inserted numbers represent the coefficient of variation.

ed method for calculation of RWGP and the method used for the plotting of figures 2, 3, and 4: the latter was done in retrospect. In other words, a weekly growth rate was not assumed but was calculated by summing all the weekly rates for each species and dividing by 11, the number of weekly intervals. This calculation gave the assessed variation in terms of treatment, effect, and sensitivity of the method to varying cultural treatments.

Figures 2, 3, and 4 illustrate that weekly height growth was variable about the mean weekly growth rate amongst species and also moisture and fertility. The trend most obviously followed by seedlings of all treatments is one occurring between the theoretical curve A and curve B (fig. 1). Treatments which favor almost equal weekly growth are reflected by a relative weekly growth percentage chart similar to chart A (fig. 1). This trend of near-equal weekly growth is exhibited in jack pine (fig. 2), in treatments A x I, A x 11. B x I, and B x 11 and in black and

TABLE 1.—Weekly growth rates (WGR) and relative weekly growth percentages (RWGP) for hypothetical growth curves

	Curve							
	a		b		c		d	
Week	WGR cm/wk	RWGP %	WGR cm/wk	RWGP %	WGR cm/wk	RWGP %	WGR cm/wk	RWGP %
1	0.8	0	1.4	75	0.2	−75	0.1	−87
2	0.8	0	1.3	62	0.5	−37	0.3	−62
3	0.8	0	1.2	37	0.8	0	0.4	−50
4	0.8	0	1.0	25	1.2	50	0.5	−37
5	0.8	0	0.7	−12	1.4	75	0.7	−12
6	0.8	0	0.6	−25	1.1	37	0.8	0
7	0.8	0	0.4	−50	0.8	0	1.1	37
8	0.8	0	0.3	−63	0.7	−12	1.3	75
9	0.8	0	0.3	−63	0.6	−25	2.0	150
Mean	0.8	—	0.8	—	0.8	—	0.8	—

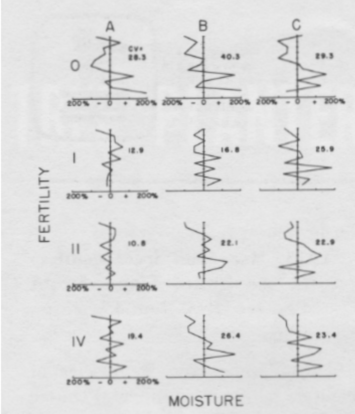

Figure 3.—Relative weekly growth percentage charts for black spruce at twelve treatment combinations of moisture (A>B>C) and fertility (O<I<II<IV). Note: Inserted numbers represent the coefficient of variation.

white spruce in treatments A x I and AxII.

Unfavorable treatments promoted rapid initial seedling growth followed by a decreasing rate of growth. This growth pattern closely approaches the hypothetical curve B (fig. 1). Seedlings subject to unfavorable treatments exhibited a rapid hypocotyl extension followed by a decreasing and often fluctuating weekly growth rate.

The degree to which seedling growth rates were affected by treatment is reflected in the wide erratic variation about the mean growth rate (0.0 percent on the relative weekly growth percentage chart), particularly in the C moisture regime at all four fertility levels. Coefficient of variations (CV) were calculated for each treatment combination and thus provided a basis for comparing growth percentage charts as to how representative the RWGP's are in reflecting weekly height growth variation (h_c - h_m) about the mean growth rate (h_m). Growth percentage charts which possess a low coefficient of variation (relative to other values) indicate that weekly growth rates varied less about the mean during the growing period than in treatments with higher coefficient of variation values. It is not surprising to find that lower CV values extend into the B (moderately moist) moisture regime and intermediate fertility levels for jack pine but not for the spruces. This has important management implications when considering soil management techniques for jack pine (with large root area) and black and white spruce (with small root area).

presented to aid in developing the relative weekly growth percentage exhibited growth percentage charts different from those of the specific example, but this was due to the manner in which the mean weekly growth rate was calculated; this did not, however, invalidate the use of the specific example.

Inasmuch as height growth patterns of young nursery grown seedlings are distinct under a given level of nursery soil management, they can be utilized to monitor numerically or graphically, seedling stock growth. Interpretative monitoring necessitates knowing the characteristic height growth pattern for a species under a given set of management practices. Thus, when weekly growth increments are recorded and relative weekly growth percentages are calculated, divergence from the normally desired growth pattern can be detected. Divergence would suggest an anomaly in nursery soil management. Corrective measures would then be initiated to realign the growth progression to that desired. It should be kept in mind, however, that all cultural treatments plus uncontrollable factors interact to affect seedling growth. The degree to which the controllable factors are varied to modify growth patterns may first have to be implemented on a trial-and-error basis, then refined through experience and observation.

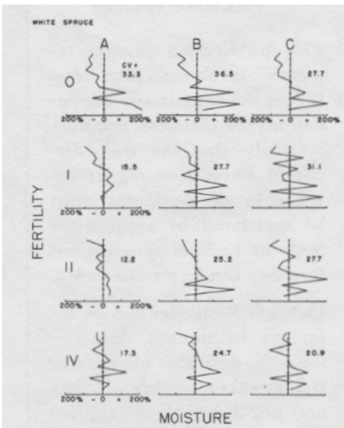

Figure 4.—Relative weekly growth percentage charts for white spruce at twelve treatment combinations of moisture (A>B>C) and fertility (O<I<II<IV). Note: Inserted numbers represent the coefficient of variation.

Discussion

From height growth data of three species of conifer seedlings which were each grown at three regimes of soil moisture and four levels of fertility, relative weekly growth percentages were calculated and shown to reflect variable cumulative height growth patterns caused by treatment interaction (figs. 2,3, and 4). The general case (fig. 1) which was

Literature Cited

1. Armson, K. A.
1965. Seedling growth. In Proceedings of Nursery Soil Improvement Sessions. State University, College of Forestry, Syracuse University.

2. McClain, K. M.
1973. Growth responses of some conifer seedlings to regimes of soil moisture and fertility under greenhouse and field nursery conditions. MScF thesis. Faculty of Forestry, University of Toronto. Ontario. Canada.