Managing Crop Uniformity in Weyerhaeuser Nurseries

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Abstract

The primary goal during the culture of the 1+1 crop at Weyerhaeuser's nurseries is to achieve seedlings that uniformly meet target specifications. Target specifications are based on a combination of morphological and physiological characteristics that improve outplanting performance. Morphological attributes include height, stem diameter, root volume, root fibrosity, root-to-shoot ratio, shoot and root form, and bud development. Physiological attributes include foliar nutrition, water potential, and pathogen load. Other tests which indirectly measure physiology include cold hardiness, root growth potential, and dormancy status. The nursery staff uses these various seedling attributes to create crop development curves for the first and second years of 1+1 culture. They also use in-house research and information from the literature to choose those nursery cultural practices that ensure 1+1 crops follow the target growth trajectory. This results in anticipation of important cultural decisions, choice of the optimal treatment, and, ultimately, the ability to cost-effectively grow and ship a uniform crop that meets the expected targets.

Key Words

Nursery culture, target seedling, bareroot, 1+1 seedling, *Pseudotsuga menziesii*

Introduction

At Weyerhaeuser Company, Douglas-fir bareroot transplants (1+1) are the principle stocktype used for regenerating newly harvested sites in Washington and Oregon. All 1+1 seedlings are grown by the company at 4 Weyerhaeuser nursery facilities: Mima, Aurora, Turner, and Medford. Mima nursery, the largest facility, is located about 12 miles south of Olympia, Washington. Since Mima supplies about half of the 1+1 seedlings planted on company lands, and the authors are most familiar with this facility, much of the following information comes from Mima nursery.

The primary goal for any nursery is to grow a seedling crop where most seedlings reach some predetermined target specification. The most cost effective means of achieving this goal is to maximize yields through careful planning and intelligent choice of cultural practices. This then minimizes the numbers of seedlings that are discarded at pack. While yield is a significant economic driver for the nursery business, it is not necessarily considered the "bottom line" at Weyerhaeuser. Since the Weyerhaeuser nurseries grow seedlings for internal customers, there is considerable focus on through-the-system seedling quality. In other words, the nurseries are continually looking for opportunities to improve seedling field performance and thereby significantly increase the company's return on investment and improve the quality of stock for all customers.

At all the nursery facilities, 1+1 seedlings are cultured such that they uniformly meet a combination of morphological and physiological target specifications, or, as defined by Ritchie (1984a), material and performance targets. The morphological, or material, targets can be directly measured and include height, caliper, root volume (or mass), root fibrosity, root-to-shoot ratio, shoot and root form, and bud development. Physiological targets, such as foliar nutrition, water potential, and root pathogen load, would also be considered material attributes. However, cold hardiness conditioning, root growth potential, and dormancy status are performance attributes because they are indirect measures that integrate a variety of morphological and physiological elements of a seedling.

Many studies have shown that the aforementioned material targets have a significant effect on field survival and growth. Moreover, the tests of seedling performance have proven to be reliable descriptors of seedling quality. It is obvious that considering all attributes together would provide a more realistic measure of potential for field performance, but it is not clear how to combine all measures into one index.

For many years, considerable research effort focused on understanding how season, environmental conditions, and cultural practices affected material and performance attributes of bareroot seedlings. Weyerhaeuser nurseries have drawn very heavily upon this information to develop best practices. In addition, the nursery business had a seedling testing group that intensively measured seedling characteristics at the end of the growing season and throughout winter. Results communicated to the nurseries guided lifting and packing decisions. Communications to the customers included a description of seedling quality and recommendations for storage duration and handling practices.

Today, the nursery staff is much reduced. Even within 1 nursery such as Mima, it is impractical to evaluate the morphology and physiology of 20 million seedlings from multiple seed lots and families grown in several nursery blocks. Instead, the traits of interest are used to establish a final seedling target that is achieved by describing a target growth trajectory and then using best practices to keep the crop on this trajectory. This approach requires a detailed understanding of seedling development and considerable information regarding the impact of various cultural practices. Obviously targets and best practices change as new technologies are introduced but it is the expectation that this system can be continually improved.

Definition of Target Seedling Specifications and the Target Growth Curve

Height and stem diameter are the primary descriptors for the target Douglas-fir 1+1 seedling at Mima and other nurseries. Height and stem diameter are easily measured and, although there are some contradictory results (Thompson 1984), most studies show that both are positively related to field performance. For example, Newton and others (1993) showed that taller Douglas-fir seedlings exhibited enhanced growth and over-topped the competing vegetation. Long and Carrier (1993) found increased stem diameter of 2+0 Douglas-fir had a significant effect on tree height at age 5 years. In addition, 2-year survival and height of Douglas-fir rooted cuttings, 2+0 seedlings, and 1+1 transplants were strongly related to stem diameter at time of planting (Ritchie and others 1993).

Average expected height and stem diameter of 1+1 seedlings are constrained by environmental conditions and current operational practices at Mima nursery. However, the actual height and stem diameter targets used by the nursery do not reflect the natural variation in seedling morphology. Instead, they are market driven and based on customer demands. Therefore, to remain competitive, the nursery staff must develop a cultural plan which combines transplant date, years from fumigation, growing density, grading, and other treatments to achieve a uniform 1+1 seedling population that meets target specifications.

A relatively intensive sampling plan is used to track height growth during the first year and height and stem diameter growth during the second year of 1+1 culture. Trees are measured on a predetermined schedule and the data are immediately processed and compared to growth in previous years. The results show if the crop is growing at a rate which will produce the target seedling height and stem diameter or if proactive measures are required to accelerate or slow growth. Most importantly, continually tracking the progression of the crop allows a timely decision to begin dormancy induction treatments that will stop shoot growth and allow seedling tissues to mature.

Target height and stem diameter curves show the very different growth rates over the season. For example, cool air and soil temperatures limit first year seedling growth at Mima nursery for some weeks following germination. However, as summer temperatures began to increase, there is a distinct shift to a phase of rapid shoot elongation. This latter phase continues until the beginning of dormancy induction treatments in late summer (table 1). The development of the 1+1 crop is very similar. For the first few weeks following spring bud flush, shoot elongation is relatively slow. Then, about the same time that the first year seedlings are beginning rapid growth, the 1+1 seedlings start a second flush, and they, too, begin to grow rapidly (table 2).

A description of the target 1+1 seedling at Mima nursery includes other morphological attributes such as root volume (or mass), root fibrosity, root-to-shoot ratio, shoot and root form, and bud development. Unlike height and stem diameter, these measures are only occasionally used for crop tracking. They are

Table 1. Approximate timing of shoot developmental stages and nursery cultural activities during the first year of the 1+1 crop at Mima Nursery.

Date	Stage Shoot Growth	Nursery Activities
Aug - Sep		- Fumigation
Sep - Mar		- Orders received - Planning
Feb - Mar		- Seed stratified and treated
Apr		- Pre-plant fertilization - Soil preparation - Sow - Herbicide treatments - Irrigation
May	Germination Lag Phase	- Fertilization
Jun		-Fungicide treatments
Jul	Rapid Growth Phase	
Aug		- Shutdown treatments and root culture
Sep	Reduced growth	
Oct	Growth cessation and dormancy	
Nov		
Dec		- Lifting, grading, packing - Freezer Storage
Jan		
Feb		
Mar		

Table 2. Approximate timing of shoot developmental stages and nursery cultural activities during the second year of the 1+1 crop at Mima Nursery.

Date	Stage Shoot Growth	Nursery Activities
Aug - Sep		- Fumigation
Sep - Mar		- Planning
Feb - Mar		
Apr	Lag Phase	- Pre-plant fertilization - Soil preparation - Transplant - Herbicide treatments - Irrigation
May		- Fertilization
Jun		-Fungicide treatments
Jul	Rapid Growth Phase	
Aug	Reduced growth	- Shutdown treatments and root culture
Sep		
Oct	Growth cessation and dormancy	
Nov		
Dec		- Lifting, grading, packing - Freezer Storage
Jan		- Cooler Storage
Feb		
Mar		

primarily used to characterize seedling developmental stages, to determine optimal timing for applying treatments, and to evaluate the effects of specific cultural practices. In other words, cultural practices that maximize root size and fibrosity, optimize root-to-shoot ratio, maintain good root and shoot form, and promote normal bud development are the treatments added to the nursery "tool kit" of best practices.

Physiological targets for 1+1 seedlings include foliar nutrition, water potential, and fungal pathogen load. Foliar nutrient levels are analyzed periodically throughout the growing season. These data and information from the literature are used to establish the seasonal targets for foliar nutrition. The historical data are also used to develop a fertilizer schedule that maintains foliar elements at optimal levels throughout the year. Seedling water potential is monitored with a pressure chamber during the drought stress treatment used to initiate dormancy. To reduce the impact on root growth, target levels of predawn moisture stress are the minimum required to initiate dormancy. Levels of soil-borne pathogens in the soil and on seedling roots are also evaluated at several points during the season. This service is provided by our in-house pathogen testing lab staffed by Dr Will Littke and John Browning. Results are used to develop fumigation plans and to guide seedling handling during lifting and storage.

Seedling quality tests that provide an evaluation of seedling physiology include tests of cold hardiness, root growth potential, and dormancy status. The targets for fall and winter cold hardiness levels are very specific and were established by the considerable efforts of Dr Yasuomi Tanaka and the seedling testing team at Weyerhaeuser (see Tanaka and others 1997 for description of methodology). There are also relatively specific targets for root growth potential. Root growth potential fluctuates seasonally but indicates whether a seedling is in optimal physiological condition (Stone and others 1962). Root growth potential has been used most extensively to develop detailed guidelines for lifting and storing Douglas-fir bareroot seedlings (Ritchie 1987). Finally, dormancy status is measured as the number of days to bud break in a forcing environment and is modulated by a combination of accumulated chill hours in the field and number of hours in storage (van den Driessche 1977; Ritchie 1989). Dormancy status is well correlated with seedling resistance to the stress of lifting, handling and storage (Lavender and Wareing 1972). This test has been used to develop guidelines for duration of storage based on time of lifting (Ritchie 1984b).

Seedling Development and Crop Culture During Year 1

Since a 1+1 seedling is cultured over 2 growing seasons, there are many opportunities for variable weather to cause a reduction in crop uniformity. Consequently, considerable effort is focused on those nursery practices that most influence crop development and compensate for aberrant environmental conditions. Tables 1 and 2 describe the timing of cultural practices relative to the first and second year development of the 1+1 crop.

Growing a 1+1 crop obviously begins with sowing the seed in the 1+0 beds. As stated by numerous authors, the uniformity of this first year crop is very dependent upon the quality of the seed (Tanaka 1984). At Weyerhaeuser, seed is processed and then tested for purity and germination efficiency (Tanaka 1984). The number of weeks of stratification depends on the origin of the seed source.

The next major limiting factor to a uniform first year crop is disease. Prior to sowing, the seed is chemically treated to reduce damping-off and bird predation. The seed is then sown in the warmest blocks where soil conditions are optimal and drainage is good. However, the most important practice for controlling disease in the first year seedlings is fumigation in the late summer or fall preceding sowing.

Seed is sown by the most experienced staff member using an Oyjörd sower. For uniform germination and subsequent height growth, the seed must be sown over a relatively short period of time at a uniform depth and spacing.

Throughout the 1T and 1+1 growing seasons, the competing vegetation is minimized by controlling weeds in adjacent areas, applying pre-emergent herbicides, and hand weeding. Other crop diseases, such as fungal pathogens and insects, are controlled by applying preventive fungicides and insecticides. Various chemistries with different modes of action are used to prevent build-up of resistance. In addition, timing of applications is based on historical expectations of increased potential for disease as a function of the developmental stage of the crop or other cultural activities.

During the transition from slow to rapid growth, irrigation and fertilization schedules are important for sustaining rapid shoot elongation of first year seedlings. The crop must be irrigated frequently and uniformly to ensure seedlings are not adversely affected by moisture stress. Irrigation uniformity is maximized by maintaining equipment and watering in the morning when wind speeds are minimal.

Fertilizer applications occur as preplant additions to the soil prior to sowing and as soluble fertilizers sprayed over the seedlings during the growing season. Regular sampling during each crop year serves to ensure seedlings have optimal levels of all essential elements.

During rapid shoot growth, first year seedlings are actively initiating and elongating new stem units and, given optimal moisture and nutrients, they will continue to grow late into the fall. Although first year seedlings rarely achieve the target height by late summer, dormancy induction treatments must be initiated at this time to allow a sufficiently long period for development of other target morphological and physiological characteristics. Timely cessation of shoot growth allows an opportunity for roots, vascular cambium, needles, and buds to grow and mature before air and soil temperatures become completely limiting. Maturity of the plant tissues is key to achieving: 1) cold hardiness levels needed to survive potentially early cold events; and 2) stress resistance needed to withstand the trauma of lifting, grading, storage, and transplanting. Dormancy is induced through nutrient stress, root culture, and relatively mild water stress. Since it takes some time before the first year seedlings respond and set bud, seedlings continue to grow and the population “coasts” into the target height specification.

The strategy for lifting the first year seedlings is based largely on timing. Chill hour accumulation in both the field and in storage is used to guide timing of lifting and duration of storage for seedlings (Ritchie and others 1985; Ritchie 1989). These guidelines suggest seedlings become sufficiently resistant to the stress of lifting and storage by about mid-December. This is also the time when seedling roots become increasingly resistant to exposure (Hermann 1967). After lifting, Ritchie (1989) recommended those lots that are first into freezer storage should be last to come out of storage. Therefore, much of the decision about when to lift certain lots is dependent upon the plan for timing of transplant (discussed below). The exception being lots that are most susceptible to cold damage are lifted first. These lots are identified based on elevation and latitude of origin, past experience, or data from Dr. Roger Timmis’ screening of cold hardiness characteristics of Weyerhaeuser improved families.

All first year seedlings are stored in the freezer to arrest pathogen growth and control the rate of dormancy release.

Seedling Development and Crop Culture During Year 2

The 1+1 year begins with a transplant plan that is largely based around fumigation and time of transplant. Fumigation is an important consideration because not all of Mima nursery’s 14 blocks are fumigated each year. There are many reasons to minimize fumigation. These include the negative impact on the environment, the increasingly high cost of fumigants, and the reduction or elimination of advantageous microorganisms such as mycorrhizal fungi. Dr Will Littke has worked very closely with each Weyerhaeuser nursery to develop fumigation plans that minimize fumigation while maintaining soil-borne pathogens at acceptable levels for production of quality seedlings. Nonetheless, it is well known that newly fumigated soil produces large seedlings presumably because of reduced pathogen load in the soil and higher concentrations of inorganic nitrogen (Hansen and others 1990).

Time of transplant is also very important because transplanting at Mima occurs over about a 6-week period and the seedlings that are transplanted earliest are often the largest by the end of the growing season. Therefore, when developing the transplant plan, the general rule is to transplant first into those beds that have the most years since fumigation. This strategy has one of the greatest impacts on ensuring that all 1+1 seedlings uniformly achieve the target height and stem diameter specifications.

There are, of course, other considerations included in the transplant plan. One is the degree of cold hardiness of certain lots. Cold susceptible lots are transplanted into the warmest blocks and into areas that are relatively well-drained. The latter allows better access in the event that conditions are wet when this stock is removed early in the lifting season. This same strategy is used when a customer requests December or early January delivery of stock. In some cases, a customer may request 1+1 seedlings that are larger than the typical height and caliper targets for the nursery. Although this stock is more expensive, there are several options for growing such seedlings, such as transplanting earlier, transplanting into a recently fumigated field, growing at a lower density, or culling more heavily after lifting.

The development of the 1+1 crop is somewhat different from that of the first year crop, but the principles of crop culture remain very similar. Irrigation and fertilization are very important throughout the year, but become most critical when the seedlings second flush and begin to rapidly grow.

Irrigation is monitored with irrometers and, once more, moisture stress is avoided. The fertilization schedule is based on historical data and continuous crop monitoring of foliar nutrients. The strategy is to match soluble nitrogen addition with the changes in growth rate and prevent deficiencies of any other nutrient element.

Both height and caliper are measured intensively during the 1+1 year to ensure crops in all blocks are following the target growth curves. If seedlings in a block are exceeding the target height trajectory, dormancy induction may be initiated early. On the other hand, if seedlings are behind the trajectory, nitrogen fertilization will be increased and those seedlings may be allowed to continue to grow until the latest possible dormancy induction date. However, as in the first year crop, it is well understood that it is absolutely essential to stop 1+1 height growth early enough in the season to allow sufficient time for growth and maturation of the rest of the plant tissues.

Root cultural activities coincide with the dormancy induction treatments, since this is the time when shoot growth is slowing and root growth is increasing. Root cultural treatments are intended to maximize volume and fibrosity in the portion of the root system that will be lifted and remain intact following root pruning in the packing room.

As the season progresses into the fall and early winter, anxiety mounts over the potential for early winter cold damage. Of course the nursery staff frost protects during most cold events. In addition, the historical cold hardiness data provides a reasonable estimate of the levels of cold 1+1 seedlings can tolerate as long as crops were shutdown sufficiently early. However, in the event of unusually cold weather, air temperature is monitored continuously at all nurseries and the staff can quickly determine if there was a potential for seedling damage. If that uncertainty exists, then nursery research has maintained the capacity to test levels of cold damage in the crop and advise customers if there appears to be significant losses.

Weather permitting, the goal is to lift the 1+1 crop when it is resistant to stress; from mid-December to February. As previously determined in the transplant plan, the most cold susceptible lots are lifted first and transferred to freezer storage where they will maintain optimal physiological condition for approximately 4 months (Ritchie 1989). In addition, customers ordering high elevation lots typically prefer freezer storage and these, too, are lifted earliest. When customers specify cooler storage, the seedlings are lifted no more than a few weeks preceding planting, thereby minimizing duration of cooler storage and the potential for physiological decline.

Summary

Although we have used Mima nursery as the model for this discussion, these same best practices are shared across the other Weyerhaeuser facilities. Each facility faces its own challenges but evaluation of the crops and management decisions are made using a common strategy. To date, the business has been successful at producing good quality, uniform 1+1 seedlings, and although one can cite good cultural practices, the real key is the vast knowledge and deep commitment of Weyerhaeuser's nursery staff.

References

Hansen EM, Myrold DD, Hamm PB. 1990. Effects of soil fumigation and cover crops on potential pathogens, microbial activity, nitrogen availability, and seedling quality in conifer nurseries. Phytopathology 80:698-704.

Hermann RK. 1967. Seasonal variation in sensitivity of Douglas-fir seedlings to exposure of roots. Forest Science 13:140-149.

Lavender DP, Wareing PF. 1972. Effects of daylength and chilling on the responses of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings to root damage and storage. New Phytologist 71:1055-1067.

Long AJ, Carrier BD. 1993. Effects of Douglas-fir 2+0 seedling morphology on field performance. New Forests 7:19-32.

Newton M, Cole EC, White DE. 1993. Tall planting stock for enhanced growth and domination of brush in the Douglas-fir region. New Forests 7:107-121.

Ritchie GA. 1989. Integrated growing schedules for achieving physiological uniformity in coniferous planting stock. Forestry Supplement 62:213-225.

Ritchie GA. 1987. Some effects of cold storage on seedling physiology. Tree Planters' Notes 39:11-15.

Ritchie GA. 1984a. Assessing seedling quality. In: Duryea ML, Landis TD, editors. Forest nursery manual: production of bareroot seedlings. The Hague/Boston/Lancaster: Martinus Nijhoff/Dr W Junk Publishers, for Forest Research Laboratory, Oregon State University, Corvallis. p 243-259.

Ritchie GA. 1984b. Effect of freezer storage on bud dormancy release in Douglas-fir seedlings. Canadian Journal of Forest Research 14:186-190.

Ritchie GA, Roden JR, Kleyn N. 1985. Physiological quality of lodgepole pine and interior spruce seedlings: effects of lift date and duration of freezer storage. Canadian Journal of Forest Research 15:636-645.

Ritchie GA, Tanaka Y, Meade R, Duke SD. 1993. Field survival and early height growth of Douglas-fir rooted cuttings: relationship to stem diameter and root system quality. Forest Ecology and Management 60:237-256.

Stone EC, Jenkinson JL, Krugman SL. 1962. Root-regenerating potential of Douglas-fir seedlings lifted at different times of the year. Forest Science 8:288-297.

Tanaka Y, Brotherton P, Hostetter S, Chapman J, Dyce S, Belanger J, Johnson B, Duke S. 1997. The operational planting stock quality testing program at Weyerhaeuser. New Forests 13:423-437.

Tanaka Y. 1984. Assuring seed quality for seedling production: cone collection and seed processing, testing, storage, and stratification. In: Duryea ML, Landis TD, editors. Forest nursery manual: production of bareroot seedlings. The Hague/Boston/Lancaster: Martinus Nijhoff/Dr W Junk Publishers, for Forest Research Laboratory, Oregon State University, Corvallis. p 27-39.

Thompson BE. 1984. Seedling morphological evaluation - What you can tell by looking. In: Duryea ML, editor. Evaluating seedling quality: principles, procedures and predictive abilities of major tests; 1984 Oct 16-18; Corvallis, OR. Corvallis (OR): Forest Research Laboratory, Oregon State University. p 59-72.

van den Driessche R. 1977. Survival of coastal and interior Douglas-fir seedlings after storage at different temperatures, and effectiveness of cold storage in satisfying chilling requirements. Canadian Journal of Forest Research 7:125-131.