TRANSPLANTING THE DOUGLAS FIR PLUG

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INTRODUCTION

Container production of reforestation stock in the U.S. Pacific Northwest is a relatively new technique that has been undergoing exponential growth during the first half of this decade, yet has diminished somewhat during the second half. In 1970, about 90 thousand plugs were produced in Oregon and Washington and by 1976 nearly 54 million were grown (1). After 1976, the enthusiastic growth for container production has actually decreased to 44 million seedlings. In relation to the bare-root tree production of 170 million, the container trees represent about 20% of the total production of reforestation stock in the Pacific Northwest.

The decline of container production in the Northwest is partly due to some reforestation failures on difficult sites where plugs had been used. These difficult sites are frequently areas with brush competition and mammal browsing. Small plugs have little chance of surviving, let alone growing, when brush forms an overstory above the seedling and provides habitat for browsing by mountain beaver, rabbit, and deer.

Due to these failures, many foresters have tried to plant a larger tree, such as a 2-1 transplant or a 3 year-old seedling. This type of tree would have enough height to be less affected by brush and weed competition and also would possess more lateral branches so that if animals remove some of the foliage, there would still be enough remaining to keep the tree growing. These trees would take 3 years of nursery care before they could be outplanted and are more expensive compared to the plug or 2-0 bare root.

Two years ago, our nursery was approached by a few timber companies which possessed some of these difficult sites and also operated their one plug nurseries. It was felt that the plug seedling could be transplanted in a nursery growing area and within 2 years reach the needed size for outplanting, rather than the typical 3 years with bare-root stock. In addition, the container nursery could double it's production by producing plugs for late summer transplanting in August and, also, produce a crop of plugs for winter planting in the woods. Our main concern was the ability of the plug to develop a suitable root system that could support a large top upon outplanting. After producing 500,000 of these in 1977, we felt confident enough in the tree that we transplanted an additional 2 million in the spring and 2 million in the fall of 1978. The plug transplant has unique properties in it's morphological character that make it a valuable addition to the variety of stock available for the forester to choose among when selecting the type of tree most suited for his site.

We will discuss the cultural techniques that are used in the production of the plug transplant and show a cost comparison between this and other reforestation types.

CULTURAL TECHNIQUES

We prepare our ground as soon as we can work up the soil. Usually this entails plowing, discing, and rototilling. The ground is fumigated under tarp with 380 lbs. of 66% methyl bromide and 33% chloropicrin. After removal of the tarp the ground is again disced and harrowed.

The transplanting is done with a mechanical transplanter planting six lines, eight inches apart, and with three inches between trees in a line. We use two machines and have the capacity to plant up to 160 thousand trees per day. Each transplanting crew consists of 11 members: 1 foreman, 1 tractor driver, 6 planters, 2 trailers, and 1 loader. The foreman is responsible for insuring that the trees are planted upright with a straight root system and firmly-packed base. The two trailers fill in any skips in the beds by handplanting trees so we can maximize production per acre. About 140 thousand trees can be planted per acre. Special racks were built to handle plugs coming to us in Styroblock containers. The containers slide down in front of each person who is planting; he can extract the trees directly from the block and feed them into the planting wheel. Plugs that arrive to us already extracted at the greenhouse are just laid in a tray in front of each planter. Transplanting plugs results in fewer "J"-root problems than occurs with bare-root stock. The root system is in a "plug" shape and allows the tree to be firmly anchored in the soil by the packing wheels of the planter. With bare-root stock, we have had problems with one tree binding the next in a tangle of roots and, in so doing, drags it into a sharp angle in the soil.

A serious problem that many transplant nurseries face is the quality of the stock on arrival at the nursery. This is particularly a problem during the spring when trees have been held in cold storage for transplanting. Some trees may be in storage for 1 to 4 months before being transplanted into the field. Hemlock, in particular, is susceptible to damage if stored for over two months and we prefer these trees to be transplanted in the fall.

A great advantage of the plug over a bare-root seedling is that it can be transplanted in late summer with no intermittant period of storage. Plugs that are held through the winter can become root-bound in the Styroblock or cell. Early bud break can also occur since the container nursery must continue to fertilize the plug while at the greenhouse to keep it from becoming chlorotic. If the plug is extracted during the winter and held in storage, it can have many of the same problems as barefoot stock with disease and lost vigor.

Sometimes the container nursery must transplant the plugs in the spring. In this case, we recommend that plugs be extracted from the container when the seedling is fully dormant and then put into cold storage. A plastic wrap with an open end, forming a bundle of 50 plugs, has usually been satisfactory. The bundles can then be placed in a box or bag and stored under refrigeration.

The highest quality plug for transplanting is one that has been cultured at the greenhouse for the specific purpose of a late summer transplanting. In order for these trees to become ready, they must be sown earlier in the greenhouse, such as the first part of December, and must be "hardened-off" with firm buds by early August. A plug that is transplanted in late summer will be about 10 cm larger than a spring-transplanted plug. It's caliper is usually over 8 mm and the root system is much more developed than that of a spring transplant, since the tree has gone through two additional periods of active root growth in the fall and early spring.

Our disease control program is mainly preventative maintenance. This begins with sterilizing the soil with a fumigant such as methyl bromide/chloropicrin and proceeding with cultural practices that will minimize reinoculation by pathogens.

Tilling equipment that is used in a suspected area should be cleaned of all residual soil and sterilized with an antibacterial detergent before using in newly-fumigated ground. A common source of disease is infected stock brought in from another nursery or field. We require all stock coming to us for transplanting to be inspected for disease. This usually entails an agar culture treatment of seedling sections and identifying the disease growth through a microscope. Any seedlings showing high potential risk can either be refused for transplanting or accepted, but restricted to a certain area removed from our healthy trees.

The trees are inspected daily for the appearance of unusual color or growth. If a symptom can be recognized in its earliest stages there is a much better chance of arresting or preventing future damage with the use of certain fungicides. In analyzing disease problems, the visual symptoms should not be the only means of determining the identification of the disease. Visual symptoms mainly indicate that a problem exists but is not a confirmation of what the specific disease is.

The agar plate technique can be very useful in determining the effectiveness of various fungicides on the disease by incorporating the funigicides in the agar medium and viewing it's control. Once the disease has been identified, we can apply the desired fungicide on the field by either tractor or airplane.

We use about ten different herbicides on our transplant fields according to the time of year, weed species present, and physiological state of the trees. These herbicides include atrazine, simizine, prometryne, glyphosate, dicamba, Dacthal, Enide, bifenox, 2,4-D, and 2,4,5-T ester. Our major weed problems are subclover, dog fennel, horsetail, mustard, and sheep sorrel. With the use of these herbicides and fumigation we have seen a steady decline in the number and proficiency of weeds in the field. However, even with the use of herbicides, we still have a need for handweeding at various times during the growing season.

We can get a good understanding of our nutrient status from soil lab reports and incorporate the proper amount of nutrients into the soil before transplanting. Not all of our fields have the same soil type and therefore we have to independently sample stratified areas. The levels of nutrients which we feel are sufficient for our fields are given in Table 1.

Table 1. Levels of Nutrients

pH	: 5.2 to 5.6		
organic matter:	3 to 4%		
CEC	: 15 to 20 meq/100g		
NO_3	: 150 to 200 ppm	Cu	: 1.0 to 1.5 ppm
NH_4	: 50 to 100 ppm	Zn	: 1.5 to 2.0 ppm
PO_4	: 50 to 100 ppm	Mn	: 5 to 10 ppm
K	: 250 to 350 ppm	Fe	: 10 to 15 ppm
Ca	: 9.0 to 13.0 meq/100g	B	: 3.5 to 4.0 ppm
Mg	: 2.0 to 3.0 meq/100g		

Not all lab tests use the same method of extraction and might give a wide range of figures. We try to have our soils tested by only one lab so that soil fertility levels may be easily correlated each year to former tests. Soil type and it's cation exchange capacity also influence the nutrient availability of the soil. Each nursery should determine its own sufficient levels.

Once we have incorporated the proper fertilizers before transplanting to reach an optimum level, we continue a fertilizer program during the growing season to accelerate growth and development. We check our nutrient levels at various times during the growing season with a soil test kit and pH meter. A late summer transplant does not receive any additional fertilizer until early spring when we apply a complete fertilizer (20-20-20) at about 100 lbs/acre to enhance bud break, root development, and shoot growth. During late spring and early summer we concentrate on nitrogen applications such as ammonium sulfate at 80 lbs/acre. Nitrogen is necessary for continued shoot elongation and diminishes from the soil quickly due to irrigation during this period. In early August, we apply a phosphate-potassium fertilizer to initiate the "hardening-off" process and influence root elongation. This is our last fertilizer application for the year so that second-flushing from early fall rains will not occur and result in frost damage by late fall. We prefer to apply small amounts of fertilizer frequently so that the transplant receives a uniform amount of nutrients throughout the growing season.

The soil texture can influence the growth of the plug to a great extent. In sandy soils, the plug root system will put out many lateral roots so that the 'plug' shape becomes almost indistinguishable from a 2-1 bare root after a year in the transplant beds. On the other hand, clay type soils will keep the plug shape intact and very few lateral roots will extend through the soil. Most of the root growth in clay soils is in a downward direction and the tree is not balanced in its root:shoot ratio due to this poor root development.

Proper irrigation is important to the growth and development of the plug transplant yet it is difficult to determine how much water should be applied and when to apply it. We not only depend on water to encourage growth and induce dormancy, but also for it's function in disease control by reducing soil temperatures. We have tried the "farmer's approach" and irrigated when we thought we should. However, with a relatively new nursery and new personnel, this approach was less than optimal. During the past growing season we have used the pressure bomb as developed by Waring and Cleary (2). With this tool one can determine the water stress of the tree at that period of time. By relating the stress readings to research data one can determine whether to irrigate or not. This instrument becomes very important to us during the late summer when we want to hold back the water to induce dormancy but not so much that the vigor of the tree is threatened.

Before lifting the trees from the beds some clients prefer to have their trees sprayed with a mammal repellent. We apply these chemicals with a spray tank but have been considering the use of an airplane or helicopter. The repellents have been successful in some areas to a certain degree, but do not provide total control. Nor do they have a long period of activity, only about 3 to 4 weeks. Unless the trees are resprayed in the woods the new foliage from subsequent bud burst is unprotected and can be browsed.

The trees are lifted starting about December 1 and continuing through late February. This is the period when the trees are in their deepest dormancy and can withstand the shock of being removed from the soil. During this operation the roots must be protected from exposure to drying conditions. The trees are either lifted by machine completely out of the ground or the ground is agitated sufficiently to allow hand pulling without damage to the roots. We load the trees into large boxes on trailers and bring them to the packing shed as soon as possible. There the trees get rinsed down to remove any dirt on the foliage and to re-moisten the roots. The trees are then stacked into a cold room kept at 33-34°F and 90% humidity for further processing.

The trees are graded and root-pruned if the client desires. Trees that are culled would be those of poor root or shoot growth, damaged, or diseased. The graded trees are counted, bundled and sent down the conveyor belt to a person who packs them in either bags or boxes. Packing material is sometimes requested as shingletoe, peat moss, or tree moss. Our experience receiving trees from other nurseries indicates that bags with no packing material have generally contained the freshest trees. Once packaged, the trees go back into the cold storage room to await shipment.

OUTPLANTING

It is much too early to form a definite picture as to how plug transplants will perform in the woods since we have only one crop out on the sites. However, the preliminary surveys are encouraging. In 1978, 500,000 plug transplants were sent to 3 locations in the Coastal Range of Southern Oregon. Each of these locations were considered difficult areas for regeneration due to heavy weed encroachment and severe mammal browsing. Past experiences using either the plug or 2-0 bare root usually resulted in low survival figures or very limited growth. The 2-1 bare root transplants were tried and because the trees were larger with more lateral buds, the survival is high, as is the capability for continued growth of these trees despite the browsing.

The plug transplant seems to show an additional improvement over the 2-1 due to it's vigorous growth. Upon browsing, a 2-1 would usually not resume considerable shoot elongation but wait until the following spring before pushing up new growth. The plug transplant, however, seems to have the ability to continue pushing out new growth despite the browsing. This additional vigor may be due to the more developed root system it has compared to the 2-1 bare root.

A comparison study between the plug and plug transplant was done near Gold Beach, Oregon by Champion Timberland foresters. The trees were planted in the same watershed in the spring of 1978. Both types had 90% or better survival, but 35% of the plugs had been browsed so heavily that survival in the near future was questionable. On the other hand, the plug transplant had 0% in the "questionable" category and all seemed firmly established on the site (personal communication).

Table 2. Cost Comparisons Among Types of Reforestation Stock.

	2-0	2-1	plug	plug-1
Trees planted/acre	680	550	680	550
Establishment percentage	70%	90%	55%	92%
Number of trees est./acre	476	495	347	506
Number of trees to replant/acre	24	5	126	—
Site prep. costs/acre	$190	$190	$190	$190
Stock costs/acre	$41	$66	$51	$66
Planting cost/acre	$52	$61	$45	$61
Respray cost/acre	—	—	$14	—
Replant cost/acre	—	—	$10	—
Establishment cost/acre	$283	$317	$310	$317

From the regeneration cost data we received from the Gold Beach operation, there appears to be little difference among the 2-1, plug, and plug transplant establishment costs. The 2-0 type was a little lower (Table 2). However, these costs do not show the relative advantages that the plug transplant has over the other types of stock. These advantages are:

1. The plug transplant represents a two year regeneration plan whereas a 2-1 takes three years before the tree is brought to the woods.

2. A plug transplant is usually a more consistent tree than the bare root 2-1, or the 2-0 in height, root system, and caliper.

3. The plug transplant is larger than the 2-1 when it has been fall-transplanted and much larger than a 2-0 or a plug.

4. Plugs can be transplanted in late summer with no storage transition between the seedling beds and transplant beds. Bare root transplants usually have a period of storage which declines vigor.

5. A container nursery has much more control over the seedling's environment than a bare root nursery and, therefore, it becomes a much safer, consistent area to grow seedlings. As seed costs rise and expensive, genetically improved, seed be-

comes more available the most efficient use of that seed will probably be within the container greenhouse rather than open fields. The plug transplant will allow these container trees to achieve some of the advantages that bare root transplants have in size and increase their success in the woods.

LITERATURE CITED

1. Ter Bush, F.A. Forestation Notes. No. 52 August 1978.
2. Waring R.H. and B.D. Cleary. 1967. Plant moisture stress: evaluation by pressure bomb. *Science* 155 (3767):1248-1254.