ROOT FORM OF PLANTED TREES

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Abstract.-- The degree of root deformation of newly planted trees is governed by nursery practice, container design, planting method and quality, and site conditions. Evidence suggests that root systems of planted trees become increasingly "normal", and that toppling of planted trees will not be a major problem in Canadian forests.

Résumé.--Chez les arbres nouvellement plantés, le degré de déformation des racines dépend des pratiques utilisées en pépinière, de la forme des contenants, de la méthode de plantation et de sa qualité ainsi que des conditions de l'emplacement. D'après certains indices, le système racinaire des arbres plantés devient de plus en plus "normal", et la perte de vitalité des arbres plantés ne représentera pas un problème majeur dans les forêts canadiennes.

INTRODUCTION

Root form of planted trees is a topic of recurring interest. The current cycle of interest and debate on this topic appears to have been precipitated by the rapid expansion in production and planting of container-grown stock.

Root systems of planted trees initially differ substantially in form from those of naturally established trees, regardless of environmental conditions at time of establishment or the nursery practices and planting techniques employed. Alteration of the "natural" or "normal" root form clearly originates in the nursery with both bare-root and container stock. Although the form and size of root system can be manipulated in both stock types through various nursery practices (such as undercutting, air-pruning, mechanical or chemical pruning, wrenching, transplanting, fertilization and irrigation regimes) the nature of root deformation in the two stock types is essentially different. Root deformation in bare-root stock is attributable primarily to deficiencies in quality control in the nursery or at outplanting, as a result of human error and/or constraints imposed by soil and site conditions. The root form of container stock, on the other hand, is governed mainly by nursery factors, principally container design, since the potential for poor planting is minimized as a result of the consistency in shape and size of the root system.

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ROOT DEVELOPMENT IN PLUG STOCK

The development and testing of the Walters bullet system, which was undertaken by the Canadian Forestry Service and the British Columbia Ministry of Forests in the late 1960s, had as one of its long-term objectives the evaluation of the root morphology and development of variously grown and planted trees. Results of those studies were first reported by Van Eerden and Arnott (1974) at the North American Containerized Forest Tree Seedling Symposium in Denver and, more recently, at the Root Form Symposium in Victoria (Van Eerden 1978).

The Walters bullet system was designed specifically to improve planting productivity through manual and, ultimately, mechanized injection planting. To assess the effects of the bullet container on root development and morphology, seedlings were planted with and

without the container, the latter being called "bullet-plugs". Survival and growth of the relatively small bullet stock compared favorably with those of larger bare-root stock, and some of these early bullet plantations have grown into excellent stands, in spite of juvenile root deformation. Nonetheless, bullet seedling planting has not been widely accepted. This lack of acceptance is associated primarily with concern over the potentially constricting influence of the bullet container on the root system. Although the performance of bullet-plugs generally resulted in only marginal improvements in survival and growth in comparison with that of seedlings planted with the bullet container intact, the "plug" concept found wide acceptance.

Because the Walters bullet was not designed to produce plugs it had some obvious shortcomings as a plug container. As a result, a new container, the BC/CFS styroblock, was designed and developed in 1969/70 specifically for the production of plug stock. The basic design features of the Walters bullet, the tapered tip to the drainage hole at the bottom of the bullet and the provision for air-root pruning, were retained in the design of the styroblock cavities. To control cross-over and inter-twining of primary laterals, vertical ribs were later incorporated into the design of the styroblock.

About the same time that the BC/CFS styroblock was being developed, the multipot or K-pot was being introduced in Sweden. Although the British Columbia and Swedish plug containers were identical in concept, there were two significant differences in design and cultural approach. Unlike the BC/CFS styroblocks, the multipots were patterned after traditional plant pots, having a flat bottom with a central drainage hole and no vertical ribs. It is well known from horticultural experience that such a design inevitably results in extensive coiling of lateral roots in the bottom of the container, commonly referred to as "potbinding". In addition, and probably duplicating the then current paperpot practice, multipot crops were generally grown on the ground, where air-root pruning could not be carried out. The multipot has now been modified to eliminate the flat bottom and include vertical ribs, while more recent cultural practices generally include provision for air-pruning.

Another well known container, the Spencer-Lemaire "Rootrainer", has vertical grooves rather than ribs to control cross-over of lateral roots.

Notwithstanding the design features of these and other containers, all of them still create a vertical root cage. It is this root cage that is of concern with respect to root deformation, particularly in the pines. It is feared that this vertically shaped root system will result in a fulcrum, which will predispose the planted tree to basal sweep, instability, and, under certain climatic and soil conditions, toppling. This concern should not be dismissed lightly. Many examples of plantation failure cited in the literature have been attributed to root deformation.

SUMMARY OF ROOT FORM SYMPOSIUM

To bring you up to date on recent information on the subject, I take this opportunity to provide a summary and my perspective of the recent Symposium on the Root Form of Planted Trees (Van Eerden and Kinghorn 1978). This symposium provided irrefutable evidence that all nursery and planting techniques cause some degree of root deformation to newly planted trees. It was shown that:

1) root deformation occurs with both bare-root and container-grown stock;

2) the potential for deleterious root deformation is strongly species-related, particularly in the pines;

3) root deformation in young plantations does not inevitably lead to total plantation failure;

4) where plantation failures have occurred as a result of root abnormalities the effects of root deformation have frequently been compounded by other factors, such as:

   - unfavorable site conditions (heavy, shallow or poorly drained soil) or poor site preparation;
   - climatic conditions (gales, hurricanes, heavy snow);
   - the growth characteristics of a given species (Pines are generally more subject to instability and basal bowing than most other species because of their characteristically rapid early height growth and relatively slow root growth. They are consequently top-heavy and can become highly unstable under unfavorable site and climatic conditions.);

5) root systems repair themselves with time, and increasingly acquire a "normal" or natural habit;

6) study of root form has generally focused on relatively small trees, so that it remains a matter for conjecture whether or not root deformation represents an economic risk with respect to long-term stand stability and yield;

7) potential solutions to the "problem" of root deformation in container stock particularly will have to originate in the nursery through improved cultural practices and/or changes in container design.

Perhaps inevitably, the symposium provided primarily a diagnosis of the causes and symptoms of root deformation in planted trees, with a promise of remedies for correcting or minimizing the problem. The quantitative relationship between early root form of planted trees and yield at rotation age remains undefined.

HOW DO WE DEAL WITH THE RISK OF ROOT DEFORMATION?

In my view, there are three approaches to dealing with root deformation:

1) cease planting of container-grown stock for species that are particularly susceptible to root deformation;

2) assess the risks associated with root deformation of container stock in economic terms, and then decide whether to accept the risk or not;

3) minimize root deformation through improvements in container design and cultural practice.

Determining the Risk

As a result of their ability to produce adventitious roots, white spruce *(Picea glauca* [Moench] Voss) seedlings can quickly overcome the imprint and effects of the container on the root system. Consequently, the risk of toppling in this species appears to be minimal.

The effects of the container on root form in lodgepole pine *(Pines contorta* Dougl. var. *latifolia* Engelm.) are longer lasting than in spruce. This species does not produce adventitious roots, and the roots have a strong tendency to spiral, creating a convoluted root ball with a profusion of weak lateral roots at the base of the root system. Such a root ball fails to provide firm anchorage and predisposes trees to toppling under adverse soil and climatic conditions. In contrast to the relatively slow initial root growth, juvenile height growth in lodgepole pine is usually rapid, creating a potential imbalance between the crown and root system. However, by the fourth or fifth year after planting, or when the trees reach 2.5 to 3 m in height, the apparent effects of root deformation become less visible. By then, anchoring appears to have improved and basal sweep, if it occurred earlier, becomes less obvious. Excavation of complete root systems shows that healthy and normally oriented tissue has started to surround the original root ball, and that individual roots within that root ball have started to graft at the point of contact. Graham and Bormann (1966) indicate that such grafted roots will eventually establish vascular continuity.

On the basis of my personal observations, I suggest that the risk of significant economic loss due to toppling of container stock of white spruce and lodgepole pine in British Columbia, and probably in the boreal and sub-boreal forests throughout Canada, is small. In fact, the risk of loss due to root deformation in white spruce is minimal and, generally, less than 10% in lodgepole pine. Studies of other west coast conifers indicate that a similar conclusion is justified for other species.

Remedying Root Deformation

Reduction or prevention of the effects of the container imprint on early root system form will require significant efforts in research and development, both in container design and in cultural practice.

The notion that root problems can be averted if seedlings are kept small and are not grown much beyond the germinant stage hardly deserves consideration. Although relatively small lodgepole pine is capable of high survival and rapid early growth, container stock of white spruce needs to be substantially larger if it is to perform well after planting. The era of the "micro-seedling in the mini-container" which was largely responsible for the demise of the Ontario tubeling system, and which has detracted from the potential of container seedling reforestation, should never again be considered as a viable planting stock option.

In the short term, chemical pruning with copper carbonate (Burdett 1982) appears to provide a simple and effective resolution of this difficult problem. In the longer term, suggestions for modification of container design advanced by Kinghorn (1978) and Rie-

dacker (1978) merit serious consideration and further development. The new "skeletal" container design developed by Stora-Kopparberg (Andreason 1982) in Sweden also deserves close attention with regard to performance and costs over the next several years. Regardless of the cultural technique or container design employed, any modification must be integrated with the rest of the container system and must be cost-effective. In other words, if the risk of loss due to root deformation by containers is low and the cost of eliminating or significantly reducing that risk is high, it will be difficult to justify the added expense for modification of existing techniques.

CONCLUSION

Field observations and a review of the literature confirm that containerization, like bare-root practice, does modify the natural root form of planted trees. However, in Canada, the economic risk associated with root deformations imparted by the principal container systems currently in use appears to be low. Also, root abnormalities become less evident with time. Roots of planted trees increasingly resemble those of natural trees with advancing age (Gillgren 1972), and any differences between planted trees and natural trees become negligible 30 to 40 years after planting (Bibelriether 1966). Root deformation is just as common in bare-root stock as it is in container-grown stock and, in the case of the former, is both less consistent and less predictable. It might well be asked why container stock precipitated the current concern over root deformation. Part of the answer to this question may lie in the fact that the advent and expansion of container seedling planting were seen as a challenge and threat to the long-established technique of bare-root planting.

The causes and symptoms of root deformation are well understood and have been adequately described in biological terms, while promising remedies have been proposed and are under development. However, the economic significance of the biological observations and potential remedies remain poorly defined.

In conclusion, I suggest that the view of root deformation expressed by Dr. Olavi Huuri of the Finnish Forest Research Institute (Huuri 1978) provides a most perceptive understanding of early root deformation:

"It is possible that Scots pine roots have for decades suffered much more than is commonly known. They have in silence overcome the difficulties caused by the planter. The plantations have developed into great stands and yielded their crop. The roots of the planted trees, those 'forgotten victims of the underground prison', have occasionally been pulled out into the light too early, before they have had time to hide their damage. At this stage they have caused common consternation among tree planters. This has happened at about twenty to thirty year intervals...."

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