QUESTIONS AND DISCUSSION — MINIMIZING ROOT PROBLEMS

Discussion Leader: T. G. Honer

Comment (Greene): In our discussion of different containers to alleviate root problems, I draw your attention to the wall-less container concept, i.e., a growing medium that holds itself together. This approach has received some attention in Denmark and also in Sweden with rock wool. In Sweden some consideration is also being given to peat as a self-cohesive medium. By using the principle of a wall-less container, the roots are not artificially shaped but are kept inside the wall-less medium by appropriate spacing and air-pruning on all sides.

Comment (Stein): In our enthusiasm for modifying containers and reforming roots to overcome root deformation, I recognize a tendency to forget the reason for using planting stock, either bared-root or container stock. I submit that nature has provided one of the best containers in the form of the seed coat. However, in contrast to man-made containers, the seed coat container miniaturizes rather than containerizes. The reason for abandoning that container stems from the need to avoid some of the losses that occur with young seedlings during and immediately after germination. In our efforts to minimize container effects on root form, there appears to be a tendency to go to smaller and younger seedlings. In so doing we are again approaching the risks associated with establishment of very small seedlings. Thus, there is a limit to the extent that we use very small seedlings and gain anything over direct seeding.

Question (McGarva): It seems to me that this whole week's symposium boils down to the question of what the field forester wants. The answer appears to be that he wants a natural root form, i.e., retaining or reforming to a natural root form. Retention of that form is quite simple and is a matter of timing and can be accomplished by using small seedlings, as suggested by Dr. Stein. In horticulture, this practice originated with the use of Finspots and paperpots. Reforming of the natural root form is done through pruning, a subject which we have not adequately discussed, and where a terrific amount of work needs to be done. To begin with, we need a clear definition of pruning. We have been told about clipping and breaking off the ends, but such practices more closely resemble hedge trimming rather than pruning. There really is not very much to be gained by trimming off the outside shoots. Reshaping needs to be done at the base of the root system, as is done with some horticultural species when the roots are cut back to within about 4 inches of their origin. Does anyone have any comments on these suggestions?

Harris: I agree that to just stub an apple tree back along the top is probably not the correct way of pruning. However, when we work with young seedlings and we prune the roots back to 5 cm, we really get back near the base. Any new roots that form will therefore be near the base. Consequently, if you pinch off or break off the root tip, especially of the taproot, branching will occur above the point of pruning and create more root mass where you want it.

Question (Spencer): If the base of a tree gets woodier and heavier because it has been flexed by wind, would there be any merit in providing wind artificially during the hardening process and build the muscles of the lateral roots and, hence, reduce the risk of blowdown?

Fayle: It is probably not that important at the seedling stage in the nursery. The disposition of the root system does become of consequence, however, once the tree is in the ground and is subject to stresses.

Harris: Flexing of the top of a tree may reduce height growth and result in greater taper. Consequently, the tree will withstand more wind, because it can bend at the top and stress is more uniformly distributed throughout the length of the stem. Although the tree may not be quite as tall, it will have a stronger base and, possibly, a somewhat larger root system. Thus, without contradicting Dr. Fayle, we end up with more stem flexibility and a more uniform distribution of stress.

Comment (Tinus): We have heard several suggestions to change the configuration of the container. However, when you change the
shape of the container, as suggested by Kinghorn and Riedacker, it becomes more difficult to plant the container-grown stock. We know that ribs and air-pruning in a number of presently used containers shape root systems in a certain way. After outplanting, trees from those containers commonly show a proliferation of roots at the base of the plug but lack the surface-feeding lateral roots important in providing windfirmness. If we stayed with the common configuration of current containers, which are either square or round in cross section and are more or less tubular, but had slots instead of ribs, and provided for air-pruning between the containers, then we would end up with a totally different shape of root system. In addition to the proliferation of roots at the bottom, there would also be a proliferation of lateral roots at the sides. Because the basic overall shape of the plug has not been changed, there is no increase in the difficulty of planting. This approach resembles that of Walters' bullet system, with the exception that when bullets are packed in a tight block, there is no provision for lateral air-pruning.
SUMMARY ADDRESS

Mr. Kenneth Armson was introduced by Mr. John Bruce, Forester-in-charge of the Reforestation Division of the British Columbia Ministry of Forests.

Mr. Armson is well qualified to summarize this particular Symposium. For over twenty-five years he was Professor of Silviculture at the University of Toronto. His main areas of research are forest soils, tree nursery soil management, soil/tree inter-relationships, forest fertilization and forest regeneration. Throughout his work he has maintained a particular interest in the roots of trees. Amongst his numerous publications in the field of silviculture, highlights are his books on forest soils and forest tree nursery soil management and related practices. Besides teaching and research he has been an active member of several professional and scientific forestry organizations. He has undertaken many consulting assignments concerning soils and seedlings, including a review for the British Columbia Forest Service on container seedling production in relation to planting sites. More recently he has been actively engaged in studies concerning the management of forests in the Province of Ontario, and Canada as a whole. Mr. Armson recently left the University of Toronto to serve as special advisor to the Ontario Ministry of Natural Resources.
ROOTS OF THE NEW FOREST

K. A. Armson

Abstract.—Studies of tree roots inevitably involve comparisons. While the norm is usually the natural root system, we have little knowledge of the extent of genetic variation and control of root form for many of our species. The production of clonal material for experiments with tree roots seems necessary. Root form is discussed as it relates to:
(1) cultural practices in the nursery and at outplanting,
(2) modification by environmental factors, (3) changes in stand development and management practices, (4) the new forest and soil development.

The task of providing a summation paper for this symposium is somewhat analogous to the position of a chef, who being provided with an array of comestibles is told to arrange, mix, simmer, bake or broil and thus create from the wholesome ingredients a new dish suitably spiced and garnished. At the same time it must stimulate the appetite and satisfy the palate (jaded, perhaps, after a symposium of this length) without losing the worth and taste of the basic stock.

There has to be throughout this entire discussion an overriding question, often unspoken, which is "Compared to what?" The usual standard of comparison is the same species as that under study but originating from seed in the outplanting area. But what of the genetic variation in root development within a species? More particularly, what is the capability within a species for it to respond to different growing conditions? We have evidence both from this meeting and elsewhere that seed origin or provenance and genetic control within a species can significantly affect root development. Foresters have long observed the variation in above-ground form of trees and made selections and cultured those trees that suited their purposes; in the field of fruit growing, the importance of the root stock has long been recognized. We have reached the stage in our investigation of the roots of forest trees where the use of general seed sources for experimentation is to be deplored. The controls or standards used in our studies must be similar or identical genetically. The need for the large-scale operational production of clones of conifer species is obvious and, in my opinion, imperative. Without a high degree of certainty about the genetic similarity of the experimental material, there will inevitably be anomalies and contradictory conclusions which will perpetuate myths and inhibit our clearer understanding of the factors governing forest growth.

For convenience I have arbitrarily separated the topic "Root Form of Planted Trees" into four sections:

1. Root form as influenced by cultural practices either in the nursery or at outplanting.
2. Root form as modified by environmental factors.
3. Root form as it changes with time, stand development and management practices.
4. Root form and the new forests.

grown seedlings and yet in North America and Europe the vast majority of trees produced for forest outplanting are still grown in conventional nurseries as bare-root stock. Has the very act of growing trees in containers put the roots into a position of access and visibility to the grower which does not occur when the seedlings are in the ground?

Often it seems that the form or distortion of roots that occurs is seen in simple physical terms rather than in relation to the biology of the seedling's development. Much concern exists over coiling of roots in the container, yet in the longer run there is little or at best conflicting evidence that such distortions have a deleterious affect on subsequent growth. Finally, it seems that the myth of 'root strangulation' may be laid to rest. Is it because roots of trees have been so little considered by forest scientists that such anthropomorphic terms as 'strangulation' and the notion of roots seeking or divining water are embraced and become part of our pseudo-intellectual baggage?

Roots of seedlings are centrifugal and, in confined volumes as in containers, they tend to form an external 'cage' at the boundaries of the container. The form of the roots is governed by the period of time the roots are confined - the longer the time the greater the development; the rate of growth - the greater the rate of growth the greater the root development, and lastly - the form of the container - vertical ribs will result in a vertical root 'cage'. Each one of these - length of time, rate of growth, and nature of container - are controllable and should be prescribed in relation to the species and the results desired.

The interactions between root form of the planted tree and the cultural practices at out-planting appear to have received much less attention than those practices in the nursery. There is evidence that the nature of site preparation may well affect the suitability of planting stock and this in turn relates to the soil conditions of the planting site. The chief factor is the degree to which the roots can exploit the soil in which they are placed. The dynamics of soil water movement and the evapo-transpirational losses from the seedlings should be the focus of attention. Thus a study of initial outplanting survival can only be interpreted sensibly if the root-soil water dynamics are considered as the central theme. Results with plugs or tubes, from roots that grow from the bottom of the container, or the presence of adventitious roots and the extent of root development can then be placed in the context of plant-soil water relationships.

Discussions of the influence of cultural practices on root form serve to emphasize how little our appreciation is of the physiological controls of root growth for many of our forest tree species.

2. Root form as modified by environmental factors.

There is a voluminous literature which deals with observations of tree root systems in relation to environmental factors, mainly soil properties. Yet clearly, relationships may vary for the same species under a different combination of environmental circumstances but with certain factors constant. Determination of the extent of genetic control would appear to be necessary prior knowledge if interpretation of results is to be meaningful. To a large degree we have been on the horns of a dilemma. Most of our present knowledge derives from observational studies - non experimental and largely lacking in controls. In order to gain statistically valid experimental data, we have usually opted for shorter term studies which may be erroneous if extrapolated to the longer time period over which most of our forests grow.

I believe that, starting with our present knowledge of root-environment relations, we could well re-appraise some of our conclusions, or at least the conclusions which are commonly espoused by field management foresters. For example, the planting of a species with an inherently shallow-root form on deep unconsolidated geological materials - often erroneously equated with deep soils - would generally be considered inappropriate. But such a planting could be successful, from a management point of view, if the soil profile in the deep unconsolidated materials was shallow and reflected a very superficial zone of optimum moisture and nutrient supply.

3. Root form as it changes with time, stand development and management practices.

This is the area of knowledge which is most scant. It relates largely to the sources of our information, already mentioned, which are either observational at one point in time or derived experimentally over relatively short periods of time. There is no basic substitute for proper documentation over the long period on stand development in relation to
known conditions of root form and environmental factors. The challenge is to obtain data in the shorter run which will enable us to draw conclusions about the 'most probable' results from some set of circumstances. Usually, our first urge is to set up a new research project. I admonish caution and a conservative approach! Frequently, present knowledge, placed in logical sequence, followed by appropriate observation can provide a satisfactory 'most probable' conclusion without the necessity of prolonged, expensive and often inconclusive experimentation. Let me cite an example. The twisting of seedling roots, especially in containers gave rise to the notion that entwined roots could, in fact, 'strangle' or so distort the flow of photosynthate, water and nutrients as to seriously affect the tree's development. Yet, we have known for decades that root fusions or grafting were a common phenomenon in many of our tree species and that it took place without any seemingly deleterious results. We also have many plantations both of bareroot and container stock in which a simple destructive sampling below the root collar would illustrate the results of fusion of seedlings' roots such that many cambia unite to form one circumferential cambium. Knowledge of the extent and rapidity of intraspecific root grafting would seem to me to give the clue as to whether or not possible difficulties might emanate from roots growing in close contact.

At this symposium there has been valid concern expressed about the influence of root form on stand performance especially as it affects windfirmess. The capability of a species to generate adventitious roots would be a prime disposing factor. Thus 'a priori' the probable predisposition of certain species - some of the pines, for example - to lack of windfirmess is likely because of their lesser ability to produce adventitious roots. Greater attention must then be focused on these species in relation to cultural practices affecting root form including the actual outplanting practices. The appropriate form or stage of seedling developed together with the selection of a proper planting technique, may obviate a problem without the need for large-scale experimentation.

Relatively little information is available on the changes in root form and extent with stand density. Lack of windfirmess which may be evident a few years after planting as each tree develops a larger crown may disappear as the crowns close and the stand becomes self-supportive. Hence, the initial density at which a plantation is established and the rate of crown closure will determine to some degree the period over which the stand may be most sensitive to wind. As the process of natural thinning occurs those trees that are less windfirm, possibly because of root deformation will likely succumb earlier and this may account for the observation in one of the papers that with increasing age of stand the frequency of trees with root deformation tends to decline. Other related factors affecting the tree's ability to compete in the stand may stem from root form. The behaviour of a clonal stand would provide some interesting insights into certain aspects of stand development.

Although the possible increase in susceptibility to disease of trees with root deformation has been mentioned, there does not appear to be much clear evidence, one way or the other, on this matter. Again, I suspect that generalizations should be ruled out of order. It is quite conceivable that if root form were to reduce a tree's vigour then this could predispose it to certain pathogens. Here again the interplay between root extent, environmental factors, stage and rate of stand development provide a complexity which I suspect precludes simple answers, although I would suggest that a simple approach to such a complex system is indicated. Much previous work suggests that the situations in which a modified root form would have the greatest effect in predisposing the tree or stand to disease or insect attack will likely be where periodic and significant changes in moisture supply and aeration in the rooting zone occur.

Fundamentally, as development of even-aged plantations proceeds there is, normally, a reduction in stand density. The degree to which management practices such as thinning, and fertilization will change the pattern of stand growth and development may well modify the effects that initial root form may have. Thinning normally releases additional rooting space for the residual trees. If residual trees already have root fusions with roots of the trees whose boles are removed, an instant root expansion has effectively taken place.

4. Root form and the new forests.

Apart from scientific justification and interest, studies of root form can be considered in the context of the objectives for which a new forest is being created. Concern over root form may be misplaced if it can be shown that it plays no significant role in the development or the yield of the new forest where short rotation plantations are established to provide maximum fibre yield. Our concern for root form effects may well be limited to initial survival and early stand development.
Where longer rotations and greater sizes are the objectives, then certain alternatives may arise. If we know that our nursery practices will produce a certain number of malformed root systems which, while not affecting initial field survival, will predispose the trees to mortality in the sapling and polewood stages of development then, we have built in a 'natural' thinning process. It is analogous to a row by row by row mixture of two species such as red pine (Pinus resinosa Ait.) and eastern white pine (Pinus strobus L.) which under certain conditions after the first 10 to 15 years of almost equal species' development reverts gradually to an almost pure red pine stand in 30 to 40 years and most of the white pine is outgrown. The alternative may be that we do not want a natural thinning but desire to make thinnings not only to provide intermittent yields but also to allow for conscious selection towards the ultimate crop trees. With these objectives the production of seedlings with uniform and optimum root form may have a high priority.

So far attention has been given to the trees of the new forest, but if we look not only at this forest, but also at the soil processes related to it, we may perceive an area of interest that has received less attention than it deserves. Anyone who has examined soil profiles in relation to forest trees exhibiting a wide range of root form cannot help recognizing the implications of roots in many of the soil weathering processes. The distribution and movement of water in soil is closely related to tree roots; the production of carbon dioxide together with the array of biological, chemical and physical effects associated with the rhizosphere serve to emphasize root forms as integral components in soil profile development. By a deliberate choice of species with its associated root form and development we are setting in place in the soil something which may alter the extent of soil processes. The alteration may not be easily assessed, if recognized at all, in the short term but may, over a period of several decades, exert a profound influence on both the nature of the soil and future forest development.

In conclusion, this symposium will have been a success not because it has provided an opportunity for so many investigators to share the results of their studies; this can be done through the medium of scientific and professional journals. Rather, it will have been a success because it provides an opportunity, collectively, for us to see not so much the state of our present knowledge, but the vacuums in both knowledge and understanding that we have of root form and development.
CLOSING REMARKS

J. B. Bruce
Forester i/c
Reforestation Division
Ministry of Forests
Province of British Columbia
Victoria, B.C., Canada

First, on behalf of all of us, I would like to express my appreciation to the Co-chairmen, Jim Kinghorn and Ev Van Eerden, and to their committee, for organizing such a successful symposium. It has not been an easy task, in view of the many countries involved, and it has occupied much of their own time during the past year.

Secondly, my sincere thanks to all the speakers, and a special word of thanks to those from outside the North American continent who had to travel vast distances to get here. My thanks also go to Ken Armson, our summary speaker, who succeeded in putting the discussions of the entire meeting in a realistic perspective.

Finally, improvement of practices involves problem identification, innovative research and development, practical implementation of new knowledge and technology, and, above all, effective communication. Therefore, in closing this meeting and wishing you a safe journey home, I express the sincere hope that you will continue that vital process of international communication which figured so prominently in the conduct of this meeting.
APPENDIX I -- BIBLIOGRAPHY ON ROOTS OF TREES

Joanne M. Burgess and E. Van Eerden

This bibliography on tree roots was prepared to broaden the information base on tree roots provided by the papers in these Proceedings. From the preliminary compilation of titles prepared for the Symposium, we have expanded the bibliography to include all pertinent references cited in various Symposium papers, as well as various other titles brought to our attention subsequent to the Symposium. It is emphasized, however, that we made no attempt to review all literature on roots, but searched for and included in the bibliography only those references which were deemed to be relevant to the subject: "Root Form of Planted Trees".

2/ Respectively, Forest Assistant and Forester, Reforestation Division, Ministry of Forests, Province of British Columbia, Victoria, B.C.


(Translation, Environment Canada No. 00ENV TR-1149. 1976. 10 p.)


James, J. E., and H. V. S. Dier. 1968. Wind damage in Forestry Commission forests and its influence on management. Supplement to Forestry, p. 78-83.


Lindström, A. 1978. Rotdeformation i olika typer av plantodlingssystem samt möjligheter att begränsa rotdeformation. [Root deformation in different types of plant growing systems and possibilities of reducing root deformation.] Institutionen För Skogsföryngring Rapporter och Uppsatser No. 91, 95 p. (Environment Canada Translation O0ENV TR-1710, 93 p.)


Roze, E. 1938. Stādu saknu sakārtojuma un vasas angstuma pieauguma korrelācija. [Correlation between the disposition of the roots and the height growth of plants.] Reports of the Latvian Forest Research Station No. 9, 61 p.


APPENDIX II -- REGISTRATION LIST

Clark Akins,
Murray Pacific Corp.,
P. O. Box 184,
Eatonville, Washington 98328,
U.S.A.

Alvin Alm,
University of Minnesota,
Cloquet Forestry Center,
175 University Road,
Cloquet, Minnesota 55720,
U.S.A.

Dick Altmann,
Department of Energy &
Natural Resources,
Forest Technology School,
Box 880,
Hinton, Alta. T0E 1B0

Earl Anderson,
Syncrude Canada Ltd.,
Conservation Department,
P.B. #4009,
Fort McMurray, Alta. T9H 3L1

David Armit,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

Kenneth A. Armstrong,
Ontario Ministry of Natural
Resources,
Room 3605, A, Whitney Block,
Parliament Buildings,
Toronto, Ontario M7A 1W3

James T. Arnott,
Canadian Forestry Service,
Pacific Forest Research Centre,
506 W. Burnside Road,
Victoria, B.C. V8Z 1M5

Al Attema,
Beaver Plastics Limited,
12806 - 63 Street,
Edmonton, Alta. T5A 0W2

Charles Backman,
MacMillan Bloedel Ltd.,
Sarita Division,
Port Alberni, B.C. V9Y 7N3

William J. Ball,
Canadian Forestry Service,
Northern Forest Research Centre,
Department of Environment,
5320 - 122nd Street,
Edmonton, Alta. T6H 3S5

Robert M. Barron,
Head Paper Co.,
P. O. Box 508,
Escanaba, Montana 49829,
U.S.A.

T. Ian W. Bell,
Fiji Pine Commission,
P. O. Box 521,
Lautoka, Fiji

M. Victor Bilan,
Stephen F. Austin State
University,
P. O. Box 6109,
Nacogdoches, Texas 75962,
U.S.A.

Alfred Borchert,
Bureau of Land Management,
Colton, Oregon 97017,
U.S.A.

J. Denys Bourque,
Fraser Companies Limited,
27 Rice Street,
Edmundston, N.B. E3V 1S9

Ralph Bower,
MacMillan Bloedel Ltd.,
65 Front Street,
Nanaimo, B.C. V9R 5H9

L. G. Brace,
Canadian Forestry Service,
Northern Forest Research Centre,
5320 - 122 Street,
Edmonton, Alta. T6H 3S5

Douglas W. Brewis,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

Robin G. Brown,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

John B. Bruce,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

A. Nigel Burdett,
Ministry of Forests,
Province of British Columbia,
514 Government Street,
Victoria, B.C. V8W 3E7

William C. Carlson,
Crown Zellerbach Corporation,
P. O. Box 509,
Aurora, Oregon 97002,
U.S.A.

James H. Cayford,
Canadian Forestry Service,
Great Lakes Forest Research
Centre,
Box 490,
Sault Ste. Marie, Ontario P6B 5S3

G. D. Chaster,
Municipality of Saanich,
520 Selkirk Avenue,
Victoria, B.C. V9A 2T1

C. Geoffrey R. Chavasse,
New Zealand Forest Service,
c/o Forest Research Institute,
Private Bag,
Rotorua, New Zealand

M. Bruce Clark,
Ministry of Forests,
Province of British Columbia,
515 Columbia Street,
Kamloops, B.C. V2C 2T7

Richard Clarke,
Ontario Ministry of Natural
Resources,
108 Robinson Drive,
Thunder Bay, Ontario P7A 6G5

Brian D. Cleary,
Oregon State University,
Extension Service,
Corvallis, Oregon 97331,
U.S.A.

Russell D. Cozens,
Ministry of Forests,
Province of British Columbia,
1600 3rd Avenue,
Prince George, B.C. V2L 3G6

Andre L. D'Aoust,
Centre de Recherches Forestieres
des Laurentides,
C.P. 3800,
Ste-Foy, Quebec G1V 4C7
Jean de Champs,  
Association Forêt-Cellulose,  
11 Blvd. Victor Hugo,  
86000-Limoges,  
France 87000

W. J. Bruce Devitt,  
Pacific Logging Co. Ltd.,  
P. O. Box 10,  
Victoria, B.C. V8W 2M3

Ken Donkersley,  
Pacific Logging Co. Ltd.,  
P. O. Box 10,  
Victoria, B.C. V8W 2M3

Michael H. Drinkwater,  
Canadian Forestry Service,  
Pacific Forest Research Centre,  
506 W. Burnside Road,  
Victoria, B.C. V8Z 1M5

John M. Duncan,  
MacMillan Bloedel Ltd.,  
Kennedy Lake Division,  
Ucluelet, B.C. V0R 3A0

Lorne F. Ebell,  
1653 Longacre Drive,  
Victoria, B.C. V8N 2M9

Slavoj Eis,  
Canadian Forestry Service,  
Pacific Forest Research Centre,  
506 W. Burnside Road,  
Victoria, B.C. V8Z 1M5

David C. F. Fayle,  
Ontario Forest Research Centre,  
Ontario Ministry of Natural Resources,  
Maple, Ontario L0J 1E0

Stephen Ferdinand,  
Alberta Forest Service,  
23 Flint Crescent,  
St. Albert, Alta. T8N 1Y7

Bent Gerdes,  
Silvaseed Company,  
P. O. Box 118,  
Roy, Washington 98580,  
U.S.A.

Alex Geodhard,  
Weyerhaeuser Co.,  
P. O. Box 540,  
Chehalis, Washington 98532,  
U.S.A.

Ralph Gray,  
Grayco Harvesters,  
P. O. Box 86,  
Heidelberg, Ontario NOB 1Y0

Søren Grene,  
Forester, Danish Land Development Service,  
P. O. Box 110,  
DK-8800 Viborg,  
Denmark

Stig Hagner,  
Svenska Cellulos,  
S-851 88 Sundsvall,  
Sweden

Helmer Hahn,  
Ministry of Forests,  
Province of British Columbia,  
355 Burrard Street,  
Vancouver, B.C. V6C 2H1

Philip F. Hahn,  
Georgia-Pacific Corporation,  
P. O. Box 1618,  
Eugene, Oregon 97401,  
U.S.A.

Carl Halland,  
Forestry Branch,  
Department of Tourism & Renewable Resources,  
Room 300, Prov. Office Building,  
Prince Albert, Saskatchewan S6V 1B5

Ronald D. Hallett,  
Canadian Forestry Service,  
Maritime Forest Research Centre,  
P. O. Box 4000,  
Fredericton, N.B. E3B 5P7

Richard W. Harris,  
University of California,  
Environmental Horticulture,  
Davis, California 95616,  
U.S.A.

H. P. Harrison,  
University of Alberta,  
Department of Agricultural Engineering,  
Edmonton, Alta. T6G 2E1

Renald Hawey,  
Quebec Department of Lands & Forests,  
200 B Chemin Ste-Foy,  
Quebec, Quebec G1R 4X7

Ronald L. Hay,  
University of Tennessee,  
Department of Forestry,  
Wildlife & Fisheries,  
P. O. Box 1071,  
Knoxville, Tennessee 37901,  
U.S.A.

Peter Heide,  
Scott Paper Company,  
Northwest Operations,  
Hamilton, Washington 98255,  
U.S.A.

A. Kåre Hellum,  
University of Alberta,  
Department of Forest Science,  
Edmonton, Alta. T6G 2E6

Wayne A. Hite,  
Champion International Corp.,  
Champion Timberlands,  
1600 Valley River Drive,  
Eugene, Oregon 97401,  
U.S.A.

Eef Hoedemarker,  
Corbit's Nurseries,  
2396 - 272nd Avenue,  
Aldergrove, B.C. V0X 1A0

John Hopkins,  
Canadian Forestry Service,  
Pacific Forest Research Centre,  
506 W. Burnside Road,  
Victoria, B.C. V8Z 1M5

Terence G. Honer,  
Canadian Forestry Service,  
Pacific Forest Research Centre,  
506 W. Burnside Road,  
Victoria, B.C. V8Z 1M5

Ralph F. Huber,  
Canadian Forestry Service,  
Northern Forest Research Centre,  
5320 - 122nd Street,  
Edmonton, Alta. T6H 3S5

J. Hughes,  
U.S. Forest Service,  
Portland, Oregon 97208,  
U.S.A.

Håkan Hultén,  
Royal College of Forestry,  
Garpenberg,  
Sweden S 770 73

Steven Hutchison,  
Georgia-Pacific Corporation,  
P. O. Box 1618,  
Eugene, Oregon 97401,  
U.S.A.

Olavi Huuri,  
Finnish Forest Research Institute,  
Unioninkatu 17A,  
00170 Helsinki 17,  
Finland
Karl-Åke Jansson, 
Korsnäs-Marja AB, 
Forest Dept., 
Gävle, 
Sweden S-801 11

Sally John, 
MacMillan Bloedel Limited, 
65 Front Street, 
Nanaimo, B.C. V9R 5H9

Harry Johnson, 
Canadian Forestry Service, 
Northern Forest Research Centre, 
5320 - 122 Street, 
Edmonton, Alta. T6H 3S5

Robert C. Jones, 
Ministry of Forests, 
Province of British Columbia, 
557 Superior Street, 
Victoria, B.C. V8W 3E7

Ingemar S. Karlsson, 
Ministry of Forests, 
Province of British Columbia, 
Mesachie Lake, B.C. V0R 2N0

James M. Kinghorn, 
Canadian Forestry Service, 
Pacific Forest Research Centre, 
506 W. Burnside Road, 
Victoria, B.C. V8Z 1M5

Clarence M. Kooistra, 
Ministry of Forests, 
Province of British Columbia, 
3605 - 192nd Street, 
Surrey, B.C. V3S 4N8

Vladimir J. Korelus, 
Pacific Logging Co. Ltd., 
P.O. Box 10, 
Victoria, B.C. V8W 2M3

Dick Kosick, 
Tahsis Company, 
Box 220, 
Gold River, B.C. VOP 1G0

Peter Laird, 
U.S. Forest Service, 
Region I, Federal Building, 
Missoula, Montana 59807, 
U.S.A.

Raymond Lamarre, 
Quebec Lands & Forests Dept., 
200 B Chemin Ste-Foy, 
Quebec, Quebec G1R 4X7

Wesley Lawrence, 
Procter & Gamble Cellulose, 
Mail Bag 1020, 
Grande Prairie, Alta. T8V 3A9

Albert L. Leaf, 
State Univ. of New York, 
College of Environmental 
Science and Forestry, 
Syracuse, New York 13210, 
U.S.A.

Robert M. Lee, 
Champion Timberlands, 
P.O. Box 547, 
Lebanon, Oregon 97355, 
U.S.A.

Ola Lindgren, 
College of Forestry, 
Skogshögskolan, S-10405, 
Stockholm, Sweden

Gary C. Lloyd, 
Ministry of Forests, 
Province of British Columbia, 
Market Place, 
Prince Rupert, B.C. V8J 1B9

James N. Long, 
Weyerhaeuser Company, 
Western Forestry Research 
Center, 
505 North Pearl Street, 
Centralia, Washington 98531, 
U.S.A.

Stephen W. Lorimer, 
Crown Zellerbach Canada, 
Box 609, 
Ladysmith, B.C. VOR 2E0

Anthony J. Lukes, 
Champion Timberlands, 
Box 3598, 
Missoula, Montana 59806, 
U.S.A.

David G. Lund 
General Delivery, 
Armstrong, B.C. V0E 1B0

Bryon W. Loucks, 
Weyerhaeuser Company, 
Western Forestry Research 
Center, 
505 North Pearl Street, 
Centralia, Washington 98531, 
U.S.A.

Keith W. McClain, 
Ministry of Natural Resources, 
Province of Ontario, 
P.O. Box 2960, 
Thunder Bay, Ontario P7C 5G5

John F. McGarva, 
Technolog Inc., 
P.O. Box 25, 
Bandar Pahlavi, Iran

Robert G. McIninn, 
Canadian Forestry Service, 
Pacific Forest Research Centre, 
506 W. Burnside Road, 
Victoria, B.C. V8Z 1M5

Donald McMullan, 
B.C. Forest Products Ltd., 
Box 130, 
Crofton, B.C. V0R 1R0

Gale W. Matson, 
3M Company, 
3M Center, Bldg. 219-1, 
St. Paul, Minnesota 55101, 
U.S.A.

Bill Mattes, 
Silviculture, 
Northwestern Pulp & Power Ltd., 
Box 2116, 
Hinton, Alta. TOE 1B0

R. Glenn Matthews, 
Ministry of Forests, 
Province of British Columbia, 
557 Superior Street, 
Victoria, B.C. V8W 3E7

Owe Martinsson, 
Swedish College of Forestry, 
S-90187 Umeå, Sweden 
(visiting scientist at 
Pacific Forest Research Centre, 
506 W. Burnside Road, 
Victoria, B.C. V8Z 1M5)

John W. Maxwell, 
Ministry of Forests, 
Province of British Columbia, 
3605 - 192nd Street, 
Surrey, B.C. V3S 4N8

John Moxal, 
Weyerhaeuser Company, 
Southern Forestry Research 
Centre, 
Hot Springs, Arkansas 71901, 
U.S.A.
Troy K. Moore, Publishers Paper Co., 419 Main Street, Oregon City, Oregon 97045, U.S.A.

Helmut Mueller, Ministry of Forests, Province of British Columbia, Kokkilah Nursery, Box 816, Duncan, B.C. V9L 3Y2

Lawrence Newman, Canadian Forestry Service, Forest Management Institute, Ottawa, Ontario K1G 3Z6

Göran Örlander, Swedish State Forestry Board, Skogsvårdsstyrelsen, Gävleborgs Län, S02 28 Gävle, Sweden

Lars-Olof Österström, Vänernsk Economic Association, Box 326, 651 05 Karlstad, Sweden


Gary A. Patrunco, MacMillan Bloedel Limited, MacMillan Bloedel (Alberni) Ltd., Port Alberni, B.C. V9Y 7N4

Joseph J. Pegues, Crown Zellerbach Canada, Box 609, Ladysmith, B.C. V9L 2E0

Norman R. Pelton, Pelton Reforestation Ltd., 1227 York Street, Maple Ridge, B.C. V2X 5S1

Frank Pendl, Ministry of Forests, Province of British Columbia, 355 Burrard Street, Vancouver, B.C. V6C 2H1

Per Persson, Svenska Cellulosa Aktiebolaget, SCA, S 851 88 Sundsvall, Sweden

Carol L. Preisig, Crown Zellerbach Corporation, P. O. Box 509, Aurora, Oregon 97002, U.S.A.

Fred A. Prince, Jr., 1076 Broadway Hwy., R.2, Charlotte, Michigan 48813, U.S.A.

Norman O. Rischbieter, Weyerhaeuser Co., 505 N. Pearl Street, Centralia, Washington 98531, U.S.A.

Gary A. Ritchie, Weyerhaeuser Co., 505 N. Pearl Street, Centralia, Washington 98531, U.S.A.

Jack L. Robinson, Ministry of Forests, Province of British Columbia, 515 Columbia Street, Kamloops, B.C. V2C 2T7

Peter E. Robson, Ministry of Forests, Province of British Columbia, 557 Superior Street, Victoria, B.C. V8W 3E7

James Rodgers, Georgia Pacific Corp., P. O. Box 580, Toledo, Oregon 97391, U.S.A.

James K. Roush, Department of Natural Resources, Forest Land Management Division, Olympia, Washington 98504, U.S.A.

Richard Schaefer, Potlatch Corporation, P. O. Box 1016, Louisville, Idaho 83501, U.S.A.

Ralph L. Schmidt, Ministry of Forests, Province of British Columbia, 557 Superior Street, Victoria, B.C. V8W 3E7

Jimmy Sedore, Department of Natural Resources, Forest Land Management Division, Olympia, Washington 98504, U.S.A.

Lorie Selander, Illinois Tool Works Incorporated, 1140 West Bryn Mawr Avenue, Itasca, Illinois 60143, U.S.A.

Marcel Simard, Quebec Lands and Forests Department, 200 B Chemin Ste-Foy, Quebec City, Quebec G1R 4X7

Nils E. Sjoberg, Ministry of Forests, Province of British Columbia, 557 Superior Street, Victoria, B.C. V8W 3E7

Henry A. Spencer, Spencer-Lemaire Industries, 10310 - 112th Street, Edmonton, Alta. T5K 1N1


Karel J. Stoszek, University of Idaho, College of Forestry, Wildlife and Range Sciences, Moscow, Idaho 83843, U.S.A.

Bruce C. Suffern, Illinois Tool Works Inc., 1140 West Bryn Mawr Avenue, Itasca, Illinois 60143, U.S.A.

Roy F. Sutton, Canadian Forestry Service, Great Lakes Forest Research Centre, P. O. Box 490, Sault Ste. Marie, Ontario P6A 5M7

L. Svensson, Swedish Forest Service, Stockholm, Sweden

James R. Sweeten, Ministry of Forests, Province of British Columbia, 3605 - 192nd Street, Surrey, B.C. V3S 4N8
Frank A. Ter Bush,
USDA Forest Service,
Box 3623,
Portland, Oregon 97208,
U.S.A.

Jean-Pierre Tetreault,
Quebec Lands and Forests Dept.,
200 B Chemin Ste-Foy,
Quebec City, Quebec G1R 4X7

Richard W. Tinus,
USDA Forest Service,
Bottineau, North Dakota 58318,
U.S.A.

O. Raymond Travers,
Ministry of Environment,
Parliament Buildings,
Victoria, B.C. V8W 3E7

Jan Twetman,
Hilleshog AB,
S-261 23 Landskrona,
Sweden

Evert Van Eerden,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

Philip F. Van Mol,
Ministry of Forests,
Province of British Columbia,
540 Borland Street,
Williams Lake, B.C. V2G 1R8

Alan H. Vyse,
Ministry of Forests,
Province of British Columbia,
540 Borland Street,
Williams Lake, B.C. V2G 1R8

R. Arthur Waldie,
Ministry of Forests,
Province of British Columbia,
518 Lake Street,
Nelson, B.C. V0L 4C6

Brian Wallach,
Alberta Forest Service,
11th Floor, Petroleum Plaza
South,
9915 - 108 Street,
Edmonton, Alta. T5K 2C9

David P. Wallinger,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

Gordon W. Wallis,
Canadian Forestry Service,
Pacific Forest Research Centre,
506 W. Burnside Road,
Victoria, B.C. V8Z 1M5

Glenn Weyenberg,
Keyes Fibre Company,
160 Summit Avenue,
Montvale, New Jersey 07645,
U.S.A.

Paul Wilén,
Korsnäs-Marma AB,
Forest Department,
Gävle, Sweden S-801-11

John G. Wittmeyer,
U.S. Department of Interior,
Bureau of Land Management,
Coos Bay District,
333 South Fourth Street,
Coos Bay, Oregon 97420,
U.S.A.

Michael H. Wyeth,
Ministry of Forests,
Province of British Columbia,
557 Superior Street,
Victoria, B.C. V8W 3E7

Cheng-Ping Yen,
University of Missouri -
Columbia,
1-30 Agriculture Building,
School of Forestry,
Columbia, Missouri 65201,
U.S.A.

Edward L. Young,
Ministry of Forests,
Province of British Columbia,
Parliament Buildings,
Victoria, B.C. V8W 3E7

Joe B. Zaarr,
Forestry School,
Oregon State University,
Corvallis, Oregon 97331,
U.S.A.

Robert E. Zeller,
ITT Rayonier Incorporated,
P.O. Box 539,
Hoquiam, Washington 98550,
U.S.A.
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Direct enquiries to .

Director, Silviculture Branch
Ministry of Forests
Province of British Columbia
Legislative Buildings
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or

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