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STRATEGIC REVIEW OF PHYSIOLOGY

Ministry of Forests
Research Branch
Victoria
BC

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FOREWORD AND ACKNOWLEDGEMENTS

The internal Strategic Review of Physiology Research was initiated by Henry Benskin while he was Manager, Forest Renewal Research, Research Branch, Ministry of Forests. The review was conducted by C.D.B. Hawkins, Ph.D. and P. Puttonen, Ph.D. Authorship was determined alphabetically by surname.

All participants are thanked for taking time from their schedule to discuss the issues with the authors and for their valuable input into the review process. Ian Cameron, Al Mitchell and John Russell are thanked for their reviews of the draft.

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1 INTRODUCTION

1.1 Societal and forestry needs for new research

The practice of forestry and forestry research has changed from being internally focused and directed to being focused on issues raised by people and organizations outside of the traditional forestry community, the public. Society is identifying what it thinks to be important. This not only has had a significant impact on forestry practices but on what are topical, high priority research issues. Such issues include (not inclusive nor ranked):

biodiversity,
old growth,
integrated resource management,
gene resource management,
forest management alternatives to clearcuts,
sustainability of ecosystems, and
climate change.

Common or typical to these issues is that they are ecological, stress related, non reductionist and display many dimensions and time scales and are even more complicated than regeneration physiology. In many instances, physiological research would facilitate understanding of these issues if a systems view were taken. However, it is not economical to solely apply the research approach of 'measure and reaction' because field experiments tend to grow in scope and number (Smolander and Raitio 1991). Also, 'measure and reaction' and the individual researcher, *i.e.* the 'traditional approach', does not generate information about the responses of forests to environmental changes fast enough and with sufficient detail to be of great use for resource managers. The emerging research issues require integration of several research approaches and disciplines.

1.2 Objectives of the Strategic Review of Physiology

The objectives of the review were fourfold:

- (i) determine the present direction of the overall physiology program;
- (ii) ascertain the strengths and weaknesses of the overall program;
- (iii) identify non traditional areas where physiological research could assist in answering some of the present and future high priority research issues;
- (iv) highlight where organizational structure and resource allocation are impediments to meeting current and long-term physiological research obligations.

The review was accomplished by discussions with Research Branch Physiologists, Regional Forest Science Officers, Silviculture Branch Director, Forestry Canada Scientists and Research Managers, faculty from Simon Fraser University and the Universities of British Columbia, Northern British Columbia and Victoria, Forest Engineering Institute of Canada Silviculture Researcher and industrial practitioners (Appendix I).

2 CURRENT IMPACT OF PHYSIOLOGY RESEARCH PROGRAM

2.1 Role of physiology research

Plant physiology relates the effect of environment on plant processes at various hierarchical levels of organization: such as, organelle-cell-organ-tissue-single plant. The response of plant-population-ecosystem

levels and associated processes to their environment is in the field of ecology. Physiology can contribute significantly to understanding of ecological phenomena through investigation of underlying mechanisms and their regulation.

The Research Branch has 13 plant physiology researchers. They are Drs. W. Binder, P. Comeau, C. Hawkins, C. Leadem, S. L'Hirondelle, P. Puttonen, M. Stoehr, R. van den Driessche, J. Weber and Misters G. Harper, M. Krasowski, J. Russell and D. Simpson. Their fields of specialization include nutrition, water relations, cold hardiness, manipulation of dormancy, seed germination and biochemistry, pollen, flowering, seed production, genetics, nursery culture, stock quality assessments, vegetation and hardwood management (for more detail see Appendix II). Though focused on seed and seedlings, their research methods and technical expertise can, in most cases, also be applied to trees.

Most of the physiology projects and the program have had a provincial or regional (particularly the Research Stations) impact. The impact is, however, difficult to quantify as informal discussions and recommendations leading to operational implementation are seldom documented. A recent bibliography of forest practices in British Columbia, includes documents produced by Forest Renewal Physiologists (Anonymous 1992a). Research accomplishments that have increased the success and profitability of reforestation include production of better quality and quantity of seed orchard seed, improved seed handling protocols, improved nursery practices and stock quality assessments, site preparation research and testing of brushing treatments which in all likelihood, have jointly facilitated the increase in plantation survival during the past decade in British Columbia from 50 to 80 plus percent.

External discussions indicate the research is well received and accepted in the Forest Regions and the forestry community in general. However, the perception is that the focus was and is on seedling research (*i.e.* nursery). The regions will seek physiological collaborators for their projects as required. For apparent basic physiology problems, they go to universities rather than Research Branch because of apparent reluctance by some Branch staff to collaborate with regions. Concern was expressed by the regions that regional staff have been viewed as technical support rather than as professional colleagues by physiologists in the past. National and international impact has mainly been in the research community. The impact has probably been greater at the international rather than the national level.

Products from physiology research include research results presented in writing for journals, books, and proceedings, orally at technical meetings, technical advice to operations including operational implementation, seminars, workshops and training. In an applied organization, it is difficult to weight the relevance of these and thus, to assess the impact of the overall program.

Most of the research has focused on practical problem solving with less emphasis placed on the generation of scientific knowledge or the basic research component. However, all interviewees agreed that any applied program requires a basic component to be successful for the long-term. The size of the basic component is certainly program specific, depending on the state of knowledge in the field.

2.2 Strengths of the physiology program

Research scientists in the Physiology Program have various professional skills. They work on applied research problems and when required, have a basic research component. The scientists have many roles. They i) generate new knowledge through their original work to solve present and future problems, ii) assess future options by critically evaluating alternatives of specified forest management practices (which include physiological components) and predict their consequences, iii) provide technical information for

use in forest policy making, and iv) disseminate information by other means (see products above). The traditional research of physiology, until now applied to forest management, is also available for application to new research issues in ecosystem management. This is an advantage of physiological research because research information in the form of applications is a perishable resource. It requires continued updating from applied and basic research sources.

The Physiology Program was recognized, in discussions both outside and in house, to have a high level of expertise in the fields represented. The fields represented and the relevance of the work were questioned by some. However, the quality of research was not an issue. The Physiology Program has credibility. The recent recruitment of experienced scientists probably reflects positively on the external opinion held of the Physiology Research Program. For the most part, the staff are dedicated and highly educated.

The physiologists, generally, thought they had adequate modern equipment. Support in biometrics, computer systems and audiovisual services was considered to be good. Access to and knowledge of good field sites was viewed as an asset by external colleagues.

Research Branch Physiologists are sought by the Silviculture Institute of British Columbia as lecturers because of their technical expertise and operational understanding, particularly in seedling establishment.

Research Stations are a strength. Station staff are more aware of problems and issues and are better suited to visit the field and deal with operational issues than are Victoria based staff.

2.2 Weaknesses of the physiology program

At present, there is no formal strategy for Forest Renewal or Physiology Research. A five-year strategic plan 1991/92 - 1995/96 for a research program includes Forest Renewal Research with a short description of issues (Anonymous 1990a).

Inadequate communication among Physiology Program Scientists and the rest of Research Branch was recognized most often as a major obstacle. The plant physiology expertise of the Research Branch could be better utilized in the many multifaceted research issues at hand which include a physiology component. Physiologists have a dismal record of internal cooperation, though their cooperation record with outside scientists is better. Outside scientists usually do not have an overall appreciation of what is happening in the Physiology Program.

There likely is a critical mass of physiologists in Research Branch for current research. At individual installations, where there are one or two physiologists, scientific isolation is a major problem and there is no critical mass. If research areas (fields) increase, there will no longer be a critical mass of physiologists in the Research Branch. This concern was voiced both internally and externally to the Physiology Program.

The Physiology Program has no molecular biologist and this subject is crucial in areas of stress, disease, insects and seed quality. An applied molecular biologist would complement the program.

The Physiology Program while very broad has little depth except in stress physiology, perhaps because of the way scientists appear to have been recruited. As new issue areas arose, another staff member was added (suggested above for molecular biology). This approach tends to promote an individualistic rather

than a collaborative approach. Breadth without depth ensures all the bases are covered but the work may not be up to international standards (Smolander and Raitio 1991). Linked with this is scientific mentoring or guidance; staff are recruited usually with a fresh degree, and then expected to develop a new program, for the most part on their own. A mentor or collaborative project leader would smooth this phase, promote collaboration, and add depth to the Physiology Program. At Research Stations, it would make departures of scientists less disruptive.

There is a tendency for scientists to work alone, both in laboratory and field situations, either because of individual choice or location. Fallers and buckers are not allowed to work alone and there are written work procedures to maintain 'buddy' safety (Anonymous 1990b). The same principle should apply to scientists working in the field, regardless of situation, and in the laboratory too, but for intellectual safety.

There is a general reluctance (not eager) to work in new areas. This again could be related to individualistic attitudes. It also could occur because there are no formal study leave or visiting scientist policies in place to encourage physiologists to take time and broaden their knowledge base.

The Physiology Program has not been field or 'big' tree oriented. Also, there has been little emphasis on hardwood physiology. Many of the arising physiological concerns appear to be related to these topics.

Issues raised by district and industrial staff appear to be viewed as being of less value than do those issues raised by Headquarters staff. Generally, there is little effort expended at gaining credibility with district and industrial staff, the operational community. This criticism was levelled across Research Branch, not just at the Physiology Program. There is no communication at this level!

3 NEW RESEARCH AREAS (OPPORTUNITIES)

3.1 Overall direction

The role of the Forest Service is stewardship and management of sustainable forest ecosystems. Forests are subject to greater stresses today than historically because of disease, pest and anthropogenic influences. This makes it increasingly difficult to guarantee the next generation of forests unless what is being managed is understood. To meet such objectives, increased basic knowledge is required. The National Science and Engineering Research Council (NSERC) is reducing operational funding in basic research to university scientists with the goals being to emphasize specific research areas and encourage applied (operationally relevant) work. Physiology Program Scientists may require a larger basic research component in their programs to offset this reduction, but the crux is, that it should not be at the expense of losing their operational relevance (Prof. David Ford, pers. comm.). That can be maintained with close contact to operational silviculture. The need, extent and depth of the basic component varies by research field.

It was recognized as management's (resource and research) responsibility to identify general areas of importance or issues to be addressed. The scientist's responsibility was to investigate and identify the major problems in that field. For forest research to be relevant to forest resource managers, the subject areas should be determined by working down from the information needs of management (Baskerville 1986). The research manager and scientist would then jointly set priorities of problems to be investigated while considering the feasibility of solving the problem and the cost of doing so. Management's role in leading the direction of research would be strengthened if there were more communication among research managers and scientists and there were strategic research plans in place (see Binkley and Watts 1992).

The above problem identification approach should also be taken with larger collaborative projects, either in house or between agencies.

The lack of an identified strategic plan for Forest Renewal and the Physiology Program may have restricted adoption of a broader view by the individual research programs. A plan is a set of guidelines that are continually updated and revised, not a set of hard and fast rules. If a strategic plan is extant, the lack of awareness reflects on the degree of communication between research managers and scientists. Scientists should be invited to participate with resource and research managers in developing a strategic research plan as it impacts on both groups. The success of one depends on the other. This approach implies continued manager-scientist dialogue and commitment of resources, such as personnel, land and financial support (Binkley and Watts 1992), to research.

Generally it is difficult to see new trends develop in research more than a few years in advance. This emphasizes the role of basic research and a proactive, yet flexible strategic plan. Because of uncertainties, we have to be prepared to adapt or make changes as new conditions arise. However, the priorities of clients - practitioners change frequently, so research program stability must be based, in part, on acquisition of new knowledge rather than client's immediate priorities for problem solving. Binkley and Watts (1992) conclude forest sector research should be driven by a strategic vision for the sector, not by a list of client needs. This may be more true now that issues come from society at large rather than the operational - research community.

Research should be a generator of new information and not only a clearinghouse of existing information. The latter role should be adopted by extension specialists in close collaboration with the scientists and operations' staff. We must move away from today's, often repeated, first rather than last step of large scale operational field testing of unsubstantiated hypotheses.

3.2 Areas of research

Four high priority areas where physiological research is most applicable and required have been identified based on discussions with the interviewees (Appendix I):

- i) ecosystem function and structure,
- ii) forest health and pest management,
- iii) silviculture, and
- iv) tree improvement.

The proposed research areas follow Roussel *et al.* (1991) who grouped research into three categories.

- i) Incremental - supporting specific field operations and derived from direct needs defined by operational staff. Results available in the short-term, one to two years.
- ii) Strategic - designed to provide new strategic options for resource management. Managed with clear time lines. Results probably available in three to five years, although the duration may be longer.
- iii) Support - the basic science relevant to forestry. Results and payoff in 10 to 20 years.

The priority areas, i-iv, belong to the strategic and support categories, thus emphasizing a long-term commitment to research. Also, the importance of incremental research is recognized and suggested to be maintained by a better liaison between extension and research. In this way, both specific operational and research goals can be met.

The current relevance of Physiology Program work in cold hardiness and drought resistance is associated with the predicted changes of global climate and their implications on forest management. Climate change will be difficult to address initially from a physiological perspective because of the immensity of the issue, its specific complexity in British Columbia, and the poor model resolution for the province. Gene resource allocation strategies may be an approach to addressing climate change (species, provenance deployment). Once such research were established, physiological issues could then be tackled. However, initiating physiological programs solely in this area, today, is premature.

The gap between ecophysiology and ecosystem studies seems to have widened. In some fields, like system oriented physiology, physiological entomology, and physiological pathology, successful linkages have been established. The lack of tradition in 'crossover' disciplines means well planned and directed collaborative projects will be required to address many of the non traditional research issues. However, current ecophysiological expertise at Research Branch is limited and focussed primarily at the single tree or seedling level. Provided the research were relevant, physiology would identify regulatory processes and intelligent forest management decisions could then be made based on the acquired information.

3.2.1 Forest ecosystem research

The present direction of forest management is towards ecosystem management and many decisions must be made at the landscape level. This demands knowledge of processes at the underlying lower level of hierarchy, *i.e.* stand and plant level. The stand level would appear to be an appropriate level of focus for research and management decisions because it is the basic management unit of a forest ecosystem. Ecosystem management has enhanced the need for stand level ecophysiology research. The complexity of ecosystem level questions requires close cooperation among ecophysiology, micrometeorology, ecology and growth modelling researchers.

The field is crucial to the sustainable management of the forest. Few initiatives are ongoing in this area. An understanding of the dynamics of natural stands, the response of trees to treatments or disturbance, and the performance of natural versus planted seedlings and stands will foster long-term forest sustainability. This is pursued in biological diversity and silvicultural systems research. Management of mixedwood and hardwood ecosystems should be considered a priority, especially in the northern interior.

Biological diversity

Biological diversity refers to the variety of all living organisms at all levels of organismic integration from DNA molecules to ecosystems.

At the species level, genetic diversity, phenotypic and racial, is assumed to be important to ecosystem function (Ledig 1992). Both loss of species and populations within species and subsequently among ecosystem processes will have an effect on ecosystem productivity and health. The retention of gene pools is critical to the diversity issue.

Management of non crop tree species may be vital in maintaining biological diversity. Due to a small knowledge base, the impacts of various forest management decisions are not understood across a range of biogeoclimatic zones and subzones. This could impact on the biological diversity and sustainability of these units. A related issue is the relationship between the physiology of mixedwood and coniferous stands and wildlife habitat.

Biological diversity requires a better understanding of ecosystem development. This constitutes basic knowledge about carbon cycling and nutrient dynamics of stands, adaptation of trees and other vegetation in their environment, and death processes of trees in managed and unmanaged stands, and decay of snags and fallen logs. The later two topics belong to the fields of adaptive physiology of trees and forest health, respectively. These will be described later.

The practice of high technology, intensive, sustainable forestry on some lands would allow more lands to be managed primarily for non commodity values. Plantation forestry allows one to practice biodiversity and yet maintain an economic base. This assumption (intensive silviculture) must be validated too. To do so, requires an understanding of short rotation hardwood and conifer plantation biology and physiology. Research into sustainable commodity silviculture is required to maintain viable economic levels in British Columbia.

Soil disturbance and site productivity

Harvest of thinnings, mature timber and regeneration cuttings may cause soil disturbance. A biological definition of soil degradation and its prevention or rehabilitation on such sites is crucial to sustaining long-term site productivity. In coastal British Columbia, the emphasis should be on terrain stability (landslides), mainly rehabilitation, while in the interior, it should be on vehicular compaction (prevention). Biological indicators of productivity loss are required. Tree physiology can assist in reforming the present site degradation guidelines based on soil physics and empirical biology by adding quantitative biology and physiology to the guidelines. Though short-term in outlook, the field is linked to root biology, soil biology, plantation stability (prevention of windthrow) and long-term, sustainable forest productivity.

3.2.2 Forest health and pest management

The greatest potential danger to sustainability of forests comes from this broad area (Prof. John Borden, pers. comm.). The use of silvicultural systems, other than clearcutting, is not yet based on realistic management objectives with regard to forest health. Little is known about the ecology of various pests in alternative silvicultural systems management (Anonymous 1992b). There are large areas endemic with root rots, in the interior, ready to proliferate if incorrect management decisions are made. Similarly, there are thousands of hectares of immature spruce plantations susceptible to weevil damage.

An understanding of the regulation of pathogens in forest stands (resistance and infection) is critical to good management. The physiological regulation of insect pests on spruce and pine and their impacts on growth and development is also important. The ecological role of mycorrhiza in forest establishment and development is still an issue. There also is an obvious linkage between this field, tree breeding and silvicultural research where new reforestation strategies are being tested in areas endemic with disease and pest populations.

A substantial increase in the net productivity of British Columbia forests can be gained through enhanced disease and pest management practices. Discussions should be initiated immediately to determine the best ways plant physiology can contribute to this critical area.

3.2.3 Silvicultural research

Silvicultural research includes measures to secure early establishment (site preparation, nursery culture, brushing, weeding), stand tending, partial cutting methods with thinning and regeneration cuttings, fertilization, and pruning. As such, it will be, for the most part, a major new field of research in British Columbia and forge collaborative relationships between physiology and several other programs. The research focus should be on understanding the regulation of carbon allocation both at the tree and the ecosystem level.

Nursery research

Seedling physiology, stock quality assessments and nursery cultural research were very relevant to support the rapidly expanding artificial regeneration programs of the 1970s and 1980s. The research was what research managers required at that time. There was no justification or demand for other physiological research. However, seedling physiology, stock quality assessments and nursery cultural research are becoming less important. The region of diminishing returns was reached, due, in part, to the efforts of FRDA I. Most remaining nursery problems are small issues (except to holder of problem) and short-term. They can be solved by supervised senior technical staff. Work would also be written up under supervision by senior technical staff and extended by extension specialists. Cultural issues associated with seed orchard seed is an exception and requires scientific staff and large scale collaboration across a variety of disciplines and organizations.

There is an opportunity to take what has been learned from nursery stock quality research, couple it with site limiting factors, and thereby create a physiological based risk assessment model of stock and site allocation.

Establishment

Plantation establishment and site preparation research needs to continue. This will ensure the most suitable techniques are utilized when establishing industrial forests. Failure to continue this work could have long-term productivity implications.

Forest vegetation management

There is a continuing need for research directed at answering key forest vegetation management questions. Field staff require background information to answer vegetation management questions when prescribing treatments. Questions include: i) is treatment required (is there or will there be a 'brush' problem)?; ii) what treatment should be used (site preparation- fire, mechanical, herbicide, livestock, mower; brushing- manual, herbicide, livestock)?; iii) what will be gained through treatment; and iv) what are the impacts of treatment options on other resources?

Much of the research applying to forest vegetation management has been of an empirical, applied nature (*i.e.* measure crop seedling response to different levels of competition or different treatments). Such studies are essential for demonstration, and hypothesis testing and generation.

Growth analysis techniques and gas exchange measurements have been and continue to be used in forest vegetation management studies. These should contribute to an understanding of the

mechanisms involved in competition and in crop response to different treatments. Research includes physiological implications of seedling size, seasonal timing of treatment, and different treatments for establishment and growth of crop trees.

A critical problem with applying traditional seedling physiological methods has been in linking measured physiological effects upwards to effects on whole seedling growth. Measurable (empirical) growth responses can only be detected three years following vegetation management treatment, and in many cases five or more years are required. Field staff are rarely willing to wait that long for answers. Strengthening linkages between physiological responses and whole plant growth responses might permit earlier detection of treatment effects. This deserves further exploration.

This field links with establishment (above) biodiversity, ecology and other fields in that it involves or impacts on them. Critical ecological questions include interactions between crop and non crop species, effects of non crop vegetation on seedling microenvironments and seedling responses to these conditions, development of vegetation following different disturbances, and treatment impacts on ecosystems. Biodiversity issues relate primarily to impacts of treatment options (including none) on non timber resources and values.

Partial cuttings

Partial cutting refers to any harvest entry in which less than 100 percent of the standing volume is removed: it includes stand tending, thinnings and regeneration cuttings with tree retention. The need to study alternatives to conventional clearcutting highlights the scaling issue in integrating many levels of biological organization into forest and landscape level management. In this hierarchy, the role and possibilities of physiology must be well thought out.

At these levels physiology is useful only when physical environment is the limiting factor on behaviour of the system (Allen *et al.* 1992). Most aspects of physiology are not predictive principles in large scale ecological systems. For example, in situations where the environmental constraints are reproductive, involving dispersal processes or disturbance, physiology or ecological physiology may be an unfruitful approach.

Some of the physiological research issues relating to partial cuttings as regeneration methods are being studied in the Silvicultural Systems Program of the Ministry of Forests and others. However, only a fraction of the important tree physiological questions can be addressed in this program.

Greater emphasis on natural regeneration will require a better understanding of the factors regulating cone and seed production of natural stands. An understanding of the regulation of seed germination and seedling growth and development in this competitive environment will also be required. Maintenance of or creation of biological diversity may require better information on seed banks, germination characteristics and demography of non coniferous tree species. This topic is linked with the work mentioned in 'Establishment' above.

Many research questions relate to shade tolerance of plants and competitive processes. Research in this area would benefit from ecophysiology and micrometeorology being associated with process based modelling.

In some areas of the province, forests are becoming more important as suppliers of fresh water than timber. There is a need to understand the forest's role in regulating water flow and where stand level ecophysiology is applicable in these areas.

Stand tending

Free growing standards are based on empirical observations. There is a requirement to understand the biological basis of free growing seedlings. This is especially crucial for other than clearcut silvicultural systems and for the role of hardwoods in a mixed species stand.

Fertilization

Documentation of internal nutrient cycling of British Columbia species is required for better stand management. No one is doing research on nutrition between establishment and the growth and yield phase. This is an important issue related to sustainability of productivity as is the role of hardwoods in this process. Direct and indirect effects of fertilization on the growth of individual trees and stands should be included in growth and yield models with cooperation from physiologists.

Growth and yield

Growth and yield research historically has concentrated on even aged monocultures. The capabilities of existing growth models reflect this emphasis. The increasing demand for models of mixed species and uneven aged stand management highlights the limitations of the pure and empirical approach to stand development and yield prediction. Information is required on thinning, fertilization, vegetation management, tree improvement, and prediction of the impact and control of insects and disease. Understanding the role of roots as a sink in carbon allocation is crucial in tree growth models. This issue ties closely to the role of soil biota in carbon allocation and nutrient cycling.

The current trend in growth modelling is the development of models that are more mechanistic and less empirical than previous models. Within Research Branch, the Forest Productivity and Decision Support Section is restructuring some components of the TASS model around physiological processes. Scientists in the Physiology Program could help develop components and define suitable parameters for components. Physiologists could provide biological input by offering advice, synthesizing existing information, or initiating new research efforts. They could also assist in defining the limits to which physiological processes should be used in predictive systems. The new generation models could be used to validate basic silvicultural system and tree improvement assumptions.

3.2.4 Tree breeding and improvement

Tree breeding has the opportunity to provide stock with superior qualities for industrial forestry, without threatening the biological diversity of the species. Currently there is genetically known material available for studies using seedlings as a bioassay. In these cases, the focus of research should be at the family rather than at the species level. Research issues containing a tree improvement component are adaptive physiology of trees and roots, genetics of seeds and competition processes. There is a general lack of

knowledge in adaptive physiology of trees, especially regarding nutrition and the interaction of tree with site. The role of roots and associated nutritional aspects of adaptability are also poorly understood.

Adaptive physiology will allow the breeder to ascertain physiological effects of different genetic combinations. Research on adaptive physiological traits includes stress resistance, growth and carbon allocation. Currently, tree improvement physiology is not well covered. Research on adaptive traits for selection criteria of second generation seed sources is needed. The Physiology Program's expertise in frost hardiness is available to this end but more effort is required.

The whole process of producing improved seed would benefit from physiological research. Environmental effects and impact on seed orchard seed (pollen and flower) production needs to be defined. For example, genetic parameters of seeds (seed orchard or wild collections) with respect to germination responses and patterns to environment are inadequately known. This carries forward to the nursery where cultural effects (environment) on clonal material must be quantified. Subsequent impacts on field performance should also be documented so expected gains from the breeding program materialize at rotation. This issue also requires a better understanding of the interaction between family and site. In terms of biological diversity, evaluation of genetic diversity in plantations established from seed orchard seed are requisite.

Biotechnological research on tissue culture has provided considerable new knowledge on plant organogenesis and early seedling growth and development. At this time, further investments into tissue culture by Research Branch may be premature because the funds deployed elsewhere may provide a greater return and possibly the public is not ready to accept the technology. There is a need to get the complete tree improvement story out to the public: an extension not a research topic.

Research issues and researchers should be characterized by the issues (seed orchard seed diversity in nurseries) rather than by discipline (seedling physiology). Physiologists could participate in reviews of tree breeding and improvement programs and projects, and vice versa.

3.3 Cooperation

3.3.1 Critical mass

Cooperation allows a better use of resources, be it personnel, laboratory space, equipment or funding. Few, if any, university faculty work alone. A critical mass of scientists is important for successful research progress. Only a few institutions can be self sufficient in this respect. The Physiology Program is no exception. Critical mass can be attained through liaison and cooperation with internal or external colleagues.

There are no physiologists assigned to the Regional Forest Science Programs. Regional staff and Branch physiologists can benefit from collaborative endeavours. Regional staff have more possibility of interacting with the people who have the problem. Thereby, they would bring an operational focus to cooperative projects. This would be a viable cooperative arrangement if entry level scientists were included as part of the Research Branch Physiology Program at the Research Stations. Scientists would gain regional field experience, bring physiological expertise to the regions, and increase the depth of the program at the Research Station.

All individual or organizations canvassed expressed a desire to continue, increase or initiate project specific cooperation with Research Branch physiologists.

3.3.2 Provincial

All of the scientists surveyed expressed their willingness to cooperate and decrease institutional separation; share equipment and facilities rather than duplicate them. This would allow for both a broader and deeper physiology research program in the province. To cooperate, colleagues require knowledge of what is ongoing and planned in the Physiology Program. This information is not readily available inside or outside the organization.

Regional staff, while not overly critical of working relationships with Research Stations, would like to establish new collaborative efforts with them.

3.3.3 National

The Physiology Program would benefit from visiting scientists. This is particularly true at the start of major new research projects or where the research field has no provincial tradition. Cooperation with recognized experts in the field should prevent reinventing the wheel. The concept holds true as to the utility of national and international distinguished scientists. A formal mechanism to facilitate the process must be defined.

3.3.4 International

The fairly large forest science research community in British Columbia, a critical mass, will help in attracting international scientists, particularly if there is true cooperation within the local scientific community. The nursery, stock quality, research of the past few years is viewed internationally as being among the most advanced research programs in the field. Though winding down, it still would attract foreign scientists to the province. New high priority areas and programs would benefit from international input, first in the planning phase and later in the implementation phase.

Tropical forestry

Tropical forestry issues will become even more visible because of extensive forest management and regeneration problems in these lands. The Ministry of Forests is also an executing agency for the CIDA (Canadian International Development Agency), ASEAN (Association of South East Asian Nations) project. Directing a research component to such questions may not be warranted but a technology transfer responsibility may be a viable compromise.

4 RESEARCH BRANCH ORGANIZATION AND THE PHYSIOLOGY PROGRAM

4.1 Responsibilities

The role of physiology researchers requires better definition of how much time should be devoted to research, extension/teaching and administration. A clear distinction should be made between research, development, and application rather than lumping them together as research. The levels of risk and associated time frames are quite different among the three. Job expectations are often poorly defined: what the scientist and manager think to be important are not the same, possibly because clear distinctions are not made amongst research, development and application. A formalized protocol should alleviate this concern.

Lack of communication inhibits the transfer and implementation of ideas and technology. Communications between researchers and practitioners is a major problem. They have different perceptions, different time frames, and operate on different systems levels. These differences may unintentionally decrease credibility and relevance of the research. Extension and Communication Services section could alleviate this problem.

Scientists indicated that short-term, small scale, development and application needs related to problem solving and operational concerns should be handled by extension specialists in consultation with the project specific scientist.

4.2 Recognition of risk

A progressive research program will recognize there are failure risks involved with some projects. Research projects have a greater probability of failure than do development or application projects. We must get away from the we require a product syndrome which results in the continuation of unsuitable projects. There has to be an agreed method to terminate unsuccessful projects. To minimize the initial risk of failure, research proposals must continue to be subjected to external peer review. If the payoff of an ongoing project becomes dismal, as judged by peer review and project goals, it should be terminated.

4.3 Collaborative projects

Outside individuals and organizations expressed concern there was no formal competitive process to obtain Ministry of Forests funds for collaborative physiological research projects or contract projects. It was suggested that if competitive funds were made available for collaborative projects among external and Physiology Program scientists, this would foster cooperation and alleviate the impression that project rating and funding were done behind closed doors. It should be noted there are funds that university and industrial colleagues have access to and Research Branch physiologists do not. In this vain, it was also suggested the peer review process move from using regional/provincial reviewers to using national/international reviewers.

4.4 Technical support

New research topics may need new technical equipment or facilities. Also, maintenance and upgrading of existing research facilities will be required to properly carry out projects according to accepted standards. Such requirements should be identified as early as possible in the planning process. Lack of a shared building by Research Branch easily creates discipline and scientist isolation.

4.5 Remuneration of scientists

The discrepancy in pay between biologist and forester (Licensed Science Officer) is demoralizing to scientists. This implies the government does not consider the biologist a professional and considers one's bachelor degree more important than the job being done. The pay level is also lower than in other institutions employing research scientists with similar backgrounds (ForCan, FERIC, OMNR). Secondly, the only way to increase salary is through an adversarial move to management. This removes needed expertise from the research program. This is not the case at universities and some research organizations, both government and industrial, where technical experience is recognized as being a critical and valuable contribution to the success of the organization and is rewarded accordingly.

4.6 Travel policy

Technical meetings of scientists are needed for information exchange and to maintain current knowledge in their specific fields. Travel to technical meetings cannot be viewed as a reward. It is a necessary element for progress in research, particularly when starting in new fields. With respect to this, the current out of province travel criteria are restrictive. There is considerable cooperation with researchers and institutions in the Pacific Northwest (Alberta, Washington, Oregon, Idaho and Montana). The present travel policy limits the potential to increase cooperation, develop new cooperative research areas and gain insights into new forestry practices and research issues. A more liberal approach should be taken to out of province travel in the Pacific Northwest. If the travel is planned and is in the scientist's budget, the trip should be treated much as travel within British Columbia is today. The costs of going from Victoria to Prince George or Edmonton are identical and somewhat greater than the cost of travel to Washington or Oregon.

4.7 Continuing education

In research, there is a continuous need to maintain and upgrade scientific skills because of the rapid evolution of most fields. The need is particularly great when research in new areas commences. New training can be acquired in the form of study leave, participation in advanced special courses, inviting visiting scientists and so on. Many of our external interviewees were surprised there was no formal study leave policy in place at Research Branch.

4.8 Executive briefing

Senior management in the Ministry of Forests needs to understand the uniqueness of research. Scientists are not widget producers, though the feeling among scientists is that they are often treated as if they were. Outside of physicians and perhaps, senior lawyers, research scientists are the most educated and independent segment of the Provincial Public Service. Periodical meetings between some members of the executive, senior research managers and practicing scientists could alleviate this perception/feeling.

5 CONCLUSIONS

The traditional areas of research expertise of the Physiology Research Program in plantation establishment and related topics are still important. However, there are issues emerging critical to forest management in British Columbia. Ecosystem function and structure, forest health, silviculture, and tree improvement are identified as such. These fields have physiological components and physiologists can have a substantive impact on them. However, a shift in emphasis is required. The emergent issues are primarily ecophysiological in nature. The past issues of the program have been more in the realm of "traditional" physiology. Therefore, research programs will be required to evolve or change direction totally to meet the anticipated demand of the identified challenges. It is prudent to change direction in a series of steps because of scientists' commitments to ongoing research and uncertainties about funding sources and levels.

There is a lack of communication among Physiology Program scientists, between scientists and regional forest science staff, between scientists and Research Branch management, between Physiology Program scientists and scientists of other organizations, and between scientists and their clients.

There is a willingness but little demonstration on the part of the Research Branch physiologists and most interviewees to foster communications and collaboration. If collaboration is important, a source of motivation will be required.

All scientific positions are relatively autonomous and senior. This promotes individualism and non collaborative research.

A strong applied research program has a basic research component to it. If the basic component is lacking, there will be no long-term applied research and development. This is of more concern today than in the past because NSERC is reducing its funding of basic research.

The Physiology Program and its scientists are considered to be technically sound though the relevance of some research was questioned. There also is a reluctance by Physiology Program scientists to tackle research in new areas.

The lack of an identifiable Strategic Research Plan hinders coordinated research planning at the scientific level. The present program consists of several independent research components. Coupled with the poor communications, the result is a Physiology Program in name only.

There are no formal study leave career development or visiting scientist protocols in place. This could be responsible for some of the reluctance shown by scientists to tackle new research areas.

Pay equity is an issue both from internal and external perspectives as is salary progression commensurate with growth of an individual's technical expertise.

6 RECOMMENDATIONS

6.1 High priority research

- **Four high priority areas where physiological research is most applicable have been identified.**

The areas and some important research topics are:

- i) **ecosystem structure and function,**
 - a) allocation of carbon in trees and stands,
 - b) nutrient dynamics of stands,
 - c) adaptation of trees in their environment (competition) and relationships to growth processes, and
 - d) seed germination under natural conditions;
- ii) **forest health and pest management,**
 - a) physiological basis of host-pest relationships, and
 - b) physiological impacts on growth and yield projections;
- iii) **silviculture,**
 - a) continued research on establishment physiology including comparisons between artificial and natural regeneration regimes,
 - b) physiology of conifer release, and
 - c) physiology of stand tending treatments and implications in growth and yield projections; and
- iv) **tree breeding and improvement,**
 - a) adaptation of trees,

- b) interaction of nutrients and site conditions, and
- c) genetics, physiology and disease and pest resistance and impacts on growth.

Some of these topic areas should be dealt with immediately. Collaborative or contract research projects could address some immediate issues. Redirection of some senior staff to these areas and creation of entry level scientific positions would be an expedient approach. Regardless of approach, there are new topic/issue areas to researched.

- **Organize seminars and planning sessions in the four recommended new research fields.**
Their purpose being to discuss problems, define problem statements, establish collaborative relationships, and implement the research. Along with strategic planning, this would ensure research efforts were not duplicated and that the most important work was being done in a timely and cost effective manner.
- **A five year (long-term) strategic plan should be developed in cooperation among resource and research managers and scientists.**
This would facilitate research planning and promote communications. Communication cannot be legislated. The more opportunities there are for two way exchanges, the better communications and cooperation will be and the greater utility the strategic plan would have. The plan must be flexible and should be reviewed annually to include important developments.

6.2 Communications and cooperation

- **Communication and cooperation between research managers and scientists should be promoted by identifying a major high priority topic area and having scientists and managers plan, administer and execute the project jointly.**
Prompt delivery of component parts would be rewarded by more research recognition (funds) while non delivery would be rewarded with less research recognition. Peer pressure would likely prevent the latter from occurring. A similar approach could be taken at the regional, provincial, national and international levels. A surprisingly small budget would go a long way. This approach could also be taken when awarding funds to external organizations, provided the research was collaborative with Branch scientists. Funds intended for external competition must be accompanied by explicit criteria of the funding. The approach could also focus required research in the identified high priority fields.
- **Group scientists to address research issues rather than grouping them by discipline.**
This will promote communication and collaboration as geography, regardless of scale, is a deterrent to both. The starting point in promoting research groups is through recognition of and emphasis of the strengths of individual scientists. Groups need to be flexible as projects and issues change.
- **Hold Research Branch wide and discipline specific technical meetings on a biennial or annual basis to promote dialogue.**
Outside scientists should be invited to both sessions to promote a sense of community. An annual update of publications, projects underway and a brief description of scientist's

programs (Appendix II) would communicate to outsiders what the Physiology Program is doing and raise the profile of the Research Branch.

- **Initiate discussions with extension personnel of both the Ministry of Forests and other extension agencies in British Columbia to facilitate timely and adequate dissemination of research results and other new information.**
These discussions will clarify roles and responsibilities of research and extension staff and promote dialogue among the groups.

6.3 Administrative

- **Entry level scientific positions should be established under the guidance of senior researchers or collaborative project leaders.**
Most, if not all physiologists were appointed to independent research positions regardless of previous experience, which in most cases was limited. This practice discourages communication and cooperation, whereas entry level positions could promote them. Such an approach would also ensure well qualified scientists were available to replace senior members who leave or move into management. These positions could be created by upgrading technical or junior management FTE's when they become vacant.
- **There should be a willingness or recognition on managements part to accept the inherent risk associated with doing research.**
Adequate peer review of research proposals has to be maintained to minimize the initial risk of failure. Unsuccessful or failed projects should be written off early, regardless of cost, rather than later when more has been spent and it is more difficult for the scientist to let go. This approach would make better use of limited resources and allow emergent research issues to be addressed more effectively.
- **A five year (long-term) strategic plan should be developed in cooperation among resource and research managers and scientists.** See section 6.1.
- **Liberalize Pacific Northwest travel policies.**
This would ensure that Research Branch Scientists can adequately participate in information sharing with colleagues in adjacent jurisdictions.
- **Formal programs for study leave and visiting scientists should be established.**
Such programs are crucial to ensure continued development of the physiology program and its scientists. A small budget and space at the various research facilities would allow visiting scientists to come and exchange ideas and do meaningful research. A formalized study leave policy, identifying requirements, frequency and procedures would enable scientists to have a career development plan in place. While more expensive than the current practice, it is a relatively inexpensive and rapid means to upgrade scientific skills or gain skills in new fields.
- **Pay equity is requisite within the Forest Service for doing the same job.**
Physiologists are called Research Scientists, require a Ph.D. for the position (there are exceptions), but are classified according to their undergraduate training as Biologists, Licensed Science Officers or Science Officers. All have quite different rates of pay and

benefit schedules. It may be time to create a Research Scientist position based on duties performed rather than on formal undergraduate training. If this position were created, pay could progress from entry level, \$40,000, to a senior management equivalent level, \$80,000, for the best scientists.

• **The review process undertaken here should be repeated in five years to ensure the relevance of the program and to assess the impact of these recommendations.**

This would give more validity to the present review. The credibility of a review would be enhanced if one of the members of the review committee were external to the Physiology Program and the Forest Service.

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APPENDIX I

Physiology Review Interviewees

BC Research Corporation

Dr. B. Sutton, FBC

Dr. S. Grossnickle, FBC

Forest Engineering Research Institute of Canada

Mr. E. Stjernberg, RPF

Forestry Canada

Mr. J. Arnott

Ms. A. Eastham, P.Ag.

Dr. K. McClean

Dr. A. Mitchell

MacMillan Bloedel

Ms. J. Kumi, RPF, LUPAT

Mr. C. van Oosten, RPF, AP MacBean Nursery & Poplar Program

Ministry of Forests

Mr. R. Adams, Res. Br.

Mr. H. Benskin, RPF, Silv. Br.

Mr. I. Cameron, Res. Br.

Ms. E. Hamilton, RPBio, Res. Br.

Mr. C. Heamen, RPF, Res. Br.

Dr. J. King, Res. Br.

Dr. D. Lousier, Prince George Reg.

Ms. T. Newsome, RFP, Cariboo Reg.

Mr. M. Osberg, P.Ag, Res. Br.

Mr. J. Pollack, RPF, Nelson Reg.

Dr. J. Pojar, Prince Rupert Reg.

Mr. T. Rollerson, P.Ag, Vancouver Reg.

Mr. C. Sutherland, RPF, Cariboo Reg.

Mr. A. Vyse, RPF, Kamloops Reg.

Mr. J. Woods, RPF, Res. Br.

Dr. A. Yanchuk, Res. Br.

Dr. C. Ying, res. Br.

Simon Fraser University

Prof. J. Borden

Dr. G. Lister

University of British Columbia

Dr. P. Burton, Forest Sci.

Dr. R. Guy, Forest Sci.

Prof. P. Jolliffe, Plant Sci.

University of Northern British Columbia

Prof. F. Gilbert

Prof. W. Morrison

University of Victoria

Dr. B. Hawkins

Dr. N. Livingston

Prof. J. Owens

APPENDIX II

Research Branch Physiologists and Overview of Their Programs

W. Binder, Forest Research Laboratory

Seedling Physiologist

The program deals with the broad field of seedling physiology, specifically biological evaluation of seedling quality. The objective of this work is to permit better predictions of performance as well as to improve production and handling practices.

Evaluation, in most cases is carried out according to two basic biological procedures:

- i) evaluation of physiological traits that can be measured (quantified) and
- ii) performance evaluation of the whole seedling when subjected to specific stresses.

P. Comeau, Bastion Square

Vegetation Management

The program has four major areas:

- i) provide technical advice and assistance to research and operations;
- ii) extension and training;
- iii) evaluation of different vegetation control methods, herbicides, phytotoxins, mycoherbicides, manual or physical. George Harper is initiating a project in 1993 to look at the physiology and timing of manual conifer release; and
- iv) development and evaluation of methods for assessing vegetation management problems and needs. There are opportunities for a variety of physiological and ecological studies on sites established for this trial series.

G. Harper, Bastion Square

Vegetation Management Research Assistant

- i) assist in implementation of the vegetation management program and
- ii) initiating a project concerned with conifer response to timing of manual conifer release.

C. Hawkins, Red Rock Research Station

Establishment Physiologist

Presently completing work on Stress Induced Volatile Emissions, stocktype allocation, and physiological standards for nursery planting stock.

No new program in place.

C. Leadem, Forest Research Laboratory

Seed Physiologist

- i) Seed research in support of provincial reforestation program. Specifically, nursery production, harvesting, processing and storage of tree seeds collected from seed orchards and wild stands:
 - a) increased seedling production and vigour through dormancy release techniques and optimizing conditions for germination;
 - b) increased sowing efficiency/seedling production; and
 - c) optimize handling and use of seed orchard seeds, refine prescriptions of storage, testing and use of seeds obtained from seed orchards and wild stands.
- ii) Technical advisor to province in area of tree seed biology and use:
 - a) technical audits of Tree Seed Centre to improve seed handling/testing capabilities

- and operational efficiency;
- b) assist in automation of Tree Seed Centre operations;
- c) improve seed testing techniques, monitoring and reporting of seed quality in seed register; and
- d) improve efficiency of seedling request system by providing more seed quality information on which to project seedling production values.
- iii) Training and technology transfer in area of tree seeds:
 - a) in future, more research/technical advice directed to tropical forestry, especially ASEAN.

S. L'Hirondelle, Forest Research Laboratory

Adaptive Physiologist

The current objectives of the program are to:

- i) develop and evaluate physiological tests for assessment of adaptation of selected progeny to environmental stresses, to assist in developing seed transfer guidelines;
- ii) clarify the importance and nature of seed orchard environment after effects on progeny performance by assessing physiological traits related to adaptation; and
- iii) identify the physiological components of superior growth (and associated risks of maladaptation), and to develop physiologically based procedures to assist in early identification of genetically superior provenances, families, or clones.

M. Krasowski, Red Rock Research Station

Post-planting Physiologist & Developmental Plant Anatomy

Program is composed of a number of issues with the following objectives:

- i) evaluate the influence of nursery regimes on post planting growth and performance,
 - a) relationship between nursery dormancy induction methods and seedling morphology, bud morphogenesis and shoot growth phenology after planting, and
 - b) influence of seedling production method on root form and mechanical stability of planted stock. This also involves evaluation of silvicultural treatments on root form and mechanical stability of planted and naturally regenerated trees;
- ii) evaluate planted stock for their response to low temperature and drought stress. Identify injury causes and physiological, morphological and site specific conditions that either predispose seedlings to injury or reduce their risk of injury.

P. Puttonen, Bastion Square

Establishment Physiologist and Silviculturist

Presently finishing research work on acclimation of yellow cypress, acclimation of conifer seedlings to cold soil, competition in conifer deciduous stands, and root structure, biomass and stability of pine plantations.

Current position, technical advisor for Silvicultural Systems Program.

No research program yet in place.

J. Russell, Cowichan Lake Research Station

Geneticist

Three major themes in program. Themes and objectives follow.

- i) yellow-cedar genetic research and tree improvement,
 - a) description of patterns of genetic variability in morphological and physiological traits and to relate any genetic variability to seed origin (adaptive variation),

- b) development and implementation of a recurrent selection program for deployment of genetically superior clones for reforestation;
- ii) redcedar genetic research,
 - a) determination of the extent and pattern of genetic variability in redcedar for growth, adaptability, and wood quality traits,
 - b) comparison of selfed progeny to outcrossed progeny;
- iii) Yew gene conservation program.

D. Simpson, Kalamalka Research Station

Seedling (Tree?) Physiologist

Presently changing direction of research program. The old program had two themes:

- i) definition of nursery cultural treatments that result in improved (better) planting stock; and
- ii) development of assessments to measure the potential quality of forest seedling planting stock. The relationship between cold hardiness, dormancy, and root growth potential, and survival and growth were examined.

Preliminary investigations have started to document physiological processes in stands to understand regulation of growth and why some trees grow more than others. This will improve the effectiveness of tree improvement, vegetation management, and growth and yield research programs.

M. Stoehr, Forest Research Laboratory

Seed Production Physiologist as of 9 December 1992

Preliminary objectives of the program are to:

- i) initiate work on the Seed Orchard Rating protocol;
- ii) start work on evaluation of the genetic diversity of seedlings derived from seed orchard seed; and
- iv) commence work in flower induction in seed production areas (stands).

R. van den Driessche, Forest Research Laboratory

Senior Seedling Physiologist

The program broadly deals with production and conditioning of nursery stock that is resistant to abiotic and biotic stresses. Working areas of the program are:

- i) mineral nutrition,
- ii) water relations,
- iii) triazoles and plant growth regulators,
- iv) rooting of Sitka spruce cuttings, and
- v) root form and function.

J. Weber, Forest Research Laboratory

Seed Production Physiologist

Research emphasizes the basic biology of sexual reproduction in B.C.'s important conifer and hardwood species to address seed supply issues for the Ministry of Forests. Program objectives include:

- i) delivery of genetic gain potential through seed orchards; and
- ii) seed production requirements for basic reforestation needs and in the implementation of silvicultural systems. Specific research areas include:
 - a) flowering - mechanisms, sex expression, gametic selection and cone carrying capacity,

- b) flower induction - hormonal, cultural and environmental effects,
- c) pollen management - collection, storage, in vitro viability tests, and application
- d) seed orchard management - crown management, seed yields, genetic efficiency, contamination and adaptation effects, seed crop rating and seed handling,
- e) alternate orchard strategies - mini orchards, clonal rows and container orchards,
- f) seed stand production - sites, silvicultural treatments, induction and crop protection.



To: Dale Draper
Manager, Forest Renewal
Research Branch

From: RRRS
Date: January 29 1993
File:

Enclosed is the Strategic Review of Physiology by Hawkins and Puttonen for your action.

After discussion amongst the Research Branch physiologists, we would like to recommend that your former management position become a Research Scientist classification. This position would be responsible for facilitating the new collaborative research ventures outlined in the review.

We and our colleagues have put considerable time, effort and thought into the document. The recommendations are important for the long-term success of our group and the Research Branch.

Chris Hawkins
Research Scientist

Pasi Puttonen
Technical Advisor,
Silvicultural Systems

cc: W. Binder
P. Comeau
G. Harper
C. Leadem
S. L'Hirondelle
M. Krasowski
J. Russell
D. Simpson
M. Stoehr
R. van den Driessche
J. Weber