Employment of Pathogens to Constrain Growth of Undesirable Forest Vegetation

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Abstract

Microbiological bioherbicides have been used but rarely in forest vegetation management in North America although the technique has been in use for years in agriculture. The Canadian Forestry Service has restricted initial field research with and application of biological control agents to indigenous microorganisms. The ENHANCEMENT option was developed to replace, partially or completely, the classical and the inundative options in forest weed biological control in order to limit movement of exotic pathogens in the transcontinental forest continuum. The most useful pathogens found to date are facultative heterothallic. Consequently, reduction of host vigour and promotion of superoptimum microbial growth conditions were chosen as the primary means both of stimulating the pathogenic interaction and localizing the resultant epidemic. Primary target weeds identified to date are Acer macrophyllum, Abies rubra, Epilobium angustifolium, Gaultheria shallon and Rubus spp. Primary pathogens isolated thus far are Armillaria, Acremonium, Apioспорina, Botrytis, Cephalosporium, Ditylenchus, Mycopapillus and Nectria. Pathogenicity tests are in progress at present with several of these fungi. Unfortunately, there is practically no information re. races or strains of the fungi employed nor of existence of varieties of the host plants. It is necessary to gain information in these categories simultaneously and quickly without diminishing the statistical acceptability of the results. To date, primary pathogenicity of Melanconis thelebola and Nectria distincta was demonstrated and that of Ditylenchus elongatus, Mycopapillus alni, Nectria sp. and Rhizocnia sp. is inferred by observation and from literature reports. Similarly, tests to demonstrate varietal differences among geographic collections of E. angustifolium and G. shallon are in progress.

Introduction

It is a pleasure to introduce ourselves - The Pacific Forestry Centre - and to bring to your attention our efforts to incorporate biological control in our forest research program as a potential tool for forest vegetation management in the Pacific Region of Canada. We have on record what I can confidently describe as excellent research within the Canadian Forestry Service with respect to biological control of forest insects. This effort to incorporate a biological control option in our forest vegetation management program is not unprecedented (Wall 1986); however, there has been very little research in this area previously. This presentation will indicate the premises on which we have based our work and the natural, social and political circumstances from which these premises have been developed. More important, I will leave on record with you the experimental results we have to date, the general direction of our research and an indication of what we hope to report in particular detail at a subsequent meeting.

Research Rationale

Current reforestation efforts in British Columbia, the Province that occupies the entire Pacific Coast of Canada, involve planting of more than 200 million conifer seedlings/year. More than one billion seedlings/yr are planted throughout Canada and still the amount of forest land that is insufficiently stocked with trees is great. This is largely a result of earlier forest practice which involved, to some extent, poor planting stock, lack of certain relevant forest management knowledge and inadequate techniques to achieve proper control of brush (= undesirable woody vegetation) (Dofiner and Borden 1984) and of other weeds.
Approximately 2.9 million ha of "brush land" exist in British Columbia and that is increasing by approximately 49,000 ha p.a. (Boateng 1986). Were all such areas reforested successfully and brought to maturity on an overall sustaining basis, the increase in forest value would be $717 million shipment value (1983 dollars Canadian) (Boateng 1986).

The major problem in reforestation deficit is not lack of interest on the part of forest managers but rather the difficulty of reforesting many of the tracts where brush is a major competitor. One of the primary impediments to successful forest regeneration is competition by annual/perennial non-crop vegetation (weeds). Marked losses among newly established forest trees and, consequently, dollar loss measured as amplified reforestation cost and as decreased crop value, occur in the drier regions of British Columbia. On the west coasts of Vancouver Island and mainland British Columbia, where rainfall exceeds 500 cm/year in some places, extraordinary growth of forest weeds severely constrains early growth and survival of seedlings. Further to that, the usual difficulties with competition for nutrients and water and possibly with allelopathy occur as well. In a practical sense, the weed: forest tree competition problem is comprised of diverse components in British Columbia and each component must be dealt with as a separate entity, all of which are then to be amalgamated into a unified, forest regeneration program.

Social and political concerns are notable considerations in the Province of British Columbia where the population includes a particularly active environmentalist element. Reforestation must proceed and this involves considerable site preparation work, including both pre- and post-replant vegetation management. Unwanted forest vegetation is most effectively controlled prior to planting by proper application of prescribed burns and, after planting, through use of chemical herbicides. The use of even the most innocuous chemical herbicides is open to constant reconsideration with development of more sensitive means of chemical residue measurement, wider-spectrum screening of effects of chemicals on plants and animals and a generally negative public perception of the matter of chemical application as a whole. Despite moves by the chemical industry and the Government of Canada to develop safer chemical herbicides, there is distinct public pressure toward development of alternative methods of weed control. Research at the Pacific Forestry Centre is intended to make available the greatest possible number of practical management alternatives in order to meet the varied requirements of industry, various governmental groups and the public generally. In all probability, however, viable alternatives to chemical herbicides will be required within the next decade.

Consequently, the Pacific Forestry Centre (PFC) of the Canadian Forestry Service has embarked on programs over the past several years to develop silvicultural alternatives to chemical herbicides. This work is now being pursued within a multidisciplinary team of silviculturists, plant ecologists, and pathologists. This team works in immediate cooperation with other PFC scientists as required and with researchers in other institutes.

Two years ago the PFC initiated research in biological control of weeds and now employs two research people and two support staff to conduct that work. The goal is identification and specification of forest weed situations in British Columbia that are amenable to biological control, identification and collection of microorganisms potentially useful as biological control agents, and promotion of such biological control agents to positions of operational use immediately short of industrial production and distribution. Two guiding terms explicit in this project from the beginning are "constraint" (rather than eradicate) and "operator control". In these respects, it is rarely necessary or even desirable to eliminate weeds in a forest replant area, as is often done in agricultural operations with chemical herbicides. Rather, it is sufficient merely to limit growth of weeds for several years in the immediate vital growth zone of young trees until approximately the time of tree crown closure. Second, it is necessary that technique overall be sufficiently well standardized that the operator can specify the results of a biological control agent job, both quantitatively and qualitatively. These approaches, along with that using only those biological control agents derived from the geographic area of application, will insure environmental acceptability of both the experimental and applied results. We wished to place our particular protocol and philosophy on record as early as possible in order to generate comment within the scientific community and, hopefully, to establish at least preliminary guidelines for other forest weed biological control work.
Experimental Protocol

Forest weed competition must be dealt with from the standpoint of a variety of weed species and biogeoclimatic zones, each of which requires somewhat or totally different technology. Individual weed species of maximum importance were first identified for each zone from the literature (Harrington 1954, Haussler and Coates 1986, Muenscher 1980), canvass of opinion and personal observation (Table 1).

Table 1. Important forest weed species by zone.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Weed Species</th>
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<tbody>
<tr>
<td>Southern Interior</td>
<td><em>Epilobium angustifolium</em> L. (Onagraceae)</td>
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<tr>
<td></td>
<td><em>Rubus idaeus</em> L. (Rosaceae)</td>
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<tr>
<td></td>
<td><em>Rubus parviflorus</em> Nutt. (Rosaceae)</td>
</tr>
<tr>
<td>Northern Interior</td>
<td><em>Calamagrostis canadensis</em> (Michx.) Beauv. (Gramineae)</td>
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<td></td>
<td><em>C. rubescens</em> Buck.</td>
</tr>
<tr>
<td></td>
<td><em>Epilobium angustifolium</em> L.</td>
</tr>
<tr>
<td></td>
<td><em>Populus tremuloides</em> Michx. (Salicaceae)</td>
</tr>
<tr>
<td></td>
<td><em>Rubus idaeus</em> L.</td>
</tr>
<tr>
<td>Vancouver Island</td>
<td><em>Acer macrophyllum</em> Pursh. (Aceraceae)</td>
</tr>
<tr>
<td></td>
<td><em>Alnus rubra</em> Bong. (Betulaceae)</td>
</tr>
<tr>
<td></td>
<td><em>Epilobium angustifolium</em> L.</td>
</tr>
<tr>
<td></td>
<td><em>Gaultheria shallon</em> Pursh. (Ericaceae)</td>
</tr>
<tr>
<td></td>
<td><em>Rubus idaeus</em> L.</td>
</tr>
<tr>
<td></td>
<td><em>R. parviflorus</em> Nutt.</td>
</tr>
<tr>
<td></td>
<td><em>R. spectabilis</em> Pursh.</td>
</tr>
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</table>

Additional species may be described as genuine problems in local areas and, by the same token, some of the above species may represent no problem at all in parts of the area for which they are listed. The most geographically restricted of the species listed are *G. shallon* and *A. rubra*, which are almost entirely west coast species. Conversely, *E. angustifolium* occurs nearly worldwide and *Rubus* spp., by whatever names, are similarly worldwide.

Equally important: for each species that one person or more terms a weed, there will be at least one proponent. Certain of the above species may have purely environmental and wildlife management proponents whereas proponents of species such as *A. rubra* and *P. tremuloides* may point with good basis to the potential if not the present economic value of these species.

The last point leads directly to one made by Agriculture Canada (J. Dueck, pers. comm., 1987) who noted that we already have mycoherbicides for many plant species and one has only to term species "valuable" before the situation is termed a disease. That fear was voiced as well by various individuals who have indicated the need for caution in development of biological control agents against weed species which are closely related valuable agricultural plants. With respect to the research being conducted at the PFC, only indigenous candidate biological control agents are being used. Those which could be implicated in diseases of agricultural species (or others) are first tested through challenge of somaclonal tissue cultures of potentially susceptible species. Thereafter (or immediately, with regard to obligate fungal parasites and viruses) the candidate biological control agents are to be tested in whole plants under quarantine conditions. Only when they are certified as environmentally safe to non-target species may such biological control agents be tested in the natural environment.
Candidate biological control agents were selected almost entirely by isolation from unhealthy specimens of the target weed species. Identification of isolates was accomplished by the author and by Dr. Funk (PFC Mycologist). The majority of fungi isolated thus far have been described (Funk 1981, 1985) and most of them isolated are typically facultative biotrophs. Most of the species of fungi on weeds have been little studied save for mycological characterization.

Types of Pathogenic Interactions

A great many fungi and bacteria are noted in association with the weed species under study (Ginns 1986, Funk 1981 and 1985, Lowe 1987). A choice had to be made of those microorganisms which were potentially useful in routine vegetation management among all the microorganisms with potential to cause disease. It was necessary then to choose microorganisms that could be tested and proved in the course of laboratory experimentation but were amenable to promotion, through industrial fermentation processes, to field operational status. Further, weeds could be categorized in terms of competition type: crown, stem, root or a combination of same. For example, it might be least efficient to use a defoliating mycoherbicide against a weed that is a competitor primarily by means of root competition.

Whereas larger A. rubra limit growth of primary conifers such as Pseudotsuga menziesii (Mirb.) Franco by site occupation generally and by overshadowing, E. angustifolium (Fireweed) competes primarily by means of dense shallow rhizomes. Conversely, E. angustifolium causes major damage in areas of high snowfall by smothering young seedlings when the dead E. angustifolium tops are depressed onto seedlings by snow. Both the tops and the rhizomes of E. angustifolium are obvious targets for interposition of biological control agents. A lethal stem-cankering agent would be useful for control of A. rubra, particularly along watercourses where use of chemical herbicides is prohibited.

On the positive side, A. rubra is responsible for a general increase in nitrogen in the forest floor (Bollen and Ku 1968) and possesses timber and bulk fiber value as well. The ideal bioherbicide would be one that constrained growth of A. rubra until conifer seedlings were 1 to 2 m high or until conifer crown closure occurred. The bioherbicide-stunted alder would then be naturally suppressed by the growing conifers and nitrogen elaborated within the alder root nodules would become available during plant senescence. Assuming such release of nitrogen occurred during the logarithmic stage of conifer growth, the benefits of bioherbicide application would be compounded.

E. angustifolium is responsible for winter smothering of many conifer seedlings but, conversely, these succulent herbs provide a measure of protection for the young conifers as well. A small but locally significant honey harvest is obtained from E. angustifolium as well.

Additional examples are available (Haeussler and Coates 1986) which indicate that an advocate can be found for each species of plant that others term weeds.

Selected Mycoherbicide Alternatives Under Consideration

1. Armillaria sp. (Hymenomycetes)

An isolate of Armillaria sp. collected by Dr. A. Funk near Victoria, British Columbia was characterized by Dr. D. Morrison (both scientists are with the PFC) as Armillaria Group V (Anderson and Ullrich 1979). The fungus is associated with E. angustifolium plants that are stunted and, consequently, do not smother young tree seedlings. This isolate is being tested for pathogenicity (Group V is often considered saprophytic) and virulence, as well as for specificity with respect to diverse collections of E. angustifolium from different areas of British Columbia, and for negative effects on commercial conifer seedlings. The aim will be incorporation of the biological control agent plus a nutrient base in the planting medium that
forms a routine part of the containerized seedlings. It is hoped thereby to constrain growth of fireweed for 3 to 5 yrs after planting.

2. Botrytis sp. and Acremonium sp. (Hyphomycetes)

These fungi are associated with foliar diseases of E. angustifolium and are being tested as potential defoliators. Similarly, the insect Brontis obscuris (L.) (Coleoptera: Chrysomelidae) is an effective predator of E. angustifolium, both of the thymes and of the foliages. Hopefully, one and/or another of these can be used in appropriate circumstances to constrain growth of the weed.

3. Melanconis spp. (Ascomycetes)

A. rubra may form dense thickets in the first several years of growth that completely exclude conifer seedlings. This problem is best controlled by elimination of a large number of the stems. Melanconis spp. are associated with alder mortality that may affects as many as 90% of the stems in such thickets.

Nectria ditissima Tul. (Ascomycetes) is another pathogen of red alder stems and branches (Funk 1981) being tested.

4. Phyllosticta sp. (Fungi Imperfecti)

G. Shallon is probably the most important forest weed on the Vancouver Island and lower British Columbia Mainland west coast areas. Numbers foliar pathogens exist (Lowe 1977). Most prevalent of the pathogens noted recently is a species of Phyllosticta which is associated with dead and dying G. Shallon foliage and meristems throughout much of the British Columbia coastal range of the plant. This and other foliar pathogens are in test and will be given consideration as bioherbicides. The obvious target for growth constraint of this weed, however, is the root and root-collar area because of the extensive, heavy root system of the plant which is a serious detriment to conifer growth on dryer sites. On wetter sites, dense foliage obstructs passage of sunlight to the ground and foliar pathogens might provide additional relief for growing seedlings.

5. Phomopsis sp. (Coelomycetes)

A. macrophyllum produces large quantities of coppice after the main stem is removed, and the resultant large crowns interfere with growth of young conifers. The fungus Phomopsis sp. was isolated from severely cankered coppice, purified in culture and inoculated into healthy coppice, with results as yet undefined.

Additional species of weeds and microorganisms are collected in British Columbia by the Weed Biological control Project and the PFC Forest Insect and Disease Survey of the PFC, as well as by cooperators. The Canadian and British Columbia Governments cooperate to generate forest resource information essential in reforestation under the Forest Resource Development Agreement. This agreement will finance work by the British Columbia Ministry of Forests and Lands that is designed to elucidate the autecology of G. Shallon. Systematic development of bioherbicide is dependent on a full understanding of the autecology of the target host species.

Research Goal

The aim of this work overall will be elaboration of a response model program [WEED SPECIES (PROVENANCE); BIOLOGICAL CONTROL AGENT; BIOGEOCLIMATIC ZONE; WEED PREDISPOSITION TECHNIQUE]. Once completed, a situation can be described to the model and the query will elicit a response in terms of potentially useful
biological control agents, appropriate technology of application and requirements for host predisposition to gain a particular degree of weed control.

Acknowledgments


References


