BIOLOGICAL CONTROL OF WEEDS IN REFORESTATION AREAS

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ABSTRACT - Unwanted vegetation (weeds) in reforested areas interfere with productivity of the crop species and reduce the yield and quality of the produce. Even though chemical herbicides are used to reduce competition and interference by forest weeds, growing political and environmental concerns have necessitated the search for alternative methods. Biological control (use of sheep, natural herbicides, allelopathy and bioherbicides) offers great promise but no successful bioagent is currently available to replace the herbicide option. A new bioherbicide approach is being experimented; the merits and demerits of this method together with the special features of forests weeds are discussed.

Introduction

There is a great need to afforest new plantation areas in order to meet the growing needs of wood supply in the 21st century. Demand for wood products keep on rising and the land area for afforestation is shrinking. Therefore, intensive silviculture is needed to meet the rising demands for wood products. In new reforestation areas, competing vegetation (weeds) or unwanted vegetation, interfere with the productivity of the forests and must be controlled intelligently in order to meet the objectives of the plantation (Wallstad & Kuch 1987). The competing vegetation, not only reduces the yield but also increases the rotation cycle and production costs of the conifer plantations. Of the various methods of forest weed control, chemical herbicides are rated as the most efficacious and cost-effective tool (Sundaram and Prasad 1984). However, owing to growing environmental concerns and opposition by the public, chemical herbicides are gradually being phased out of forestry in USA, Canada, Sweden and newer ecologically-acceptable and environmental-benigh methods such as biological control are being tested (Dorworth 1990, Wall 1994, Prasad 1996).

Characteristics of forest weeds

Forest weeds are different from agricultural weeds in that they are woody perennials, often trees like aspen (*Populus tremuloides Michx*) birch (*Betula papyrifera*, L.)

red alder (*Alnus rubrum* Bong) speckled alder (*Alnus incana* Moench) bigleaf maple (*Acer macrophyllum* Pursh) and smaller shrubs and forbs (Table 1). They have extensive root and shoot systems or thick glabrous leaves as in salal (*Gaultheria shallon* Pursh.) and need special management techniques e.g. aerial application of chemical herbicides for control.

Table 1. Major weed species competing with commercial forest trees in Canada and forest regions where they predominate

Species	Regions of major impact
Acer macrophyllum Pursh. Big leaf maple	Coastal British Columbia
Acer rubrum L. Red maple	Ontario, Quebec, Maritimes
Acer spicatum Lam. Mountain maple	Ontario, Quebec, Maritimes
Alnus incana (L.) Moench. Speckled alder	Transcontinental
Alnus rubra Bong. Red alder	Coastal British Columbia
Calamagrostis canadensis (Michx.) Beavu. Bluejoint	Alberta, Interior British Columbia
Corylus cornuta Marsh. Hazel	Interior British Columbia to Quebec
Epilobium angustifolium L. Fireweed	Transcontinental
Gaultheria shallon Pursh. Salal	Coastal British Columbia
Kalmia angustifolia L. Sheep laurel	Maritimes, Newfoundland
Populus tremuloides Michx. Aspen	Transcontinental
Prunus pensylvanica L. f. Pin cherry	Ontario, Quebec, Maritimes
Peridium aquilinum (L.) Kuhn Bracken fern	Transcontinental
Ribes spp. Currants and gooseberries	British Columbia, Ontario, Quebec, Maritimes
Rubus idaeus L. Raspberry	Ontario, Quebec, Maritimes
Rubus parviflorus Nutt. Thimbleberry	British Columbia
Rubus spectabilis Pursh. Salmonberry	Coastal British Columbia
Salix spp. Willows	Transcontinental
Sambucus spp. Elderberries	Transcontinental

Biocontrol alternatives in forestry

Recently, as a result of these concerns, there has been a flurry of activities in the biocontrol of forest weeds and these can be grouped in four categories:

1. **Allelopathy**: is the phenomenon of suppression of growth of one plant (weed) species by a chemical exudate of another higher plant species. A classical example of this approach, often cited, is some early research done on juglone produced by the black walnut tree (*Juglans nigra* L.). This natural compound inhibited the growth of vegetation underneath the tree (Schmidt, 1988). More recently Jobidon et al. (1989a) have experimented with exudates from straw mulches of barley, oats and wheat and found strong suppression of growth of raspberries (*Rubus ideaus* L.). It was further found (Jobidon et al. 1989b) that these allelochemicals strongly inhibited nitrate reductase and nitrification in soils. However, this approach does not lend itself to large scale application in forestry and does not seem to be a practical or viable option.

2. **Natural Herbicides**: refer to some microorganisms and higher plants that produce myriads of natural compounds acting as chemical warfare agents against pests (Duke & Lydon 1987). Using natural product chemistries as the basis, new pesticides (pyrethroids) have been synthesized. Two such herbicides, bialophos (aminohydroxy-phosphovinyl-butyryl-alanine) and its chemical analog glufosinate (aminohydroxy-phosphovinyl-butyric acid) have been recently isolated and adapted as natural herbicides for control of weeds in rice, soyabean and vegetable crops in Japan and other countries (Prasad and Dixon-Warren 1992; Prasad, 1993a). These compounds were originally isolated from *Streptomyces viridochromogens* and their

chemistries were refined to confer herbicidal properties. Generally, these herbicides are used in low dosages and possess good attributes of toxicological and environmental safety. However, the limiting factor for natural herbicides is their high cost of production. Inspite of costs, recent findings by Jobidon (1991) and Prasad (1993a) show that bialophos and glufosinate can suppress perennial forest weeds without causing undue damage to conifer (*Picea glauca* Moench/Voss) crops.

3. **Animal grazing**: has been practised for years in Ireland, New Zealand, Australia, California, Canada and Sweden for controlling weeds in forests but considerable damage to conifer seedlings and soil has been recorded (Cayford 1993). Detailed field experiments carried out in British Columbia on the role of sheep in biocontrol of fire weeds (*Epilobium aungustifolium* L) bracken fern (*Pteridium aquilinum* L) and blackberry (*Rubus ursinus* L) and salal (*Gaultheria shallon* Pursh) demonstrated varying effectiveness. Browsing sheep removed significant amounts of vegetation from the vicinity of conifer seedlings (*Picea glauca*, *Picea engelmanni*) but the impact on conifer-release, soil erosion, water quality and on carnivores population remains largely unknown. Apparently some predation of sheep by grizzly bears has caused ecological problems. (Anonymous 1995; Sutherland 1987).

4. **The classical strategy**: involves introduction of an exotic biocontrol agent (insect or pathogen) to reduce the population of the target weeds. The rationale of this method is that the host weed has no built-in defense mechanisms and thus easily succumbs to the imported parasite. Although such a procedure is popular in agriculture (Batra 1980), for example in the control of opuntia, *Opuntia vulgaris* by the beetle (*Dactylopus celonicus* Green) and of skeleton weed (*Chondrilla juncea*) by the European rust (*Puccinia chondrillina* B & S) no such effective methods have been found for forest weeds. However, there are two examples which may be closely related to forestry situations: (a) the control of blackberry (*Rubus constrictus* Leferve/Meuller and *Rubus ulmifolius* Schott.) by the rust (*Phragmidium violaceum* Schultz/Winter) in Chile (Oehrens 1977). But this biocontrol resulted in reduction of honeybee production in Chile and caused concerns, (b) the control of the gorse weed (*Ulex europeus* L.) by the mite (*Tetraynchus lintearis* Dufor) in New Zealand forests. But Syrett et al (1984) cautioned that since this mite easily hybrizes with the local spotted mite, the use of this bioagent may result in a controversy. These public concerns halted the exotic introduction of weed pests.

5. **The inundative (bioherbicide) strategy**: refers to release of native parasite-predators and their improved formulation in large numbers to overwhelm the host weed species (Charudattan & Walker 1982, Hasan & Ayres 1990, Templeton 1982, Watson 1989). Generally, these biocontrol agents are specific to a host weed and can be contained within a geographic area. Thus, the mycoherbicide (bioherbicide) approach is based on deliberate use of a natural fungal pathogen to suppress the growth or reduce the population of a weed (Watson 1989). Some success has been achieved by employing plant pathogens to control agricultural weeds. Examples: (i) strangler vine has been controlled by DeVine® (*Phytophthora palmivora* L.) in citrus groves (Ridings 1986); (ii) northern-joint vetch has been controlled by Collego® (*Colletotrichum gleosporoides* f. sp. *aeschynomene*) in rice and soybeans (Templeton 1982); (iii) the aquatic weed,

water hyacinth has been suppressed by *Cercospora rodmanii* in waterways of Florida (Charudattan 1986) and (iv) Biomal® (*Colletotrichum gleosporoides* Penz var *malvae*) was recently produced in Canada for the control of annual weed, mallow (*Malva pusilla* Sm.) in agriculture by Makowski and Mortenson (1992). Unfortunately none of these products remain commercially available. No mycoherbicide for forest weeds has been commercially developed because of a narrow market and lack of research (Dorworth 1996).

The bioherbicide option

Therefore, there is a need to find a cost-effective and environmentally-acceptable method of weed control in forestry. Recently we have found a new bioherbicide strategy using a native fungus (*Chondrostereum purpureum* Fr./Pouzar) to be a potentially useful option (Wall 1990, Prasad 1992). Developed by three Dutch scientists (deJong, Scheepens and Zadoks 1990) for control of blackberry weed (*Prunus serotina* Ehr.) in conifer plantation in Holland, we have adopted, refined its formulation and patented to control hardwood weeds of North American forests. *Chondrostereum purpureum* is a basidiomycete fungus widespread in North American forests and fruit orchards and acts as a saprophyte on wounded hardwoods (aspen, poplar, alders, birches). It becomes parasitic by invading the cambium in the injured area thus killing resprouts of these perennial species. It may invade the conifer species but it has not been shown to cause any significant disease symptoms (Wall, 1990).

Chondrostereum purpureum (Cp) has been extensively researched in our laboratory and is now entering into registration and commercialization phases. Since Cp is a wound parasite and operates through cut ends, it can be integrated with manual/mechanical cleaning of hardwood weeds and thus reducing the burden of chemical herbicides. It has been applied through cut-stump and stem-girdling of red alders (Wall 1994) and in both cases found to be efficacious. Considerable research has been carried out with its formulation development (Prasad 1993b, Prasad 1994, Prasad 1995) and recently we obtained a U.S. Patent from the Patent Office, Washington, D.C. (Wall, Prasad & Sela 1996)[1]. Extensive field trials have been conducted all across Canada and the results are very promising. As is evident from Table 2, the mycoherbicide appears more efficacious under moist conditions (lowland site with a streamflow) than at upland and dry sites where relative humidity is low. This is generally true with many other fungal pathogens (Dimock & Baker 1951; Quimby and Boyette, 1987).

Table 2. Efficacy of a *Chondrostereum purpureum* formulation on red alder (*Alnus rubra*) stump regrowth and infection under field conditions two years after treatment

Site	Treatment	Sprouts/ stump	Height/ sprout	Area of stumps covered by basidiocarps[1]
		(number)	(cm)	(%)
	Control	1.80 a	14.6 a	7.4 a
Moist (Lowland)	Treated	0 b	7.8 b	43.2 b
	Control	2.81 c	21.5 c	1.8 c
Upland (Dry)	Treated	1.05 d	11.3 d	21.3 d

[1] Treatments statistically analysed. Means in the same column followed by the same letter are not statistically different (<0.05) according to Duncan Multiple Range Test.

Discussion, conclusions and future prospects

Weeds or unwanted vegetation, in cutover area or reforestation areas, are competitive with the forest crop species

[1] R. Wall, R. Prasad and E. Sela. 1996. Biological control of weed trees. U.S. Patent #5,487,150. Office of U.S. Patents, Washington, D.C.

and must be managed intelligently to raise the productivity and quality of the produce. Of the several options for control, such as mechanical, incendiary and chemical methods, probably the herbicide option is the most efficient and cost-effective. But repeated use of chemical herbicides in forests are likely to pose public concern and opposition and therefore research must be carried to seek or research alternate methods. Amongst the experimental options available, it seems the bioherbicide approach (for the control of forest weeds by pathogens and their products), is gaining momentum and offers an attractive alternative (Prasad 1996). Some of these tools can be integrated with existing methods e.g. after manual cutting of weeds, the mycoherbicide (Cp) can be applied to cut ends or stumps of hardwoods to prevent resprouting. Thus it would reduce the input of chemical herbicide in the environment and yet it is fully compatible with the existing vegetation management practice. However, there is considerable variability in the microorganisms and host (Hasan & Ayres 1990) and much research needs to be done before their mode-of-action can be elucidated. Also considerable research needs to be done on formulation and application technology of the organisms; they are living entities and their germination, infectivity and efficacy depend upon environmental factors (light, temperature, relative humidity). As stated earlier, there is not yet a single mycoherbicide available for tropical or temperate forestry but research is underway to produce one.

Some desirable attributes of bioherbicides

Bioherbicides must be able to grow readily on artificial culture media, produce abundant and durable propagules or other reproductive structures (spores). They must be able to readily infect its target host under a variety of environmental conditions and suppress competition within a short period of time. Such products should also possess a reasonably long storage (shelf) life and be easily compatible with ingredients of tank-mixes. The bioherbicides should be such that can be easily adopted to common application technology and must be cost-effective in order to compete with chemical herbicides (Hess 1992, Prasad 1992). Finally, the product should not cause undue damage to environment and other cultivated crops. Very few pathogens approach these ideals and so constant research is needed to modify their performance. It seems reasonable to speculate that bioherbicides are likely to succeed in a forest environment where shade and high humidity conditions prevail or dominate. Therefore, it is possible that moist tropical forests may provide a good reservoir of native organisms to search for development of bioherbicides. Lastly, bioherbicides should not be viewed as a total replacement of chemical herbicides but rather as complimentary tactics in integrated weed management systems (Watson 1989). For example, combination of systemic chemical herbicides with bioherbicides may be more effective (Templeton 1990; Watson 1989) in controlling woody perennial weeds than with either of these methods alone.

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