Selecting Herbaceous Plant Covers to Control Tree Invasion in Rights-of-Way

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Following construction of a right-of-way, environmental regulation often requires the rapid restoration of a herbaceous plant cover to control erosion and/or attenuate visual impact. Herbaceous species can be selected with the added long-term goal of inhibiting tree invasion. We present a review of empirical evidence that can guide species selection. This review is based on an extensive survey and critical evaluation of relevant North American studies published in scientific papers, technical reports, and conference proceedings. Vegetation managers and scientists were also consulted for up-to-date information on on-going experiments. Observational and experimental evidence of inhibition in both natural and managed communities confirm that the biological control approach has significant potential. However, scientific evaluation of the long-term inhibition capacity of seeding mixtures is still rare. Ecological mechanisms favoring competitive ability are not always well understood but involve the sequestration of available resources and the modification of environmental conditions. Two approaches characterized experimental inhibition studies in rights-of-way. The first aims to test the interference potential of commercially available species commonly used in restoration, while the second favors the establishment of wild communities. Both approaches have their advantages and limitations, but several studies show that the establishment phase is crucial. Knowledge is lacking especially for the establishment of wild species. This review allowed us to identify 66 herbaceous species based on a critical assessment of the evidence provided. Besides inhibition potential, factors such as species availability and possible nuisance should also be considered.

Keywords: Biological control, cover crop, inhibition potential, restoration, seeding, vegetation management

INTRODUCTION

There has been a great deal of interest in reducing both the costs and the environmental impact of vegetation management practices in utility rights-of-way. As ecological studies have demonstrated the ability of some herbaceous and shrub communities to inhibit tree invasion (Pound and Egler, 1953; White, 1965), vegetation managers have been encouraged to use highly selective herbicide applications or cutting practices that minimize disturbance to competitive cover when present (Niering and Goodwin, 1974; Bramble and Byrnes, 1983). But such cover could also be introduced right after construction, when environmental regulation requires the restoration of the site to control erosion and/or attenuate visual impact (Brown, 1995). This approach implies that species should be selected not only to satisfy immediate restoration concerns, but also for their potential to form, in the long-term, low-maintenance communities capable of inhibiting tree invasion. However, information on the inhibition potential of herbaceous species or on selection criteria for improving seeding mixtures is not readily available and, despite the obvious need for such information, there have been very few attempts to summarize current evidence from the literature (but see Brown, 1989). Apart from introducing competitive cover in rights-of-way, knowing which species have the potential to form stable communities could also help managers target more efficiently practices that will help maintain

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or spread them. As well, summarizing the currently available information on species potential to inhibit tree invasion is essential to orient future research needs on the integration of ecological principles in vegetation management strategies.

This study was prompted by the need expressed by vegetation managers working with Gas Metropolitain in Quebec (Canada) to improve restoration practices of newly constructed pipelines with the added goal of long-term vegetation control. Our objective was to assess the available empirical evidence on the use of herbaceous cover to control tree invasion in order to identify species that could be of interest in future vegetation management program. Although some shrub species have demonstrated strong inhibition potential, our study focuses on herbaceous species compatible with pipeline utilities. We report here our findings on observational and experimental studies of inhibition in both natural and managed communities and submit a list of the species whose capacity to inhibit tree invasion has been observed or tested.

METHODS

This review is based on an extensive survey and critical evaluation of relevant North American studies published in scientific papers, technical reports, and conference proceedings. Several vegetation managers and scientists were also consulted for up-to-date information on on-going experiments. Relevant scientific papers have been mainly accessed through searching different databases including AGRICOLA (U.S.D.A.), BIOLOGICAL ABSTRACTS, ICIST, and CURRENT CONTENT. The NTIS (National Technical Information Service) database was used to obtain information from US and Canadian government agencies and other sources from the private sectors in order to locate research reports often not available in other databases. All previous issues of the proceedings of the International Symposium on Environmental Concerns in Rights-of-Way Management were also searched for relevant information. Internet sites reporting information on research activities in universities, research institutes, federal or provincial agencies and ministries, and utility companies (e.g., Canadian Gas Association, Empire State Electric Energy Research Corporation, Gas Research Institute, Hydro-Québec, Ontario-Hydro, etc.) were consulted. Several of these sites identified people responsible for research activities, some of whom were contacted.

RESULTS

From more than 700 references uncovered in the literature search, 214 were found relevant and were retained for final analysis. Our review included a critical summary of ecological principles involved in inhibition studies that will be published separately. In order to identify species that presented a potential for the establishment of a stable cover in our area, we focused especially on information relevant to a north-eastern American context.

Evidence of inhibition comes from various sources including experimental evaluations in field or in greenhouse conditions of the inhibition potential of selected species, or field observation, in natural or managed environment, of relatively stable herbaceous communities. Ecological mechanisms favoring competitive ability are not always well understood but involve the sequestration of available resources and the modification of environmental conditions. Allelopathic effects, the emission by some species of substances capable of inhibiting germination or growth of neighboring species, are often cited as a possible competition mechanism (Horsley, 1977a,b; Tillman, 1982). Such processes remain controversial however (Byrnes et al., 1993), but the fact that complex competition mechanisms are not always well understood does not prevent using competitive effect to our advantage.

Summary of the available evidence allowed us to identify 66 herbaceous species whose potential to form stable populations or communities resistant to tree invasion has been observed or tested (Table 1). They include 25 grasses or sedges, 11 legumes, 25 herbaceous dicots, and 5 pteridophytes.

For each species, we provide a list of the scientific studies consulted (Table 1). Evidence comes from various sources. Because objectives and methodology widely differ from study to study, reliable comparisons and a definite assessment or ranking of the inhibition potential of a particular species are difficult to achieve. For example, a naturally occurring population of a species may have been investigated in the field for its capacity to form a stable cover, but such capacity may not have been demonstrated in experimental seeding. On the other hand, experimental seeding may have been conducted, but if the population failed to establish an efficient cover for different reasons (inadequate site preparation, unreliable seed sources, constraining environmental conditions, etc.), then it does not necessarily mean that the species has no potential for future use. Consequently, instead of trying to establish a definite ranking of the species that were uncovered in our literature search, we chose to report, for each species, the type of scientific evidence used to compile our list. Evidence was classified according to the following categories.

Experimental seeding in right-of-way

The 46 species in this category have all been planted in experimental plots in electrical, pipeline, or highway rights-of-way using a replicated design or, for two studies, as regular cover crop for restoration purposes that were later evaluated through observational design (Suffling, 1979; Sharp et al., 1980). A total of

Table 1. Herbaceous species whose capacity to inhibit tree invasion has been observed or tested

Species	Experimental seeding in rights-of-way	Field evaluation of inhibition potential	Greenhouse evaluation of inhibition potential	Observation of stable communities	Origin, uses or possible nuisance
	Reference number				
Grasses and sedges					
Agropyron repens[1]	21	32	20	4	Int-Inv
Agrostis alba	24-35-44-47-48-49		8-10	4	Ero-For-Int-Inv-Res
Agrostis canina			10		Int-Inv-Orn
Agrostis stolonifera		42			Int-Inv
Andropogon gerardii	35-43-48-49			37	Ero-For-Inv-Res
Bromus inermis[2]		31-42	2-10		Ero-For-Int-Inv
Carex sp.				51	
Carex crinita	47				
Dactylis glomerata[1]	11	18-39	8-9-10-40		For-Int-Inv-Orn
Danthonia spicata		5-14			
Elymus canadensis	43				For-Inv
Festuca arundinacea[1,2]	35-48-49	5-39-46	8-10		Ero-For-Int-Inv-Orn
Festuca ovina			10		Ero-Inv-Orn-Res
Festuca rubra[1]	11-21-24-30-35-44-48-49	12-19	8-9-10-20	33-37-41	Ero-Inv-Orn
Lolium perenne	21-35-48-49	12	20		Ero-For-Int-Inv-Orn
Panicum virgatum	35-48-49			37	Ero-For-Inv-Res
Phalaris arundinacae[2]	21-24-30-44-47	42	10		Ero-For-Inv-Orn
Phleum pratense	21-24-30-44-47	13-42	8-10	4-41	For-Int-Inv
Poa annua	44				Int-Inv
Poa compressa		42		4	Ero-Int-Inv-Orn
Poa pratensis	21-44-47	13-19	8-10-40	4	Ero-For-Inv Orn
Schizachyrium scoparium[1]	35-43-48-49	16-25		17	For-Inv
Scirpus pedicellatus	47				
Scirpus rubrotinctus	47				
Sorghastrum nutans	43				For-Res
Legumes					
Coronilla varia[1]	11-35-48-49	38-42	8-9-10		Ero-For-Int-Inv-Orn
Lathyrus sylvestris[1]	35-48-49			37	Int-Res
Lotus corniculatus	11-35-48-49	32-42	8-9-10		For-Int
Medicago sativa		1	9-10		Int
Melilotus alba		18-42	8-10		For-Int-Inv
Melilotus officinalis			8-10		For-Int-Inv
Trifolium hybridum	21				Ero-For-Int
Trifolium pratense	21				For-Int
Trifolium repens	24-30	12-42	8-10		For-Int-Inv
Vicia cracca	21		20		Int-Inv
Vicia sativa	44				Int-Inv
Dicots					
Achillea millefolium				4	Ero-Inv-Orn
Anaphalis margaritacea				4	Orn
Aster ericoides	15			3	Orn
Aster nova-angliae	15				Orn
Aster ontorianis	47				
Aster pilosus	15				
Aster ptarmicoides	15				
Aster puniceus	15				
Aster simplex	15				
Aster umbellatus	15				
Aster sp.	21-47			4-51	
Centaurea nigra[1]	21		20		Int-Inv
Desmodium canadense	43				
Epilobium angustifolium			9		Inv-Orn
Eupatorium maculatum	47				
Hypericum perforatum	21		20	4-41	Int-Inv
Hypericum repens			9		
Monarda fistulosa	43				Orn
Rudbeckia hirta	43				Orn
Solidago canadensis	15-47				Inv
Solidago gigantea	47				

Table 1. (continued)

Species	Experimental seeding in rights-of-way	Field evaluation of inhibition potential	Greenhouse evaluation of inhibition potential	Observation of stable communities	Origin, uses or possible nuisance
	Reference number				
Solidago graminifolia	15	5-14			
Solidago nemoralis	15				
Solidago rugosa		5-14			
Solidago sp	21-47			33-51	
Ferns					
Athyrium filix-femina			9		Orn
Dennstaedtia punctilobula[1]		5-14-25-29		36	Orn
Onoclea sensibilis			9	37	Orn
Pteridium aquilinum	47		9		Inv
Thelypteris noveboracensis		29		36	Orn

Numbers in the table refer to documents from the reference section.
Origin, uses or possible nuisance, according to USDA–NRCS (1999): Ero = erosion control; For = forage; Int = introduced; Inv = invasive; Orn = ornamental (lawn, etc.); Res = restoration.
[1]Best inhibition potential in field conditions.
[2]Best inhibition potential in lab conditions.

eleven studies, conducted in eastern United States and Canada, were included in this category. Their objective was generally to assess inhibition potential of one or several herbaceous covers seeded in the right-of-way or, at the very least, to determine the seeding conditions necessary for the establishment of a presumably low-maintenance herbaceous cover (U.D.A. Inc., 1996; Cain, 1997; Suffling, 1998). Monitoring of species establishment and competitive effect had been conducted for 1 year after seeding at the time of publication (Suffling, 1979; U.D.A. Inc., 1996) up to 10 or more years (U.S.D.A., 1981, 1983; Oyler and van der Grinten, 1984). Preselection of species to conduct experiments was based mostly on observed evidence of inhibition in natural or managed communities and/or, in a few cases, on greenhouse screening tests of inhibition potential (Brown, 1995; FRDF, 1993). Species traits such as rapid growth, vigorous vegetative reproduction, abundant seed production, dense underground, and/or aerial structures that are thought to correlate with competitive ability were often favored. Estimation of inhibition potential was done mostly through a statistical evaluation of the relationship between herbaceous cover and tree density in seeded and control plots. Failure of establishment of a cover dense enough to control tree invasion was occasionally invoked to explain a species relatively low performance in the field. There were, however, usually no thorough investigation of the factors that may have led to poor establishment. Inadequate site preparation and/or environmental constraints were generally suggested as possible causes.

Field evaluation of inhibition potential

This category comprises 16 studies that had as a main objective to provide a quantitative or semi-quantitative evaluation of inhibition of establishment or growth of tree species by a competitive herbaceous cover in field condition for forestry or horticultural purposes, or in natural environment. Inhibition, in these cases, is mostly seen as a non-beneficial effect. We have also included in this category studies that aimed to identify naturally occurring low-growing communities in rights-of-way and that provided a statistical evaluation of the potential of such communities to limit tree establishment under different abiotic conditions (Bramble and Byrnes, 1976; Byrnes et al., 1993; Canham et al., 1993; Hill et al., 1995). A total of 22 species were evaluated in these conditions, 13 of which were also included in the previous category (Table 1). Parameters used to evaluate inhibition potential in experimental plots compared to controls included survival, density, height, diameter, and biomass of tree species seeded, transplanted or naturally occurring in the parcels.

Greenhouse evaluation of inhibition potential

Six studies tested inhibition of establishment or growth of tree species by a total of 26 herbaceous species in greenhouse assays. Parameters used to evaluate inhibition potential included survival, density, height, and biomass of tree species grown in containers with herbaceous competitors. Experiments in controlled environment have generally been useful to rapidly screen species for inhibition potential for further field experiments (Brown, 1990, 1992, 1993; FRDF, 1993), but results in such conditions do not necessarily guarantee that the species will express the same potential in nature (FRDF, 1994).

Observation of stable low-growing communities

Included here are 8 studies reporting the observation of naturally established herbaceous communities that appeared to have been stable for several years in sites that were presumably capable of supporting trees, although there were no experimental evaluation or comparison of inhibition potential of the species involved. Twenty species were identified in this category. Several ecological studies on successional dynamics in old-fields or rights-of-way that greatly contributed to current interest in biological control approaches in vegetation management are included here (Bard, 1952; Pound and Egler, 1953; Beckwith, 1954; White, 1965; Stalter, 1978; Niering, 1987). Resistance to invasion by woody species was generally assumed to be the result of the highly competitive ability of the herbaceous cover, although other factors such as constraining abiotic conditions or low invasion pressure have not necessarily been ruled out.

Finally, the analysis of the evidence provided allowed us to identify a subset of 11 species for which experimental results demonstrated best potential in field and/or in lab conditions (Table 1). For example, *Dactylis glomerata* was tested in lab (Shribbs et al., 1986; Brown, 1990, 1992, 1993) and in right-of-way conditions for 5 years (Brown, 1995) where it was found to affect tree survival. As well, *Coronilla varia* and *Lathyrus sylvestris* have been the object of long-term monitoring that demonstrated their strong capacity to inhibit tree invasion (U.S.D.A., 1981, 1983; Oyler and van der Grinten, 1984). Information on best potential is given as an indication and readers are encouraged to consult available published data for detailed evaluation of a particular species.

DISCUSSION

In spite of the strong interest in enhancing ecological practices in right-of-way vegetation management, there are surprisingly few long-term experimental evaluations of inhibition potential of herbaceous cover in rights-of-way, or results of such evaluations are not readily available. Information from rigorous experimental settings in right-of-way conditions is extremely valuable and should be used whenever possible to determine species potential. Nevertheless, the majority of studies presented here suggest that low-growing species can be used to delay invasion of trees, and that some covers are better than others in doing so. However, information on a particular species inhibition potential is often hard to obtain. Because methodologies vary widely from study to study, it is not obvious, from a management point of view, how to select appropriate species. This, combined with a lack of critical synthesis of the available evidence, likely contributes to delay applications.

Apart from the evidence mentioned, other factors must be carefully considered especially when it comes to the introduction of species in rights-of-way. Among those, origin (indigenous, naturalized or exotic), ecology, use (erosion control, forage crop, ornamental, restoration), possible nuisance (e.g., invasive species, potential host to crop pests, toxicity to livestock), and availability of seeding mixtures are especially important. These factors must be carefully weighed against other possible benefits in terms of vegetation control before implanting a species. We are including, as an indication, information on origin and some potential uses and nuisance (Table 1). The latter point is especially important since species are selected for traits that can potentially make them aggressive in new habitats. Indeed, 31 of the species in our list have been reported as showing invasive behavior in some conditions or others (U.S.D.A.–N.R.C.S., 1999). It remains to be assessed locally how such behavior would limit applicability. A light-requiring species that has the potential to invade agricultural fields, for instance, may cause little problem in a forested context. It is therefore essential, if introduced in a new environment, that a species propensity to invade or modify adjacent habitats be closely monitored.

Two approaches broadly characterized inhibition studies in rights-of-way. The first aims to test the inhibition potential of regular cover crops generally widely used for erosion control and restoration purposes (e.g., Suffling, 1979; U.S.D.A., 1981, 1983; Brown, 1995), while the second favors the establishment of wild communities that have been shown to be relatively stable (e.g., U.D.A. Inc., 1996; Cain, 1997). Both approaches have advantages and limitations, and managers are faced with choices on the basis of available evidence. Indeed, some commercially available cover crops (e.g., *Dactylis glomerata, Coronilla varia*) have demonstrated their inhibition potential and such species could easily be integrated into a restoration program or could be used to fine-tune mixtures currently used. However, species in this category are usually of introduced origin, although most have long been naturalized in North America. As said before, the introduction of non-native organisms in a new environment should always be considered with extreme care. More data are needed, however, to determine inhibition potential of currently available cover crops, as relatively few studies have compared several crops for their long-term performance.

On the other hand, several vegetation management projects have promoted the use of wild species (e.g., Gouveia, 1987; Harper-Lore, 1996; Honig and Wieland, 1997; Suffling et al., 1998). This is especially true in the Prairies, where exotic species are seen as a threat to local diversity, or in highway rights-of-way, where local display of wild flowers often receive driver's as well as conservationist's approbation, while reducing maintenance cost. The establishment of communities of wild species known to form relatively stable communities in natural settings (e.g., *Solidago, Aster*) offers an interesting alternative for vegetation control in rights-of-way.

Such species are assumed to require little maintenance and contribute to enhance local biodiversity. Local species can be found for a wide range of environmental conditions. Moreover, the introduction of attractive communities of wildflowers, especially in areas where public acceptance and aesthetic appreciation is important, can facilitate right-of-way integration in the landscape. Often, commercially available non-native species are seeded with wild species to facilitate the establishment of the latter or to provide a ground cover prior to wild species establishment. Nevertheless the studies reviewed here show that several constraints still limit their use. There is still much to learn on how to establish wild communities and how to formulate seeding mixtures best adapted to local environmental conditions in rights-of-way. When experimental seeding fails, there is often no follow-up that would help correct problems and improve conditions for subsequent introductions. Getting a reliable local source of quality seeds may still be a problem in some areas, and quantities are often limited.

CONCLUSION

Ever since the studies of Pound and Egler (1953) and Niering and Goodwin (1974) on stable communities, there has been an interest in using low-growing species to interfere with tree establishment and/or growth for management purposes. The evidence presented in this paper is in support of this approach, but there are still several constraints that limit broad range applicability in rights-of-way, especially when it comes to species introduction. In particular, thorough investigation of the potential of species widely used in restoration programs to form relatively stable communities in the long-term is lacking, whereas the conditions of establishment of wild communities are often poorly known, at least in northeast Canada. Information from the studies that have been conducted is often not readily available, especially to the manager that has to make an efficient decision on which strategy and species to use to satisfy both immediate concerns with site restoration and long-term vegetation management objectives. Regarding the latter point, there is most certainly an advantage in coupling information on species ability to stabilize sites after construction with data on their long-term capacity to form stable communities that inhibit tree invasion, and this right form the early stages of restoration planning. By providing a synthesis on available evidence of inhibition for herbaceous species, we hope this review will facilitate further applications.

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