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Using cover crops to establish white and black spruce on abandoned agricultural lands
Utilisation de plantes compagnes lors de la plantation d’épinettes blanches et d’épinettes noires sur des terres agricoles abandonnées

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Résumé de l'article

Le contrôle de la végétation constitue une préoccupation majeure lors du reboisement des terres agricoles abandonnées. Dans ce contexte, l'utili sation de plantes compagnes pourrait constituer une alternative à l'usage des herbicides. Les plantes compagnes pourraient compétitionner les mauvaises herbes et avoir une influence positive sur la survie et le taux de croissance des arbres. Une expérience a été menée à quatre sites pour étudier cette hypothèse. L'expérience comprenait trois facteurs. Le premier consistait à appliquer ou non de la chaux. Le second comprenait les cinq niveaux de la culture compagne : un témoin; un mélange d'orge d'automne (*Hordeum vulgare*) et de lotier (*Lotus corniculatus*); un mélange d'orge d'automne et de pâturin du Kentucky (*Poa pratensis*); un mélange d'orge d'automne et de trèfle ladino (*Trifolium repens*); et un mélange d'orge d'automne, de pâturin du Kentucky et de trèfle ladino. Le troisième facteur considérait l'espèce de conifère, soit l'épinette blanche (*Picea glauca*) ou l'épinette noire (*Picea mariana*). L'orge d'automne ne s'est pas implantée facilement. Néanmoins la présence de la céréale a permis de réduire les populations de mauvaises herbes au cours de la première année. Chez les dicotylédones cette réduction ne s'est pas manifestée au cours des années subséquentes. Cependant, chez les graminées l'augmentation des populations de mauvaises herbes a été moins rapide en présence de cultures compagnes. L'implantation des autres espèces compagnes a été très variable d'un site à l'autre. Il n'a pas été possible de déterminer si cet échec relatif est dû aux conditions de croissance, à la mauvaise implantation de l'orge d'automne ou à d'autres facteurs. Le chaulage et le type de plante compagne ont eu peu d'effet sur la croissance des arbres. Il a cependant été noté qu'à deux des quatre sites, l'épinette noire atteignait une plus grande hauteur que l'épinette blanche. Il a aussi été noté que le diamètre basai de l'épinette blanche était généralement plus important que celui de l'épinette noire. Ceci pourrait constituer un avantage pour l'épinette blanche dans les champs où les espèces nuisibles risquent de provoquer la verse des plants forestiers. Finalement, le taux de survie qui a été enregistré dans cette expérience est exceptionnellement élevé.

Using cover crops to establish white and black spruce on abandoned agricultural lands

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Vegetation control is a critical factor in reforestation. On abandoned agricultural lands, an alternative to herbicide application is the use of cover crops to compete with the weeds and to improve survival and growth rates of transplanted species. A factorial experiment was carried out on four sites to test this hypothesis. The experiment included three factors. The first factor consisted of lime versus no lime application. The second factor included four cover crop combinations and a control. Cover crop combinations were winter barley (*Hordeum vulgare*) underseeded with either birdsfoot trefoil (*Lotus corniculatus*), Kentucky bluegrass (*Poa pratensis*), ladino clover (*Trifolium repens*), or a mixture of Kentucky bluegrass and ladino clover. The third factor consisted in planting either white (*Picea glauca*) or black (*Picea mariana*) spruce seedlings. Winter barley did not establish as rapidly and vigorously as expected. Nevertheless, the cereal reduced weed populations in the establishment year. For broadleaf weeds, this reduction was not large enough to allow a carryover during subsequent years. In contrast, subsequent increase of the grassy weed populations was slowed down in the presence of cover crops. The establishment of the other cover crops was poor and highly variable from site to site. It is not clear whether this relative failure was due to growing conditions, poor establishment of the cereal cover crop, or to other factors. Liming and cover crops had little effect on spruce growth but black spruce seedlings grew taller than white spruce seedlings at two out of four sites, and basal diameter of white spruce reached larger values than did black spruce. For white spruce, this might constitute an advantage in old fields where seedlings are prone to lodging under weed pressure. Finally, it was noted that seedling survival was exceptionally high in all treatments.

[Utilisation de plantes compagnes lors de la plantation d'épinettes blanches et d'épinettes noires sur des terres agricoles abandonnées]

Le contrôle de la végétation constitue une préoccupation majeure lors du reboisement des terres agricoles abandonnées. Dans ce contexte, l'utilisation de plantes compagnes pourrait constituer une alternative à l'usage des herbicides. Les plantes compagnes pourraient compétitionner les

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mauvaises herbes et avoir une influence positive sur la survie et le taux de croissance des arbres. Une expérience a été menée à quatre sites pour étudier cette hypothèse. L'expérience comprenait trois facteurs. Le premier consistait à appliquer ou non de la chaux. Le second comprenait les cinq niveaux de la culture compagne : un témoin; un mélange d'orge d'automne (*Hordeum vulgare*) et de lotier (*Lotus corniculatus*); un mélange d'orge d'automne et de pâturin du Kentucky (*Poa pratensis*); un mélange d'orge d'automne et de trèfle ladino (*Trifolium repens*); et un mélange d'orge d'automne, de pâturin du Kentucky et de trèfle ladino. Le troisième facteur considérait l'espèce de conifère, soit l'épinette blanche (*Picea glauca*) ou l'épinette noire (*Picea mariana*). L'orge d'automne ne s'est pas implantée facilement. Néanmoins la présence de la céréale a permis de réduire les populations de mauvaises herbes au cours de la première année. Chez les dicotylédones cette réduction ne s'est pas manifestée au cours des années subséquentes. Cependant, chez les graminées l'augmentation des populations de mauvaises herbes a été moins rapide en présence de cultures compagnes. L'implantation des autres espèces compagnes a été très variable d'un site à l'autre. Il n'a pas été possible de déterminer si cet échec relatif est dû aux conditions de croissance, à la mauvaise implantation de l'orge d'automne ou à d'autres facteurs. Le chaulage et le type de plante compagne ont eu peu d'effet sur la croissance des arbres. Il a cependant été noté qu'à deux des quatre sites, l'épinette noire atteignait une plus grande hauteur que l'épinette blanche. Il a aussi été noté que le diamètre basal de l'épinette blanche était généralement plus important que celui de l'épinette noire. Ceci pourrait constituer un avantage pour l'épinette blanche dans les champs où les espèces nuisibles risquent de provoquer la verse des plants forestiers. Finalement, le taux de survie qui a été enregistré dans cette expérience est exceptionnellement élevé.

INTRODUCTION

Weeds growing on abandoned agricultural lands can impair the establishment of transplanted conifer seedlings. Although herbicides are available in Quebec to control undesirable species, use of chemical control will become less of an alternative as new regulations are enforced (Gouvernement du Québec 1991a). Alternative methods of weed control thus need to be developed. One possibility is the use of legume or grass cover crops on mechanically prepared sites.

Cover crops were found to improve establishment, yield, mineral nutrition, quality, to reduce soil compaction, and to control weed populations and soil erosion in several orchard and tropical forest plantations (Bugg *et al.* 1991; Catzeflis 1988; Laosuwan *et al.* 1988; Layne and Tan 1988; Mustaffa 1988; Vosatka 1989; Yogaratnam *et al.* 1984). However, little is known of the positive or negative effects associated with the use of cover crops under the climatic conditions of eastern Canada.

A study conducted in Quebec involving various hardwood species did not demonstrate the potential benefits of legume cover crops over herbicides or bare soil treatments (Cogliastro *et al.* 1990). On the other hand, in Norway spruce [*Picea abies* (L.) Karst.] plantations in Belorussia, the presence of perennial lupines (*Lupinus* spp.) resulted in increased tree diameter, height, and volume (Rikhter *et al.* 1985). There are few published articles that clearly demonstrate advantages or disadvantages of using cover crops to improve conifer seedlings establishment on abandoned agricultural lands (Mays and Bengtson 1985; McLaughlin *et al.* 1987; Nwonwu and Obiaga 1988; Shribbs and Skroch 1985).

In Quebec, reforestation with conifers covers more than 80 000 ha of land annually (Gouvernement du Québec 1996). Part of this area comes from abandoned agricultural lands dominated by herbaceous and small woody species. Under these conditions, conifer seedlings are usually transplanted without any site preparation and they suffer greatly from competition; the rate of mortality is high (Delisle 1993; Sutton and Weldon 1995) and the stage at which tree seedlings will dominate the canopy is delayed.

Under the latter conditions, cover crops may well constitute a relevant practice and this study was initiated to test the assumption that cover crops will favour white and black spruce growth. It is part of the assumption that competition from cover crop species would be less detrimental to tree seedlings than competition from weed species. This belief relates to the fact that cover crop species generally do not grow as tall as weed species and consequently, tree seedlings may be able to outgrow herbaceous species earlier under these conditions. In yr one, winter barley should establish rapidly and as the plant requires vernalization, growth should stop before heading. Cultivar OAC Elmira was selected because it could not survive Quebec winters. Thus the plant died during the first winter, leaving a natural mulch. In yr one, this management program was expected to provide competition against weeds and to favour the establishment of transplanted tree seedlings and slow-growing forage crops (trefoil, clover and bluegrass). In subsequent yr, forage crops were expected to compete with weeds and to slow down their development.

This work investigated the capacity of different cover crops 1) to compete with the weeds emerging after elementary site preparation and 2) to favour survival and growth of transplanted coniferous seedlings, given the latter condition.

MATERIALS AND METHODS

A factorial experiment was established at Valcartier (lat. 46°59' N, long. 71°29' W), Quebec, in 1991 (designated «Valcartier Site 1»), and replicated in time on an adjacent site in 1992 (designated «Valcartier Site 2»). The experiment was also established at Rimouski (lat. 48°23' N, long. 68°34' W), Quebec, in 1991 and 1992 (designated «Rimouski Site 1» and «Rimouski Site 2», respectively). The Valcartier sites were located in an *Acer saccharum Marsh./Betula alleghaniensis Britt./Fagus grandifolia Ehrh.* association (Thibault 1985), on the lowest terrace of the Jacques-Cartier River. The soil was a loamy sand originating from an alluvial deposit. It was well drained and had a slope of 1-2%. The Rimouski sites were located in an *Acer saccharum/Betula alleghaniensis/ Abies balsamea (L.) Mill.* association (Thibault 1985). The soil was a well-drained gravelly loam from glacial origin (till), with a slope of 5-10% (Drolet and Gagné 1989).

Plots were established on abandoned agricultural fields. The Valcartier sites had been abandoned for 30 yr. The Rimouski sites were last cultivated in 1984. The exact agricultural history of all sites (cropping, fertilization, etc.) is not well known, but they were last used for hay production.

A split-split-plot layout with five replications was used at all sites. Main plots were assigned to the lime factor and consisted of either with or without lime. Sub-plots were assigned to the cover crop factor and consisted of five levels: level 1 comprised a control with no cover crop, while levels 2 to 5 were drilled with 'OAC Elmira' winter barley (*Hordeum vulgare* L.) and with either 'Leo' birdsfoot trefoil (*Lotus corniculatus* L.), 'Georgestown' Kentucky bluegrass (*Poa pratensis* L.), 'California' ladino clover (*Trifolium repens* L.), or a mixture of Kentucky bluegrass and ladino clover. Sub-sub-plots were assigned to the species factor and consisted of either white or black spruce. Sub-sub-plots were 2 m x 3 m (1.5 m x 3 m at the Valcartier Site 2 experiment) and were separated from each other by a 2-m buffer zone (1 m at the Valcartier Site 2 experiment). This spacing was considered suitable as white spruce root extension is known to be on the order of 0.3 m per yr in a sandy soil (Grose 1968).

As mentioned above, the current practice is to establish conifer seedlings without any site preparation, but cereal and forage crop establishment would require some preparation. Consequently, to suit the objectives of this study, we used elementary site preparation. Sites were rototilled in the fall prior to establishment and immediately before cover crop seeding. At the first pass, lime was applied at 7 500, 11 000, 7 250, and 10 000 kg ha^{-1} at Valcartier Site 1, Valcartier Site 2, Rimouski Site 1, and Rimouski Site 2, respectively. No fertilization was applied as fertilization is not a common practice in forestry (Gouvernement du Canada 1987; Gouvernement du Québec 1991b). While such an elementary site preparation is expected to favour tree species establishment (Oswald 1990), it is obviously not ideal for forage seedlings and consequently, we used seeding rates 60% higher than recommended for forage species (Fergus and Buckner 1973; Leffel and Gibson 1973; Seaney 1973).

At Valcartier Site 1, cover crops were planted on 23 May 1991 with a Wintersteiger™ drill, in 15 cm rows. Barley was seeded at 100 kg ha^{-1}; Kentucky bluegrass at 16 kg ha^{-1} in the absence of ladino clover and 8 kg ha^{-1} when the latter species was present; ladino clover at 5 kg ha^{-1} in the absence of Kentucky bluegrass and 3 kg ha^{-1} when seeded in mixture with the bluegrass; and birdsfoot trefoil at 20 kg ha^{-1}. At Rimouski Site 1, seeding was performed as above on 30 May 1991. At Valcartier Site 2 and Rimouski Site 2, seeding was performed on 25 May 1992 and 26 May 1992, respectively. At the latter two sites seeding proceeded as above with two exceptions: small seeded cover crops were planted with a Brillon™ seeder; and barley was seeded at 150 kg ha^{-1}. Five soil cores were collected in each main plot at the time of seeding to determine pH levels.

Seedlings of both spruce species were grown in IPL 45-110 Rigipot™ (IPL inc., Bellechasse, Quebec, Canada) containers for 2 yr prior to the beginning of the experiment. The seedlings were planted by hand within 2 wk of cover crop seeding. Each sub-sub-plot contained eight seedlings arranged in two rows. Spacing was 0.35 m between trees and 1 m between rows.

Sampling and analysis

Cover crops and weeds were sampled in late June and in October during the yr of establishment, and in October during subsequent yr. For both seeding yr, plots were last sampled in October 1993. This sampling was conducted at the sub-plot level; it did not take into account spruce species. Two quadrats (33 cm x 75 cm) were positioned at random within each sub-plot to evaluate cover crops and weeds. Abundance of cover crops and grass weed species was estimated by visual rating using a scale of 0 to 100, where a value of 0 denotes the absence of the species and a value of 100 means that, viewed from the top, the species covered 100% of the quadrat. Dicotyledonous weed species were counted to determine the number of individuals in each quadrat.

Abundance data from cover crops and weed species were subjected to an analysis of variance. At each site, lime, cover crops and their interaction were considered fixed effects and blocks were considered random effects. Differences among treatments were assessed using contrast analysis.

Growth of white and black spruce was obtained by measuring plant height and root collar diam at ground line at planting and in the fall of 1993. Tree survival was assessed in 1993, concurrently with tree measurements. Mixed linear models were constructed to analyse plant height and root collar diam of transplanted seedlings at the end of the 1993 growing season. Initial height and root collar diam were used as covariates in their respective models. In order to stabilize the variance of the residuals and to achieve normality, all variables were transformed to their square root. At each site, liming, cover crops, spruce species and their interactions were considered fixed effects. Effects of blocks, plots, sub-plots, sub-sub-plots and tree seedlings were considered random. The variance components associated with each random effect were tested for significance in a hierarchical fashion starting with components from the most complex sources of variation and working up the variance structure. Random effects with non-significant variance component (α = 30%) were removed from the model (Milliken and Johnson 1984). The significance of fixed effects was assessed from the final reduced model. Means shown in the tables are back-transformed. All calculations and statistical analyses were performed using SAS™ (SAS Institute Inc. 1989).

RESULTS AND DISCUSSION

General growing conditions

At both sites in 1991, precipitation during the month of April was higher than average, but conditions were very dry later on. Total rainfall from April to July was only 72% of average at Valcartier and 65% of average at Rimouski. In June and July, both sites received less than 50% of the average amount of water. In contrast, 1992 was a rainy yr and, from April to July both sites received slightly more than the average rainfall (117% of average at Valcartier; 136% of average at Rimouski). However, precipitation was not evenly distributed throughout the season, particularly at Valcartier, where July rainfall was only 57% of the long-term average.

At Rimouski, pH at the time of seeding was unexpectedly high with values of 6.9 and 7.2 in 1991 and 1992, respectively. Soils with pH values in that range are usually suitable for the establishment of most cereals and forages (St-Pierre and Gendron 1982; Woodhouse and Griffith 1973), and consequently are not expected to impair cover crop establishment and growth. Similarly, spruce seedlings should grow normally under such conditions (Burns and Honkala 1990; Pritchett and Fisher 1987). At this location, liming increased soil pH by 0.5 and 0.4 units in 1991 and 1992, respectively.

At Valcartier, pH was 5.5 and 5.6 in 1991 and 1992, respectively. Values in that range have the potential of reducing cereal and forage crop establishment and growth and one would normally raise the pH to ensure adequate yields (St-Pierre and Gendron 1982; Woodhouse and Griffith 1973). Conversely, pH values in that range are commonly found on sites used for reforestation and spruce seedlings have the potential of doing relatively well under such conditions (Burns and Honkala 1990; Pritchett and Fisher 1987). Liming at Valcartier increased soil pH by 0.7 and 0.8 units in 1991 and 1992, respectively.

Cover crop establishment and growth

Under normal agricultural conditions, *i.e.* appropriate soil preparation, drainage, fertilization, etc., barley ground cover should have reached 50% or more by the end of June. At Valcartier Site 1 and at Rimouski Site 1, winter barley established very slowly, while at Valcartier Site 2 and at Rimouski Site 2, establishment was good (Table 1). The success or failure of winter barley growth can be related, at least in part, to the general growing conditions described above; a dry season in 1991 and a low pH in the no lime treatment at Valcartier. Cereal growth was faster in 1992 than in 1991 but the low pH characterizing the no lime treatment at the Valcartier site was detrimental to crop growth. The results indicate that under the experimental conditions that prevailed in this study, winter barley was sensitive to water shortage and to low pH.

The success of forage cover crop establishment varied between sites (Table 2): establishment of birdsfoot trefoil

Table 1. Percent cover of winter barley measured in June and October of the establishment yr at the Rimouski and Valcartier sites

Treatment	Rimouski				Valcartier			
	Site 1		Site 2		Site 1		Site 2	
	Jun. 91	Oct. 91	Jun. 92	Oct. 92	Jun. 91	Oct. 91	Jun. 92	Oct. 92
	% cover [a]							
Barley + B. trefoil + Lime	15	75	55	80	5	30	85	75
Barley + B. trefoil + No lime	15	75	50	70	0	10	60	50
Barley + K. bluegrass + Lime	20	70	55	70	5	35	85	75
Barley + K. bluegrass + No lime	20	80	60	65	0	10	55	45
Barley + K. bluegrass + L. clover + Lime	15	65	60	70	5	35	90	75
Barley + K. bluegrass + L. clover + No lime	20	80	60	70	0	10	50	35
Barley + L. clover + Lime	15	65	65	70	5	30	90	75
Barley + L. clover + No lime	15	70	60	70	0	0	50	45
Probability of a significant effect of :	P <							
Liming	NS	0.01	NS	NS	0.01	0.01	0.01	0.01

[a] Average of five replicates to the nearest 1% between 1 and 5 and to the nearest 5% above 5.

failed at Valcartier and was moderately successful at Rimouski, establishment of Kentucky bluegrass succeeded only in the limed plots at Valcartier Site 2, and establishment of ladino clover was generally poor except at Rimouski Site 2. Gadgill *et al.* (1988) also showed inconsistent results during forage cover crop establishment in *Pinus radiata* (D. Donn.) plantations. In our experiment, factors that may have influenced forage establishment include site preparation, fertility level, and weed pressure. In this study we deliberately planned to use elementary site preparation. As a consequence, the seedbed did not compare to what could have been achieved with more conventional soil preparation, *i.e.*, moldboard plow, disk and optimum soil amendment. These factors may have influenced forage species establishment and increasing forages species seeding rates did not compensate for disadvantages brought forward by the use of elementary site preparation. The presence of weeds is another factor that may have influenced forage crop establishment. Part of the rational for using the barley companion crop was to reduce weed competition and to favour forage establishment (Decker *et al.* 1973). However, in this study barley establishment was sometimes impaired, resulting in less than optimum weed control in yr one, which may also have had a negative impact on forage species establishment.

Weed control

At Rimouski, the composition of the weed community was almost identical at both sites. Dominant dicotyledonous species present at Rimouski Site 1 and Rimouski Site 2 were *Chrysanthemum leucanthemum* L., *Hieracium aurantiacum* L., and *Vicia cracca* L. Among the 10 most important dicotyledonous species recorded, eight were present at both sites (data not shown). Species that were important at Site 1 but not important at Site 2 were *Oxalis stricta* L. and *Equisetum arvense* L. At the latter site, these two species were replaced by *Stellaria graminea* L. and *Stellaria media* (L.) Cyrill. Important grasses observed at Rimouski were *Bromus inermis* Leyss and *Festuca* spp.

Table 2. Percent cover of birdsfoot trefoil, Kentucky bluegrass and Ladino clover measured at the Rimouski and Valcartier sites after two (Site 2) or three (Site 1) growing seasons

	Birdsfoot trefoil				Kentucky bluegrass				Ladino clover			
	Rimouski		Valcartier		Rimouski		Valcartier		Rimouski		Valcartier	
Treatment	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
	% cover [a]											
Barley + B. trefoil + Lime	20	15	0	1	0	0	1	1	1	5	0	0
Barley + B. trefoil + No lime	10	15	0	1	1	1	0	1	1	5	0	0
Barley + K. bluegrass + Lime	0	0	0	0	1	1	1	55	0	5	0	0
Barley + K. bluegrass + No lime	0	0	0	0	0	1	0	3	1	5	0	0
Barley + K. bluegrass + L. clover + Lime	1	1	0	0	0	1	1	30	1	15	0	0
Barley + K. bluegrass + L. clover + No lime	0	1	0	0	0	1	0	3	1	15	0	0
Barley + L. clover + Lime	0	0	0	0	0	0	1	2	1	25	0	0
Barley + L. clover + No lime	1	1	0	0	0	1	0	0	1	20	0	0
Probability of a significant effect of :	$P <$											
Cover crops (C)	0.01	0.01	0.01	0.01	NS	0.04	0.04	0.01	0.02	0.01	NS	NS
Birdsfoot trefoil vs Others	0.01	0.01	NS	0.01	-	-	-	-	-	-	-	-
Kentucky bluegrass vs Others	-	-	-	-	NS	0.05	0.01	0.01	-	-	-	-
Ladino clover vs Others	-	-	-	-	-	-	-	-	0.01	0.01	NS	NS
Liming (L)	NS	NS	NS	NS	NS	NS	0.02	0.01	NS	NS	NS	NS
Interaction C x L	0.01	NS	NS	NS	NS	NS	0.01	0.01	NS	NS	NS	NS

[a] Average of five replicates to the nearest 1% between 1 and 5 and to the nearest 5% above 5.

The composition of the weed community at the Valcartier sites differed from the Rimouski sites. But again, 8 of the 10 most important dicotyledonous species were recorded on both Valcartier sites (data not shown). Dominant dicotyledons were *Rumex acetosella* L., *Solidago* sp., and *Spiraea latifolia* (Ait.) Borkh. Species that were important at Valcartier Site 1 but not important at Valcartier Site 2 were *Lysimachia terrestris* (L.) BSP. and *Sisyrinchium* sp. At the latter site, these two species were replaced by *Solidago rugosa* Mill. and *Viola* sp. At those sites, the grass community was dominated by a single botanical group, *Agrostis* spp.

Overall, in the yr of establishment, the presence of barley contributed to a reduction of the weed populations (Tables 3, 4). When averaged over all sites and cover crops, and compared to the control treatment, dicotyledonous weeds were reduced by 34% and grassy weeds by 67%. Furthermore, the abundance of weedy plants decreased with liming. In limed plots pH was raised above 6.0, which resulted in better growth of winter barley. In turn, the cereal provided competition against weeds. However, subsequent growth of broadleaf weed populations, as measured by abundance data recorded in October 1993, was generally not affected by the cover crop treatments or by the lime treatments (Table 3). Significant differences were only noted in the Valcartier Site 2 experiment, in which broadleaf weeds density was lower in the control treatment than in the other treatments; an unexpected and unexplained result. On the other hand, with the exception of the Rimouski Site 1 experiment, subsequent growth of grassy weed populations, as measured by cover data recorded in October 1993, was affected by cover crop and lime treatments (Table 4). At all sites, more grassy weeds were found in the control treatments than in the cover crop treatments which means the use of a companion crop slowed down the development of grassy weed populations. Finally, as far as grassy weed populations are concerned, inconsistencies were observed with respect to the lime treatment and no clear conclusion can be drawn with respect to that variable.

These results are in general agreement with data obtained in experiments aimed at studying the impact of cover crops on forage establishment for hay production (Lemieux *et al.* 1987). The latter study showed that broadleaf weeds dominated the weed community after a few years when the use of a companion crop was the only weed control measure. In this study, the development of broadleaf weed populations was delayed by one yr, while the development of grassy weed populations was slowed down over the duration of the experiments. With the exception of a few species, the dominant broadleaf and grassy weeds observed at all sites were perennials which were present prior to the beginning of the experiment. The results observed might be due to how effective the site preparation was in destroying the vegetative reproductive organs of each species or group of species and of how effective were cereal and forage crops in competing with each weed or group of weeds. But within the scope of this project we cannot distinguish between the two.

White and black spruce growth and survival

Liming and cover crops generally had no consistent effects on seedling growth (Tables 5, 6). With respect to tree growth, the most significant effects observed relate to spruce species. At Valcartier black spruce seedlings generally grew taller than white spruce seedlings (Table 5). The effect of tree species was highly significant on site 2, and significant at $P = 0.0635$ at site 1. However, no significant effect of tree species was observed at the Rimouski sites. On the other hand, in all sites except Valcartier Site 1, basal diam of white spruce reached larger values than black spruce basal diam (Table 6). At Valcartier Site 1, the effect of tree species on basal diam was only significant at $P = 0.0850$ but white spruce outgrew black spruce in 8 out of 10 treatments. The greater radial growth of white spruce may allow the stem to develop

Table 3. Density of dicotyledonous weeds measured in October of the establishment yr (Oct. 91/Oct. 92) and in October 1993 (Oct. 93) at the Rimouski and Valcartier sites

	Rimouski				Valcartier			
	Site 1		Site 2		Site 1		Site 2	
Treatment	Oct. 91	Oct. 93	Oct. 92	Oct. 93	Oct. 91	Oct. 93	Oct. 92	Oct. 93
	Number m^{-2} [a]							
Barley + B. trefoil + Lime	21	30	24	40	40	52	10	25
Barley + B. trefoil + No lime	28	32	33	50	74	54	27	26
Barley + K. bluegrass + Lime	31	30	39	57	36	57	10	16
Barley + K. bluegrass + No lime	33	39	32	63	59	32	18	18
Barley + K. bluegrass + L. clover + Lime	21	35	34	64	40	49	7	23
Barley + K. bluegrass + L. clover + No lime	16	32	33	51	66	53	31	29
Barley + L. clover + Lime	17	32	20	36	33	50	10	25
Barley + L. clover + No lime	25	33	26	41	76	55	27	18
Control + Lime	44	33	49	58	60	45	15	14
Control + No lime	53	34	53	50	65	40	41	19
Probability of a significant effect of :	*P <*							
Cover crops[b]	0.01	NS	0.01	0.01	NS	NS	0.05	0.01
Control vs Cover crops	0.01	NS	0.01	NS	NS	NS	0.01	0.01
Liming	NS	NS	NS	NS	0.01	NS	0.01	NS

[a] Average of five replicates.
[b] The Cover crop x Liming interaction was not significant at the 0.05 level.

Table 4. Percent cover of grassy weeds measured in October of the establishment yr (Oct. 91/Oct. 92) and in October 1993 (Oct. 93) at the Rimouski and Valcartier sites

	Rimouski				Valcartier			
	Site 1		Site 2		Site 1		Site 2	
Treatment	Oct. 91	Oct. 93	Oct. 92	Oct. 93	Oct. 91	Oct. 93	Oct. 92	Oct. 93
	% cover [a]							
Barley + B. trefoil + Lime	2	25	0	3	15	5	5	80
Barley + B. trefoil + No lime	3	25	3	10	25	15	20	75
Barley + K. bluegrass + Lime	3	25	1	5	20	5	5	35
Barley + K. bluegrass + No lime	1	20	1	10	40	15	25	85
Barley + K. bluegrass + L. clover + Lime	1	25	1	3	30	5	3	45
Barley + K. bluegrass + L. clover + No lime	0	10	2	2	30	20	25	70
Barley + L. clover + Lime	1	20	3	15	25	5	3	80
Barley + L. clover + No lime	2	20	1	4	20	15	30	85
Control + Lime	5	25	4	10	35	10	75	85
Control + No lime	5	55	15	20	45	20	75	85
Probability of a significant effect of :	*P <*							
Cover crops (C)	0.01	NS	0.01	0.01	0.01	0.01	0.01	0.01
Control vs Cover crops	0.01	NS	0.01	0.01	0.01	0.01	0.01	0.01
Liming (L)	NS	NS	0.05	0.04	NS	0.01	0.01	0.01
Interaction C x L	NS	NS	NS	NS	NS	0.01	0.05	0.05

[a] Average of five replicates to the nearest 1% between 1 and 5 and to the nearest 5% above 5.

Table 5. Shoot height of white and black spruce measured at the Rimouski and Valcartier sites after two (Site 2) or three (Site 1) growing seasons

Treatment	Rimouski		Valcartier	
	Site 1	Site 2	Site 1	Site 2
	cm [a]			
White spruce				
Barley + B. trefoil + Lime	36.8	33.3	54.0	44.9
Barley + B. trefoil + No lime	42.9	32.8	51.6	42.6
Barley + K. bluegrass + Lime	36.0	34.2	57.5	43.8
Barley + K. bluegrass + No lime	41.5	35.0	53.9	44.2
Barley + K. bluegrass + L. clover + Lime	40.5	33.3	55.6	46.4
Barley + K. bluegrass + L. clover + No lime	40.9	33.8	55.8	42.8
Barley + L. clover + Lime	37.0	34.4	55.1	47.3
Barley + L. clover + No lime	39.4	33.5	47.5	41.9
Control + Lime	38.4	34.6	54.5	48.8
Control + No lime	36.7	33.6	54.9	45.7
Black spruce				
Barley + B. trefoil + Lime	38.6	33.7	53.7	48.0
Barley + B. trefoil + No lime	40.5	35.7	52.6	45.8
Barley + K. bluegrass + Lime	36.6	32.8	55.3	47.9
Barley + K. bluegrass + No lime	40.8	34.6	58.9	44.4
Barley + K. bluegrass + L. clover + Lime	37.9	34.4	57.9	50.0
Barley + K. bluegrass + L. clover + No lime	42.2	35.6	59.3	45.4
Barley + L. clover + Lime	39.1	33.8	54.0	49.9
Barley + L. clover + No lime	37.2	34.5	56.9	47.3
Control + Lime	38.7	34.7	54.8	54.4
Control + No lime	38.5	34.8	57.7	49.6
Probability of a significant effect of:	$P <$			
Tree species (S)	NS	NS	NS	0.01
Cover crops	NS	NS	NS	0.01
Liming (L)	NS	NS	NS	0.01
Interaction L x S[b]	NS	NS	0.02	NS

[a] Least squares means computed over five replicates.
[b] All other interactions were not significant at the 0.05 α level.

a better resistance to weed competition. This advantage of white spruce over black spruce might be useful in old fields, where seedlings are prone to lodge under weed pressure. However, one must also consider that white spruce growth appears to be more sensitive than black spruce on sites with greater nutrient limitations (Van Cleve and Harrison 1985).

We experienced a very low rate of mortality in this study and as a consequence it was not possible to perform statistical analyses on those data. Nevertheless, mortality rates are meaningful and some are reported herein. The lowest percentage of mortality was observed at Valcartier Site 1, Valcartier Site 2 and Rimouski Site 2. At these sites, only five, one and two seedlings out of 800 died respectively. The highest mortality (4.4%) was observed at Rimouski Site 1. This mortality corresponded only to 35 seedlings out of 800, after three growing seasons. Mortality rates reported in the literature vary from 15 to 35% (Delisle 1993; Sutton and Weldon 1995), which is much higher than what was observed in this study. Oswald (1990) pointed out the importance of adequate site preparation in reforestation and we may suppose that site preparation, which was uniform for all treatments in this study, is responsible, at least in part, for the high survival rates observed.

In this study, it was not possible to identify a treatment capable of reducing competition from broadleaf weeds over the entire duration of the experiment. In the better case, the development of broadleaf weed populations

Table 6. Basal diameter of white and black spruce measured at the Rimouski and Valcartier sites after two (Site 2) or three (Site 1) growing seasons

	Rimouski		Valcartier	
Treatment	Site 1	Site 2	Site 1	Site 2
	cm [a]			
White spruce				
Barley + B. trefoil + Lime	5.4	5.1	8.5	8.3
Barley + B. trefoil + No lime	6.7	5.0	9.1	8.2
Barley + K. bluegrass + Lime	5.8	5.0	7.5[b]	8.1
Barley + K. bluegrass + No lime	6.6	5.4	7.5[b]	8.1
Barley + K. bluegrass + L. clover + Lime	6.1	4.9	8.6	8.4
Barley + K. bluegrass + L. clover + No lime	6.8	5.2	10.2	8.1
Barley + L. clover + Lime	5.8	5.2	9.5	9.2
Barley + L. clover + No lime	6.4	5.2	9.3	7.9
Control + Lime	6.3	5.1	9.4	8.9
Control + No lime	6.2	5.2	10.0	7.9
Black spruce				
Barley + B. trefoil + Lime	5.2	4.1	8.1	7.8
Barley + B. trefoil + No lime	5.7	4.3	8.8	7.8
Barley + K. bluegrass + Lime	5.4	3.9	6.6[b]	7.2
Barley + K. bluegrass + No lime	5.8	4.2	7.1[b]	7.4
Barley + K. bluegrass + L. clover + Lime	5.1	4.1	8.7	8.0
Barley + K. bluegrass + L. clover + No lime	6.8	4.4	10.0	7.9
Barley + L. clover + Lime	5.5	4.1	8.6	7.8
Barley + L. clover + No lime	5.4	4.3	9.8	7.7
Control + Lime	5.6	4.4	8.7	8.9
Control + No lime	5.5	4.4	9.9	7.5
Probability of a significant effect of:	$P <$			
Tree species	0.01	0.01	NS	0.01
Cover crops	NS	NS	0.03	NS
Liming[c]	NS	NS	0.01	NS

[a] Least squares means computed over five replicates.
[b] Least squares means computed over four blocks due to missing data.
[c] All interactions were not significant at the 0.05 α level.

was only delayed by 1 yr. On the other hand, we were able to slow down the development of grassy weed population over the duration of the experiment. However, this was not enough to increase survival and growth of transplanted coniferous species compared to the controls without cover crops. Nevertheless, we believe that the approach deserves further work as winter barley establishment was not always good under the soil and climatic conditions of this study. We observed that winter barley did not play adequately its expected role, that is to provide competition against weeds, and to favour establishment of transplanted seedlings and slow-growing forage crops. Other cereal cover crops might be more robust during the establishment phase. We suggest that spring oat be considered in future work as it has been successfully used for balsam fir [*Abies balsamea* (L.) Mill.] establishment (Dirkman 1971). Reforestation with coniferous species on abandoned agricultural lands requires more study to determine which species are the ideal cover crops to deal with and to better understand the effects of site preparation on cover crop establishment and on tree growth and survival.

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