Plant Composition in Relation to Vole Damage in Coniferous Plantations

by

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Abstract

We analysed the plant composition of several coniferous plantations of Eastern Townships of Quebec to examine the relationships between biomass patterns and levels of damage made by meadow voles (*Microtus pennsylvanicus*) to young trees. The biomass of the most abundant grass species was compared in severely damaged, lightly damaged and undamaged plantations. Damage indices per plantation were standardized using the composite Mizushima (1976) index. Total biomass did not differ between the three categories of plantations analysed. However, heavily damaged plantations contained significantly more biomass of Virginia strawberry (*Fragaria virginiana*) and less of couch-grass (*Agropyron repens*). Debarking damage by voles was not concentrated on specific coniferous species but occurred rather in meadows where *Fragaria* was relatively more abundant. To reduce tree loss due to vole debarking, we recommend an initial survey of the biomass be made at future planting sites and seedlings be planted in meadows with low biomass. Sites with low biomass of *Fragaria* and high biomass of *Agropyron* would probably be the best ones.

Key words: Plantations, conifers, damage, debarking, voles, biomass, *Microtus pennsylvanicus*, *Fragaria virginiana*, *Agropyron repens*, Quebec.

Résumé

Nous avons analysé la composition végétale de plusieurs plantations de conifères des Cantons de l'Est (Québec, Canada) afin d'étudier les relations entre les patrons de biomasse et les niveaux de dommages causés aux jeunes arbres par le campagnol des champs (*Microtus pennsylvanicus*). La biomasse de chacune des espèces végétales a été comparée entre les plantations ayant subi beaucoup, moyennement ou peu (sans) de dommage. Les indices de dommage ont été établis à partir de l'indice de Mizushima (1976). La biomasse totale des prairies analysées ne différait pas selon les catégories de plantations. Toutefois, les plantations sévèrement endommagées contenaient des niveaux de biomasse significativement plus élevés de fraisier de Virginie (*Fragaria virginiana*) et moins élevés de chiendent (*Agropyron repens*). L'écorçage des arbres par les campagnols n'était pas restreint à une espèce de conifère en particulier mais plutôt aux champs où le Fraisier de Virginie était relativement important. Dans le but de réduire les risques de dommages causés par les campagnols, nous recommandons aux intervenants sylvicoles/forestiers: 1) d'éviter d'utiliser comme futurs sites de reboisement les champs dont la biomasse totale est très élevée; 2) et de localiser les futures plantations dans les habitats où il y a peu de *Fragaria* et beaucoup d'*Agropyron*.

Mots-clés : Plantations, conifères, dommages, écorçage, campagnol, biomasse, *Microtus pennsylvanicus*, *Fragaria virginiana*, *Agropyron repens*, Québec.

Introduction

Reforestation programs in the province of Quebec are progressing rapidly. In the Eastern Townships alone, nearly 60 million coniferous seedlings were planted in 1987 and this figure increases by approximately 10% annually. Survival of young trees in the plantations is strongly linked to soil types in which they are planted, to maintenance practices during the first two or three post-planting years and depredation levels by biotic elements such as insects, fungal and mammalian pests. Seedlings are generally planted in abandoned or vacant lots without consideration of the biophysical conditions. Unfortunately, techniques to improve the survival of young trees under field conditions have not kept pace with planting efforts.

Soil quality and the physical conditions of the land used in reforestation have failed as predictors of future biomass loss caused by mammalian pests (Sartz 1970, Pigott 1985).

Among the biotic factors that cause tree losses in the first decade after planting, rodents and lagomorphs are the two most widespread causes of mortality whereas deer (*Odocoileus virginianus*), porcupine (*Erethizon dorsatum*) and squirrel (*Tamiasciurus hudsonicus*) have merely sporadic and local effects. The impact of population fluctuations of small mammals on tree losses and their effects on reforestation programs have been studied in Finland, Norway and Sweden by Myllymaki (1970), but he was unable to find a common cause for these recurrent losses. Nevertheless, voles of the genus *Microtus* were generally implicated in seedling losses. Their North American relatives, the meadow voles (*Microtus pennsylvanicus*), are also regarded as important agricultural pests (Kaukeinen 1982) and past studies of Cayford and Haig (1961), Santamour *et al.* (1963) and Buckner (1972) clearly showed that they could become important forest pests by destroying between 8% and 40% of young trees in plantations.

Voies generally damage trees during winter (Baumler 1975), particularly in years when snow cover is deep (Colvin and Jackson 1982) and after summers of high population

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densities (Hansson and Larsson 1978, Teivainen 1984). To date, it has been impossible to predict peaks in population density that would permit timely application of control techniques. This is due to a lack of long-term studies of population dynamics of voles. The meadow vole is a generalist herbivore living in wet or mesic areas where grasses, sedges and forbs represent the bulk of their diet (Batzli 1985). For reasons that may be associated with food scarcity, their diet also includes bark from the stems, roots and twigs of shrubs and young trees (Green 1978). Even though they eat very small quantities of these food items, this feeding behaviour is the most destructive for young trees because voles remove the outer bark and devour the underlying cambium layer of either trunk or roots (Radanyi 1974, Pigott 1985). Water and carbohydrates can no longer be translocated (Westveld 1942, Smith 1962), weakening young trees and favoring attacks by fungi and other pathogens. Young plantations (< 2 years) are particularly vulnerable to such losses while older ones suffer less (Larsson 1973, Teivainen 1984). However, Hansson (1985) showed that conifers may still suffer from vole attack 10 to 15 years after planting, especially when tree growth is slow.

Vegetation composition, moisture conditions and abundant ground cover appear to be the most important factors favoring high densities of voles (Getz 1985). Population densities are usually higher on sites with greater biomass (> 450 gDM/m²) (Eadie 1953, Birney *et al.* 1976). In winter, grasses are structural elements that help to establish a deep snow cover and a subnivean space in which small mammals build their tunnels. This subnivean space is important to the winter distribution, activity and survival of small rodents (Pruitt 1957, Coulianos and Johnels 1963). Consequently, a dense herbaceous biomass can increase winter survival of voles and eventually lead to a population build-up that could be related to tree losses in plantations (Schlegel-Bechtold 1980). Like Schlegel-Bechtold (1980), we think that when plantations are put in meadows that have abundant cover or high biomass of preferred foods, these factors could favor high population densities of voles, and consequently, high damage losses. We designed our study to determine ways of improving reforestation success. We were particularly interested in determining whether there was a relationship between biomass patterns in plantations suffering high and low damage levels and in identifying specific plant associations in meadows that could make favorable or unfavorable habitats for conifer seedlings.

Methods

In 1986 and 1987, we located 14 plantations that had been planted for less than six years with the most popular coniferous species of the region under study and for each species, sites with and without evidence of debarking by voles. During the spring of 1986 and 1987, after snowmelt, 5 to 10% of the trees in each plantation were located and examined for vole damage. Vole debarking was distinguishable from that of other pest species because they usually attack the basal area of young seedlings and leave tooth marks.

Each tree was assigned a damage level based on the severity of damage: (0) – no damage; (1) – one or two superficial small wounds on trunk or branches; (2) – one large or several small wounds on trunk or branches; (3) – strip of bark removed on trunk or lower branches and parts of trunk gnawed; (4) – complete girdling of trunk. These damage levels were adapted from those of Byers (1977), Byers and Cummins (1977), and Hansson (1985) to suit our experimental conditions.

Each plantation was then attributed a composite index of overall damage using the formula of Mizushima (1976) that accounts for the number and severity of damaged trees:

$$\% \text{ damage in plantation} = 100 \times \frac{\sum(n \times d)}{N \times K}$$

where **n** = number of trees observed for one damage level

d = damage level value (0 to 4)

N = total number of trees examined per plantation

K = number of **d** levels in the numerator greater than 0.

This permitted us to separate *a posteriori* the 14 plantations into three categories: "severely damaged" for those with a composite index > 8%; "lightly damaged" for those between 1% and 8%; and "undamaged plantations" for those in which the overall index was ≤ 1%.

Biomass of grasses and herbs was sampled in July, the peak of the growing season for the Eastern Townships region. Fifteen quadrats of 625 cm² were randomly distributed in each plantation. Plants of each quadrat were cut one cm above ground, separated by species, weighed, oven-dried at 60°C for 48 hours, and reweighed. All biomass values are presented in grams of dry matter/m².

We performed statistical analyses on the 20 most frequent plant species found on the 14 plantations. Species were weighed for each quadrat in every plantation. When a species was missing, it was given a biomass value of 0. The large number of 0 entries for many species violates the assumptions of parametric analyses and justifies the use of non-parametric statistical procedures. Kruskal-Wallis tests (non-parametric equivalents of one-way analyses of variance) were performed to compare biomass values between the three damage categories. These tests were followed by a multiple comparison test (Noether 1971) when the null hypothesis (no difference between groups) was rejected.

Results

Five of the 14 plantations surveyed were classified as heavily damaged compared with three that were lightly damaged and six that showed few signs of vole attacks (Table 1). Damage was relatively recent and may have resulted from the last vole population peak that occurred in 1984. All plantations had similar biomass figures, but they were consistently less than that of ideal habitat for voles (Birney *et al.* 1976). Severely damaged plantations had a mean (± 1 S.E.) total biomass of 241.7 ± 47.8 g/m² (N=5), compared to 281.8 ± 79.1 g/m² (N=3) and 307.6 ± 62.8 g/m² (N=6) for the lightly damaged and undamaged plantations, respectively. Despite the fact that total biomass of these old-field habitats seemed to be inversely related to damage levels inflicted to conifers, we were unable to detect any significant differences in biomass patterns between the plantation categories.

Relative proportions of total biomass contributed by the six most abundant plant species (*Agropyron*, *Agrostis*, *Festuca*, *Moss*, *Phleum*, *Poa*) and by a seventh series of plants (including all other species) were compared between plantations classified by damage category. There were no significant differences among the types of plantations ($X^2_{0.05,12} = 10.53$; $p = 0.57$). We conclude that none of the abundant plant species could be associated with heavily damaged sites and be used to predict site quality. However, 57 plant species were censused in all plots from which 20 species

occurred regularly enough to be used in further statistical analyses. Comparison of the 20 most frequent species revealed that six rarer species varied significantly among the plantation categories (Table 2). Differences between severely damaged (high) and undamaged (none) plantations were particularly noticeable for four of them: *Leontodon autumnalis*, *Ranunculus acris*, *Agropyron repens* and *Fragaria virginiana*.

Severely damaged plantations had significantly more biomass of strawberry (*F. virginiana*) and significantly less of couch-grass (*A. repens*) which are two species generally included in the summer diet of voles (Bélanger and Bergeron 1987, Bergeron and Jodoin 1987). Severely damaged plantations also had significantly lower biomass values of fall dandelion (*L. autumnalis*) and buttercup (*R. acris*).

Table 1. Classification of Eastern Townships coniferous tree plantations by damage categories.

Coniferous species	Trees examined		0	Number of trees per index category				Percent of trees damaged	Damage index ¹
	N	% in plantation		1	2	3	4		
Severely damaged									
<i>Picea abies</i>	200	6.7	152	6	21	21	0	24.0	13.88
<i>Picea abies</i>	783	14.9	628	59	80	16	0	19.8	8.52
<i>Pinus resinosa</i>	350	11.7	215	37	45	53	0	38.6	20.43
<i>Pinus strobus</i>	206	4.1	104	19	83	0	0	49.5	22.45
<i>Pinus strobus</i>	300	15.0	247	19	23	10	0	17.3	8.25
Lightly damaged									
<i>Picea abies</i>	200	9.1	192	0	3	5	0	4.0	2.62
<i>Picea abies</i>	1100	5.0	1023	47	25	5	0	7.0	2.55
<i>Picea abies</i>	448	3.4	422	14	11	1	0	5.8	2.18
Undamaged									
<i>Picea abies</i>	190	3.2	84	6	0	0	0	3.2	0.79
<i>Picea abies</i>	600	5.1	599	1	0	0	0	0.2	0.04
<i>Picea glauca</i>	200	4.0	200	0	0	0	0	0.0	0
<i>Pinus divaricata</i>	1000	9.1	992	4	2	2	0	0.8	0.35
<i>Pinus strobus</i>	400	20.0	391	9	0	0	0	2.2	0.56
<i>Pinus resinosa</i>	200	3.1	199	0	1	0	0	0.5	0.25

¹ Composite index: $100 \times \frac{[(152 \times 0) + (6 \times 1) + (21 \times 2) + (21 \times 3) + (0 \times 4)]}{200 \times 4} = 13.88$

Table 2. Differences in specific biomass values between damaged and undamaged coniferous tree plantations of Eastern Townships (Quebec, Canada).

Plant species	N ¹	Mean biomass value (gDM/m ²)	Average rank from Kruskal-Wallis tests	H value	P	Damage categories ²
<i>Leontodon autumnalis</i>	90	1.0848	133.58	35.63	0.0001	none a
	45	0.0982	84.51			low b
	75	0.0582	84.40			high b
<i>Vicia Cracca</i>	45	0.6346	133.21	10.06	0.0001	low a
	75	0.3181	107.62			high b
	90	0.1590	89.88			none b
<i>Ranunculus acris</i>	45	0.7996	118.02	8.86	0.0002	low a
	90	0.6237	115.90			none a
	75	0.0948	85.51			high b
<i>Galium palustre</i>	45	0.0343	119.92	7.48	0.0007	low a
	90	0.0075	106.04			none ab
	75	0.0011	96.19			high b
<i>Agropyron repens</i>	45	1.2803	127.00	7.07	0.0011	low a
	90	1.4153	109.49			none a
	75	0.8485	87.81			high b
<i>Carex spp.</i>	45	0.2631	115.20	6.80	0.0014	low a
	90	0.0025	104.40			none b
	75	0.0000	101.00			high b
<i>Fragaria virginiana</i>	75	0.3258	120.73	6.17	0.0025	high a
	90	0.3210	99.62			none b
	45	0.1368	91.98			low b
<i>Rumex acetosella</i>	75	0.1869	116.07	6.74	0.0030	high a
	90	0.3106	105.45			none ab
	45	0.0092	87.98			low b

¹ Number of quadrats censused.

² Categories with the same letter are not significantly different.

Discussion

Meadow voles inflicted damage but no mortality to many species of conifers suggesting that factors unrelated to the trees are probably and partly involved in debarking. Coniferous plantations did not seem to suffer high tree losses in meadows with high plant biomass that provides voles with abundant ground cover. A dense ground cover is not sufficient to sustain high population densities of voles because these plant species may not provide adequate food. In spite of the fact that the most abundant plant species of various vole habitats did not differ between heavily damaged and undamaged tree plantations, a few rarer species seemed to be highly associated with sites suffering heavy tree losses. However, this could be a consequence of small sample size. Virginia strawberries are a highly preferred food for meadow voles (Bélanger and Bergeron 1987). This species had a higher biomass value in meadows where voles had inflicted heavy damage to seedlings. The other plant species that varied significantly between heavily damaged and undamaged plantations are not known to be particularly important as ground cover or as important foods of voles (Zimmerman 1965, Bergeron and Jodoin 1987).

Our data indicate that we cannot use biomass values of the most common plant species to predict areas favourable for planting. Biomass determinations of couch-grass and Virginia strawberry could be used as criteria when deciding which sites to reforest. Heavy bark damage was associated with habitats having low biomass of couch-grass and high biomass of strawberries and these sites were less favourable for planting with conifers. Strawberries and couch-grass are easily identified in the field and their relative biomass could be readily assessed using vegetation sampling procedures similar to those used in this study. Vole densities have been relatively low for the past year (J.-M. Bergeron, unpubl. data) and should soon increase to higher densities. Although our results are only preliminary, we recommend that foresters test our criteria for selecting plantations by planting seedlings for the next few years in low-*Fragaria*/high-*Agropyron* sites and compare damage levels of those sites with those found on other sites to see whether this improves reforestation success.

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