Canadian Plant Disease Survey

Inventaire des maladies des plantes au Canada

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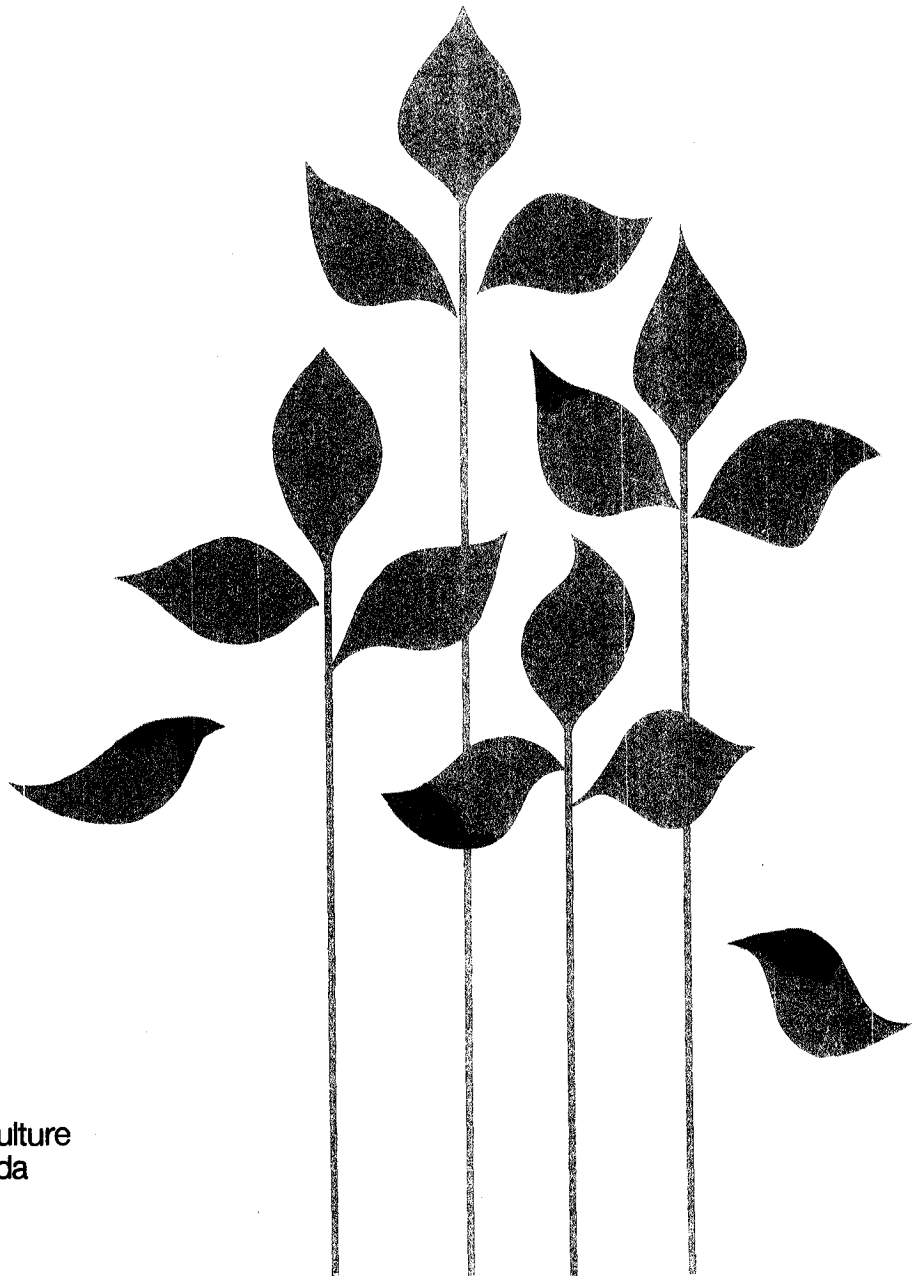

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The *Canadian Plant Disease Survey* is a periodical of information and record on the occurrence and severity of plant diseases in Canada and on the assessment of losses from disease. Other original information such as the development of methods of investigation and control, including the evaluation of new materials, will also be accepted. Review papers and compilations of practical value to plant pathologists will be included from time to time.

L'inventaire des maladies des plantes au Canada est un périodique d'information sur la fréquence des maladies des plantes au Canada, leur gravité, et les pertes qu'elles occasionnent. La rédaction accepte d'autres communications originales notamment sur la mise au point de nouvelles méthodes d'enquête et de lutte ainsi que sur l'évaluation des nouveaux produits. De temps à autre, il inclut des revues et des synthèses de rapports d'intérêt immédiat pour les phytopathologistes.

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Beech bark mycoflora and its distribution in relation to the presence of the scale insect, *Cryptococcus fagisuga* Lind.

Myriam R. Fernandez[1] and Michael G. Boyer[2]

Beech trees in several locations in the Toronto area were examined for bark fungi and their distribution in relation to diameter of trees and scale insect (*Cryptococcus fagisuga* Lind.) infestation classes. The distribution of some of these fungi indicated a possible role in the development of infestations of beech trees by the scale insect.

Can. Plant Dis. Surv. 69:2, 101-103, 1989.

On a examiné des bouleaux situés à différents endroits de la région de Toronto afin de déceler la présence de champignons corticoles et de déterminer leur distribution en fonction du diamètre des arbres et des catégories d'infestation par la cochenille (*Cryptococcus fagisuga* Lind.). La distribution de certains champignons indique que ceux-ci favorisent peut-être l'infestation du bouleau par la cochenille.

Introduction

Fernandez and Boyer (1988) reported on the presence and distribution of one of the known causal organisms of Beech Bark Disease, the scale insect *Cryptococcus fagisuga* Lind., in the Toronto area. Assays for the presence of bark fungi yielded no evidence of the presence of the other causal agent, the fungus *Nectria coccinea* var. *faginata* Lohman, Watson & Ayres (Shigo, 1963).

Houston *et al.* (1979) found the patterns of colonization of individual beech trees by *C. fagisuga* to be markedly influenced by the bark flora, and reported positive and negative associations with respect to different organisms. Given the potential of the bark microflora to influence the development and course of disease (Bier, 1963; Bier and Rowat, 1962) it would be interesting to determine whether the distribution of the beech scale insect reported by Fernandez and Boyer (1988) is correlated with the presence of any inhabitant of the bark which could potentially be considered as biological control agent. This represents a preliminary survey of the bark fungi of *C. fagisuga*-free and infested beech trees in the Toronto area.

Materials and methods

A total of six stands, in mixed maple beech communities around the Toronto region, were examined in the summer of 1982. Trees were classified according to diameter class (3-10, 10-17, 17-24, 24-31, 31-38, 38-45, 45-55, and > 55 cm) and infestation with *C. fagisuga* (0, 1-25, 25-50, 50-75, and 75-110 colonies/25 cm^2) as reported by Fernandez and Boyer (1988).

Within each stand, trees representative of diameter and scale insect infestation classes were sampled for epiphytic fungi, with a total of 47 trees being examined. A 5 cm^2 portion of the bark was rubbed with a moist sterile cotton pad, which was then gently pressed on Oxoid malt agar (1.2%) plates amended with streptomycin. To obtain an estimate of the abundance of the fungi, the swab was placed in 75 cc of sterile distilled water, and after shaking for 5 minutes, 0.5 ml was spread on the same medium, each sample being replicated four times. Plates were incubated in the dark at 25°C for 7 days.

Most fungi were identified to genera or species. Frequency of isolation was calculated as the percentage number of trees from which a fungus was isolated at least once, and abundance as the average number of colonies of that fungus per plate.

Results

Thirty-four species of fungi were isolated from the bark of the 47 beech trees examined (Table 1). The most frequent and abundant fungi were *Aureobasidium pullulans* (de Bary) Arnaud, *Cladosporium herbarum* (Pers.) Link ex S.F. Gray, and a 'White Yeast'. Other frequently isolated and/or abundant fungi were: *Alternaria alternata* (Fr.) Keissler, *Aposphaeria* sp., *Gliocladium roseum* Bain., *Fusarium* sp., *Papulospora* sp., *Trichoderma viride* Pers. ex S.F. Gray, and the unidentified fungi BC-13, OP-23, and a 'Pink Yeast'.

Chi-square tests for number of species present (Table 2) indicated that there was no significant difference in the mean number of species among diameter classes (χ^2 (.05), df: 7, 6.81, $.3 < P < .5$). Any attempt to correlate the presence of bark fungi with scale insect infestation classes is limited by the small sample size of the two highest infestation classes (Table 3). However, some trends were apparent. Examination of the distribution of these fungi among trees in the different scale insect infestation classes revealed that some were more frequently isolated from trees in the lower than the higher infestation classes, or non-infested trees (Table 3). (Chi-square on contingency table: χ^2 (.05), df: 3, 13.18, $.001 < P < .01$; Mann-Whitney test indicated the difference lay between the 1-25 class and the rest).

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Table 1. Percent isolation and abundance of bark fungi from beech trees in the Toronto area.

Fungus	Percent Isolation	Abundance No. Colonies/ Plate)
Alternaria alternata (Fr.) Keissler	44.4	1.0
Aposphaeria sp.	23.8	58.2
Arthrinum sp.	1.6	6.5
Aspergillum niger van Tieghem	7.9	2.2
Aureobasidium pullulans (de Bary) Arnaud	61.9	15.0
Camarosporium sp.	1.6	1.0
Cladosporium herbarum (Pers.) L. ex S.F. Gray	84.1	13.2
Coniothyrium sp.	4.8	1.0
Cytospora sp.	3.2	1.0
Epicoccum nigrum Link.	1.6	1.0
Fusicoccum sp.	9.5	7.5
Fusarium sp.	4.8	14.6
Cliocladium roseum Bain.	23.8	20.8
Mortierella ramanniana (Moller) Linnem.	3.2	2.0
Mortierella sp.	6.4	1.0
Mucor sp.	39.7	1.3
Cylindrocarpon sp.	18.0	2.0
Nematogonium sp.	3.2	2.5
Nigrospora sp.	7.9	1.0
Papulospora sp.	36.5	4.3
Penicillium sp.	30.2	3.0
Pestalotia sp.	3.2	1.0
Phoma sp.	1.6	2.0
Trichoderma viride Pers. ex S.F. Gray	31.8	3.5
Unidentified filamentous fungi		
BC-13	17.5	1.8
DW-8	3.2	1.0
GC-34	3.2	1.0
MS-1	3.2	1.0
OP-23	38.1	28.0
PC-35	7.9	42.2
Yeasts		
Black Yeast	9.5	6.0
Pink Yeast	34.9	9.0
White Yeast	85.7	26.2

Table 2. Richness of bark fungi by diameter class.

Diameter Class (cm)	No. Trees Sampled	Mean No. Fungal Species +SE
3 - 10	5	5.8 + 0.8
10+ - 17	12	7.1 + 0.9
17+ - 24	9	7.0 + 1.0
24+ - 31	7	7.8 + 0.9
31+ - 38	6	8.2 + 0.7
38+ - 45	5	6.0 + 0.8
45+ - 55	2	10.0 + 1.0
>55	1	7.5

Table 3. Richness of bark fungi by scale insect infestation class.

Infestation Class (colonies/25 cm^2)	No. Trees Sampled	Mean No. Fungal Species +SE
0	16	6.3 + 0.8
1 - 25	22	8.3 + 0.4
25+ - 50	6	7.0 + 0.5
75+ - 110	3	4.5 + 0.8

Fungi most frequently isolated from non-infested or lightly-infested trees (Table 4), and thus could possibly play a role in development of infestations, were *A. pullulans, G. roseum* and *T. viride. C. herbarum* and the 'White Yeast' seemed to be isolated with a high frequency regardless of the level of scale infestation of the tree.

Discussion

This survey of beech bark fungi revealed a large mycoflora present in trees of different sizes and stands, but with a very limited number of frequently isolated fungi (*i.e.* 'residents'). Despite the fact that there was a higher number of fungi isolated from lightly-infested trees than from non-infested ones, the majority of the most abundant and/or frequent fungi were present in both scale-infested and non-infested trees. Cotter and Blanchard (1982) isolated similar genera from American beech trees in New Hampshire, but reported that most of them were also isolated with similar frequencies from trees with than without Beech Bark Disease. In our study, the higher number of fungi isolated from lightly-infested trees than from non-infested ones may reflect the utilization of habitats created by the effects of colonization by the insect. Age, however, does not seem to give a similar increase on the number of bark fungi present.

Table 4. Percent isolation of bark fungi by scale insect infestation class of beech trees.

Fungus	Infestation Class (colonies/25 cm^2)			
	0	1-25	25+-50	50+-100
A. alternata	33	50	17	25
A. pullulans	76	68	50	0
Aposphaeria sp.	13	38	17	0
C. herbarum	83	83	100	100
Fusarium sp.	13	46	50	0
G. roseum	57	42	28	0
Papulospora sp.	13	40	33	25
T. viride	50	50	17	0
BC-13	33	13	17	25
OP-23	57	40	33	25
White Yeast	83	100	100	75

Fungi that were not isolated from heavily infested trees but were present in relatively high frequency in non-infested and lightly-infested trees were *A. pullulans*, *G. roseum* and *T. viride*. The antagonistic nature of the latter two fungi has been widely documented (Barnett, 1963; Barnett and Lilly, 1962; Bell *et al.* 1982; di Menna, 1962; Dubos and Bulit, 1981; Reinecke, 1981; Shigo, 1958; Skidmore, 1976; Wood, 1951). The antagonism of *A. pullulans* towards pathogenic organisms has also been reported in several studies (Deo Bhatt and Vaughan, 1963; Fokkema, 1973; Fokkema and Lorbeer, 1974; Pace and Campbell, 1974; Warren, 1972).

Future work on the possible role played by these fungi in the establishment of the insect should concentrate on 'resident' fungal species which were most frequently isolated from non-infested trees, such as *A. pullulans*. The feasibility of manipulating the environment to increase populations of other potential antagonists present in lower frequencies should also be investigated. In any case, selection and manipulation of potential antagonists should foremost take into account the period of dissemination of the insect (June to November).

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Infection of species of the Gramineae by *Erysiphe graminis* f. sp. *hordei* and *Erysiphe graminis* f. sp. *tritici*

J.G. Menzies[1] and B.H. MacNeill[2]

The ability of 19 isolates of *Erysiphe graminis* f. sp. *hordei* (*Egh*) and 34 isolates of *E. graminis* f. sp. *tritici* (*Egt*) to infect cultivated and wild species of Gramineae common to southern Ontario was examined. A high level of parasitic specialization of *Egh* was demonstrated by the failure of these isolates to infect any of the 22 species of Gramineae tested, except barley. In contrast, isolates of *Egt* were observed to infect wheat, meadow brome and downy brome. We suggest that these alternative hosts of *Egt* may act as oversummering reservoirs of inoculum for infection of fall sown winter wheat, as well as sources of some of the genetic variability found in the natural populations of the wheat pathogen in southern Ontario.

Can. Plant Dis. Surv. 69:2, 105-108, 1989.

On a examiné la capacité de 19 souches de *Erysiphe graminis* f. sp. *hordei* (*Egh*) et de 34 souches de *E. graminis* f. sp. *tritici* (*Egt*) d'attaquer des espèces cultivées et sauvages de graminées que l'on trouve couramment dans le sud de l'Ontario. On a de plus démontré un haut degré de spécialisation parasitique de *Egt*, car les souches de cette forme n'ont pu attaquer les 22 espèces de graminées éprouvées, à l'exception de l'orge. En revanche, les souches de *Egt* ont infesté le blé, le brome des prés et le brome des toits. Nous pensons que ces hôtes substituts de *Egt* servent à conserver pendant l'été des souches qui infecteront à l'automne les semis de blé d'hiver et qu'ils sont aussi à l'origine d'une certaine variabilité génétique de l'agent pathogène du blé observée dans les populations naturelles du sud de l'ontario.

Introduction

Surveys of the virulence spectra of *Erysiphe graminis* f. sp. *hordei* (*Egh*) and *E. graminis* f. sp. *tritici* (*Egt*) have indicated that natural populations of these pathogens in southern Ontario possess a wide range of genetic variability (Bailey and MacNeill, 1983; Menzies and MacNeil, 1986; Louter *et al.*, 1987; Menzies *et al.*, 1989). Possibly, the presence of known genes for resistance in commercial cultivars of barley (Martens *et al.*, 1984) is a source of some of the genetic variability of natural populations of *Egh* through the selection of certain genes for virulence. However, not all the genetic variability observed in natural populations of *Egh* in southern Ontario can be explained in this way. Commercial cultivars of wheat used in southern Ontario do not possess any of the known *Pm* genes for resistance to *Egt* (Martens *et al.*, 1984) that might account for the spectrum of virulence in the natural population of the latter pathogen.

The possibility that genetic variability in a pathogen population may be due to selection pressure exerted by alternative hosts rather than the "preferred host" should be examined. Eshed and Wahl (1970) in Israel have demonstrated that both *Egh* and *Egt* enjoy a host range within the family Gramineae that is wider than the *forma specialis* designations would suggest. Fall infection of wild grasses in Israel by ascospores of *Egt* liberated from cleistothecia which have ovesummered on wheat stubble have been observed by Eshed and Wahl (1975). Colonies of *Egt* on wild grasses act as foci from which conidia are disseminated to cultivated wheat crops throughout

Table 1. Species of Gramineae tested for compatibility with *Erysiphe graminis* f.sp. *tritici* and *Erysiphe graminis* f. sp. *hordei*.

Scientific Name	Common Name
Agrostis palustris Huds.	Creeping Bentgrass
Alopecurus pratensis L.	Meadow Foxtail
Avena fatua L.	Wild Oats
Avena sativa L.	Oats
Bromus biebersteinii Roem.Schult.	Meadow Bromegrass
Bromus inermus Leyss.	Smooth Bromegrass
Bromus tectorum L.	Downy Brome (Chess)
Dactylis glomerata L.	Orchard Grass
Digitaria ischaemum (Schreb.) Muhl.	Smooth Crabgrass
Digitaria sanguinalis (L.) Scop.	Hairy Crabgrass
Echinochloa crusgalli (L.) Beauv.	Barnyard Grass
Festuca rubra L.	Creeping Red Fescue
Hordeum vulgare L.	Barley
Lolium perenne L.	Perennial Ryegrass
Panicum capillare L.	Witch Grass
Panicum miliaceum L.	Proso Millet
Phalaris arundinacea L.	Reed Canary Grass
Phleum pratense L.	Timothy
Poa pratensis L.	Kentucky Bluegrass
Setaria glauca (L.) Beauv.	Yellow Foxtail
Setaria viridis (L.) Beauv.	Green Foxtail
Triticum aestivum L.	Wheat

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Table 2. The compatibility of isolates of *Erysiphe graminis* f. sp. *hordei* and *Erysiphe graminis* f. sp. *tritici* inoculated to different species of Gramineae commonly found in southern Ontario.

Gramineae Species	Egh[+]		Egt[†]	
	Number of inoculated isolates	Number of compatible isolates	Number of inoculated isolates	Number of compatible isolates
Wheat (cv Augusta)	13	0	32	32
Barley (cv Bonanza)	19	19	22	0
Creeping Bentgrass	9	0	18	0
Coated Meadow Foxtail	9	0	17	0
Wild Oats	9	0	19	0
Domesticated Oats	10	0	18	0
Meadow Brome	9	0	27	10
Smooth Brome	9	0	23	0
Downy Brome	5	0	18	4
Orchard Grass	9	0	17	0
Smooth Crabgrass	15	0	34	0
Hairy Crabgrass	9	0	18	0
Barnyard Grass	9	0	15	0
Creeping Red Fescue	9	0	17	0
Perennial Ryegrass	9	0	21	0
Witch Grass	10	0	16	0
Proso Millet	5	0	18	0
Canary Grass	9	0	17	0
Timothy	9	0	18	0
Kentucky Bluegrass	10	0	22	0
Yellow Foxtail	9	0	14	0
Green Foxtail	7	0	10	0

[+] *Erysiphe graminis* f. sp. *hordei*
[†] *Erysiphe graminis* f. sp. *tritici*

the growing season. In Israel, wild grasses infected by *Egh* and *Egt* bridge the gap between the different growing seasons for wheat, and may also be selecting for genetic variability in the two *formae speciales* involved.

In the present study the ability of *Egh* and *Egt* to infect cultivated and wild species of gramineae common to southern Ontario was examined.

Materials and Methods

Twenty two species of the Gramineae (Table 1) were tested for their receptivity to various isolates of *Egh* and *Egt*. The plants represented cultivated and weedy grass species common to southern Ontario. Five to 10 seeds of each grass were sown separately in 10 cm plastic pots and grown for 14 days in a growth room at $20 \pm 1°C$ and 14-h photoperiod.

Nineteen isolates of *Egh* were used in these experiments and were derived from single colonies collected from various regions of southern Ontario in 1986 (Louter *et al.*, 1987) and 1987. Thirty-four isolates of *Egt* were used and derived from monoconidial and single colony isolates collected from various regions of southern Ontario during 1981 to 1987 (Bailey and MacNeill, 1983; Menzies and MacNeill, 1986; Menzies *et al.*, 1989). Inoculum of the isolates of both *Egh* and *Egt* was obtained by the inoculation of the individual isolates of *Egh* onto a 10-day old plant of barley (cv Bonanza) and of *Egt* onto a 10-day old plant of wheat (cv Augusta); 8 days later approximately 5 mg of conidia of either an isolate of *Egh* or an isolate of *Egt* was used to inoculate the different species of Gramineae. The inoculum was applied in a settling tower (Eyal *et al.*, 1968), the plants were capped with glass chimneys (Bailey and MacNeill, 1983), then incubated in a growth room for 8 days at $20 \pm 1°C$ and a 14-h photoperiod. After 8 days, the plants were assessed for the presence or absence of colonies of *E. graminis*. Included in each set of inoculations of the different species of Gramineae was the barley cultivar Bonanza for *Egh* and the wheat cultivar Augusta for *Egt*. These plants acted as controls to ensure that conditions were favourable for infection by the powdery mildew isolates.

Results and Discussion

A high level of parasitic specialization of *Egh* in southern Ontario was demonstrated by the failure of isolates of *Egh* to infect any of the species of Gramineae tested except barley

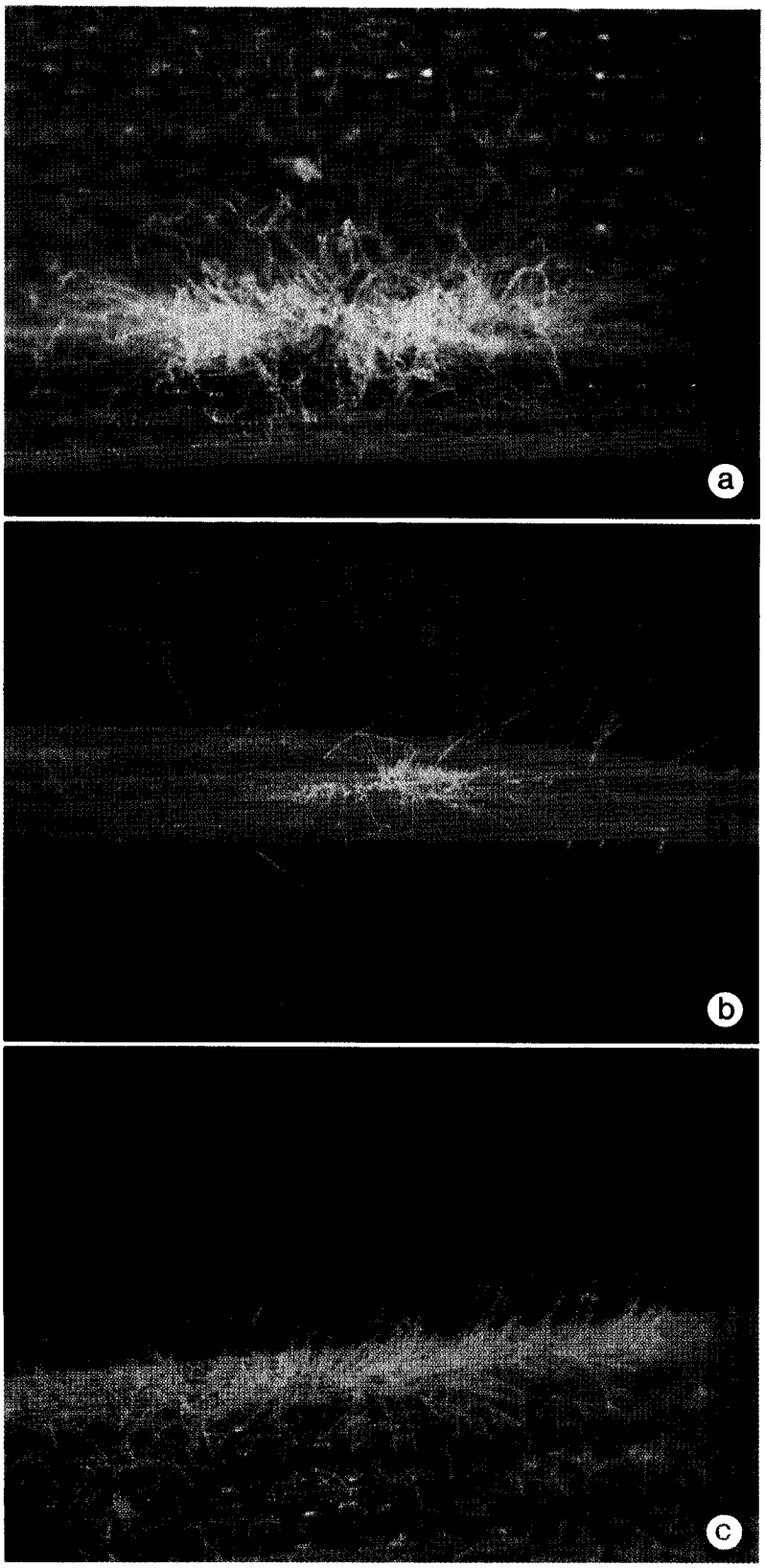

Figure 1. Colonies of *Erysiphe graminis* f. sp. *tritici* on; a) winter wheat; b) meadow brome; c) downy brome.

(Table 2). In Israel, Eshed and Wahl (1970) observed *Egh* on a wide spectrum of native grasses, and artificially infected 18 of 60 genera of Gramineae. Unlike our experiments, they observed compatible relationships between their isolates of *Egh* and downy brome. The differences between the results of Eshed and Wahl (1970) and ours may be due to different selection pressures within the natural population of *Egh* in the two different regions. The Mediterranean region is known to be the centre of origin and diversification of some of the progenitors of barley and wheat (Eshed and Wahl 1970). Greater diversity of host genotypes in the Mediterranean region as compared to southern Ontario may result in selection pressure leading to a broader spectrum of genotypes in the natural population of *Erysiphe graminis* in the former region.

Erysiphe graminis f. sp. *tritici* was not observed to be as host specific as *Egh* in southern Ontario; isolates of *Egt* infected wheat, meadow brome and downy brome (Table 2, Figure 1). Infection of downy brome by *Egt* has also been reported in Israel (Eshed and Wahl, 1970), but meadow brome was not tested in their trials. In the present study, cultures of *Erysiphe graminis* observed on plants of meadow brome and downy brome were confirmed as *Egt* by re-inoculation to wheat (cv Augusta).

The presence of alternative hosts for *Egt* in southern Ontario presents the possibility of another source of selection pressure leading to genetic variability. Pressure exerted by downy brome and meadow brome may explain the common occurrence of certain genes for virulence (*p*Ma, *p*3c and *p*4) in southern Ontario (Bailey and MacNeill, 1983; Menzies and MacNeill, 1986; Menzies *et al.*, 1989). Certainly the role of such alternative hosts in contributing to greater variability of *Egt* needs to be examined.

Additionally, the fact the *Egt* infects downy brome and meadow brome in southern Ontario may also allow the pathogen to use these hosts as oversummering reservoirs of inoculum. The cleistothecia of *Egt* have been postulated to be the oversummering state of the pathogen in Canada (Cherewick, 1944). Menzies (1986) in 1984 and 1985 observed the maturation of cleistothecia of *Egt* in late July with ascospores being ejected in August, September and to a lesser extent in October. Ascospore ejection occurred, however, during periods when winter wheat was not being grown in southern Ontario. That is, between the harvest of the winter crop and the autumn planting of the next crop. Eshed and Wahl (1975) have suggested that in Israel, ascospore inoculum is important in infection of wild grasses, leading to the formation of colonies of powdery mildew and production of conidia on these grasses. The colonies on the wild grasses act as foci from which conidia of *Erysiphe graminis* are disseminated to cultivated small grain crops throughout the growing season. In southern Ontario, colonies of *Egt* on meadow brome and downy brome, whether they are produced by ascospore or asexual conidial inoculum, may be important in the survival of *Egt* from the time of harvest of winter wheat in July, to the emergence of newly seeded winter wheat in October.

Acknowledgements

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Incidence of Septoria canker of hybrid poplars in eastern Ontario

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Septoria musiva is an endemic pathogen that causes leaf spots and cankers on hybrid poplar (*Populus* spp.) clones. Although canker incidence was lower in eastern Ontario, a 1984 study found little difference in the morphology and physiology of different isolates of *S. musiva* collected from plantations in the north central United States and those collected in eastern Ontario. By 1987, however, a high incidence of severe cankers in a few plantations was observed. A survey of canker incidence in all plantations (203 ha) of six exotic *P. nigra* x *maximowiczii* (NM) clones found that 79% of the area was affected to some degree with Septoria damage. This represented 11% of the total area planted to hybrid poplar (1,450 ha) in eastern Ontario. Three things are speculated to have contributed to the increase in Septoria damage: (i) the area planted to susceptible NM clones had increased dramatically since 1981, (ii) the amount and type of secondary inoculum produced by the fungus in these exotic clones, rather than in the native poplar, may differ in aggressiveness and (iii) precipitation levels for the 1986 growing season were higher than normal. Five of the clones were determined to be too susceptible for further plantation establishment.

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Septoria musiva est un agent pathogène endémique responsable de la tache des feuilles et du chancre chez des clones de peupliers hybrides (*Populus* spp.). L'incidence du chancre est plus basse dans l'est de l'Ontario, mais une étude réalisée en 1984 a démontré qu'il existe peu de différences morphologiques et physiologiques entre les isolats de *S. musiva* provenant de plantations du centre-nord des États-Unis et ceux de l'est de l'Ontario. Par contre, en 1987, quelques plantations ont été gravement frappées par le chancre. Une enquête sur l'incidence du chancre dans toutes les plantations (203 hectares) de six clones exotiques de *P. nigra* x *maximowiczii* (NM) a révélé que 79% de la superficie avait subi des dommages plus ou moins importants. Ce pourcentage représentait 11% de la superficie totale de culture du peuplier hybride (1 450 hectares) dans l'est de l'Ontario. On croit que trois facteurs ont contribué à l'augmentation des dommages causés par *Septoria*. En premier, la superficie de culture des clones NM sensibles à l'agent pathogène a augmenté de façon spectaculaire depuis 1981. Deuxièment, l'aggressivité de Septoria peut être affectée par des différences dans la quantité et le type d'inoculum secondaire produit par le champignon entre les clones exotiques et les peupliers indigènes. Et finalement, les précipitations ont été plus abondantes que la normale pendant la saison de croissance de 1986. On a déterminé que cinq des clones sont trop sensibles pour servir à l'établissement d'autres plantations.

Introduction

Septoria musiva Peck (teleomorph *Mycosphaerella populorum*), a pathogen that causes leaf spots and cankers on hybrid poplar (*Populus* spp.) clones, has become an increasing concern for many poplar programs in both the United States and Canada. *S. musiva* is indigenous to North America; on native poplars it exists predominantly as a leaf spot and rarely develops into a canker (Bier, 1939). Septoria canker is primarily reported on clones with Tacamahaca origin (Waterman, 1946).

Hybrid poplar plantations established in the north central United States during the mid-seventies were extensively damaged by *S. musiva* (Ostry and McNabb, 1985). Although canker incidence was lower in eastern Ontario, a 1984 study found little difference in the morphology and physiology of different isolates of *S. musiva* collected from plantations in the north central United States and those collected in eastern Ontario (Spielman *et al.*, 1986). However, population levels of *S. musiva* in eastern Ontario have risen since then.

In 1976, a dwindling wood supply in eastern Ontario led to the development of a cooperative program between the Ontario Ministry of Natural Resources and Domtar Incorporated, for the establishment and management of hybrid poplar plantations. To date, approximately 1,450 hectares of hybrid poplar have been planted within a 25 km radius of the Cornwall fine paper mill. During the early years of the program, primarily clones of Aigeiros (*i.e. P. deltoides* x *nigra* hybrids) origin were screened for growth and adaption to eastern Ontario soil and climatic conditions. However, following a recommendation by an international committee of poplar breeders who reviewed the program in 1981, screening of clones with exotic Tacamahaca parentage began.

During the 1978-1982 period no Septoria canker was found in any of the plantations surveyed (Spielman *et al.*, 1986). In 1984 and 1985, an increase in Septoria leaf spot and cankers was observed. During the two following years leaf infection became severe on many clones, thereby increasing the amount of inoculum in many plantations.

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In 1987, a high incidence of severe cankers was observed in a few hybrid poplar plantations in the Cornwall district of eastern Ontario. The need to determine the extent of the disease damage, and the clones affected, became apparent. Septoria canker damage was particularly evident on six clones of *P. nigra* x *maximowiczii* origin. Due to limited resources, it was decided to concentrate a survey on plantations of these clones.

Methodology

The Septoria survey was conducted from August 1st through August 20th, 1987 on the Domtar Agreement Lands (DALs), and from October 1st to the 30th, 1987 on the Tree Farm Agreements (TFAs). DALs are owned by the company, but managed by the Ministry of Natural Resources whereas the TFAs are leased from local landowners and managed by the company. DALs have been established since 1975 whereas the TFAs have been established more recently, since 1982. Therefore, survey results have been kept distinct.

Six *P. nigra* x *maximowiczii* (NM) clones were surveyed and their origins are given in Table 1. *P. maximowiczii*, a species in the Tacamahaca Section of the genus *Populus*, is native to Japan and Korea. Five of the clones were imported from West Germany to Canada in the late 1970s, although they were originally selected in Japan from open-pollinated seedlings. The clone NM1 was imported directly from Japan. It is not known if any of the clones are related.

Table 1. Origins of clones surveyed for *S. musiva*.

Clone Identification				Country of Origin
West Ontario	Germany	Parentage (OJI Paper Co.)		
NM1	n/a	*P. nigra x maximowiczii*		Japan
NM2	MAX1	"	NM101	Japan
NM3	MAX2	"	NM102	Japan
NM4	MAX3	"	NM106	Japan
NM5	MAX4	"	NM105	Japan
NM6	MAX5	"	NM104	Japan

All properties planted with NM clones from 1981 through 1986 were surveyed. Properties on which hybrid poplar clones are planted vary in size, and monoclonal blocks of several clones are commonly planted at each site. A single clonal block is usually one to four hectares in size, rarely exceeding four hectares. In total, 97 stands comprising 131 hectares of DALs and 36 stands comprising 72 hectares of TFAs were surveyed.

After walking the two diagonal transects in each stand, two observations were made: (i) the severity of damage to the trees and (ii) the percent incidence of damage within the stand. The severity criteria used were as follows:

Negative = trees sampled show no signs of *S. musiva*;
Low = new or small cankers just starting to develop;
Moderate = any number of cankers on a tree which together cover less than half the circumference of the tree;
High = any number of cankers on a tree which together cover more than half the circumference of the tree, resulting in severe girdling and broken tops.

Percent incidence of Septoria damage within a stand was calculated based on a random sample of 100 trees per stand. Estimates of severity and percent incidence were made by the same person to avoid biasing the results.

Results

Of the 1,450 ha of production plantations established to date, 13.8% are planted to NM clones on DALs and 13.3% are planted to NM clones on TFAs. The total area planted to NM clones, and affected to some degree with Septoria damage comprised 9.3% and 11.9% of the total area planted to hybrid poplar on DALs and TFAs, respectively.

Figures 1 and 2 show the area affected by severity class for the DALs and TFAs, respectively. The largest percentage of stands surveyed were affected to a low degree, 46.8% and 53.4% for the DALs and TFAs, respectively. However, the second largest percentage of stands were affected to a high degree, 38.5% and 25.2% for the DALs and TFAs, respectively. A total of 38.7 ha (2.7%) of plantations were rated as having very high Septoria canker damage and these stands were subsequently harvested prematurely.

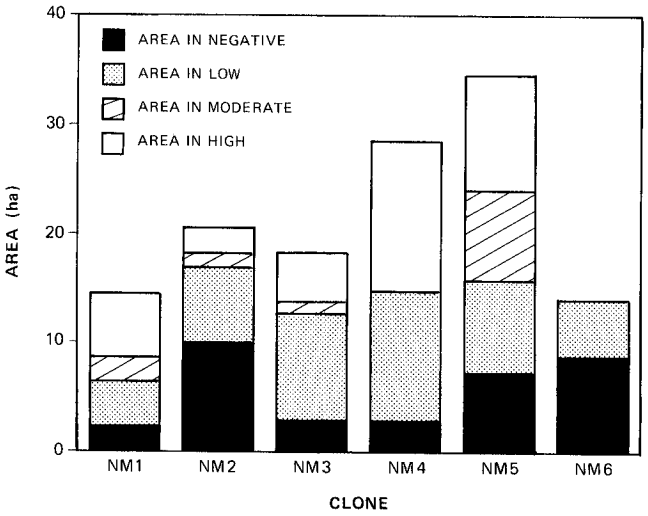

Figure 1. Area in each severity class by clone for DALs.

The area affected by clone is summarized in Table 2. Only one of the clones, NM6, appears to be much less susceptible than the other NM clones. Clones NM3 and NM4 appear to be the most susceptible, while clones NM1, NM2 and NM5 are also too susceptible to consider for further plantation establishment. Figure 3 shows that no areas were found with moderate or high severity for the clone NM6. No relationship between severity of Septoria damage and year of plantation establishment could be determined.

During the early summer of 1988, several samples of canker damage from the study area were sent to the Forest Insect and Disease laboratories in Sault Ste. Marie for verification of *S. musiva* as the causal agent. From these samples, seven

Table 2. Percent incidence of Septoria damage by clone.

Clone	Domtar Agreement Lands (DALs)			Tree Farm Agreements (TFAs)		
	Area Planted (ha)	Area Affected (ha)	Percent Affected %	Area Planted (ha)	Area Affected (ha)	Percent Affected %
NM 1	14.6	12.2	83.6	15.3	13.4	87.0
NM 2	20.6	10.5	51.0	0.0	0.0	0.0
NM 3	18.4	15.3	83.0	4.0	4.0	100.0
NM 4	28.6	25.6	89.5	8.4	8.4	100.0
NM 5	34.6	27.1	78.3	33.1	30.8	93.0
NM 6	14.2	5.2	36.6	11.3	7.7	68.1
Total	131	95.9		72.1	64.3	

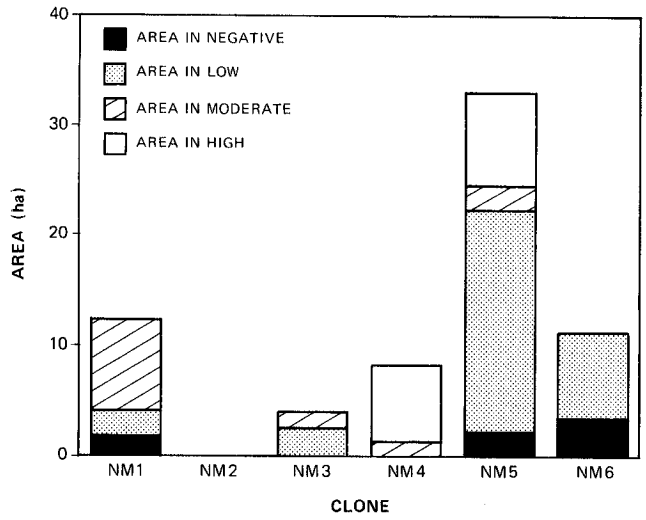

Figure 2. Area in each severity class by clone for TFAs.

isolations of *S. musiva* have been made (C.N. Davis, Pathology Technician, Great Lakes Forest Research Centre, Sault Ste. Marie, pers. comm.).

Discussion

In 1984, Spielman *et al.* (1986) speculated that the incidence of Septoria canker may be rising in Ontario due to the increasing area being planted to susceptible clones of Tacamahaca origin. The area planted to NM clones increased dramatically from 1981 to 1984 (see Table 3). At the same time the area planted with other susceptible Tacamahaca clones, for example, *P. jackii, P. deltoides* x *trichocarpa* and *P. maximowiczii* x *deltoides*, was also increasing. It is conceivable that the higher incidence of Septoria canker found in 1987 may be a result of the greater availability of susceptible hosts.

However, Zalasky *et al.* (1968) offer an alternative explanation. Although *S. musiva* is indigenous to these sites, it also must adapt itself to the introduced hosts. Therefore, the differences in severity and incidence of Septoria canker found between 1984 and 1987 may also be an expression of the amount and type of secondary inoculum produced by the fungus in the new hosts, rather than in the native poplar nearby. This may explain why several *P. deltoides* x *nigra* clones are now showing varying degrees of susceptibility to Septoria canker.

Table 3. Area planted to NM clones from 1981 to 1986.

Year	Area Planted D.A.L. (ha)	Area Planted T.F.A. (ha)	Total Area Planted (ha)
1981	13.6	00.0	13.6
1982	26.4	00.0	40.0
1983	34.1	22.3	96.4
1984	17.5	31.0	144.9
1985	00.0	8.2	153.1
1986	32.0	10.7	195.8

Spielman *et al.* (1986) also theorized whether changes in climate could be responsible for increases in Septoria canker incidence in the future. Data obtained from the Kemptville, Ontario weather station (see Table 4) indicate that precipitation levels for the 1986 growing season were higher than normal (B. Hosie, Ontario Agriculture and Food Weather Station, Kemptville, Ontario, pers. comm.). The heavier precipitation would certainly have contributed to greater spread of spores and higher incidence of new infections during the 1986 growing season.

Management implications:

The results of this survey led to a number of developments in an attempt to reduce the further spread of *S. musiva*. The clones NM1, NM2, NM3, NM4 and NM5 have been eliminated from stoolbeds at the OMNR Kemptville, Ontario nursery which supplies cuttings for the establishment of plantations. Many of the NM6 plantations were close to highly affected

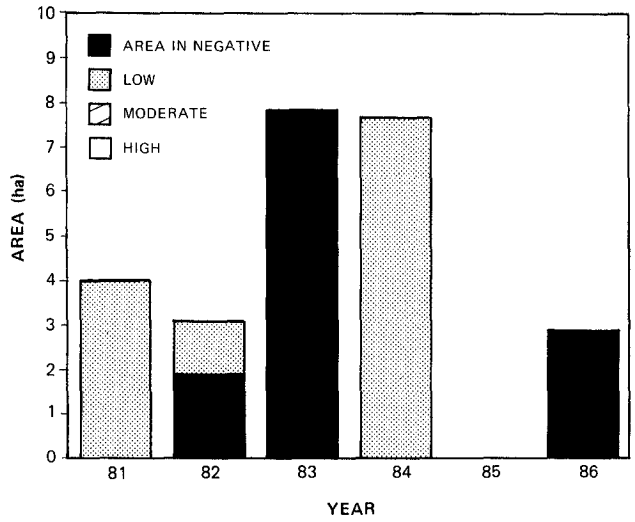

Figure 3. Severity by year for clone NM6 in DALs and TFAs.

NM4 and NM5 plantations and did not have high Septoria canker incidence, therefore it was felt that NM6 showed field tolerance and could continue to be planted on a small scale.

The stands which had a very high incidence of Septoria canker (38.7 ha) were harvested prematurely to reduce the inoculum levels in those plantation areas. It is hoped that this measure will slow the speed of infection to nearby plantations of other susceptible clones. To assist managers in making stand management decisions, the severity and incidence information obtained from this survey was added to the information database which estimates current stand yields.

It is apparent, however, that local screening for resistance is the most promising long-term control strategy in areas where *S. musiva* is known to be a problem (Bussieres and Vallee, 1987). To increase the reliability of artificial screening tests, support research must be conducted. Little is known about the genetic variation of the fungus throughout its range in northeastern North America and it is important to understand the natural range of variation of inoculum virulence to select meaningful isolates for artificial screening tests.

Table 4. Precipitation levels (cm) for the period 1982 to 1987 at Kemptville, Ontario.

	Year					
Month	1982	1983	1984	1985	1986	1987
April	51.8	71.0	147.7	43.4	36.8	40.1
May	55.6	117.0	104.5	65.6	140.6	80.7
June	105.3	33.1	43.3	73.7	118.2	123.2
July	137.3	101.6	113.3	65.2	170.2	62.0
Aug.	94.5	30.9	158.0	63.7	125.9	28.7
Sept.	84.6	57.0	30.4	63.6	115.2	139.2
Oct.	44.1	118.2	34.2	75.9	89.6	86.6
Total	573.1	528.8	631.4	451.1	796.5	560.5

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Source of resistance to clubroot (*Plasmodiophora brassicae* Wor.) in triazine-resistant spring canola (rapeseed)

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A total of 31 cultivars and lines of spring canola (rapeseed, *Brassica napus* L.) were evaluated for their resistance to clubroot (*Plasmodiophora brassicae* Wor. race 2) under greenhouse assay conditions. The most resistant selections were swedish lines SV8525952 and SV8525953, Svalöf, Sweden and canadian cultivar OAC Triton from Ontario Agriculture College. The resistance appears to be a nuclear phenotype character which is lost in progeny.

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Une évaluation de résistance à la hernie des crucifères (*Plasmodiophora brassicae* Wor. race 2) a été réalisée sur 31 cultivars et lignées de canola de printemps (colza, *Brassica napus* L.) dans des conditions contrôlées en serre. Les lignées les plus résistantes ont été celles d'origine suédoise SV8525952 et SV8525953 de Svalöf, Suède ainsi que le cultivar canadien OAC Triton du "Ontario Agriculture College". Le caractère de résistance semble être d'origine nucléique qui disparaît chez les descendants.

Introduction

Spring canola is an oilseed crop increasing in popularity in Eastern Canada and more recently in Quebec where clubroot is one of the most destructive diseases of crucifer crops. The canola trade mark is given in Canada to rapeseed cultivars or lines which have less than 30 micromoles of glucosinolates per gram of oil-free meal and less than 2.0% erucic acid in the oil (10). The disease incidence and severity has been observed to be greater in regions with severe winters when compared to milder winter climates (11).

In Europe, clubroot damage on winter oilseed rape has been observed since 1981 in France (13) where most cultivars produced in that country are very susceptible to the clubroot pathogen (12). Many physiological races of this organism are found, but race 2 or ECD 14/02/31 (1) and race 6 or ECD 16/02/30 predominate in Quebec (5).

There are few economical means of controlling clubroot. Therefore, developing resistance in oilseed rape through breeding appears to be a most promising and effective means of control since resistance to clubroot is quite common in *Brassica napus* especially in Sweden (9).

Breeding programs for clubroot resistance in oilseed rape have been undertaken using nonspecific resistance in *Brassica campestris* and backcross with existant *Brassica napus* containing race-specific genes (8). The present screening test was aimed at finding the susceptibility of recent canola cultivars to this disease.

The other purpose of the present screening test was to find out the susceptibility of recent canola lines and cultivars to this disease.

Materials and methods

In two greenhouse tests, a clubroot-free soil, mixture of 1:1 perlite and pasteurized mineral soil, was heavily inoculated with a suspension of resting spores of *P. brassicae* mainly race 2, at a soil concentration of 5×10^6 spores per dm^3 of soil. The technique of infestation has been previously described (5). The original inoculum source came from *P. brassicae* – infected roots of cabbage (*Brassica oleracea* L. var. *capitata* L.) obtained from a heavily infested field located on the L'Acadie experimental farm, L'Acadie, Quebec. Rutabaga (*B. napus* L. ssp. *rapifera* L.) clubroot sensitive cv. Laurentian was used as a control. A severity damage index (D.I.) was assessed 45 days after seeding according to the following 4 grades (G.) of severity (6):

G.0 = number of plants with 0% of the root system affected.
G.1 = very small clubs on lateral roots (1 to 10%).
G.2 = moderate clubs on lateral roots and/or taproot (11-50%).
G.3 = severe clubbing on lateral roots and/or taproots (51-100%).

The equation used for the calculation of the disease index is the following:

$$D.I.\% = \frac{[(G.0) \times 0 + (G.1) \times 1 + (G.2) \times 2 + (G.3) \times 3] \times 100}{(3 \times \text{total number of plants})}.$$

Data were collected on an average of 32 plants, distributed at the rate of 4 plants per 5 cm-diameter plastic pot (4). A 20-20-20 soluble fertilizer was applied once a week on all plants.

Results and discussion

Of the 31 entries in the first screening test, two Swedish lines, SV8525952 and SV8525953 from Svalöf AB, a private plant breeding company, and the Canadian cultivar OAC Triton, from the University of Guelph, showed some resistance to

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Table 1. List of spring canola (*Brassica napus* L.) entries for resistance to clubroot, their origin, number of plants in disease grade and disease indices from two greenhouse tests with race 2 of *P. brassicae*.

Entry	Origin	Disease grade				Disease indices %	Resistant (R) or susceptible (S) to triazine herbicides
		0	1	2	3		
				TEST I			
Plant breeder lines:							
81-17016A	Canada	0	1	0	22	97	S
BS-1-87	Canada	0	0	2	28	95	S
BS-2-87	Canada	0	0	0	33	100	S
LD 9922	Canada	0	0	1	30	99	S
OAC SC 86-02	Canada	0	0	0	28	100	R
OAC SC 87-01	Canada	0	0	0	27	100	R
OAC SC 87-02	Canada	0	0	0	31	100	S
S81-2716	Canada	1	0	0	26	96	S
SEMU DNK 237/84	W. Germany	0	0	0	32	100	S
SEMU DNK 244/84	W. Germany	0	0	0	32	100	S
SEMU DNK 85/201	W. Germany	0	0	0	34	100	S
SEMU DNK 86/224	W. Germany	0	1	1	27	97	S
SV02402	Sweden	0	0	0	31	100	S
SV02404	Sweden	0	0	0	33	100	S
SV8323005	Sweden	0	0	2	28	98	S
SV8525952	Sweden	9	3	1	18	63	R
SV8525953	Sweden	12	3	4	7	41	R
WW 1398	Sweden	0	0	0	30	100	S
WW 1427	Sweden	0	0	0	30	100	S
WW 1447	Sweden	0	0	0	31	100	S
WW 1467	Sweden	0	0	0	28	100	S
WW 1471	Sweden	0	0	3	23	96	S
Commercial cultivars:							
GLOBAL	Canada	0	0	2	29	98	S
HANNA	Canada	0	0	0	33	100	S
OAC TRIUMPH	Canada	0	0	0	32	100	R
OAC TRITON	Canada	14	1	2	16	54	R
PIVOT	Canada	0	0	0	32	100	S
TOPAS	Canada	0	1	1	30	97	S
TRIBUTE	Canada	1	0	2	29	95	R
WESTAR	Canada	0	0	0	32	100	S
LAURENTIEN*	(control)	0	0	0	32	100	S
				TEST II			
Plant breeder lines:							
SV8323005	Sweden	3	1	3	23	84	S
SV8525952	Sweden	6	8	1	5	42	R
SV8525953	Sweden	6	8	1	7	47	R
Commercial cultivars:							
OAC TRITON	Canada	7	10	5	1	33	R
OAC TRIUMPH	Canada	3	2	2	9	69	R
TRIBUTE	Canada	0	0	0	7	100	R
BIRD'S RAPE**	Canada	14	8	3	0	19	R
LAURENTIEN	(control)	0	1	2	31	96	S

*Rutabaga (*B. napus* L. ssp. *rapifera* L.);

**Triazine resistant bird's rape (*Brassica campestris* L.).

clubroot (Table 1). The two Swedish lines had an average disease index of 52% while the Canadian cv. had an index of 54%. All three lines exhibiting some clubroot resistance were resistant to triazine herbicides. None of the triazine-resistant lines which also did not exhibit clubroot resistance.

In the second screening test with the best entries found in the first test, both Swedish lines and Canadian cv. OAC Triton had a mean index of 45% and 33%, respectively. The actual number of clubroot infected plants was lower in this test, possibly because several plants were infected by root rot pathogens, including *Rhizoctonia solani* Kühn.

The triazine resistant parent of OAC Triton (triazine resistant bird's rape (*B. campestris* L. x Tower, backcrossed four times to Tower)) (1) also was investigated to detect the source of the clubroot resistance. Tower had no resistance to clubroot infection (disease index = 97%) in an earlier screening test (7).

Triazine herbicide resistant bird's rape had a disease index of 19%. The triazine-resistance of bird's rape is maternally inherited via a single chloroplast gene. OAC Triton contains the cytoplasmic genetic complement (chloroplast and mitochondrial genes) of triazine-resistant *B. campestris* and the nuclear complement of *B. napus* (1). With strict maternal inheritance of the triazine resistance, other triazine-resistant lines should also have *B. campestris* cytoplasm. The resistance to clubroot in OAC Triton appeared to be diminished, compared to bird's rape.

Clubroot resistance in SV8525952 and SV8525953, derived from OAC Triton as the original female parent, did not appear to be further diminished, although clubroot resistance in OAC Triumph, a result of crossing OAC Triton with Topas and backcrossing to Topas, did increase. The recently developed University of Guelph lines OAC SC86-02, OAC SC87-01 and OAC SC87-02, which are another cycle of crossing removed from OAC Triton, appear to have lost all resistance to clubroot. The results suggest that, in spring canola, clubroot resistance exhibits nuclear inheritance and that the trait was lost rapidly as progeny lines progressed further from the original source in bird's rape.

According to Chiang and Crête (3), the disease index of an entry is a weighted average of infection. A breeder should look at the frequency of plant distribution in each disease grade rather than depend only on the index to assess the resistance of a particular line or cultivar. The relative high number of plants in '0' grade of the three above mentioned entries indicate truly resistant plants rather than escapes and could be a good source of clubroot resistant germplasm, since all the plants of cv. Laurentian were heavily infected.

Conclusion

The triazine herbicide tolerant canola cultivar OAC Triton (resistant *Brassica rapa* L. x susceptible *Brassica napus* L. cv Tower) appears to have some resistance to the clubroot pathogen race 2, with an average disease index of 33% while its parent, triazine tolerant bird's rape, had a much lower index of 19% compared to its progeny.

Although triazine-resistant bird's rape appears to be a better source of clubroot resistance than the three triazine-resistant spring canolas, using the latter as clubroot resistance sources in canola breeding programs would be desirable because they have low erucic acid and glucosinolate contents.

Further studies are necessary to establish the inheritance of resistance before undertaking a clubroot-resistant canola breeding program.

Acknowledgements

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Susceptibility of primocanes of six red raspberry cultivars to late yellow rust [*Pucciniastrum americanum* (Farl.) Arth.]

Margie Luffman[1] and Deborah Buszard[2]

Late yellow rust [*Pucciniastrum americanum* (Farl.) Arth.] is a sporadic problem on *Rubus idaeus* L. (red raspberry) in the Atlantic Provinces of Canada. Differences in primocane infection were observed among cultivars *in vivo*. Infection studies done *in vitro* established a clear-ranking order from least to most resistant: Carnival, Festival, Heritage, Royalty, Boyne, and Nova, respectively. Nova and Boyne showed a hypersensitive reaction and apparently possess partial resistance to late yellow rust. Royalty and Heritage also appear to have partial resistance.

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La rouille jaune tardive [*Pucciniastrum americanum* (Farl.) Arth.] est un problème sporadique du framboisier rouge (*Rubus idaeus* L.) dans les provinces Atlantique du Canada. Des différences de niveau d'infection dans les tiges végétatives de divers cultivars ont été observées *in vivo*.

Des études d'infection faites *in vitro* ont établit un classement net des cultivars, du moins résistant au plus résistant: Carnival, Festival, Heritage, Royalty, Boyne et Nova, respectivement. Nova et Boyne ont démontré une réaction hypersensible et semblent posséder une résistance partielle à la rouille jaune tardive. Les cultivars Royalty et Heritage semblent aussi avoir une résistance partielle.

Introduction

Late yellow rust [*Pucciniastrum americanum* (Farl.) Arth.] on red raspberry (*Rubus idaeus* L.) is a sporadic problem in the Atlantic Provinces of Canada (Luffman and Buszard, 1988). Nickerson and Mahar (1987) in Nova Scotia noted that the cultivars Carnival and Festival appeared susceptible to the rust while Nova and Boyne showed some resistance; similar observations were made in 1984 and 1985 in New Brunswick (Luffman, unpublished data). The mechanics of this resistance have not been previously studied. This paper describes the response of primocanes of six raspberry cultivars to infection by *Pucciniastrum americanum* in controlled inoculation experiments in a greenhouse.

Materials and methods

The source of *P. americanum* used was infected leaves of the cultivar Festival collected from the field in Bouctouche, New Brunswick. Urediniospores were brushed from the adaxial leaf surface of the infected leaves onto the adaxial surface of leaves of 3 month-old virus-free greenhouse grown plants of the same cultivar which were then placed in a darkened mist chamber at 20°C for 48 hours. Urediniospores were produced on inoculated leaves in about 7 days. Inoculum was increased and maintained on greenhouse plants throughout the work.

Urediniospores vacuum harvested into a vial were suspended in distilled water. Spore concentration was determined using a haemocytometer (Tuite, 1969); distilled water was added as necessary to dilute the suspension to 30,000 spores/ml. Previous research showed this concentration resulted to successful infection of susceptible cultivars (Nickerson, personal communication).

Urediniospore viability was determined *in vitro* using a modified version of the method used by Anthony *et al.* (1985). Spore suspension was sprayed onto 1.5% distilled water agar (DWA) in four petri dishes per test which were placed in the dark at 20°C. Nickerson (personal communication) observed spore germination in as little as 6 hours. Percent germination was determined after 8 hours by counting all spores in each of four fields chosen at random in each plate and averaging the percent germination in each field. The spores were considered to have germinated when germ tube length equalled spore diameter (Zadoks and Schein, 1979).

The cultivars Festival, Carnival, Boyne, Nova, Heritage, and Royalty were inoculated by spraying the adaxial leaf surface of the two youngest fully expanded leaves of 4 month-old virus-free greenhouse grown plants with 0.5 ml of spore suspension per trifoliolate leaf. The plants were then placed in a darkened mist chamber at 20°C for 48 hours. Following this they were kept in a greenhouse at 20°C under a 16-hour photoperiod with supplemental lighting (0.8-1.0 klx, high pressure sodium lamps). There were four replicate plants of each cultivar per test, and the test was repeated four times.

Chlorosis and necrosis of leaves resulting from infection were recorded 28 days after inoculation. Development of the uredinia was also measured; this included the latent period (the time from inoculation to the beginning of sporulation), and the leaf area covered by lesions at the first appearance of spores and 28 days after inoculation. Leaf area covered by uredinia was traced on a transparent acetate sheet and the affected area was determined using a planimeter. After 28 days the leaves were detached, photocopied, and total leaf area was determined by planimeter. Percent leaf area affected by the rust was calculated at the onset of sporulation and after 28 days. A test of homogeneity of variance showed

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Table 1. Response of six red raspberry cultivars to inoculation with urediniospores of *Pucciniastrum americanum* (Farl.) Arth. under controlled environment conditions.

Cultivar	Latent period (days)	Percentage of leaf area diseased at onset of sporulation*	Percentage of leaf area diseased 28 days after inoculation*
Nova	15.50a	0.12a	0.20a
Boyne	12.19b	0.41b	1.08a
Royalty	8.81c	0.90c	41.51b
Heritage	7.63d	0.99d	49.59c
Festival	7.19d	1.36e	60.53d
Carnival	7.19d	1.39f	71.96e

*Arcsin transformation used for analysis; untransformed means presented in table.

a-f Within each column means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

no differences among the four tests so the results were pooled before analysis of variance was performed on the data; Duncan's multiple range test was used to separate the means (Steel and Torrie 1980).

Results

Germination of the urediniospores was in the range of 51-60% in all 16 fields per test. The average germination was 57, 56, 55, and 57% for tests 1, 2, 3 and 4, respectively. The germ tubes tended to grow straight up from the DWA plate, so that it was sometimes difficult to see them.

Sporulating uredinia were produced on inoculated leaves of all six cultivars. The latent period was significantly longer on Nova than on all other cultivars. The next longest was on Boyne, followed by Royalty. Festival, Carnival, and Heritage had the shortest latent periods (Table 1). There were significantly fewer and smaller uredinia produced on Nova than on the other cultivars at the onset of sporulation. Only a few of these uredinia sporulated, most simply produced necrotic flecks. Boyne developed more sporulating and larger uredinia but less necrotic flecking than Nova. Carnival had the greatest area covered by uredinia at the onset of sporulation. Festival followed Carnival with significantly more and larger uredinia developed at this stage compared with the other cultivars.

Nova and Boyne still had the smallest and fewest uredinia at the end of the 28-day observation period. The area affected on Nova had increased from 0.12% to 0.20%, and on Boyne from 0.41% to 1.08%. Carnival had the greatest area (71.96%) covered by sporulating uredinia, with Festival second. The uredinia were filled with masses of yellow-orange urediniospores. The flecking on Nova and Boyne persisted throughout the experiment, and was not observed on any other cultivars.

No symptoms were present on the abaxial leaf surface of any of the six cultivars at the onset of sporulation. By the end of the 28-day period, Nova and Boyne had some very small chlorotic lesions and some necrotic flecking. Almost all of the abaxial leaf surfaces of both Carnival and Festival were generally chlorotic with spreading necrotic lesions. Curling of the leaves was also evident. Heritage and Royalty were similarly affected, but to a lesser extent.

Discussion

The observed differences among the six cultivars in response to artificial inoculation with urediniospores of *Pucciniastrum americanum* clearly established a ranking order from the least to most resistant: Carnival, Festival, Heritage, Royalty, Boyne, and Nova, respectively. The ranking of Carnival and Festival as least resistant and Boyne and Nova as most resistant confirms observations of field infection previously reported (Nickerson and Mahar, 1987; Luffman and Buszard, unpublished data).

Nelson (1978) classified disease resistance into two major types. In the first, the host restricts the infection site and the infection process; this is often referred to as hypersensitivity. In the second type, following successful infection, the host resists subsequent colonization and reproduction of the parasite. This is characterized by the terms partial resistance and slow rusting. Applying Nelson's definitions, Nova and Boyne were the only cultivars which showed a hypersensitive reaction.

The range of latent periods observed is similar to that (7-11 days) found by Darker (1929) in his inoculation work using aeciospores from the alternate host, *Picea glauca* (Moench) Voss. The longer latent period and fewer and smaller uredinia developed on Nova and Boyne very markedly slowed the rate of disease increase, indicating that these cultivars also possess "partial resistance" as defined by Nelson (1978), comparable to "slow-rusting" in cereals (Wilcoxson, 1981).

Disease severity is usually the cumulative result of infection frequency, latent period, spore production, and infectious period. Disease symptoms usually quantitatively reflect growth of the pathogen in the host, and are a measure of disease severity (Parlevliet, 1979). Disease severity (percent of plant area diseased) can be used to assess disease resistance. Both spore production and percent leaf area affected were reduced on Royalty and Heritage, *i.e.*, development of the pathogen was quantitatively hindered. Royalty and Heritage can therefore be assumed to have partial resistance to the rust.

The race composition of the rust present in any given raspberry producing area must be determined for a better understanding of cultivar reactions. Even in the absence of such information, the use of cultivars with some resistance to late yellow rust is recommended in areas where this disease is a problem. As all tests were made by mass inoculation with field inoculum, no information was obtained on the possible differential reaction of the cultivars studied to various races of the pathogen.

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Incidence and severity of Melampsora leaf rust of poplar grown under controlled conditions

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Poplar leaf rust caused by *Melampsora occidentalis* was epidemic in a nursery near Edmonton, Alberta in 1988. All six poplar clones grown under controlled conditions suffered, to varying degrees, from Melampsora rust. Average percent incidence and disease severity were 79% and 1.22 (on a scale of 0-4), respectively.

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En 1988, on a observé un foyer d'infection de la rouille des feuilles du peuplier causée par *Melampsora occidentalis* dans une pépinière située près d'Edmonton (Alberta). Les six clones de peupliers cultivés dans des conditions contrôlées ont été attaqués par la rouille causée par *Melampsora* à des degrés divers. Le pourcentage moyen d'incidence et la gravité de la maladie ont été respectivement de 79 % et 1,22 (selon une échelle de 0 à 4).

Introduction

Poplar leaf rust caused by species of *Melampsora* Cast. is one of the most serious foliage diseases of poplar (*Populus* spp.) (2, 12). Heavy rust infections not only cause premature defoliation and growth suppression of the poplar, but also predispose it to cold injury and secondary pathogens such as *Cytospora* and *Dothichiza* (2, 4, 6, 7).

When poplar seedlings are grown in protected environments such as a lathhouse or intensively managed nurseries, natural selection due to disease is often precluded (7). However, in 1988, Melampsora rust was epidemic on some poplar clones grown in a nursery near Edmonton, Alberta. Studies were therefore undertaken to determine the identity, incidence and severity of Melampsora rust on various clones of poplar and hybrids.

Materials and methods

All six clones of poplars used in this investigation were established with stem cuttings collected in the early winter of 1987 (9). In May 1988, seedlings of *P. trichocarpa* Torr. and Gray, and *P. balsamifera* L. clones were grown in a lathhouse in 15-cm-diameter plastic pots containing a peatmoss and perlite mixture (1:1, v/v) with the following ingredients: lime (1.5 g/L), calcium carbonate (0.5 g/L), gypsum (l.6 g/L), super phosphate (1.36 g/L), potassium nitrate (0.11 g/L), potassium bicarbonate (1.5 g/L), chelated micronutrients (0.06 g/L) and iron (0.07 g/L). Seedlings of the remaining four clones – *P. deltoides* Bartr., *P. deltoides* x *P. balsamifera* cv. Northwest, *P. deltoides* x *P. petrowskyana* Brooks No. 1 and No. 6 – were planted in the field. Fifty rows of each clone were planted in separate plots 110 m wide by 20 m long. Seedlings were placed 20 cm apart in the rows spaced 40 cm apart. Plots were separated by a 10 m strip that was kept harrowed throughout the growing season.

Using a W-pattern transect through the lathhouse and each clone plot, 10 seedlings at each of 10 sites were visually assessed for disease incidence. Ten leaves from the middle portions of the hundred seedlings of each clone were evaluated for severity of Melampsora rust. Severity ratings were assigned based on a scale of 0 to 4 where 0 = clean, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, and 4 = 76-100% of leaf area infected with rust (Figs. 1-4).

Species determinations were carried out by examining morphological characteristics of urediniospores. Leaf segments with uredinial pustules were fixed in 2% glutaraldehyde in 0.1 M cacodylate buffer at pH 7.2 for 16 h, washed in 0.1 M cacodylate buffer pH 7.2, and postfixed in 1% osmium tetroxide in the same buffer for 4 h. The samples were then dehydrated through an ethanol series, critical point dried (using liquid CO_2 as transitional fluid), and affixed to metal stubs with silver paint. The specimens were sputter coated with gold (15 nm thick) and examined and photographed with a Hitachi S510 SEM.

Results and discussion

Uredinial pustules on leaves were first noticed in July 1988, and the level of rust infection of poplar clones was low. By Sept. 1988, all six clones of poplars suffered, to varying degrees, from Melampsora rust (Table 1). *P. deltoides* x *P. petrowskyana* Brooks No. 1 and No. 6 had the least disease with percent incidence and severity ratings of 38% and 0.38, and 50% and 0.51, respectively, whereas *P. balsamifera* and *P. trichocarpa* had the most at 100% and 2.35, and 100% and 1.91, respectively. Overall, disease incidence and severity of Melampsora rust averaged 79% and 1.22 (on scale of 0-4), respectively.

Poplar leaf rust was easily recognized throughout most of the growing season by the bright orange-yellow urediniospores, which appeared as powdery masses on the lower surface of infected leaves. Very few uredinia developed on the upper surface of leaves. Urediniospores were produced in uredinia which had broken through the leaf epidermis (Fig. 5). Uredinia were mainly hypophyllous and were often in clusters. Mature urediniospores were covered with minute spines, most of which were perpendicular to the spore surface, although

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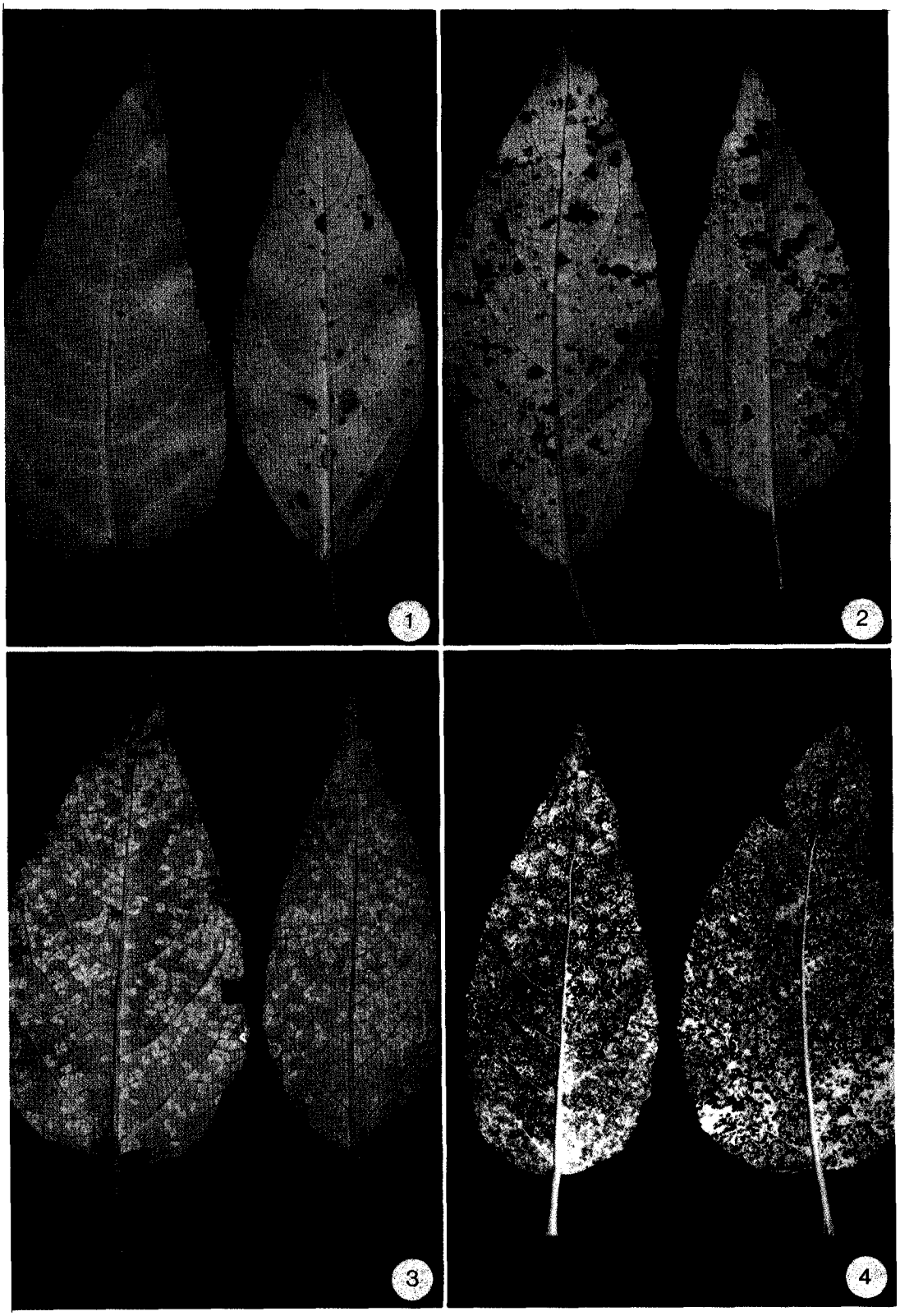
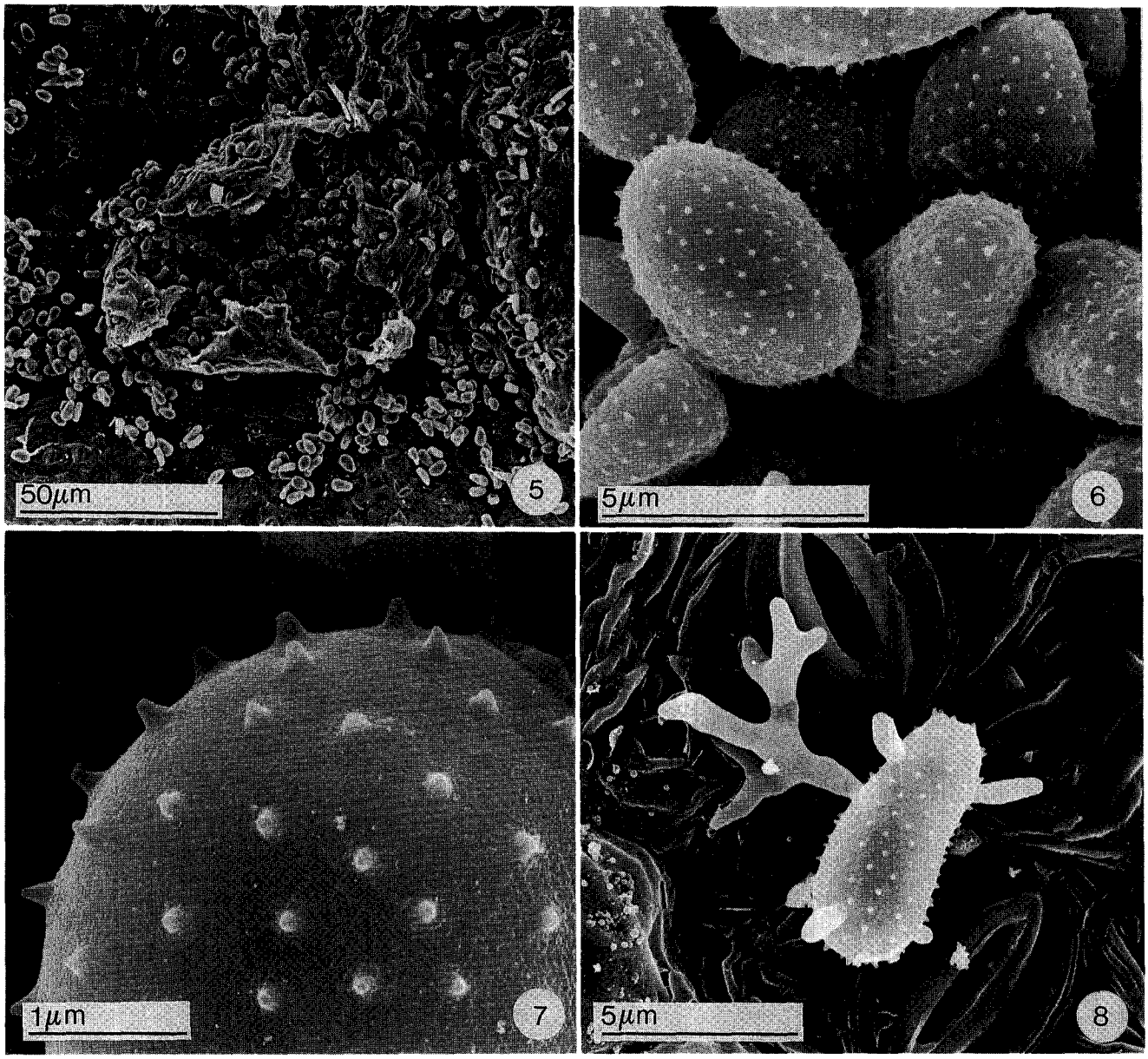


Figs. 1-4. Disease severity ratings of 0-4 of *Melampsora occidentalis* on the lower surface of the leaves of *Populus balsamifera* where 0 = clean, 1 = 1-25% (Fig. 1), 2 = 26-50% (Fig. 2), 3 = 51-75% (Fig. 3), and 4 = 76-100% (Fig. 4) of the leaf area rusted.



Figs. 5-8. Uredinial state of *Melampsora occidentalis*.

Fig. 5. Mature uredinia on leaf surface. Note hundreds of urediniospores within the uredinia. x600

Fig. 6. Mature urediniospores covered with spines. x8000

Fig. 7. Higher magnification of the mature urediniospore covered with spines. x24000

Fig. 8. The mature urediniospore showing the germ tubes. x6000

Table 1. Disease incidence and severity of Melampsora rust on different clones of poplar.

Clone	Incidence %	Severity Rating*
Populus balsamifera	100	2.35
P. trichocarpa	100	1.91
P. deltroides x *P. balsamifera*		
cv. Northwest	99	1.26
P. deltroides	84	0.92
P. deltroides x *P. petrowskyana*		
Brooks No. 1	38	0.38
Brooks No. 6	50	0.51
Average	79	1.22

*Melampsora rust severity rating scale: 0 = clean, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, and 4 = 76-100% of the leaf area rusted.

some extended at various angles (Fig. 6). The spines were evenly distributed over the entire spore surface (Fig. 7). Germ pores were not observed, but germ tubes were seen from scattered points on the spore surface (Fig. 8). Dark brown to black telia were also observed on hanging or fallen leaves in late fall and early winter.

Based on the morphological characteristics of urediniospores (14), *M. occidentalis* Jacks. was the only species of *Melampsora* found in the nursery. This confirms an earlier study (14) which indicated two species of *Melampsora* occur in Canada: *M. occidentalis* in the west, and *M. medusae* in the east. The very high incidence and severity of Melampsora rust on some poplar clone seedlings grown in the nursery confirms earlier reports that high-density planting can lead to more severe rust infestations (7). As a precaution, poplar seedlings should not be planted too densely. *M. occidentalis* has been reported to have a wide host range and occurs only in areas where its alternate coniferous hosts grow (9, 11, 13). It has been suggested that poplar plantations should be no closer than 0.8 km to the nearest alternate host (7).

Clones of *P. deltoides* x *P. petrowskyana* Brooks No. 1 and No. 6 were resistant while clones *P. balsamifera*, *P. trichocarpa*, and *P. deltoides* x *P. balsamifera* cv. Northwest were highly susceptible. On the resistant clones, fewer sori developed and defoliation was not as severe as on the susceptible clones. These results confirm previous studies that poplar clones vary in their resistance to Melampsora leaf rust (6, 8). Moreover, resistance of poplars to Melampsora rust has been reported to be under strong genetic control and not to be readily overcome in genetically uniform plantations (1, 3, 7). Since the use of rust-resistant poplar clones offers the most promising means of controlling the disease (1, 6, 7), selection and breeding programs should emphasize not only rapid height and diameter growth, but also rust resistance. Because different leaf rust species and biotypes exist in various regions (5, 10, 14), leaf rust resistance must be evaluated on a regional basis.

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First report of eyespot [*Pseudocercosporella herpotrichoides*] in spring barley in Alberta

Stephen W. Slopek[1]

Pseudocercosporella herpotrichoides [(Fron) Deighton], the causal agent of eyespot was isolated from the stubble of spring barley near Olds, Alberta in January 1987. This is the first report of this disease in barley in Alberta. As far as can be determined there are also no other reports of the causal agent infecting barley in Canada or other cereals in the Prairie Provinces. Eyespot in barley has been noted at several locations in Central Alberta and in the Peace River Region. In one particular field of barley, cv. Johnston, located near Airdrie, Alberta, 87.8 percent of the stems had eyespot lesions.

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On a isolé l'espèce *Pseudocercosporella herpotrichoides* [(Fron) Deighton], responsable de la tache ocellée, à partir d'échantillons de chaume d'orge de printemps recueillis près de Olds (Alberta) en janvier 1987. C'est la première fois qu'on signale la présence de cette maladie chez le blé en Alberta. Nous n'avons pu trouver d'autres rapports d'infection du blé au Canada ou d'autres céréales dans les provinces des Prairies par cet agent pathogène. On a signalé des cas de tache ocellée chez l'orge à plusieurs endroits du centre de l'Alberta et dans la région de la rivière de la Paix. Dans un champ d'orge Johnston situé près de Airdrie (Alberta), 87,8 pour cent des tiges présentaient des lésions dues à la tache ocellée.

Pseudocercosporella herpotrichoides [(Fron) Deighton)], the causal agent of eyespot which is also known as foot rot or strawbreaker, was isolated from the stubble of spring barley near Olds, Alberta in January 1987. During the summers of 1987 and 1988 the fungus was observed infecting spring barley in fields near Olds, Airdrie, Innisfail, Rimbey, Wetaskawin and Fairview. As far as it can be determined this is the first report of this disease infecting a cereal crop in Alberta. In Canada, the disease has been reported on wheat in Ontario, Quebec and British Columbia, but never before on any cereal crop in the Prairie Provinces (Conners, 1967; Ginns, 1986). The fungus was positively identified by R.A. Shoemaker of the Biosystematics Research Centre, Agriculture Canada, Ottawa (DAOM 196996). All isolates have produced even-edged colonies characteristic of the wheat-type (W-type) pathotype of *Pseudocercosporella herpotrichoides* (Scott, Hollins & Muir, 1975). Host range studies with the differential hosts, barley, wheat and rye have not been conducted.

Eyespot is a widespread disease of wheat, barley and rye crops in Europe, the USSR, South Africa, parts of North America and Australasia (Anon., 1981). The disease reduces the yield of the crop through direct effects on the movement of water and nutrients in the host and through indirect effects resulting from lodging. Eyespot can cause yield losses of up to 50% in winter wheat (Bruehl *et al.*, 1968), but is rarely of any importance in spring cereals.

Eyespot lesions in barley are usually located on the stem within 5 cm of the crown of the plant (Mathre, 1982). In Alberta, however, it has not been uncommon to find barley stems with eyespot infections higher up on the stem. These

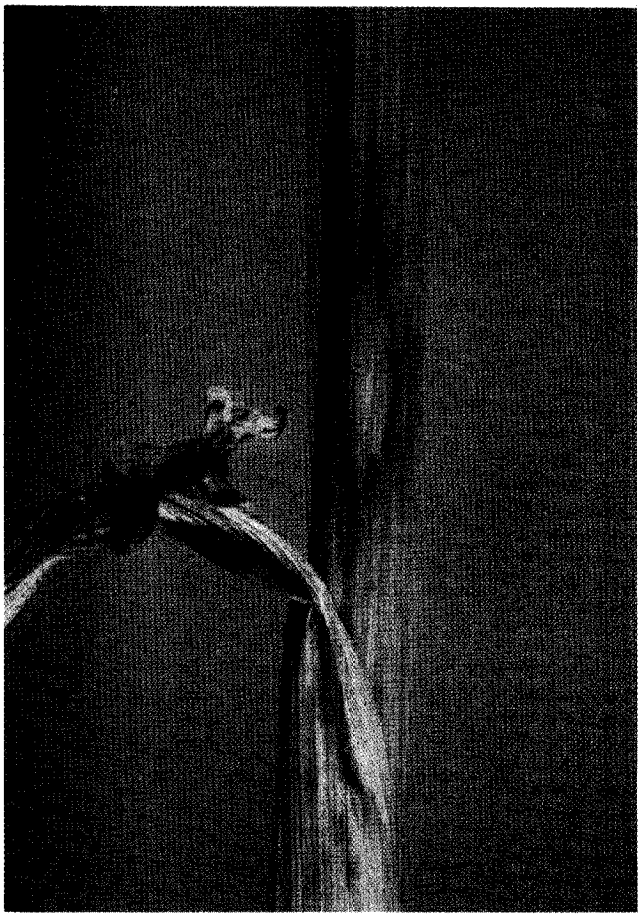

Figure 1. Eyespot lesion located near the leaf collar.

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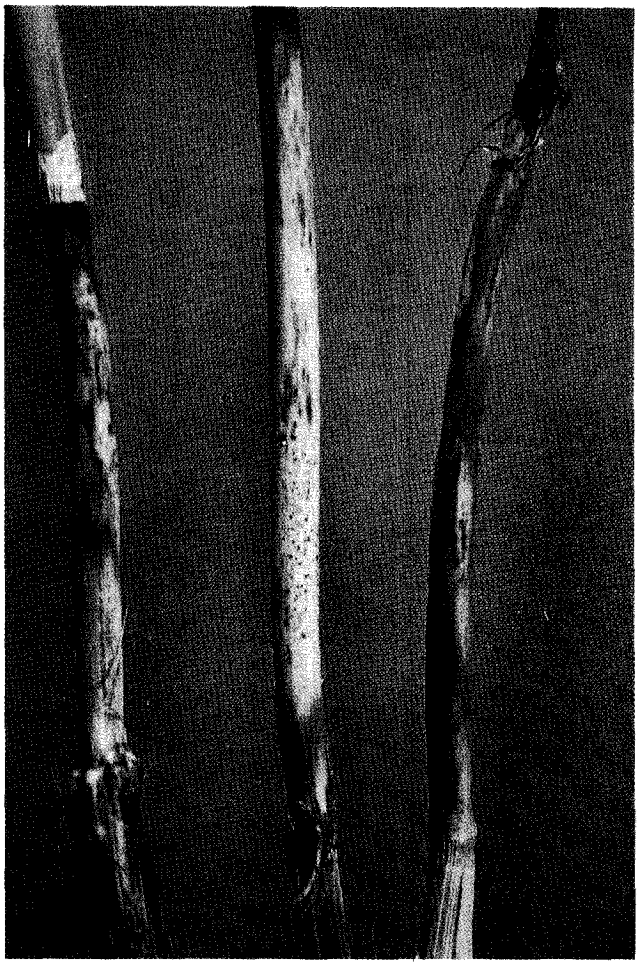

Figure 2. Stems with multiple eyespot lesions with fungus-darkened areas.

infections tend to occur near the leaf collar and auricles (Figure 1). It is very common to have an accumulation of free moisture at this location on the plant which may provide suitable conditions for spore germination and infection. Spores might also be concentrated in this region as a result of runoff from the leaf lamina towards the stem. Eyespot infections with fungus-darkened centers were not found in 1987, but were common in 1988 (Figure 2). Wefts of mycelium were often present within the lumen of infected stems (Figure 3).

In 1988, a field of spring barley, cv. Johnston, west of Airdrie, Alberta had a very high incidence of eyespot. A random sample of 410 stems were collected along a "V" pattern from the field at Zadoks growth stage (ZGS) 85 (Zadoks *et al.*, 1974). The stems were rated using the scale developed by Scott & Hollins (1974):

0 uninfected;
1 slight eyespot (one or more small lesions occupying in total less than half the circumference of the stem);
2 moderate eyespot (one or more lesions occupying at least half the circumference of the stem);
3 severe eyespot (stem completely girdled by lesions; tissue softened so that lodging would readily occur).

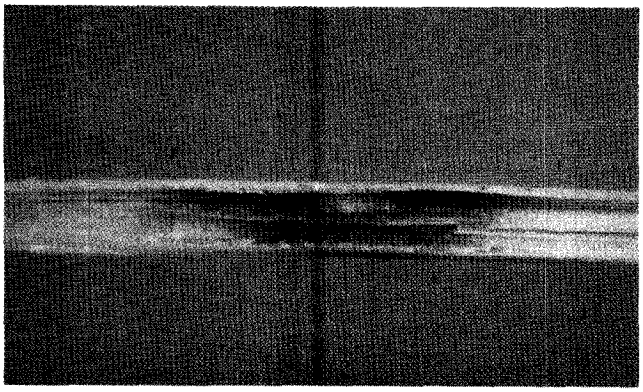

Figure 3. Wefts of mycelium within the lumen of an infected stem.

A total of 87.8% of the stems had eyespot lesions (Table 1). The majority of the stems fell in the moderate eyespot category. Many of the stems were completely girdled which would place them in the severe eyespot category. However, the stem tissue was not softened in any of these stems, and thus should be placed in the moderate category (Hollins, 1989). Although girdling of the stem did not cause softening of the stem tissue leading to lodging, it did appear to be responsible for the production of a significant amount of whiteheads (Figure 4). There was no appreciable amount of common root rot (*Cochliobolus sativus, Fusarium* spp.) or take-all (*Gaeumannomyces graminis*) present which could explain the whitehead symptoms. Whitehead symptoms resulting from eyespot infections which can girdle the stem are a common expression of the disease in Washington State. Whiteheads, however, do not always appear when the stems are girdled. Whitehead symptoms appear to be related to the water status of the plant. Under dry conditions, infected stems die and produce whiteheads whereas under moister conditions the plants survive longer and whiteheads are not produced (Murray, 1989).

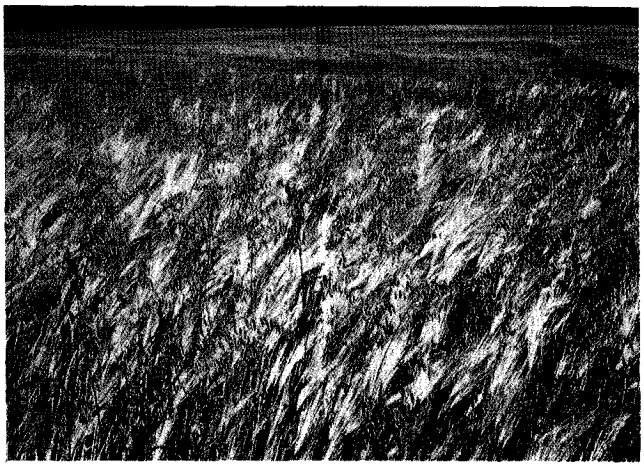

Figure 4. Whitehead symptoms resulting from eyespot infection in a field of barley, cv. Johnston, near Airdrie, Alberta. A high level of tame oat volunteers were present in this field.

Table 1. Severity of eyespot in spring barley, cv. Johnston near Airdrie, Alberta, August 1988.

Disease Rating*	Percentage of Stems
0 - uninfected	12.2 (12.2)**
1 - slight	19.5 (19.5)
2 - moderate	68.3 (17.1)
3 - severe	0.0 (51.2)

*Scott & Hollins (1974) rating system.
**Percent infected stems assuming that girdled stems that do not have softened stems are considered severely infected.

Slight eyespot infections do not cause any yield reduction; moderate infections only reduce 1000 kernel weight, and severe eyespot infections reduce both grain number per head and 1000 kernel weight (Scott & Hollins, 1974). Yield loss increases when lodging occurs. In England and Wales, the Agricultural Development and Advisory Service (ADAS) in conducting eyespot surveys uses the Scott & Hollins (1974) rating system and the yield loss formula developed by Clarkson (1981) to estimate yield losses. For a given crop:

$$Y = [(0.1n_2 + 0.36n_3)/ n_t]x100\%$$

where Y is percent yield loss and n_2 and n_3 are the numbers of stems in the moderate and severe categories and n_t is the total number of stems in the sample. Stems should be collected at ZGS 75. In the Airdrie field n_2 and n_3 were 68.3% and 0.0%, respectively. Based on the Clarkson (1981) formula, the yield loss in the Airdrie field was 6.8%, although, this may be an overestimation since samples were collected at ZGS 85.

The eyespot rating system used in Washington State considers an infection as severe if the stem is girdled by one or more lesions, regardless of tissue softening (Murray, 1989). Under dry conditions yield losses resulting from girdling of the stem may be severe, irrespective of lodging. Using this rating system, 51.2% of the stems were rated as having severe infections. Based on this method of rating disease severity, it is likely that yield losses were higher than 6.8%.

Despite the difficulties of obtaining an accurate estimate of yield loss, it is apparent that eyespot is widespread and its incidence in a crop may be very high. The disease will hopefully remain a minor problem in spring cereals. The real concern exists with winter cereals. At present, fall rye is the only cereal grown to any extent in the areas where the disease has been found. However, breeders are attempting to develop winter wheat cultivars that are adapted to this area. It may be necessary to incorporate resistance to eyespot in these new cultivars.

Acknowledgements

Thanks are expressed to Teb Labun, Ciba-Geigy, Canada for mentioning to me in the fall of 1986 that he had noticed eyespot-type lesions in some of his research plots and to Barbara Archibold, District Agriculturist, Airdrie for bringing to my attention a field west of Airdrie which had a very high incidence of eyespot.

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Effect of repeated cultivation during summer fallow on *Cylindrocladium floridanum* in two Ontario forest nurseries

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The effect of repeated cultivation on microsclerotial densities of *Cylindrocladium floridanum* Sob. & C.P. Seym. in field soil was determined during three trials at two Ontario provincial nurseries. Repeated treatment during summer months of 1986 and 1987 did not significantly alter the germinable propagule levels in the field soil at Midhurst Nursery and Kemptville (= Howard J. Ferguson) Nursery. Although cylindrocladium root rot incidence and mortality of black spruce transplanted into one trial area were higher and the root collar diameters and seedling heights were lower in cultivated plots than untreated plots, the differences were not significant. Disease incidence and mortality of transplants in cultivated plots were, however, significantly higher than in spruce in fumigated plots ($p > 0.05$), while root collar diameters were significantly lower ($p > 0.05$). Repeated cultivation is not recommended as a means of reducing inoculum levels of *C. floridanum* in Ontario nursery soils. Its use may also negatively affect survival and growth of spruce transplants.

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On a déterminé l'effet du travail répété du sol sur la densité de microsclérotes de *Cylindrocladium floridanum* Sob. et C.P. Seym. dans le sol, au cours de trois essais réalisés à deux pépinières provinciales de l'Ontario. L'application répétée de traitements au cours des mois d'été de 1986 et 1987 n'a pas permis de modifier significativement le taux de germination des propagules présents dans le sol aux pépinières de Midhurst et de Kenptville (= Howard J. Ferguson). L'incidence du pourridié causé par *Cylindrocladium* et le taux de mortalité des épinettes noires repiquées dans une parcelle d'essai étaient plus élevés dans les parcelles où l'on avait travaillé le sol que dans les parcelles non traitées. En revanche, le diamètre des collets et la hauteur des plantures y étaient inférieures. Ces différences n'étaient toutefois pas significatives. Par contre, l'incidence de la maladie et le taux de mortalité des épinettes repiquées étaient significativement plus élevés dans les parcelles où l'on avait travaillé le sol que dans les parcelles fumigées ($P > 0,05$), tandis que le diamètre des collets y était significativement plus faible ($P > 0,05$). On ne recommande pas de répéter le travail du sol en vue de réduire la quantité d'inoculum de *C. floridanum* présent dans les sols des pépinières de l'Ontario. Cet usage peut aussi nuire à la survie et à la coissance des épinettes repiquées.

Introduction

Cylindrocladium floridanum Sob. & C.P. Seym. causes an important root rot of conifers in forest nurseries (Bugbee and Anderson, 1963; Cox, 1954; Thies and Patton, 1970). All conifer species grown in Ontario provincial forest nurseries are susceptible with the possible exception of eastern white cedar (*Thuja occidentalis* L.).

The distribution of and losses due to the disease appear to have increased since it was first detected in a provincial nursery in 1974 (Juzwik *et al.*, 1987). Approximately 430,000 spruce seedlings were identified as culls due to the root rot in an assessment of six compartments in five nurseries (Juzwik *et al.*, 1988).

Chemical fumigation has been the main means of controlling cylindrocladium root rot in conifer nurseries (Berbee, 1973). The use of flax, corn, and sorghum-sudangrass as organic amendments has also been found to reduce populations of *C. floridanum* in soil in Minnesota and Wisconsin studies (Thies, 1969; Berbee, 1973; Hadi, 1974; Menge and French, 1976). The effect of other cultural practices on fungus populations in the soil and on disease incidence in seedlings is not clear.

Tilling of fallow fields is practiced in nurseries for physical weed control (Owston and Abrahamson, 1984). Fallowing and cultivation have been used to reduce soil populations of fungi such as *Fusarium*, and *Phytophthora* in British Columbia bareroot nurseries (J. Sutherland, pers. comm.). In a preliminary trial conducted in 1982 at Kemptville Nursery in Ontario, a reduction in recovery of *C. floridanum* from soil was associated with repeated cultivation of a fallow field during July and August (OMNR, unpub. file report). An alfalfa bioassay was used for assessing fungus presence.

Repeated plowing and discing of nursery soils during summer months would expose propagules of the fungus to higher temperatures at the soil surface and to drying. These environmental factors may result in a reduction in infective propagule levels of *C. floridanum* in the soil (Thies and Patton, 1970; Zarnstorff, 1983). Thies and Patton (1970) reported a decreased recovery of *C. scoparium* microsclerotia when soil samples were subjected to air-drying. Similar treatment of field soil resulted in no recovery of *C. crotalariae* microsclerotia, but after re-wetting of the soil to near field capacity for 1-4 weeks, partial recovery of microsclerotia occurred (Griffin, *et al.*, 1978). The reduced recovery of microsclerotia may have been caused by a temporary decrease in propagule germinability, not a true loss in viability.

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Two bareroot nurseries began using repeated cultivation during summer fallow on a limited basis in an attempt to reduce the level of *C. floridanum* in field soil. Although published reports and results of the 1982 preliminary trial suggested a value for the practice, further investigation was warranted because detrimental effects of the treatment (*e.g.* dispersal of inoculum, breakdown of soil structure) could outweigh any benefits. The effect of repeated cultivation on levels of *C. floridanum* in field soil in three trials at two Ontario nurseries are reported here. Results on treatment effect on subsequent root rot incidence, mortality, and growth of spruce transplants in one trial area are also included.

Materials and methods

Nursery compartments

Field trials were conducted in compartment A33 (CA33) at Midhurst Nursery, near Barrie, in 1986 and 1987, and in compartment 30 (C30) at Kemptville (= Howard J. Ferguson) Nursery, near Ottawa, in 1987. The previous crop in CA33 was 1.5 + 1.5 black spruce (*Picea mariana* [Mill.] B.S.P.) which was lifted in April 1986. Approximately 55% of the stock had been culled due to cylindrocladium root rot (Juzwik *et al.*, 1987). Little was known about the distribution of the fungus in the compartment soil so the compartment was graded in May 1986 in an attempt to minimize the clustering of *C. floridanum* propagules prior to trial establishment. The grading of the field involved wind-rowing the top 12-14 cm of soil and re-distributing the wind-rows until the field was level again. This was completed in both a N-S direction and an E-W direction. The soil in CA33 is a sandy loam with a pH of 6.2, maximum water holding capacity of 23%, and an average bulk density of 1.3 g/cm^3.

Previous soil sampling work had revealed a wide and fairly even distribution of *C. floridanum* in C30 (Juzwik, unpub. data) and grading was not considered necessary. The previous crop, 3 + 0 white spruce (*Picea glauca* (Moench) Voss), had been lifted in April 1987. The estimated cull in the spruce due to *C. floridanum* at time of lifting was 13.2% (Juzwik *et al.*, 1988). The soil in C30 is a sandy loam with a pH of 5.5, maximum water capacity of 20%, and an average bulk density of 1.00 g/cm^3.

Experimental design

The 1986 cultivation trial was conducted in the north end of A33. A randomized complete block (RCB) design with nine replications of each treatment was used. The trial was repeated in the south end of CA33 in 1987 using the same design. All treatment plots were 12 m x 1 m with a 1 m wide buffer surrounding each plot which also allowed for access to the plots. The RCB trial at Kemptville Nursery was established in the middle of the compartment where data on the fungus distribution had previously been obtained. Ten replications of the cultivation and the control treatments were included in one block. The plots were 10 m x 4.5 m and oriented in a N-S manner. Buffer areas at the end of each plot allowed for turning of equipment during treatment.

Treatment

The treatments at Midhurst Nursery involved tilling the plots with a rotary cultivator equipped with L-shaped tines. The cultivator has a swath width of 40 cm, therefore, three passes were required to treat the 1 m wide plots. The soil in each plot was cultivated to a 20 cm tine depth once per week for 8 consecutive weeks. Treatment periods were July 8 – September 1 in 1986 and July 10 – August 28 in 1987. Control plots were left undisturbed. Weed control in the trial area in 1986 was achieved through early August by one application of a tank-mix of chlorthal-dimethal (5 kg a.i./ha) and prometryne (0.5 kg a.i./ha). Plots were hand-weeded as required in the latter part of the season. In 1987, both trial areas were treated with glyphosate (5.0 – 5.6 L prod./ha) on April 24 and June 23. Additional glyphosate was applied July 22 in the south area and September 15 in the north.

At Kemptville Nursery, a tractor-mounted cultivator ('Do-It-All', Laning Farm Equipment Distrib.) equipped with harrows, rotating blades and plow teeth was used to turn the soil to a 20 cm depth. The cultivator width (4.5 m) required only one pass per treatment plot. The soil in the plots was tilled once per week between June 9 and July 21, and on August 21. Effort was made to schedule the treatment during the hottest, driest period of each week. The control plots were left undisturbed. Because weed control was required for the control plots and buffer areas, the entire trial area received an application of glyphosate (1.24 kg a.i./ha) plus 2,4-D (0.8 kg a.i./ha) in late June 1987.

Seedling transplanting

In a preliminary effort to evaluate effect of repeated cultivation on infection, disease development, and plant growth and survival, black spruce seedlings were transplanted in the 1986 treatment plots in CA33. Seedlings were also transplanted into two other sets of nine replicated plots for comparison. The soil in one set had been undisturbed except for rototilling on June 17, 1986, to incorporate 0.25 m^3 of sphagnum peat per plot. The remaining plots had been fumigated with dazomet 98% (Basamid, P.C.P. no. 15032) at a rate of 400 kg prod./ha in July 1986. A polyethylene tarp was used as a seal during fumigation. The mean density of *C. floridanum* in the fumigated plots prior to transplanting was 0.08 prop./g dry soil.

The 1.5 + 0 spruce used for transplanting were from a small portion of one row in compartment DE7 at Swastika Nursery. The trees were obtained during an operational lifting of stock from the compartment on July 6, 1987. The majority of the seedlings lifted were destined for transplant fields at the nursery. The seedlings were considered to have no or a very low level of cylindrocladium root rot because the disease had not been detected during 1986 and 1987 seedling surveys and the fungus was not recovered from soil during a fall 1986 soil survey.

The seedlings were immediately transported to Midhurst Nursery after lifting and were transplanted in the three sets of plots on July 7. Four 12 m long drill lines (16 seedlings/m) were established in each plot. The seedlings were considered to be in fair condition based on usual nursery parameters of shoot height and root development. Although isolations were not conducted, no evidence of *C. floridanum* infection (*i.e.* root lesions) was observed. Normal nursery practices, such as fertilization and irrigation, were conducted in the plots with the transplants.

Sample collection

Pre-, mid-, and post-treatment soil samples were collected from the cultivated and the control plots in both areas in CA33. Samples were taken with a soil sampling tube (2.0 cm dia) to a vertical depth of 20 cm, yielding about 50 cm^3 of soil per core. Five soil cores were collected at 2 m intervals along the longitudinal centreline of each plot. The five cores for each plot were then bulked in a polyethylene bag, sealed, labelled, and stored at room temperature until further processed. Pre-, mid-, and post-treatment samples were collected on June 9, July 21, and August 21 in C30. Four soil cores were systematically taken from each plot in a manner similar to that described previously. Storage was the same as for samples from CA33.

Transplant seedlings were observed on August 18, 1987, and sampled on July 19, 1988, for root rot caused by *C. floridanum*. Disease incidence was determined by randomly locating three 0.25 m^2 subplots in each plot, collecting all living seedlings in the subplots, and isolating for the fungus from the trees. Morphological characteristics and mortality were also recorded for the seedlings on June 9 and July 18, 1988, respectively. Height and root collar diameter were measured on 10 randomly selected seedlings in each plot. Seedling mortality was determined for a 33% area sample of the 12 m^2 plots.

Sample processing

A modified wet-sieving technique was used to determine the number of *C. floridanum* propagules in the soil (Juzwik *et al.*, 1988). The propagules (primarily microsclerotia) were first separated on the basis of size and density, and then allowed to germinate on a selective medium. Following 10 days of incubation at 20°C, the *C. floridanum* colonies were counted. The number of fungus propagules per gram of dry soil (prop./g) were then determined.

Fungus isolations were made from the roots and lower stems of each seedling with lesions. Plant tissue segments (approx. 1 cm long) were immersed in 10% NaOCl for 3 min, rinsed in sterile distilled water, and small pieces of tissue excised and placed on a *Cylindrocladium* selective medium in petri dishes (Phipps *et al.*, 1976). The dishes were examined for *C. floridanum* after 10 days of incubation at room temperature.

Data analyses

The fungus population values were individually transformed using the sum of the square root of each subsample value plus 1.0 x 10^{-8}. Analyses of covariance (ANCOVA) were performed and treatment comparisons were made using standard t-tests (Steel and Torrie, 1980). If adjustment of variate values was not warranted, analysis of variance (ANOVA) was performed. ANOVA and ranking of means by Least Significant Difference method (Ray, 1982) were used to analyze the seedling transplant data. The disease incidence data were first transformed by an arcsine square root method.

Results

Analysis of population values from the Midhurst trials did not reveal significant differences between the mid- and post-treatment populations in the 1986 cultivated plots compared to the untreated one (Table 1). Less variability in populations was observed with the 1987 trial data, but no significant differences were found in *C. floridanum* levels in the mid- and post-treatment samples between the cultivation and untreated plots. No significant differences in soil moisture content existed between cultivation and untreated plots for the pre-, mid-, and post-treatment soil samples for the 1986 and 1987 trials at Midhurst. In the Kemptville trial, there were no significant differences in the transformed numbers of propagules recovered from cultivated plots versus untreated plots at the mid- and post-treatment sampling dates. The actual mean number of recovered propagules in the cultivation and untreated plots increased from 3.97 to 5.08 prop./g soil and 3.21 to 4.21 prop./g soil, respectively, during the time of the treatment period. The cultivation treatments significantly reduced soil moisture content in comparison to that of the untreated plots at both the mid- (13.8 vs. 15.2%) and post-treatment (11.5 vs. 13.0%) sample dates ($p = 0.001$).

Table 1. Number of *Cylindrocladium floridanum* propagules recovered from plots before, during and after cultivation treatment in compartment A33, Midhurst Nursery.

Trial area	Sampling time[a]	Treatment	
		Cultivation	Control
North	Pre-treatment	5.69	3.85
	Mid-treatment	6.40	3.79
	Post-treatment	4.85	3.65
	April 1987	6.51	4.62
	April 1988	5.63	4.85
South	Pre-treatment	4.98	4.19
	Mid-treatment	4.30	2.79
	Post-treatment	4.10	4.07
	April 1988	4.00	4.20

NOTE: Values expressed as mean numbers of propagules per gram of dry soil. Each value is the mean number of nine replications.

[a]Cultivation treatment conducted between July 8 and September 1, 1986, in north area and July 10 and August 28, 1987, in south area.

Weather data recorded during the cultivation periods were obtained from the two nurseries. Maximum daily ambient air temperature ranged from 9.8 to 26.0°C in 1986 and 11.6 to 27.0 in 1987 at Midhurst and from 12.4 to 26.7 at Kemptville Nursery in 1987. Rainfall events were more frequent during the trial periods at Midhurst (23 in 1986 and 16 in 1987) than at Kemptville (9 events). Similarly, cumulative rainfall over the trial period was higher for the Midhurst trials (194 mm in 1986 and 220 mm in 1987) than the Kemptville one (134 mm).

Table 2. Disease incidence (DI) and mortality of black spruce transplants in repeated cultivation, control, and fumigation plots in north end of compartment A33, Midhurst Nursery.

Treatment	DI (%)	Mortality (%)
Cultivation	11.9 y[a]	51.3 y
Control	6.7 y	40.1 yz
Fumigation	1.4 z	29.5 z

NOTE: Values expressed as mean of nine replications.

[a]Means with the same letter within a column are not significantly different (LSD, alpha = 0.05).

Table 3. Growth parameters of transplants in cultivation, control and fumigation plots in north end of compartment A33, Midhurst Nursery.

Treatment	Growth parameter	
	RCD[a] (mm)	Height (cm)
Cultivation	2.25 y[b]	14.62 y
Control	2.36 y	14.90 y
Fumigation	2.59 z	16.19 y

NOTE: Values are means of nine replications.

[a]RCD = root collar diameter measured with stem caliper.

[b]Means with the same letter in a column are not significantly different (LSD, alpha = 0.05).

Root rot incidence due to *C. floridanum* and transplant seedling mortality in the north CA33 plots were highest in the tilled plots (Table 2). The differences in disease incidence and mortality were not significant between the tilled and untreated plots, but were between the tilled and fumigated ones ($p < 0.05$). The smallest root collar diameters and seedlings heights were found in the transplants in the tilled plots (Table 3). The root collar diameters of the trees in the tilled and non-treated plots were significantly less compared to trees in the fumigated plots ($p < 0.05$). Seedling heights of transplants in tilled plots were also less than in the fumigated ones, but differences were not significant ($p = 0.06$).

Discussion

Repeated tilling of fallow nursery soil during summer did not significantly alter *C. floridanum* populations in three trials conducted at two Ontario nurseries. The effect of fallowing on the fungus in the soil has been previously reported. Although some reduction in propagules does occur, *C. floridanum* can survive for 9 years in the field in fallow nursery soil and may be capable of surviving as microsclerotia for 15 years or more (Thies and Patton, 1970; French and Menge, 1978).

Maximum ambient air temperature recorded by the nurseries during the trial periods was 28°C. The optimum range for microsclerotial production by five *Cylindrocladium* spp., including *C. floridanum*, is 24-28°C (Hunter and Barnett, 1976). Stevens *et al.* (1986) reported 27°C as the optimum temperature for *Cylindrocladium scoparium*. Therefore, the maximum daily temperatures during the three trials would not have been deleterious to microsclerotia survival, and in fact, were probably optimal for their production.

Cumulative rainfall was significantly less during the Kemptville trial than during the Midhurst ones. This may have contributed to the significant reduction in soil moisture content found in the cultivated plots compared to the controls. However, lower microsclerotial densities were not associated with this reduction. Drought during June 1975 was associated with a reduction in microsclerotial populations of *C. crotalariae* in the upper 13 cm of field soil (Taylor *et al.*, 1981).

Although differences were not significant, disease incidence and mortality were higher while root collar diameters and seedling heights were smaller for spruce transplants in cultivated plots than those in untreated plots. However, disease incidence and mortality of spruce in cultivated plots were significantly higher than that observed in fumigated plots, while root collar diameters were significantly smaller. Based on these results, it appears that repeated cultivation may be detrimental to subsequent seedling survival and growth. Excessive tillage in nursery soils generally results in detrimental changes, such as soil compaction (Warkentin, 1984). The aggregates created by rototilling are too small for optimum seedling growth to be achieved.

A significant part of the spruce mortality observed in all treatment plots may have been due to the condition of the seedlings at time of lifting or related to the lapse of time between lifting and transplanting (24 to 30 hr). The level of tree mortality observed in fumigated plots supports either hypothesis. The average survival rate of black spruce transplants following operational transplanting at Swastika Nursery is 80 to 85% (E. Reitenan, pers. comm.).

In summary, repeated cultivation of nursery soil during summer fallow did not significantly alter populations of *C. floridanum* and was correlated with poorer seedling survival and growth. The practice is not recommended as a means of reducing inoculum levels in Ontario nursery soils.

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Cereal diseases in Prince Edward Island, 1987

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A disease survey of Prince Edward Island indicated little change in the profile of diseases of wheat, oats, and barley compared to previous surveys. Disease severity was in general low, in part due to relatively dry environmental conditions on P.E.I. in 1987. Septoria leaf and glume blotch were the major diseases on both spring and winter wheat. Septoria leaf blotch was predominate on oats though significant levels of avenacea leaf blotch were also observed. Net blotch, and to a lesser extent scald, were predominate on barley. One field of barley did have a very severe infestation of speckled leaf blotch.

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Une enquête menée à l'Île-du-Prince-Édouard sur les maladies du blé, de l'avoine et de l'orge n'a pu démontrer de changement important du profil de ces maladies par rapport aux données recueillies lors d'enquêtes précédentes. Les conditions relativement sèches qu'a connues l'Île-du-Prince-Édouard en 1987 ont été partiellement responsables du faible degré de gravité de la plupart des maladies. La tache septorienne des glumes et des feuilles a été la principale maladie retrouvée sur le blé de printemps et d'hiver. Chez l'avoine, c'est la tache septorienne qui a prédominé, bien qu'on ait aussi observé des taux significatifs de rayure des feuilles. Les principales maladies de l'orge ont été la rayure réticulée et, à un degré moindre, la tache pâle. On a observé une très grave infestation de tache septorienne dans un champ d'orge.

Introduction

Previous surveys of grain diseases in Prince Edward Island were from the summers of 1976 and 1977 (Clough and Johnston, 1978a,b). Since then there have been changes in production technology such as the development of intensive management, the introduction of winter wheat, and a decline in oats as a feed crop. New cultivars have also been introduced, some with enhanced disease resistance, and there has been the introduction of foliar fungicides. The following survey of cereals in Prince Edward Island was conducted in 1987 on pure stands of barley, oat, and spring and winter wheat, to determine the incidence and severity of major cereal diseases.

Materials and methods

Seventy one commercial cereal fields (30 barley, 15 winter wheat, 14 spring wheat, and 12 oat) were randomly selected to represent all growing areas of Prince Edward Island. In barley, 40 percent of the fields were planted with the cultivar Leger; other barley cultivars were Birka, Micmac, and Rodeo. Valor and Borden were the main winter wheat cultivars (5 fields of each) while Max was the most common spring wheat cultivar in the survey. Among the oat cultivars, Tibor, a hulless oat cultivar, was the most common. Four fields had an unknown oat cultivar.

Field assessments were conducted using an inverted "W" pattern, covering an area of 25 x 25 m, located 25 m away from the road and neighbouring fields. A total of fifty tillers or plants were collected from the assessment area, and rated at each growth stage.

Seedling blight was estimated at Zadoks Growth Stage (ZGS) 20 (Zadoks *et al.*, 1974) using a 0 to 4 scale: 0–no symptoms; 1–slight discolouration; 2–discolouration obvious; 3–lesions present; 4–roots badly damaged or dead. Incidences of other diseases such as smuts and take-all were visually assessed during field sampling.

Fields were rated for foliar disease symptoms at ZGS 20 (tillering), ZGS 31 (stem elongation, first node detectable), ZGS 55 (half of inflorescence emerged), and ZGS 73 (early milk). One rating was made at ZGS 85 (soft dough) for head diseases of wheat. Both foliar and head disease ratings were made using the Horsfall-Barratt rating system (Horsfall and Cowling, 1978). The first ratings were taken from leaf 3, except for wheat, at ZGS 20, which was rated on both the 3rd and 4th leaves. At ZGS 73, ratings were made on leaf 2 for oats and barley, leaf 1 for spring wheat, and leaves I and 2 for winter wheat. Leaves were counted from the head down. Only 14 of the 15 winter wheat fields were evaluated at ZGS 20. In order to confirm the identity of certain leaf spot diseases, it was often necessary to perform pathogen isolation or to induce sporulation on moist filter paper. On barley leaves, brown to black spots which did not produce spores or mycelium were considered to be a physiological disorder (Clark *et al.*, 1979).

Results and Discussion

Most of the cereals were sown during early to mid May. While the mean daily temperatures were similar to the 78 yr average during the growing season, May through August, there was lower than average rainfall (Table I). While June precipitation was 76% above normal, precipitation in May, July, and August was 49%, 90%, and 43% below normal. Hours of bright sunshine were 15.3% above normal for the growing season.

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Table 1. Climatic Data, Charlottetown, P.E.I., 1987.

	May	June	July	August
Mean Daily Temperature	9.5	14.3	19.5	18.0
78-yr Average	(9.2)	(14.8)	(18.9)	(18.5)
Rainfall	39.9	138.2	7.8	49.0
78-yr Average	(78.4)	(78.6)	(77.8)	(86.0)
Mean Daily Maximum	14.9	18.8	24.3	23.0
Mean Daily Mean	4.1	9.7	14.7	12.9
Sunshine (Bright)	240	230	285	277
78-yr Average	(204)	(222)	(246)	(227)

The lower precipitation, and longer hours of bright sunshine may both have been responsible for reductions in duration of leaf wetness which may have resulted in low overall disease development.

While seedling blight was evident in nearly all fields examined the severity was very low (Table 2). The mean field ratings never exceeded a rating of 1, with many fields exhibiting only a slight trace of root rot symptoms. The major diseases observed in 1987, incidence and severity, are presented in Table 2.

Winter wheat:

Stands of winter wheat were generally of very good quality. Observations of fields in the middle of April, shortly after snow melt, were made to estimate winter kill and snow mold damage. The snow cover was adequate during the previous winter and there was little frost in the ground. The usual mid winter thaw, which is often related with ice sheeting and winter kill did not occur. As a result of these factors winter kill occurred only in a few areas. Snow mold was present in most fields but damage was significant at only two sites where it affected from 5 to 10 percent of the plants. Pink snow mold, as incited by *Fusarium nivalis* (Fr.) Ces. was the most frequent species identified.

Only two foliar diseases were of major importance in 1987: septoria leaf blotch, caused by *Septoria* sp., and powdery mildew, caused by *Erysiphe graminis* DC. ex. Merat.

Septoria leaf blotch symptoms appeared early in the season. At the first rating, it was found in 100% of fields surveyed with an overall average severity of 4.4 percent. Septoria leaf blotch moved slowly from the lower to upper leaves; severity averaged only 0.6 percent on ZGS 31, and increased to the peak of 11.4 percent at ZGS 73. At this point, the disease was present in all fields and the leaf area infected ranged from 10 to 23 percent, in 65% of the fields. Levels of septoria glume blotch were somewhat lower than septoria leaf blotch, being above 5 percent in only six fields, with an average severity of only 4.8%. Septoria glume blotch was observed in only 80% of fields surveyed.

Severity levels of powdery mildew remained relatively low, at an average of less than 3%. However, in two fields in the western part of P.E.I., severity reached 19.3 and 10.3 percent at ZGS 55, on Borden and Valor, respectively.

Ascochyta leaf spot, a new disease in the Maritime provinces, caused by *Ascochyta tritici* Hori & Enj., was observed in four fields. Typical symptoms of ascochyta leaf spot were irregular spots which were light in colour with a dark border. Only a small number of spots related to ascochyta leafspot were found. There was also one minor case of tan spot, incited by *Pyrenophora tritici-repentis* (Died.) Drechs, identified at ZGS 73. Several fields were affected by take-all. However, take-all was not widespread, nor severe in 1987. Fusarium head blight, incited by *Fusarium graminearum* Schwabe was not a problem in 1987.

Spring wheat:

Septoria leaf blotch, *Septoria* sp. was the only important disease on spring wheat. The disease, although widespread in 71% of fields, was not severe at the initial rating, which corresponded with a low disease severity at the second rating of winter wheat. Dry conditions at this time were probably responsible for arresting disease development. After the initial assessment, the severity of septoria leaf blotch increased to an average level of 10.9 and 15.5 percent, respectively, at the final two assessments with 100% incidence. In some individual fields, levels greater than 30 percent were observed at later growth stages. Severity levels varied widely within each cultivar and may have been a reflection of management inputs, such as the application of foliar fungicide.

Powdery mildew, *E. graminis*, was not important on spring wheat, except for one field planted with the cultivar Opal, where it reached 40.5 percent of leaf area at ZGS 55. This cultivar is very susceptible to powdery mildew. Max spring wheat was, in 1987, classified as resistant to powdery mildew. Powdery mildew was observed on Max wheat in 1988.

Spot blotch, incited by *Cochliobolus sativus* Ito & Kurib (*Bipolaris sorokiniana* Sacc. in Sorok.) and tan spot, incited by *P. tritici-repentis*, were observed only once. Very low incidence of loose smut, incited by *Ustilago tritici* (Pers.) Rostr. was observed in some fields.

Barley:

Net blotch incited by *Pyrenophora teres* Drechs., scald incited by *Rhynchosporium secalis* (Oud.) J.J. Davis, and speckled leaf blotch, incited by *Septoria* sp. (Sacc.), were the three most common diseases of barley, though they were observed in quite different patterns. Scald was present in up to 90% of fields, but the hot and dry weather seemed to have prevented its development on the upper foliage toward the end of the season. Except for ZGS 31, scald ratings were always below one percent, indicating a lack of development or progression up the plant.

Net blotch was present in all fields at some time during the season although several fields exhibited only trace amounts. Net blotch showed a slow and steady progression from each sampling date and reached a peak in severity of 3.0 percent

Table 2. Incidence and severity of cereal diseases at various growth stages (Zadoks Growth Stages) on P.E.I., 1987.

Disease	Incidence and Severity (%)									
	Growth Stage 20		Growth Stage 31		Growth Stage 55		Growth Stage 73		Growth Stage 85	
	*Severity	Incidence**	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence
WINTER WHEAT DISEASES										
Seedling blight	0.4	93	–	–	–					
Septoria blotch	4.4	100	0.6	87	3.4	100	11.4	100	–	–
Powdery mildew	0.4	64	1.5	67	2.4	47	1.2	67	–	–
Sooty mold	0	0	0	0	0	0	0.1	33	–	–
Septoria head	–	–	–	–	–	–	–	–	4.8	80
Powdery mildew head	–	–	–	–	–	–	–	–	0.6	33
Fusarium head	–	–	–	–	–	–	–	–	0.2	40
SPRING WHEAT DISEASES										
Seedling blight	0.1	93	–	–	–	–	–	–	–	–
Septoria blotch	0.3	71	1.0	93	10.9	100	15.5	100	–	–
Powdery mildew	0.0	14	0.0	21	2.9	7	0.9	7	–	–
Sooty mold	0	0	0	0	0	0	0.1	7	–	–
Septoria head	–	–	–	–	–	–	–	–	6.8	86
Powdery mildew head	–	–	–	–	–	–	–	–	1.3	7
Fusarium head	–	–	–	–	–	–	–	–	0.2	14
BARLEY DISEASES										
Seedling blight	0.2	93	–	–	–	–	–	–		
Net blotch	0.2	60	1.2	83	2.3	86	3.0	77		
Scald	0.5	70	1.6	90	0.5	63	1.0	70		
Speckled leaf blotch	0.1	3	0.2	23	0.1	17	3.4	63		
Spot blotch	0.2	10	0.1	3	0.1	23	0.4	37		
Physiological spot	0.4	10	0	0	0.4	27	0.1	7		
Halo spot	0	0	0	0	0.1	10	0.1	13		
OAT DISEASES										
Seedling blight	0.1	33	–	–	–	–	–	–		
Septoria leaf blotch	0.1	42	0.3	67	6.0	83	12.9	92		
Avenacea leaf blotch	0.1	17	1.4	58	0.8	42	4.8	17		

*Overall percent leaf area infected estimated with the Horsfall-Barratt rating system (severity), except for root rot which is 0-4 scale where 0 is symptom free.

**Incidence: percent of fields surveyed with the disease present.

at ZGS 73. The severity of this disease varied greatly from field to field, probably as a result of the use of fungicides or the crop grown during the previous season. Severity on Leger barley varied from trace amounts to 16.8%, at the ZGS 73 assessments. While net blotch levels were probably too low to cause a significant yield loss in most fields, four fields were above 10 percent at the last two sampling dates.

At the last rating (ZGS 73) severity of net blotch was surpassed by that of speckled leaf blotch, which reached an average of 3.4 percent. This, relatively uncommon disease in the region, which was found at low levels throughout the season, seemed to have rapidly increased by ZGS 73. This outbreak may have been on account of the unusually hot weather late in the season. A level of 55 percent was seen in one field of Leger, and four other fields had levels ranging from 5 to 12 percent. Given favourable climatic conditions, this disease may have the potential to be destructive in certain years.

Other diseases were also present, however, both incidence and severity were low. Spot blotch, incited by *B. sorokiniana*, and halo spot, incited by *Selenophoma donacis* var. *stomaticola* (Baeumler) Sprague & A.G. Johnson, were observed in a few fields at ZGS 55 and 73. Incidence of the two diseases was 37% and 13%, respectively, at ZGS 73 while severity in the infected fields was only 1% and 0.5%, respectively. Scattered powdery mildew lesions were observed in four fields of Leger. Leaf rust incited by *Puccinia hordei* Otth was identified on one occasion. Loose smut, incited by *Ustilago nuda* (Jens.) Rostr., was observed in several fields. No instances of viral diseases were observed.

Oat:

Oat diseases consisted essentially of septoria leaf blotch, incited by *Septoria avenae* Frank, and avenacea leaf blotch, incited by *Pyrenophora avenae* Ito & Kuribayashi. Septoria leaf blotch was insignificant at the first two ratings but jumped to 6.0 and 12.9 percent by ZGS 55 and 73, respectively, and affected 92% of fields. Three fields had severity levels in excess of 30 percent. Avenacea leaf blotch was observed in up to 58% of fields but was important only in one, where severity exceeded 50%. No viral infections were observed, and there was a single possible case of bacterial blight.

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Incidence and severity of root rot disease complex of field pea in northeastern Alberta in 1988

S.F. Hwang[1] and K.F. Chang[2]

Twenty-nine pea fields in northeastern Alberta were surveyed in 1988 for the presence and severity of root rot disease complex. Mean disease incidence and severity were 31% and 0.57 (on a scale of 0-4), respectively. Populations of *Fusarium* spp. and *Pythium* spp. in these pea fields averaged 58 x 10^2 and 6.0 x 10^2 propagules/g soil, respectively. *Fusarium* was the most frequently isolated genus from root-rot lesions of diseased pea plants. *Rhizoctonia solani* and *Pythium* spp. were isolated only occasionally. The ratio of *F. solani* :*F. oxysporum* :other *Fusarium* spp. was 1:3:8.

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En 1988, on a examiné vingt-neuf champs de pois du nord-est de l'Alberta afin de déceler la présence des différents agents pathogènes responsables du pourridié et d'évaluer la gravité des foyers d'infection. L'incidence moyenne de la maladie et l'indice de gravité étaient respectivement de 31 % et de 0,57 (selon une échelle de 0 à 4). On a relevé en moyenne 58 x 10^2 propagules de *Fusarium* spp. par gramme de sol et 6,0 x 10^2 propagules de *Pythium* spp. par gramme de sol dans ces champs de pois. C'est le genre *Fusarium* que l'on a isolé le plus fréquemment des lésions des racines des pois malades. Ce n'est qu'occasionnellement que l'on a isolé *Rhizoctonia solani* et *Pythium* spp. Le ratio *F. solani* : *F. oxysporum* : autres espèces de *Fusarium* était de 1:3:8.

Introduction

Field pea (*Pisum sativum* var. *arvense* L.) is well-adapted to a cool climate and can withstand considerable frost. In recent years the acreage of field peas in north-central Alberta has dramatically increased due to its value as a cash crop, use in rotation with cereals, high protein content (26%) which is suitable for human and livestock consumption, and atmospheric nitrogen-fixing ability (1).

The root rot disease complex of pea is a worldwide problem which can seriously reduce yield and quality of the crop (5, 6, 11). More than 20 different fungi have been implicated as causal agents in different regions of the world. To obtain more information on root rot of field pea in northeastern Alberta, a survey was carried out to determine the incidence and severity of root rot and to isolate and identify fungi associated with the root rot disease complex.

Materials and methods

Twenty-nine pea fields in northeastern Alberta were surveyed between late May and mid-June in 1988 for root rot (Fig. 1). Ten plants, along a W-pattern transect through each field, were dug up at each of 10 points. All roots were stored in a cooler at 5°C. Roots were washed and the incidence (%) and severity of root rot assessed. Severity ratings were assigned based on a scale of 0 to 4 where 0 = healthy, 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, and 4 = 51-100% root discoloration.

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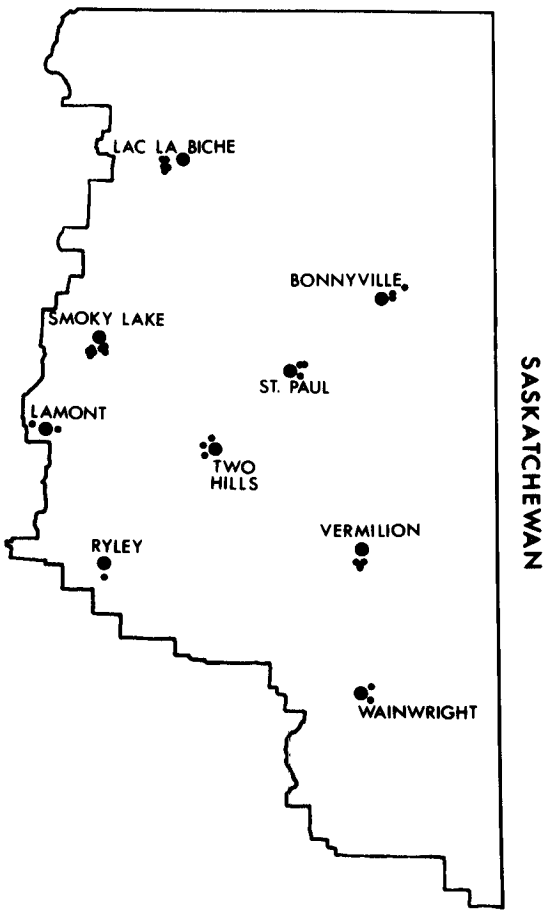

Fig. 1. Map of northeastern Alberta showing the approximate locations of the fields surveyed in 1988.

Five pieces (0.2 x 0.2 cm) of discolored root tissue were taken from each of five randomly selected plants from each of the 29 fields sampled. The root tissue was surface sterilized in 0.6% sodium hypochlorite for 2 min, rinsed in sterile water, blotted dry, and placed on acidified potato dextrose agar (PDA). Five pieces of tissue were plated in each petri plate and incubated 5 days at room temperature. Hyphal tips growing out from the tissue were cut off and transferred to PDA slants for further growth and identification.

Five surface soil sub-samples were collected at random from each of the 29 naturally infested pea fields one month after planting to estimate the numbers of *Fusarium* and *Pythium* propagules. All soil sub-samples from the same field were passed through a 1.68 mm screen and thoroughly mixed together. Soil dilution series of 1:10 and 1:200 (w/v) were prepared for each air-dried sample with 0.2% sterile water agar, then 1 mL of the soil dilution was spread onto a pentachloronitrobenzene (PCNB) medium plate, which is selective for *Fusarium* (9), and onto a pimaricin-vancomycin agar plate (MPVM) with rose bengal (0.02 g/L), which is selective for *Pythium* (8). Five plates were prepared for each sample. The PCNB plates were incubated under fluorescent light at room temperature and the number of *Fusarium* colonies recorded after 7 days. The MPVM plates were incubated for 48 h in darkness at room temperature, then washed under a slow stream of water to remove materials other than *Pythium* colonies which had grown into the medium. The number of *Pythium* colonies was then recorded.

Results and discussion

Peas with root rot were found in all fields surveyed. Average disease incidence and severity of root rot were 31% and 0.57 (on a scale of 0-4), respectively (Table 1). Populations of *Fusarium* spp. and *Pythium* spp. averaged 58 x 10^2 and 6 x 10^2 propagules/g soil, respectively. *Fusarium* was the most frequently isolated genus from root rot affected pea plants; *Rhizoctonia solani* and *Pythium* spp. were isolated only occasionally. Of the total *Fusarium* cultures recovered, the ratio of *F. solani* : *F. oxysporum* : other *Fusarium* was 1:3:8.

Previous studies have indicated that *F. solani* f. sp. *pisi* is the primary causal agent of root rot of green pea in Canada (2, 10). However, in our study, the high frequency of isolation of *F. oxysporum* indicates that it is a major fungal component of the root rot disease complex in northeastern Alberta. The unidentified *Fusarium* spp. are probably of little importance in causing root rot of field pea (11).

Several *Pythium* spp. have been reported as the major incitants of seed decay and preemergence damping-off of pea in other countries (4, 5). Although the frequency of isolation of *Pythium* spp. from root tissues was very low, the populations of *Pythium* spp. varied considerably between fields. In addition, a few isolates of *Pythium* spp. obtained from infected peas were found to be highly pathogenic on the pea cultivar Tipu (Hwang, unpublished). It has been reported that *Pythium* spp. may play a significant role in the pea root rot disease complex in the early growth stage of pea plants and when the soil is poorly drained and cold (3, 5).

Fusarium wilt disease is a potentially serious threat to field pea production in that area. Since both *Fusarium* and *Pythium* are soil-inhabitants and may survive for a long time, a four-year crop rotation is recommended (6, 7, 11). Unfortunately, some Alberta pea growers continue to grow pea year after year in the same field because of its high value as a cash crop. This practice will likely increase the prevalence and severity of the root rot disease complex, which could become a major limiting factor in pea production. Therefore, to assess the potential for root rot, a large-scale screening and isolation of pathogens based on a more extensive field survey is needed in order to identify the race(s) of *F. oxysporum* f. sp. *pisi* and the other pathogens associated with root rot. Since the use of wilt- and root rot-resistant pea cultivars offers the

Table 1. Incidence and severity of pea root rot and populations of *Fusarium* spp. and *Pythium* spp. in pea fields surveyed in northeastern Alberta in 1988.

Location	No. of fields	Incidence (%)		Severity*		Propagules/g air-dried soil	
		Mean	Range	Mean	Range	*Fusarium* (x10^2)	*Pythium* (x10^2)
Bonnyville	3	38	15-53	0.76	0.29-1.29	40	4.6
Lac La Biche	5	48	31-59	1.07	0.54-1.50	43	5.2
Lamont	2	28	28-28	0.48	0.38-0.57	29	6.4
Ryley	1	22	–	0.26	–	70	6.6
Smoky Lake	7	29	2-76	0.55	0.02-1.94	59	10.1
St. Paul	3	20	1-31	0.27	0.03-0.37	62	4.5
Two Hills	3	57	39-87	1.05	0.62-1.81	64	3.6
Vermilion	3	22	15-30	0.43	0.36-0.53	82	7.2
Wainwright	2	14	2-26	0.24	0.02-0.46	71	5.6
Total/Average	29	31	–	0.57	–	58	6.0

*Root rot severity rating scale: 0 = clean; 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, and 4 = 51-100% of the root discolored.

best possibility for controlling the diseases, greater efforts are also needed to develop pea cultivars, not only with specific resistance to the *Fusarium* wilt pathogen, but also with nonspecific resistance to *Fusarium, Pythium*, and other root rot pathogens.

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Fungi detected on *Acroptilon repens* (Russian knapweed) during surveys from 1981 to 1988

K. Mortensen and M.M. Molloy[1]

Five fungi, *Physarum cinereum*, *Phomopsis* sp., *Sclerotinia sclerotiorum*, *Puccinia acroptili*, and *Alternaria cichorii* were detected on *A. repens* in western Canada and investigated for biological control. This is the first record of *A. cichorii* on *A. repens* in Canada, and the pycnia stage of *P. acroptili* was found for the first time. *P. acroptili* has some potential for classical biological control. None of the fungi are promising as bioherbicides.

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Cinq agents pathogènes, *Physarum cinereum*, *Phomopsis* sp., *Sclerotinia sclerotiorum*, *Puccinia acroptili*, et *Alternaria cichorii* ont été décelés sur *A. repens* dans l'ouest du Canada et évalués comme agents de lutte biologique. C'est la première mention de *A. cichorii* sur *A. repens* au Canada et du stage pycnia de *P. acroptili*. Il a été démontré que *P. acroptili* pourrait être un agent classique de lutte biologique. Aucun des champignons semble prometteur comme herbicide biologique.

Introduction

Acroptilon repens (L.) DC. (*Centaurea repens* L.; Russian knapweed) is an introduced persistant perennial weed, which is commonly found in western Canada and to a lesser extent in Ontario (15). It originated from southern Russia and Asia Minor, and was introduced to Canada with Turkestan alfalfa in the early 1900's (5). Patches of *A. repens* were visited regularly during the period from 1981 to 1988 as a result of a biological control attempt with the nematode, *Subanguina picridis* (Kirjanova, 1944) Brzeski, 1981, syn.: *Paranguina picridis* (Kirjanova, 1944) Kirjanova and Ivanova, 1968 (16, 17). Diseased plants of *A. repens* were diagnosed, disease causing organisms identified, and potential of fungi for biological control evaluated. The following is a summary of the results.

Materials and methods

Diseased *A. repens* samples were collected by the authors unless stated otherwise, and analysed using common plant pathology procedures. Plants of *A. repens* used for testing were grown from root stocks in a sandy loam mixed with peat moss and vermiculite (3:2:1, v/v/v) on greenhouse benches at 18 to 24°C with a 14-h day extended with incandescent and fluorescent light (280 μmol.m^{-2}.s^{-1}). *Phomopsis* sp. (Sacc.) Sacc. was isolated and single spore cultures increased on potato dextrose agar (PDA). Inoculation was done either by spraying a spore suspension on plants to runoff using an air brush (Paasche Airbrush (Canada) Ltd. Type H-5), or slightly wounding stem areas, placing spores and mycelium in the wound and covering it up with wet cotton. Inoculated plants were kept in a cool mist chamber for 48 h. The mist chamber was constructed on a greenhouse bench and enclosed with transparent polyethylene. Light and temperature in the chamber were similar to those of the greenhouse. For *Alternaria cichorii* Nattrass, inoculation was only done by spraying a water suspension of spores, mycelial fragments and chlamydospores on *A. repens* and incubating for 48 h in the cool mist chamber. The host range of *A. cichorii* was tested using well-established plants of *Centaurea diffusa* Lam., *C. pannonica* (Heuff.) Simon., *C. nigrescens* Willd., *C. rocheliana* (Heuff.) Dost., *C. nigra* L., *C. weldeniana* Reichenb., *C. sadlerana* Janka, *Arctium minus* (Hill.) Bernh., and *Onopordum acanthium* L.; and on *Carthamus tinctorius* L., *Helianthus annuus* L., *Chichorium intybus* L., *C. endivia* L., and *Zinnia elegans* Jacq. in the 4-8 leaf stages, grown from seeds in the greenhouse. Inoculated plants were removed from the mist chamber and kept on greenhouse benches. Inoculated plants were inspected for disease symptoms at least once weekly and a final disease rating was given 14 to 30 days after inoculation.

Results and discussion

Physarum cinereum (Batsch.) Pers. (Myxomycetes)

Physarum cinereum were observed on a stem of *A. repens* in irrigated alfalfa-brome hayland (S 1/2 24-23-27 W. of 3rd) at Leader, Sask., along the South Saskatchewan River, August 23, 1988 (collected by P. Harris). Grayish blue fruiting bodies occurred abundantly on the centre part of a stem (about 5 cm) at a branch axil on a somewhat stunted plant (only observed on one plant in the area, identified by J.A. Parmelee, Sept. 7, 1988). This fungus has no plant pathological importance.

Phomopsis sp. (Sacc.) Sacc. (Coelomycetes)

Wilting shoots of *A. repens* were first observed in a weed garden at Agriculture Canada, Research Station, Regina, Sask., in October of 1981, but the cause was not detected, only saprophytic bacteria and fungi were isolated. In 1982, wilting shoots occurred in June. Again several saprophytic bacteria and fungi (*Alternaria* spp. and *Fusarium* spp.) were isolated, but were not identified to species. A *Phomopsis* sp. was frequently isolated, and when inoculated back on wounded *A. repens* stems, it caused wilting of inoculated

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stems, but new shoots were healthy. A culture (CMI No. 274636, 10 March 1983) was identified as *Phomopsis* by J.E.M. Mordue. In June 1986, scattered wilting shoots were observed in a natural infestation of *A. repens* 6.4 km west and 8 km north of Leader, Sask. (S 1/2 24-23-27 W. of 3rd) along the South Saskatchewan River. A *Phomopsis* sp. identical to the 1982 isolate was consistently recovered. Pathogenicity tests showed that it only caused infections when inoculated into a wound. In July 1986, *A. repens* plants showing similar symptoms were submitted by A.D. Muir from Cache Creek, BC, and the same *Phomopsis* sp. was isolated from the roots.

Since infections on *A. repens* were obtained only through wounds and new shoots from inoculated plants were healthy, the fungus has little potential for biological control.

Sclerotinia sclerotiorum (Lib.) de Bary (Helotiales)

A few wilting plants of *A. repens* were observed in an irrigated wheat field 3.2 km south and 4.8 km east of Pike Lake, Sask., along the west side of the South Saskatchewan River in June of 1986. Browning lower part of stems that showed some shredding, cultured on PDA, resulted in typical growth and sclerotia formation of *Sclerotinia sclerotiorum*. Due to the wide host range of *S. sclerotiorum* (7), it has not been tested as a biological control agent.

Alternaria cichorii Nattrass (Hyphomycetes)

An *Alternaria* sp. was isolated from leaf spots on *A. repens* plants collected in rangeland at Cache Creek, BC, by A.D. Muir, July 1986. Conidia produced singly were somewhat narrowly obclavate with long, narrow colourless to pale beaks. Conidia transferred to PDA produced a dark greenish-black culture with very little aerial mycelium and few spores. Chlamydospore like structures were produced readily in culture. Inoculation of the *Alternaria* sp. resulted in severe leaf spots on older as well as younger leaves of inoculated *A. repens* plants. Conidia were produced readily on inoculated leaves when detached and placed on moist filter paper in a petri dish. A culture was identified as *Alternaria cichorii* Nattrass by M.P. Corlett. *A. cichorii* has not previously been reported from Canada (1, 4), but has been reported from the U.S.A. (3, 14). In none of the above references and others checked (6, 8, 10, 11, 12, 13) have *Alternaria* spp. been reported from *A. repens*. Thus, this is the first report of *A. cichorii* on *A. repens*.

Host range tests with *A. cichorii* showed that *Centaurea diffusa*, *C. pannonica*, *C. nigrescens*, *C. rocheliana*, *C. nigra*, *C. weldeniana*, *C. sadlerana*, *Arctium minus*, and *Onopordum acanthium* plants did not show any signs of infection by *A. cichorii* when well-established plants were inoculated. *Carthamus tinctorius*, *Helianthus annuus*, *Chichorium intybus*, *C. endivia*, and *Zinnia elegans* showed some slight leaf spotting on older leaves after onset of senescing. *Alternaria cichorii* did not cause leaf spots on healthy and developing leaves except on *A. repens*. This indicates that our isolate of *A. cichorii* is specific to *A. repens*.

Under greenhouse conditions, inoculated leaves of *A. repens* wilted severely, but none of the plants died. A small plot of *A. repens* at Leader, Sask., was inoculated with a spore and mycelial suspension of *A. cichorii* May 21, 1987. Dry conditions occurred the following two weeks after inoculation and when inspected three weeks later and again at the end of the season, no symptoms of *A. cichorii* were detected. With no plant kill under greenhouse conditions and no infection at all in the field plot, *A. cichorii* would not be sufficiently effective as a bioherbicide on dry rangeland.

Puccinia acroptili P. Syd. and H. Syd. (Uredinales)

This rust (*P. acroptili*) was observed on *A. repens* from four locations in Saskatchewan and from two locations in British Columbia:

1. Agriculture Canada, Research Station, Regina, Sask., in an established patch of *A. repens* about 20 m^2, August, 1984 (DAOM 192620).

2. Leader, Sask. (S 1/2 24-23-27 W. of 3rd), occurring in patches of *A. repens* (up to 0.4 ha) in a pasture, along the South Saskatchewan River, May 22, 1985 (DAOM 192619), and August 30, 1985 (DAOM 194911). In May, both pycnia and uredinia were present on older leaves of about 5% of the plants which were bolting, and few pustules occurred on the upper leaves. In August, primarily telia were present on upper leaves of mature plants. In June, 1987, *P. acroptili* was observed on galls of the nematode (*Subanguina picridis*) in a site where the nematode had been released on *A. repens* the previous year by P. Harris. Nearly all galls were heavily infected with the rust, both outside and in the cavities inside the galls. Only urediniospores were observed. It appeared as though the gall tissue was exceptionally susceptible to *P. acroptili*.

3. Saskatchewan Landing Provincial Park, Sask., on *A. repens* in a camping area, August 30, 1985, collected by P. Harris (DAOM 194912). Primarily telia were present on upper leaves of mature plants.

4. Pike Lake, Sask. (3.2 km south and 4.8 km east), on *A. repens* in an irrigated wheat field, along the west side of the South Saskatchewan River, June, 1986. Only uredinia were present on leaves.

5. Campbell Creek, LaFarge Yard, Kamloops, BC, on *A. repens* in rangeland, September 5, 1985, collected by P. Harris (DAOM 194913). Primarily telia were present on upper leaves.

6. McQueen Creek, Lac du Bon, BC, on *A. repens* in rangeland September 22, 1986, collected by A.D. Muir. Primarily telia were present on leaves (about 50% of leaf area covered with pustules).

Samples (indicated by DAOM No.) were identified as *P. acroptili* P. Syd. and H. Syd. by J.A. Parmelee. Both Savile (9) and Cummins (2) reported that pycnia are unknown for *P. acroptili*. Therefore, this is the first time that pycnia of *P. acroptili* have been reported. *P. acroptili* was only reported from California and from Grand Forks, BC, in North America (9). According to Savile (9), only light infections occurred on the specimens, and he suggests that perhaps more aggressive types of *P. acroptili* should be imported for biological control of *A. repens*. Since *P. acroptili* has now spread to several other areas in British Columbia and Saskatchewan and appears to be well-established on

A. repens, there is no need to import new types of the rust. However, distribution of the rust as a classical biological control agent to uninfested areas would be worthwhile, because it appears to inflict considerable stress on *A. repens* in heavily infected patches.

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