Blackleg and other diseases of rapeseed in Saskatchewan, 1978 to 1981[1]

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The prevalence and incidence of the virulent strain of blackleg (*Leptosphaeria maculans*) increased tenfold in standing crops of rapeseed (*Brassica napus* and *B. campestris*) in Saskatchewan between 1978 and 1981, but the overall yield loss from basal stem cankers was slight. Virulent blackleg was most prevalent in northeastern and central areas (crop districts (C.D.) 6b and 8), occurring in over 40% of the fields sampled over the 4-year period. It was least prevalent in the southeast (C.D. 1, 2 and 5), occurring in only 1.5% of the fields. Damping-off and seedling blight, caused primarily by *Rhizoctonia solani* were severe in 1979. Footrot (*R. solani* and *Fusarium roseum*) affected 81% of the fields that year with a mean incidence of 16%. White rust (staghead) declined in importance on *B. campestris* over the 4 years, but a different race of *Albugo candida* became more prevalent on *B.* juncea. Grey leaf spot or altarnaria black spot (A. *brassicae* and A. *raphani*) was often widespread, but rarely severe. White leaf spot and grey stem (*Pseudocercosporella* capsellad, pod drop (cause unknown) and aster yellows were generally of minor importance. "Hybridzation nodules" on the roots of rape plants were prevalent in dry areas in 1979.

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La distribution et la frbquence d'une souche virulente du champignon de la jambe noire (*Leptosphaeria maculans*) ont augmenté par un facteur de dix dans les champs de colza (*Brassica napus* et *B. campestris*) de la Saskatchewan entre 1978 et 1981, mais la perte de rendement due au chancre de la tige est demeurbe peu élevée. La jambe noire virulente btait plus rbpandue dans le nord-est et le centre de la province (région agricole (R.A) 6b et 8), btant présent dans 40% des champs échantillonnés sur une période de 4 ans. Elle était moins rbpandue dans le sud-est de la province (R.A. 1, 2 et 5), n'étant prbsente que dans 1.5% des champs. La fonte des semis et de brûlure des plantules, causbes principalement par *Rhizoctonia solani* ont été sévères en 1979. La pourriture des racines (*R. solani* et *Fusarium roseum*) affecta 81% des champs cette année-là, avec une frbquence moyenne de 16%. La rouille blanche diminua en importance sur *B. campestris* durant ces quatre ans, mais une race diffbrente d'*Albugo candida* gagna de l'importance sur *B. juncea*. La tache grise ou la tache noire (*Alternaria brassicae* et A. *raphani*) furent souvent très rbpandues mais rarement sévères. La tache blanche foliaire et la tige grise (*Pseudocercosporella capsellae*), la tombée des siliques (cause inconnue) et la jaunisse étaient généralement de peu d'importance. La prbsence de "Nodules d'hybridization" sur les racines des plantes de colza btait générale dans les regions sèches en 1979.

Introduction

Our primary objective in annual disease surveys of Saskatchewan rapeseed crops has been to monitor the spread of a virulent form of blackleg (***Leptosphaeria maculans*** (Desm.) Ces. & de Not.), first found in the province on residue of the 1975 crop (5, 13). At that time it was detected at low levels in three widely separated fields, at Star City (crop district (C. D.) 8a), Humboldt (C. D. 8b) and Rosthern (C. D. 6b). In 1977, a severe localized outbreak of this strain occurred near Star City (13). Its incidence was 100% in a large portion of one field examined. In another field that had been seeded or had volunteered in stubble from the previous year, the yield loss from blackleg basal stem cankers was estimated conservatively at 20%. Abnormally high summer precipitation in northeastern Saskatchewan in 1977 contributed to the spread of the pathogen (1).

Other objectives of the annual surveys have been to monitor damping-off and footrot (***Rhizoctonia solani*** Kuhn and ***Fusarium roseum*** Lk. emend. Snyder and Hansen), several diseases of lesser importance, and damage from environmental or other factors.

Methods

Two series of surveys were conducted each year in fields having rapeseed that year, one series in standing crops and one in stubble. The first was started in late June or early July and was largely completed by early August. In this survey, plants were examined for early ***L. maculans*** infections on the leaves and stems, because such infections cause the maximum loss in yield from basal stem cankering (6). The stubble survey began late in August and was usually completed by the end of September. The extent of L. ***maculans*** infection on stubble is an indicator of inoculum levels (numbers of ascospores) in subsequent years. Routes were mapped out each year, and approximate locations of fields to be sampled marked equidistantly along them. In standing crops, five plants were pulled at each of five sites along an inverted "V" course. In stubble surveys, 10 stubble plants were pulled at each of five sites per field. Blackleg and footrot were rated independently using the 0-3 scale of severity established for footrot in earlier surveys (11). Other diseases were rated as in earlier surveys (8, 10).

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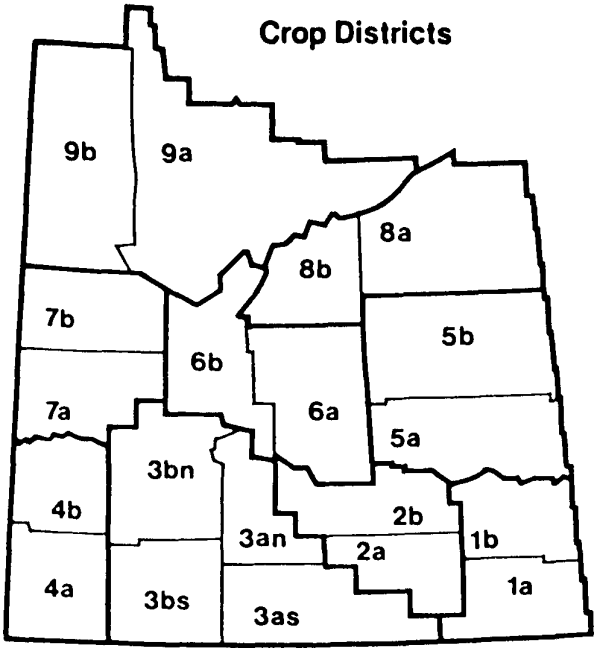

Figure 1. Saskatchewan crop districts and sub-districts.

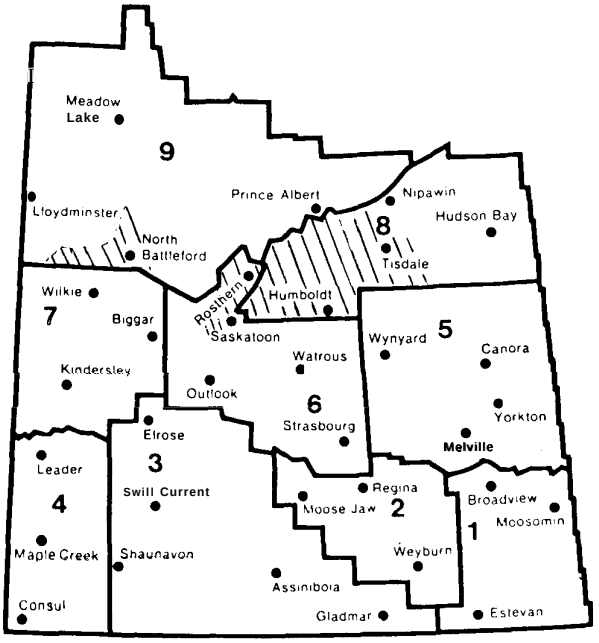

Figure 2. Major areas of infestation by the virulent strain of blackleg. Cross-hatched areas are those in which fields having more than 10% infection by the virulent strain were located. Data from all surveys (1978 to 1981) combined.

The principal cultivars of Argentine rape (*Brassica napus* L.) and Polish or turnip rape (*B. campestris* L.) grown each year and the percentage of the total hectares of rapeseed seeded to each cultivar were available from the annual crop variety survey published by the Canadian Co-operative Wheat Producers Ltd. (2) (Table 1). As relatively few fields of *B. campestris* were encountered, the two species generally are not differentiated in the subsequent tables. The crop districts referred to throughout this report are illustrated in Fig. 1 and Fig. 2.

Results

1978

The Star City-Nipawin area, location of the 1977 outbreak of blackleg, was visited in June and early July, 1978, prior to the principal surveys. On June 28, abundant leaf spots caused by the virulent strain were found in fields planted next to two of the 1977 fields. In one of these, stem girdling was noted on a small number of the young plants. The area was visited again on July 7. Additional infections were not apparent; spots were confined to the lower leaves and many of these were senescent. On July 14, scattered leaf spots were observed in fields throughout northeastern Saskatchewan. Although rainfall in the area was above normal in June, July precipitation was below normal (1). As part of the July-August 1978 survey, which covered much of the province, the northeast was visited again on July 26. The incidence of virulent blackleg was low, as it was in other areas where it had occurred previously. None was found in southeastern or east-central districts. In late August, 16 standing crops examined in C.D. 8a and 8b (the northeast) were affected, but the incidence of infection did not exceed 10%.

In August and September of 1978, 56% of the stubble fields examined were infected, with the Rosthern area having the highest levels. No blackleg occurred in the five mustard fields surveyed. Brown or oriental mustard (*Brassica juncea* (L.) Coss) and yellow mustard (*B. hirta* Moench = *Sinapis alba* L.) are resistant to the virulent strain (Petrie, unpublished). All the blackleg survey data are summarized in Tables 2, 3 and 4. As with other diseases, mean severity ratings for blackleg generally were very low throughout the 4-year period. Therefore, only data for prevalence and incidence appear in the tables. Figure 2 illustrates the major areas of infestation by the virulent strain between 1978 and 1981.

1979

A preliminary survey was again conducted in the Star City area in 1979. In that year, May was abnormally cool and wet, and heavier than normal precipitation continued in June. Relatively little blackleg was seen on a July trip. Symptoms consisted of scattered leaf spots that likely had arisen from ascospore infection during the fourth week of June. The first general survey was started July 19 and continued through August. Although the virulent strain was prevalent in the Melfort-Star City and Rosthern areas, occurring in 60% of fields examined, its average incidence and severity were low in all areas. In July, the most heavily infected field (16%) occurred near Cutknife in crop district 9b. Levels of infection of this magnitude had not previously been found west of Saskatoon. The virulent strain also was found in three fields not examined in the general survey. These were near Laird (C.D 6b), Rosthern (C.D 6b) and Wakaw (C.D. 8b).

In the August-September 1979 survey of stubble fields, blackleg incidence was again generally low, although in areas in which it had become well established (Melfort, Humboldt, and Rosthern) it occurred in up to 88% of the fields. The virulent strain again was not detected in southeastern and east-central crop districts 1 and 5a, or in the Meadow Lake (northwest) or Asquith-Delisle areas, which were surveyed extensively.

1980

Disease development was retarded by a prolonged dry spell. Little blackleg was found in standing crops, apart from those in the Melfort-Star City area. Although most of the fields there had 10-15% infected plants, one had over 80%. In the fall stubble survey, one specimen infected by the virulent strain was obtained from a field near Churchbridge, near the Manitoba border. This is the only instance in which this strain has been found in the east-central or southeastern part of the province prior to 1983. In a heavily infected field south of Laird, the virulent strain occurred on 50% of the plants. The most likely source of the early basal stem infections of these plants was ascospores from old rape residue in the field.

1981

Precipitation in June and July was above normal and plants in a few fields had basal stem infections by late June. A high incidence of the virulent strain of blackleg was found in four fields in the Waldheim-Rosthern area and in one near Humboldt. In late June, 20% of the plants were infected in two fields west of Rosthern. In late July, the blackleg incidence in one of these fields had reached 100%, whereas in the other the incidence was much the same as it had been a month earlier, and plants cankered at the time of the initial survey were prostrate under the plant canopy. Discharge of ascospores in close proximity to the second field likely did not continue during July. In late July two other fields in the same general area were found with blackleg incidences close to 70%. Infection consisted of small lesions on the upper parts of the stems. A field near Fulda, in the Humboldt area, had 48% infection in early July. Ascospore-bearing residue from the previous rape crop occurred in this field. As in the case of the Waldheim and Rosthern fields, leaf and upper stem infections predominated; only 8% basal stem infection was recorded.

In the August-October 1981 survey, the virulent strain occurred in all fields entered in C.D. 6b and 8. There was also an increase over the preceding two years in fields having over 10 and 20% incidence of infection (Table 3). In September basal cankering and premature ripening were noted in fields near Cudworth and Fulda in crop district 8b. All eight fields in the Asquith-Delisle area west of Saskatoon had the virulent strain, whereas two years earlier it could not be detected in this area. In a sample of foundation seed from near Melfort, infection by the virulent strain of blackleg exceeded 8%. an unusually high level of seed infection for this disease (14).

Damping-off, seedling blight, and footrot (*Rhizoctonia solani* Kiihn, *Fusarium* spp., and *Pythium* spp.). The data for footrot from 1978 to 1981 are presented in Table 5. This disease complex is prevalent in at least some parts of Saskatchewan every year. Several heavily infected fields were encountered in a earlier survey (11). The disease was particularly noteworthy in 1979 (Table 5). Damping-off and seedling blight caused widespread damage in the spring, especially between North Battleford and the Alberta border. Cool wet conditions stimulated the proliferation of seedling blight fungi while retarding seedling development. Later in the season, numerous enquiries were received dealing with further manifestations of the problem. For example, "wire-stem" symptoms were common in mid-June in a field near Lone Rack (C.D. 9b), and rotting and breakage of stems at soil level occurred in fields at North Battleford, Cutknife, and Maidstone (C.D. 9b) in July and August. Premature ripening often accompanied the basal stem rot. Rape plants with white mould on the roots were received from Meath Park (C.D. 9a), and yellow mustard rotting at the base and at the lower leaf nodes was collected north of Birch Hills (C.D. 8b). In these two instances, *Fusarium roseum* Lk. emend. Snyder and Hansen was isolated.

Table 1. Rapeseed/canola varieties grown in Saskatchewan, 1978-1981.*

Species and variety	% of total seeded hectares for years			
	1978	1979	1980	1981
B. campestris				
Candle	5.9	12.6	19.4	20.8
Torch	20.6	18.3	10.7	7.2
B. napus				
Altex	0.0	0.6	8.9	17.9
Midas	24.3	11.9	6.7	4.0
Regent	1.9	26.5	38.3	38.5
Tower	44.8	27.2	14.5	8.2
Other varieties	2.5	2.9	1.5	3.4
Total hectares,				
Sask. x 1,000	1,133.1	1,335.5	890.3	526.1
Acres x 1,000	2,800.0	3,300.0	2,200.0	1,300.0

*Crop Varietal Survey, Canadian Co-operative Wheat Producers Ltd. Reprinted in (Rapeseed) Canola Digest. "Canola" refers to cultivars having low levels of erucic acid and glucosinolates; i.e., Candle, Altex, Tower and Regent.

Sclerotinia stem rot (*Sclerotinia sclerotiorum* (Lib.) de Bary). The surveys described in this paper frequently could not properly assess sclerotinia stem rot. Surveys completed in July will either miss *Sclerotinia* entirely, or often greatly underestimate the amount of stem rot because the disease does not develop until crops are in the mid-flowering stage (7). Ascospore infection occurs during flowering and often this is not complete until the end of July or later. Stubble surveys also will underestimate the incidence of stem rot, as upper stem infections cannot be assessed.

Sclerotinia stem rot was found most consistently in the northeast, less regularly in northwestern and north-central areas, and infrequently in central areas and in the southeast. In areas where the disease was detected in standing crops in late July or in August, or in stubble crops, between 20 and 30% of the fields were usuallly affected. In 1978, 80% of stubble fields in the Melfort area had stem rot.

Table 2. Prevalence and incidence of blackleg in standing crops of ***Brassica napus*** and ***B. campestris*** in Saskatchewan, 1978-81.

Year	No. fields	Virulent strain		All strains		% fields with over	
		% fields infected	% plants infected	%fields infected	% plants infected	10% virulent blackleg	20% virulent blackleg
1981	41	53.7	4.3	68.3	5.0	14.6	2.4
1980	46	45.7	3.8	45.7	3.8	8.8	6.6
1979	85	20.0	0.6	31.8	1.2	2.4	2.4
1978	125	5.6	0.2	13.6	1.1	0.0	0.0
4-year average	74	31.3	2.2	39.8	2.8	6.5	2.9

White rust (staghead) (***Albugo candida*** (Pers. ex Lev.) Ktze. Leaf rust was widespread in most fields of turnip rape (***B. campestris***) and brown mustard (***B. juncea***) (Table 6). Hypertrophies of the inflorescence (stagheads) generally occurred in 50% or more of the fields examined in a given year, but the mean incidence was relatively low. A distinct race of ***Albugo candida*** occurs on each of ***B. carnpestris*** and ***B. juncea*** (Petrie, unpublished). ***Brassica napus*** cultivars grown in Canada are immune to both races, and Canadian yellow mustard (***Sinapis alba***) cultivars are resistant to both. The ***B. juncea*** race has been found in plots at Saskatoon for at least ten years. Its severity has increased since 1977, both in commercial fields and in breeders' plots. For example, severe staghead infection occurred in a field near Blaine Lake in 1977; the estimated loss in yield (4) was 15%. In April 1978, three commercial seed samples of brown mustard were examined for oospores of ***A. candida*** using a washing and filtration technique (12). All three contained oospores and two had relatively high levels of 85 spores per gram of seed. In the 1978 survey two widely separated fields of ***B. juncea*** each had a leaf rust incidence of 100%. In one, 16% of the plants had terminal hypertrophies on one or more branches.

Grey leaf spot or alternaria black spot (***Alternaria brassicae*** (Berk.) Sacc. and ***A. raphani*** Groves and Skolko). In 1978 both the prevalence and incidence of ***Alternaria*** infection were high in standing crops of all ***Brassica*** species, but disease severity was low. In July, infection was recorded in 70% of the fields; in late August it occurred in 94% of the fields, with a mean incidence of 69%. The situation in 1979 was similar. The disease was recorded in 76% of the fields, with a mean incidence of 49%. However, crops in the Humboldt area and in southeastern Saskatchewan had relatively little black spot. It was most severe in fields in the Meadow Lake area, which were examined relatively late in the growing season. It also was severe on pods of swathed plants in several fields in the Middle Lake and Melfort areas in mid-September, 1979. Black spot was less apparent in 1980 and 1981 surveys, being recorded in 10.9% and 23.7% of the fields, respectively. Incidence of infection was also low.

White leaf spot and grey stem (***Pseudocercosporella capsellae*** El 1. and Ev.) Deighton). In earlier survey reports this disease was called ringspot (***Mycosphaerella brassicicola*** (Duby) Lind.) (10). However, in a recent paper a case was made for changing the names of both disease and pathogen (15). White leaf spot was of minor importance from 1978 to 1981, and little grey stem was found in standing crops. In stubble, however, the grey stem phase of the disease was prevalent in 1979 and 1981. It occurred in 80% of the fields in 1979 (mean incidence: 36.4%) and 94.4% of the 1981 fields (mean incidence: 56.4%). The grey stem phase of the disease is thought to cause little loss in yield because it appears late in the growing season.

Pod drop (cause unknown). Pod drop (10) was noteworthy only in 1978. In July it occurred in 74% of the ***B. napus*** fields in northeastern areas (primarily crop districts 8a and 9a). In late August, 93.8% of 16 fields of ***B. napus*** in C.D. 8 were affected, with a mean incidence of 36.5%. Pod drop was also frequently observed in fields of cultivated mustards in 1978 but was rare in fields of ***B. campestris.*** These differences in occurrence on different species are consistent with observations made in earlier surveys (10).

Aster yellows mycoplasma. Aster yellows was of minor importance over the four-year period. In 1978 and 1979 trace amounts were observed in a few fields, mostly in central and east-central areas. In 1981, 71% of ***B. napus*** fields and 33% of ***B. campestris*** fields in the northwestern area (C.D. 9b) were lightly infected. The disease was also of little significance in recent Manitoba surveys (16) and earlier Saskatchewan surveys (8).

Root nodules up to several mm in diameter were common on rape plants in parts of the province in 1979. Most affected were central areas, particularly around Humboldt, where plants in 77% of the fields displayed these symptoms. In the southeast (C.D. 1a and 5a) 57% of the fields were affected. Not only were large numbers of fields involved; in some fields all the plants pulled had root nodules. The mean incidence of infection was 46% in the Humboldt area; in the southeast it was 45%. There were lesser amounts in the Meadow Lake, Rosthern and Vonda areas. In 1981, 30% of the fields in the Humboldt area were affected, with a mean incidence of 23%.

Hail damage was widespread in 1978 and in a few cases severe; 20% of the fields in the northwest were affected, 13% in the northeast, and 12% in central areas. Fungi often had entered the hail wounds and produced lesions around them. Stem lesioning of this kind caused by ***Alternaria*** spp. was pronounced in two fields of ***B. campestris*** in crop districts 1a and 7b. Hail damage was also thought to have enhanced ***Alternaria*** infection in two mustard fields (one yellow and one brown) in C.D. 1a. In 1980 the virulent strain of blackleg and hail injury

Table 3. Prevalence and incidence of blackleg in stubble fields of Brassica spp. in Saskatchewan, 1978-81

Year	No. fields	Virulent strain %fields infected	Virulent strain % plants infected	All strains %fields infected	All strains % plants infected	% fields with over 10% virulent blackleg	% fields with over 20% virulent blackleg
1981	45	73.3	8.6	100.0	20.6	24.3	13.2
1980	42	54.8	4.1	71.4	7.6	11.9	4.8
1979	50	46.0	2.0	84.0	8.3	4.0	4.0
1978	32	56.3	7.3	90.6	27.2	18.8	12.5
4-year average	42	57.6	5.5	86.5	15.9	14.8	8.6

were associated in a North Battleford field. In 1981 hail damage was reported in six fields. *Alternaria* was associated with the damage in fields near Aberdeen and Fulda (C.D. 8b). *Fusarium roseum* was isolated from black lesions around hail wounds on material from one field.

Herbicide injury was observed in each of the four years. Profuse development of the weakly virulent strain of blackleg on herbicide-damaged plants has been reported (9). In 1978 this strain was again associated with pronounced stem twisting and basal stem proliferations in a Brooksby field (C. D. 8b). In 1979 herbicide-induced basal stem galls and the virulent strain were associated in a field near Waldheim.

Table 4. Geographical distribution of the virulent strain of blackleg within Saskatchewan, 1978 to 1981.

Area	Crop districts*	% of fields having the virulent strain (standing plus stubble crops) 1978	1979	1980	1981	1978-81
Northeast	8a	17.4	62.5	90.0	100.0	43.8
Northwest	8b	4.4	11.1	60.0	30.0	19.1
Central	8b, 6b	36.4	35.1	51.9	72.4	48.7
Southeast	1, 2, 5	0.0	0.0	7.1	—	1.5
Averages		15.9	29.6	50.0	65.1	35.4

*See Figure 1.

Heat canker on rape was reported from Dundurn (C.D. 6a) and Chelan (C.D. 8a) in mid-June. The condition occurred uniformly throughout the Dundurn field and resulted in many plants breaking off at the narrowly constricted point at soil level. Four fields were severely affected in the Chelan area. Vanterpool has described this symptom in flax, and a similar one caused by frost (17, 18).

Discussion

The virulent strain of blackleg is most damaging when it attacks the crown of the plant, severing the stem at its base. The younger the plant, the more susceptible it is to basal stem infection. Only mild basal cankering results when plants are infected after the six-leaf stage of growth, that is after the end of June (6). Observations made in 1978 and 1981 left no doubt that infection can occur in June. The prevalence of early season infection largely depends upon when ascospore production by the pathogen commences. This differs on one- and two-year-old rape stubble residue (6). The subject will be discussed further in a subsequent paper. The survey results indicate that, fortunately, infection of young plants was not widespread during this four-year period. However, it is apparent that the prevalence, incidence and severity of blackleg increased between 1978 and 1981. In addition, the disease has spread into parts of Saskatchewan where it had not been found prior to 1978. In 1981 it occurred throughout the Asquith-Delisle area, although it had not been found there two years previously. In 1980 it was detected for the first time in east-central Saskatchewan. It still has not been found in parts of northwestern Saskatchewan including the Meadow Lake area and in the part of north-central Saskatchewan to the northeast of Prince Albert. Rimmer and Platford (16) did not find the virulent strain of blackleg in recent surveys in Manitoba. No reports of it in Alberta crops appeared prior to 1983.

Table 5. Footrot prevalence and incidence in standing and stubble crops of Brassica spp. in Saskatchewan, 1978-81.

Year	No. of fields	% fields infected	Mean % incidence	% fields with over 10% footrot	% fields with over 20% footrot
1981	86	74.3	5.6	17.1	8.6
1980	88	71.7	4.5	8.8	6.6
1979	135	80.7	16.0	52.6	26.7
1978	157	41.4	6.7	14.7	8.3
Means	117	67.0	8.2	23.3	12.6

Damping-off and seedling blight, caused primarily by *Rhizoctonia solani,* are often important, as in 1979, in preventing adequate stand establishment in rapeseed fields. Footrot, in which most of the same pathogens are involved, is less important, occurring as it does late in the growing season. An exception to this generalization is premature ripening in mid-season resulting from basal stem infections by *Rhizoctonia* and *Fusarium.* Prematurely ripened plants setting little seed may often be seen scattered throughout rapeseed fields.

Table 6. Prevalence and incidence of Albugo ***candida*** (white rust and staghead) in standing crops of turnip rape ***(Brassica carnpestris),*** brown mustard ***(B. juncea)*** and yellow mustard ***(B. hirta)***.

Species and year	No. of fields	Crop Districts* Represented	White rust on leaves % fields	% plants	Floral hypertrophies (stagheads)** % fields	% plants
B. campestris						
1978	14	1, 5, 7, 8, 9	57.1	31.4	50.0	3.6
1979	9	1, 2, 8, 9	100.0	82.2	55.6	6.1
1981	3	9	100.0	90.7	100.0	2.0
3-year average			85.7	68.1	68.5	3.9
B. juncea						
1978	2	1, 8	100.0	100.0	50.0	8.0
B. hirta						
1978	3	1, 8	0.0	0.0	0.0	*0.0*

*See Figure 1.
**Average loss in yield due to staghead for the three years estimated at < 2.0%.

The percentage loss in yield of B. ***campestris*** due to staghead (*Albugo candida*) during the 1978-81 period was much less than the six and nine percent calculated for the years 1971 and 1972, respectively (8). In addition, there has been a reduction in the percentage of the total rapeseed acreage sown to B. ***campestris*** from 63% in 1970 to 28% in 1981 (2). The 147,000 hectares planted to this species in 1981 represent only 22.4% of the total sown a decade earlier. The almost complete replacement of the cultivar Torch, by Candle between 1978 and 1981 has had little effect on losses caused by white rust, as both are susceptible, but the new cultivar Tobin, licensed in 1981, is resistant. The race attacking B. ***juncea*** remains a potentially serious problem.

Alternaria black spot was frequently widespread but only occasionally damaging. In recent Manitoba surveys (16) and an earlier series in Saskatchewan (10) the pattern of high prevalence and incidence and low severity was also found.

The nodules observed on the roots of rape plants appear to be the result of a physiological disorder and have been referred to as "hybridization nodules" in crosses of swedes and rape (3). Our observations led us to relate them to drought stress. In 1979 in the southeastern part of the province and in the Humboldt area, nodules were abundant on plants in many fields that suffered from drought and were uneven in height. In some fields nodulation was clearly more common on plants on more exposed, drier sites.

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