FUNGI ASSOCIATED WITH SEEDS OF RAPE, TURNIP RAPE, FLAX, AND SAFFLOWER IN WESTERN CANADA, 1968-73[1]

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Alternaria brassicae and A. raphani were the only important path genic Alternaria spp. isolated from seeds of oleiferous Brassica spp. cult vated in western Canada. In 4 of 5 years, 95% or more of Saskatchewan seed samples of B. campestris (turnip rape) were infested by one or both of these pathogens, and levels within samples increased from 3.6% in 1969 to 9.0% in 1972. B. campestris samples had higher levels of A. brassicae than of A. raphani. B. napus (rape) seed contained considerably lower levels of both Alternaria species. The highest infestation levels occurred in seed from northern Alberta, northern and eastern Saskatchewan, and northwestern Manitoba. In heavily infested seed of B. campestris 73% of the A. brassicae and 90% of the A. raphani occurred on the seea surface. Storage of infested seed for 6-8 months at 25 C reduced the levels of infestation by more than 50%. There appeared to be no correlation between amount of seed infestation and reduction in seedling stand in laboratory or greenhouse tests. Fusarium roseum 'Acuminatum' and Botrytis cinerea were less prevalent than the Alternaria spp. on Brassica seed. Polyspora lini was the most abundant pathogen on flax (Linum usitatissimum) seed, but Alternaria linicola, F. roseum 'Acuminatum', and B. cinerea were also important. A. raphani and A. brassicae, although non-pathogenic on flax seedlings, were found in 20-30% and 1-3% respectively of the Saskatchewan flax seed samples. In safflower (Carthamus tinctorius) samples, Alternaria carthami occurred on up to 95% of untreated seed and 76% of surface-disinfested seed; Botrytis cinerea and F. roseum were found on up to 20% of the seeds in some samples, and A raphani was found in two of seven lots.

Alternaria brassicae et A. raphani ont été les seuls champignons pathogènes importants du genre Alternaria isolés des graines de crucifères (Brassica spp.) oléagineuses cultivées dans l'ouest du Canada. Quatre années sur cinq, au moins 95% des échantillons de graines de B. campestris (navette) provenant de la Saskatchewan ont été infestés par l'un de ces champignons pathogènes ou les deux à la fois, et les niveaux d'infestation des Bchantillons ont passé de 3.6% en 1969 à 9% en 1972. Les Cchantillons de B. campestris étaient davantage infestés par A. brassicae que par A. raphani. Les graines de B. napus (colza) etaient beaucoup moins infestées par les deux espèces d'Alternaria. On a trouvé les plus forts niveaux d'infestation dans les graines provenant du nord de l'Alberta, du nord et de l'est de la Saskatchewan et du nord-ouest du Manitoba. Dans les graines fortement infestées de B. campestris, on a trouvé 73% de A. brassicae et 90% de A. raphani sur les téguments des graines. L'entreposage des graines infestées pendant 6 à 8 mois à 25°C a réduit les niveaux d'infestation de plus de 50%. Il semble n'y avoir aucune correlation entre l'importance de l'infestation des graines et la reduction des peuplements des plants susmentionnés dans les essais en laboratoire ou en serre. Fusarium roseum "Acuminatum" et Botrytis cinerea etaient moins abondants que Alternaria spp. sur les graines de Brassica. Polyspora lini était le champignon pathogène le plus répandu sur les graines de lin (Linum usitatissimum), mais Alternaria linicola, F. roseum "Acuminatum" et B. cinerea etaient Cgalement abondants. Même s'ils n'infestaient pas les plants de lin, on a trouvé A. raphani et A. brassicae dans 20 à 30%et 1 à 3% respectivement des échantillons de graines de lin provenant de la Saskatchewan, Dans les échantillons de carthame (Carthamws tinctorius), on a trouvé Alternaria carthami sur près de 95% des graines non traitées et sur 76% des graines désinfectées en surface; on a trouvé Botrytis cinerea et F. roseum sur près de 20% des graines de certains échantillons, et A. raphani dans 2 lots sur 7.

There are few recent papers in the literature which describe in detail the extent to which fungal pathogens are transmitted with seed of rape, turnip rape, flax, or safflower in western Canada. Vanterpool (15) reported Alternaria brassicae (Berk.) Sacc. as the only pathogen isalated from rapeseed samples produced in Saskatchewan in 1948. However, by 1959 the list of species obtained from this source had grown appreciably and included species of Alternaria, Botrytis cinarea Pers., Fusarium

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acuminatum Ell. & Ev., Mycosphaerella brassicicola (Duby) Lind., Rhizoctonia spp. and Rhizopus spp. (16, 17). Four years later it was reported (18) that seed from the 1963 rape crop carried "unusually high" levels of A. brassicae and lesser amounts of A. raphani Groves & skolko. McDonald (7) isolated A. brassicae from 14 of 25 samples of registered rapeseed grown in Manitoba in 1956. The highest level of infection found in any sample was 4%. The most recent study of pathogens found on flax seed in western Canada was the 1971 report of Henry and Ellis (5) from Alberta, which dealt exclusively with Polyspora lini Laff.

The work described here was undertaken to determine the extent and significance of infestation of rape and turnip rape seed by fungi. It was started in 1968 and later expanded to include an examination of seed of flax and safflower, cruciferous weeds, and garden crucifers. The occurrence of Alternaria spp. on garden crucifer seed entering Canada's prairie provinces from British Columbia and abroad (11) and the transmission of Leptosphaeria maculans (Desm.) Ces & Not. on crucifer seed (12) have been reported previously.

Materials and methods

Samples of rape (Brassica napus L.) and turnip rape (B. campestris L.) seed were obtained from the Plant Products Division of Agriculture Canada and from the Canadian Grain Commission. A large proportion of samples in the first group represented Foundation or Certified seed, whereas those in the second were drawn from growers' commercial seed entering country elevators. The seed originated in all parts of the rape-growing area of western Canada. Over 100 samples were plated each year from 1968 to 1971, with over 1000 being examined in 1970 (Table 1). Relatively few were plated in 1572 and 1973. Five years' data were obtained from Saskatchewan farm samples, four for those from Alberta, and three for those from Manitoba. The cultivars of rape and turnip rape changed during the course of the study with the advent of low erucic acid types. By 1970, Echo and Target had become the established cultivars of turnip rape and rape, respectively. Small amounts of several additional ones were grown in 1971. In 1972, however, an abrupt change to the low erucic types Span (B. campestris) and Zephyr (B. napus) took place (14).

seed from the 1973 western Canadian cooperative rapeseed varietal tests was also secured to permit a closer comparison of seed infestation of the different cultivars. Data from five regional cooperative tests in Saskatchewan crop districts 5, 8 and 9 provided a comparison of fungal infestation levels on the B. campestris cultivars Echo, Span, and Torch, and the B. napus cultivars Target, Zephyr, and Midas for 1973. In some instances seed of the turnip rape line R-500 ('Yellow Sarson') was also plated for comparison.

Flax (Linum usitatissimum L.) samples grown in Saskatchewan and Alberta were obtained from the Plant Products laboratories at Saskatoon and Edmonton. Three years' data were obtained for Saskatchewan, with Alberta samples being limited to 27 from 1969. A total of seven safflower (Carthamus tinctorius L.) sesd samples were secured from several sources, including plants pulled in a farmer's field. Flax cultivars plated were principally Noralta and Redwood 65, with smaller numbers of Norland, Raja, and others. The safflower samples were not identified to cultivar.

Table 1. Number and source of growers' seed samples plated for detection of pathogenic fungi

	Turnip rape (Brassica campestris)			Rape (Brassica napus)			Total Brassica samples	Flax	Safflower
Year	Sask.	Alta.	Man.	Sask.	Alta.	Man.			
1968	36	47	6	22	0	30	141	0	0
1969	172	48	0	133	0	0	353	144*	0
1970	513	200	19	264	3	28	1,027	107	6
1971	219	11	34	0	0	19	283	0	1
1972	10	0	0	22	0	0	32	61	0
	B. campestris			B. napus					
Totals	1,315			520			1,836	312	7

Includes 27 Alberta samples.

With the exception of those of safflower which were plated with forceps, untreated seeds were picked up 15 or 20 at a time by means of a vacuum plate seeder and deposited on V8 juice agar containing 40 ppm rose bengal and 100 ppm streptomycin sulfate. For each of the first few hundred samples, 300 seeds were plated but this was reduced to 200 for the remaining ones. The apparatus was disinfected with alcohol halfway through each sample and between samples. After 7 to 10 days' incubation under diffuse light at room temperature, a record was made of the fungi present. Colonies were routinely examined microscopically at a magnification of 40X. Fresh subsamples from seed lots yielding high levels of certain fungi were surface disinfested in 10% Javex (0.6% available chlorine on dilution) for 20 min and plated to determine levels of internal infection.

The effect of storage of Brassica seed on survival of the two principal Alternaria pathogens was also studied. Sixty-six heavily infested samples were plated a second time 6 to 8 months following the first plating. In the interval, the samples were stored at room temperature in the laboratory.

In order to obtain an indication of the effect of seed-borne fungi on emergence, naturally infested seed was plated untreated on moist filter paper and was also sown in pots of sand or sandy loam soil, 20 seeds to a plate or pot, with at least five replicatons. The plates were assessed at 10 days, whereas pots were usually kept for 2 to 3 weeks and seedling stand counts made at least once a week. For comparison with naturally infested seed, samples of span and Zephyr rape were heavily inoculated with spore suspensions of Alternaria spp. and sown in soil. Pots were moistened to field capacity from reservoirs below as required.

Results

1. Saprophytic fungi encountered

The most common 10 or 12 saprophytes in the rape, turnip rape, flax and safflower samples were remarkably similar. Alternaria alternata (Fries) Keissler, Cladosporium spp. and Penicillium spp. were, with a few exceptions, the most prevalent, usually occurring in over 80%, and often over 90%, of the samples plated in a given year. Epicoccum sp., Arthrinium sp., Rhizopus sp. (and related genera), Stemphylium spp., miscellaneous pycnidial fungi, Fusidium spp., Gonatobotrys sp. and a few others normally were found less often, but the first two occasionally appeared in over 70% of a year's seed lots. Rhizopus and related genera were usually found in from 1/3 to 1/2 of the samples.

2. Pathogenic Alternaria species

Those parasitizing Brassica spp. were limited to A. brassicae and A. raphani; A. brassicicola (Schw.) Wiltshire was not recovered from any of the more than 1800 samples. An interesting saprophytic Alternaria which somewhat resembled A. brassicicola occurred in crucifer, flax and safflower samples.

Each year, with the exception of 1969, 95% or more of the Saskatchewan B.

Table 2. Prevalence of *Alternaria brassicae (A.b.)* and *A. raphani (A.r.)* in seed samples of *Brassica* spp. produced in Saskatchewan

	% of samples infested			% of seeds infested per sample					
				Average			Highest recorded infestation		
Year	*A.b.*	*A.r.*	One or both	*A.b.*	*A.r.*	Total	*A.b.*	*A.r.*	One or both
				Brassica campestris					
1968	88.9	86.1	97.2	2.9	3.3	6.2	10.0	15.7	23.7
1969	85.7	63.4	87.4	2.3	1.3	3.6	18.0	13.0	28.7
1970	92.4	71.5	96.3	5.2	1.2	6.4	27.5	11.0	29.0
1971	91.3	72.2	94.5	5.6	2.1	7.7	25.2	49.1	55.3
1972	90.0	100.0	100.0	5.9	3.1	9.0	11.4	8.1	12.9
				Brassica napus					
1968	86.4	68.2	90.9	1.0	0.8	1.8	6.7	4.0	10.4
1969	53.7	61.9	76.9	0.6	0.9	1.5	4.7	10.7	12.4
1970	63.3	62.5	80.7	1.1	0.9	2.0	18.0	10.0	19.0
1972	36.4	68.2	17.3	0.4	1.1	1.5	3.3	13.3	13.3

Table 3. Prevalence of *Alternaria brassicae* and *A. raphani* in *Brassica campestris* seed samples produced in Alberta

Year	% of samples infested			% of seeds infested per sample					
				Average			Highest levels		
	A.b.	*A.r.*	One or both	*A.b.*	*A.r.*	Total	*A.b.*	*A.r.*	One or both
1968	51.1	55.3	68.1	0.9	1.1	2.2	10.5	10.0	16.2
1969	66.7	72.9	81.3	2.5	4.4	6.9	15.0	29.0	41.3
1970	70.9	69.0	84.2	3.4	1.8	5.2	25.5	22.0	28.0

Table 4. Prevalence of *Alternaria brassicae* and *A. raphani* in *Brassica* seed samples produced in Manitoba

Year	% of samples infested			% of seeds infested per sample					
				Average			Highest levels		
	A.b.	*A.r.*	One or both	*A.b.*	*A.r.*	Total	*A.b.*	*A.r.*	One or both
				Brassica campestris					
1968	83.3	33.3	83.3	3.8	0.3	4.1	10.7	1.3	10.9
1970	79.0	42.1	79.0	2.1	0.4	2.5	7.5	1.5	9.0
1971	76.5	53.0	85.3	2.3	0.8	3.1	11.9	8.1	15.3
				Brassica napus					
1968	36.7	10.0	43.3	0.1	0.1	0.2	0.7	1.0	1.3
1970	10.7	25.0	32.1	0.1	0.2	0.3	1.5	1.3	1.5
1971	15.8	15.8	26.3	0.1	0.1	0.2	0.5	1.2	1.2

campestris samples were infested with one or both pathogenic Alternaria spp. (Table 2). Fewer of the B. napus samples were affected, the decrease being more pronounced in the incidence of A. brassicae. Results on a "seeds per sample" basis followed a similar trend. Total infestation of B. napus seed lots remained consistently low, whereas after an initial decrease, a trend toward higher levels was evident in the turnip rape samples. In the most heavily diseased sample, a 1971 lot of turnip rape, 55.3% of the seeds yielded a pathogenic Alternaria. In Alberta seed, the incidence of A. brassicae was much lower relative to A. raphani and to the Saskatchewan samples (Table 3). Nevertheless, a pathogenic Alternaria was recovered from over 80% of the seed lots in 2 of the 3 years. The Manitoba data are presented in Table 4.

In Table 5, all the Saskatchewan samples are grouped into five arbitrary infestation severity categories. The distribution of B. napus samples having A. brassicae and A. raphani were remarkably alike, in about 3% of them more than 5% of the seeds were affected. B. campestris seed lots carrying A. raphani had heavier infestations; 7% of these were in the two higher categories. However, none of the preceding pairings approached the B. campestris - A. brassicae combination in this regard; in over 35% of these 5% or more of the seeds yielded the pathogen.

Next to Polyspora lini, Alternaria tenuicola Groves & Skolko was the major pathogen on flax seed in Saskatchewan (Table 11). Nevertheless, its importance declined considerably over the period of study (Table 6). The prevalence of A. raphani and A. brassicae in flax samples was surprising. Although the latter was uncommon, the former occurred at low levels in over 30% of the 1970 seed lots and in 27% of those from 1969 (Table 6). Although highly virulent on Brassica spp., isolates of these two species aid not cause appreciable damage to flax

Table 5. Percentage of *Brassica* seed samples in each of five infestation severity categories (Saskatchewan samples)

Alternaria species	*Brassica* species	Categories (% of seeds infested per sample) 0	<1	1-4.9	5-9.9	10 and over
A. brassicae	*B. campestris*	9.2*	10.1	45.3	21.2	14.2
	B. napus	39.8	26.6	30.5	2.7	0.2
A. raphani	*B. campestris*	29.0	23.3	40.7	5.0	2.0
	B. napus	37.1	29.9	30.3	2.3	0.5

* Figures represent all samples plated from 1968 to 1972 inclusive.

Table 6. Extent of infestation of Saskatchewan flax seed samples by selected fungi

Year	Fungal species *Alternaria linicola*	*Alternaria raphani*	*Alternaria brassicae*	*Fusarium roseum*	*Botrytis cinerea*
			% of samples infested		
1969	49.6	27.4	0.9	27.4	8.6
1970	41.5	30.2	2.8	34.0	18.9
1972	24.6	19.7	1.6	23.0	13.1
			% of seeds per sample infested (avg)		
1969	5.5	0.2	<0.1	0.3	0.1
1970	3.7	0.3	<0.1	0.3	0.2
1972	0.5	0.2	<0.1	0.2	0.2
			highest infestation recorded (% of seeds infested)		
1969	72.0	2.0	0.5	5.0	1.5
1970	46.0	4.5	1.0	2.0	2.0
1972	5.0	1.6	0.5	1.3	4.0

seedlings in pathogenicity tests. Both were also found in **1969** flax samples from Alberta (Table **7**). A. linicola was much less prevalent in that province as a whole than it was in Saskatchewan in **1969**.

Isolates resembling A. linicola in cultural and conidial morphology occurred in both rape and turnip rape seed lots from Saskatchewan. In **1968**, **3.4%** of Brassica samples yielded such isolates, and in **1969** and **1970**, respectively, **2.6%** and **1.0%** were infested. Generally 0.5% or less of the seeds in a sample bore the fungus. It was not detected in **1971** or **1972** seed. Inoculation tests were not conducted to confirm the identity of this species.

The levels of Alternaria carthami Chowdhury encountered in some safflower samples were indeed striking (Table 8). In **1970** leaf lesioning caused by this Alternaria was general and severe throughout Saskatchewan. A. raphani was isolated from two of the seven seed lots but A. brassicae was not detected.

The **1969** and **1970** data for turnip rape seed infestation by Alternaria spp. in Alberta are grouped in Table **9** according to agricultural reporting area (ARA) . The south to north progression is perhaps not surprising. However, the sharp decrease in A. brassicae in the Peace River region (ARA **7**) should be noted. This was again observed

Table 7. Infestation of 27 Alberta 1969 flax seed samples by fungal pathogen:; of flax and rape

Agricultural reporting area	Alternaria linicola	Alternaria raphani	*Alternaria* brassicae	*Fusarium roseum*	Botrytis cinerea
		% of samples infested			
1–3	0.0	0.0	6.7	6.7	13.3
4–7	41.7	25.0	8.3	58.3	58.3
1–7	18.5	11.1	7.4	29.6	33.3
		% of seeds per sample infested *(avg)*			
1–3	0.0	0.0	<0.1	<0.1	0.1
4–7	3.1	0.1	<0.1	0.7	1.0
1–7	1.4	0.1	<0.1	0.3	0.5
		highest infestation level recorded (% of seeds infested)			
1–3	0.0	0.0	0.5	0.5	1.0
4–7	23.5	0.5	0.5	2.5	6.0
1–7	23.5	0.5	0.5	2.5	6.0

Table 8. Pathogenic fungi present in Saskatchewan safflower seed samples, 1970–71

Sample and locality	Treatment*	Fungi present and % of seeds affected per sample			
		Alternaria carthami	*Alternaria* raphani	Botrytis cinerea	*Fusarium roseum*
C-1 (Rosthern)	SD	36.7	0.0	3.3	0.0
	UT	94.7	0.0	8.3	2.0
c–2 (Saskatoon)	UT	4.5	0.5	4.5	20.0
c–3 (Saskatoon)	UT	26.0	0.0	5.3	0.0
c–4 (Elrose)	SD	2.0	0.0	10.5	0.0
	UT	19.5	1.5	17.5	0.0
C–5 (Briercrest)	UT	3.6	0.0	0.0	11.8
C–6 (Balcarres)	SD	76.0	0.0	0.5	0.0
	UT	95.0	0.0	0.5	0.5
c–7 (Lake Lenore)	SD	51.7	0.0	0.0	0.0
	UT	71.7	0.0	0.0	0.0

* SD = surface–disinfested; UT = untreated.

in the few 1971 samples examined. The average infestation levels in three Peace River samples were A. brassicae 0.7%, and A. raphani 14.3%. In contrast the averages for eight samples from ARA 6, were 9.0% and 4.0%, respectively. In Saskatchewan the incidence of Alternaria on Brassica seed increased along an approximate southwest to northeast axis (Table 10). The trends for the flax samples for the two provinces may be seen in Tables 7 and 11. Brassica seed lots from southern Manitoba were :Largely free of pathogenic fungi but. infestation was appreciably higher in the northwest (crop districts 10 to 14).

High levels of A. brassicae and A. raphani occurred in samples from the 1973 cooperative varietal tests that had been located in crop districts 5, 8, and 9 in

Table 9. Average infestation levels of Alternaria brassicae *(A.b.)* and A. raphani *(A.r.)* in seed samples of Brassica campestris from Alberta

Agricultural reporting area	Average % of seeds infested per sample					
	1969			1970		
	A.b.	*A.r.*	Total	*A.b.*	*A.r.*	Total
1–2	0.6	0.2	0.8	0.3	0.2	0.5
3	1.1	0.6	1.7	0.9	0.2	1.1
4	1.0	2.1	3.1	4.2	1.1	5.3
5	3.1	1.3	4.4	3.6	1.4	5.0
6	8.3	9.7	18.0	9.6	2.3	11.9
7	0.9	9.3	10.2	1.1	3.2	4.3
Provincial avg	2.5	4.4	6.9	3.4	1.8	5.2

Saskatchewan (Table 12). More A. raphani was found on B. campestris than on B. napus. The same was true of A. brassicae, although the differences were much less marked. The results agreed with those obtained for the farm samples (Table 1), with the exception of the wide differences here in amounts of A. brassicae and A. raphani found on B. napus. Had the B. campestris entries in Table 12 included the line R-500 ('Yellow Sarson') the overall species average would have been considerably higher, for R-500 seed carried substantially greater amounts of Alternaria. Differences in levels of infestation between the standard cultivars of each Brassica species occurred but they were not consistent from station to station.

Table 13 shows the effect of surface disinfestation on levels of Alternaria in 151 Brassica seed samples, most of which were B. campestris. On an average, 72.8% of the A. brassicae and 90.0% of the A. raphani occurred on the Seed surface. After 6 to 8 months storage of seed an average of 47.2% of the original A. brassicae and 51.1%of the A. raphani remained.

seed germination and seedling emergence apparently were not directly related to total seed infestation by pathogenic Alternaria species. Twenty-six samples naturally infested with A. brassicae, A. raphani, or both were plated without pretreatment on filter paper moistened with sterile water. On an average, 17.9% of the seeds per sample carried a pathogenic Alternaria, the range being 10–27%. Considering all samples, an average of 94.6% of the seeds germinated, 3.2% of the seedlings subsequently died, and 16.2% either died before or after emergence or exhibited disease symptoms but survived until the test was concluded. When the amount of Alternaria in each sample was matched with the number of seedlings of that sample killed or exhibiting some disorder, no correlation could be recognized. Again, when naturally infested seed was sown in sand or soil, seedling emergence and survival appeared to be completely unrelated to level of Alternaria in the sample. In the soil tests, amounts of infestation ranged from 1.9% to 27.0% and with the exception of a few samples, final emergence was generally close to 90%. When seeds of rape and turnip rape were heavily inoculated with spores of A. raphani or A. brassicae and sown in soil, the reduction in stand due to A. raphani in a representative experiment was approximately 15% in both B. campestris and B. napus; A. trassicae reduced the stand by no more than 8%.

Table 10. Average infestation levels of *Alternaria* spp. in Saskatchewan seed samples of *Brassica campestris* by geographical area

Region	crop district	Avg % of seeds per sample infested by both A. brassicae & A. raphani		
		1969	1970	1971
south	1–4		2.9	0.4
West central	7	0.6	1.8	2.4
Central	6*	1.9	2.7	4.7
	8B**	1.5	4.6	9.6
East central	5A*		4.4	4.0
	5B**	4.4	4.1	9.8
Northeast	8A	4.7	7.7	11.4
North central and northeast	9A	4.6	10.0	6.3
Northwest	9B		4.7	7.0
Provincial avg		3.6	6.4	7.7

* Southern part of the region.
** Northern part of the region.

3. Fusarium roseum, Botrytis cinerea and other species

Fusarium roseum Lk. emend. Snyder & Hansen (largely 'Acuminatum') was found, usually at low levels, in 20.3% of all the Saskatchewan turnip rape samples and in 13.6% of those of rape plated from 1968 to 1972 (Table 14). It was somewhat more common in flax seed lots (Table 6). Three years' data for Brassica seed from Alberta and Manitoba are presented in Table 15. F. roseum occurred in 58.3% of the flax samples from Alberta ARA's 4 to 7 in 1969 (Table 7). It was found in four of seven safflower samples from Saskatchewan (Table 8); in samples from Saskatoon and Briercrest, 20.0 and 11.8% of the seeds were infested, respectively.

A few fusaria isolated from seed were used to inoculate rape and flax. Some of the flax isolates infected Brassica spp. in addition to flax, while others were not very virulent on either. Cultures from seed of

Table 11. Prevalence and incidence of infestation of Saskatchewan flax seed samples by rape and flax pathogens; 3-year averages (1969, '70, '72) by crop district

Crop district	Polyspora lini	Alternaria linicola	Alternaria raphani	Alternaria brassicae	Fusarium roseum	Botrytis cinerea
	Percentages of seed samples infested (avg)					
1	80.0	44.2	24.2	0.0	40.8	3.3
2	75.9	11.9	24.7	2.2	29.6	1.9
3–4	66.7	5.6	22.2	0.0	16.7	0.0
5	88.0	53.0	26.6	0.0	15.5	13.7
6	76.1	36.1	16.3	2.8	17.9	12.4
7	89.0	37.7	26.9	0.0	20.7	14.5
8	85.2	67.5	18.4	4.8	26.7	31.2
9	100.0	60.7	39.3	0.0	32.2	14.3
Overall	81.0	48.5	25.8	1.8	28.1	13.5
	Average infestation levels					
1	2.9	2.0	0.2	0.0	0.4	0.1
2	1.6	1.5	0.2	<0.1	0.2	0.1
3–4	2.2	<0.1	0.3	0.0	0.1	0.0
5	2.8	3.8	0.2	0.0	0.1	0.1
6	2.4	0.3	0.1	<0.1	0.1	0.1
7	3.2	0.2	0.4	0.0	0.2	0.1
8	2.8	8.6	0.1	<0.1	0.3	0.7
9	5.3	7.5	0.3	0.0	0.2	0.1
Overall	2.6	3.3	0.2	<0.1	0.2	0.2

rape and turnip rape frequently attacked flax.

Botrytis cinerea Pers. isolates, whether from Brassica, flax, or safflower seed were highly virulent on crucifer and flax seedlings. The percentages of Saskatchewan Brassica seed samples naturally infested in the 4 years 1968-71 were 1.7, 3.0, 1.2 and 1.4, respectively. The highest percentage of flax samples affected was 18.9 in 1970, and the lowest, 8.6 in 1969 (Table 6). Generally, the levels of infestation within samples were low. In 1969, over 58% of the flax seed lots from more northerly parts of Alberta had Botrytis, with up to 6% of the seeds yielding the pathogen (Table 7). safflower too often carried considerable Botrytis, much of which was within the seed coat (Table 8).

Sclerotinia sclerotiorum (Lib.) de Bary was an infrequent contaminant of Brassica seed lots and was not found in those of flax or safflower. only five samples, all of which were B. napus, yielded Sclerotinia out of a total of over 1800. Three of these

Table 12. Extent of Alternaria brassicae and A. raphani infestation of Brassica seed from five Saskatchewan regional varietal tests, 1973*

Brassica species and cultivar	A. brassicae	A. raphani	Total
B. campestris (avg)	10.8	6.4	17.2
Torch	10.5	8.3	18.8
Echo	11.1	5.0	16.1
Span	10.8	5.9	16.7
B. napus (avg)	9.6	1.9	11.5
Target	9.5	1.8	11.3
Zephyr	11.1	2.0	13.1
Midas	8.2	1.9	10.1

* The five locations were Melfort, Parkside, Lake Lenore, Kelvington and Somme. The seed was plated untreated.

Table 13. Effect of surface-disinfestation on levels of Alternaria in 151 Brassica seed samples

Treatment	Average % of seeds with Alternaria spp.		
	A. brassicae	A. raphani	Total
Untreated	8.1	4.9	13.0
Disinfested*	2.2	0.4	2.6
% of total Alternaria			
Within the seed coat	27.2	10.0	20.0
On the seed surface	72.8	90.0	80.0

* 10% Javex (0.6% available Cl on dilution), 20 min.

Table 14. Prevalence of Fusarium *roseum* in turnip rape and rape seed samples produced in Saskatchewan

Year	*Brassica campestris*			Brassica napus		
	% of samples infested	Infestation level (%)		% of samples infested	Infestation level (%)	
		Avg	Highest		Avg	Highest
1968	19.4	0.1	1.0	13.6	<0.1	0.3
1969	11.1	0.1	3.3	9.0	<0.1	1.0
1970	20.3	0.2	6.0	14.8	0.1	1.0
1971	26.5	0.2	2.9			
1972	50.0	0.3	1.0	32.0	0.2	1.0
Overall	20.3	0.2	6.0	13.6	0.1	2.5

represented 1968 seed from Saskatchewan. In four of the five instances, the fungus grew out from a seed, rather than originating from a sclerotium in the sample. As no intensive search for sclerotia was undertaken, it is possible that the amount of Sclerotinia present might have been considerably underestimated. However, most sclerotia likely were removed when the seed was cleaned.

The results from the 1973 rapeseed varietal tests for Fusarium, Botrytis and sclerotinia were as follows: S. sclerotiorum grew from 0.5% of the seeds from one of the 53 seed lots, a Winnipeg sample. No significant infestation by the other two pathogens was detected in samples from Winnipeg, Saskatoon, and Beaverlodge. However, striking amounts occurred in some of these from five regional tests in Saskatchewan (Table 16). A sample of Span from Kelvington carried 17.4% Fusarium, and one of Torch, 7.5%. A Torch sample from Lake Lenore had 6.0% infested seed. Levels approaching these were rarely encountered in growers' seed during 5 years of plating. Few samples of B. napus were infested. Botrytis was also much more common than usual, occurring in high percentages of seed lots of both species (Table 16). Surface-disinfestation eliminated almost all of the Fusarium and Botrytis.

Polyspora lini occurred in 67.51, 88.7%, and 86.9% of the Saskatchewan flax samples from 1969, 1970, and 1972, respectively. The corresponding average levels of infestation per sample were 1.1%, 4.2%, and 2.6% and the highest levels encountered in any seed lot, 14.5%, 22.5%, and 14.71. Of the samples from Alberta, 33.3% of those from ARA's 1 to 3 and 91.7% of those from ARA's 4 to 7 carried P. lini. Slightly more than 58% of all the seed lots were infested. About 29% of those plated by Henry and Ellis (5) had the pathogen. Presumably their samples were produced in 1970.

Table 15. Prevalence of *Fusarium roseum* in *Brassica* seed samples produced in Alberta and Manitoba

Year	Alberta			Manitoba		
	% of samples infested	Infestation level (%) Avg	Highest	% of samples infested	Infestation level (%) Avg	Highest
1968	8.5	<0.1	0.3	2.8	<0.1	0.2
1969	31.3	0.1	0.7			
1970	26.7	0.8	2.5	13.0	0.1	1.0
1971				9.4	<0.1	1.0

Table 16. Extent of seed infestation with *Fusarium roseum* and *Botrytis cinerea* in Saskatchewan rapeseed varietal tests, 1973 (avg of 5 locations*)

Brassica species and no. samples plated	Fungal species	% samples infested	Infestation level (%) Avg	Highest
B. campestris (14)	*F. roseum*	78.6	3.2	17.4
	B. cinerea	50.0	0.6	3.0
B. napus (13)	*F. roseum*	7.1	<0.1	0.5
	B. cinerea	42.9	0.4	1.5

* The data for three cultivars were averaged for each of the two species at each location (see text).

Discussion

several examples have been provided of the high prevalence and incidence of certain pathogenic Alternaria spp. often encountered on seed of oilseed crops, of which Alternaria carthami on safflower is perhaps the most striking. By its very abundance, seed infestation would seem to be strongly implicated as a prime source of early spring infections in the field. This may be the case, but conclusive proof has yet to be obtained. In addition, certain factors which would tend to minimize the harmful effects of seed contamination have been identified. By simply storing Brassica seed from one crop year to the next one may reduce the viable inoculum by 50% or more under certain conditions. However, the rates of decline of infestation levels may be much less at temperatures below 25°C, the approximate average temperature prevailing during the present experiment. From the seed storage results it is also apparent that the tabulated infestation data underestimate the levels present when the seed was harvested. A few months delay between harvest and the time the seed was plated was unavoidable. It may also be noted that routine cleaning of the seed probably eliminated a considerable proportion of the more severely diseased seeds in many samples.

Another important consideration is the fate of seed-borne inoculum after the seed is sown in soil. It would appear from the few experiments conducted that the levels of Alternaria naturally occurring on Brassica seed may frequently be suboptimal for the induction of symptoms and that the soil microflora might reduce the inoculum's effectiveness. The latter appears to happen in the case of Polyspora lini on flax seed (4). The results of Richardson's study (13) of Alternaria brassicicola and A. brassicae in this regard is even more pertinent. He concluded from the results of a field trial that natural seed infestation had no effect upon emergence in the case of either pathogen. It is felt that the effect of seed infestation upon establishment of Alternaria in the subsequent crop requires considerable further study.

The effect of fungicidal treatment of Brassica seed was not examined, but as the bulk of the Alterndria inoculum was superficial, it would be readily accessable to chemicals. Mills and Wallace (8) included rapeseed in an evaluation of a number of fungicidal formulations. The production of clean seed in areas such as southern Manitoba which have been producing relatively disease-

free seed is another possibility to be considered. The development of cultivars resistant to alternaria black spot is a worthwhile objective. B. napus appears to possess greater resistance to the disease than B. campestris (2, 3, 6, 9), and it certainly had less Alternaria seed contamination in this study. The saprophytic development of some pathogens, particularly A. raphani, in association with nonsusceptible hosts may also be a factor in their dissemination worthy of consideration.

The apparent increase in Fusarium roseum on Brassica seed (Tables 14 and 16) and its consistently wide pxevalence on flax seed may be significant. Pootrot of crucifers in which the 'Acuminatum' type of F. roseum is also a major participant, showed a substantial increase between 1970 and 1972 (10) and Fusarium-Rhizoctonia root rot of flax has teen the main problem causing inquiries in the spring from farmers in recent years. It also has been shown that at least a few variants of F. roseum 'Acuminatum' have wide host ranges among oilseed crops grown on the Canadian prairies.

It is thought that Botrytis cinerea has great potential importance in some areas due to its high virulence on all the oilseed crops studied and the fact that it can be widespread in some years (Tables 7 and 16). In Europe it is a major cause of seedling losses in flax (1). Although Rhizopus was grouped with the saprophytic species in this paper, it too can cause an important seed and pre-emergence seedling rot of rape, as Vanterpool (16) has pointed out.

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Literature cited

1. Anselme, C., and R. Champion. 1964. L'analyse sanitaire des semences. Resultats obtenus sur des semences de Lin issues des campagnes 1960, 1961, et 1962. Compt. Rend. Hebd. Seanc. Acad. Agr. France 50:522-526. Abstr. in Rev. Appl. Mycol. 44:142.

2. Bhander, D. S., and N. S. Maini. 1965. studies on the resistance of oleiferous Brassicas to alternaria blight. Indian Oilseeds J. 9:58-60.

3. Degenhardt, K. J. 1973. Alternaria brassicae and A. raphani: Sporulation in culture and their effects on yield and quality of rapeseed. M. Sc. thesis, Univesity of Alberta, Edmonton. 91 pp.

4. Henry, A. W., and J. A. Campbell. 1938. Inactivation of seed-borne plant pathogens in the soil. Can. J. Res. 16:331-338.

5. Henry, A. W., and C. Ellis. 1971. seed infestation of flax in Alberta with the fungus causing browning or stem-break. Can. Plant Dis. Surv. 51:76-79.

6. Husain, A., and R. N. Thakur. 1963. some sources of resistance to alternaria blight of rapeseed and mustard. Indian Oilseeds J. 7:259-261.

7. McDonald, W. C. 1959. Gray leaf spot of rape in Manitoba. Can. J. Plant Sci. 39: 409-416.

8. Mills, J. T., and H. A. H. Wallace. 1972. Differential action of fungicides upon fungi occurring on wheat, barley, buckwheat, and oil seeds. Can. J. Plant Sci. 52:281-290.

9. Petrie, G. A. 1973. Diseases of Brassica species in Saskatchewan, 1970-72. II. Stem, pod, and leaf spots. Can. Plant Dis. Surv. 53:83-87.

10. Petrie, G. A. 1973. Diseases of Brassica species in Saskatchewan, 1970-72. III. Stem and root rots. Can. Plant Dis. Surv. 53:88-92.

11. Petrie, G. A. 1974. Alternaria brassicicola on imported garden crucifer seed; a potential threat to rapeseed production in western Canada. Can. Plant Dis. Surv. 54:31-34.

12. Petrie, G. A., and T. C. Vanterpool. 1974. Infestation of crucifer seed in western Canada by the blackleg fungus, Leptosphaeria maculans. Can. Plant Dis. Surv. 54:31-34.

13. Richardson, M. J. 1970. Investigations on seed-borne pathogens of Brassica spp. Proc. Int. Seed Test. Ass. 35: 207-223.

14. Saskatchewan Wheat Pool. 1972. Grain varieties survey, Saskatchewan - 1972.

15. Vanterpool, T. C. 1950. Rape-seedling blight and leaf spot. Page 31 in 29th Annu Rep. Can. Plant Dis. surv.

16. Vanterpool, T. C. 1958. Rape diseases in Saskatchewan in 1957. Pages 38-39 in 37th Annu. Rep. Can. Plant Dis. Surv.

17. Vanterpool, T. C. 1960. Rape diseases in Saskatchewan in 1959. Pages 30-31 in 39th Annu. Rep. Can. Plant Dis. Surv.

18. Vanterpool, T. C. 1963. Rape diseases in Saskatchewan in 1963. Can. Plant Dis. Surv. 43:212-214.