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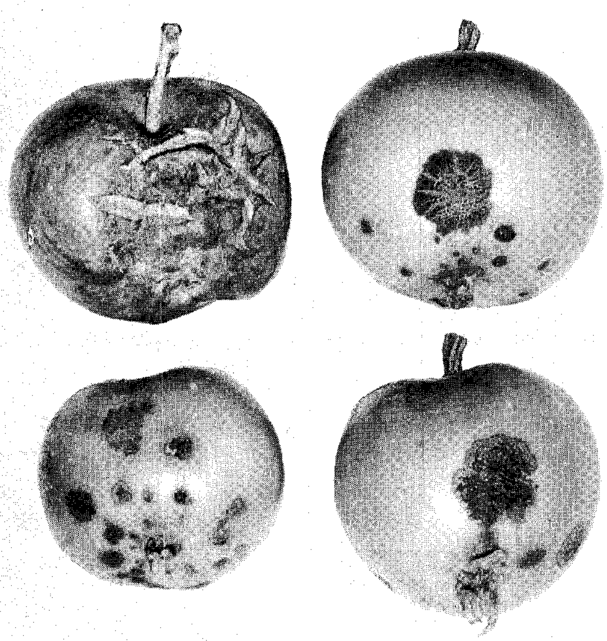

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CANADIAN PLANT DISEASE SURVEY

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CEREAL RUSTS IN CANADA IN 1960[1]

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RUST DEVELOPMENT IN WESTERN CANADA IN 1960

Influence of Weather on the Prevalence of Rust in Western Canada in 1960

In the rust area of Western Canada the spring began with abundant, and in some places over-abundant, soil moisture derived from the heavy rainfall of the autumn of 1959. For this reason seeding began late and was further delayed by a snowfall on April 25 and 26. Fine weather in early May allowed seeding to become general and, owing to abundant moisture, emergence and early growth of cereals were generally good. Warm, sunny weather, which was badly needed, arrived late in June and continued into August, and resulted in rapid plant growth. The high temperatures of July were already creating a need for moisture by mid-July and rain was generally needed by the end of the month. Moderate to heavy rains in early August made possible an average grain crop which, owing to the hot dry weather of July, was largely harvested by mid-September.

Late seeding and the lushness of early cereal growth appeared, in the early part of the summer, to expose the crop to the threat of rust infection, especially in view of the considerable leaf rust and stem rust infection that occurred in eastern Kansas and Nebraska in June. Heavy spore showers of both rusts, carried probably from the Kansas-Nebraska area, occurred over Manitoba from June 24 to 27. These spores and subsequent inoculum would have sufficied to produce considerable rust infection on susceptible cereals if weather conditions had been favorable. However, the warm, dry weather of July prevented any considerable infection. After the rains of early August rust infection broke out on susceptible varieties in Manitoba but occurred too late in the season to cause appreciable damage.

An unusual occurrence was the development, in Manitoba and Saskatchewan, of what farmers generally called "green rust" on standing and swathed grain after the rainfalls in early August. The condition was caused by the abundant growth of the molds (*Cladosporium* and *Alternaria*. The unusual abundance of these molds was probably caused by the combination of abundant moisture and premature ripening of the plants by hot weather which left a considerable amount of untranslocated carbohydrates in leaves and stems and thereby created a favorable substrate for fungal growth.

Prevalence of Air-borne Rust Spores in Western Canada

Following the practice of former years, the amount of air-borne rust inoculum over Manitoba and Saskatchewan was determined by counting the spores caught on vaseline-coated slides exposed in spore traps located at Winnipeg, Morden, and Brandon in Manitoba and at Indian Head and Regina

1. Issued as Report #16, Plant Pathology Section, Canada Agriculture Research Station, Winnipeg, Man.
2. Plant Pathologists.

in Saskatchewan. The Research Station at Saskatoon reported on the number of air-borne spores in that area. The number of spores caught in 48-hour exposures, expressed as the number of stem rust and leaf rust spores per square inch of slide, are shown in Table 1.

The first important spore-shower of the season occurred from June 25-27. Relatively large numbers of spores were caught at Winnipeg and Morden in the Red River Valley; smaller numbers were caught at Brandon; and few, if any, spores were carried very far into Saskatchewan. The area of spore deposition can be related directly to the winds which were southerly in Manitoba and westerly in Saskatchewan from June 24 to 27. A possible source of the inoculum was eastern Kansas and south-eastern Nebraska where rust infections were severe in many fields at the end of the first week of July. Spore-showers of a similar pattern occurred from July 7 to 11, on July 19 and 20, and from July 23 to 25 when winds were southerly in Manitoba. The large numbers of spores caught after the first week in August were probably produced locally throughout the spring wheat region.

Leaf Rust of Wheat

Leaf rust of wheat was the most prevalent cereal rust in Western Canada in 1960, but, in aggregate, it caused little damage. It was found first in Manitoba at Morden on June 14. about the usual time for its appearance, but subsequent development was slow. By the end of June there was a mere scattering of resistant-type infections throughout the Red River Valley on the widely grown resistant variety Selkirk and very light infections (up to 5 per cent) on the lower leaves of susceptible varieties in experimental plots. A year earlier, at about the same date, infections ranged up to 60 per cent. Dry, hot weather prevailed during July and for much of this month rust development was slow. In early August infections on susceptible varieties in the Red River Valley ranged from 10 to 50 per cent, while farther west, at Brandon, the very susceptible variety Thatcher had only 5 per cent leaf rust infection. The hot dry weather during July rapidly forced the crop towards maturity and after early August there was little opportunity for further rust development. In Saskatchewan and Alberta, leaf rust was less prevalent than in Manitoba. In most of Saskatchewan only traces of rust could be found although moderate to severe infections were reported in the north-eastern part as indicated in Figure 1.

Stem Rust of Wheat

Wheat stem rust was scarce on wheat in farm fields in 1960. Only traces were found on varieties such as Selkirk, Pembina, and Ramsey in Manitoba and it was even less common farther west in Saskatchewan and Alberta. The scarcity of stem rust on the widely grown varieties was mostly due to the predominance of race 56, to which these varieties are resistant.

In 1960 wheat stem rust was found first on June 28, nine days later than last year, on the susceptible variety Red Bobs at Morden, Manitoba, and on susceptible varieties in experimental plots at Winnipeg. The hot, dry weather during July restricted rust development. In early August susceptible varieties in experimental plots in the Red River Valley were infected only

Table 1. Numbers of stem rust and leaf rust spores caught on vaseline-coated slides, exposed at three locations in Manitoba and three locations in Saskatchewan in 1960.

Winnipeg, Man. 1/						Morden, Man. 1/					
Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust
May 23-24	1	1	July 14-15	1	1	May 24-25	1	0	July 13-14	4	11
25-26	0	0	16-18	2	1	26-27	1	0	15-16	1	1
27-30	1	0	19-20	11	39	28-29	1	0	17-18	0	2
May Total	2	1	21-22	10	26	30-31	1	0	19-20	27	105
May 30-			23-25	15	51	May Total	4	0	21-22	0	1
June 1	0	0	26-27	1	5	June 1-2	0	0	23-24	31	204
June 2-3	0	32	28-29	1	26	3-4	0	2	25-26	1	23
4-6	0	1	July Total	75	277	5-6	0	1	27-28	1	28
7-8	1	2	July 30-			7-8	0	1	29-30	3	6
9-10	0	5	Aug. 2	9	5	9-10	0	0	July Total	170	959
11-13	0	0	Aug. 3	19	5	11-12	0	0	July 31-Aug. 1	8	6
14-15	0	1	4-5	1	3	13-14	0	1	Aug. 2-3	1	2
16-17	0	0	6-8	15	48	15-16	1	0	4-5	0	0
18-20	1	0	9-10	3	13	17-18	1	1	6-7	0	0
21-22	0	1	11-12	79	124	19-20	1	1	8-9	17	22
23-24	0	0	13-15	9	64	21-22	0	0	10-11	8	81
25-27	401	176	16-17	5	124	23-24	0	1	12-13	49	87
28-29	6	6	18-19	21	71	25-26	316	219	14-15	0	0
30	2	1	20-22	37	32	27-28	5	9	16-17	21	216
June Total	411	225	23-24	917	272	29-30	0	2	18-19	1	7
July 1-4	1	9	25-26	1	5	June Total	324	238	20-21	5	15
5-6	0	9	27-29	18	0	July 1-2	1	0	22-23	18	4
7-8	5	31	30-31	97	26	3-4	0	6	24-25	16	14
9-11	27	79	Aug. Total	1231	792	5-6	3	25	26-27	19	32
12-13	1	0	Total	1719	1295	7-8	88	530	28-29	16	25
						9-10	10	15	Aug. Total	179	511
						11-12	0	2	Total	677	1708

Table 1. Cont'd.

Brandon, Man. 1/						Indian Head, Sask. 1/					
Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust
May 24-26	0	0	July 15-16	0	6	May 27-28	0	0	July 14-15	4	13
27-29	0	0	17-18	0	0	29-30	0	0	16-17	0	6
30-31	0	0	19-20	0	6	May Total	0	0	18-19	0	16
May Total	0	0	21-22	0	4	May 31-June 1	0	1	20-21	0	2
June 1-2	0	0	23-24	3	32	June 2-3	0	0	22-23	2	26
3-4	1	0	25-26	0	3	4-5	0	0	24-25	0	9
5-6	0	2	27-28	0	6	6-7	0	0	26-27	0	7
7-8	1	6	29-30	1	8	8-9	0	0	28-29	0	21
9-10	0	0	July Total	6	103	10-11	0	0	30-31	0	16
11-12	0	3	July 31-Aug. 1	0	9	12-13	0	0	July Total	8	133
13-14	0	1	Aug. 2-3	0	0	14-15	0	0	Aug. 1-2	0	0
15-16	0	1	4-5	1	13	16-17	0	4	3-4	0	31
17-18	1	1	6-7	4	15	18-19	0	4	5-6	0	35
19-20	0	2	8-9	1	2	20-21	0	0	7-8	0	34
21-22	0	1	10-11	0	10	22-23	0	1	9-10	0	102
23-24	0	0	12-13	5	68	24-25	1	4	11-12	4	186
25-26	30	104	14-15	0	48	26-27	0	5	13-14	0	43
27-28	7	5	16-17	0	36	28-29	0	2	15-16	11	116
29-30	1	7	18-19	5	20	June Total	1	21	17-18	2	1106
June Total	41	133	20-21	69	34	June 30-July 1	0	0	19-20	0	65
July 1-2	0	2	22-23	58	25	July 2-3	0	3	21-22	1	24
3-4	0	0	24-25	2	0	4-5	1	2	23-24	0	62
5-6	0	2	26-27	0	0	6-7	0	0	25-26	4	16
7-8	1	4	28-29	5	4	8-9	1	6	27-28	2	27
9-10	0	19	30-31	26	26	10-11	0	4	29-30	16	86
11-12	0	4	Aug. Total	176	310	12-13	0	2	Aug. Total	40	1933
13-14	1	7	Total	223	546				Total	49	2087

Table 1. Cont'd.

Regina, Sask. 1/						Saskatoon, Sask. 2/					
Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust	Date	Stem Rust	Leaf Rust
May 22-23	0	4	July 8-9	1	1	May 16-17	0	0	July 7-8	0	3
24-25	1	1	10-11	0	1	18-19	0	0	9-10	0	4
25-26	0	1	12-13	1	2	20-21	0	0	11-12	0	23
27-28	0	0	14-17	0	4	23-24	0	0	13-14	0	21
29-30	0	0	18-19	2	28	25-26	0	0	15-16	0	8
May Total	1	6	20-21	4	1	28-29	0	0	17-18	0	58
May 31-June 1	1	3	22-23	0	11	30-31	0	0	19-20	0	18
June 2-3	0	0	24-25	1	1	May Total	0	0	21-22	-	135
4-5	0	0	26-27	0	1	June 1-2	0	0	23-24	0	40
6-7	0	7	28-29	0	2	3-4	0	0	25-26	0	43
8-9	0	2	30-31	0	6	6-7	0	0	27-28	0	61
10-11	1	8	July Total	10	59	8-9	0	0	29-30	0	25
12-13	0	0	Aug. 1-2	0	1	10-11	0	0	July Total	0	321
14-15	0	1	3-4	0	8	13-14	0	0	July 31-Aug. 1	0	171
16-17	1	9	5-6	0	23	15-16	0	0	Aug. 2-3	0	61
18-19	0	1	7-8	0	108	17-18	0	0	4-5	0	38
20-21	0	0	9-10	0	18	20-21	0	0	6-7	0	79
22-23	0	0	11-12	0	258	22-23	0	0	8-9	0	24
24-25	0	1	13-14	9	563	24-25	0	0	10-11	0	169
26-27	0	1	15-16	2	80	27-28	0	5	12-13	0	754
28-29	0	2	17-18	0	207	29-30	0	0	14-15	0	1232
June Total	3	35	19-20	11	1993	June Total	0	5	16-17	0	650
June 30-July 1	1	0	21-22	11	257	July 1-2	0	3	18-19	0	6773
July 2-3	0	0	23-24	0	12	3-4	0	12	Aug. Total	0	9951
4-5	0	0	25-26	2	46	5-6	0	2	Total	0	10,277
6-7	0	1	Aug. Total	35	3574						
			Total	49	3674						

1/ Numbers of spores per quare inch of slide.
2/ Number of spores per slide.

lightly (10 per cent) and only traces of stem rust were present on the susceptible Hordeum jubatum L. throughout southern Manitoba. After the rains of early August rust was able to develop and by about August 20 stem rust was common on H. jubatum throughout the Province and moderate in some late fields of susceptible barley. Stem rust was first reported in Saskatchewan at Saskatoon on August 1, on barley, but continued scarce there until the end of the growing season.

Stem Rust of Oats

Stem rust of oats was remarkably scarce in 1960 and caused no damage in Western Canada. It appeared very late in the season. The first collection was made on August 4 at St. Labre, in the south-eastern part of Manitoba. The oat crop was well advanced by that date and there was little opportunity for stem rust to develop in commercial fields. Weather conditions during August favored the rust and by August 20 it was common on susceptible wild oats throughout Manitoba.

Crown Rust of Oats

Crown rust of oats appeared late in Manitoba. It was first observed on July 27 at Morden. Much of the oat crop was approaching maturity by that date and the rust could not increase fast enough to damage most commercial fields. It developed rather slowly during August and on August 22 only traces of crown rust were found in the rare late oat fields and on susceptible wild oats throughout the Province.

Other Cereal Rusts

Leaf rust of barley was not found until after the middle of August when very light infections were observed in the few late barley fields still standing in Manitoba. As usual, leaf rust of rye appeared relatively early on fall sown rye. It was first observed at Morden, Manitoba, on June 28.

CEREAL RUSTS AND OTHER DISEASES IN THE RUST NURSERIES IN 1960

In 1960 the rust nurseries were grown at 35 locations in Canada with at least one nursery in each province. Most of the nurseries were planted and cared for by co-operators whose assistance makes this project possible. When the plants were approaching maturity, the co-operators cut a small sheaf from each row in the nursery and forwarded the sheaves to Winnipeg where disease ratings were made. These ratings appear in Tables 2 to 7.

The varieties grown in the nurseries are: Wheat: McMurachy, R.L. 1313; Lee, R.L. 2477; Kenya Farmer, R.L. 2768; Red Bobs; Marquis, R.L. 84; Mindum, R.L. 1344; Thatcher, R.L. 1945; Selkirk, R.L. 2769; Canthatch, R.L. 2936; Exchange, R.L. 1803; Frontana, R.L. 2336; Ramsey, Ld. 369; Pembina, R.L. 2814. Oats: Bond, R.L. 1130; Trispernia, R.L. 3; Exeter, R.L. 53; Garry, R.L. 1692.27; Clinton, R.L. 66; Landhafer, R.L. 91; Rodney, R.L. 2123; R.L. 2278. Barley: Montcalm, C.A.N. 1135; Vantage, Br. 1356; Parkland, Br. 3833. Rye: Prolific. Flax: Bison, Dakota, and Raja.

Stem Rust of Wheat

The amount of wheat stem rust in the nurseries in 1960 (Table 2) is one of the smallest on record. There was no stem rust in any nursery grown west of Manitoba, excepting a trace on the very susceptible variety Red Bobs at Creston, B.C., nor was there stem rust in the nurseries from Quebec and the Maritime Provinces, excepting a very light infection on Red Bobs at L'Assomption, Quebec. Stem rust was present in all nurseries in Manitoba but the infections were less severe than usual. In Ontario the susceptible varieties Red Bobs and Marquis were severely attacked at Fort William and at Mindemoya but in all other nurseries infections were light or absent.

Only the susceptible varieties Red Bobs and Marquis had infections of more than trace or 1 per cent. The variety McMurachy, which carries the gene Sr6 was severely attacked in earlier years in Ontario and Quebec by races 48A and 29-1 (Can.) but this year there were only traces of rust on it at Guelph, Ontario, and at Morden, Manitoba. The varieties Lee and Thatcher, which were severely attacked by race 15B in former years, were nearly free from rust in 1960. The durum variety Mindum, which is susceptible to several races including 15B and 11, was also nearly free from rust. The scarcity of rust on the above mentioned varieties indicates, not only the general scarcity of stem rust in 1960, but the predominance of race 56 which is avirulent on all varieties in the nurseries except Marquis and Red Bobs.

The resistant commercial varieties Selkirk, Canthatch, Ramsey, and Pembina were nearly free from stem rust. No stem rust was found on the variety Kenya Farmer, which has been used as a source of resistance for many years.

Leaf Rust of Wheat

Development of leaf rust in most of the rust nurseries was similar to that in 1959. Severe infections occurred at Morden but infections in other Manitoba nurseries were comparatively light for this area (Table 3).

The infections on Mindum, Ramsey, Selkirk, and Pembina were all of a resistant or moderately resistant type. Exchange and Frontana were highly resistant at all locations

Stem Rust of Oats

Stem rust of oats was scarce in most rust nurseries in 1960 (Table 4). In Western Canada very light infections occurred only in the nurseries in British Columbia and in two nurseries in the Red River Valley of Manitoba. Light infections occurred in some nurseries in Quebec and the Maritime Provinces. The disease occurred in five out of eight nurseries in Ontario but moderate and moderately severe infections occurred only at Ottawa and Kemptville, respectively. Barberry bushes probably contributed to the development of stem rust in these areas.

The rusting of Garry and Rodney at Kemptville, Ottawa, and Merrickville in Ontario was caused by races such as 6A, 8A, and 13A which have been prevalent in these areas since 1957.

Table 2. Per cent infection of stem rust of wheat (Puccinia graminis tritici) on 13 wheat varieties in uniform rust nurseries in Canada in 1960

Locality	McMurachy	Lee	Kenya Farmer	Red Bobs	Marquis	Mindum	Thatcher	Selkirk	Canthatch	Exchange	Frontana	Ramsey	Pembina
Creston, B.C.	0	0	0	t	0	0	0	0	0	0	0	0	0
Brandon, Man.	0	0	0	10	5	t	0	0	0	0	0	t	0
Morden, Man.	t	t	0	30	40	t	0	t	0	t	3	t	0
St. Agathe, Man.	0	0	0	50	60	0	t	0	t	0	0	0	0
The Pas, Man.	0	0	0	20	10	0	0	0	0	0	t	0	0
Winnipeg, Man.	0	0	0	10	20	t	0	0	0	t	t	0	0
Fort William, Ont.	0	t	0	80	80	t	t	0	0	t	t	0	0
Guelph, Ont.	t	0	0	30	20	0	0	0	0	1	0	0	0
Kemptville, Ont.	0	0	0	20	15	0	0	0	0	0	0	0	0
Ottawa, Ont.	0	0	0	t	t	0	0	0	0	t	0	0	0
Merrickville, Ont.	0	0	0	1	3	0	0	0	0	0	0	0	0
Mindemoya, Ont.	0	t	0	70	60	0	0	0	0	1	0	0	0
L'Assomption, Que.	0	0	0	0	1	0	0	0	0	0	0	0	0

Crown Rust of Oats

Crown rust infections were light or absent at most of the localities in Canada where rust nurseries were located in 1960 (Table 5). The light infections on Trispernia at 3 nurseries were caused by race 264. Race group 290 was prevalent at Mindemoya and occurred in trace amounts at the four other locations where Landhafer was infected.

The Rusts of Barley and Rye

Stem rust and leaf rust of barley (Table 6) were distributed like the wheat rusts. Barley leaf rust was more common than stem rust but leaf rust was severe only at Guelph, Ontario. Light stem rust infections on barley occurred in a few nurseries in Manitoba and Ontario. The 25 per cent infection on the resistant variety Parkland at Ottawa was apparently caused by rye stem rust which can attack barley varieties resistant to wheat stem rust. Prolific rye, which was next to Parkland in the nursery, also showed 25 per cent stem rust infection. A severe infection of powdery mildew may have hastened the maturity of the varieties Vantage and Montcalm, leaving little time for rust to spread uniformly through the nursery.

Table 3. Per cent infection of leaf rust of wheat (Puccinia recondita) in 1960 on 13 wheat varieties in uniform rust nurseries at 28 locations in Canada.

Locality	McMurachy	Lee	Kenya Farmer	Red Bobs	Marquis	Mindum	Thatcher	Selkirk	Canthatch	Exchange	Frontana	Ramsey	Pembina
Agassiz, B.C.	70	0	0	50	30	0	60	0	60	0	0	0	0
Creston, B.C.	30	5	5	40	30	0	40	5	40	0	0	0	5
Edmonton, Alta.	t	t	0	t	t	0	t	0	t	0	0	0	0
Lethbridge, Alta.	3	2	2	5	2	0	5	1	3	0	0	0	1
Lacombe, Alta.	3	t	t	3	2	0	3	t	3	0	0	0	t
Melfort, Sask.	25	3	5	25	15	0	25	5	25	0	0	0	2
Indian Head, Sask.	t	0	t	t	t	0	t	0	t	0	0	0	0
Brandon, Man.	60	30	20	60	40	t	30	25	40	2	t	t	30
Morden, Man.	90	40	20	60	70	t	90	30	80	t	0	0	20
The Pas, Man.	40	5	5	40	40	0	40	5	40	0	0	0	5
Ste. Agathe, Man.	30	10	5	50	70	t	70	20	60	t	0	t	10
Winnipeg, Man.	40	10	5	50	50	0	50	10	50	0	0	0	5
Fort William, Ont.	40	5	5	40	40	0	40	5	40	0	0	0	5
St. Catharines, Ont.	50	15	15	30	45	0	30	5	20	0	0	0	0
Guelph, Ont.	50	25	20	75	60	5	60	10	70	0	0	0	5
Kemptville, Ont.	45	25	15	65	70	5	80	10	70	0	0	0	10
Ottawa, Ont.	50	2	2	90	50	15	70	10	60	0	0	0	10
Merrickville, Ont.	50	0	0	50	50	15	50	0	50	0	0	0	0
Mindemoya, Ont.	80	15	10	80	80	10	80	15	80	0	0	0	10
Macdonald College, Que.	50	t	1	50	50	0	50	1	50	0	0	0	t
Lennoxville, Que.	50	2	10	50	60	0	60	10	40	0	t	0	10
Normandin, Que.	80	2	3	60	60	t	70	5	70	0	0	t	3
L'Assomption, Que.	60	t	3	50	60	0	60	5	60	0	0	t	t
Fredericton, N.B.	60	t	t	40	40	0	60	0	60	0	0	0	0
Kentville, N.S.	40	5	5	40	30	0	40	5	40	0	0	0	3
Nappan, N.S.	30	1	1	30	30	0	40	0	30	0	0	0	0
Glenora Falls, N.S.	40	t	5	40	40	0	50	t	50	0	0	0	t
Charlottetown, P.E.I.	3	t	t	3	2	0	3	0	3	0	0	0	0

Table 4. Per cent infection of stem rust of oats (Puccinia graminis avenae) in 1960 on 8 oat varieties in uniform rust nurseries in Canada.

Locality	Bond	Trispernia	Exeter	Garry	Clinton	Landhafer	Rodney	R.L. 2278
Agassiz, B.C.	t	t	0	t	0	10	0	t
Creston, B.C.	0	t	0	0	0	t	0	0
Morden, Man.	1	t	t	0	5	1	0	0
Ste. Agathe, Man.	t	0	0	0	t	0	t	0
Guelph, Ont.	1	2	t	0	1	1	1	0
Kemptville, Ont.	60	30	60	50	20	40	60	50
Ottawa, Ont.	25	1	2	2	t	t	15	t
Merrickville, Ont.	1	3	2	t	2	2	10	3
Mindemoya, Ont.	0	0	0	0	t	0	0	0
Macdonald College, Que.	t	0	t	t	t	0	t	0
Lennoxville, Que.	t	t	t	0	t	-	0	0
Normandin, Que.	t	1	t	t	t	1	t	0
L'Assomption, Que.	0	5	0	0	0	5	0	0
Nappan, N.S.	t	0	0	0	0	0	0	0
Charlottetown, P.E.I.	1	t	t	0	0	t	0	0

Table 5. Per cent infection of crown rust (Puccinia coronata avenae) of oats in 1960 on 8 oat varieties at 19 locations in Canada.

Locality	Exeter	Garry	Landhafer	Clinton	Rodney	Bond	Trispernia	R.L. 2278
Lacombe, Alta.	t	0	0	0	0	0	0	0
Melfort, Sask.	t	t	0	0	0	0	0	0
Indian Head, Sask.	t	0	0	0	0	0	0	0
Morden, Man.	35	5	0	1	30	0	0	0
Ste. Agathe, Man.	10	0	0	0	t	10	0	0
Winnipeg, Man.	2	0	0	t	0	2	0	0
Fort William, Ont.	1	0	0	0	0	0	0	0
Guelph, Ont.	50	15	2	25	1	50	1	0
Kemptville, Ont.	t	t	t	t	t	10	t	t
Ottawa, Ont.	t	t	0	t	t	t	0	t
Merrickville, Ont.	t	t	0	t	t	t	0	0
Mindemoya, Ont.	30	30	10	30	20	30	3	20
Macdonald College, Que.	t	0	0	0	t	t	0	0
Lennoxville, Que.	t	0	t	0	0	0	0	0
L'Assomption, Que.	t	0	0	0	0	t	0	0
Fredericton, N.B.	1	0	0	t	0	t	0	0
Nappan, N.S.	t	t	0	t	t	t	0	0
Glenora Falls, N.S.	t	t	0	t	0	t	0	0
Charlottetown, P.E.I.	t	t	t	t	0	t	0	0

Table 6. Per cent infection in 1960 in stem rust (Puccinia graminis) and leaf rust (P. hordei) on 3 barley varieties and of stem rust and leaf rust (P. secalina) on Prolific rye in uniform rust nurseries at 35 locations in Canada.

Locality	Stem Rust			Leaf Rust			STEM RUST	LEAF RUST
	Montcalm	Vantage	Parkland	Montcalm	Vantage	Parkland	Prolific Rye	
Saanichton, B.C.	0	0	0	0	0	0	0	0
Agassiz, B.C.	0	0	0	t	5	5	0	30
Creston, B.C.	0	0	t	0	0	0	10	t
Beaverlodge, Alta.	0	0	0	0	0	0	0	0
Edmonton, Alta.	0	0	0	0	0	0	0	0
Lethbridge, Alta.	0	0	0	0	0	0	0	0
Lacombe, Alta.	0	0	0	0	0	0	0	3
Scott, Sask.	0	0	0	0	0	0	0	0
Melfort, Sask.	0	0	0	0	0	0	0	0
Indian Head, Sask.	0	0	0	-	-	-	0	-
Brandon, Man.	1	0	0	-	-	-	0	50
Morden, Man.	10	0	0	-	-	-	5	40
Ste. Agathe, Man.	30	t	0	t	t	1	0	5
The Pas, Man.	0	0	0	0	0	0	t	3
Winnipeg, Man.	t	0	0	-	-	-	0	-
Fort William, Ont.	5	t	t	0	0	0	20	20
Kapuskasing, Ont.	0	0	0	0	0	0	0	0
St. Catharines, Ont.	0	0	0	0	0	0	0	35
Guelph, Ont.	t	0	0	60	70	40	30	35
Kemptville, Ont.	t	1	1	t	t	t	65	25
Ottawa, Ont.	1	t	25	t	t	t	25	35
Merrickville, Ont.	5	t	t	10	25	15	75	-
Mindemoya, Ont.	0	0	0	40	40	40	5	30
Macdonald College, Que.	0	0	0	0	0	0	0	10
Lennoxville, Que.	0	0	0	0	0	0	5	20
Ste. Anne de la Poc., Que.	0	0	0	0	0	0	-	t
Normandin, Que.	0	0	0	0	0	0	0	40
L'Assomption, Que.	0	0	0	0	0	0	t	55
Fredericton, N.B.	0	0	0	0	0	0	40	50
Kentville, N.S.	0	0	0	0	0	0	t	0
Nappan, N.S.	0	0	0	0	0	0	0	40
Glenora Falls, N.S.	0	0	0	0	0	0	0	55
Charlottetown, P.E.I.	0	0	0	1	1	1	20	10
St. John's West, Nfld.	0	0	0	0	0	0	0	10
Doyles, Nfld.	0	0	0	0	0	0	-	-

Table 7. Incidence[1/] of certain pathogenic fungi on wheat, oats, barley and rye at 35 locations in Canada in 1960.

Locality	WHEAT				OATS			BARLEY						RYE	
	P. gr. tritici	P. recondita	Erysiphe graminis	Septoria spp.	P. gr. avenae	P. cor. avenae	Septoria avenae	P. graminis	P. hordei	Erysiphe graminis	S. passerinii	P. teres	B. sorokiniana	P. gr. secalis	P. secalina
Saanichton, B.C.	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0
Agassiz, B.C.	0	4	0	3	2	0	0	0	2	4	-[2/]	-	-	0	3
Creston, B.C.	1	3	0	3	1	0	3	1	0	3	0	0	3	2	1
Beaverlodge, Alta.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Edmonton, Alta.	0	1	0	2	0	0	0	0	0	0	0	2	0	0	0
Lethbridge, Alta.	0	2	1	1	0	0	0	0	0	3	0	0	0	0	0
Lacombe, Alta.	0	2	0	2	0	1	0	0	0	0	0	0	0	0	2
Scott, Sask.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Melfort, Sask.	0	3	0	3	0	1	0	0	0	0	1	2	0	0	0
Indian Head, Sask.	0	1	0	1	0	1	0	0	-	0	0	0	1	0	-
Brandon, Man.	2	4	0	0	0	0	0	1	-	0	0	0	0	0	3
Morden, Man.	3	4	0	0	2	3	2	2	-	-	2	1	1	2	3
Ste. Agathe, Man.	4	4	-	-	1	2	0	3	1	-	0	1	1	0	2
The Pas, Man.	2	3	0	3	0	0	0	0	0	0	4	0	0	1	2
Winnipeg, Man.	2	3	-	-	0	2	-	1	-	-	-	-	-	0	-
Fort William, Ont.	4	3	0	1	0	1	4	2	0	0	0	0	2	2	2
Kapuskasing, Ont.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
St. Catharines, Ont.	0	3	2	0	0	0	0	0	0	4	0	0	-	0	3
Guelph, Ont.	3	4	3	3	2	3	4	1	4	4	1	-	-	3	3
Kemptville, Ont.	2	4	2	1	4	2	3	1	1	3	0	0	0	4	3
Ottawa, Ont.	1	4	3	2	3	1	1	3	1	4	0	0	-	3	3
Merrickville, Ont.	2	3	3	2	2	1	1	2	3	0	1	0	0	4	-
Mindemoya, Ont.	4	4	0	2	1	3	1	0	3	0	0	0	0	2	3
Macdonald College, Que.	0	3	4	1	1	1	3	0	0	3	0	0	0	0	2
Lennoxville, Que.	0	4	0	2	1	1	2	0	0	0	1	0	3	2	2
Ste. Anne de la Poc., Que.	0	0	0	0	0	0	2	0	0	0	0	0	0	-	1
Normandin, Que.	0	4	0	3	1	0	4	0	0	0	4	0	0	0	3
L'Assomption, Que.	1	4	-	-	2	1	1	0	0	0	0	0	2	1	4
Fredericton, N.B.	0	4	0	1	0	1	2	0	0	0	0	0	2	3	3
Kentville, N.S.	0	3	0	0	0	0	1	0	0	0	0	0	0	1	0
Nappan, N.S.	0	3	0	0	1	1	4	0	0	0	0	0	3	0	3
Glenora Falls, N.S.	0	3	-	-	0	1	4	0	0	-	-	-	-	0	4
Charlottetown, P.E.I.	0	2	0	0	1	1	4	0	1	0	0	0	1	2	2
St. John's West, Nfld.	0	0	0	1	0	0	2	0	0	0	0	0	0	0	2
Doyles, Nfld.	0	0	-	0	0	0	0	0	0	-	0	0	1	-	-

1/ 1=trace, 2=light, 3=moderate, 4=heavy.
For the rusts 1=tr. - 1%, 2= 2 - 20%, 3 = 21 - 50%, 4 = over 50%.

2/ A dash signifies no observation was made.

Stem rust and leaf rust of rye (Table 6) occurred in all provinces except Alberta and Saskatchewan. For a number of years heavy stem rust infections on rye had often been accompanied by infection of the wheat stem rust resistant barley varieties Parkland and Vantage. In 1960 this did not occur, except at Ottawa as already mentioned.

Flax Rust

Traces of flax rust occurred on the susceptible variety Bison at Beaverlodge, Edmonton, and Lethbridge in Alberta. Dakota and Raja were free from rust at these locations. Flax was most severely attacked by rust at The Pas in northern Manitoba where Bison showed 60 per cent infection and Dakota 10 per cent, while Raja was free from rust.

Diseases other than Rusts

The incidence, in the nurseries, of several diseases other than rusts and a summary of the rust data appear in Table 7. Powdery mildew of wheat and barley (*Erysiphe graminis* DC. ex Mérat) were most common in Ontario. Light infections occurred in British Columbia and south-western Alberta. *Septoria avenae* Frank was widely distributed on oats, occurring in nurseries in all provinces except Saskatchewan and Alberta. *Septoria passerinii* Sacc. occurred sporadically on barley in nurseries from Saskatchewan to Quebec. Light infections of net blotch of barley (*Pyrenophora teres* (Died.) Drechs.) occurred only in the Prairie Provinces but spot blotch (*Bipolaris sorokiniana* (Sacc. in Sorok.) Shoemaker) occurred in all provinces except Alberta. Scald of barley (*Rhynchosporium secalis* (Oud.) J.J. Davis), not shown in Table 7, occurred only in nurseries at Edmonton and Lacombe in Alberta.

DISTRIBUTION OF PHYSIOLOGIC RACES

Puccinia graminis Pers. f. sp. *tritici* Erikss. & Henn.

Twelve races and subraces of wheat stem rust were identified in 1960 (Table 8) as against 20 in 1959. Race 56 predominated throughout Canada and increased from 45 per cent of the isolates in 1959 to 68 per cent in 1960. The prevalence of race 15B continued to decline slowly but the most prevalent subrace, 15B-4 (Can.), was nearly as common as in 1959. The other races identified in 1960 occurred in trace amounts.

Races were identified on the standard differential hosts and subraces on the supplementary hosts Lee, Golden Ball, Selkirk, Yuma, and Bowie. Lines of Marquis wheat carrying genes *Sr6* to *Sr10* were used with the other varieties. They helped in identifying races and subraces but they do not differentiate between some important races nor did they distinguish new biotypes in 1960.

A new, potentially important subrace of 15B, designated 15B-5 (Can.), was found. It was distinguished from other subraces of 15B, described last year in Report No. 15, by a new combination of virulence on the varieties Golden Ball, Selkirk, and Pembina. The three isolates of this race were obtained in August from late fields in Manitoba; one isolate came from

Table 8. Distribution by provinces of physiologic races of Puccinia graminis f. sp. tritici collected on wheat, barlev and grasses in 1960.

Race	Province						Total Isolates	Per Cent of Total Isolates
	Que.	Ont.	Man.	Sask.	Alta.	B.C.		
2	-	-	-	-	1	1	1	.6
11	-	-	4	-	-	-	4	2.4
11-1 (Can.)	1	-	4	-	-	-	5	3.0
11-2 (Can.)	-	-	1	1	-	-	2	1.2
15	-	-	1	-	-	-	1	.6
15B-1 (Can.)	-	1	-	-	-	-	1	.6
15B-1L (Can.)	-	-	2	-	-	-	2	1.2
15B-3 (Can.)	-	-	3	-	-	-	3	1.8
15B-4 (Can.)	-	2	19	3	-	-	24	14.6
15B-5 (Can.)	-	-	3	-	-	-	3	1.8
29-1 (Can.)	-	-	6	-	-	-	6	3.7
56	-	7	88	16	1	-	112	68.3
Total No. of Isolates	1	10	131	20	1	1	164	

Table 9. Distribution by provinces of physiologic races of Puccinia graminis f. sp. tritici collected on susceptible varieties of wheat and barley and Hordeum jubatum L. in 1960

Race	Province					Total Isolates	Per Cent of Total Isolates
	Ont.	Man.	Sask.	Alta.	B.C.		
2	-	-	-	-	1	1	.8
11	-	4	-	-	-	4	3.1
11-1 (Can.)	-	1	-	-	-	1	.8
11-2 (Can.)	-	-	1	-	-	1	.8
15B-1 (Can.)	1	-	-	-	-	1	.8
15B-1L (Can.)	-	2	-	-	-	2	1.5
15B-3 (Can.)	-	2	-	-	-	2	1.5
15B-4 (Can.)	2	12	2	-	-	16	12.2
29-1 (Can.)	-	6	-	-	-	6	4.6
56	6	78	12	1	-	97	74.0
Total No. of Isolates	9	105	15	1	1	131	

Selkirk at Dauphin, one from Selkirk at MacDonald, and one from Thatcher at Ashville.

Cultures of a second new and possibly important race, designated 11-2 (Can.), originated at Christie, Manitoba and Regina, Saskatchewan. This race attacks seedlings of Selkirk and Pembina. Final assessment of its importance must await adult plant tests since adult plant resistance from H-44 has protected these varieties from earlier cultures of race 11.

The reappearance of race 15B-3 (Can.) is of interest. This race, which also can attack Selkirk and Pembina, was isolated in 1953, 1954, and 1955 and then disappeared although the widespread cultivation of Selkirk should have favored its increase. It has been regarded as the greatest threat to Selkirk and Pembina, although race 15B-5 (Can.) must now be ranked with it. The reactions of the supplementary host varieties and lines of Marquis with genes Sr6 to Sr10 to races 15B-3 (Can.), 15B-5 (Can.), and 11-2 (Can.) appear in Table 10.

The races isolated from susceptible hosts are shown in Table 9. Most of the rust from Manitoba was collected on susceptible varieties and on susceptible wild barley (*Hordeum jubatum* L.) because rust was scarce on the widely grown resistant varieties. Urediospores from the initial increase of each collection were bulked in lots of about ten collections and inoculated onto the highly resistant varieties Mayo 54, Mida-McMurachy-Exchange II-47-26, Frontana-Kenya 58-Newthatch II-50-17, R.L. 4125, C.T. 250, D.T. 161, St 464, C.I. 8155, and C.I. 7805. Susceptible infections appeared only on the varieties C.T. 250 and R.L. 4125. Races 11-2 (Can.), 15B-3 (Can.), and 15B-5 (Can.) were isolated from the susceptible infections on C.T. 250, and race 15 was isolated from R.L. 4125. Kenya Farmer was resistant to all the 1960 isolates.

Puccinia recondita Rob. ex Desm.

Seven races of wheat leaf rust were isolated in the 1960 race survey (Table 11). Race 15 was the most prevalent race in Manitoba and Saskatchewan but was less abundant east and west of this area. Races 1 and 11 were predominant in southern Alberta and British Columbia while race 58 was dominant in Eastern Canada. This pattern of race distribution has existed for a number of years.

Single-pustule isolates were used for all race determinations. A number of additional varieties were also inoculated with each single-pustule isolate. Rio Negro and Wardal were susceptible to all isolates of race 9 and resistant to all other isolates. Waban was highly resistant to all cultures tested in 1960. Lee was more resistant than Westar although the two varieties reacted similarly to many isolates. Ninety per cent of the isolates from Manitoba attacked Lee and Westar; one per cent of the isolates from Ontario attacked Lee and 58 per cent of the Ontario isolates attacked Westar.

Bulked collections of rust from each area were used to inoculate a group of highly resistant varieties. No type 4 pustules were found on Agrus, Exchange, Klein Lucero, Klein Titan and Transfer (Chinese x *Aegilops umbellulata*). One small sporulating pustule was observed on Transfer. Inoculum from this pustule was increased and identified as race 15. A type 1^+

Table 10. Seedling reaction of supplementary hosts and other wheat varieties to three races of wheat stem rust

Variety	Physiologic Race		
	11-2 (Can.)	15B-3 (Can.)	15B-5 (Can.)
Lee	1	3+	3
Golden Ball	3+	2	4
Selkirk	3+	4	4
Yuma	;	;, 1	;, 1
Bowie	;	;, 1	;, 1
Pembina	3+	3+	4
Sr6	3+	4	4
Sr7	2 to 3 cn	2 to 3cn	2 to 3cn
Sr8	2	2	2
Sr9	4-	4	4
Sr10	4-	4	4
Kenya Farmer	1cn	1cn	1cn

Table 11. Distribution by provinces of physiologic races of *Puccinia recondita* isolated in Canada in 1960

Race		Province									Total Isolates	Per Cent of Total Isolates
	UN	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.		
1	1	-	-	-	-	-	-	7	16	4	27	7.7
2	15	2	1	-	2	10	93	54	3	6	171	49.0
3	58	3	7	3	22	41	3	-	2	-	81	23.2
5	5	-	-	-	-	-	8	8	-	-	16	4.6
6	105	-	-	-	-	1	-	-	-	-	1	0.3
9	9	-	-	-	-	-	8	-	1	3	12	3.4
10	11	1	-	-	7	9	1	3	8	12	41	11.8
Total No. of Isolates		6	8	3	31	61	113	72	30	25	349	100.0

reaction was consistently produced on Transfer by this culture. This appears to be the highest degree of virulence on Transfer to be observed in North America. Rust reactions on Aniversario were markedly affected by environmental conditions. At Winnipeg, Aniversario was susceptible to isolates of race 58 in August and highly resistant to these same isolates in December.

Puccinia graminis Pers. f. sp. avenae Erikss. & Henn.

Thirteen races and subraces of stem rust of oats were identified in Canada in 1960 (Table 12). An interesting culture of race 12, isolated from rust collected at Agassiz, B.C., had moderate virulence on seedlings of the variety Saia (Avena strigosa Schreb.). No other race virulent on Saia has been found in Canada.

The race distribution in Eastern Canada in 1960 (Table 12) was similar to the distribution in 1959. Race group 6A-13A predominated and races 6, 7A, and 8A were not uncommon. The well-known races 7 and 8 which were common in Western Canada were not found in the East. Our co-operators in Eastern Canada sent a number of rust collections from their localities. The races prevalent in each locality are shown in Table 12. Race group 6A-13A was confined to eastern Ontario and Quebec as in former years.

For the first time, race 7A was isolated more frequently in Manitoba than any other race. Race 7, which has predominated for several years, and race 8, which was scarce last year, were about equally prevalent. Race 6, usually rare in Western Canada, was isolated from five collections. The change in race distribution, with race 7A becoming the most prevalent race in Manitoba, might be expected to have economic importance because 7A can attack the resistant variety Rodney which is grown on much of the oat acreage in that province. However, the status of Rodney may not have changed a great deal because the prevalence of 7A increased by only five per cent over 1959 and its predominance resulted mainly from a sharp decrease in the amount of race 7, the formerly predominant race. The widespread cultivation of Rodney tends to exaggerate the prevalence of 7A. Isolates from susceptible varieties (Table 13) indicate there was not much difference in the prevalence of races 7, 7A, and 8.

Races were identified on the differential hosts White Russian (D gene), Richland (A gene), and Sevnothree (E gene). The varieties Rodney (B gene), Garry (AB genes), and Saia, were used as supplementary hosts. Subraces virulent on Rodney are designated by the letter A (6A, 7A, 8A, 13A etc.). Garry was used to assist in identifying races virulent on the AB combination of resistance genes. R.L. 524.1 and C.I. 4023 were used as hosts for the first time in 1960 because they are resistant to all races including 6A, 8A, and 13A.

Races 4A, 6A, and 13A, which are among the most dangerous known in North America, are differentiated from each other on the variety Sevnothree. This variety has an unstable reaction and it is sometimes difficult to separate race 4A from 13A and 13A from 6A. The Sevnothree type of resistance (E gene) is not important commercially, and for reasons of practicability these three races are treated as a group in this report.

Table 12. Distribution by provinces of physiologic races of Puccinia graminis f. sp. avenae isolated in Canada in 1960.

Province and Location	Physiologic Race													Total Isolates
	1	2	4	6	7	7A	8	8A	12	13	4A	6A	13A	
P.E.I. (Charlottetown)	-	-	1	2	-	-	-	-	-	-	-	-	-	3
Quebec (St. Anne de la Poc.)	-	-	-	4	-	-	-	1	-	-	-	10	2	
" (St. Hyacinthe)	-	-	-	-	-	-	-	-	-	-	-	-	1	
" (Normandin)	-	-	-	-	-	-	-	-	-	-	-	2	-	
" (Riviere Ouelle)	-	-	-	-	-	-	-	1	-	1	-	-	1	
" (Lennoxville)	-	-	-	1	-	-	-	-	-	-	-	-	-	
Total	-	-	-	5	-	-	-	2	-	1	-	12	4	24
Ontario (Guelph)	-	-	-	3	-	2	-	-	-	1	-	-	-	
" (Ottawa)	-	-	-	-	-	2	-	-	-	-	1	5	4	
" (Appleton)	-	-	-	-	-	-	-	-	-	-	-	-	6	
" (Kemptville)	-	-	-	-	-	-	-	-	-	-	-	4	1	
" (Merrickville)	-	-	-	-	-	-	-	1	-	-	-	3	2	
Total	-	-	-	3	-	4	-	1	-	1	1	12	13	35
Manitoba	1	5	-	5	9	21	11	-	-	-	-	-	-	52
Saskatchewan	-	-	-	-	-	2	-	-	-	-	-	-	-	2
B.C. (Agassiz)	-	2	-	-	-	-	-	-	1	-	-	-	-	3
Total Isolates	1	7	1	15	9	27	11	3	1	2	1	24	17	119
Per Cent of Total Isolates	0.8	5.9	0.8	12.6	7.6	22.7	9.2	2.5	0.8	1.7	0.8	20.2	14.3	

Table 13. Distribution by provinces of physiologic races of *Puccinia graminis* f. sp. *avenae* isolated in Canada from susceptible oats in 1960.

Province	Physiologic Race											Total Isolates
	1	2	4	6	7	7A	8	8A	12	6A	13A	
P.E.I.	-	-	1	1	-	-	-	-	-	-	-	2
Que.	-	-	-	3	-	-	-	-	-	3	1	7
Ont.	-	-	-	2	-	2	-	1	-	3	4	12
Man.	1	5	-	4	9	10	10	-	-	-	-	39
B.C.	-	1	-	-	-	-	-	-	1	-	-	2
Total Isolates	1	6	1	10	9	12	10	1	1	6	5	62
Per Cent of Total Isolates	1.6	9.7	1.6	16.1	14.5	19.3	16.1	1.6	1.6	9.7	8.1	

Puccinia coronata Cda. f. sp. *avenae* Erikss.

Twenty-three races of crown rust were identified in 1960 (Table 14). Bond and Victoria races were predominant in Western Canada; races pathogenic on Landhafer and Santa Fe were not isolated in this area. Four races with pathogenicity to Landhafer and Santa Fe were isolated in Eastern Canada (races 264, 290, 293, 294).

Garry, Rodney, and Ceirch dubach were tested with each isolate. Seventy-eight per cent of the isolates from Quebec and the Maritimes, 100 per cent from Ontario and 82 per cent from Manitoba were pathogenic to Garry. Thirty per cent, 96 per cent and 71 per cent of the isolates from Quebec and the Maritimes, Ontario and Manitoba respectively were pathogenic to Rodney. Virulence to these varieties is widely distributed in the rust population and is not limited to the Victoria races. Ceirch dubach was resistant to all isolates of race 264 and race group 290 which were tested. This variety was suceptible to most of the races that attacked Saia but was highly resistant to race 296.

Table 14. Distribution by geographic areas of physiologic races of Puccinia coronata avenae collected on oats in Canada in 1960

Physiologic race	Geographic areas					
	Que. and Maritime Provinces	Ontario	Total Isolates East	Per Cent of Total Isolates, East	Prairie Provinces	Per Cent of Total Isolates, West
201	0	0	0	0	1	1.8
202	0	0	0	0	3	5.4
203	0	1	1	1.2	8	14.3
209	3	0	3	3.6	3	5.4
210	3	17	20	24.3	2	3.6
211	3	1	4	4.8	5	9.3
212	4	1	5	6.0	1	1.8
216	1	2	3	3.6	9	16.6
226	0	0	0	0	2	3.6
228	0	4	4	4.8	0	0
229	0	2	2	2.4	1	1.8
231	2	0	2	2.4	2	3.6
235	1	0	1	1.2	0	0
239	1	1	2	2.4	0	0
240	1	0	1	1.2	2	3.6
264	0	6	6	7.2	0	0
274	0	5	5	6.0	10	18.2
280	0	0	0	0	2	3.6
284	0	6	6	7.2	4	7.4
290	1	1	2	2.4	0	0
293	0	2	2	2.4	0	0
294	0	10	10	12.2	0	0
296	3	1	4	4.8	0	0
Total No. of Isolates	23	60	83	100.0	55	100.0

Puccinia hordei Otth

Seventeen collections of barley leaf rust were studied in 1960. All collections from Manitoba and Saskatchewan were identified as race 44 while races 4 and 44 were obtained from Ontario and Prince Edward Island.

Melampsora lini (Ehrenb.) Lev.

Races of flax rust identified in 1960 with the number of isolates in brackets are: race 166 (5), race 238 (1), and race 243 (2). The isolate of race 238 originated in Alberta; the other isolates were from Manitoba.

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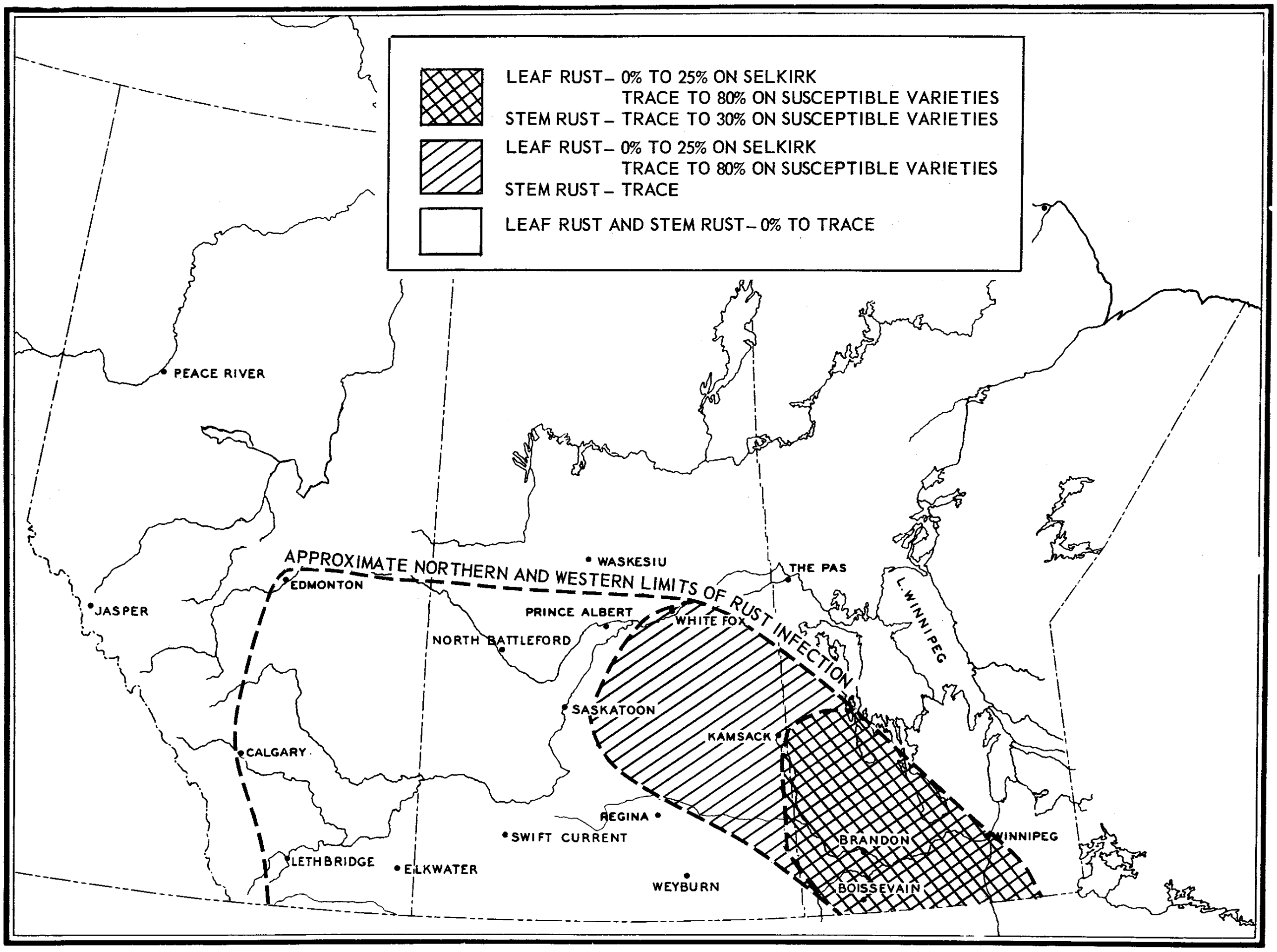

FIG. 1. OUTLINE MAP OF PRAIRIE PROVINCES SHOWING APPROXIMATE AVERAGE INTENSITIES OF LEAF RUST AND STEM RUST OF WHEAT IN 1960.

IMPROVING THE PROTECTIVE FUNGICIDAL ACTIVITY OF NICKEL SULFATE AGAINST LEAF RUST OF WHEAT AND CROWN RUST OF OATS[1]

F. R. Forsyth and F. Jursic

Abstract

A marked improvement in the retention of protective activity of 400 p.p.m. nickel sulfate hexahydrate against leaf rust of wheat and crown rust of oats was noted when the non-ionic surfactant Triton X-114 at 0.1% or the anionic surfactants sulfonated castor oil at 0.1% or a constituent of Atlox G-3300 at 0.25% were included in the solution. The polybutene Indopol L-10 at 0.25% and the petroleum oil Imperial Oil 862-B at 0.3% (the latter for leaf rust only) were also effective. This activity persisted after the application of one-half inch of simulated rain. Less improvement was shown with the addition of the non-ionic surfactants Triton X-100 at 0.1% and Triton B-1956 at 0.08%, the anionic surfactant dodecylbenzene sodium sulfonate at 0.25% or the cationic surfactant Hyamine 3500 at 0.03%. The chemicals Indopol L-10 at 0.75%, dodecylbenzene sodium sulfonate at 0.25%, the constituent of Atlox G-3300 at 0.25%, Hyamine 3500 at 0.03% and the petroleum oil Imperial Oil 862-B at 0.3% were fungicidal in the absence of nickel sulfate. The protective activity of the Indopol L-10, the Imperial Oil 862-B and dodecylbenzene sodium sulfonate, all used with nickel, persisted through the application of one-half inch of rain.

Introduction

Inorganic salts of nickel have been used (5) to control wheat leaf rust (*Puccinia recondita* Rob. ex Desm.) on Thatcher, Marquis and Red Bobs wheat in the field. The success of the nickel salts in field use seemed attributable to their ability to eradicate the rust infections present in the leaf and not to any protective action of the nickel. This was somewhat surprising since nickel compounds had been shown to be effective as protective fungicides against leaf rust in the greenhouse (5) at concentrations one-fourth of those required for eradicative action. However, it had been shown (5), (6) that the protective action of the nickel was rather easily removed with simulated rain. Various surfactants had been used in studies (5), (6) and (7) of nickel as a fungicide but no systematic study had been made of the relative effectiveness of spray additives in improving the protective fungicidal activity of the nickel ion. The present study is a report of greenhouse experiments designed to compare the effectiveness of various compounds, mainly surface active agents, in enhancing the protective action of inorganic nickel compounds both with and without simulated rain.

[1] Contribution No. 191 from the Pesticide Research Institute, Canada Department of Agriculture, Research Branch, London, Canada.

The polybutene (Indopol L-10) was included because of the report (4) that the polybutenes control powdery mildew of roses (Sphaerotheca pannosa (Wallr. ex Fries) Lév.

The Imperial Oil 862B was included since similar oils are known to be efficient (2) in controlling Mycospharella musicola Leach (Cercospora musae Zimm.) and because it had shown some promise as a protective fungicide against the cereal rusts in preliminary field tests at Winnipeg.

Methods

Plant material was obtained by growing Thatcher wheat or Victory oat seedlings in soil in 4-in. earthenware pots. When the first leaves of the seedlings were about 3 in. long they were used in the test of protective activity. The fungicides were applied to the surface of the seedling leaves by atomizing 100 ml of solution onto the seedlings in 6 of the pots. There were 8 - 10 seedlings in each pot. A paint sprayer nozzle operated by compressed air was used to direct the atomized spray onto the seedlings as the pots were rotated on a turn-table. The seedlings were allowed to dry before rust urediospores were sprayed on with a second spray nozzle. The urediospores were dispersed in a water solution by shaking rusted leaves in a weak solution of sulfonated castor oil in water (3 drops per 100 ml). The urediospores in water were applied at the rate of 50 ml to 20 pots of seedlings. The seedlings were then incubated for 24 hours in a moist chamber. The number of uredia on each leaf was counted 10 days later.

The average number of infections per untreated leaf varied from one experiment to the next, the range being between 50 and 200. To present the data as percentage infection the values have all been adjusted to correspond with a value of 100 infections per leaf on the untreated plants. For example, if the average number of infections per leaf on the untreated leaves in an experiment was 50.0 and for treatment A it was 3.0 then each value would be multiplied by 2 and the values entered in the table as 100 for the untreated and 6.0 for treatment A.

In experiments to determine the effective life of the fungicide on the leaf surface it was necessary to mark each leaf at the time of application by searing the leaf with the tip of a small soldering iron at a point approximately 1 cm above the base of the leaf blade. Whenever counts were made of the number of infections per leaf only the infections above this necrotic spot were counted.

Distilled water directed with a pressure of 10 pounds/sq. in., through a nozzle giving a fan shaped spray pattern, was used to simulate rain. The spray was directed on the seedlings as the pots rotated on the turn-table. A Petri dish marked at the one-half inch depth rotated with the seedlings and was at the same height as the soil surface in the pots. When the spray water was one-half inch deep in the dish it was considered that the seedlings had received the equivalent of one-half inch of rain.

Atlox G3300 (supplied by Atlas Powder Company, Canada Ltd., Brantford, Ont.), mentioned in the Tables, was actually a fraction of this compound. The Atlox, in water solution, was extracted with petroleum ether and the water soluble fraction was passed through the Dowex 50 W X 8 ion exchange resin column. The material that passed through the Dowex 50 was evaporated to dryness and used as the additive. The fraction was presumably a sulfonic acid constituent of the original mixture.

Santomerse I (obtained from Monsanto Canada Ltd., Montreal, Que.) was extracted with absolute ethyl alcohol and the alcohol was filtered to remove sodium sulfate. The ethyl alcohol was removed under vacuum and the material remaining, presumably dodecylbenzene sodium sulfonate, was used as the spray additive.

A 25% stock solution of Indopol L-10 (supplied by R.J. Brown of Canada Ltd., Toronto, Ont.) was prepared by mixing 50 ml xylene, 50 ml Indopol L-10, 1 ml Tween 81 and 99 ml water.

Triton X-114 (a water soluble octylphenoxypolyethoxy ethanol) and Triton X-100 (a water soluble iso-octylphenoxy polethoxy ethane) were considered to be 100% active and were used as supplied by the Rohm and Haas Co. of Canada, West Hill, Ont. Triton B-1956 (modified phthalic glycerol alkyd resin, from the same source was considered to be 77% active. Hyamine 3500, also from Rohm and Haas Co. of Canada, is a 50% aqueous solution of a selected blend of alkyl dimethyl benzyl ammonium chlordies.

The Imperial Oil fraction 862B (a petroleum oil fraction) was obtained from Imperial Oil Ltd., Sarnia, Ont. A 25% stock solution was prepared as for Indopol L-10.

Results

Surfactants and Indopol L-10 as additives: The first spray additive in these tests to prove effective in enhancing the protective action of solutions of inorganic salts of nickel was sulfonated castor oil. Various other additives were then tested along with the nickel sulfate against race 5a of leaf rust of wheat and the results are presented in Table 1. The numbers given are the averages from three separate experiments. The surfactants and Indopol L-10 with and without nickel were all excellent protective fungicides in the absence of rain. This has little practical significance except in the control of foliage diseases in the greenhouse. On the other hand the persisting protective action of many of these solutions after exposure to one-half inch of simulated rain was significant. This demonstrated the feasibility of using nickel salts as protective fungicides providing the proper surfactant or other additive was used.

The Indopol L-10 at 0.75% was a good protective fungicide against leaf rust of wheat when used alone. However, it also was an aid in maintaining the activity of the nickel since whenever the L-10 at 0.25% was used alone it did not give reliable protection but when used with 400 p.p.m. nickel sulfate an effective protective fungicide was produced.

The Santomerse at 0.25% proved to be an effective fungicide against leaf rust with and without rain. When it was combined with nickel the protective action in presence of rain was partially lost.

The fact that there are only about 19 infections per leaf on the nickel sulfate treated leaves after rain washing may seem to indicate considerable efficiency on the part of the inorganic salt alone. However, the presence of 19 infections on a wheat leaf provides such a large amount of inoculum that subsequent increase in the number of infections is very rapid. Probably an average of not more than 1.0 infection per leaf should be considered successful protection.

Table 1. The protective activity of nickel sulfate combined with surfactants, Indopol L-10 or Imperial Oil 862-B against leaf rust on Thatcher wheat.

Chemical			Percent Infection No rain	Percent Infection 1/2" rain	Phytotoxicity
Nickel sulfate[a] 400 p.p.m.	+ Triton X-114	0.1%	0.9[b]	0.2	slight
"	+ Triton X-100	0.1%	0.3	2.2	"
"	+ Triton B-1956	0.08%	0.1	6.0	negligible
"	+ sulfonated castor oil	0.1%	0.0	0.4	"
"	+ castor oil	0.1%	0.8	18.4	"
"	+ Atlox G-3300	0.25%	0.0	0.6	"
"	+ Santomerse I	0.25%	0.0	3.9	slight
"	+ Hyamine 3500	0.03%	0.0	2.3	negligible
"	+ Indopol L-10	0.25%	0.0	1.1	"
"	+ Indopol L-10	0.75%	0.0	0.7	"
"	+ Imperial Oil 862-B	0.3%	0.0	0.4	"
Indopol L-10 0.25%			15.3	9.4	"
Indopol L-10 0.75%			1.0	0.6	"
Santomerse I[c] 0.25%			0.0	0.3	slight
Atlox G-330[d] 0.25%			0.3	15.4	negligible
Hyamine 3500 0.03%			1.7	11.8	"
sulfonated castor oil 0.1%			76.3	68.3	"
Imperial Oil 862-B 0.3%			0.7	0.9	"
Triton X-100 0.1%			100.0	100.0	slight
Nickel sulfate 400 p.p.m.			1.88	19.3	negligible
Untreated			100.0	100.0	

[a]Nickel sulfate as $NiSO_4 . 6H_2O$

[b]Each value is the average number of infections per leaf, based on counts of 90 leaves in three separate experiments. All averages have been adjusted on the basis of the untreated leaf having 100 infections.

[c]The dodecylbenzene sodium sulfonate obtained from Santomerse I was used.

[d]The constituent of G-3300 obtained as described in the methods was used.

Table 2. The protective activity of nickel sulfate combined with surfactants or Indopol L-10 against crown rust on Victory oats.

Chemical			Percent Infection		Phytotoxicity
			No rain	1/2" rain	
Nickel sulfate[a] 400 p.p.m.	+ Triton X-114	0.1%	0.7	1.4	medium toxicity
"	+ Triton X-100	0.1%	0.1	0.8	very slight toxicity
"	+ Triton B-1956	0.08%	0.6	1.6	negligible
"	+ sulfonated castor oil	0.1%	1.5	2.0	"
"	+ Atlox G-3300	0.25%	0.0	0.7	reduced growth
"	+ Santomerse I	0.25%	0.0	-	negligible
"	+ Hyamine 3500	0.03%	0.0	-	"
"	+ Indopol L-10	0.25%	0.5	1.4	"
Indopol L-10 0.25%			12.3	4.5	"
Indopol L-10 0.75%			0.3	0.3	"
Santomerse I[b] 0.25%			0.4	2.1	"
Atlox G-3300[c] 0.25%			0.0	22.0	"
Hyamine 3500 0.03%			0.6	-	"
Nickel sulfate 400 p.p.m.			6.3	26.1	"
Untreated			100.0	100.0	"

[a]Nickel sulfate as $NiSO_4 . 6H_2O$

[b]The dodecylbenzene sodium sulfonate obtained from Santomerse I was used.

[c]The constituent of G-3300 was used.

The data presented in Table 2 shows that the activity of the surfactants and Indopol L-10 with and without nickel was about the same when used in solutions against crown rust of oats (*Puccinia coronata* Corda f. sp. *avenae* Erikss.) as against leaf rust of wheat.

Sulfonated castor oil as an additive for other metal salts:

Since the sulfonated castor oil was so effective in enhancing the activity of nickel, experiments were carried out to compare the activity of nickel, copper, zinc and manganese sulfate salts along with sulfonated castor oil against leaf rust of wheat and crown rust of oats. The order of effectiveness was the same for both organisms, with and without rain; nickel > copper > zinc > manganese. Of the metal salts tested in the presence of sulfonated castor oil only the nickel would be considered an efficient protective fungicide with and without simulated rain.

Table 3. Protective activity of copper, zinc, manganese and nickel sulfate salts with sulfonated castor oil

Chemical		Percent Infection: Leaf rust of wheat, No rain	Leaf rust of wheat, 1/2" rain	Crown rust of oats, No rain	Crown rust of oats, 1/2" rain	Phytotoxicity
Copper sulfate[a] 200 p.p.m.						
+ sulfonated castor oil	0.1%	3.2	18.1	7.0	7.5	negligible
Zinc sulfate[b] 400 p.p.m.						
+ sulfonated castor oil	0.1%	9.0	41.9	9.7	27.5	"
Manganese sulfate[c] 400 p.p.m.						
+ sulfonated castor oil	0.1%	22.3	48.8	21.6	41.2	"
Nickel sulfate[d] 400 p.p.m.						
+ sulfonated castor oil	0.1%	0.0	0.6	0.0	0.5	"
Nickel sulfate 400 p.p.m.		25.8	55.5	21.7	34.4	"
Untreated		100.0	100.0	100.0	100.0	

[a]Copper sulfate as $CuSO_4.5H_2O$, [b]Zinc sulfate as $ZnSO_4.7H_2O$

[c]Manganese sulfate as $MnSO_4.H_2O$, [d]Nickel sulfate as $NiSO_4.6H_2O$

Table 4. Protective activity of nickel sulfate and Indopol L-10 against leaf rust of wheat over a five day period

Chemical		Percent Infection — Day of inoculation with rust, 0 being the day of application of the chemical: 0	0 + 1	0 + 2	0 + 3	0 + 4	0 + 5
Nickel sulfate 400 p.p.m.		0.0	8.1	11.7	13.8	17.7	9.1
Nickel sulfate 400 p.p.m.							
+ sulfonated castor oil	0.1%	0.0	4.9	0.5	9.4	1.5	0.5
Nickel sulfate 400 p.p.m.							
+ L-10	0.75%	0.0	0.7	0.3	0.4	0.3	1.0
L-10	0.75%	0.3	4.5	0.3	0.3	1.3	0.9
Untreated		100.0	100.0	100.0	100.0	100.0	100.0

Protective activity during a 5 day period:

The results reported in Tables 1-4 show the effectiveness of sulfonated castor oil and L-10 as additives for increasing the retentive properties of nickel. The method used demonstrated protective activity for only a few hours because the chemical was applied, the leaves were dried, rainwashed and then inoculated all on the same day. This was not a reliable indication of the stability of the protective action over a period of several days.

In Table 4 the results are presented to show the protective action persisting up to five days after the chemical was first applied to the leaf surface. The nickel sulfate plus sulfonated castor oil, nickel plus L-10 at 0.75% and L-10 alone at 0.75% all retain the protective action against leaf rust of wheat for a period of five days. The L-10 at 0.75% by itself appears to be an efficient protective fungicide. In fact the activity of nickel plus L-10 could be accounted for by the activity of the L-10 alone. However, it will be remembered (Table 1) that the L-10 does aid in the retention of protective activity of nickel.

The next question to answer was whether or not, after a period of weathering in the greenhouse followed by a one-half inch of simulated rain, there would still be sufficient nickel or L-10 on the leaf to protect against leaf rust. In Table 5 the results are shown for the same chemicals as in Table 4 except that in each instance one-half inch of simulated rain was applied three hours before the rust was applied whether this was 0, 1, 2, 3, 4 or 5 days after the chemical was applied.

Table 5. Protective activity of nickel sulfate and Indopol L-10 over a five day period against leaf rust of wheat, 1/2" of rain applied.

Chemical		Percent Infection Day of inoculation with rust[a], 0 being the day of application of the chemical					
		0	0 + 1	0 + 2	0 + 3	0 + 4	0 + 5
Nickel sulfate 400 p.p.m.		33.9	22.5	35.4	48.5	37.0	24.9
Nickel sulfate 400 p.p.m. + sulfonated castor oil	0.1%	1.6	0.6	1.3	3.4	1.4	4.4
Nickel sulfate 400 p.p.m. + L-10	0.75%	0.1	0.05	0.9	0.4	0.14	0.2
L-10	0.75%	0.2	0.7	1.3	0.9	2.3	0.8
Untreated		100.0	100.0	100.0	100.0	100.0	100.0

[a]The plants were washed with 1/2" of rain, allowed to dry and then were inoculated.

The nickel sulfate with sulfonated castor oil or with L-10 and the L-10 alone at 0.75% provided effective protection even after one-half inch of rain. This rain could be applied from 0-5 days after the application of the chemicals without removing the protective action. There are a few instances in Table 5 of more than the theoretical maximum of 1.0 infection per leaf, for effective protective action, but the improvement in tenacity of the nickel with the additives is obvious.

Discussion

The possibility existed that one or more of the surfactants or additives used in this study would interfere with the protective activity of nickel sulfate even in the absence of rain. During the incubation period of inoculated seedlings there is a certain amount of drip-off of water from the leaves. This might have been accentuated by the presence of surfactants. However, the results indicate no such interference. On the contrary a decided improvement in the retention of protective activity of nickel sulfate in the presence of rain was found with added Triton X-114, sulfonated castor oil, Atlox G3300 and Indopol L-10. Less improvement was shown with added Triton X-100, Triton B-1956, Santomerse I and Hyamine 3500. In the case of the surfactants the most logical explanation for this added protection is the formation of a complex between the nickel and the additive. The Indopol L-10 and Imperial Oil 862B may act by a physical interference with the washing action of the rain on nickel sulfate. Furthermore, at the concentrations used, Indopol L-10, Santomerse I, Atlox G3300, Hyamine 3500 and Imperial Oil 862B were fungicidal when used without nickel sulfate.

The fact that Indopol L-10 at 0.75%, Santomerse at 0.25% and Imperial Oil 862B at 0.3%, all showed effective protective action in absence of nickel and after simulated rain is of considerable practical interest. Fisher (4) reported that a 5% emulsion of L-10 provided excellent protection from infection with powdery mildew of cucumbers in thegreenhouse. The 0.75% emulsion of L-10 required here is less than that required to protect against mildew but is nevertheless a high concentration of fungicide. The low cost of the polybutenes allows further consideration of these compounds as possible fungicides. The L-10 and L-100 polybutenes were found in preliminary tests to be superior to the more viscous polybutenes in controlling leaf rust of wheat and crown rust of oats. More detailed information about the comparative effectiveness of the polybutenes will be published at a later date.

Santomerse as used here was the sodium salt of dodecylbenzenesulfonic acid. It has consistently provided somewhat better protection against the rusts when used alone than when used with nickel compounds in the presence of simulated rain. It will be interesting to compare the mode of action as a fungicide (of this anionic surfactant) with that of the cationic surfactants (e.g. dodine (1)).

Imperial Oil 862B and presumably other closely related hydrocarbon fractions can be applied in the form of emulsions in low volume and with good leaf coverage. Calpuzos et al. (3) have noted fungistatic activity of an oil spray used against *Mycosphaerella musicola*. Imperial Oil 862B is fungistatic to rust infections when applied post-infection in greenhouse tests, but the delay in growth of rust infections (leaf rust of wheat and crown rust of oats) lasts for 3 or 4 days only and the final extent of growth of the rust infection is approximately that of the checks. In these tests there is definite evidence of protective fungicidal activity on the part of the oil.

The results of this paper have shown that it is possible to enhance the residual protective action of nickel salts with surfactants and other additives. They also provide evidence that the polybutene Indopol L-10, certain anionic (dodecylbenzene sodium sulfonate and the constituent of Atlox G-3300) and cationic (Hyamine 3500) surfactants and the oil Imperial Oil 862-B can be effective fungicides against the cereal rusts.

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