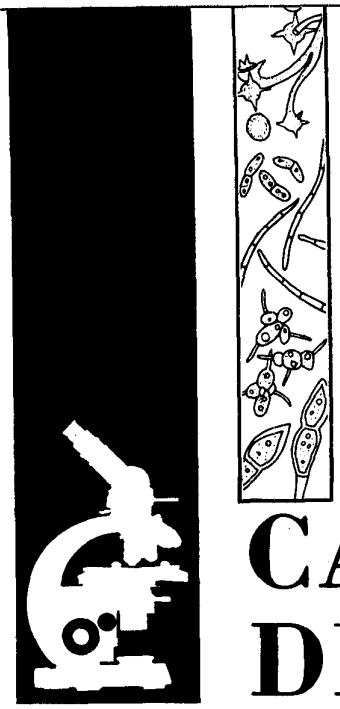
VOL.49, No.3, SEPTEMBER, 1969



CANADIAN PLANT DISEASE SURVEY

EDITOR W.L. SEAMAN

RESEARCH BRANCH CANADA DEPARTMENT OF AGRICULTURE

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CONTENTS

"The Canadian Plant Disease Survey is a periodical of information and record on the occurrence and severity of plant diseases in Canada. It will also accept other original information such as the development of methods of investigation and control, including the evaluation of new materials. Review papers and compilations of practical value to phytopathologists will be included from time to time."

ARSENICAL INJURY TO APPLE FOLIAGE FROM SPRAY MIXTURES CONTAINING LEAD ARSENATE[1]

R.G. Ross and K.H. Sanford[2]

Abstract

Cover spray mixtures of captan and lead arsenate were relatively non-phytotoxic to 'Cortland' apple foliage. The amount of arsenical injury was increased when ryania was present in dodine - lead arsenate and captan - lead arsenate mixtures. Injury was not consistently reduced when zineb was added to lead arsenate or to a mixture of lead arsenate and dodine, glyodin, or ryania. Azinphos-methyl safened the mixture of dodine and lead arsenate in the first year it was tested but not in the second.

Introduction

In a previous paper, Ross and Sanford (2) reported on the efficacy of fungicides as safeners for lead arsenate on apple foliage. They found that lead arsenate was relatively non-phytotoxic in cover sprays of captan or zineb. Ferbam at the higher of two rates used was better than captan in safening a mixture of dodine and lead arsenate but it did not safen a mixture of glyodin and lead arsenate.

Further experiments have been done on the phytotoxicity to apple foliage of various pesticidal cover spray mixtures containing lead arsenate. Results obtained are presented in this paper.

Materials and methods

In 1966 and 1967 the same 'Cortland' apple trees and the same randomized block design of three replicates of 10 treatments were used as in previous work (2). Dilute sprays were applied with a hand gun and the trees were sprayed to run-off. Each year the trees were sprayed eight times, but the treatments containing lead arsenate (Table 1) were applied only in the last three applications, at about 10-day intervals beginning near July 1. Prior to the lead arsenate treatments the plots receiving treatments 1 and 8 were sprayed five times with captan; treatments 2, 3, 4, and 5, with dodine; and treatments 6, 7, 9, and 10, with glyodin.

In 1968 and 1969 another orchard of mature 'Cortland' apple trees, located on light sandy soil was divided into three blocks, each containing seven 6-tree plots. Prior to the lead arsenate treatments the orchard was sprayed regularly with dodine. The treatments were put on as in 1966 and 1967 and consisted of the same number of applications applied at about the same times.

The materials used were:

Cyprex 65-W, dodine 65%. Cyanamid of Canada, Ltd., Rexdale, Ont.

"Crag" Glyodin Solution Protective Fungicide, glyodin, 34%. Union Carbide Canada Ltd., Toronto, Ont.

Captan 50-W, captan, 50%. Stauffer Chemical Co., New York, N.Y.

Parzate C, zineb, 75%. DuPont of Canada, Ltd., Montreal, P.Q.

Glyodex, dodine, 16.35% + glyodin, 50.09%. Green Cross Products, Montreal, Que.

Lead arsenate. Niagara Brand Chemicals, Burlington, Ontario.

Ryanicide 50 WP, ryania (powdered stem of Ryania speciosa), 50%. S.B. Penick and Co., New York, N.Y.

Guthion 25-W, azinphos-methyl, 25%. Niagara Brand Chemicals, Burlington, Ontario

In September the foliage of each tree in each plot was rated for arsenical injury on a scale of 0 to 5, 0 being the foliage of trees with no arsenical injury and 5 being the most severely injured. At a rating of 5 about 50% of the leaves on a tree would have necrotic areas or marginal necrosis. With a rating of 1, there would be only a trace of injury and with a rating of 2, the injury would be light and not considered serious.

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[1] Contribution No. 1366, Research Station, Canada Department of Agriculture, Kentville, Nova Scotia.

[2] Plant Pathologist and Entomologist, respectively.

Table 1. Arsenical injury on apple foliage in 1966 and 1967

Treatment and rate per 100 gal	Arsenical injury*		
	1966	1967	Avg
Lead arsenate, 3.0 lb +			
1. captan, 50%, 1.5 lb	0.6	1.0	0.8
2. dodine, 65%, 0.5 lb	1.8	1.8	1.8
3. dodine, 65%, 0.5 lb + zineb,75%, 0.5 lb	2.4	1.0	1.7
4. dodine, 65%, 0.5 lb + captan, 50%, 0.5 lb	0.8	1.7	1.2
5. dodine, 65%, 0.5 lb + ryania, 50%, 6.0 lb	2.3	3.5	2.9
6. glyodin, 34%, 1.0 qt (Imp.)	1.8	4.3	3.0
7. glyodin, 34%, 1.0 qt + zineb, 75%,0.5 lb	2.6	1.8	2.2
8. zineb, 75%, 2.0 lb	1.7	0.3	1.0
9. Glyodex†, 0.5 lb	2.4	3.3	2.8
10. Glyodex†, 0.5 lb + zineb, 75%, 0.5 lb	1.3	2.5	1.9

* 0 = no injury; 5 = most severe injury.

† Glyodex contains dodine, 16.35%, and glyodin, 50.09%.

Results and discussion

The results given in Tables 1 and 2 are the average of the three replicates for each treatment in each year. The variation among years agrees with a previous test (2). Mixtures of glyodin and lead arsenate are usually very phytotoxic but in 1966 they caused little injury (Fig. 1). In 1967 they were the most phytotoxic of the treatments. Previously (2) zineb was considered to be a good safener, but its effectiveness apparently varies from year to year whether used with lead arsenate alone or with lead arsenate in combination with other fungicides.

In cover sprays ryania and lead arsenate are often used together to control the codling moth and apple maggot, respectively. Adding ryania to the fungicide - lead arsenate mixture increased the amount of arsenical injury more with dodine as the fungicide than with captan or zineb. In 1968 azinphos-methyl, which is used for codling moth control, safened dodine and lead arsenate, but it was not as effective in 1969.

Captan appears to be the most reliable safener for lead arsenate, particularly when the mixture contains ryania (Table 2). Here (Table 1) and in previous work (2), captan at 0.5 lb/100 gal has also been fairly effective as a safener for a dodine - lead arsenate mixture. In Nova Scotia zineb is considered to be more effective than captan as a final cover spray on apples for the control of late or pin-point

Figure 1. Arsenical injury on leaves of 'Cortland' apple.

Table 2. Arsenical injury on apple foliage in 1968 and 1969

Treatment and rate (lb/100 gal)	Arsenical injury*		
	1968	1969	Avg
Lead arsenate, 3.0 +			
1. captan, 50%, 1.5	1.3	1.6	1.5
2. captan, 50%, 1.5 + ryania, 50%, 6.0	1.7	2.2	1.9
3. dodine, 65%, 0.5	2.4	2.8	2.6
4. dodine, 65%, 0.5 + ryania, 50%, 6.0	3.5	3.3	3.4
5. dodine, 65%, 0.5 + azinphos-methyl, 25%, 1.0	1.1	2.4	1.7
6. zineb, 75%, 2.0	2.7	2.3	2.5
7. zineb, 75%, 2.0 + ryania, 50%, 6.0	2.9	3.2	3.0

* 0 = no injury; 5 = most severe injury.

scab. The results here show that it is not always an effective safener for lead arsenate, although this might depend on the orchard in which it is used. The tests in which it was not too effective (Table 2) were conducted in a different orchard than the one from which the results reported in Table 1 and in previous work (2) were obtained. The pre-treatment sprays schedules also differed in the two orchards.

The variability of results between orchards and among seasons may be due to the pre-lead arsenate spray program or, as has been suggested before (2), to the nutritional status of the orchard and climatic conditions. In Nova Scotia arsenical injury rarely occurs in orchards on the heavier soils. July and August of 1968 and 1969 were drier than normal and, except where azinphos-methyl was used, the results were quite similar for the 2 years. Rainfall for these 2 months in 1966 was 2.6 inches less than for the same period in 1967 and there was considerable variation in the 2 years' results. According to Hilborn et al. (1) lead arsenate is more injurious in hot dry summers. The results here suggest that the seasonal effect may also vary with the components of the spray mixture in which lead arsenate is used.

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EFFECT OF BENOMYL ON BLACK ROOT ROT OF TOBACCO CAUSED BY THIELAVIOPSIS BASICOLA[1]

S.K.Gayed [2]

Abstract

Benomyl at concentrations of 1-2 ppm was fungistatic to Thielaviopsis basicola (Berk. and Br.) Ferr. in culture, whereas 5 ppm was fungicidal. Dipping roots of 4-week-old tobacco (Nicotiana tabacum L.) seedlings in a suspension containing 15 ppm benomyl protected them against black root rot infection under controlled conditions in a growth chamber, but such treatment failed to protect older seedlings when transplanted into heavily infested soil in the field. Benomyl mixed with infested soil in pots at concentrations of 1,3, and 10 ppm significantly reduced black root rot infection. In a heavily infested field, row treatment at the rate of 6.25 kg benomyl/ha considerably checked the disease. The effectiveness of benomyl on black root rot may be due to the contact effect of the fungicide on T. basicola as well as to the systemic effect.

Introduction

Black root rot of tobacco caused by the soil borne fungus Thielaviopsis basicola (Berk. and Br.) Ferr. is the most serious disease of flue-cured tobacco in Canada. It attacks the root system forming black lesions of disintegrated tissue. Maturity of infected plants is delayed and, as they are stunted, their yield is poor.

The new systemic fungicide Benlate (Du Pont of Canada Ltd., Toronto, Ont.), previously known as Fungicide 1991, is a 50% wettable powder of benomyl (1-[butylcarbamoyl]-2-benzimidazole carbamic acid, methyl ester). It has been effective in controlling several fungal diseases, e.g. damping off (2), verticillium wilt (3), powdery mildews (4), and fruit rots (6). The present paper reports the effect of benomyl on the growth of T. basicola in culture and on the black root rot disease under controlled conditions and in the field.

Materials and methods

In all experiments concentrations of benomyl are expressed as amounts of active ingredient.

For testing the effect of benomyl on the growth of Harrow and Ky 1238-1 strains of T. basicola, the chemical was mixed with potato dextrose agar (PDA) at rates between 0.01 and 100 ppm and poured into petri dishes. Four dishes were prepared for each concentration, inoculated with standardized mycelial discs of either Harrow or Ky 1238-1 strain, and incubated for 2 weeks at 25C. Linear growth was measured daily. Mycelial discs which did not grow in the presence of benomyl were transferred to PDA to find out whether the treatment was fungicidal or fungistatic.

To evaluate the effect of benomyl on black root rot, experiments were carried out in a growth chamber and in the field.

GROWTH CHAMBER EXPERIMENTS

The fungicide was applied as a root dip or as a soil amendment:

Root dip - Roots of 4-week-old tobacco seedlings were dipped in water or in a 5 ppm suspension of benomyl for 24 hr. The water or suspension was continuously stirred by a magnetic stirrer. The seedlings were then planted in pots in steam-sterilized sandy soil which was subsequently infested with T. basicola endoconidia at a rate of 10,000 endoconidia per gram soil;

Soil treatment - inoculated sandy soil was mixed with benomyl at the rate of 0,1,3, or 10 ppm by weight and distributed in pots. After 3 days seedlings were transplanted to the pots.

In growth chamber experiments, the Harrow strain of T. basicola was used as inoculum. Each treatment consisted of twelve pots with two seedlings of tobacco (Nicotiana tabacum L.), variety Hicks Broadleaf. The pots were randomized in a growth chamber adjusted to 17-19C, a relative humidity of about 68%, and light intensity of about 3,000 ft-c for 16 hr/day. After 5 weeks, the seedlings were carefully uprooted and the roots cleaned and rated for disease lesions, using a scale of 0-5, with 0 representing no lesions and 5,

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[1] Contribution No. 49, Research Station, Canada Department of Agriculture, Delhi, Ontario.

[2] Plant Pathologist.

complete coverage of the root by lesions. The fresh and dry weights of the seedlings were obtained, and the results were statistically analysed.

FIELD TRIALS

An experiment was carried out in 1968 in a heavily infested field grown with tobacco for the last 13 years. The experiment consisted of single-row plots 10.5 m long with 105 cm between the rows and 45 cm between plants. Three treatments and two checks were arranged in a randomized block design replicated four times. Benomyl was applied as follows:

Root dip - roots of tobacco seedlings at the transplanting stage were dipped for 24 hr either in stirred water of in a suspension containing 5 ppm benomyl.

Soil treatment - 7.22 g of the wettable powder (equivalent to 6.25 kg/ha) was suspended in 1 liter of water and was uniformly sprayed in a 20-cm band along the row. A rototiller was used to incorporate the chemical in the soil to a depth of 10 cm. The treatment was made on June 3, eight days before planting;

Treatment of the planting water - 150 cc/plant of a suspension containing 15 ppm benomyl was used as planting water.

Shoot length was measured on July 15. On August 21, plants number 4,7,10,13, and 16 in each row were dug out carefully. Their roots were cleaned and black root lesions were rated. Fresh and dry weight of shoots were obtained.

Results and discussion

Low concentrations of benomyl in PDA medium were highly toxic to Harrow and Ky 1238-1 strains of T. basicola in culture. Increasing the concentration of benomyl in the medium between 0.1 and 1.0 ppm gradually decreased the growth rate of the fungus. Concentrations between 1 and 2 ppm were fungistatic, whereas 5 ppm was fungicidal.

In the soil inoculation experiment, dipping roots of 4-week-old tobacco seedlings in a 5 ppm suspension of benomyl for 24 hr induced protection against black root rot under controlled conditions in the growth chamber (Table 1). Such treatment failed, however, to protect 7- to 8-week-old transplanted tobacco seedlings against infection in the field (Table 3). This may have been due to the difference in age of the treated seedlings or to the prevailing environmental conditions, including temperature, inoculum potential of the pathogen, and soil water content. It has been established that these factors affect the incidence and severity of the black root rot disease of tobacco (5).

Treatment of infested soil with benomyl at concentrations of 1,3, and 10 ppm checked black root rot infection in pots and increased growth of tobacco seedlings, as compared with seedlings grown in infested, untreated soil (Table 2).

Under heavy field infestation, benomyl rototilled into the row at a rate of 6.25 kg/ha considerably reduced black root rot infection. Such effect was clear in July and became more pronounced in August (Table 3). At harvest, roots and shoots of plants in the treated rows were much further developed than the check plants, which were stunted and had root lesions ratings significantly higher than the treated plants (Fig. 1). Effectiveness in the field may be due to a contact effect of the fungicide on T. basicola in the soil, as well as to systemic action. Since the manufacturers of benomyl suspect the stability of the compound (1), a decomposition product (3) may also be a factor in black root rot control.

Table 1. Effect of dipping roots of tobacco seedling in benomyl suspension for 24 hr on black root rot infection under controlled conditions in a growth chamber

Treatment	Seedling fresh weight (g)	Seedling dry weight (g)	Root lesion rating*
Benomyl, 5 ppm	5.08 ± 0.41**	0.39 ± 0.03**	1.45 ± 0.19**
Water (check)	1.62 ± 0.11	0.19 ± 0.01	3.38 ± 0.17

* 0 = no visible lesions, 5 = lesions covering the root surface

** Significant compared with the check (P = 0.01)

Table 2. Effect of soil treatment with benomyl on severity of black root rot under controlled conditions in a growth chamber

Concentration of benomyl (ppm)	Seedling fresh weight (g)	Seedling dry weight (g)	Root lesion rating*
1	4.97 ± 0.67**	0.52 ± 0.065**	0.17 ± 0.047**
3	4.40 ± 0.48**	0.45 ± 0.045**	0.05 ± 0.021**
10	5.18 ± 0.55**	0.51 ± 0.052**	0.02 ± 0.01**
Check	2.59 ± 0.23	0.28 ± 0.026	2.63 ± 0.23

* 0 = no visible lesions, 5 = lesions covering the root surface

** Significant compared with the check (P = 0.01)

Table 3. Effect of different treatments with benomyl on the severity of black root rot of tobacco in a highly infested field, 1968

Treatment	Shoot length (cm)		Shoot fresh wt (g)	Shoot dry wt (g)	Root lesion rating*
	July 15	August 21			
Seedling roots dipped in 5 ppm benomyl for 24 hr	12.8	54.7	224	29.0	3.8
Seedling roots dipped in water for 24 hr	12.5	52.8	166	26.1	3.8
Benomyl rototilled into the row at 6.25 kg/ha	16.2	102.0	559	77.5	1.2
Benomyl in planting water, 15 ppm; 150 cc/plant	13.5	62.8	228	30.0	3.6
Check	12.9	55.6	169	25.5	3.6
L. S. D. 0.05	1.89	13.16	98.97	12.76	0.40
0.01	2.66	18.47	136.92	17.91	0.56
Coefficient of variation	9%	13%	24%	22%	8%

* 0 = no visible lesions, 5 = lesions covering root surface.

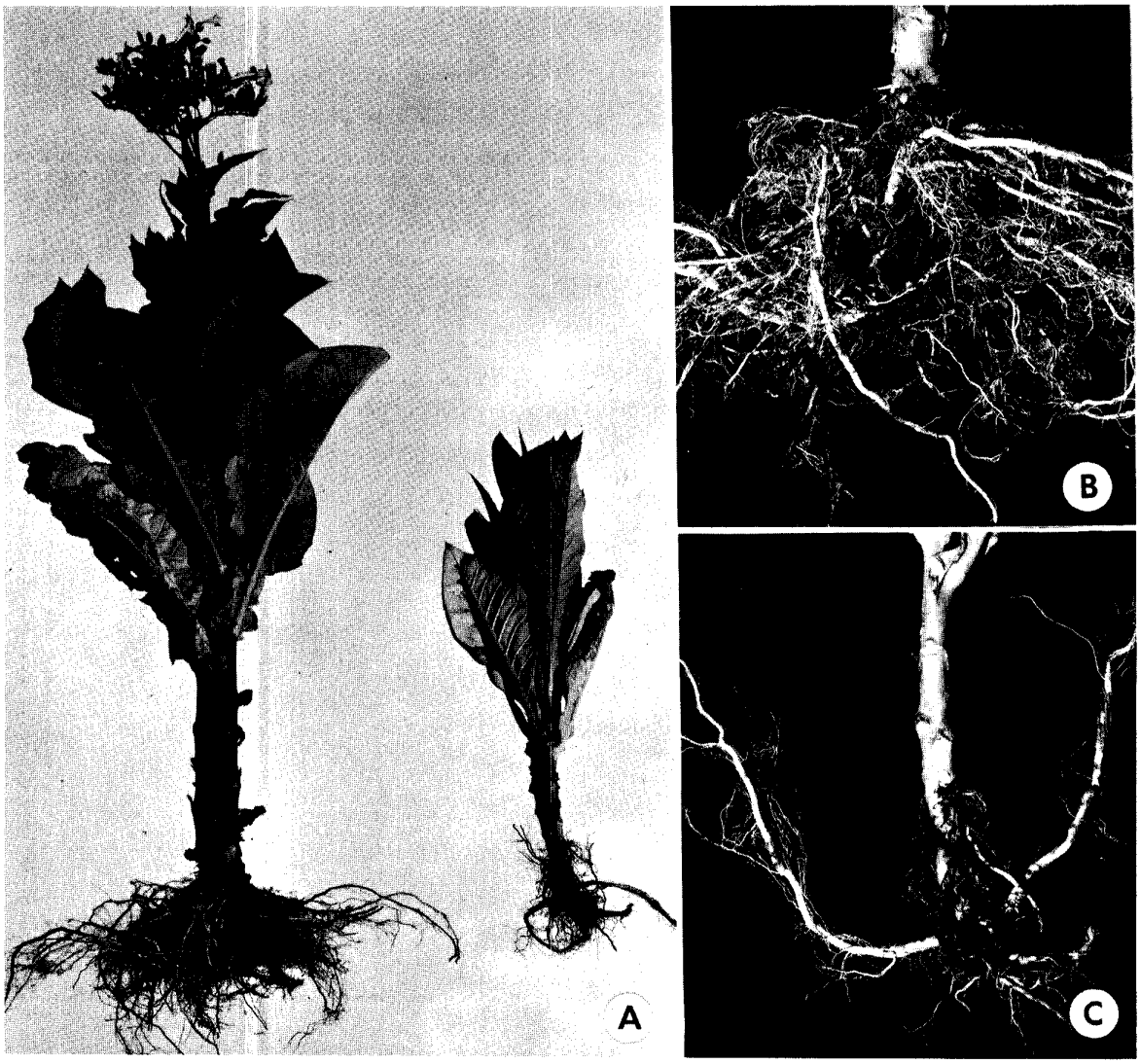

Figure 1. Relative development of tobacco plants grown in a field heavily infested with *Thielaviopsis basicola*. A) (left) plant treated with benomyl rototilled into the row at the rate of 6.25 kg/ha; (right) untreated check; B) root from treated soil; C) root from untreated soil.

Benomyl applied in the planting water at a concentration of 15 ppm had no appreciable effect on the disease in the field. Trials on the effect of benomyl on the physical and chemical properties of tobacco leaf are in progress.

Acknowledgments

Thanks are due to D.A. Brown for his technical assistance throughout this work. Thanks are also due to N.L. Jerry, CDA Research Institute, London, Ontario, for preparing the photographs.

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SCREENING OF POTATO FUNGICIDES IN 1969[1]

L.C. Callbeck[2]

Introduction

Although weather conditions were often suitable to the development and spread of late blight fungus, Phytophthora infestans (Mont.) de Bary, potato growers of the province of Prince Edward Island enjoyed a relatively disease-free season in 1969. Because there had been almost no disease in the dry summer of 1968, sources of inoculum were probably few in the spring of 1969, thus limiting the number of fields initially attacked. This, coupled with adequate spray schedules, held the disease in check and losses were negligible.

A severe epidemic developed in the test plots following inoculations made in late July, making it possible to obtain relative comparisons on the efficacies of the several products in controlling the disease.

Materials and methods

The nine fungicides briefly described below were entered in the 1969 Screening Test at Charlottetown. Of these, numbers 1, 6, and 7 were being studied for the first time.

1. CA 6904. Cela, Ingelheim, Germany. Confidential. 1.0 and 1.5 lb/acre.

2. Daconil 2787 75W. Diamond Shamrock Chemical Company, Painesville, Ohio, U.S.A. Tetrachloroisophthalonitrile. 1.5 lb/acre.

3. Difolatan 4 Flowable. Chevron Chemical Company, Cherry Hill, N.J., U.S.A. N(1,1,2,2, tetrachloroethyl) sulfenyl-cis-4-cyclohexene-1, 2-dicarboximide. 0.8 Imp. qts/acre.

4. Dithane M-45 80W. Rohm and Haas Company of Canada Limited, West Hill, Ontario, Canada. Zinc coordinated manganese ethylenebis-(dithiocarbamate). 1.5 lb/acre.

5. Du-Ter 50W. Philips-Duphar, Amsterdam, Holland. Triphenyltin hydroxide. 7.0 oz/acre.

6. MBR 4880 50W. 3M Company, St. Paul, Minnesota, U.S.A. Confidential. 1.5 lb/acre.

7. NF-35. Nippon Soda Company Limited, Tokyo, Japan. 1,2-bis(3-ethoxycarbonyl-2-thioureido) benzene. 1.75 lb/acre.

8. Polyram 80W. Niagara Brand Chemicals, Burlington, Ontario, Canada. Zinc activated polyethylene thiuram disulfide. 1.5 lb/acre.

9. Siaprit. S.I.A.P.A., Rome, Italy. Ethylene thiuram monosulfide. 3.5 lb/acre.

The plots, each 50 feet long by four rows wide, were planted on June 6, 50 seed pieces of the blight-susceptible variety Green Mountain being dropped in each row. Single rows of the same variety were planted as buffers between plots and as borders for the area. The treatments were randomized and replicated in five ranges.

Insects were controlled by spraying all the rows with endosulfan on July 10 and August 11 and 29.

The fungicides were applied by means of a tractor-sprayer unit, the boom of which carried four nozzles per potato row, two being above the plants and two on drop pipes. The dates of the applications were July 16 and 24, August 1, 8, 15, and 22, and September 4 and 11. The test was terminated by spraying the plants with a sodium arsenite top killer on September 23.

An epidemic of late blight was introduced by sprinkling the buffer and border rows with a water suspension of spores of race 1, 2, 3, 4, 5, 6, 7 in the evening of July 25 when dew was accumulating and in the morning of July 27 following a rain of 0.42 inches. There was a trace of rain on the 28th and a recordable amount on each of the next 3 days. A few lesions were observed on July 30. By mid-August the unsprayed check plots had reached a mean defoliation of 20 percent and the means of the treated plots varied from a trace to 10 percent. The disease was rather inactive during the dry period of August 21 - September 5 but developed well under the influence of later rains. Rains of 1.40, 0.06, 0.44, and 0.08 inches were recorded for the 4 days of September 6-9 and of 0.02, 0.04, 0.96, and 0.04 inches for the 4 days of September 15-18.

Defoliation readings were taken at appropriate intervals until September 18, after which an unusually early frost (September 20) caused some injury and made further accurate readings impossible. On

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[1] Contribution No. 213, Research Station, Canada Department of Agriculture, Charlottetown, Prince Edward Island.

[2] Plant Pathologist.

Table 1. Percentage defoliation

Treatment	Aug. 18	Aug. 27	Sept. 10	Sept. 18
Daconil 2787	Trace	Trace	1	3
Dithane M-45	Trace	1	1.5	3
Polyram	Trace	1	2	4
CA 6904 (1.5 lb.)	Trace	Trace	1	5
Siaprit	0.5	2	4	7
Difolatan 4F	0.5	2	5	7
CA 6904 (1.0 lb.)	0.5	1	3	8
MBR 4880	4	6	14	24
Du-Ter	4	10	16	24
NF-35	10	16	35	67
Check	20	25	60	97

Table 2. Effects of treatments on yield and rot

Treatment	Total (bu/acre)	Smalls (bu/acre)	Rot (bu/acre)	No. 1 (bu/acre)	Rot (%)
Daconil 2787	510.2	63.6	0.0	446.6	0.0
Dithane M-45	506.0	65.5	1.8	438.7	0.4
Polyram	502.9	66.2	1.1	435.6	0.2
Siaprit	500.5	70.6	5.3	424.6	1.1
CA 6904 (1.5 lb.)	483.7	64.0	0.4	419.3	0.1
Difolatan 4F	490.1	71.7	0.0	418.4	0.0
CA 6904 (1.0 lb.)	489.7	73.5	1.3	414.9	0.3
MBR 4880	427.1	75.0	2.4	350.2	0.6
Du-Ter	426.1	77.2	3.5	345.4	0.8
NF-35	351.1	82.7	1.8	266.6	0.3
Check	338.1	93.0	3.5	241.6	1.0
LSD 0.05	56.4			57.3	0.5
LSD 0.01	75.1			76.3	0.7

this basis, the relative performances of the fungicides are shown in Table 1.

The tubers were lifted, graded, and examined for late blight rot on October 16-17. These data are presented in Table 2.

Results and discussion

Under the conditions of the test, the fungicides Daconil 2787, Dithane M-45, Polyram, CA 6904, Siaprit, and Difolatan 4F gave good control of late blight on the foliage. MBR 4880, Du-Ter, and NF-35 gave poor control, the last named showing no merit. In general, the effectiveness of the fungicides in controlling boliage blight was reflected in the yields of tubers; yields of the plots treated with the three inferior fungicides were significantly lower than those of the plots treated with the six that provided good protection.

The losses from tuber rot were small in 1969 and two of the fungicides, Daconil 2787 and Difolatan 4F, gave complete control.

None of the fungicides showed phytotoxic effects.

AIR-BORNE RUST INOCULUM OVER WESTERN CANADA IN 1969[1]

G.J. Green[2]

Urediospores were caught on vaseline-coated microscope slides exposed in spore traps at six locations in Manitoba and Saskatchewan. The procedures were consistent with those used previously in this project. Slides were coated with vaseline, placed in protective frames, and carefully wrapped to prevent contamination at Winnipeg. They were sent to the spore trap locations, excepting Saskatoon, where they were exposed for 48-hour periods in spore traps that held them at an angle of 45 degrees from the horizontal. After exposure they were returned to Winnipeg, where they were examined by means of a microscope for the presence of urediospores. Slides exposed at Saskatoon were prepared and examined by the staff of the Canada Department of Agriculture Research Station, Saskatoon.

Small numbers of spores were caught in 1969 (Table 1). Stem rust spores (Puccinia graminis Pers.) were much scarcer than usual and the leaf rust (P. recondita Rob. ex Desm. and P. coronata Cda.) counts, although much larger than those of stem rust, were small when compared with former years. There was more inoculum in Manitoba than in Saskatchewan. More spores were caught at Regina than at Brandon (Table 1) but most of the Regina spores were caught during two exposures and may not be representative of actual conditions. The trapping of relatively large numbers of spores during the last half of June at Saskatoon was unexpected. The build up of inoculum at Saskatoon normally is later than at the other locations and its early appearance seems to be a local peculiarity in 1969.

Small numbers of stem rust and leaf rust spores were carried into Western Canada during May and June, but rust was not found until July 9. Light infections of leaf rust developed on commercial wheat varieties (Triticum aestivum L.) during the remainder of the season, but wheat stem rust was not found in farm fields and developed only in plots of susceptible varieties and on susceptible wild barley (Hordeum jubatum L.). It could not be found readily on wild barley in eastern Saskatchewan until early October. Heavy infections of oat crown rust developed in late oat fields in Manitoba during the first half of August and probably contributed to the number of spores caught. Oat stem rust infections were light. The number of spores trapped during late July and August parallels rust development in the field. Ten days to two weeks after the first appearance of rust in plots of susceptible varieties on July 9, the numbers of spores caught began to increase and reached a maximum about August 20.

Rust development and the number of spores trapped may have been governed largely by weather conditions in 1969. The early part of the growing season was cool and wet, but hot dry weather prevailed during much of August. Rust development seems to have been delayed by the cold weather early in the season but was encouraged by the warm weather in August.

[1] Contribution No. 407, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

[2] Plant Pathologist.

Table 1. Number of urediospores of stem rust and leaf rust per square inch caught on vaseline-coated slides exposed for 48-hour periods at three locations in Manitoba and three locations in Saskatchewan in 1969

Date	Winnipeg		Morden		Brandon		Indian Head		Regina		Saskatoon	
	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust
May 16-17	0	0	0	0	0	0	0	0	0	0		
18-19	0	0	0	0	0	0	0	0	0	0		
20-21	0	0	0	0	0	0	0	0	0	0	0	0
22-23	0	2	0	0	0	1	0	0	0	0	0	0
24-25	0	0	0	0	0	0	0	1	0	0	0	0
26-27	1	2	0	0	0	0	0	0	0	1	0	0
28-29	0	0	0	0	0	0	0	1	0	0	0	0
30-31	0	0	0	0	0	0	0	0	0	0	0	0
May Total	1	4	0	0	0	1	0	2	0	1	0	0

Table 1 (Cont'd.)

Date		Winnipeg		Morden		Brandon		Indian Head		Regina		Saskatoon	
		Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust
June	1-2	0	0	0	0	0	0	0	0	0	1	0	0
	3-4	0	0	0	0	0	0	0	0	0	0	0	0
	5-6	0	0	0	0	0	1	0	0	0	0	0	0
	7-8	0	0	0	0	0	1	0	0	0	0	0	0
	9-10	0	0	0	0	0	0	0	0	0	0		
	11-12	0	0	0	0	0	0	0	0	0	0	0	0
	13-14	0	0	1	0	0	0	0	1	0	0	0	0
	15-16	0	0	0	0	0	0	1	0	0	0	0	0
	17-18	0	1	0	1	0	0	0	0	0	0	0	26
	19-20	0	1	0	0	0	0	0	0	0	0	0	0
	21-22	0	0	0	0	1	1	0	0	0	0	0	12
	23-24	0	0	0	0	1	1	1	1	1	1	0	12
	25-26	0	0	0	0	1	0	0	0	0	0	0	26
	27-28	0	0	0	0	1	0	0	0	0	0	0	15
	29-30	0	1	0	0	0	0	0	0	0	0	0	9
June Total		0	3	1	1	4	4	2	2	1	2	0	100
July	1-2	1	0	0	0	1	0	0	0	0	0	0	10
	3-4	0	0	0	0	1	0	0	0	0	0	0	30
	5-6	0	2	0	0	0	0	0	0	1	1	0	4
	7-8	1	1	1	2	0	2	0	1	0	0	0	7
	9-10	1	1	1	1	0	0	0	0	0	0	0	15
	11-12	0	4	2	5	2	2	0	11	1	7	0	5
	13-14	1	1	0	3	0	0	0	0	0	1	0	0
	15-16	0	1	1	1	1	2	0	1	0	0	0	0
	17-18	0	2	0	0	0	0	5	13	0	0	0	30
	19-20	0	1	0	0	0	1	1	2	0	0	0	5
	21-22	2	6	2	8	2	17	1	6	0	1	0	9
	23-24	0	5	2	3	0	3	1	4	1	1	0	22
	25-26	0	5	0	4	0	12	9	19	0	1	0	29
	27-28	0	0	0	8	0	11	1	9	0	0	0	57
	29-30	0	25	1	1	1	7	0	6	0	1	0	0
July 31-Aug.	1	0	0	1	7	0	1	1	8	0	2	0	24
July Total		6	54	11	43	8	58	19	80	3	15	0	247
Aug.	2-3	5	67	22	544	1	97	1	5	1	25	5	34
	4-5	1	153	8	230	0	1	1	17	1	32	0	1
	6-7	0	7	11	74	2	87	1	4	0	0	0	18
	8-9	5	75	7	89	2	28	2	8	1	6	11	64
	10-11	4	46	18	150	0	4	2	19	2	16	7	109
	12-13	84	480	38	228	2	140	2	13	2	45	7	20
	14-15	9	70			6	242	2	40	0	0	6	60
	16-17	47	284	28	487	35	693	6	194	6	273	0	45
	18-19	0	15	23	101	13	289	5	150	12	1343	10	70
	20-21	45	449	47	621	46	292	4	100	8	100	1	27
	22-23	120	1029	205	2475	28	1379	5	54	26	918	1	34
	24-25	176	1270	148	2021	29	982	14	124	150	3357	4	34
	26-27	135	1319	62	2070	30	932			6	202	2	62
	28-29	9	137	18	421	19	300	2	41	12	133	1	1
	30-31	14	205	2	69	18	263	2	24	14	504	0	18
Aug. Total		654	5606	637	9580	231	5729	49	793	241	6954	55	597
TOTAL		661	5667	649	9624	243	5792	70	877	245	6972	55	944

LEAF RUST OF WHEAT IN CANADA IN 1969[1]

D.J. Samborski[2]

Disease development and crop losses in Western Canada

Leaf rust was first found in Manitoba on July 9, which is about 2 weeks later than usual. The presence of resistant varieties further delayed rust development and none of the crop was damaged in western Manitoba and Saskatchewan. Late fields in central and eastern Manitoba probably suffered some yield loss but this would not exceed 2 to 3 bushels/acre.

Leaf rust in the rust nurseries

Ratings of leaf rust intensity on 15 wheat varieties grown at nurseries across Canada are shown in Table 1. Leaf rust was widely distributed in Canada but infections were severe only in Manitoba and at a few locations in Ontario. A trace of leaf rust was recorded on 'Frontana' in Manitoba but the infections were of a resistant or moderately resistant type.

Physiologic specialization

In 1969, eight single gene backcross lines were used to study physiologic specialization in leaf rust. These lines contain most of the genes present in earlier sets of differential varieties. In addition, these lines contain all the important genes for seedling resistance in commercial varieties grown in the Prairie Provinces. The distribution of virulence on the individual single gene lines is shown in Table 2. A majority of the isolates were virulent on gene Lr3. Compared to 1968, there was a marked drop in the number of isolates virulent on genes Lr10 and Lr16.

Fifteen virulence combinations were obtained in 1969 (Table 3). The majority of isolates were virulent on only gene Lr3 or on genes Lr3 and Lr10.

The commercial variety 'Manitou' is susceptible to leaf rust in the seeding stage but adult plants are resistant in the field. This adult plant resistance is conditioned by gene Lr13 which was derived from 'Frontana'. The resistance is poorly expressed in the greenhouse, and variable results are obtained when tests are carried out at different times of the year. Twenty-eight cultures obtained from Manitoba in 1968 were tested on adult plants of 'Manitou' during the winter and spring of 1968-69, and two cultures were virulent on adult plants in each test. This is the first indication of virulence in the North American leaf rust population to adult plant resistance derived from 'Frontana'. However, this resistance is probably still reasonably effective under field conditions.

Composite collections of leaf rust were used to inoculate the highly resistant varieties 'Agatha', 'Transfer', 'Klein Lucero', 'Aniversario', 'Wanken', 'Maria Escobar', 'Rio Negro', 'El Gaucho', 'Terenzio' 'Preska', 'Timpaw', and 'Norteno 67'. Susceptible-type pustules were obtained on 'Maria Escobar', 'Rio Negro', 'Terenzio' and Norteno 67'. A comparison of the pattern of rust reactions on 'Norteno 67' and the single-gene lines indicated that 'Norteno 67' possesses genes Lr1 and Lr2.

Acknowledgments

I am grateful for assistance given by cooperators in the care of the rust nurseries and the collection of rust specimens. Mr. W.O. Ostapyk performed the technical work of the program.

[1] Contribution No. 411, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

[2] Plant Pathologist.

Table 1. Percentage infection by Puccinia recondita on 15 wheat varieties in uniform rust nurseries at 27 locations in Canada in 1969

Location	Lee	Pitic 62	Selkirk	Red Bobs	Manitou	D.T. 316	Kenya Farmer	R.L. 5404	R.L. 5406	Mindum	Stewart 63	Tc^6 x Transfer Exchange	Frontana	D.T. 191
Agassiz, B.C.	0	0	0	tr*	0	0	0	0	0	0	0	0	0	0
Creston, B.C.	10	20	40	90	0	40	10	40	50	1	15	0	0	0 30
Edmonton, Alta.	0	0	tr	tr	0	0	0	0	0	0	0	0	0	0 0
Lacombe, Alta.	3	0	3	10	0	0	3	0	0	0	0	0	0	0 0
Lethbridge, Alta.	2	tr	0	5	0	0	tr	tr	tr	0	0	0	0	0 0
Indian Head, Sask.	tr	tr	tr	3	0	0	tr	0	0	0	0	0	0	0 0
Scott, Sask.	0	0	0	5	0	0	0	0	0	0	0	0	0	0 0
Melfort, Sask.	tr	tr	tr	5	0	0	tr	0	0	0	0	0	0	0 0
Brandon, Man.	60	50	35	90	5	45	60	30	10	0	0	0	0	tr tr
Morden, Man.	70	60	40	100	15	60	60	40	10	0	0	0	0	tr 2
Glenlea, Man.	50	30	30	90	7	10	50	3	1	tr	tr	0	0	0 tr
Williamstown, Ont.	15	15	0	50	0	0	20	tr	0	0	0	0	0	0 tr
Douglas, Ont.	tr	0	0	40	0	0	0	tr	0	0	0	0	0	0 0
Alfred, Ont.	10	0	10	25	tr	10	15	tr	0	0	tr	0	0	0 10
Kapuskasing	30	15	40	65	5	tr	35	0	0	0	0	0	0	0 tr
Fort William, Ont.	2	tr	tr	40	0	0	tr	0	25	tr	0	0	0	0 0
Ottawa, Ont.	tr	0	0	10	0	tr	tr	0	0	0	0	0	0	0 0
Appleton, Ont.	tr	tr	tr	10	tr	tr	tr	tr	tr	0	0	0	0	0 0
Morewood, Ont.	10	tr	tr	40	tr	tr	10	0	0	0	0	0	0	0 0
Vineland, Ont.	30	20	10	80	10	20	20	5	5	0	0	0	0	0 20
La Pocatière, Que.	1	0	tr	25	0	tr	3	0	0	0	0	0	0	0 0
Macdonald College, Que.	0	0	tr	35	0	tr	tr	0	0	0	0	0	0	0 tr
Lennoxville, Que.	0	0	0	5	0	tr	0	0	0	0	0	0	0	0 0
L'Assomption, Que.	0	0	0	tr	0	0	0	0	0	0	0	0	0	0 0
Normandin, Que.	tr	0	0	10	0	tr	0	tr	0	0	0	0	0	0 0
Kentville, N.S.	0	0	0	tr	0	0	0	0	0	0	0	0	0	0 0
Truro, N.S.	0	0	0	20	0	0	tr	0	0	0	0	0	0	0 0

* tr = trace

Table 2. Virulence of isolates of Puccinia recondita on back-cross lines containing single genes for resistance to leaf rust in Canada in 1969

Resistance genes	No. of isolates from: Ont. & Que.	Man.	Sask.	B.C. & Alta.	Total no. of virulent isolates	% total isolates
Lr1	0	2	0	0	2	1.4
Lr2	0	1	0	0	1	0.7
Lr2D	10	3	5	8	26	18.3
Lr3	14	81	32	6	133	93.3
Lr10	14	24	20	8	66	46.4
Lr16	0	3	1	0	4	2.8
Lr17	0	2	2	2	6	4.2
Lr18	6	20	3	0	29	20.4

Table 3. Virulence combinations of Puccinia recondita isolates on back-cross lines containing single genes for resistance to leaf rust in Canada in 1969

Virulence formula (effective/ineffective host genes)	No. of isolates from:				Total no. of isolates
	Que. & Ont.	Man.	Sask.	Alta. & B. C.	
1, 2, 2D, 10, 16, 17, 18/3	1	46	13	0	60
1, 2, 2D, 16, 17, 18/3, 10	6	13	14	0	33
1, 2, 2D, 10, 16, 17/3, 18	1	9	1	0	11
1, 2, 3, 10, 16, 17, 18/2D	1	0	0	0	1
1, 2, 3, 16, 17, 18/2D, 10	1	1	1	1	4
1, 2, 10, 16, 17, 18/2D, 3	1	0	0	0	1
1, 2, 2D, 16, 17/3, 10, 18	0	8	1	0	9
1, 2, 2D, 17, 18/3, 10, 16	0	2	0	0	2
1, 2, 16, 17, 18/2D, 3, 10	2	0	1	0	3
1, 2, 3, 16, 17/2D, 10, 18	2	0	1	1	4
1, 2, 16, 18/2D, 3, 10, 17	0	0	2	6	8
1, 2, 16, 17/2D, 3, 10, 18	3	0	0	0	3
1, 2, 2D, 17/3, 10, 16, 18	0	1	0	0	1
2, 10, 16/1, 2D, 3, 17, 18	0	1	0	0	1
10, 16/1, 2, 2D, 3, 17, 18	0	1	0	0	1

STEM RUST OF WHEAT, BARLEY, AND RYE IN CANADA IN 1969

G.J. Green[2]

Prevalence and importance in Western Canada

Wheat stem rust (Puccinia graminis Pers. f. sp. tritici Eriks. and E. Henn.) was scarce in western Canada in 1969. It was first observed in plots of the susceptible variety Red Bobs on July 9 at Morden in southern Manitoba. Cool weather during July and the resistance of the widely used varieties delayed development. Despite warm weather in August, stem rust could not be found readily on susceptible wild barley (Hordeum jubatum L.) in much of Manitoba and south-eastern Saskatchewan until early October.

Infections on wild barley were heaviest in south-eastern Manitoba, decreasing to the north and west. They were difficult to find at Yorkton, Saskatchewan, in October but were easily found 100 miles to the south. Mere traces of stem rust were reported in central and western Saskatchewan. Much of the rust on wild barley was rye stem rust (P. graminis f. sp. secalis).

There was little or no damage to most commercial wheat varieties, but moderate infections of a new race developed late in the season in small plantings of the recently licensed variety 'Pitic 62'.

Stem rust of wheat, barley, and rye in the rust nurseries

Wheat stem rust was observed in only 13 of the 35 rust nurseries grown at various locations across Canada. Infections of 50% or greater on the very susceptible variety 'Red Bobs' occurred at only eight locations (Table 1). 'Pitic 62' was infected at one location in Manitoba and at two locations in Ontario. These infections were caused by a

[1] Contribution No 412, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

[2] Plant Pathologist.

Table 1. Percentage infection of stem rust (Puccinia graminis f. sp. tritici) on 15 wheat varieties in uniform rust nurseries at 13 locations* in Canada in 1969

	Common wheat											Durum wheat			
Location	Red Bobs	Lee	Selkirk	Manitou	Kenya Farmer	Thatcher[6] x Transfer	Pitic 62	Exchange	Frontana	R.L. 5404	R.L. 5406	Mindum	Stewart 63	Hercules	D.T. 316
Creston, B.C.	50	0	0	0	0	0	0	0	tr**	0	0	0	0	0	0
Brandon, Man.	70	10	0	0	0	tr	0	5	0	0	50	40	0	0	0
Morden, Man.	70	30	0	0	0	20	0	5	tr	25	70	30	0	0	5
Glenlea, Man.	80	30	tr	0	0	5	5	tr	1	5	60	40	0	tr	10
Fort William, Ont.	100	15	0	0	0	50	0	tr	0	tr	90	10	0	0	0
Williamstown, Ont.	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas, Ont.	80	20	tr	0	5	10	5	5	tr	10	60	40	0	0	0
Kapuskasing, Ont.	90	40	0	10	30	5	20	5	tr	10	80	25	0	0	0
Guelph, Ont.	5	tr	0	0	0	0	tr	0	tr	1	25	5	0	0	0
Morewood, Ont.	70	0	0	0	0	1	0	tr	0	tr	0	0	0	0	0
Normandin, Que.	0	0	0	0	0	0	0	0	0	tr	1	tr	0	0	0
La Pocatière, Que.	tr	tr	0	0	0	0	0	0	0	0	tr	0	0	0	0
Lennoxville, Que.	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* No rust was observed in nurseries at 22 locations: Agassiz, B.C.; Edmonton, Beaverlodge, Lacombe, and Lethbridge, Alta.; Scott, Melfort, and Indian Head, Sask.; The Pas, Man.; Alfred, Kemptville, Ottawa, Appleton, and Vineland, Ont.; Macdonald College, Québec, and L'Assomption, Qué.; Kentville and Truro, N.S.; Charlottetown, P.E.I.; Doyles and St. John's, Nfld.

** tr = trace

new race which may also have caused the 10 percent infection on 'Manitou' at Kapuskasing, Ontario. 'Manitou' was free from infection at all other locations and 'Selkirk' had only traces of rust at two locations. 'Kenya Farmer' has been highly resistant in the nurseries for many years but it was infected at the two locations in Ontario where 'Pitic 62' was attacked. 'Lee' and 'Thatcher^{6} x Transfer' are susceptible to race C18 (15B-1L), which predominated in 1969. They had moderate infections at most locations where 'Red Bobs' was severely attacked. 'R.L. 5404' and 'R.L. 5406' are hexaploid derivatives of Triticum monococcum L. with different degrees of resistance. The durum wheat varieties 'Stewart 63' and 'Hercules' were highly resistant at all locations.

Stem rust occurred on barley or rye at 16 of the 35 nursery locations (Table 2). The widespread infection of 'Prolific' rye demonstrates the prevalence of rye stem rust in 1969.

Distribution of physiologic races

Physiologic races were identified by the methods decribed in earlier reports in this annual series.

In 1969, 172 isolates of wheat stem rust were separated into nine virulence formulas corresponding to seven physiologic races (Table 3). Race C18 (15B-1L) (82% of the isolates) has predominated since 1964 and continued to predominate in 1969. The inclusion in the survey of 62 single pustule isolates from 'Red Bobs' at Morden may have exaggerated its prevalence. Race C18 does not attack the resistant varieties now grown in Western Canada. The second race in order of prevalence, C33 (15B-1L), resembles C18

Table 2. Percentage infection of stem rust (Puccinia graminis) on three varieties of barley and one variety of rye in uniform rust nurseries at 16 locations* in Canada in 1969

	Barley			Rye
Location	Montcalm	Parkland	C.I. 10644	Prolific
Agassiz, B. C.	0	0	0	20
Creston, B. C.	5	tr**	0	60
Brandon, Man.	20	0	0	30
Morden, Man.	0	0	0	10
Glenlea, Man.	0	0	0	30
Fort William, Ont.	tr	0	0	0
Williamstown, Ont.	0	0	0	30
Douglas, Ont.	10	0	0	15
Alfred, Ont.	0	0	0	10
Kapuskasing, Ont.	5	tr	0	0
Guelph, Ont.	0	0	0	tr
Vineland, Ont.	0	0	0	10
La Pocatière, Que.	tr	tr	0	40
Macdonald College, Que.	0	0	0	10
Lennoxville, Que.	0	0	0	tr
Kentville, N. S.	0	0	0	10

* No rust was observed in nurseries at 19 locations: Edmonton, Beaverlodge, Lacombe, and Lethbridge, Alta.; Scott, Melfort, and Indian Head, Sask.; The Pas, Man.; Kemptville, Ottawa, Appleton, and Morewood, Ont.; Quebec, L'Assomption, and Normandin, Que.; Truro, N. S.; Charlottetown, P. E. I.; Doyles and St. John's, Nfld.

** tr = trace

Table 3. Distribution by provinces of physiologic races of Puccinia graminis f. sp. tritici collected on wheat, barley, and grasses in 1969

Virulence formula number	Physiologic race number	Number of isolates from						Total number of isolates	Percent of total isolates
		P. E. I.	Que.	Ont.	Man.	Sask.	B. C.		
C9	15B-1L(Can.)	0	0	0	1	0	0	1	0.6
C17	56	0	0	0	0	0	1	1	0.6
C18	15B-1L(Can.)	2	2	19	107*	11	0	141	82.0
C20	11	0	0	3	2	0	0	5	2.9
C27	59	0	0	0	0	0	1	1	0.6
C33	15B-1L(Can.)	0	2	7	0	2	0	11	6.4
C35	32-113	0	2	5	2	0	0	9	5.2
C36	48	0	0	0	0	0	1	1	0.6
C37	15	0	2	0	0	0	0	2	1.1
Total wheat stem rust isolates		2	8	34	112	13	3	172	100.0
Rye stem rust isolates		0	1	2	62	28	1	94	

* Sixty-two isolates of C18 were from single pustules collected on the susceptible variety 'Red Bobs' at Morden, Man., on July 24.

except that it is virulent on Marquis-Sr8. A single culture was identified late in 1967 but it disappeared in 1968. Its reappearance at five locations in three provinces in 1969 (Table 4) indicates it is a potentially important race. The third race in order of prevalence is a new one, C35 (32-113). Infection types produced on the 'Marquis' backcross lines were clear (Table 5) but this race could not always be readily identified on the "standard" differential hosts. It was clearly in the 11-32-113 race group and could usually be separated from race 11 by the mesothetic reaction of 'Mindum' (race 11 is type 4). The infection type produced on 'Marquis' was unstable, varying from mesothetic (race 113) to 4- (race 32). Race C35 was collected mainly on the variety 'Pitic 62' and attacked seedlings of this variety in the greenhouse. It caused an infection of 60 percent in plots of 'Pitic 62' at Glenlea, Manitoba. It is moderately virulent on seedlings of 'Manitou' and 'Neepawa' but plots of 'Neepawa' near the rusted 'Pitic 62' were free from rust and it was not found in farm fields of 'Manitou', the predominant variety in the rust area of Western Canada. The seedling reactions of 'Selkirk' to different cultures of race C35 indicate at least two biotypes that cannot be separated using the backcross lines of 'Marquis' carrying identified resistance genes. Race C35 was found at five locations in three provinces (Table 4). Race C20 (11), fourth in order of prevalence, has been found each year since 1964 and may have been present before that time. It does not threaten the resistant varieties now grown. Race C17 (56) has declined steadily in prevalence since 1961 when it predominated

Table 4. Number of locations at which two potentially important new races were found in 1969

Virulence formula number	Province				Total number of locations
	Que.	Ont.	Man.	Sask.	
C33	1	2	0	2	5
C35	2	1	2	0	5

Table 5. Virulence formulas, formula numbers, and corresponding physiologic race numbers used from 1964 to 1969

Year found	Formula number	Virulence formula (Effective/Ineffective host genes)	Physiologic race
1964	C1	1, 5, 6, 7, 9a, 9b, 10, 11, 13/8, 14, 15, 16	17
	C2	5, 6, 7, 9a, 9b, 10, 13/8, 11, 14, 15, 16	17A
	C3	5, 6, 9a, 11/7, 8, 9b, 10	29-4(Can.)
	C4	5, 6, 11/7, 15, 16	23
	C5	5, 9a, 9b, 11/6, 7, 8, 10, GB	29-1(Can.)
	C6	5, 9a, 9b, 11, GB/6, 7, 8, 10	29-2(Can.)
	C7	5, 11, GB/6, 7	48
	C8	5, 11/6, 7, GB	48A
	C9	6, 7, 8, 9a, 9b, 10, 13, 15/1, 5, 11, 14, 16	15B-1L(Can.)
	C10	6, 7, 8, GB/1, 5, 9a, 9b, 10, 11, 13, 14, 15, 16	15B-1(Can.)
	C11	6, 7, 8/5, 9a, 9b, 10, 11, GB	15B-4(Can.)
	C12	6, 7, 9a, 9b, 10, 11/5, 8	11
	C13	1, 6, 7, 10, 11, 13/5, 8, 9a, 9b, 14, 15, 16	32, 113
	C14	6, 7, 10, 11/5	14, 38
	C15	6, 7, 10/5, 8, 9a, 9b, 11	11, 32, 113
	C16	6, 7, 11/1, 5, 10, 15, 16	39
	C17	1, 6, 8, 9a, 9b, 11, 13/5, 7, 10, 15, 16	11, 56
	C18	6, 8, 9a, 9b, 13, 15/1, 5, 7, 10, 11, 14, 16	15B-1L(Can.)
	C19	1, 6, 10, 11/5, 7, 15, 16	10, 38
	C20	1, 7, 8, 11/5, 6, 9a, 9b, 10, 14, 15, 16	11, 87
	C21	9a, 11/5, 6, 7, 8, 9b, 10	32
	C22	1, 9a/5, 6, 7, 8, 9b, 10, 11, 14, 15	32
	C23	/5, 6, 7, 10, 15, 16	38

Table 5 (Continued)

Year found	Formula number	Virulence formula (Effective/Ineffective host genes)	Physiologic race
1965	C24	5, 7, 9a, 9b, 10/6, 8, 11	17
	C25	/5, 6, 7, 10, 11	38
	C26	6, 7, 8, 9b, 13, 15/1, 5, 9a, 10, 11, 14, 16	15B-4(Can.)
	C27	6, 11/5, 7, 10, 15, 16	33, 59
	C28	1, 6, 8, 9b, 11/5, 7, 9a, 10	18, 54
	C29	1, 5, 6, 7, 9a, 10, 11/8, 9b	17
	C30	1, 9a, 9b/5, 6, 7, 8, 10, 11	29
1966	C31	5, 6, 7, 10, 11/	27
1967	C32	1, 9a, 9b, 11/5, 6, 7, 8, 10	32
1968	C33	6, 9a, 9b/1, 5, 7, 8, 10, 11	15B-1L(Can.)
	C34	1, 6, 7, 9a, 9b, 11/5, 8, 10, 13, 14, 15, 16	32
1969	C35	1, 10, 11, 13/5, 6, 7, 8, 9a, 9b, 14, 15, 16	32-113
	C36	5, 6, 7, 11/10, 15, 16	48
	C37	6, 8, 9a, 9b, 11, 13/1, 5, 7, 10, 14, 15, 16	15

(72.8 percent of the isolates). This well-known race has nearly disappeared as it did in the early 1950's when C10 (15B-1) predominated. The remaining races (Table 3) occurred in trace amounts and do not appear to be important.

Rye stem rust occurred widely in 1969 (Table 3) as it did in 1968. The prevalence of rye stem rust is probably exaggerated by the scarcity of wheat stem rust.

The race distribution shown by isolates from susceptible, non-selective varieties has been given in earlier years, but in 1969 nearly all rust collections were from susceptible varieties, excepting a few collections of race C35 (32-113) from 'Pitic 62'.

During 1969, wheat lines carrying resistance genes Sr1, Sr13, Sr14, Sr15, and Sr16 were tested to cultures identified before these lines were available. The virulence formulas have been revised to include the results of these tests. The list of formulas now in use and equivalent physiologic race numbers appear in Table 5.

Most of the resistance genes (Sr1, Sr5, Sr6, Sr8, Sr9a, Sr9b, and Sr11) give clear infection types with all cultures; others (Sr10, Sr13, Sr14) give clear infection types with most cultures; and others (Sr7, Sr15, and Sr16) give variable infection types that are often difficult to interpret. Sr7 is noteworthy because it gave a reasonably clear resistant reaction to race C10, the original 15B, and to several other races such as C1 and C20. The best indication of its

Table 6. Percent of total isolates avirulent on single identified resistance genes and number of avirulent races in 1969

Resistance gene	Avirulent isolates (%)	Number of avirulent races
Sr1	8.7	3
Sr5	0.6	1
Sr6	91.9	7
Sr7	4.1	3
Sr8	87.2	5
Sr9a	90.7	5
Sr9b	90.7	5
Sr10	5.8	2
Sr11	11.0	6
Sr13	89.5	5
Sr14	0	0
Sr15	82.0	2
Sr16	0	0

resistant reaction was diffuse necrosis of the seedling leaves. This symptom is not present with most of the races encountered in recent years. Instead, various infection types and degrees of chlorosis occur. The effectiveness of Sr7 appears to have eroded instead of being lost by the one-step process observed with other genes. The variety 'Norka' is used to test for the effectiveness of Sr15. It is mesothetic to races C9 and C18 and susceptible to all other races. The mesothetic response is interpreted as a resistant reaction. A line carrying Sr16 derived from 'Thatcher' was suceptible to most cultures. Occasionally it showed type 3 infections but for practical purposes it was considered to be susceptible. The interpretation of the reaction of this line may require revision. It is recorded in the formulas only where the infections were clearly type 4.

The percentage of isolates avirulent on each identified resistance gene (Table 6) show that gene Sr6, Sr8, Sr9a, Sr9b, Sr13, and Sr15 conferred resistance to most isolates. These genes confer resistance to race C18, which constituted 82 percent of the rust population. Sr6 was effective against more races than any other gene (Table 6).

Composite collections of urediospores from all cultures studied in the survey were used to inoculate a group of highly resistant varieties. Race C35 was isolated from large pustules on the varieties 'Chris', 'Mida-McMurachy-Exchange II-47-26', 'Frontana-K58-Newthatch II-50-17', 'C.T. 296' (Pembina^2 x Magnif Entrerriano), 'C.T. 299' (Lake x Selkirk), and 'Minn.II-58-14'. Race C33 was isolated from 'Chris' and race C20 from 'C.T. 296'. 'Minn.II-54-30' showed many susceptible pustules but no isolations were made. 'Wis. 261' was highly resistant to most composites but showed type 2 and 3+ infections in one test. 'Inia 66' showed type 2 infections in all tests. 'ND 264', 'St 464', 'C.I. 8155', 'Hercules', 'D.T. 316' (Lk^2 x Pelissier), 'D.T. 317' (Lk^2 x Pelissier), and a line of 'Manitou' with a translocation from rye were highly resistant to all composites.

Acknowledgments

The cooperation of those who cared for the rust nurseries and supplied collections of rust is appreciated. Mr. J.H. Campbell did the technical work of the program.

STEM RUST OF OATS IN CANADA IN 1969[1]

J. W. Martens[2]

Prevalence and crop losses in Western Canada

Stem rust of oats caused by Puccinia graminis Pers. f. sp. avenae Eriks. & E. Henn. was first found in Manitoba on July 29. Very light infections were common in Manitoba and eastern Saskatchewan by the end of August but there were no crop losses, except in the Red River Valley where infections of 30% or more developed in late fields.

Uniform rust nurseries

Oat stem rust was scarce in the rust nurseries grown at 35 locations across Canada (Table 1). Rust was observed in only 10 of the nurseries, and infections of over 5% were found only in Manitoba.

Identification and distribution of physiologic races

Physiologic races were identified by the methods used in previous years (1). In addition to varieties with the genes listed in Table 2, a supplementary set consisting of 'Kyto' (pg.12), 'Saia' and a line with resistance from a Tunisian collection of Avena sterilis L. was used. All 186 collections were avirulent on the

[1] Contribution No. 400, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

[2] Plant Pathologist.

Table 1. Percentage infection by Puccinia graminis f. sp. avenae on 11 oat varieties at 10 uniform rust nurseries* in Canada in 1969

Locality	Bond	Trispernia	Landhafer	C. I. 4023	Saia	Rod ABDH	C. I. 3034	Rodney	Garry	R. L. 2895	R. L. 2896
Creston, B. C.	0	0	tr**	0	0	0	0	0	0	0	0
Brandon, Man.	2	0	0	tr	0	0	0	0	0	0	0
Glenlea, Man.	60	30	30	5	tr	tr	tr	80	10	60	60
Morden, Man.	5	1	0	0	0	0	0	tr	tr	tr	tr
Douglas, Ont.	0	tr	0	0	0	0	0	0	0	0	0
Kapuskasing, Ont.	5	tr	0	0	0	0	0	0	0	0	0
Vineland, Ont.	0	0	0	0	0	0	0	tr	0	0	0
Williamstown, Ont.	0	0	0	0	0	0	0	tr	tr	0	0
La Pocatière, Que.	0	0	0	0	0	0	0	0	0	0	tr
Kentville, N. S.	0	0	0	0	0	0	0	0	tr	0	0

* No rust was observed in 25 other nurseries located at Agassiz, B. C.; Beaverlodge, Edmonton, Lacombe, and Lethbridge, Alta.; Indian Head, Melfort, and Scott, Sask.; The Pas, Man.; Alfred, Appleton, Ft. William, Guelph, Kemptville, Morewood, and Ottawa, Ont.; L'Assomption, Lennoxville, Macdonald College, Normandin, and Qué., Qué.; Truro, N. S.; Charlottetown, P. E. I.; Doyles and St. John's, Nfld.

** tr = trace infection.

Table 2. Distribution by provinces of physiologic races of Puccinia graminis f. sp. avenae isolates in Canada in 1969

Race formula no.	Virulence formula (effective/ineffective Pg host genes)	Number of isolates from					Total isolates	Percentage of total isolates
		B. C.	Sask.	Man.	Ont.	Que.		
C3	2, 8/1, 3, 4, 9	0	2	10	1	0	13	7.0
C4	1, 4, 8, 9/2, 3	1	0	0	0	0	1	.5
C5	4, 9/1, 2, 3, 8	0	2	7	0	0	9	4.8
C8	3, 8/1, 2, 4, 9	0	0	0	13	0	13	7.0
C9	8/1, 2, 3, 4, 9	0	0	0	12	1	13	7.0
C10	9/1, 2, 3, 4, 8	1	16	111	1	0	129	69.4
C14	8, 9/1, 2, 3, 4	0	0	0	1	0	1	.5
C23	2, 4, 9/1, 3, 8	0	1	3	3	0	7	3.8
Total		2	21	131	31	1	186	100.0

supplementary set. The race distribution in Western Canada has changed relatively little since 1965, when C10 first became dominant. In 1969, races C10, C3, and C5 comprised 83%, 8%, and 6%, respectively, of all isolates from Manitoba and Saskatchewan. Race C23, not previously described, was also found in both provinces. In Eastern Canada, race C9 and the closely related C8 have continued to predominate. Race C10, which was common in Ontario in 1967 and 1968 (2), was isolated only once in 1969. The new race, C23, was also found in Ontario. The widespread appearance of C23 is surprising since this race is avirulent on both Pg2 resistance and Pg4 resistance which are present, singly or in combination, in most of the oat varieties grown in Canada. Race C23 may be similar to the old race 7 that was common from 1953 to 1959, but no such isolate has been found in Canada since the present differential set was first used in 1964.

The virulence range of the rust population has been maintained at a high level (Table 3). Approximately 90% of all

Table 3. Frequency of virulence in the stem rust population on various types of resistance in Canada in 1969

Geographic area	Percentage of isolates virulent on varieties with the following genes for resistance:						Total no. isolates	Mean* virulence capability
	Pg-1	Pg-2	Pg-3	Pg-4	pg-8	pg-9		
Eastern Canada	100	87.5	59.4	90.6	12.5	84.4	32	4.3
Western Canada	99.4	89.6	100	90.9	91.6	7.8	154	4.8

* Mean virulence capability = frequency of virulence on Pg-1 + ... + pg-9/total no. isolates.

isolates in both Eastern and Western Canada are virulent on varieties carrying Pg2 and Pg4 resistance. Since these are the only types of resistance present in commercial oat varieties, conditions favoring rust development could result in serious crop losses.

Acknowledgments

The assistance of cooperators who cared for rust nurseries and submitted rust collections from various parts of Canada is gratefully acknowledged. Mr. Peter K. Anema performed the technical operations necessary for the identification of physiologic races. Dr. W.L. Seaman and Dr. R.V. Clark provided most of the collections from Ontario.

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CROWN RUST OF OATS IN CANADA IN 1969[1]

G.Fleischmann[2]

Disease development and crop losses in Western Canada

Oat crown rust caused by Puccinia coronata Cda. f. sp. avenae Eriks. was first found near Plum Coulee, Manitoba, on July 24th. Despite the late date of initial occurrence, crown rust was generally present on oats in the province during the first week in August and increased in intensity in the Red River Valley and in southwestern Manitoba during the remainder of the summer. Crown rust was observed and collected from oat fields as far west and north as Canora, Saskatchewan, during the first week in September.

Yield reductions from oat crown rust in experimental plots at Glenlea, Manitoba, were 34% and 28% for the varieties 'Eagle' and 'Kelsey', respectively. Crown rust damage to the crop was anticipated in 38 of 49 late sown farm fields examined during the first week in August. In these fields disease development was evident on flag leaves by the early milk stage, and, in accordance with previous findings (1), losses were to be expected. The yield loss estimates were calculated separately for each of the 11 crop districts in Manitoba in which oats are grown in substantial quantity. Only late-sown fields that were in the milk stage or at an earlier stage of development were taken into consideration in arriving at yield losses. Thus, the acreage affected was determined by multiplying the fraction of fields inspected that were late in their development by the total oat acreage in the district. The yield in each district in bushels per acre was based on Manitoba Department of Agriculture figures for 1969. It was estimated that in excess of 3.5 million bushels of oats in late sown fields would be lost due to crown rust. At prices of 50 cents per bushel, this loss is in the order of $1,750,000 from yield reduction alone. Qualitative losses reflected by groats, % hull, and bushel weight were not taken into consideration. Losses to individual late fields ranged from 5% to 30%, but on average were 10% to 20%, considerably less that the losses demonstrated in the experimental plots. The estimate of about two million dollars loss due to crown rust in Manitoba is, for the

Table 1. Percentage infection of crown rust on 11 oat varieties at 15 locations in Canada

Location	Bond	Trispernia	Landhafer	CI 4023	Saia	Rodney ABDH	CI 3034	Rodney	Garry	RL 2895	RL 2896
Melfort, Sask.	tr*	0	0	tr	0	0	0	0	0	0	0
The Pas, Man.	tr	0	0	tr	0	0	0	0	tr	0	0
Morden, Man.	90	30	50	70	20	50	70	90	90		
Winnipeg, Man.	80	10	30	50	10	40	50	50	60	40	50
Williamstown, Ont.	30	0	0	20	tr	40	20	40	30	10	tr
Alfred, Ont.	20	0	0	30	0	20	20	30	20	0	tr
Kemptville, Ont.	40	0	0	40	0	20	10	50	50	tr	tr
Fort William, Ont.	20	0	0	10	0	tr	tr	10	10	tr	0
Ottawa, Ont.	30	0	0	20	0	10	10	20	20	1	1
Appleton, Ont.	30	0	0	20	0	20	20	30	30	5	5
Morewood, Ont.	60	tr	10	40	1	50	40	60	60	20	10
Vineland, Ont.	30	tr	5	30	5	30	30	30	30	10	30
La Pocatière, Que.	30	0	tr	20	tr	10	10	20	20	tr	tr
L'Assomption, Que.	20	0	0	10	0	5	10	20	10	0	0
Normandin, Que.	20	0	0	5	0	10	5	20	20	0	0

* tr = trace infection, less than 1%

[1] Contribution No. 403, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

[2] Plant Pathologist.

above reasons, considered to be very conservative. Detailed results are presented in another paper (3).

Rating of crown rust intensity on 11 oat varieties grown at nurseries in Saskatchewan, Manitoba, Ontario, and Quebec are presented in Table 1. Ommitted from this table are nurseries in which no crown rust was found on any of the 11 oat varieties, as well as nurseries from which rust intensity could not be estimated because of the mildewed or shrivelled condition of the leaves.

The intensity of crown rust infection from the Manitoba nurseries at Morden and Winnipeg relects conditions prevailing just prior to maturity in mid-August. The reading for Ontario and Quebec nurseries were taken fairly early in the growing season and crown rust severity probably increased considerably on the commonly grown susceptible varieties. The highest intensity of infection in Ontario occurred in the vicinity of dense buckthorn infestations, i.e. the Kemptville, Morewood, Williamstown and Appleton nurseries.

Table 2. Distribution of physiologic races of crown rust in Canada in 1969

Physiologic race	West		East		W & E totals	
	No. of isolates	% of all isolates	No. of isolates	% of all isolates	No. of isolates	% of all isolates
202	1	0.5	0	0.0	1	0.5
203	7	3.8	4	13.2	11	5.2
210	1	0.5	7	23.1	8	3.7
216	14	7.7	3	9.9	17	8.0
226	1	0.5	1	3.3	2	1.0
228	0	0.0	1	3.3	1	0.5
237	1	0.5	0	0.0	1	0.5
241	1	0.5	1	3.3	2	1.0
263	2	1.1	0	0.0	2	1.0
264	31	17.0	1	3.3	32	15.0
276	7	3.8	0	0.0	7	3.3
290	2	1.1	0	0.0	2	1.0
295	40	22.0	2	6.6	42	19.1
325	9	5.0	1	3.3	10	4.7
326	34	18.7	0	0.0	34	16.0
327	4	2.2	0	0.0	4	1.9
332	1	0.5	1	3.3	2	1.0
333	2	1.1	0	0.0	2	1.0
338	1	0.5	0	0.0	1	0.5
341	3	1.6	4	13.2	7	3.3
342	0	0.0	1	3.3	1	0.5
360	0	0.0	1	3.3	1	0.5
368	1	0.5	0	0.0	1	0.5
419	1	0.5	0	0.0	1	0.5
421	1	0.5	0	0.0	1	0.5
427	3	1.6	0	0.0	3	1.4
444	1	0.5	0	0.0	1	1.0
446	3	1.6	2	6.6	5	2.3
453	1	0.5	0	0.0	1	0.5
1, 3, 7, 10	2	1.1	0	0.0	2	1.0
1, 3, 4, 8, 9, 10	1	0.5	0	0.0	1	0.5
2, 4, 8, 9	1	0.5	0	0.0	1	0.5
4, 8, 9, 10	2	1.1	0	0.0	2	1.0
4, 8, 9	1	0.5	0	0.0	1	0.5
Total races	31		14		34	
Total isolates	180		30		210	
Race:Isolate ratio	1:6		1:2			

Some degree of crown rust resistance appeared in the 'Rodney ABDH' backcross line containing additional stem rust resistance genes. As in the previous report (2), this was reflected by a lower intensity of crown rust on it than on ordinary 'Rodney' at nearly all of the rust nurseries where crown rust occurred.

Distribution of physiologic races

The frequency of occurrence and distribution of 34 physiologic races of crown rust identified from 210 Canadian isolates is presented in Table 3. Although 31 physiologic races were identified in the west, three of these, 264, 295, and 326, comprised nearly 60% of the isolates. These races, as well as most of the others isolated attacked the differential varieties 'Landhafer' and 'Santa Fe'.

Only 30 isolates were obtained from Eastern Canada, but 14 physiologic races were identified in this small sample. The 'Victoria'-virulent races 203, 210, 216, and 341 comprised 56% of the population. In contrast to Western Canada, there were very few races isolated in the east which attacked the varieties 'Landhafer' and 'Santa Fe'.

Five races with previously undescribed combinations of virulence on the differential varieties were discovered in the west during the 1969 survey. Their resistance formulae are presented in Table 2. All of them were virulent on 'Landhafer' and 'Santa Fe', but only one (resistance formula 1,3,7,10) attacked 'Trispernia' and 'Bondvic'.

Virulence on the differential varieties

The percentage of crown rust isolates virulent on each differential variety is shown in Table 3. The situation in Eastern Canada indicates increased incidence of crown rust virulent on 'Landhafer' and 'Santa Fe' and decreasing incidence of virulence on 'Anthony' and 'Appler', when compared to 1968.

In Western Canada the percent of cultures attacking 'Landhafer' and 'Santa Fe' continued at the very high level recorded last year. Those virulent on 'Trispernia' and 'Bondvic' increased and were present in

Table 3. Percentage of Canadian crown rust isolates virulent on differential host varieties, 1966 to 1969

Location and year	Anthony	Victoria	Appler	Bond	Landhafer	Santa Fe	Ukraine	Trispernia	Bondvic	Saia
Western Canada										
1969	92	62	93	94	82	82	87	30	30	5
1968	90	48	90	95	82	81	95	10	10	3
1967	72	59	72	89	68	68	80	24	31	13
1966	66	58	62	82	24	23	83	2	2	4
Eastern Canada										
1969	50	44	50	93	21	24	97	7	7	10
1968	79	40	83	87	8	9	96	2	2	7
1967	47	54	50	86	10	11	95	2	1	13
1966	51	45	30	77	9	9	85	0	0	9

about one third of western crown rust isolates. The contrast between the low level of virulence of the eastern crown rust population on 'Landhafer' and 'Santa Fe' and the high level of virulence of western isolates on these varieties is striking.

Acknowledgments

I am grateful for assistance given by the cooperators in the care of the rust nurseries and in the collection of crown rust specimens in Eastern Canada. Mr. W.L. Timlick performed the technical operations requisite to the identification of the physiologic races.

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EFFECTS OF SOME CULTURAL PRACTICES ON ROOT ROT OF BARLEY IN CENTRAL ALBERTA

L. Piening, R. Edwards, and D. Walker[1]

Abstract

In field plot experiments in naturally infested soil, root rot of barley was more severe on the varieties 'Olli' and 'Gateway' than on 'Galt' or 'Conquest'. When sown 4 inches deep 'Olli' had more root rot than when sown 2 inches deep. The addition of fertilizers containing nitrogen and phosphorus resulted in less root rot than on nonfertilized land. Urea added before seeding to both stubble and fallowed land reduced root rot, but ammonium nitrate increased root rot ratings. Bipolaris sorokiniana (Helminthosporium sativum) was isolated from the subcrown internodes of 40% of the plants tested from all treatments, Fusarium spp. from 20%.

In 1967 some observations on the incidence of root rot of barley (Hordeum vulgare L.) grown under various cultural practices were made at Lacombe, Alberta (3). These observations were continued in 1968 and 1969, and the amount of root rot was also determined in several additional experiments on these plots. Root rot was examined in relation to varietal reaction, seeding depth, fungicide treatment of the seed, the presence of ground barley in the seed bed, and date of seeding. The effect of various nitrogen containing compounds on root rot development was also tested in 1969.

Methods

The area chosen for these trials has been under cultivation since 1911. Seed was sown 2 or 4 inches deep in rod rows and each treatment was replicated four times on both stubble and fallow land. Approximately 70 to 100 plants were examined for root rot in each treatment on each of the following dates: 2 July, 14 July, 14 August, and 4 September 1968. The data presented here were recorded on 4 September. The data obtained at the other dates was of the same relative order as that obtained in September, although there was less disease. The degree of root rot was indicated by the amount of tissue disintegration and discoloration on the subcrown internode at the soft dough stage. A rating of 5 indicated the maximum amount of root rot found, whereas a trace amount of infection was rated 1. The rating indicated the average value obtained by examining 70-100 subcrown internodes from each treatment. All the 'Olli' and 'Gateway' plants examined had root rot.

Fertilizer, when used, was applied to stubble at the rate of 50 lb/acre of 11-48-0 (monammonium phosphate) and 150 lb/acre of 33-0-0 (ammonium nitrate); and to fallow at 50 lb/acre of 11-48-0.

The treatments were sown on 3 June 1968 on land that had been fallowed or in barley in 1967, except one experiment, which was sown on 12 June.

Varietal reaction to root rot was rated on 'Gateway', 'Olli', 'Conquest' and 'Galt' barley. Ratings were also made on 'Gateway' plants grown from seed that had been treated with 2 oz/bushel of the fungicide Bay 33172 (50% 2-[2-furyl]-benzimidazole) supplied by Chemagro Co., Toronto, Ontario; on 'Olli' sown with 200 g of ground barley seed mixed with the seed; on 'Olli' sown 4- and 2 inches deep; and on late-sown 'Gateway' on fertilized and nonfertilized land.

Urea, ammonium nitrate, or anhydrous ammonia, providing 50 lb of nitrogen per acre, was worked into the soil one day before seeding with 'Gateway' barley. They were applied to the fertilized and non-fertilized stubble and fallow land, each treatment covering 2500 ft^2.

Results and discussion

The results of four of these experiments are illustrated in Figure 1. There was more visible root rot of barley when it was grown on summerfallow than on stubble land. This si in agreement with the results reported from this area in 1067 (3). 'Galt' and 'Conquest', which are both widely grown in central Alberta, appeared to have less root rot than 'Gateway' or 'Olli'. Hamilton et al. (2) in a greenhouse study comparing the reaction of barley varieties to root rot found 'Olli' to be among the most susceptible varieties.

[1] Research Station, Canada Department of Agriculture, Lacombe, Alberta.

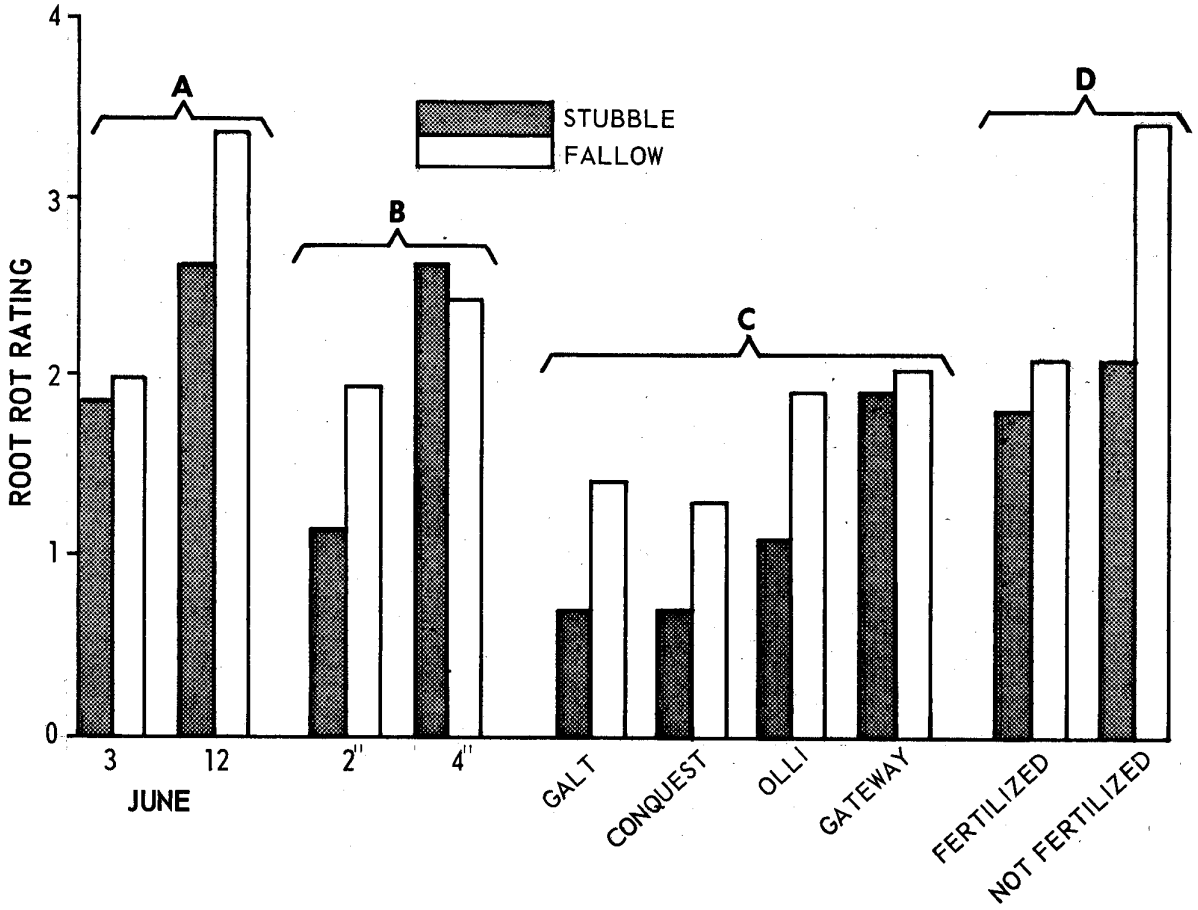

Figure 1. Root rot ratings on barley grown on stubble and fallow land. A) 'Gateway' seeded June 3 and June 12; B) 'Olli' seeded at 2– and 4–inch depths; C) Reaction of the barley cultivars 'Galt', 'Conquest', 'Olli', and 'Gateway'; D) 'Gateway' grown on fertilized and non-fertilized land.

The spring of 1968 was very dry in central Alberta and consequently many farmers seeded their grains deeper than usual. In our trials, seeding 'Olli' 4 inches deep resulted in more root rot, especially on fallow soil, than seeding at 2-inch depths.

With late-sown 'Gateway', root rot ratings were higher on plants grown in nonfertilized soil than on those grown in fertilized soil. Similar results were observed in 1967. It is possible that the effect of the fertilizers may increase host vigor and growth, so that the amount of diseased tissue compared to healthy tissue may be less. The work of Broadfoot and Tyner (1) indicated that a close relationship existed between host vigor and susceptibility to disease. In the 1969 experiment, urea reduced root rot slightly on nonfertilized fallow and on stubble, but anhydrous ammonia reduced root rot only on fallow soil. Root rot was increased when ammonium nitrate was applied (Table 1).

'Gateway' barley sown on 12 June 1968 had more root rot than that sown 9 days earlier. Due to the dry conditions, the later-sown seed had less moisture to start germination and growth and this may have produced somewhat weaker plants that were more susceptible to attack by root rot organisms.

It was hoped that increased microbial activity in the areas immediately around the seeds amended with barley meal would have reduced the activity of the root rot

Table 1. Root rot ratings of 'Gateway' barley on fertilized and nonfertilized fallow and stubble land treated with three compounds supplying 50 lb nitrogen/acre

Condition of land	Control		Ammonium nitrate		Urea		Anhydrous ammonia	
	F*	NF**	F	NF	F	NF	F	NF
Stubble	1.25†	1.62	1.39	1.79	1.17	1.50	1.56	2.00
Fallow	2.26	2.71	2.64	3.05	2.27	2.61	2.00	2.22

* F = fertilized; in addition to the treatment indicated, fertilized stubble received 50 lb/acre of 11-48-0 and 150 lb/acre of 33-0-0 (ammonium nitrate); and fertilized fallow received 50 lb/acre of 11-48-0.

** NF = non-fertilized.

† Root rot ratings based on a scale of 0 (healthy) to 5 (maximum disease).

pathogens. However, barley meal placed with 'Olli' seed did not reduce root rot on fallow soil and increased it slightly on stubble soil. The type of organic matter in ground barley kernels differs from barley straw which has had 4 or 5 months to decompose. Dressing 'Gateway' seed with Bay 33172 increased root rot of both fallow and stubble land. The chemical had, however, the marked effect of increasing the height of plants. On stubble the mean height of Gateway plants from seed treated with Bay 22172 was 29.1 inches compared with 23 inches forplants from non-treated seed. On fallow the treated barley averaged 33 inches in height and the untreated plants, 30.9 inches. The results suggest that this chemical may have growth promoting effects.

After harvest, the root of the plants on both stubble and fallow soil were pulled up and the roots washed 24 hr in running tap water. The subcrown internodes were cut out and placed in 10% Chlorox for 1 min and rinsed in sterile water. These sections were placed on potato dextrose agar (PDA) in petri plates and the fungi that grew from them were identified. Several hundred roots were examined on three occasions. Forty percent of the plants from all treatments yielded Bipolaris sorokiniana (Sacc. in Sorok.) Shoem. (Helminthosporium sativum Pamm., King & Bakke), and 20% yielded Fusarium culmorum (W.G. Sm.) Sacc. or Fusarium graminearum Schwabe. Tyner (4) also reported that H. sativum was isolated more frequently than F. culmorum from wheat stubble in central Alberta. In each assay, it was interesting to note that large numbers of bacteria developed on PDA about the internode sections from plants grown on fallow land but not from those grown on stubble.

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PREVALENCE OF BARLEY YELLOW DWARF VIRUS IN WINTER WHEAT IN SOUTHWESTERN ONTARIO, 1969

W.C.James[1], *C.C.Gill*[2], *and B.E.Halstead*[3]

Abstract

In 1969, 60 fields selected from the 250,000 acres of winter wheat in southwestern Ontario were sampled for the presence of barley yellow dwarf virus using a stratified sample of fields based on the acreage of winter wheat in each of twelve counties. A random sample of culms was selected (with no reference to disease symptoms) from each field and bulked to form a field sample which was tested for BYDV transmission with Macrosiphum avenae and Rhopalosiphum padi; samples from 50% of the fields were found to be infected. From the pattern of transmission by R. padi and M. avenae in the initial isolations, the characterization of selected isolates and from symptoms on test plants, most isolates appeared to belong to the strains transmitted specifically by R. padi or R. maidis.

Introduction

Barley yellow dwarf virus (BYDV) is probably the most prevalent of the cereal viruses, having been reported in oats, barley and wheat from most continents (13). Barley yellow dwarf (BYD) usually affects oats and barley more severely than wheat, but wheat is severely damaged in New Zealand (15). The distribution of the disease has been noted by many workers (1,2,6,11,14,16,17) usually using visible symptoms for the initial diagnosis followed by transmission tests with aphids for verification. However, most of the evidence is based on surveys where crops have not been selected at random and consequently the results may not be representative of the total acreage of the crop within the area surveyed.

Studies in Ontario, conducted mainly in the eastern part of the province, have revealed that BYD may be of economic importance on cereals grown there (11,12,14). BYDV has been isolated in early spring from winter wheat, indicating that the virus can overwinter in this host (12). Aphid vectors of different species are numerous during the growing season on cereals and wild grasses. Furthermore, many perennial species of grass have yielded BYDV when tested with aphids (12). These grasses as well as the winter cereals such as wheat and rye, therefore, could serve as reservoirs of virus. At least one species of the aphid vector, Rhopalosiphum padi (Linnaeus), overwinters locally in the egg stage, and becomes active early in the season. Aphids that migrate from distant sources probably also play an important role in the dissemination of the virus (12).

There is little information on the incidence of BYDV in cereals in southwestern Ontario. The climate is milder there than in eastern Ontario, and overwintering of the aphid vectors might, therefore, be more successful, and the incidence of the disease higher. Approximately 70% of the winter wheat acreage in Ontario is grown in the twelve counties surveyed (Table 1). Simcoe and York are the only counties outside the survey area in which an appreciable acreage of winter wheat is grown. This paper outlines an objective survey approach to assess the prevalence of BYDV in southwestern Ontario by estimating the percentage of field samples infected with the virus; no attempt was made to assess the percentage of plants infected within the fields. A stratified sample of fields, based on wheat acreage, was selected from 12 counties. Because symptoms of BYD in winter wheat may be very slight and therefore easily overlooked (3), and because recent work in England (6) has shown that a high proportion of spring barley plants may carry a symptomless infection of BYDV, sampling was made at random within the crops, without selecting for plants with symptoms. All samples were tested for BYDV by attempted transmission with aphids, and different species of aphids were used to obtain information on the predominant virus strains.

Materials and methods

The sample used for this survey was designed by the Dominion Bureau of Statistics (DBS) to determine the yield of winter wheat in 1967.

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[1] Contribution No. 675, Cell Biology Research Institute.

[2] Plant Pathologist, Cell Biology Research Institute, Canada Department of Agriculture, Ottawa, Ontario.

[3] Plant Pathologist, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

[4] Graduate student, Department of Plant Science, University of Manitoba, Winnipeg.

Table 1. Distribution of winter wheat in southwestern Ontario, showing number of segments and fields sampled in 1969

County	Number of segments	Number of fields	Acreage* expressed as % of total acreage
Essex	5	11	11
Kent	8	13	12
Lambton	6	10	11
Middlesex	6	6	7
Elgin	3	3	6
Huron	5	2	4
Perth	4	3	2
Waterloo	3	1	2
Oxford	3	5	2
Norfolk	3	4	7
Brant	2	2	2
Haldimand	2	3	2
Totals	50	63	68

* Based on 1966 Census.

The sample comprised 50 segments, selected in proportion to the acreage of winter wheat in each county. Each segment, which is delineated by natural boundaries and identifiable on aerial photographs, contained approximately 1000 acres and several farms. The sample design will be reported in detail in a later publication. For the purpose of this survey one quarter of each segment was selected at random and the winter wheat acreage on each farm in the chosen quarter was surveyed. One field of winter wheat per farm was selected at random for sampling. A total of 63 farms reported winter wheat; the distribution is shown in Table 1. The lists of farms and the aerial photographs of each segment were provided by DBS so that farms were easily located. A total of approximately 750 acres was surveyed.

Within each field, twelve main culms were collected at approximately equal intervals along a W pattern. Random numbers from 1 to 30 were used to select the position of the first culm, e.g. if 5 was selected as the random number, the first culm was picked 5 paces from the edge of the crop. Each field was sampled during the last week of May and during the last week of June. The crops were at Growth Stages 8 to 9, and 10.5.4 (grain watery ripe) to 11.1 (grain milky ripe) respectively, according to Feekes' Growth Stages · (7). At the first visit leaves 3 and 4 (where flag leaf=1) were detached from the culms and sent by air mail to Winnipeg for testing. The twelve third leaves were packed together and leaves four were treated in the same way. On the second sampling leaves 1 and 2 were chosen. A preliminary mailing of healthy wheat leaves from Ottawa to Winnipeg was made before the survey started, and the best method of packaging proved to be leaves enclosed in moist paper towelling and sealed in a polyethylene bag with most of the air evacuated. The samples were in transit for 1-3 days.

The younger and older groups of leaves from each field were tested separately. Each

of the 12 leaves in a package was cut in half lengthwise, the halves being placed in separate petri dishes, so that both dishes contained 12 half-leaves. To maintain turgidity, the ends of the leaves were buried in moist sand.

Virus-free apterae or late instar nymphs of Macrosiphum avenae (Fabricius) were added to one dish, and those of R. padi to the other. The dishes were maintained at 15C for 2 days; then aphids were transferred from each dish to individually caged 'Clintland' oat (Avena sativa L.) seedlings at the rate of 10 aphids on each of four seedlings. After 3 days in the greenhouse, the aphids were killed by spraying with tetraethyl-pyrophosphate (TEPP) insecticide. The test plants were maintained in the greenhouse for 4 weeks before final counts of infected plants were taken.

Characterization of six of the isolates selected at random, was made by comparing the ability of five species of aphids to transmit the virus. Two tests were run for each isolate. Clintland oats infected by R. padi, the aphid used in the original isolation from the field sample, were used as the virus source in the first tests for each isolate. Source plants for the second test were ones infected in the first test by R. padi for isolates 1, 2, and 3, and by R. maidis (Fitch) for isolates 4, 5, and 6 (Table 4). In each trial, leaves were detached from the virus source plant, each leaf was cut into five pieces and the pieces were placed in five petri dishes at random. Virus-free apterae or late-instar nymphs of M. avenae, R. padi, Schizaphis graminum (Rondani), Acyrthosiphon dirhodum (Walker), or R. maidis, were transferred from colonies to each dish, and the dishes were placed at 15C for 2 days. Then, feeding aphids were transferred from each dish and were caged in groups of five aphids on each of ten 'Clintland' oat seedlings for 2 days in the greenhouse. The aphids were then killed by spraying with TEPP and the test seedlings were maintained on a greenhouse bench for 4 weeks, when final readings of infected plants were taken.

Colonies of virus-free aphids used in this work were raised on caged 'Parkland' barley (Hordeum vulgare L.) in a growth cabinet at 18C. Sample batches of the aphids were tested at regular intervals to ensure that the colonies were free from virus. Clintland oat test seedlings were grown in wooden flats of soil. Greenhouse temperatures were regulated for an average of 20C, but occasionally daily averages rose above this temperature.

Table 2. Number of field samples in which barley yellow dwarf virus was found

	Sampling period	
	May	June
No. of field samples tested	51	60
No. of field samples in which virus was detected	11	33
% of field samples in which virus was detected	22	55

Results

Some of the samples deteriorated during transit, and this interfered with the efficiency of testing. Usually the second youngest leaves arrived in poorer condition than the youngest leaves, and there was more deterioration of leaves sampled in the first period than in the second period. Consequently, samples representing only 34 out of 51 fields in the first period and 46 out of 60 in the second period were adequately tested. In a complete test, both the youngest and the second youngest leaves were tested with each aphid species. Some of the samples that were not fully tested, included those in which only one aphid species survived the acquisition feeding or only one age of leaf was tested. Much of the deterioration resulted from a yellowing of the leaves before they were sampled, possibly because of excessive moisture in some fields that were waterlogged during the May sampling. None of the tillers sampled in this survey exhibited BYD symptoms in the field.

The number of field samples in which BYDV was found for each of the two sampling periods is shown in Table 2. An analysis of the successful transfers of BYDV from the youngest and second youngest leaves by the two species of aphids is shown in Table 3. R. padi was considerably more efficient in transferring the virus from the samples than M. avenae, and transfers were more successful from the youngest leaves than from the second youngest. Considering both sampling periods, virus was transmitted from 35 samples by R. padi only, from 6 samples by M. avenae only, and from 3 samples by both vectors; each of these samples represented all the leaves from one field. The average number of test plants per sample that became infected in the successful transfers, of 4 plants inoculated, was 2 for R. padi and 1 for M. avenae, when feeding on the youngest leaves, and 1.3 and 1, respectively, when feeding on the second youngest leaves. Generally symptoms on the oat test plants were moderate to mild, though in a few cases symptoms were severe.

Table 3. Proportion of successful transfers of barley yellow dwarf virus from detached wheat leaves to 'Clintland' oat test plants by Rhopalosiphum padi and Macrosiphum avenae, and from younger and older wheat leaves

Aphid vector or age of wheat leaf	Sampling period: May Number*	May %	June Number*	June %	Total Number*	Total %
R. padi	20/340	5.9	59/448	13.2	79/788	10.0
M. avenae	4/344	1.2	5/452	1.1	9/796	1.1
Younger leaf†	20/356	5.6	40/480	8.3	60/836	7.2
Older leaf†	4/328	1.2	24/420	5.7	28/748	3.7

* Number of test plants infected/number inoculated.

† In the May samples leaves 3 and 4 were tested: in the June samples, leaves 1 and 2 (where flag leaf = 1).

Five of the six isolates selected for characterization were transmitted from field samples by R. padi only, while the other (isolate number 3, Table 4) was transmitted by both R. padi and M. avenae. Two of these isolates were from the first period of sampling and four from the second period. The pattern of transmission for isolates 1 and 2 (Table 4) and the symptoms they produced on oats were similar to those of the strain transmitted specifically by R. padi (4,9). R. padi was the most efficient vector for isolate 3, but the occasional transmissions by M. avenae and A. dirhodum, and a stunting effect on oats, often so severe as to kill the plants, indicated the possibility that a mixture of strains was present.

Isolates 4, 5, and 6 were transmitted with low efficiency by R. padi and S. graminum, but were transmitted much more efficiently by R. maidis. The pattern of transmission for these isolates was, therefore, similar to that of the strain specific for R. maidis (4,9). Isolates of this strain are occasionally transmitted by R. padi and S. graminum, and the high temperatures that sometimes occurred in the greenhouse during the inoculation feeding may have increased the efficiency of these two vectors (10). The mild symptoms on oats of these three isolates were also characteristic of the strain specific for R. maidis.

Fig. 1 shows the distribution of fields sampled in the survey. The fields where virus was found in the second sample occur at random throughout the area surveyed, suggesting that the geographical position of a field does not increase or decrease its chances of being infected.

Discussion

Virus was recovered from more than half of the fields sampled and this is considered to be a very conservative estimate for the following reasons.

Three of the six isolates that were examined more intensively were found to be characteristic of the R. maidis - specific strain, and it is highly likely that the use of R. maidis with the other two species would have resulted in detection of virus in a larger proportion of the samples. In many of the successful transfers of virus from field samples only one of the four test plants inoculated by a given species became infected, possibly the result of using inefficient vectors for the strains concerned as, for instance, R. padi for the R. maidis strain. On the other hand, the low percentage transmission could be due to a low number of culms infected or to a low virus content in infected leaves. Also

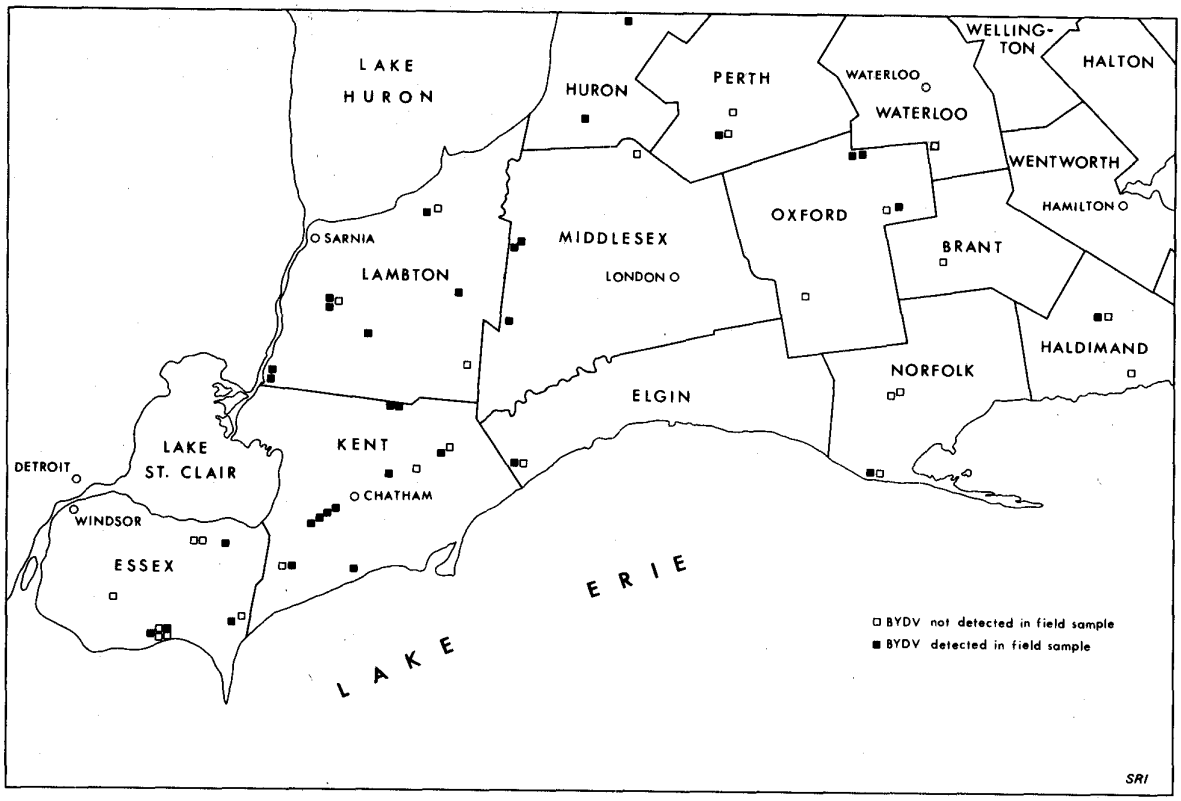

Figure 1. Distribution of barley yellow dwarf virus in winter wheat crops in southwestern Ontario, June 1969.

deterioration of leaves was probably a main factor in reducing the efficiency of transmissions. During both sampling periods (Table 3), the percentage of successful transfers was higher from the younger leaves, which showed less deterioration than the older ones. Similarly the second sampling had more successful transfers than the first sampling, when the leaves had deteriorated more due to excessive soil moisture. Consequently the increase in infection during the second sampling period is probably due to a difference in efficiency of transmission or to an increase of BYDV with the passage of time.

When comparing the distribution data for the virus from this survey with other data (1,2,11,14), it is important to note that the techniques used are different. The culms sampled in this survey were selected at random with no regard to BYD symptoms whereas other surveyors have used this as a means of diagnosing the disease. James (6) pointed out that approximately 90% of apparently 'healthy' leaf samples were infected with BYDV when random culms of barley were selected in the field. A similar result was obtained in this survey for although no obvious symptoms of BYD were observed in the field (no methodical check was conducted) more than 50% of the samples were infected. These findings stress the importance of selecting a random sample of culms when studying the distribution of the disease, especially if an attempt is being made to study the distribution of the disease within a particular crop. The sampling technique used in this survey has certain advantages over the 'ad hoc' sampling methods usually employed, because it is simple and well defined; it is therefore capable of being repeated by different people and allows valid comparisons to be made regarding the prevalence of the virus in different years, regions, varieties, etc. Although this survey was designed only to establish the number of field samples infected, some indication of the level of infection within the infected fields can be obtained. For the sample of twelve culms to be classified infected, it follows that at least 1 culm is infected; this is equivalent to 9% of culms infected. Assuming binomial distribution, the 95% confidence limits for the true infection levels are 0.2% and 39%. For the fields with infected samples, this implies that in 95 cases out of each 100 the true mean for the percentage of tillers infected will be between 0.2% and 39%. In practice,

Table 4. Transmission of six isolates of barley dwarf virus by five species of aphids

BYDV isolate	Macrosiphum avenae	Acyrthosiphon dirhodum	Rhopalosiphum padi	Schizaphis graminum	Rhopalosiphum maidis
1	0	0	15	1	0
2	0	0	18	1	0
3	1	2	14	1	0
4	0	0	1	1	10
5	1	0	3	2	13
6	0	0	3	2	13

* Figures represent number of 'Clintland' oat plants infected out of 20 plants inoculated, using five aphids per plant.

as in this survey, the amount of laboratory work involved in transmission tests severely restricts the usefulness of survey results.

Judging from the relative efficiency of transmission of the two species of aphids in the original isolations, from the symptoms of the isolates on oats, and from the characterization of six of the isolates, most of the isolates appeared to belong to the R. padi- or R. maidis-specific strains. The few isolates that were transmitted by R. padi and M. avenae, or by M. avenae only, may have been similar to the non-specific strain and the M. avenae-specific strains, respectively, but further testing of the isolates would have been necessary to prove this. Isolates similar to the latter two strains have been reported earlier from Ontario (12,14).

No estimate can be made of the losses due to BYD in winter wheat in Ontario because the data from this survey do not estimate the incidence of BYD within the crop. However, even if these data were available, present methodology on yield losses due to BYD would not allow extrapolation from survey results. Heavy losses in the yield of several winter wheat varieties have been demonstrated from controlled inoculation of experimental plots (1,5,8). In Kansas and South Dakota, infection in the autumn usually resulted in greater losses than infection in the spring (5,8). In New Zealand, however, a late infection was more injurious than an early infection (17), and in one particular year the average losses in that country on winter-sown wheat were estimated at 25% of the yield (15).

In view of these reported losses, and the fact that more than 50% of the fields were infected in southwestern Ontario in 1969, the need for meaningful methodology on yield losses due to BYD is apparent. Further sampling and testing will be necessary to determine the prevalence and incidence of the disease and to determine whether any large annual variations occur; information on the predominant virus strain is also needed. The susceptibility to BYDV of winter wheat varieties currently grown in Ontario should be determined so that recommendations can be made regarding our present varieties.

Acknowledgments

We are grateful to the Crops Section, Agriculture Division of DBS for providing details and aerial photographs for the field sample.

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