THE CAUSES AND DISTRIBUTION OF MOSAIC DISEASES OF WHEAT IN CANADA IN 1961[1]

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Abstract

Wheat striate mosaic, transmitted by the leafhopper, Endria inimica Say, was found on a trace to 1 percent of the plants in nearly all wheat fields examined along a route from Carlyle, Saskatchewan to Winnipeg, Manitoba. Ramsay, Stewart and Selkirk were among the most susceptible varieties tested at Ottawa. Winter wheat varieties grown in Ontario did not develop clear striate symptoms.

Another disease, possibly of virus origin, caused chlorosis, chlorotic leaf mottling, blotches and streaks, severe stunting and premature death of durum and hard red spring wheat, The disease was found in nearly all wheat fields examined on a route across southern Saskatchewan and Manitoba and affected a trace to 5 percent of the plants in different fields,

Agropyron mosaic, which has been recognized in Ontario since 1957, was first identified in a plot of spring-sown winter wheat in southeastern Saskatchewan in August, 1960. It was found in spring wheat in the same area in July, 1961.

A soil-borne mosaic was associated with a severe bronzing of winter wheat in early May in most of the districts in Ontario that lie north, west and southwest of Toronto., Although the mosaic symptoms were still evident in early June, the plants were not noticeably stunted. The leaf symptoms of the disease in Ontario differ from those of the soil-borne wheat mosaic in Illinois, U.S.A. It has not been induced by manual transmission, and no virus particles have been detected with the electron microscope. The nematicide Telone eliminated the infectivity of soil.

Wheat streak mosaic was absent or occurred on less than 1 percent of the plants in winter wheat crops examined in southern Alberta in 1961. Although the vector, Aceria tulipae K,, has been found in southeastern Saskatchewan and in Ontario, the virus is known in Canada only in those districts in southern Alberta and southwestern Saskatchewan where winter wheat is grown.

A virus disease similar to, but much milder than wheat spot mosaic in Alberta, was found associated with A. tulipae on wheat at Ottawa.

Introduction

Mosaic diseases of wheat and other cereals have been recognized in Canada only in the last decade. In 1961, Hagborg (2) verified that "false stripe", a disease observed on barley in Canada since 1925, was caused by a seed-borne virus now designated "barley stripe mosaic virus". In 1952, wheat streak mosaic and wheat spot mosaic were found to be caused by viruses

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transmitted by an eriophyid mite, Aceria tulipae K. in southern Alberta (6). In 1957, Agropyron mosaic, and a mosaic disease believed to be caused by a soil-borne virus, was found on wlicat in Ontario (9, 13). Although symptoms resembling wheat striate mosaic were observed on a timothy plant collected at Ottawa in 1958, and similar symptoms were found on Cornell wheat in experimental plots in 1959, transmission tests using Kent wheat as a test plant were inconclusive (8).

During 1961, wheat crops were examined for virus diseases in south-western Ontario, eastern Ontario and the Ottawa valley. In addition, a survey was made across the southern prairies, mostly in company with Dr. W. A. F, Hagborg, Canada Agriculture Research Station, Winnipeg, We were accompanied by J.S. Horricks and Dr. T.G. Atkinson, Canada Agriculture Research Station, Lethbridge, during part of the surveys in southern Alberta. The surveys, along with experiments done during the 1960-61 season, yielded new information on the causes, distribution and possible importance of mosaic diseases of wheat in Ontario and on the Canadian prairies.

Wheat Striate Mosaic in Saskatchewan and Manitoba

Probably the most significant result of surveys in 1961 was the discovery of wheat striate mosaic in southern Saskatchewan and Manitoba. This disease was first recognized in South Dakota in 1951 (5), and has been reported more recently in North Dakota (17). Although similar viruses with different vectors are now recognized in other countries (11), only one vector, the leafhopper Endria inimica Say, is known for the wheat striate mosaic virus in North America.

Stunted plants, with fine, light-green to yellow dashes and streaks on young leaves, and severe chlorosis and necrosis on older leaves, (Fig, 1) were found in fields of Ramsay durum and Selkirk spring wheat on the farm of H. Slykhuis, Carlyle, Saskatchewan on July 1, 1961. The disease was subsequently found in about. 10 other wheat fields examined in the district. About 20 additional wheat fields were examined on a survey from Carlyle through Brandon, Manitoba to Winnipeg, and the disease was found in all fields except one advanced crop in which the plants were fully headed and the leaves drying from drought. Despite the widespread occurrence of the disease, no crop was found in which striate symptoms were evident on more than 1 percent of the plants.

Diseased plants and live leafhoppers (E. inimica) were collected in southeastern Saskatchewan and taken to Ottawa. Diseased plants, collected at Winnipeg later in July by Dr. W.A. F. Hagborg, were also forwarded to Ottawa. Striate symptoms, similar to those observed in the field, developed on Ramsay durum and Selkirk spring wheat on which E. inimica, that had fed on diseased wheat for one week, were allowed to feed. An incubation period of one to three weeks was required between infection and the development of symptoms on test plants.

For further experiments, leafhoppers were collected from lawns and on grass strips between experimental plots on the Central Experimental Farm, Ottawa, E. inimica from the Ottawa area became infective after feeding on diseased wheat and were used to test the reactions of a number of varieties of durum, hard red spring, and winter wheats. It is of particular interest to note that Selkirk spring wheat and Ramsay and Stewart durum wheat, which

have been widely grown on the prairies in recent years, were readily infected with the disease and became severely stunted and necrotic. (Fig. 2). Marquis (Fig. 3) and Rcadia were slightly less severely stunted. The winter wheat variety Minter, which was the main variety used in tests with wheat striate mosaic in South Dakota in 1951 (5), proved to be the most susceptible of the winter wheat varieties tested. Nebred and Winalta were also highly susceptible. Kharkov 22 M.C. (Fig. 4) developed mild striate symptoms but was not significantly stunted. None of the Ontario-grown winter wheat varieties, including Richmond, Rideau, Genesee, Cornell and Kent developed definite symptoms. Although there is evidence that wheat striate mosiac occurs in Ontario, it is not likely to become apparent on the varieties of winter wheat being grown at present.

To determine the effects of wheat striate mosaic on the growth of wheat, selected plants showing early striate symptoms, and adjacent healthy plants of comparable size were marked by tall stakes in fields of Ramsay durum and Selkirk spring wheats near Carlyle, Saskatchewan on July 3, 1961. The plants were in the jointing to early boot stage. The co-operating farmer measured the plants at weekly intervals and noted the condition of each plant. The season was unusually dry, hence growth was less than would normally be expected for the location, The results' for pairs of plants on which satisfactory series of measurements were completed show that most of the diseased plants were severely stunted both in height and head development (Table 1). In addition, the plants died prematurely and there appeared to be poor kernel development.

Table 1. Heights of striate-diseased and adjacent healthy wheat plants measured at weekly intervals during July, 1961, near Carlyle, Sask.

Condition of plants on July 3	Height in inches, on July 3	July 10*	July 17	July 24	Heads
Ramsay durum					
Faint striate	12	17	19	19	small
Healthy	12	18	24	30	full
Mild striate	11	15	17	17	small
Healthy	14	20	26	32	full
Mild striate	10	11	16	16	small
Healthy	11	19	24	30	full
Moderate striate	10	12	16	16	small
Healthy	13	17	24	30	full
Severe striate	10	13	16	16	small
Healthy	11	13	24	30	full
Selkirk spring wheat					
Faint striate	12	13	12	12**	small
Healthy	12	20	21	21	full
Moderate striate	13	20	21	21	moderate
Healthy	13	23	23	23	full

* Plants heading ** Plant dead

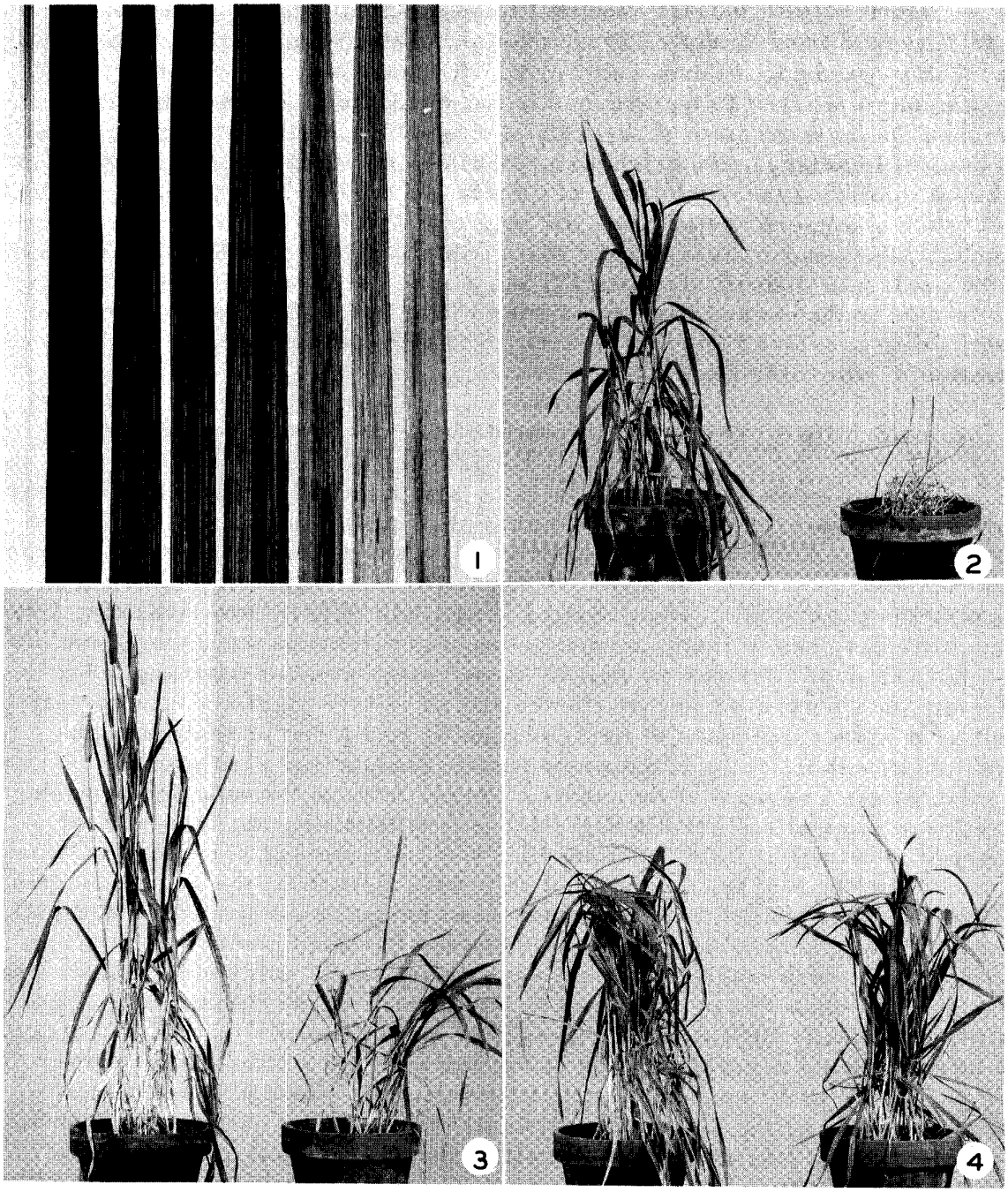


Figure 1. Fine chlorotic streaks caused by wheat striate mosaic virus on leaves of Sentry durum wheat.

Figure 2. Stewart durum wheat inoculated with wheat striate mosaic virus when in the 1 – 2 leaf stage (right) and not inocùlated (left).

Figure 3. Marquis spring wheat inoculated with wheat striate mosaic virus when in the 1 – 2 leaf stage (right), and not inoculated (left.)

Figure 4. Kharkov 22 M. C. winter wheat inoculated with wheat striate mosaic virus when in the 1 – 2 leaf stage (right), and not inoculated (left). Fine chlorotic streaks developed on the leaves but the diseased plants were only slightly stunted.

Wheat striate mosaic appeared to be uniformly distributed along the route surveyed from Carlyle, Saskatchewan to Winnipeg, Manitoba, hence it probably occurs in a much wider area. Although only 1 percent or fewer of the plants appeared to be diseased in the wheat fields examined, the diseased plants were usually severely damaged. Since the vector, E. inimica, is plentiful in southern Saskatchewan, Manitoba and Ontario, and is known to be common in other grassland areas of Canada (1), an increase in the percentage of infective leafhoppers seems to be the only additional factor necessary to cause economically serious losses in the susceptible varieties of wheat being grown on the prairies. Indeed, Timian (17) has already reported in 1959, high levels of infection in durum and hard red spring wheat in North Dakota, It may be desirable to consider including resistance to this disease when breeding new varieties of wheat for the prairies.

An unidentified "chlorosis" of wheat in Saskatchewan and Manitoba

An unidentified disease, with some symptoms of the mosaic type, was first observed in 1961 during an examination of grain fields in southwestern Saskatchewan. A few plants that were light yellow-green in color, in contrast with the dark green of the normal wheat plants, were sparsely scattered in wheat fields near Maple Creek, Swift Current and Pense, Saskatchewan. Usually, there were blotches of more intense chlorosis on some of the leaves, and often, irregular chlorotic stripes as well as some yellow to white mottling. The chlorotic plants were somewhat stunted and were less vigorous than normal plants. A higher incidence of these symptoms was found in southeastern Saskatchewan in fields in which wheat striate mosaic was also present. Approximately 5 percent of the plants in some fields of Ramsay and Selkirk wheat near Carlyle had the blotchy chlorosis symptom. The disease also occurred in all wheat fields examined between Carlyle and Winnipeg.

The effects of the unidentified chlorosis disease on the growth of Ramsay and Selkirk wheat in the field were measured by the same procedure described previously for wheat striate mosaic. Selected diseased plants and adjacent healthy plants were marked by tall stakes driven in the soil beside them. The heights of the plants were measured by the farmer at weekly intervals. The results given in Table 2 are the averages of measurements taken of all diseased and healthy plants respectively for each variety at each date. None of the diseased plants grew appreciably after July 3, and, although heads began to emerge on some of the diseased plants, all were sterile. All diseased plants were dead before July 24 while the healthy plants were still green and had developed full heads. This disease appeared to be more destructive to Ramsay and Selkirk than wheat striate mosaic.

Chlorotic plants collected in southeastern Saskatchewan and southern Manitoba were taken to Ottawa where transmission tests were done with aphids and some grass-feeding leafhoppers, Similar diseased plants collected by Dr. R. D. Tinline near Kyle, Saskatchewan were also tested. Barley yellow dwarf virus was transmitted by Rhopalosiphum padi (L.) from some of the plants, but it does not appear that this virus causes the main symptoms described, Although attempts to transmit a virus from the diseased plants with Endria inimica and Macrosteles fascifrons failed, the symptoms on the naturally diseased plants resemble symptoms of certain diseases of cereals known to be caused by leafhopper-transmitted viruses.

Table 2. Heights of wheat plants with blotchy chlorosis symptoms, and adjacent healthy plants measured at weekly intervals during July, 1961 near Carlyle, Sask.

	No. of plants measured	Average height in inches on July 3	July 10	July 17	July 24
Ramsay durum					
Diseased	6	10.0	9.0	8.5	plants dead, disintegrating
Healthy	6	11.7	17.7*	26.6	29.2; green, full heads
Selkirk					
Diseased	2	8.0	9.5	10.5	10.5; dead, sterile
Healthy	2	10.5	17.5*	20.5	20. 5; green, full heads

*Plants headed.

Agropyron mosaic on wheat in Ontario and Saskatchewan

Agropyron mosaic has been observed on scattered plants in winter wheat fields in Ontario each year since 1957. In May and June, 1961, symptoms of Agropyron mosaic (Fig. 5), were again commonly found on scattered plants in winter wheat fields throughout the Ottawa valley. The highest infection observed in a farm field was 25 percent of the plants near a grass border which included a preponderance of Agropyron repens infected with Agropyron mosaic, The incidence of diseased plants in the wheat decreased with increasing distance from the border, and few diseased plants could be found 25 yards away.

An Agropyron mosaic nursery has been developed in experimental plots at Ottawa by seeding small plots of winter wheat at 2–to–3 week intervals from early June to October. There is immature wheat in the plot area at all times, and whenever the virus spreads there are young, susceptible plants nearby. Infection ratings can be most satisfactorily made during May, The infections that developed in plots of 4 rows each, replicated 4 times, sown on different dates in 1959, were as follows: June 10-(90%), July 28-(64%), August 11-(60%), August 25-(21%), September 8-(0%), September 22-(0%). The infection resulting in similar plots in 1960 were: June 3-(loo%), June 10-(100%), June 28-(100%), July 18-(100%), July 29-(100%), August 20-(100%), August 31-(95%), September 2-(58%), September 8-(43%), September 19-(90%). These results show a very high rate of spread during the summer and fall of 1960, which is comparable to the rate of spread of wheat streak mosaic which occurs in Alberta when winter wheat is sown adjacent to naturally diseased wheat (12). Although mites are suspected to be the vectors of Agropyron mosaic, this hypothesis has not been proven,

The first evidence of Agropyron mosaic in Saskatchewan was found in a plot of Kent winter wheat that was sown in May, 1960 adjacent to natural grass pasture on a farm near Carlyle. When the plots were examined in August,

spring wheat in the area was ripe but the winter wheat in the plot was still green and, fortunately, not heavily infected with rust. Symptoms, thought at first to be wheat streak mosaic, were observed. Eriophyid mites, principally A. tulipae, were abundant, Diseased plants collected in the plots were tested at Ottawa, and it was established that the disease was Agropyron mosaic. During a visit to the same area on July 1, 1961, symptoms of Agropyron mosaic were found on plants in a field of Selkirk wheat on the same farm, On July 3, Agropyron mosaic was found on 75 percent of the plants within 10 to 20 feet of the edge of a field of spring wheat adjacent to a grass strip in which naturally diseased A. repens grew in abundance. Although some of the infected wheat plants appeared slightly stunted, it was not possible to estimate the probable effects on yield, Diseased wheat plants and A. repens from this' area were tested at Ottawa. The virus isolated from both—species was indistinguishable from the Agropyson mosaic virus normally isolated from wheat and A. repens in Ontario,

Soil-borne mosaic of wheat in Ontario

Mosaic symptoms attributable to a soil-borne agent have been observed on wheat in southwestern Ontario since 1957 (9). The leaf symptoms are a light-green to yellow mosaic including spots and short streaks (Fig. 6). Affected plants, when observed in the field, are usually not noticeably stunted, and to date no data are available on the effects of the disease on yield, Diseased plants are sometimes found scattered among healthy plants, but they usually occur in patches. Sometimes the symptoms occur on all plants in a field,

In 1961, surveys for soil-borne wheat mosaic were made on two dates, May 9 to 11 when winter wheat in most fields was in the stooling to early jointing stage, and June 6-9 when the wheat was in the boot to heading stages in the areas examined. No symptoms of the soil-borne mosaic were found east of Peterborough (Fig. 7), but westward, and southwestward as far as Essex County, the disease occurred in nearly all fields examined in counties where wheat is regularly grown as a major crop. All plants had mosaic symptoms in many fields examined in Simcoe, Huron, Lambton, Kent and Essex counties. Wheat is known to have been grown regularly in many of these fields. Little or no mosaic was found in areas where wheat is seldom grown.

The symptoms observed in early May included bronzing and necrosis of lower leaves in addition to the light-green mosaic on the younger leaves. The patches of affected plants could be located at a distance because of the bronze color not evident in mosaic-free areas. The mosaic was most common in lower, wetter areas in the fields, The high incidence of the disease in 1961 may be related to the cool, unusually wet conditions in early spring. Although plants with mosaic were obviously less vigorous than normal plants when observed in early May, they appeared surprisingly vigorous and not obviously weakened by the disease when observed in mid-June.

(a) Reactions of wheat varieties to soil-borne mosaic

The reactions of 11 varieties of winter wheat, 3 of winter barley and one of rye, when grown in diseased soil, were tested in boxes of soil at Ottawa, and in a farmer's field near Clinton, Ontario. For the test at Ottawa, soil, collected from fields in which diseased wheat had been found,

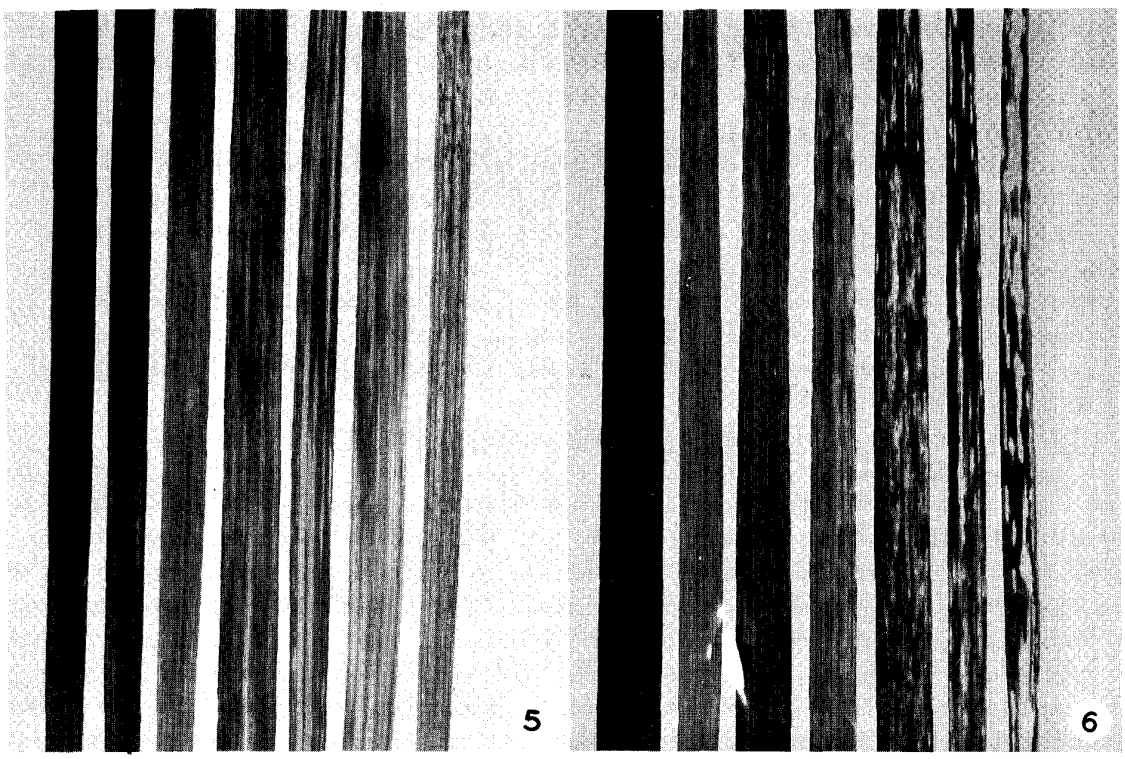


Figure 5. Symptoms of Agropyron mosaic on leaves *of* Kent wheat.

Figure 6. Mosaic symptoms of leaves of Genesee winter wheat grown in soil from an Ontario field in which the disease has been found.

was placed in boxes 15 3/4 x 15 3/4 x 6 inches. The varieties were sown September 20, 1960 and the boxes left outside throughout the fall and winter until March 21, 1961, when they were moved to a cool greenhouse (50°-65°F). Mosaic symptoms became evident on all varieties of winter wheat as new growth developed, and there appeared to be no major differences in reaction among the varieties, which included the following: Bison, Concho, Cornell, Dawbul, Genesee, Kent, Kharkow 22 M. C., Michigan Amber, Pawnee, Richmond and Rideau. No symptoms developed on Horton rye. The barley varieties Hudson, Kenate and Wong were winter killed, hence their reactions were not obtained. No mosaic symptoms developed on any of the varieties grown as checks in greenhouse potting soil.

The field test at Clinton, Ontario was sown September 22, 1960. When examined in May, 1961, all the wheat varieties expressed definite mosaic symptoms, but the rye and barley varieties did not.

(b) Quantities of diseased soil required for mosaic development

Tests were made to determine the quantities and mixtures of soils required for experiments to be done with greenhouse facilities. Boxes measuring 15 3/4 x 15 3/4 x 6 inches deep were filled with infective soil,

non-infective John Innes potting soil mixture, various depths of infective soil on top of greenhouse potting soil, or various mixtures of potting soil and infective soil. Four winter wheat varieties, Kent, Pawnee, Bison and Concho were sown in each box on September 20, 1960. The boxes were left outside throughout the fall and winter until March 21, 1961 when they were moved to a cool greenhouse (50°-65°F). Mosaic symptoms developed on all wheat plants grown in the following soil preparations:

(1) Infective field soil only.
(2) *3* inches of infective soil on top of *3* inches of non-infective potting soil,
(3) 1 inch of infective soil on top of 5 inches of non-infective potting soil.
(4) 1/4 inch of infective soil on top of 5 3/4 inches of non-infective potting soil.
(5) mixture of 1 part infective soil: 3 parts non-infective potting soil.
(6) mixture of 1 part infective soil: 15 parts non-infective potting soil.

No symptoms developed on plants grown in the non-infective potting soil.

(c) Elimination of mosaic infection with nematicide

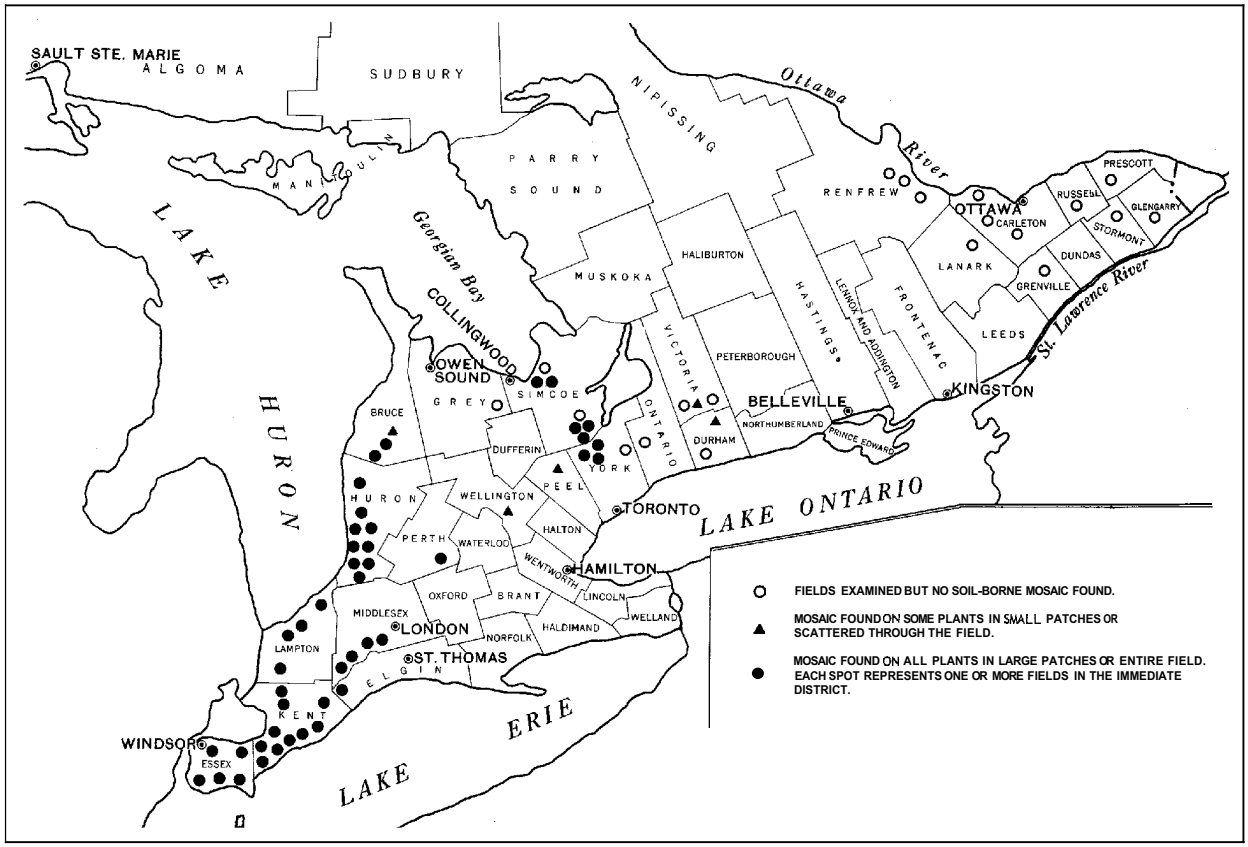
Soils collected from two fields in which mosaic occurred in 1960 were passed through a 1/4 inch screen to remove coarse particles and stones. Lots of 1/3 cu. ft. each were measured, and one lot of each soil was treated with 1 ml of ethylene dibromide, another with 1.5 ml of Telone, and another lot was left untreated. The treated soils were sealed for 1 week in polyethylene sheeting, then aired for one month and placed on top of *3* inches of John Innes potting soil mixture in boxes as described above and winter wheat test varieties were grown in the soil. Mosaic symptoms developed equally on plants in the ethylene dibromide-treated and non-treated soils but no symptoms developed on plants in either of the soils treated with Telone.

(d) Differences between mosaic from Ontario and Illinois soils

Soil from a field in Illinois, U.S.A. where the original type of soil-borne wheat mosaic was first identified (3), was obtained for comparative tests at Ottawa. The reactions of wheat and rye varieties were tested in boxes under the same conditions as used for the tests with Ontario soil, Mosaic symptoms developed on all the wheat varieties tested, but were more severe on Michigan Amber, Pawnee and Kent than on the other varieties. In addition, mosaic symptoms developed on Horton rye grown in the Illinois' soil, but not in the Ontario soil. The nature of the symptoms on wheat differed. There were no distinct spots or short streaks but, instead, there was more extensive mottling associated with the Illinois than with the Ontario disease.

Sap transmission tests have been done by rubbing dilutions of sap Srom diseased plants onto the leaves of Kent, Michigan Amber and Pawnee wheat seedlings, using celite as an abrasive. The plants were incubated at 50"-65°F. Symptoms developed on the plants inoculated with sap from diseased plants grown in the Illinois soil, but not from plants grown in the Ontario soil.

Using the electron microscope, particles that appeared to have a unit length of 140-160 mp and a width of 25 mμ have been found in sap from diseased plants grown in the Illinois soil, but no particles attributable to a virus have been Cound in sap from diseased plants from the Ontario soil.


SAULT STE. MARIE
ALGOMA
SUDBURY
NIPISSING
Ottawa River
PARRY SOUND
MANITOULIN
RENFREW
PRESCOTT
RUSSELL
OTTAWA
CARLETON
GLENGARRY
STORMONT
DUNDAS
LANARK
GRENVILLE
LEEDS
St. Lawrence River
KINGSTON
LAKE HURON
Georgian Bay
COLLINGWOOD
MUSKOKA
HALIBURTON
HASTINGS
LENNOX AND ADDINGTON
FRONTENAC
VICTORIA
PETERBOROUGH
OWEN SOUND
GREY
SIMCOE
BRUCE
DUFFERIN
YORK
PEEL
ONTARIO
DURHAM
BELLEVILLE
NORTHUMBERLAND
PRINCE EDWARD
HURON
WELLINGTON
TORONTO
LAKE ONTARIO
PERTH
WATERLOO
HALTON
HAMILTON
WENTWORTH
OXFORD
BRANT
LINCOLN
MIDDLESEX
LONDON
HALDIMAND
WELLAND
NORFOLK
LAMPTON
ST. THOMAS
ELGIN
KENT
WINDSOR
ESSEX
LAKE ERIE
FIELDS EXAMINED BUT NO SOIL-BORNE MOSAIC FOUND.
MOSAIC FOUND ON SOME PLANTS IN SMALL PATCHES OR SCATTERED THROUGH THE FIELD.
MOSAIC FOUND ON ALL PLANTS IN LARGE PATCHES OR ENTIRE FIELD. EACH SPOT REPRESENTS ONE OR MORE FIELDS IN THE IMMEDIATE DISTRICT.

Wheat streak mosaic

Wheat strealc mosaic has been found in Canada only in southern Alberta and southwestern Saskatchewan in areas where winter wheat is grown. As indicated previously, the vector, Aceria tulipae K. has been found at Carlyle, Sask., and also at Ottawa, Ontario (10), but wheat streak mosaic has not been found in these areas.

Winter wheat crops were examined in southern Alberta during June 21-23, 1961. Wheat streak mosaic was found oiily on scattered plants in experimental plots at Lethbridge, and similarly, only a trace to 1 percent of the plants were diseased in fields examined on a route from Lethbridge through Welling, Magrath, Whiskey Gap, Cardston and Hill Spring, and from Lethbridge through Nobleford, and High River to Calgary. The only winter wheat with 100 percent infection was a sparse stand of volunteer plants that had overwintered in a sweet clover crop near High River. The low incidence of wheat streak mosaic in southern Alberta is attributed to the elimination of most immature wheat that could be carrying the virus in early fall, and the delaying of seeding of winter wheat until after the first week of September, both of which are recommended for its control (12).

Wheat spot mosaic

Wheat spot mosaic, a non-sap transmitted virus, transmitted by Aceria tulipae K., is commonly associated with wheat streak mosaic in Alberta (7). The spotting symptoms are usually masked in the field because the infected plants are usually also infected with the wheat streak mosaic virus. The combined infection results, in severe streak mosaic symptoms and severe chlorosis. By painstaking mite-transmission tests, the spot mosaic virus has been isolated repeatedly from plants showing such symptoms. In 1961, the presence of spot mosaic was suspected on wheat in the Lethbridge and High River areas of Alberta, but no transmission tests were done to prove it.

A. tulipae has been found OM wheat at Ottawa and, although wheat streak mosaic has not been found, a mild disease similar to wheat spot mosaic develops on wheat after mites from field plants have fed on it (10). In 1961, spot mosaic symptoms were found on Kent winter wheat sown in plots in late August and early September, 1960. Unlike the isolates of spot mosaic found in Alberta, the virus isolated at Ottawa caused only mild chlorotic spots and chlorosis, and no severe stunting.

Discussion

Virus diseases that cause mosaic symptoms on wheat in the Prairie Provinces and Ontario are listed in Table 3. Two other viruses that can infect wheat were not included in this report, Barley yellow dwarf virus, which has a wide range of perennial grass hosts, and several aphid vectors, some of which occur in all grassland areas, has been observed by the author or reported by others in all provinces except Newfoundland (4, 15, 16). In 1961 it was observed on wheat in the three Prairie Provinces and Ontario. Barley stripe mosaic virus, which is seed-borne, may be found wherever infected barley seed is grown, but it has not been reported in commercial fields of wheat in Canada.

Table 3. Provinces in which mosaic diseases have been found in wheat.

Mosaic disease	Vector	Alta.	Sask.	Man.	Ont.
Wheat streak	mites	+	t	--	--
Wheat spot	mites	t	--	--	--
Agropyron	?	--	t	--	+
Soil-borne	?	--	--	--	t
Striate	leafhopper	--	+	+	?
"blotchy chlorosis"	?	--	+	t	--

The presence of vectors and reservoir hosts are probably the most important factors determining the distribution of the viruses that cause mosaic symptoms on wheat in Canada. The transmission of wheat streak mosaic virus is dependent on the eriophyid mite Aceria tulipae in southern Alberta and southwestern Saskatchewan. The use of winter wheat and cultural practices that provide a continuous supply of immature wheat, on which the mites can multiply, assures the multiplication of the virus. The same mite becomes abundant on winter wheat that is sown in the spring and remains green through summer and fall, both in southeastern Saskatchewan and at Ottawa, but wheat streak mosaic virus has not been detected at either location. Perhaps it is absent because there are no reservoir hosts in these areas. Conversely, Agropyron mosaic virus, for which no vector has been determined, occurs on Agropyron repens and wheat in southeastern Saskatchewan and Ontario, and in Prince Edward Island. It has not been detected in Alberta even though A. repens, a good reservoir host, is common. Possibly vectors are absent, or fur some other reason the virus has not yet spread to that area.

Endria inimica, the leafhopper vector of wheat striate mosaic virus, is common in most grassland areas of southern Canada (1), but the disease has been proven to be present only in southeastern Saskatchewan and southern Manitoba. Perhaps the appearance of the disease in this area was dependent on the extensive use of highly susceptible varieties like Ramsay and Selkirk, It is interesting to note that the disease was first discovered in South Dakota in areas where the highly susceptible varieties of winter wheat, Minter and Nebred were grown. Striate mosaic was not recognized in North Dakota until 1959, but the durum and some hard red spring wheat varieties commonly grown now are susceptible (17). Its occurrence has been suspected in Ontario, but the lack of more conclusive proof of its presence appears to be related to the lack of susceptible varieties that develop good diagnostic symptoms, and the unfortunate use of such varieties as test plants. Striate mosaic was found in Alberta. Tests at Ottawa have shown that Kharkov 22 M. C,, the most commonly-grown variety of winter wheat in southern Alberta, is highly resistant. Winalta, a new variety of winter wheat, recently developed for the area, appears lo have inherited a high degree of susceptibility from Minter. If this variety is widely used, attention should be directed toward the possible appearance of wheat striate mosaic. However, it is likely that winter wheat sown at the times recommended in southern Alberta would escape infection.

Plants showing the "blotchy chlorosis" symptoms, like plants infected with the wheat striate mosaic virus, were scattered singly among the normal wheat plants. Severely diseased plants were sometimes found closely united with normal healthy plaints. Such a situation is not usually apparent with cereal

diseases caused by fungi. Barley yellow dwarf virus may initially infect widely scattered plants but, usually, adjacent plants become infected because of local aphid movement, and the disease develops in patches. On the basis of the distribution of diseased plants as well as the nature of the symptoms, it is suspected that the "blotchy chlorosis" symptoms are caused by a leafhopper-transmitted virus,

Also, on the bases of symptoms and distribution in the field, the mosaic of wheat in southwestern Ontario is suspected to be caused by a soil-borne virus. The association with soil has been proven, but it has not been shown that a virus is the cause. Like the soil-borne wheat mosaic in Illinois, U.S.A., the Ontario disease appears to be favored by the practice growing wheat frequently on the same land, high soil moisture, and long periods of cool soil temperatures. The symptoms do not develop on wheat sown in spring or grown in a warm greenhouse. Not enough is known to suggest why this disease occurs on winter wheat in certain areas of Canada but not in others.

Literature Cited

1. BEIRNE, B. P. 1956. Leafhoppers (Hornoptera: Cicadellidae) of Canada and Alaska. Can. Entomolgist 88: Suppl. 2.
2. HAGBORG, W. A. F. 1954. Dwarfing of wheat and barley by the barley stripe mosaic (false stripe) virus. Can. J, Botany 32:24-37.
3. McKINNEY, H.H. 1930. A mosaic of wheat transmissible to all cereal species in the tribe Hordeae. J. Agr. Research 40:547-556.
4. ORLOB, G.B. and R.H.E. BRADLEY. 1960. Cereal diseases encountered in New Brunswick in 1960. Can. Plant Disease Survey 40:92-97.
5. SLYKHUIS, J.T. 1953. Striate mosaic, a new disease of wheat in South Dakota. Phytopathology 43:537-540.
6. SLYKHUIS, J.T. 1955, Aceria tulipae Keifer (Acarina: Eriophyidae) in relation to the spread of wheat streak mosaic, Phytopathology 45:116-128.
7. SLYKHUIS, J. T. 1956. Wheat spot mosaic, caused by a mite-transmitted virus associated with wheat streak mosaic. Phytopathology 46:682-687.
8. SLYKHUIS, J.T. 1959. Notes on cereal and grass viruses in 1959. Can. Plant Dis. Survey, 39th Ann, Rept. 19-20.
9. SLYKHUIS, J. T, 1960. Evidence of soil-borne mosaic of wheat in Ontario. Can. Plant Disease Survey 40:43.
10. SLYKHUIS, J. T. 1961. Eriophyid mites in relation to the spread of grass viruses in Ontario. Can. J. Plant Sci. 41:304-308.
11. SLYKHUIS, J.T. 1961. An international survey for virus diseases of grasses. Report for Plant Research Institute, Canada Agriculture, Ottawa, (unpublished).
12. SLYKHUIS, J.T., J.E. ANDREWS and V, J. PITMANN. 1957. Relation of date of seeding winter wheat in southern Alberta to losses from wheat streak mosaic, root rot and rust. Can. J. Plant Sci. 37:113-127.
13. SLYKHUIS, J.T. and R.J. BAYLIS. 1957. Agropyron streak mosaic on wheat in Ontario and the transmission by an eriophyid mite. Can. Plant Disease Survey. 37th Ann. Rept. 28.
14. SLYKHUIS, J. T. and R. J. BAYLIS. 1958. Agropyron mosaic on wheat in Ontario. Can. Plant Disease Survey. 38th Ann. Rept. 16-17.

15. SLYKHUIS, J. T., F. J. ZILLINSKY, A.E. HANNAH and W.R. RICHARDS. 1959. Barley yellow dwarf virus in Ontario. Plant Disease Reptr. **43:** 849-854.
16. SMITH, H. C. 1961. Barley yellow dwarf virus survey in Canada. 1961, Can. Plant Disease Survey 41:5, 344-352.
17. TIMIAN, R.G. 1960. A virus of durum wheat in North Dakota transmitted by leafhoppers. Plant Disease Reptr. 44:771-773.

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