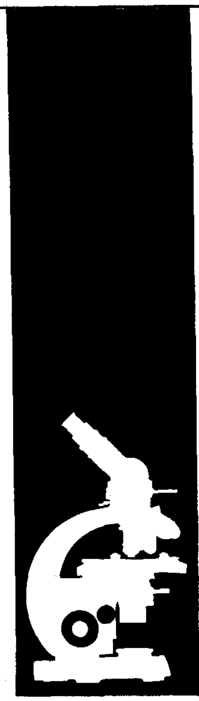

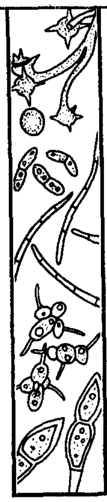

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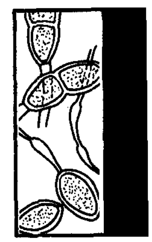
CANADIAN PLANT DISEASE SURVEY



EDITOR W.L. SEAMAN

RESEARCH BRANCH CANADA DEPARTMENT OF AGRICULTURE

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CANADIAN PLANT DISEASE SURVEY

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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. It will not accept results of original research suitable for publication in more formal scientific journals".

THE OCCURRENCE OF CEREAL ANTHRACNOSE IN ALBERTA

D. E. Harder[1] and W. P. Skoropad[2]

Abstract

A survey of wheat, oats, barley, and rye in Alberta for anthracnose caused by Colletotrichum graminicola showed that the disease was most prevalent in north-central Alberta in 1963, while only trace amounts were found in southern portions of the province. Oats was most severely affected. Anthracnose was not associated with any general soil type, but the disease was most severe on crops grown on soils low in organic matter. Crops grown on soils with very high organic matter were nearly disease free. Soil factors such as mineral salt concentration, nitrate, free lime, reaction, and conductivity could not be related to disease incidence.

Introduction

The anthracnose disease of cereals incited by Colletotrichum graminicola (Ces.) G. W. Wils. was reported in Alberta for the first time in 1933 by Sanford (4). Two years later he (5) described its effects on oats and indicated that under certain conditions this crop could be severely damaged by the root-rot phase of the disease. The disease also appeared to be associated with degraded soil.

Cereal anthracnose is difficult to diagnose during the major period of plant growth. Gross symptoms include a general reduction in plant vigor, the production of weakened, thin stems, and premature ripening. These symptoms can be mistaken for those caused by low or unbalanced soil fertility or by drought. Signs of the disease consist of black, setose acervuli that appear at plant maturity. It is at this stage that the cause of the disease can be easily determined.

More recent observations on the extent and severity of cereal anthracnose in Alberta have aroused renewed interest in the disease. Casual observations have also indicated that the disease might be favored by certain types of soil or soil conditions.

The objective of the present investigation was to survey the cereal-growing areas of Alberta in order to ascertain the distribution and severity of anthracnose on wheat, oats, barley, and rye, and to note any association of the disease with soil type or condition.

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Materials and methods

Survey of cereal anthracnose in Alberta

Six survey trips, representing 440 grain fields, were made in Alberta during the summer and fall of 1963. Fields of wheat, oats, barley, and rye were inspected at intervals of approximately 5 to 7 miles. The incidence of anthracnose could be determined most easily in stubble fields because acervuli appear most abundantly at the lower nodes. Disease ratings of 0 to 10 were made for each field and were based on the percentage of plants infected and the number of acervuli per unit area of stem. Soil characteristics such as color and texture were noted, and soil samples were collected from areas which represented variations in disease incidence.

Analysis of soils

Twenty-two soil samples were analyzed by the Provincial Soil and Feed Testing Laboratory, University of Alberta, for nitrate nitrogen, phosphorus, sulfate, free lime, reaction, and conductivity.

The total organic matter content of 26 samples was determined by the rapid wet oxidation method of Walkely (6). The results are expressed as the percentage (w/w) of organic matter in the soil. The organic matter was estimated as 1.72 times the determined organic carbon content, since soil organic matter is about 58% carbon.

Results

Anthracnose was found on wheat, oats, barley, and rye, the major cereal crops grown in Alberta. Oats was most severely affected. The area surveyed is shown in Figure 1. The prevalence of anthracnose is indicated by the relative density of

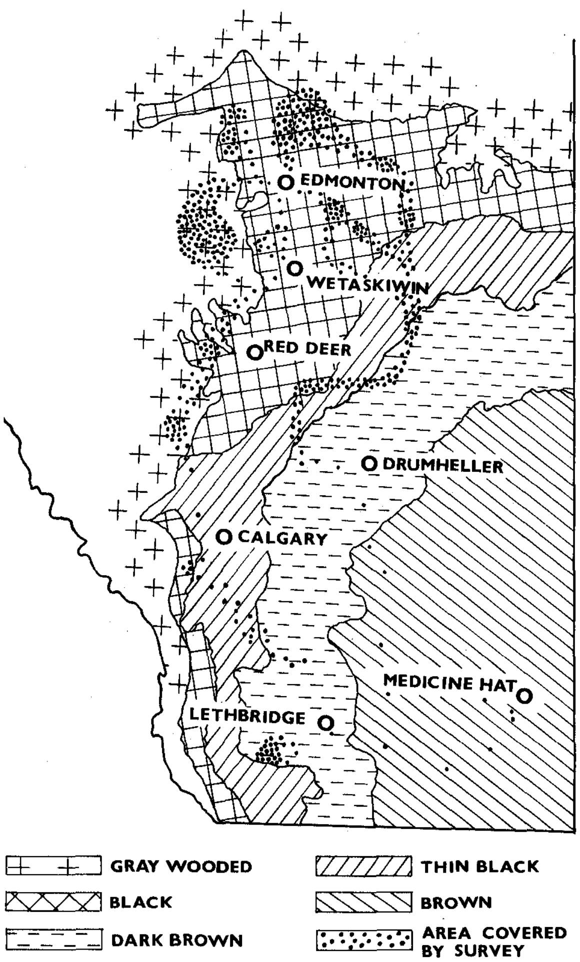

Figure 1. Distribution of cereal anthracnose in the major soil zones of Alberta in 1963. The density of dots indicates the prevalence of the disease.

black dots. Areas not showing dots were not surveyed. Also shown on the map are the major soil zones of Alberta: Brown, Dark Brown, Thin Black, Black, and Gray Wooded.

Anthracnose was most prevalent in north-central Alberta. Only traces of the disease were found in most areas south of Drumheller. However, a higher incidence of anthracnose was found near the foothills and in one small area of degraded soil southwest of Lethbridge (Fig. 1). The disease was often severe in localized areas where the soil was usually low in organic matter. A comparison of disease severity with the amount of organic matter in representative soil samples (Fig. 2) indicates that the level of organic matter influences the severity of anthracnose. In areas of low organic matter the disease was widely distributed and severe, but in areas where the level of organic matter was very high anthracnose was more limited or absent. However, in soils having moderate levels of organic matter (sample numbers 6 - 17), there was a less definite relationship. Such soil factors as conductivity, reaction, and the quantities of nitrate nitrogen, phosphorus, potassium, sulfate, or free lime did not show any relationship to severity of anthracnose (Table 1).

Some interesting observations were made in the Gray Wooded soil zone with respect to the possible influence of organic matter on disease levels. In this area the upland soils are generally composed of degraded soil of relatively low organic matter content. Some fields in this area contained low spots composed of peaty soils with very high organic matter. Crops in the portions of the field containing

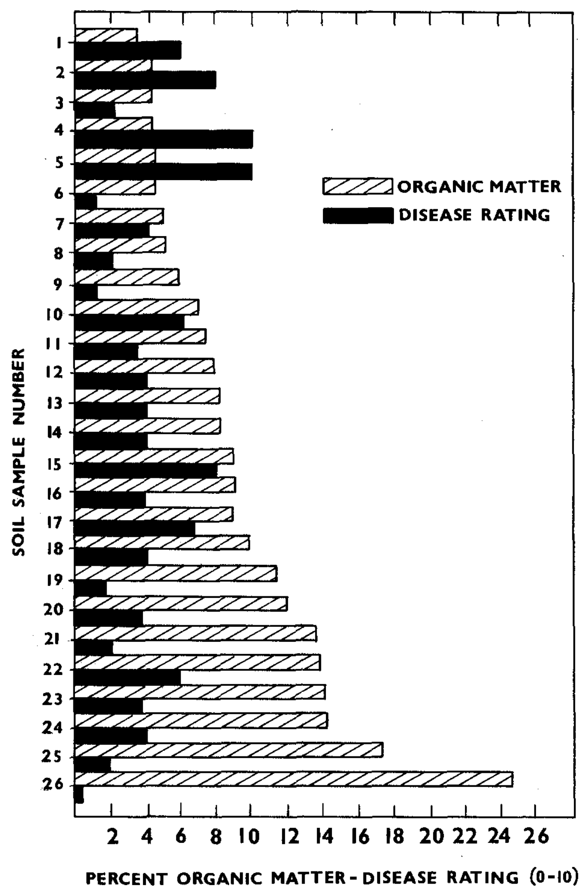

Figure 2. Levels of organic matter in soil and the severity of anthracnose in cereal fields. The disease ratings are based on a scale of 0 to 10, where 0 = no disease and 10 = severe disease, accompanied by the production of numerous acervuli of *Colletotrichum graminicola* on affected plants.

Table 1. Analysis of 22 soil samples from areas showing differences in severity of anthracnose on cereal crops

Sample no.	Nitrate nitrogen (lb/ac)	Phosphorus (lb/ac)	Potassium (lb/ac)	Soil reaction (pH)	Conductivity (mmhos)	Sulfate	Free lime	Disease rating*
1	20	51	100	6.3	0.8	0	0	6
2	13	80	76	6.7	0.3	0	0	8
3	13	46	74	6.3	0.2	0	0	2
4	38	0	206	7.7	4.3	700	very high	10
5	13	23	144	7.3	0.8	0	0	10
6	9	6	104	7.6	0.4	0	0	1
7	11	16	106	6.5	0.2	0	0	4
8	13	28	204	6.4	0.2	0	0	2
9	18	26	600	7.9	0.7	0	high	1
10	18	44	396	7.6	0.5	0	0	6
11	13	39	208	7.8	0.4	0	0	3
12	13	32	128	7.7	0.3	0	0	4
13	18	4	60	6.8	0.4	0	0	4
14	16	39	316	6.1	0.3	0	0	4
15	16	9	384	7.8	0.5	0	very high	8
16	11	73	272	7.0	0.5	0	0	4
17	18	41	232	7.4	0.4	0	0	7
18	20	23	318	7.8	0.9	0	high	4
19	11	8	48	7.1	0.4	0	0	2
20	7	144	208	6.9	0.3	0	0	4
21	11	52	74	5.5	0.3	0	0	2
22	18	30	48	5.4	0.3	0	0	6

* Where 0 = no disease; and 10 = severe symptoms and the production of numerous acervuli of *Colletotrichum graminicola* on affected plants.

degraded soil often showed a high incidence of anthracnose, but there was no trace of the disease in the peaty areas of the same field. Crops in other peat soils were also free from disease.

Discussion

The organic matter content appeared to be the only soil factor that was correlated with the severity of anthracnose. Attempts to correlate disease incidence with other soil factors may not be practicable because the cropping history of the individual fields was not known and because the soil samples represented widely divergent areas of climate and farming methods. Host specialization which has been shown for C. graminicola (1, 2, 3) was also not considered. The good correlation between organic matter content and disease incidence was especially evident in soils with very low or very high levels of organic matter. Support is given to the existence of such a relationship by the fact that anthracnose occurred in the degraded portions of a number of fields but not in peaty areas of the same fields. This situation isolates the influences of cropping history, soil management practices, or climate, and makes possible a direct comparison between organic matter content and disease incidence.

Further investigations are underway to determine how soil organic matter influences the occurrence of cereal anthracnose.

Acknowledgment

This project was supported by the National Research Council and is part of a M. Sc. thesis of the senior author.

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SOME RECORDS OF PLANT-PARASITIC NEMATODES ENCOUNTED IN CANADA IN 1967

V. Hadland[1]

Plant parasitic nematodes representing 19 genera and at least 34 species were extracted from soil and plant samples received during 1967 by the Nematology Section, Entomology Research Institute. The samples originated in various parts of Canada or were intercepted on entry from foreign countries; most were submitted by the Plant Protection Division or other government agencies.

Root-knot nematode (genus Meloidogyne)

Meloidogyne hapla Chitwood, 1949, the northern root-knot nematode, was found on Rosa sp. from Vancouver, British Columbia, and Carlisle, Ontario; on Scabiosa sp. from Galesburg, Michigan; Philadelphus sp. from Stillwater, Minnesota; Fragaria sp. from Minneapolis, Minnesota; Lycopersicon sp. from Tifton, Georgia; Ligustrum sp., Forsythia sp., Weigela sp. and Kolkwitzia sp. from Huntsville, Alabama; gooseberry (Ribes sp.) from Salem, Oregon; Weigela sp., Lonicera sp., Ligustrum sp., and Viburnum sp. from McMinnville, Tennessee; and Salix babylonica L. and Lonicera sp. from Tennessee. M. hapla was intercepted on four occasions on Rosa sp. from Tyler, Texas, and on two occasions on Rosa sp. from West Grove, Pennsylvania. Intercepted European samples showed M. hapla to be present on Clematis sp. and Populus alba bolleana (P. alba var. pyramidalis Bunge) from Boskoop, Holland, and on Rosa multiflora Thunb. from Belgium and Angers, France. A root-knot nematode, possibly M. hapla, was found on Ligustrum sp. from McMinnville, Tennessee, and on Rosa sp. from McFarland, California. Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949, the southern root-knot nematode, was found infesting Caladium sp. from Sebring, Florida, and Seattle, Washington; Deutzia sp. and Hydrangea sp. from Huntsville, Alabama; Forsythia sp., Tamarix sp., and Lonicera sp. from McMinnville, Tennessee; cabbage (Brassica oleracea var. capitata L.) and Lycopersicon sp. from Tifton, Georgia; and Lycopersicon esculentum Mill. from Richton, Mississippi. A root-knot nematode, possibly M. incognita was found on Acer sp. from Boskoop, Holland, and on Tilia platyphyllos Scop. from Holland. M. incognita acrita Chitwood, 1949 was found on Tilia cordata Mill. from Holland. M. javanica (Treub, 1885) Chitwood, 1949, the Javanese root-knot nematode, was removed from Lycopersicon esculentum from Tifton, Georgia, and a root-knot nematode resembling M. javanica was encountered on cabbage from Tifton, Georgia. Meloidogyne spp. were collected from Lonicera sp. from McMinnville Tennessee, greenhouse plants from Monaco; and Pyrethrum spp. from Twyford, Berkshire, England. Meloidogyne spp. (possibly M. hapla and M. arenaria) were intercepted from California in association with bulbs of Begonia sp.

Cyst-forming nematode (genus Heterodera)

Soil surveys for cyst-forming nematodes in the Maritimes, Ontario, and Quebec have shown Heterodera trifolii Goffart, 1932, the clover cyst nematode, to be present in soils from various areas, including Halifax, Nova Scotia; St. John, New Brunswick; Montreal, Quebec; Toronto, London, Vineland, and Long Sault, Ontario; and Abbotsford, British Columbia. Interceptions from the United States showed H. trifolii to be present in soil supporting Juniperus excelsa var. stricta Gord. and Juniperus sabina L. from Tennessee; Juniperus chinensis L. var. pfitzeriana Mast. from Athens, Alabama; pear (Pyrus communis L.) and apple trees (Malus sylvestris Mill.) from Louisiana; Hydrangea hortensia (H. macrophylla Ser.) from Bundalk, Maryland; and Poa sp. from the U.S.A. Examination of intercepted European soils showed H. trifolii to be present in those supporting Rosa sp. and Hydrangea sp. from Belgium; house plants and Clivia sp. from Germany; house plants, rosemary (Rosemarinus officinalis L.) Prunus sp., Cactus sp., Aspidistra sp., and Vitis sp. from Italy; daffodils (Narcissus sp.) and ivy (Hedera sp.) from England; and house plants from Portugal. Cysts resembling H. trifolii were removed from soil associated with mint (Mentha sp.) from Portugal; Fragaria sp. from Poland; Ficus sp. from England; and house plants from Germany. Heterodera avenae Wollenweber, 1924, was encountered in soil associated with Chrysanthemum sp. from England; fruit trees from Gorsem, Belgium; Lilium sp. from Holland; ornamentals from Germany; and Hydrangea sp. from Europe. Cysts resembling H. avenae were encountered in soil associated with Acer platanoides L. from Holland; ornamentals from Hungary; rosemary from Italy; and greenhouse plants carried in passenger baggage from Italy. H. cacti Filipjev and Schuurmans-Stekhoven, 1941, the cactus cyst nematode, was found in Tunisia's Expo 67 Pavilion in soil from greenhouse plants carried in baggage from Tunis. It was also removed from soil associated with Cactus sp.

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from Monaco and Tunisia and with Citrus sp. from McAllen, Texas. Cysts resembling H. cacti were found in soil surrounding roots of Chrysanthemum sp. from Italy and of Sansevieria sp. from San Juan, South America. Heterodera humuli Filipjev, 1934, the hop cyst nematode, was extracted from soil associated with house plants from Germany and Poland; Cantua sp. from France; ornamentals from Italy; Rosemarinus officinalis L. from Liberec, Czechoslovakia; greenhouse plants carried in a passenger's baggage from Italy; and Dahlia sp. from Europe. Heterodera cysts resembling H. humuli were found in soils associated with greenhouse plants carried in passenger baggage, Philodendron sp., Chrysanthemum sp. and Prunus sp. from Italy, and Crassula sp. from Hungary. Heterodera punctata Thorne, 1928, the grass cyst nematode, was removed from soil associated with Malus sp. and Laburnum sp. from Holland, and with ivy and Ficus sp. from England. Heterodera rostochiensis Wollenweber, 1923, the golden nematode, was found in soil associated with greenhouse plants and Chrysanthemum spp. from England; holly (Ilex sp.) from Glasgow, Scotland; shamrock(Trifolium repens L.) from Belfast, Northern Ireland; and ornamentals from Germany. Cysts resembling H. rostochiensis were taken from soil surrounding gladiolus bulbs from Hamburg, Germany. Heterodera schachtii Schmidt, 1871, the sugar-beet nematode, was found in soil supporting potatoes (Solanum tuberosum L.). Cysts of a Heterodera sp. (possibly H. cruciferae Franklin, 1945), were removed from soil around the roots of ornamentals from Italy. Cysts of what may be a new species of Heterodera were screened from soil associated with ornamentals from Hungary. Heterodera sp. larvae were extracted from soil surrounding the roots of virus-infected oats Avena sativa L. received from the Arboretum, Central Experimental Farm, Virology Section, Canada Department of Agriculture, Ottawa. Heterodera cysts of undetermined species were encountered several times during the golden nematode survey at Sidney, British Columbia. Heterodera spp. were also encountered in soils associated with Pelargonium spp. from Grand Rapids, Michigan; fern from Michigan; Magnolia soulangeana Soul. from Rives, Tennessee; Tilia cordata Mill. and Acer platanoides L. var. Schwedleri Nichols from Mechanicsburg, Pennsylvania; Dracaena sp., grape (Vitis vinifera L.) and house plants from Italy; Acer platanoides L. and Montbretia sp. from Holland; Pothos sp. from Greece; greenhouse plants from Yugoslavia; and Erica vulgaris L. (Calluna vulgaris Hull) from Inverness, Scotland.

Spiral nematode (genera Helicotylenchus and Rotylenchus)

Helicotylenchus digonicus Perry in Perry, Darling and Thorne, 1959, was found in soil associated with Tilia cordata from Gardiner, New York. Helicotylenchus dihystera (Cobb, 1893) Sher, 1961, was found at the Central Experimental Farm, Ottawa, associated with virus-infected oats. Helicotylenchus platyurus Perry in Perry, Darling and Thorne, 1959, was extracted from soils associated with Tilia cordata from Gardiner, New York, Rosa sp. from New York, Juniperus sp. from Maryland, Ligustrum vulgare L. from Holland, and house plants carried in passenger baggage from Europe. Helicotylenchus pseudorobustus (Steiner, 1914) Golden, 1956 was found in soil associated with Juniperus sp. from Maryland. A Helicotylenchus sp. (possibly H. pseudorobustus) was found in soil associated with privet (Ligustrum sp.) from McMinnville, Tennessee. Immatures of Helicotylenchus sp. were removed from soil associated with Siberian crab apple (Malus baccata Borkh.) from Lake Benton, Minnesota.

Rotylenchus robustus (de Man, 1876) Filipjev, 1936, was found in Compositae from Holland.

Root-lesion nematode (genus Pratylenchus)

Pratylenchus coffeae (Zimmermann, 1898) Filipjev and Schuurmans-Stekhoven, 1941, was extracted from soil from Germany, and P. convallariae Seinhorst, 1959 from soil surrounding the roots of Ligustrum vulgare from Holland. P. crenatus Loof, 1960, was found in soil associated with Tilia cordata from Mechanicsburg, Pennsylvania, Gleditsia triacanthos L. from Englishtown, New Jersey, Tilia cordata from Gardiner, New York, Thuja woodwardii (T. occidentalis L. var. woodwardii Spaeth.) from Butler, Pennsylvania, and in soil associated with Ligustrum vulgare, Tilia cordata, flax-like plants, and Compositae from Holland. P. neglectus (Rensch, 1924) Filipjev and Schuurmans-Stekhoven, 1941, was found in soil associated with Siberian crab apple from Lake Benton, Minnesota, and nursery stock from Sturgeon Bay, Wisconsin. P. penetrans (Cobb, 1917) Filipjev and Schuurmans-Stekhoven, 1941, was encountered in soils associated with clover roots from Charlottetown, Prince Edward Island, Siberian crab apple from Lake Benton, Minnesota, and Ginkgo biloba L. from Princeton, New Jersey. P. penetrans was also found in soil associated with Dahlia spp. from Denmark, Ligustrum vulgare, Tilia cordata and Acer platanoides from Holland, and Ligustrum ovalifolium Hassk, from Boskoop, Holland. P. pratensis (de Man, 1880) Filipjev, 1936, was screened from soil associated with Rosa sp. from New York and Ligustrum vulgare from Holland. A nematode which may be a new species of Pratylenchus was discovered in soil associated with pear trees from Holland. Pratylenchus sp. was encountered in soil associated with Juniperus virginiana L. from Wisconsin, and Ligustrum vulgare and Weigela 'Abel Carrière' from Holland.

Stunt nematode (genus Tylenchorhynchus)

Tylenchorhynchus brevidens Allen, 1955, was removed from soil associated with Ginkgo biloba from Princeton, New Jersey, pear trees and plant species from Holland, and Dahlia sp. from Denmark. T. claytoni Steiner, 1937, the tobacco stunt nematode, was found in soil associated with azalea from Beamsville, Ontario, and Rhododendron sp. from Wantagh, New York. T. dubius (Bütschli, 1873) Filipjev, 1936, was found in large numbers in soil associated with virus-infected oats from the Central Experimental Farm, Ottawa. T. dubius was also found in soil associated with African violet (Saintpaulia ionantha Wendl) from Westfield, Kings County, New Brunswick. A Tylenchorhynchus species (near T. dubius) was removed from soil associated with grass from Lethbridge, Alberta. T. nothus Allen, 1955, was extracted from Compositae from Holland. T. ornatus Allen, 1955, was removed from soil associated with house plants carried in a passenger's baggage from Poland. A Tylenchorhynchus sp. was extracted from soil associated with arborvitae (Thuja occidentalis L.) from Wisconsin.

Bud and leaf nematode (genus Aphelenchoides)

The chrysanthemum foliar nematode, Aphelenchoides ritzemabosi (Schwartz, 1911) Steiner and Buhrer, 1932, was found infesting Chrysanthemum sp. from England. An Aphelenchoides sp. (near A. parietinus (Bastian, 1865) Steiner, 1932) was found associated with Lilium spp. from Poland. A possibly undescribed species of Aphelenchoides was discovered in association with taro (Colocasia esculenta Schott) plants from Hong Kong. An Aphelenchoides sp. (an undetermined species) was found associated with Gleditsia sp. from Galt, Ontario; Ligustrum vulgare, from Holland; Viburnum spp. from Boskoop, Holland; and Chrysanthemum spp. from England.

Pin nematode (genus Paratylenchus)

Paratylenchus projectus Jenkins, 1956, was removed from soil associated with Juniperus virginiana from Wisconsin, Ginkgo biloba from Princeton, New Jersey, Quercus borealis Mich. from Mechanicsburg, Pennsylvania, and Acer platanoides from Holland. A Paratylenchus sp. (near P. projectus) was found in soil associated with house plants carried in passenger's baggage from Poland.

Ring nematode (genus Criconemoides)

Criconemoides lobatum Raski, 1952, was found in soil associated with Chrysanthemum sp. from England, and Criconemoides xenoplax Raski, 1952, in soil associated with Tilia tomentosa Moench from Boskoop, Holland. A nematode resembling Criconemoides mutabile Taylor, 1936, was extracted from Compositae from Holland, and a Criconemoides species (near C. quadricorne (Kirjanova, 1948) Raski, 1958) was found in soil associated with Juniperus sp. from Virginia.

Lance nematode (genus Hoplolaimus)

Hoplolaimus galeatus (Cobb, 1913) Thorne, 1935 was extracted from soil associated with Gleditsia spp. from Gardiner, New York; Gleditsia triacanthos from Englishtown, New Jersey; Ginkgo biloba from Princeton, New Jersey; Juniperus spp. from McMinnville, Tennessee; and house plants carried in passenger baggage from Europe.

Stem and bulb nematode (genus Ditylenchus)

Nematodes resembling the potato-rot nematode, Ditylenchus destructor Thorne, 1945, were found in soil associated with tobacco (Nicotiana tabacum L.) from Kentville, Nova Scotia. Ditylenchus sp. was removed from soil associated with lily (Lilium sp.) bulbs from Smith River, California, and Ribes sp. and Rosa sp. from Holland.

Seed gall nematode (genus Anguina)

Anguina sp. was extracted from soil associated with Poa pratensis L. from Louisburg, Cape Breton County, Nova Scotia.

Sting nematode (genus Belonolaimus)

Belonolaimus sp. was removed from soil associated with Rosa sp. from Tyler, Texas.

Dorylaimids

The American dagger nematode, Xiphinema americanum Cobb, 1913, was found associated with Acer sp. from Strathroy, Ontario; Rosa sp. from Tyler, Texas; Juniperus sp. from Virginia; Gleditsia sp. and Tilia cordata from Gardiner, New York; Gleditsia triacanthos and Gleditsia sp. from Englishtown, New Jersey; Quercus palustris Muenchh. from Princeton, New Jersey; Juniperus sp. from McMinnville, Tennessee; Tilia cordata and Quercus borealis from Mechanicsburg, Pennsylvania. Xiphinema diversicaudatum (Micoletzky, 1927) Thorne, 1932, the European dagger nematode, was found heavily infesting Rosa sp. from Brampton, Ontario. An undetermined species of Trichodorus, the stubby root nematode, was associated with azalea plants from Beamsville, Ontario. A Trichodorus sp. (possibly T. proximus Allen, 1959) was associated with Tilia cordata from Gardiner, New York.

Miscellaneous nematodes

Aphelenchus spp. were extracted from soil from Germany and from soil associated with Ligustrum vulgare from Holland; Lilium sp. from Poland, and Tilia cordata from Gardiner, New York; Siberian crab apple from Lake Benton, Minnesota; Phlox sp. from Kemptville Agricultural School, Kemptville, Ontario; and Acer platanoides from Holland. Tylenchus cancellatus (Cobb, 1925) Filipjev, 1934, was found in soil associated with Tilia cordata from Gardiner, New York. Tylenchus sp. was found in soil associated with Pelargonium sp. from Grand Rapids, Michigan; Juniperus sp. from Virginia; Taxus media var. hicksii Rehd. from Butler, Pennsylvania; Tilia cordata from Gardiner, New York; Viburnum sp., Acer platanoides, and Tilia cordata from Boskoop, Holland; Ligustrum vulgare from Holland; Lilium sp. from Poland; and tobacco from Kentville, Nova Scotia. Nothotylenchus sp. was found in soil associated with Acer saccharinum L. from Holland. Paraphelenchus sp. was found in soil associated with Thuja occidentalis var. woodwardii and Taxus media var. hicksii from Butler, Pennsylvania.

SEED-TREATMENT FUNGICIDES FOR CONTROL OF CONIFER DAMPING-OFF: LABORATORY AND GREENHOUSE TESTS, 1967

J. Belcher and L. W. Carlson[1]

Abstract

Sixty-nine seed treatment chemicals were tested in laboratory bioassays, 13 in laboratory germination tests, and 9 in greenhouse damping-off control tests. Damping-off of red pine seedlings was effectively controlled with thiram (2.0 g/g of seed, and 0.5 g/g of seed), captan (2.0 g/g of seed), and Polyram (0.5 g/g of seed). Damping-off of jack pine and white spruce seedlings was also controlled; however, the seed treatment chemicals giving control were also phytotoxic.

Introduction

The main species of conifers grown in prairie nurseries are white spruce (Picea glauca (Moench) Voss), Colorado spruce (P. pungens Engelm.), Scots pine (Pinus sylvestris L.), jack pine (P. banksiana Lamb.) and red pine (P. resinosa Ait.). Damping-off has been a problem on seedlings of all species of conifers at one time or another (1, 3). The most important pathogens involved are Rhizoctonia solani Kühn, Pythium debaryanum Hesse, P. ultimum Trow, Phytophthora cactorum (Leb. & Cohn) Schroet., and several species of Fusarium and Cylindrocarpon (3).

Numerous attempts to control conifer damping-off with chemicals have been made, but only a few seed-treatment chemicals, such as captan and thiram, have proved useful (2), and even these do not completely control the disease. The present screening program of seed-treatment chemicals is designed to evaluate by laboratory, greenhouse, and field tests the activity of these chemicals against three major pathogens, Pythium, Rhizoctonia and Fusarium. This report presents results of preliminary tests of the effect of a number of seed treatment chemicals on the in vitro growth of mycelium and germination of conifer seed, and on damping-off control in natural soil in the greenhouse.

Materials and methods

Laboratory bioassay — Sixty-nine seed-treatment chemicals (Table 1)* were tested for inhibition of mycelium growth of isolates of Pythium, Fusarium, and Rhizoctonia known to cause damping-off of conifer seedlings. A 5-mm disc of actively growing mycelium was placed at the center of a petri dish containing 25 ml of malt agar (30 g malt extract and 20 g Difco Bacto-agar in 1 liter of distilled water). Seed-treatment chemicals were suspended in acetone at rates of 10,200; 2,560; 640; 160; and 40 µg active chemical per ml. Sterile 10-mm discs of Whatman No. 1 filter paper were infiltrated with the chemicals and placed on the agar 18-20 mm from the inoculum. Three discs were used for each petri dish. The presence and amount of inhibition were recorded after 3 days at room temperature for the Pythium and Rhizoctonia cultures, and after 5 days for the Fusarium cultures. Each chemical was tested twice and there were four replications per test.

Laboratory germination tests — Seeds of jack pine, white spruce, and red pine were pelleted with seed-treatment chemicals at rates of 0.25 and 1.0 g chemical per gram of seed. Dow Latex 512R was used as a binder at a rate of 1 g of a 10% (V/V) solution per 3 grams of seed. This material was used because preliminary tests showed that it inhibited germination less than methyl cellulose. In each treatment, 100 air-dried seeds of each tree species were placed on filter paper and incubated at 100% relative humidity in a germinator that provided alternating 8-hr periods of darkness at 20 C and 16-hr periods of light (70 ft-c, fluorescent) at 30 C. The germinated seeds were counted after 14 days. Each test was repeated at least once, and some were repeated three times.

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* Chemicals were supplied by Stauffer Chemical Co. Ltd., Vancouver; Diamond Alkali Co., Painesville, Ohio; Naugatuck Chemicals, Elmira, Ont.; Niagara Brand Chemicals, Burlington, Ont.; DuPont of Canada Ltd., Montreal, Que.; Chemagro Corp., Kansas City, Mo.; American Cyanamid, New York, N. Y.; Sherwin-Williams Co. of Canada Ltd. (Green Cross Products), Montreal, Que.; Morton Chemical Co., Woodstock, Ill.; Chipman Chemical Ltd., N. Hamilton, Ont.; Interprovincial Cooperatives Ltd., Winnipeg, Man.; Dow Chemical Co., Midland, Mich.; American Hoechst Crop., North Hollywood, California.

Table 1. Source and identity of seed treatment materials

Treatment	Source	Product and formulation	Chemical name or active ingredient
1	Stauffer	Captan 50% WP	captan
2	Diamond Alkali	Daconil 2787 75% WP	tetrachloroisophthalonitrile
3	Diamond Alkali	Daconil 2787 & Captan (35-35)	
4	Naugatuck	Spergon 95%	chloranil
5	Naugatuck	Plantvax 75% (F461)	2,3-dihydro-5-carboxoanilido-6 methyl-1,4-oxathiin-4, 4 dioxide
6	Naugatuck	Vitavax 75% (D735)	2,3-dihydro-5-carboxoanilido-6-methyl-1, 4-oxathiin
7-9	Naugatuck	Numbered compounds	identity not available
10	Niagara	Phygon 50%	dichlone
11	Niagara	Polyram 80%	zinc activated polyethylenethiuram disulfide
12	Niagara	C. O. C. S. 55%	copper oxychloride sulfate
13	Niagara	Polyram 7D	zinc activated polyethylenethiuram disulfide (7% mixture)
14	Niagara	Polyram ZMCS 80	identity not available
15	Dupont	Arasan 75%	thiram
16	Dupont	Manzate D 80%	maneb
17	Dupont	Parzate C 75%	zineb
18	Dupont	Fermate 76%	ferbam
19	Dupont	Demosan 65%	1, 4 dichloro-2, 5-dimethoxybenzene
20	Chemagro	4497 50%	bis (1, 2, 2, -trichloroethyl) sulfide
21	Chemagro	Dyrene 50%	2, 4-dichloro-6-(0-chloroanalino)-S-triazine
22	Chemagro	Dexon 50%	p-dimethylaminobenzenediazo sodium sulfonate
23	Chemagro	Bay 47531	dichlofluanid
24	Cyanamid	Cyprex 65%	dodine (n-dodecylguanidine acetate)
25	Green Cross	Duter 20%	triphenyl tin hydroxide
26-43	Green Cross	Numbered compounds	identity not available
44-59	Morton	"EP"-compounds	identity not available
60-66	Chipman	Numbered compounds	identity not available
67	Co-op	Hexa	identity not available
68	Dow	Dowicil 100 95%	1-(3 chloroallyl)-3, 5, 7-triaza-1-azoniaadamantane chloride
69, 70	Hoechst	Numbered compounds	identity not available
71	Niagara	Polyram seed Protectant	zinc activated polyethylenethiuram disulfide

Greenhouse damping-off control tests —Seeds of jack pine, white spruce and red pine were pelleted with nine fungicides at rates of 0.5 and 2.0 g chemical per gram of seed and were germinated in soil from the Pineland Nursery at Hadashville, Manitoba. Dow Latex 512R was used as a binder as previously described. Seeding was done as soon after treatment as possible, but in some cases it was delayed as much as 10 days after treatment. The experimental plots contained 100 seeds per 8 inch x 9 inch plot and were arranged in a randomized block design with five replications for each treatment. Damping-off was recorded weekly from the beginning of emergence until 3 months after seeding. Supplementary lighting in the greenhouse was used from 8 AM to 8 PM and the temperature controls were set at 72°F (22.2 C).

Results and discussion

Bioassay of seed treatment chemicals —Data on the lowest concentration of seed-treatment chemicals that inhibited growth of Pythium, Fusarium, and Rhizoctonia are shown in Table 2. Thirty-one of the 69 chemicals tested showed a high level of activity (inhibitory at concentrations equal to or less than 631 μg/ml) against all three fungi. Nine others were effective against Rhizoctonia and Pythium only, and one was active against Pythium alone. High activity against Rhizoctonia was shown

Table 2. The lowest concentration of seed treatment chemical that inhibited the growth of three damping-off fungi on malt agar

Treatment number	Product and formulation	Lowest inhibitory concentration(µg/ml)		
		Rhizoctonia	Fusarium	Pythium
1	Captan 50 WP	158	200	158
2	Daconil 2787 WP	3,400	316	40
3	Daconil 2787 & Captan (35-35)	79	158	631
4	Spergon 95%	631	3,981	631
5	Plantvax 75%	10,000	10,000	5,012
6	Vitavax 75%	40	NI[a]	631
7	6638	316	NI	316
9	D-735-10D	316	2,512	2,512
10	Phygon 50%	631	1,259	158
11	Polyram 80%	317	40	158
12	C.O.C.S. 55%	NI	NI	5,012
13	Polyram 7D	NI	317	NI
14	Polyram ZMCS 80%	40	158	NI
15	Arasan 75%	1,259	1,259	40
16	Manzate D 80%	63	40	199
17	Parzate C 75%	2,512	398	5,012
18	Fermate 76%	158	79	40
19	Demosan 65%	40	40	100
20	4497 50%	40	40	158
21	Dyrene 50%	40	100	1,000
22	Dexon 50%	158	2,512	100
23	Bay 47531	40	40	40
24	Cyprex 65%	631	5,012	631
25	Duter 20%	158	158	40
26	RD 8684 15%	-	10,000	10,000
27	RD 8684 & Cyprex	631	5,012	631
28	3944X	158	398	40
29	Drillbox Lindasan	79	10,000	79
30	MHC 223	40	40	2,512
31	TMHC 175 (2)	40	158	1,259
32	TMHC 2222	79	158	2,512
34	Dual purpose Bunt No More 50%	79	631	158
35	RD 8684 & Maneb 50%	79	40	631
36	RD 8684 & Captan 50%	79	631	158
37	KHC 324	79	40	40
38	MHC 324	40	158	1,259
39	PHC 324	40	79	79
40	XHC 324	79	79	1,259
41	BHC 324	79	158	1,259
42	DHC 324	40	40	79
43	THC 324	79	40	631
44	EP 277 50%	40	316	631
45	EP 277A liquid	40	631	2,512
46	EP 279 50%	158	2,512	10,000
47	EP 279A liquid	63	40	1,000
48	EP 293 50%	100	40	631
49	EP 294 50%	63	40	126
50	EP 301B 50%	398	251	40

Table 2 (Continued)

Treatment number	Product and formulation	Lowest inhibitory concentration(µg/ml) Rhizoctonia	Fusarium	Pythium
51	EP 301C	631	158	158
52	EP 301D	631	316	631
53	EP 301E	398	63	631
54	EP 302B	398	63	1,000
55	EP 302C	100	631	398
56	EP 302D	251	100	10,000
57	EP 305	79	316	158
58	EP 306 75%	40	317	2,512
59	EP 308	40	40	2,512
60	65-S-1	317	5,012	5,012
61	65-S-7	158	158	NI
62	66-S-1	5,012	1,259	10,000
63	66-S-2	158	40	5,012
64	66-S-3	40	40	10,000
65	66-S-4	40	40	40
66	66-S-5	40	158	79
67	Hexa	398	158	158
68	Dowicil 100 95%	40	NI	40
69	2844	79	79	79
70	2874	316	631	40
71	Polyram seed protectant	40	631	NI

[a]NI indicates no inhibition at highest concentration used.

by 61 chemicals and against Fusarium by 52 chemicals. Fifteen of the 40 chemicals that showed high activity against Rhizoctonia and Pythium were more effective than the standard captan treatment.

Laboratory germination tests — Results of the seed germination tests are shown in Table 3. All 13 chemicals caused some inhibition of germination. The least inhibitory were copper sulfate (COCS) and zineb (Parzate C). Captan inhibited germination of red pine and white spruce more than jack pine; Chemagro 4497 inhibited jack pine and red pine more than white spruce; and ferbam (Fermate) inhibited white spruce more than jack pine and red pine.

Greenhouse damping-off control tests — The incidence of damping-off was greater in the greenhouse than is usually observed in the field. In the check plot, jack pine was most severely affected by postemergence damping-off (Table 4), but emergence of white spruce and red pine was reduced by apparent preemergence damping-off. Polyram, thiram, and captan showed the most promise for control of postemergence damping-off and were most effective on red pine. All seeds treated with Spergon emerged more rapidly than those that had been treated with other chemicals, and initial stands of red pine and jack pine were good; however, damping-off became quite severe 3 to 4 weeks after emergence. There was no evidence that preemergence damping-off was controlled by any of the chemicals.

Phytotoxic effects of the chemicals were severe at the higher rate of application. Duter caused the greatest reduction in emergence in all three conifer species. The percentage emergence for seed treated with Plantvax and Vitavax was inversely proportional to the amount of chemical applied. Thiram appeared to be the least injurious of the effective chemicals. Captan and polyram were phytotoxic to white spruce at both concentrations, but germination of jack pine and red pine seeds was reduced by polyram only at the higher concentration.

Seed treatment chemicals that reduced the amount of damping-off in the greenhouse tests were generally highly active against Pythium in the bioassay tests. It is possible that combinations of these chemicals would give a broader range of activity. However, control of damping-off with seed-treatment chemicals alone appears to be quite difficult to achieve at the present time, because many chemicals are effective against only part of the damping-off complex, and those that are effective against all damping-off fungi are often phytotoxic. An acceptable level of phytotoxicy might be established but only after an acceptable level of damp-

Table 3. Germination in seed germinator of conifer seeds pelleted with two amounts of seed-treatment chemicals

Treatment No. and product	Germination (%) Jack pine heavy[a]	Jack pine light[b]	White spruce heavy	White spruce light	Red pine heavy	Red pine light
1 Captan	63*	76	38*	55*	24*	31*
2 Daconil	47*	86	1*	43*	35*	17*
4 Spergon	72	89	21*	80	29*	52*
11 Polyram	32*	67*	40*	40*	5*	30*
12 C. O. C. S.	78	77	55*	70	70	94
15 Arasan	80	78	37*	50*	7*	58*
16 Manzate D	37*	60*	0*	15*	12*	19*
17 Parzate C	71	66*	52*	74	83	88
18 Fermate	55*	75	1*	14*	5*	43*
20 Chemagro 4497	2*	0*	19*	46*	0*	0*
21 Dyrene	13*	19*	4*	2*	7*	6*
23 Bay 47531	17*	50*	1*	1*	0*	1*
25 Duter	6*	4*	0*	0*	0*	0*
Untreated Check	89		83		93	

[a] heavy = 1 g chemical/gram of seed
[b] light = 0.25 g chemical/gram of seed
* Statistically significant from the check at the 5% level.

ing-off control is obtained. Our data indicate that 31 of the chemicals tested have a high degree of activity against isolates of the three main damping-off pathogens, Pythium, Rhizoctonia, and Fusarium. Of the three chemicals found effective against damping-off of red pine in greenhouse tests, thiram and captan were also found useful by Vaartaja and Wilner in controlling damping-off of Scots pine (4). The prospect of finding a satisfactory seed treatment for control of conifer damping-off seems promising, and additional laboratory and field tests are planned.

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Table 4. Effect of seed treatments on preemergence and postemergence damping-off of conifer seedlings in natural soil in the greenhouse

Treatment no. and product	Grams of chemical per gram of seed	Emergence (%)			Damping-off (%)		
		Jack pine	Red pine	White spruce	Jack pine	Red pine	White spruce
1 Captan	2.0	62.0	40.5	13.6*	68.2	34.3*	20.8*
	0.5	60.9	49.0	13.1*	71.5	44.5	37.9
2 Daconil	2.0	40.2*	15.4*	4.7*	88.3	85.2	35.4
	0.5	54.2*	19.1*	3.9*	95.7	62.5	33.6
4 Spergon	2.0	77.5	63.1	17.6*	65.9	52.7	42.9
	0.5	76.7	64.2	17.1*	74.9	61.6	53.6
5 Plantvax	2.0	8.0*	6.8*	0.2*	53.4*	3.4*	20.0*
	0.5	41.5*	45.5	11.7*	90.0	66.3	25.9*
	0.1	71.9	60.6	29.9	96.2	95.3	50.2
6 Vitavax	2.0	0.8*	3.0*	0.2*	20.0*	44.8	20.0*
	0.5	32.5*	41.7	13.9*	94.6	78.9	47.7
	0.1	71.1	72.5	22.6*	87.5	89.9	64.9
10 Phygon	2.0	23.2*	1.4*	13.6*	82.2	20.0*	61.6
	0.5	32.6*	11.8*	17.2*	88.8	60.0	55.2
11 Polyram	2.0	45.5*	29.0*	17.5*	38.9*	12.1*	26.2*
	0.5	67.7	40.7	19.9*	62.3	20.2*	24.4*
15 Arasan	2.0	78.0	45.3	28.6	79.4	26.7*	33.5
	0.5	77.6	61.6	30.1	76.7	37.0*	35.2
25 Duter	2.0	8.8*	0.3*	1.0*	45.1*	6.7*	3.3*
	0.5	21.5*	2.5*	1.1*	74.9	24.8*	10.5*
Check	-	71.6	58.4	45.1	86.3	87.3	52.6

* Statistically significant from the check at the 5% level.

A SURVEY OF FUNGAL AND BACTERIAL DISEASES OF VEGETABLE CROPS IN EASTERN AND CENTRAL ONTARIO IN 1967[1]

A. A. Reyes, R. W. Daniels, E. N. Estabrooks, C. C. Filman, L. F. Mainprize, W. M. Rutherford, C. A. Warner, and H. M. Webster[2]

A survey of diseases of vegetable crops in southern Ontario was performed in 1967 by Reyes, et al. (1). The results of a similar survey in eastern and central Ontario are presented in this report.

The counties surveyed in eastern Ontario were Dundas, and Lennox and Addington; in central Ontario the counties were Durham, Northumberland, Ontario, Prince Edward, and York. Each county was visited on a rotational basis from early May to early October. The diagnosis and prevalence of each disease was determined as reported in the earlier report (1).

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Most of the diseases observed were caused by fungi (Table 1). Species of Fusarium caused the greatest number of diseases followed in order by Alternaria, Botrytis, Pythium, and Rhizoctonia. Species of Erysiphe, Plasmodiophora, Septoria, Urocystis, and Verticillium caused one disease each. The most common causes of bacterial diseases were Xanthomonas and Pseudomonas.

A number of diseases were detected that were not observed during the survey in southern Ontario: carrot leaf blight, alternaria blights of carrot and celery, black rot of Brussels sprouts and cabbage, leaf spot of cabbage, late blight and root rot of celery, fruit rot of muskmelon, onion blast, wilt of potato, and club root of turnip.

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Table 1. Incidence of diseases of vegetable crops in eastern and central Ontario in 1967

Crop	Disease and cause	Prevalence* and county
Eastern Ontario		
Bean	Root rot (Fusarium spp.)	Tr. 1/1** field (Lennox and Addington)
Carrot	Leaf blight (Cercospora carotae)	Sev. 1/2 fields (Dundas)
Lettuce	Damping-off (Fusarium spp.)	Tr. 1/3 fields (Dundas)
	Drop (Sclerotinia sclerotiorum)	Tr. 1/3 fields (Dundas)
Tomato	Bacterial canker (Corynebacterium michiganense)	Tr. -mod. 2/2 fields (Lennox and Addington)

* Tr. (trace) = 1-10% of plants affected in the greenhouse or field; sl. (slight) = 11-30%; mod. (moderate) = 31-60%; sev. (severe) = 61-100%.

** Number of fields or greenhouses in which the disease was found/number of fields or greenhouses inspected.

Table 1 (continued)

Crop	Disease and cause	Prevalence* and county
Central Ontario		
Asparagus	Root-rot or wilt (Fusarium spp., Rhizoctonia solani, Pythium spp.)	Tr. 1/1 field (in each of Northumberland and Prince Edward)
Bean	Damping-off (Rhizoctonia solani, Fusarium spp.)	Tr. 1/1 field (Northumberland)
Beet	Damping-off (Rhizoctonia solani, Pythium spp., Fusarium spp.)	Mod. 1/2 fields (York)
Brussels sprouts	Black rot (Xanthomonas campestris)	Sev. 1/2 fields (York)
Cabbage	Black rot (Xanthomonas campestris)	Sev. 4/8 fields (York)
	Clubroot (Plasmodiophora brassicae)	Tr. 2/8 fields (York)
	Damping-off (Fusarium spp.)	Tr. 1/2 fields (Ontario)
	Leaf spot (Alternaria brassicae)	Sev. 3/8 fields (York)
	Yellows (Fusarium oxysporum f. conglutinans)	Sl. 1/8 fields (York)
Carrot	Blight (Alternaria dauci)	Sl. 1/1 field (York)
Cauliflower	Bacterial leaf spot (Xanthomonas sp.)	Mod. 3/4 fields (York)
	Black rot (Xanthomonas campestris)	Mod. 3/4 fields (York)
	Leaf spot (Alternaria brassicae)	Sl. 1/4 fields (York)
Celery	Blight (Alternaria dauci)	Mod. 1/6 fields (York)
	Late blight (Septoria apii)	Sl. - Sev. 2/6 fields (York)
	Root rot (Fusarium spp., Stemphyllium spp.)	Tr. 1/6 fields (York)
Cucumber	Angular leaf spot (Pseudomonas lachrymans)	Sl. - Sev. 5/5 fields (Durham), sev. 1/4 fields (Northumberland)
	Bacterial wilt (Erwinia tracheiphila)	Tr. 3/5 fields (Durham), tr. - sl. 3/4 fields (Northumberland)
	Leaf blight (Alternaria cucumerina)	Sev. 2/4 fields (Northumberland)
	Powdery mildew (Erysiphe cichoracearum)	Tr. 1/5 fields (Durham)

Table 1 (concluded)

Crop	Disease and cause	Prevalence* and county
Muskmelon	Fruit rot (Fusarium spp.)	Sl. 1/1 field (Prince Edward)
Onion	Blast (Botrytis spp.)	Mod. 1/3 fields (Durham), mod. - sev. 3/8 fields (York)
	Damping-off (Pythium spp., Fusarium spp.)	Tr. 1/8 fields (York)
	Pink root (Fusarium spp.)	Sl. 1/3 fields (Durham)
	Purple blotch (Alternaria porri)	Sl. 1/3 fields (Durham)
	Smut (Urocystis cepulae)	Tr. 4/8 fields (York)
Pea	Root rot (Fusarium spp.)	Tr. 1/2 fields (Northumberland), sl. - sev. 2/4 fields (Prince Edward)
Potato	Wilt (Verticillium dahliae)	Tr. 1/3 fields (Ontario)
Tomato	Bacterial canker (Corynebacterium michiganense)	Tr. 1/1 greenhouse (Durham), tr. 1/6 greenhouses (Prince Edward), mod. 2/8 fields (Prince Edward)
	Bacterial speck (Pseudomonas tomato)	Tr. 2/8 fields (Prince Edward), sl. 2/3 fields (Durham)
	Bacterial spot (Xanthomonas vesicatoria)	Tr. 1/5 fields (Northumberland), tr. 1/8 fields (Prince Edward)
	Damping-off (Pythium spp., Rhizoctonia solani, Fusarium spp.)	Tr. 3/6 greenhouses (Prince Edward), tr. 2/8 fields (Prince Edward)
	Early blight (Alternaria solani)	Sl. 1/1 greenhouse (Northumberland), sl. 3/3 fields (Durham), sl. 1/5 fields (Northumberland), sl. 2/8 fields (Prince Edward)
	Gray mold (Botrytis cinerea)	Mod. 1/5 fields (Northumberland)
Turnip	Clubroot (Plasmodiophora brassicae)	Mod. 1/4 fields (York)

ASSESSMENT OF PLANT DISEASE LOSSES

PREFACE

A panel discussion on the vital topic of plant disease losses was held at the thirty-fifth annual meeting of the Associate Committee on Plant Diseases of the National Research Council of Canada, at Saskatoon, Saskatchewan, on February 22, 1967. The panel was organized and chaired by W. E. Sackston at the request of the chairman of the Associate Committee on Plant Diseases, M. W. Cormack.

Minutes of the respective Associate Committees are not usually published. However the proceedings of this panel discussion were believed to be of general interest and importance. The contributors agreed to permit the publication of their contributions as originally submitted, or as transcribed from the tape recording of the discussion by the Secretary of the Associate Committee, R. D. Tinline, or after revision by the authors. The panel chairman expresses his sincere appreciation to all the participants for their contributions, and to the Secretary for his invaluable assistance.

In the interval of more than a year that has elapsed between the panel discussion and its preparation for publication, two significant events referred to by Mr. Creelman have taken place. One was the appearance of the excellent book prepared by Mr. I. L. Conners, An annotated Index of Plant Diseases in Canada, Canada Department of Agriculture Publication 1251, 1967. The other was the symposium on crop losses held in Rome in October, 1967, and the publication of the proceedings under the title "Papers presented at the FAO symposium on crop losses, Rome, 2-6 October, 1967", Food and Agriculture Organization of the United Nations, Rome, 1967. This is a major addition to the literature in this field, bringing together new data and previously published, but often inaccessible, information on a subject of great importance.

W. E. Sackston
Macdonald College
April 30, 1968

INTRODUCTION

W. E. Sackston[1]

The problem of assessing plant disease losses has been recognized for years in many parts of the world. Relatively little has been done about it, for various reasons. In spite of the relative gaps in our knowledge in this field, there has been extremely valuable information put forward, and there have been various symposia and review articles on the subject (2, 3, 7, 9, 10, 12).

In one such recent symposium, held in 1963 and published in Phytopathology in 1964 (1, 8, 9, 11), there were a number of very quotable statements.

Vallega and Chiarappa (11) pointed out that the problem of appraisal of plant disease losses and their effect on agricultural production is of primary importance throughout the world, for it is only through such an appraisal that rational control measures can be developed and applied. The problem of plant disease losses has received most attention in the most developed countries of the world. It is much more difficult, or even impossible, to evaluate losses in the less developed countries. These authors translate wheat loss from stem rust in Australia in one year into a loss of food to sustain 3 million people for a year; the destruction of sorghum and millets by smuts in Africa per year, as the loss of food for $5\frac{1}{2}$ million people for a year. Less dramatic, debilitating rather than destructive, diseases may cause losses equal to or greater than the obvious and dramatic diseases. With half of the world population of 3 billion humans undernourished, and with that population expected to double by 2000 A. D., we "need to make three blades of grass grow where only one now stands."

LeClerg (8) gave a number of reasons why it was important to have information on crop losses that is as accurate as possible:

> To assure the most efficient use of research effort and funds;
>
> To establish the need (financial, etc.) for field activities to control certain diseases;
>
> To direct extension efforts to the most important plant diseases;
>
> To aid in predicting crop production;
>
> To aid industry in making decisions regarding initiation of research and development of new chemical plant protectants.

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Most of our information on disease losses is derived from estimates rather than from exact measurements. To be of value, "estimates should be based on adequate field sampling by experimental evidence as to the effect of the disease on the reduction in production." The intensity of the disease must be determined, and the relationship between intensity and loss of production must be established. Classic work along these lines has been reported by Large (4, 7) for late blight of potatoes in Britain, and by Chester (2) for leaf rust of winter wheat in the United States. Pioneering studies were made in Canada by Greaney and Goulden (5, 6) and important work is continuing at laboratories throughout the country.

It is appropriate then that we discuss the assessment of plant disease losses at these meetings. It is no accident that the first paper, by D.W. Creelman, will deal with plant disease surveys to assess disease losses. The supporting experimental evidence on the effect of disease on the reduction in crop production will be provided by a galaxy of investigators from across the Prairie Provinces, who will follow this wise man from the East.

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SURVEYS TO ASSESS PLANT DISEASE LOSSES

D. W. Creelman[1]

This title brings together three separate concepts: surveys, losses, and assessment or measurement. I will discuss each of them briefly before attempting to put them into relationship with one another.

Surveys

Organized plant disease surveys on a national basis have been in existence since 1917, when, during the First World War, countrywide surveys were initiated in both Great Britain and the United States. Canada followed the trend in 1920 with the establishment of the Canadian Plant Disease Survey and, as was the case in the other two countries, proceeded to collect, identify, and catalogue the diseases occurring on crop plants. The founders of our Survey hopefully included in their terms of reference "the obtaining of accurate knowledge of the losses due to commoner plant diseases" (W. H. Rankin and W. P. Fraser, in litt, 1920). They further stated, "in no other way can pathologists approach the public for obtaining recognition of their professional work than by accurate data concerning such losses."

Insofar as building up an inventory of plant diseases in Canada our Survey has done an admirable job. The extent to which it has succeeded is now a matter of public record with the publication, in a few weeks' time, of I. L. Conners' Annotated Index of Plant Diseases in Canada. As its title suggests, it is much more than a list of diseases since the author, using the published records of the Canadian Plant Disease Survey, discusses the history, the fluctuations, the relative importance, and the geographic distribution of our major crop diseases from 1920 to 1960.

The publication of this Index could and, I firmly believe, should mark the beginning of the end of our emphasis on purely qualitative surveys. I hope that, as a result of the discussions here today, Canadian plant pathologists and those who direct policy will reevaluate their concepts of disease survey work and encourage surveys with a purpose. The purpose may be the evaluation of losses, the accurate forecasting of disease outbreaks, or the acquisition of a better understanding of the etiology and epidemiology of major diseases.

Survey resources in Canada

Three distinct plant disease survey organizations now exist in Canada. The one with which we here are most familiar is the Canadian Plant Disease Survey. It has one full-time employee in Ottawa who depends on the voluntary survey efforts of 150 plant pathologists, other plant scientists, and extension specialists in all parts of Canada. Approximately one-half of these volunteers submit their disease observations on an annual basis, and at Ottawa an attempt is made to interpret the status of plant diseases in Canada for that particular year.

You will immediately say that the observations of 75 qualified observers each year should be more than adequate to furnish all the information needed to give a complete picture of disease conditions. However, these are all part-time observers, and one man may report on 10 to 20 separate diseases encountered in a one-day excursion into the field. This is hardly reporting in depth. More important is the fact that these regular contributors tend to be concentrated in a very few areas resulting in extremely good coverage of conditions on one crop in one district and absolutely no records on other crops or from other districts. Coverage, then, as it exists can only be described as partial and spotty. I can envision no way, under the present organization of the Survey, to obtain complete coverage.

The second organized survey activity is that of the Plant Protection Division. Their surveys for both diseases and insect pests are carried out for regulatory purposes having to do mainly with the export of produce. You will be familiar with the surveys and inspections made on the seed potato crop, undoubtedly the most intensively surveyed crop in Canada. This activity consists of a four-man staff at Ottawa backed up in the field by 100 potato inspectors at various centers across the country. Their main function is to certify freedom from specific diseases of plant material moving in export, import, and interprovincial trade. Special surveys, when made, are usually limited in scope to determining the presence or absence of specific diseases in a given locality.

The third survey activity is that of the Forest Disease Survey. This activity was established in 1951 in the Department of Agriculture but now operates within the Department of Forestry and Rural Development. It employs the full-time services of 15 professional and 100 non-professional workers at seven locations across Canada. Its professional staff includes specialists in several fields of mycology. Although much of the survey work is qualitative in nature, the program is designed to yield information on losses and advice on forest management.

Losses

The extent of plant disease losses on a world basis is a matter of conjecture. In a 1963 publication from California (4), it is stated that world crop losses from plant diseases are estimated at three billion dollars annually; and it has been estimated that the annual average loss in the United States

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from diseases and air pollution, excluding nematodes, exceeded three and a half billion dollars for the years 1951-1960 (3). There are no comparable figures for Canada. I am going to break tradition and depart from what seems to be an inborn reticence among Canadian plant pathologists to mention losses and suggest that the annual crop losses in Canada from plant disease are probably between one quarter and one third of a billion dollars. These figures were derived following the method outlined by LeClerg (2).

Types of losses — Losses attributable to plant diseases may be categorized in more than one way. The simplest way is to consider them as direct losses and indirect losses. Direct losses are the most obvious and consist of visible reductions in the yield or quality of the crop, or both. Indirect losses may be very costly as well. The mere presence of some diseases, although they are the cause of little concern in crop production, may bar the crop from the export market; for example, Monilinia laxa in British Columbia, and Pseudomonas pisi in southern Alberta. The presence of certain soil-borne pathogens, such as Sclerotium cepivorum, Plasmodiophora brassicae, or Verticillium dahliae, on certain farms may force the owner to shift production to nonsusceptible but less profitable crops.

We should also consider, in the same context as losses, the increased costs of producing, grading, and storing produce as the result of the presence of diseases which, in themselves, have little effect on yield.

If the quarter-billion dollar figure for losses from disease is a valid one, and if this was added to losses caused by insects, inclement weather, and other causes, and if these losses were borne every year by growers, we would very shortly have no growers. Fortunately, the law of supply and demand takes over and it is not unusual for the grower to receive more cash income from a short crop than from a normal or bumper one. This does not mean that individual growers or groups of growers don't suffer substantial losses in some years, but decreased yields are often compensated for by higher per unit prices. Generally speaking, losses are borne by the economy of the country as a whole.

The economy of this country, in contrast to that of many others, is such that the consumer will pay the price asked for the product he wants. Furthermore, disease losses in this country rarely affect the availability of produce. Food distribution is organized on a continental basis and the chances of an epidemic affecting the potato crop, for instance, in all producing areas of North America at the same time is very remote.

Assessment of losses — Let us assume that, with some notable exceptions to be discussed by the other speakers, little attention has been paid in this country to the matter of disease losses. Little, that is, in comparison with a country like Britain where losses in crops are a matter of national concern. Everything Britain can't grow she must import and imports are a drain on depleted foreign exchange reserves.

Is it because we in Canada are so well off we can choose to ignore or shrug off losses of more than a quarter of a billion dollars annually? Is it because we are compensating for losses with great advances in productivity? Is money for research so easily available that the research does not have to be justified on a dollar return basis? I think that there is probably just enough truth in each of these premises to make us complacent. We face no impending food crisis as was the case in Great Britain in 1917, when they recognized the need of plant disease surveys, and again in 1941, when they formed a Disease Measurement Committee. There is, however, a global food crisis that will affect us either directly or indirectly in a few decades. Should we take steps now, through purposeful surveys, to learn something of the extent and nature of our disease losses, or should we continue to ignore them? This question can only be answered at a policy-making level.

Disease losses can be measured. This has been amply borne out by our colleagues at Harpenden in England. I cite the paper by Large and Doling (1) on the measurement of the intensity of cereal mildew and its effect on yield. This study conclusively proves that yield losses can be accurately predicted by the degree of infection by this disease at a specific stage of growth of the host plant. The necessity of standardized surveys is also evident from the data presented in the paper.

I submit, in conclusion, that there is a need in Canada for firstly, as I mentioned before, a change in attitude toward the value of disease survey activities; secondly, an active program of research into methods of determining disease losses; and finally, a recognition of the fact that one person, even when supported by the volunteer efforts of others, cannot possibly draw an accurate picture of the yearly impact of plant diseases on the Canadian economy.

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DISCUSSION OF THE PAPER BY D.W. CREELMAN

W.P. Skoropad: Do the figures that you cite include storage losses?

D. W. Creelman: I used a blanket 10%. Storage losses can be considerable. Regrading and repackaging may be involved. Two years ago 'shrinkage' was serious with the potato crop, yet we do not know what causes 'shrinkage'.

T. G. Atkinson: The impressive U. S. D. A. publication "Losses in Agriculture" to which you referred does not, if I remember correctly, indicate in any detail the way in which loss figures were determined. Do you know what procedures were used?

D. W. Creelman: I think greater detail is given by LeClerg in a paper presented to an American Phytopathological Society symposium on the same subject in 1964. It was the work of a committee which asked the opinions of leading pathologists and others concerned across the country, such as agronomists and persons in the trade, regarding the losses in a crop from a disease. Of course, it involved estimation. As E.C. Large pointed out in an excellent chapter in the Annual Review of Phytopathology last year, even the best of estimates are tentative and are subject to opinions and judgments throughout, and there has been little attempt to back them up with experimental evidence.

D. J. Samborski: Would you agree that many of the loss estimates are nonsense? For example, I might say with little justification that last year there was a 10% loss due to leaf rust. How credible are these estimates?

D. W. Creelman: Well, if you said it Dr. Samborski, it becomes authoritative. This situation is true for each of us. For example, in my position with the Plant Disease Survey, if I were to say that annual losses from plant diseases were a quarter of a billion dollars, this too becomes authoritative and no one can dispute me until work is done on the subject.

W. E. Sackston: I believe the reference that Mr. Creelman cited is an important one. It is the 1963 A. P. S. symposium that was published in 1964. LeClerg makes the point that there is little factual information from which to draw objective conclusions on disease losses, with very few exceptions. Chester in a publication in 1950 also emphasized this point. We appear no worse off in Canada than elsewhere. I'm certain that Dr. Greaney's sulphur experiments are still referred to often.

D. W. Creelman: Two years ago Dr. Paul Miller told me that the only group of pathologists that he believed knew their losses were those working with cotton. A comprehensive approach is used with pathologists from industry, state, and federal institutions meeting frequently. Dr. Miller thinks that this group comes up with figures very closely approximating the actual losses. I may mention that FAO is sponsoring a symposium on disease losses this fall in Rome. Canada is likely to be represented there. I hope that this current meeting will produce some ideas and information that will be valuable to the delegate from this country so that he may have something definite to say.

T. C. Vanterpool: Can indirect losses be assessed better than direct losses? For example, the cost of plant quarantines may be exactly known.

D. W. Creelman: This would be a very small amount, in the order of $1.5 million. We know how much is paid out in compensation; we know how much is paid out in plant protection, but what are we protecting and what are we saving? This is what I hope will be discussed here today.

E. R. Waygood: Are there any firm figures on losses in tobacco for Ontario?

D. W. Creelman: I have not seen any report on tobacco losses other than the one by Dr. Patrick about the time he left Harrow, in which one disease caused by Thielaviopsis basicola was claimed to cause a loss in tobacco of $1.5 million annually. Losses in quality rather than losses in quantity are very important in tobacco. As you know the leaf has to be unblemished; such things as weather speck caused by air pollution, and other leaf spots can reduce tobacco from top to bottom grade very quickly.

THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: RUSTS AND SMUTS

G. J. Green, J. J. Nielsen, W. J. Cherewick, and D. J. Samborski[1]

Smuts

The smuts were the main diseases of cereal crops in Western Canada at the turn of the century. According to Johnson (8), A. Mackay, superintendent of the Indian Head Experimental Farm, reported that in 1891 one in three bushels of wheat delivered to an elevator was damaged by smut; and in 1895, S. A. Bedford, superintendent of the Brandon Experimental Farm, reported that from 10 to 25% of the oat and barley crops was destroyed by loose smut. Bedford also reported finding fields of oats with 75% of the heads smutted. Bunt was the main disease and yield reductions of 30 to 40% were not uncommon. Losses were so severe that seed treatment with bluestone was a widely used control measure by 1892, only 13 years after the railway reached Winnipeg. The amount of smut decreased sharply as seed treatment became a common practice, but Güssow (7) estimated that the average annual loss from smut from 1920 to 1923 was 1.2, 3.0, and 3.4% for wheat, barley, and oats, respectively. The average annual monetary loss was estimated to be about 11 million dollars. Smut losses have declined steadily since that time, but reports in the Canadian Plant Disease Survey show that occasional fields of wheat and barley in Western Canada have 5 to 10% smut.

Estimates of smut losses probably have been reasonably accurate. They have been based on field counts of smutted heads, and there is evidence (1, 4, 11, 12) that 1% smutted heads cause about 1% loss in yield. The relationship may vary under abnormal conditions; for example artificial inoculation caused a yield decrease of 11.3% for each 1.13% bunt in the resistant variety 'Ridit' (4). This large decrease was attributed mainly to the deforming effect of smut infection on plants that did not produce smutted heads.

A reasonably good estimate of smut losses can be obtained by means of well-organized surveys and good sampling techniques. The main source of error is the non-random selection of fields for sampling. Smut infections are heaviest in isolated areas where farmers do not use the best cultural methods and continue to use homegrown grain for seed. Loss estimates might be more informative if they were determined for each crop zone rather than for a province.

The Board of Grain Commissioners' records of carlots graded "smutty" provide a fairly reliable indication of losses from decreases in quality.

Rusts

Rust losses, as estimated by various methods, have been enormous. Losses from the wheat rusts in some important epidemics have been estimated at 100 million bushels in 1916; 90 million in 1927; 87 million in 1935; and 150 million in 1954. The average annual loss in Manitoba and Saskatchewan from 1925 to 1935 was 35,518,000 bushels and for Manitoba alone 15,092,000 bushels. The use of resistant varieties reduced the average annual loss in Manitoba from 1953 to 1962 to 3,741,600 bushels, and most of this loss occurred between 1953 and 1956, before susceptible varieties were replaced by 'Selkirk'. In oats the average annual loss from stem rust from 1929 to 1934 was estimated at 8,334,000 bushels; and from 1953 to 1962 the use of resistant varieties reduced the average annual loss from crown rust and stem rust to 2,008,800 bushels (2, 6, 9, 10).

The potential of the rusts to cause losses has not diminished. Data from various tests frequently indicate what could have happened if resistant varieties had not been grown. In a test by A. B. Campbell at Winnipeg in 1964, 'Marquis' yielded 2.6 bu/acre; 'Selkirk', 20.6; and 'Manitou', 29.3. On the basis of these yields and estimating costs at $20.00/acre, a farmer growing 'Marquis' would have lost $15.67/acre. However a farmer growing 'Manitou' would have made $32.62/acre. In recent years 'Selkirk' and 'Pembina' have been damaged by leaf rust. In 1965, D. J. Samborski found that plants of 'Selkirk' when protected by a fungicide yielded 55.0 bu/acre in plots at Winnipeg, whereas unprotected plants of 'Selkirk' yielded 44.3 bu/acre - a loss of nearly 20%. Similar losses from oat crown rust were demonstrated by Fleischmann (3) in 1964.

The estimation of rust losses over large areas involves the effects of many variables. The methods used to obtain data for an estimate of loss should take these variables into account if the estimate is to be reasonably accurate. Four requirements seem to be necessary to obtain data that are reasonably complete and reliable. The first is frequent and thorough plant disease surveys. It is difficult to understand how loss estimates can be regarded as reasonably accurate if they are not supported by a sound knowledge of disease development in farm fields. The second requirement is experimental

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evidence of the amount of yield reduction caused by natural rust infection on the widely grown varieties. The third is an accurate and reliable method of determining the loss from reduced quality of the product. The fourth is a method of applying experimental and survey data to an area as large as Western Canada in a manner that will accurately indicate rust losses.

The fourth requirement presents the most difficulties. Obviously, the results of one experiment and limited survey data are inadequate for an accurate estimation of rust losses in Western Canada. If reasonably complete data are to be obtained, experimental work with the main varieties of each crop will be needed at many locations. The experimental data should be supplemented by thorough rust surveys and by efforts to determine the losses from reductions in grade. It might be argued that the expense of such a programme could be reduced by restricting it to the traditional rust area of Manitoba and southeastern Saskatchewan, but serious losses to wheat in this region have been limited in most recent years to the small acreage sown to susceptible varieties. Much of the loss in recent years has occurred farther west, where 'Thatcher' has been attacked by leaf rust and occasionally by stem rust, and in western Saskatchewan and Alberta, where susceptible varieties of common and durum wheat are occasionally damaged by leaf rust and stem rust. Investigations on rust losses in oats could be restricted to Manitoba and southeastern Saskatchewan, since stem rust and crown rust of oats rarely spread outside this area.

Some of the better methods for estimating rust losses have been developed in Western Canada. In the early days of rust research, F. J. Greaney (5) developed a method that "had the merit of being based on the results of controlled experiments, but is still subject to certain sources of error." He dusted plots of wheat and oats with sulfur at different rates and frequencies and controlled stem rust at different levels of infection. He then calculated the yield reduction for each 10% of rust. The total rust loss was calculated from these figures and from survey reports on the amount of stem rust in different parts of Western Canada. W. C. McDonald (9) compared the average yields in test plots of varieties with different rust reactions and computed the losses caused by each rust from the acreages sown to the different varieties.

A very good estimate of rust losses was made for the rust epidemics of 1953, 1954, and 1955 by B. Peturson (10). In Manitoba and eastern Saskatchewan in 1953, he compared the yields of 57 matching fields of rust resistant 'Selkirk' and a susceptible variety. In 1954 in Manitoba the yields of 165 fields of 'Selkirk' were compared with the yields of 168 fields of the more susceptible varieties 'Redman', 'Thatcher', and 'Lee'; and in Saskatchewan the yields of 169 fields of 'Selkirk' were compared with the yields of 169 fields of 'Thatcher'. The large number of comparisons he made in a wide variety of locations gives one confidence in his estimate despite the fact that the data were obtained from questionnaires returned by farmers rather than from controlled experiments.

We should not overlook the rapidity with which the rust situation changes. The reactions of the widely grown varieties can change dramatically in a short time. In the next year or two we expect that 'Manitou' will reduce rust losses in wheat to negligible amounts. Little would be gained by devoting time to estimating losses while its resistance is effective. On the other hand, our oat varieties are now susceptible to stem rust and crown rust. These circumstances do not seem to justify an expensive program to determine rust losses, but there is a need to obtain better information than we have had in the past.

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DISCUSSION OF THE PAPER BY G. J. GREEN, J. J. NIELSEN, W. J. CHEREWICK, AND D. J. SAMBORSKI

M. L. Kaufman: We have heard considerable discussion about making accurate estimates of loss, in this case from rust and smut diseases. I wonder if it is necessary, bearing in mind the long history of these diseases, to prove that we suffer large losses. Unless our programs are being hampered because people are not aware of this fact, I do not see the need for detailed and accurate estimates. I believe sufficient evidence was presented here to show that programs are not hampered.

G. J. Green: Certainly for most of us in agricultural research we do not have to prove again and again the destructiveness of plant diseases. We must, however, have data for the public. We may say that there is a moderately-severe infection of leaf rust on Selkirk wheat in Manitoba and eastern Saskatchewan, but few people comprehend this. Most persons want to know how much is the loss. This then requires experimental data, observation within the area, information on when the rust came in, and at what stage of plant development. When asked how great a loss there is, "no comment" would constitute an unacceptable reply. Without staff and facilities to be on top of the problem continuously, sometimes one must hazard a guess as to losses.

W. E. Sackston: I think too there are other aspects to be considered. Some of us will recall that just prior to the outbreak of the 15B race of stem rust, serious consideration was given to phasing out the breeding for rust resistance at the Winnipeg Laboratory. There seemed little justification to continue the breeding program since the rust problem had been overcome! Survey and loss information as to what was happening in the rust race picture was very pertinent and helped prevent an action which, if carried out, might have had very serious consequences. We can also recall the interest by industry in chemicals to combat rusts. Industry needs to know what the potentials for a product are before it embarks on a serious program in development.

D. J. Samborski: It's relatively easy to show losses from stem rust since the disease is very destructive. The last several years we have been predicting losses from leaf rust in Saskatchewan, and there have been substantial losses. Bumper crops, however, have been highlighted, and since leaf rust exacts only a moderate toll, our estimates receive little credence generally.

W. E. Sackston: Well, I think that this is an excellent argument for the need for accurate survey and experimentation. Mr. Creelman cited Large's work on potato blight and this, I believe, documents the case that in the years most favorable for the development of the disease, there is also a tendency to get the highest crop yields. The same conditions that favor the crop simultaneously favor the disease. This is obviously the case with leaf rust. If we had adequate documentation on the effect of disease on yields in years of optimum production we would have a better idea of the maximum potential. This, of course, is one of the objectives of assessing plant disease losses.

D. J. Samborski: There is difficulty in educating the public, because losses from diseases like leaf rust occur primarily in the best crop years. When conditions are poor, for example, very dry, there seldom is much leaf rust.

W. E. Sackston: Yes. On a disease survey in a favorable year a farmer expelled me from his field saying "Sonny, we don't want to know how to grow more wheat, we want to know how to sell it."

P. K. Isaac: With reference Dr. Samborski's comment, the attitude of the public is quite understandable. How can one lose something that you never had?

G. J. Green: A methodical way of determining losses annually would be very good. It would require additional staff and facilities. I do think that there was a considerable loss from leaf rust in northern Saskatchewan last year. Some figures I have seen would place the loss at about 6 bu/acre.

A. J. Skolko: Additional staff and funds for survey and disease loss determinations might be commendable. However, the assignment of additional support to solving our present problems may be even more meritorious.

W. E. Sackston: One of the comments by Le Clerg in the A. P. S. symposium was on why it was important to have as accurate as possible determinations of crop losses. It was to ensure the most efficient use of research effort and funds. Another was to establish the need for the control of certain diseases. A disease accepted as a minor one today may upon documented evidence turn out to be a major one. Documentation of losses is important and deserves emphasis.

D. W. Creelman: It is likely that the diseases that are considered serious in Canada today and that are subjects of research were shown to be important through plant disease surveys. We are fortunate in Canada in having a plant disease survey. Some countries do not have one. A colleague from New Zealand was commenting on this recently. Where survey is lacking, research may be subject to pressure groups.

THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: LEAF AND HEAD DISEASES OTHER THAN RUSTS AND SMUTS

W. C. McDonald,[1] S. B. Helgason,[2] W. P. Skoropad,[3] and H. A. H. Wallace[1]

Experiments designed to estimate losses from diseases in barley have been carried out over a period of years at several locations. The following methods were used:

Comparison of plots protected by a fungicide with those not so protected in the same experiment (1, 2, 4);

Comparison of plots inoculated with a specific disease with plots not inoculated (3);

Evaluation of the differential in yield of a variety resistant to a disease and one susceptible to it by comparisons of tests in heavy disease infestation with tests in which the disease had little or no effect (6, 7).

The primary objectives of the experiments were to determine the extent of losses from disease and to establish useful relationships between disease readings and effects of disease on yield and quality (5).

To what extent have these objectives been met?

The estimates of disease losses have been useful in providing an approximation of losses resulting from the complex of diseases attacking barley. Aside from the series of experiments on speckled leaf blotch at Winnipeg (C. D. A.), the estimates of losses from specific diseases must be regarded with reservations because of the difficulty of estimating individual disease effects where a complex of diseases exists, and because of inadequate sampling. However, when related to survey information, the experiments have provided an indication of the importance of breeding for resistance to the diseases involved.

The second objective is far from being met satisfactorily, but there is work in progress. This would seem to be a critical area because of the obvious difficulty and expense of adequate sampling by means of experiments in which controls are created with fungicides; and thus the need for reliable estimates based on surveys.

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Some problems with the experimental approach

The problem of adequate sampling through wide distribution of experiments over a period of years is basic to obtaining reliable loss estimates by this means. Besides the difficulty of adequate sampling, other problems are encountered in experiments:

Obtaining adequate disease control — Two or three applications of a fungicide may be adequate in some circumstances, but positive control may require five to seven. For *Septoria passerinii* Sacc., which has an incubation period of 19-21 days and in which secondary infection is of minor significance, protection from the boot stage to 6-8 days after heading is critical. With net blotch caused by *Pyrenophora teres* (Died.) Drechs. there is evidence that early spraying is critical, and the same is probably true of spot blotch caused by *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. The most complete control has been obtained with fungicide sprays begun about the flag-leaf stage and applied thereafter at no more than 10-day intervals. However, more frequent spraying may be required if rainfall is heavy, or if temperature and humidity are conducive to infection and to spread of the diseases.

Interference from diseases not controlled — Some experiments have been influenced by the occurrence of powdery mildew or bacterial streak, which are not controlled by the fungicides used for the diseases that are critically important in the prairies. For control of mildew, an over-all spray of Karathane can be valuable.

Obtaining disease in plots — Inoculation entails extra work and is often unsuccessful. The scope of an experiment can often be extended by seeding at more than one date. At Winnipeg, diseases usually increase with later seeding, and a better estimate of losses is obtained by using as many as three dates of seeding. (In 1966, an intermediate seeding date gave the heaviest disease readings, but the principle holds.)

Relating disease readings to losses — In a specific experiment, the relationship between disease readings and loss often appears meaningful, but examination of a number of experiments (1, 3) reveals wide fluctuations that are presumably not due to readings by different individuals. Experience with this type of work suggests a number of factors that should be considered in attempting to assess the relationship of leaf area destroyed to losses in yield and quality:

The time of infection in relation to the stage of the host;

The severity of the first-cycle infestation;

The environment from the onset of disease effects to maturity of the host;

The relative proportion of different diseases present.

The last point could well be highly critical, since there is little information on the combined effects of diseases on the host. Assessment of individual disease effects is the logical starting point, but obtaining exclusive infection by a disease is difficult without the use of highly selective fungicides or varieties primarily susceptible to one disease.

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DISCUSSION OF THE PAPER BY W.C. MC DONALD, S. B. HELGASON, W. P. SKOROPAD, AND H. A. H. WALLACE

A. E. Hannah: Were any of the chemicals applied systemic or were they all local in their action?

S. B. Helgason: In all of the experiments with which I am familiar the fungicides used were protectants and had no systemic action at all. To the best of my knowledge there have been few tests conducted in Canada in which systemics were employed.

W. C. McDonald: I wish to make a comment on another aspect of this general subject. The cost of research is great. There seems to be a trend toward research project costing at the present time. It therefore may be important to include in the assessment of plant disease losses the benefits derived from research in disease control. I think that differential varieties for resistance can be used to show increased productivity resulting from the use of resistant varieties, and also to show the losses that can occur. One could use plant breeders' lines in such work if they were more appropriate than licensed varieties. The cost of conducting such a series of tests would not be high and the tests should permit the derivation of dollars and cents estimates for some of our losses. Too, such tests may prevent our becoming complacent on the danger of plant diseases. Some work along this line that I did for the years 1954 and 1962 indicated that in 1962, except for resistant varieties, we would have had the worst rust epidemic recorded in western Canada. In that year the average provincial yield was 26 bu/acre; the yield of 'Marquis' was 9.1. In 1954 our provincial average was 13 bu/acre and the yield of 'Marquis' about 11.

W. J. White: Have there been any studies done to establish whether fungicides in the absence of disease have any depressing or stimulating effects on yield?

S. B. Helgason: The particular fungicides used in these experiments are not phytotoxic. There have been some, of course, used in experiments that are somewhat phytotoxic. There has been evidence that suggested that in the absence of disease, some dithiocarbamates may increase yields slightly. However, it is difficult to define slight increases that frequently are not statistically significant. I know of very few cases where in the absence of disease the reverse occurs, i.e. where the sprayed plots yielded less.

G. J. Green: With reference Dr. McDonald's comment on losses estimated on the basis of small plots, I think that such estimates would be extremely conservative and I suspect that all estimate figures cited today are also conservative. There is quite a difference between having a few 10-ft rows of a susceptible variety in a million acres of resistant material, and a million acres of a susceptible variety. The dynamics of development of an epidemic would differ greatly. I think the damage in small plots would be much less than in vast acreages of susceptible material.

W. E. Sackston: This point is mentioned by Van der Plank in his approach to epidemiology. Working in an area where there is abundant disease one obtains different reactions than working in an area where the population is mostly resistant and only some susceptible. This aspect certainly requires consideration.

J. W. Martens: Some work is underway on the effect of fungicides in the absence of disease.

D. W. Creelman: In potatoes it has been shown repeatedly that dithiocarbamate fungicides do increase yields in the absence of late blight.

W. E. Sackston: This effect has sometimes been attributed to leaf feeding with some of the metallic components.

THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: ROOT DISEASES[1]

B. J. Sallans and R. D. Tinline

Estimates of losses from root rots are desirable in order to justify expenditures in finding the means for their control. Such estimates would serve also to direct the attention of grain growers to inconspicuous diseases such as common root rot that otherwise they might not consider important. Estimates of loss, too, would serve the investigator in evaluating various methods of control where such control may be incomplete.

Basic to any estimate of losses, usually on a Provincial basis, is a survey. Surveys are limited as to time and number of samples. A compromise must be made between an adequate, random sampling of the fields of a crop and what is practicable within the limits of time and resources of personnel. In Saskatchewan we have for years aimed at inspecting a minimum of 20 fields of wheat in each crop district. We make one or two traverses through a crop district, depending on its size and location, and usually follow the same or a similar route used in previous years. The traverses tend to be along the main or better roads of the area. The number and randomness of the surveyed fields admittedly fall short of adequacy, but the surveys provide some data for relative comparisons.

General observations as a basis for estimating losses

Preliminary estimates of loss are usually made by an investigator on the basis of his observations and are expressed often in rather general terms. Such estimates are primarily on the incidence of the disease, and perhaps on stunting or premature death of plants.

Estimates of this type have been used in the study of root rots. With common root rot especially, such terms as healthy, slight, moderate, or severe disease have been employed. These terms have value, but lack clear definition and have to be converted to numerals for ready manipulation.

Sanford expressed his assessments numerically for his surveys of root rot in Alberta in 1927 and 1928. He estimated an average loss for the province of 3% in 1928 (7). He mentioned that the chief disease was take-all, caused by Ophiobolus graminis Sacc.; hence he probably took the patchy nature of the disease into account in his estimates.

Root rots that occur in patches

Browning root rot, caused by Pythium spp., and take-all characteristically occur in rather clearly defined areas, which can be estimated as a percentage of the field. A second statistic can be obtained of the comparative yields of healthy and diseased areas; and the two statistics can be combined into an estimate of the percentage loss in the field. This approach can then be extended by means of a survey of representative fields in a crop district, province, or other designated area, and an average loss or a total loss can be computed. This is essentially what Vanterpool did with browning root rot (9). He found that an average reduction in yield of 35% occurred between diseased and healthy areas in a number of fields. He then estimated, on the basis of surveys, the percentage of fields in Saskatchewan that were affected. Thirdly, he estimated the average percentage of diseased areas in infested fields. Using these data together with official figures for wheat production on summerfallow in each crop district in Saskatchewan, Vanterpool arrived at an estimated loss of just under 2 million bu of wheat per year caused by browning in Saskatchewan over a number of years. He pointed out that additional losses occurred as a result of delayed maturity abetting damage from stem rust and frost injuries when these were experienced, weed infestations associated with the reduced tillering of browning-affected plants, and reduction in the grades of grain, which lowered the value of the crop.

Losses in 1930 in individual fields where the disease was severe were estimated at 10 to 15 bu/acre (8).

Russell made estimates of loss from take-all on the basis of two statistics (3). He found that representative plants from a take-all area yielded about 20% less than an equal number of healthy plants in nearby areas. He then estimated the percentage of the field in which take-all occurred and combined the two percentages to give an estimate of loss in the whole field. Estimates of loss in ten fields in 1928 ranged from 1.6 to 18.3%.

Similarly, Sallans (unpublished data) estimated losses from take-all in Saskatchewan for the 8-year period 1928-1935 at 750,000 bu annually or about 0.425% of the wheat production.

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[1] Contribution No. 307, Research Station, Canada Department of Agriculture, Saskatoon, Saskatchewan.

Losses where root rot is not in patches

Common root rot presents special difficulties to anyone attempting to estimate losses. The primary difficulty is that generally the diseased plants are distributed throughout the field and are subject to competition from healthy plants for moisture and nutrients. Furthermore, the number of diseased plants normally increases in a field from early June to late July. Consequently the degree of stunting in the plants varies widely by harvest and the loss in yield per plant varies from 0 to 80%. Looking a little more closely at the competition factor, it appears likely that the healthy plants in a stand containing relatively few diseased plants may make up in part the loss in yield from the infected plants. On the other hand, if a majority of the plants are diseased, healthy plants may compensate for only a relatively small proportion of the loss.

The modified disease rating method applied to common root rot

A standard method of measuring disease that has been used for many years in root rot studies is the calculation of disease ratings. These are based primarily on the incidence and the degree of severity of the disease. The plants are assigned to such groups as healthy, slight, moderate, and severe lesion classes. Numerical weights are given to these classes on the basis of stunting or dry weight of the plants. For common root rot the values 0, 1, 2, and 4 have been used for healthy, slight, moderate, and severe classes, respectively (4). These values were derived from comparative reductions in yield of grain. The disease ratings were calculated on the basis of the formula:

$$\text{Disease ratings} = \frac{a + 2b + 4c}{10}$$

where a, b, and c are the percentages of plants in the classes slight, moderate, and severe, respectively. Disease ratings derived in this way are essentially estimates of yield.

A modification of this method has been in use in our surveys for several years. The main difference is that two classes of plants are used instead of four. The first class includes plants in the healthy and the slight lesion group; the second class includes those in the moderate and severe lesion groups.

Using these methods, estimates were made of common root rot losses in Saskatchewan for the years 1934-1966 (5, and unpublished data). The estimates ranged from a low of 6% in 1942 to a high of 13.7% in 1951 and average just under 10% for the whole period. Machacek used essentially the same method for his estimates of common root rot losses in Manitoba for the years 1939 to 1941 (2). They ranged from 7.5 to 16.6%. Previously, Craigie (1) reported that, on the basis of experimental plots at Winnipeg, the average annual loss in Manitoba would be not less than 5%.

Occasionally, severity of common root rot may be associated with patchiness and probably is influenced by the soil variation. Sallans and Ledingham (6) made a comparison of yields of wheat from diseased and healthy-appearing areas in several fields and estimated losses at from 8 to 42%.

Estimates of this type do not, however, make any allowance for increased yield in healthy plants, which may make up in part the losses due to the infected plants with which they grow in competition.

The regression of yield on disease in the plant disease survey

The disease ratings outlined above can be treated as measures of the incidence of the disease rather than as loss estimates. Sallans (5) studied the partial regression of yield on such disease ratings for the nine crop districts of Saskatchewan for the 10-year period 1934 to 1943. In this study the effects of a number of variables on yield and disease were measured by partial regression methods; the variables included preseasonal precipitation, June-July rainfall, June-July temperature, and insect injury. These studies led to an estimated average loss over the 10-year period from common root rot of wheat of 5.14 bu/acre, with fiducial limits of 1.55 and 8.73 bu/acre. The lower fiducial limit of 1.55 bu/acre represents a loss of about 10% of the harvested yield.

The experimental approach to estimating root rot losses

Recently, we have made use of the variation in resistance to root rot between named wheat varieties and selected lines as a basis for measuring root rot losses in both greenhouse and field studies.

Greenhouse work has indicated that substantial reductions in yield can be produced in susceptible, but not in resistant, lines by artificially inoculating the soil with *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dastur, the main cause of common root rot in Saskatchewan. The greenhouse method may have some advantages in this type of work over field methods. There are, however, grave doubts about inferring field losses on the basis of greenhouse results.

Data from 22 field experiments conducted in 1965 and 1966 gave a negative regression of yield on root rot infection. In six of these experiments, however, the regression was not significant, as judged by deviations from the regression.

The use of varieties and lines to obtain the regression of yield on common root rot infection has certain advantages:

We can obtain a measurement of losses in the experimental fields. By a judicious or random choice of fields and by a sufficient number of experiments over several years, we could make estimates of losses on a provincial or national basis.

We do obtain comparative data on the losses experienced in various varieties that should be more meaningful than comparisons of lesion data.

There is, however, an element of uncertainty in using varieties and lines, and this stems from their differing yield potentialities, especially when varieties are used in comparison with lines that have not been selected for yielding ability. Nevertheless, we believe that by using a fair number of entries covering a range of reaction from highly susceptible to highly resistant, we can place considerable confidence in the measure of loss by regressions of yield on disease.

Conclusions

While several approaches to the problem of losses caused by common root rot have been made, none has proved to be entirely satisfactory. The errors of the estimates are likely to be large. Comparisons must be made between yields from healthy units of crop and those from diseased unit areas. Ideally this could be done by protecting certain plots from infection, either by the use of systemic chemicals, or by the use of isogenic lines of wheat that differ only in resistance to the common root rot organism. Systemic fungicides that control root rot in cereals have not yet been reported. On the other hand, it would probably take at least 5 to 10 years to develop suitable isogenic lines for root-rot studies, and the amount of work involved would be hard to justify if the only objective was to improve our estimates of losses from root rot.

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DISCUSSION OF THE PAPER BY B. J. SALLANS AND R. D. TINLINE

C. F. Wehrhahn: Was the common root rot loss figure 10%?

R. D. Tinline: The estimated annual loss over a period of years averaged about 10%.

C. F. Wehrhahn: Are losses greater in some areas than in others?

R. D. Tinline: Yes, there appear to be differences between areas. Survey data are used to estimate losses by crop districts and some of these districts in Saskatchewan would seem to suffer greater losses than others.

C. F. Wehrhahn: How do black soil zones compare with brown in this respect?

R. D. Tinline: We believe the greatest damage occurs in the brown soil zones.

W. E. Sackston: Is this based on yield figures or disease intensity?

R. D. Tinline: Largely on disease intensity, although we do have some yield data from tests conducted in the different soil zones.

J. E. R. Greenshields: I wonder if the overall loss figure for plant diseases that was cited previously included a loss attributed to common root rot? If common root rot losses average about 10% the figure seems far too conservative.

W. E. Sackston: The overall loss estimate, as the author pointed out, was strictly an arbitrary one, and it was within a comparable range with loss estimates for the United States. The figure was not derived from experimental evidence. An estimated 10% average loss over a period of years is not applicable to defining the loss in a particular year. There may be a skew distribution for losses due to one disease in any given year.

THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: WHEAT STREAK MOSAIC

T. G. Atkinson and M. N. Grant[1]

Before we can assess the losses caused by a plant disease in any particular field we must be able to measure disease intensity, and we must establish the relationship between varying disease intensities and loss in yield or quality. Ideally, information on both these phases of disease-loss assessment should be obtained in studies carried out over numerous crop years and under a range of growing conditions. Such a fund of knowledge can then be used to make reasonably reliable estimates of the losses caused by that disease on a regional or national scale.

Using this approach we estimated that winter wheat yields in southern Alberta were reduced by 18% when wheat streak mosaic became epiphytotic in the 1963-64 crop. The results of these studies have been published (2), and the present report is confined to a detailed description of the procedures we used in assessing these disease losses.

Measuring disease intensity

Our study was carried out on a farmer's 25-acre field of winter wheat that was naturally infected with the wheat mosaic virus. No other leaf or head diseases were evident.

Our first measurement of disease intensity was based on the streak mosaic symptoms on samples collected from the immature crop at the end of May. Plants pulled from a 1-m length of row at each of 100 regularly spaced sampling sites were classified into three disease categories on the basis of their distinctive streak mosaic symptoms (Fig. 1). Plants

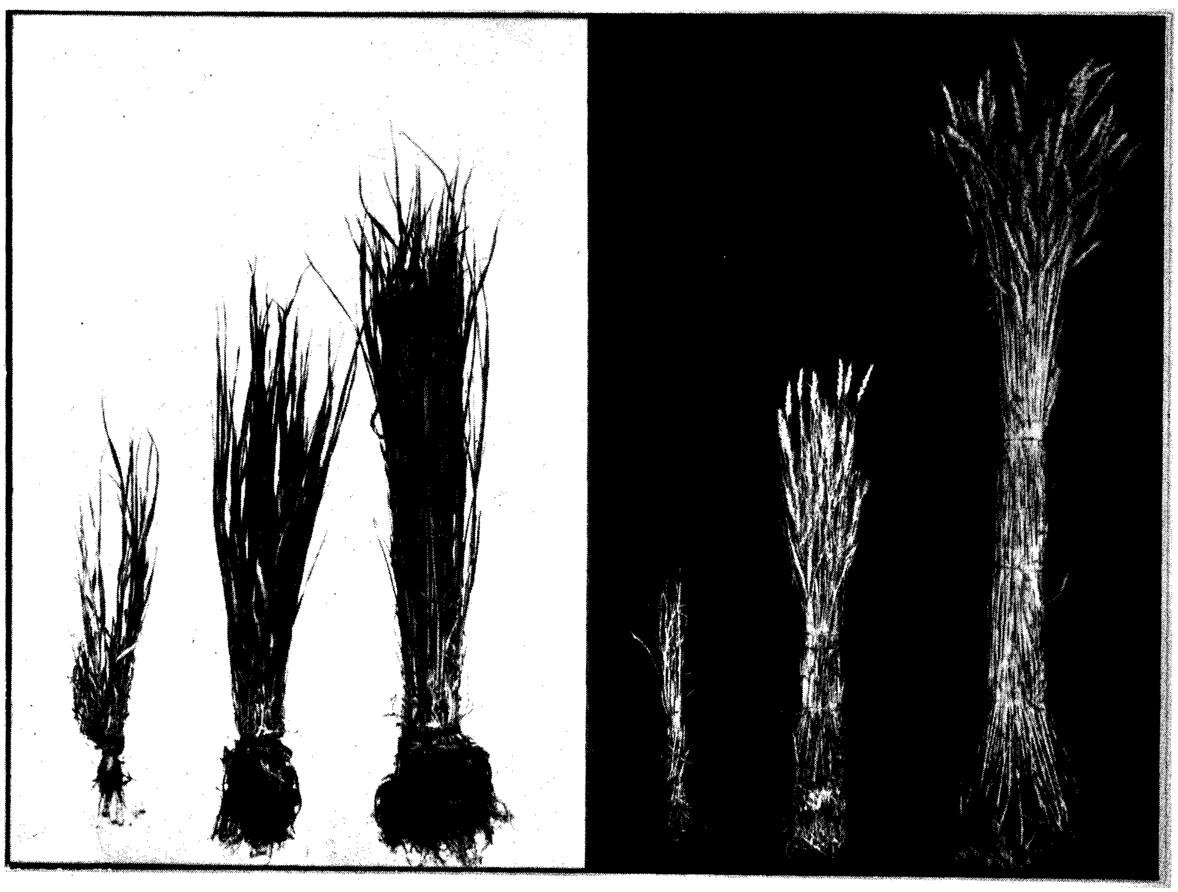

Figure 1. Plants classified, from left to right, as severe, stunted, and healthy as they appeared in May (left) and at maturity (right).
(from Atkinson and Grant, 1967)

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

classified as severe were dwarfed and had many completely yellowed leaves. Plants classified as stunted had definite but less-conspicuous streak mosaic symptoms. Plants without symptoms were classified as healthy. When these disease severity data from the 100 consecutively numbered sampling sites were arbitrarily grouped into odd and even numbered sites they showed excellent agreement (Table 1). This indicates that the procedures followed in collecting and classifying the May samples were reliable. However, in order to establish a disease-intensity-yield relationship, we needed a measure of disease intensity in the mature crop from which yield data could also be obtained.

Table 1. Numbers and percentages of plants in three disease categories from field samples of winter wheat collected in May[a], 1964

Disease category	Odd-no. samples		Even-no. samples	
	No.	%	No.	%
Severe	245	20	242	19
Stunted	465	35	470	36
Healthy	571	44	592	46

[a] The data from 100 consecutively numbered sites are grouped arbitrarily into odd- and even-numbered samples.

When the crop matured in mid-July, 25 one-square-yard yield samples were collected by pulling all the plants from one linear yard in each of six adjacent rows. The sites sampled corresponded approximately with the location of every fourth site sampled in May (Fig. 2). Fortunately, plants belonging to the disease categories used in classifying the immature plants in May could easily be recognized when mature (Fig. 1). Plants that had died without forming grain were classified as severe. The plants that produced grain fell into two distinct groups, stunted and healthy. Stunted plants were about half the height of healthy ones and had fewer and smaller heads.

Compared with the May samples, those collected in July had a smaller percentage of plants classified as severe. We attributed this primarily to the premature senescence and disintegration of severly diseased plants. This interpretation can be supported by appropriate calculations, which show that fewer plants were present in July than might reasonably have been expected had all the plants present in May survived. When plants classified as severe were excluded from the comparison, the

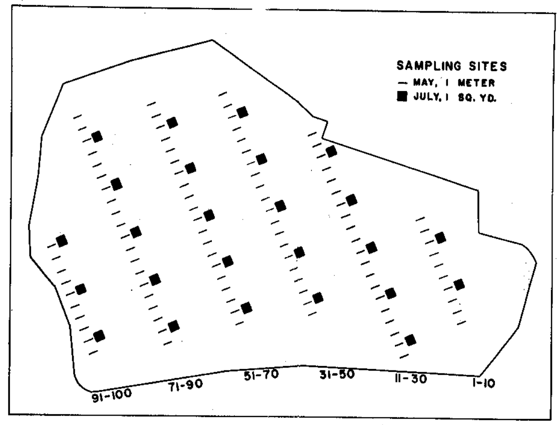

Figure 2. Plot of a 25-acre winter wheat field showing the distribution of sites sampled for wheat streak mosaic in May and July.

May and July samples contained 45% and 42% stunted plants, respectively. This agreement shows that we had correctly identified the original disease categories in the mature plants. It also supports our earlier observation (1) that spread of the disease was negligible in the spring of 1964.

Determining the relationship between disease intensity and yield

Confident that we could recognize the various disease categories in the mature plants, we attempted next to establish a relationship between yield and disease intensity. Plants in the stunted and healthy categories within each of the 25 yield samples were threshed separately and attempts were made to relate these yield data to disease intensity expressed in terms of percent stunted plants. Plants classified as severe were excluded from these calculations because we believe that their loss was fully compensated for by the remaining plants in the population. Our judgment was based on the fact that the severely affected plants had died early and that excellent moisture and fertility conditions had prevailed.

A meaningful relationship between disease intensity and yield was not at first apparent. When the total grain yield in grams from each square-yard sample was plotted against disease intensity, the result was a rather unimpressive scatter diagram (Fig. 3).

Realizing that inherent productivity differences throughout the field were probably obscuring the relationship between disease intensity and yield, we attempted to utilize the healthy plants within each sample as an internal check plot. The relationship of disease intensity to yield became obvious when the total grain yield of each square yard sample was expressed as a percentage of a theoretical "potential yield" calculated according to the following equation:

$$\% \text{ yield} = \frac{W}{W_1 \times N} \times 100$$

where W = the total weight of grain produced at a site, W_1 = the mean weight of grain produced by healthy plants at that site, and N = the total number of stunted and healthy plants at the site.

When the percentage yield data were calculated for each of the 25 samples and plotted against the appropriate disease intensity, a highly significant regression was evident (Fig. 3). This graph also shows that the yield of stunted plants, expressed as a percentage of the yield of healthy plants at the same site, was relatively constant within the range of disease intensities encountered. This indicates that in the moderately affected field that we sampled, the reduction in yield caused by the disease was directly related to the number of plants classified as stunted. Incidentally, stunted plants yielded an average of 34 kernels compared with 96 for healthy ones.

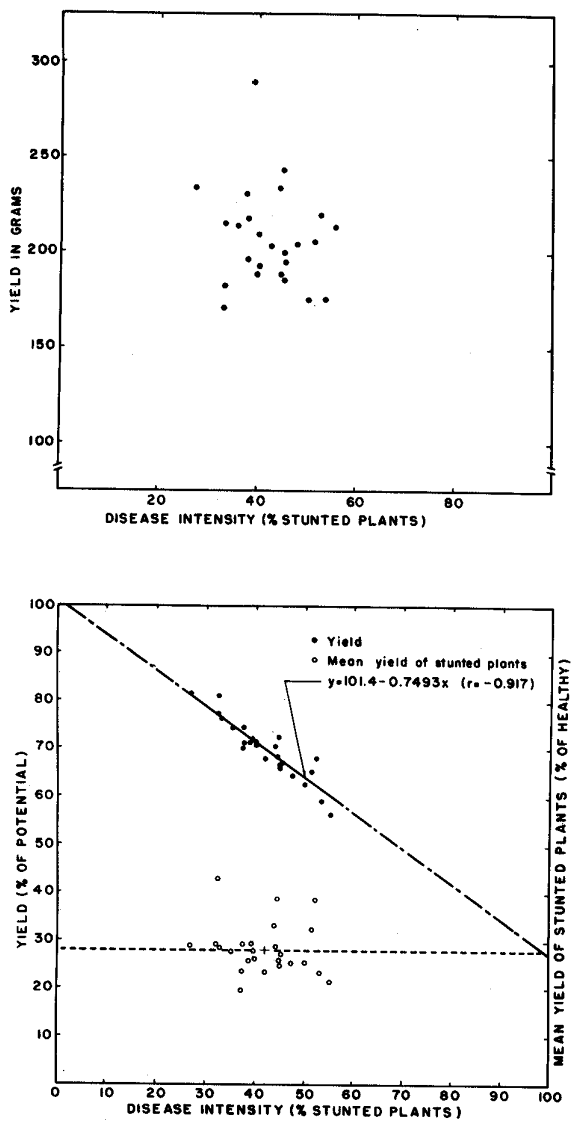

Figure 3. Relationship of yield to disease intensity shown by square-yard samples of mosaic affected winter wheat. Yield is expressed in grams (above) and as a percentage of a calculated potential yield (below).

<u>Estimating the losses in the 1963-64 southern Alberta winter wheat crop</u>

As an adjunct to our disease intensity-yield studies we carried out a survey of winter wheat acreage and streak mosaic damage with the cooperation of the elevator agents of southern Alberta. Reports such as that shown in Figure 4 were received from more than 1,100 winter wheat growers. Of the 31,430 acres of winter wheat reported to be infected with streak mosaic, 20,100 acres were cultivated out because of the disease.

These acreage data provided a basis for estimating losses caused by the streak mosaic epiphytotic. We estimated an average yield of 30 bu/acre for a healthy crop and an average reduction of 10 bu/acre caused by the disease. On the basis of the relationship between disease intensity and yield that was developed for the moderately infected crop (Fig. 3), this estimate corresponds to a disease intensity of 46%. Since most infected crops in the winter wheat area appeared to be more severely diseased than the one we studied, our estimate is undoubtedly conservative. Nevertheless, based on these estimates, winter wheat losses for the acreage surveyed exceeded 700,000 bu, or 18% of the potential yield.

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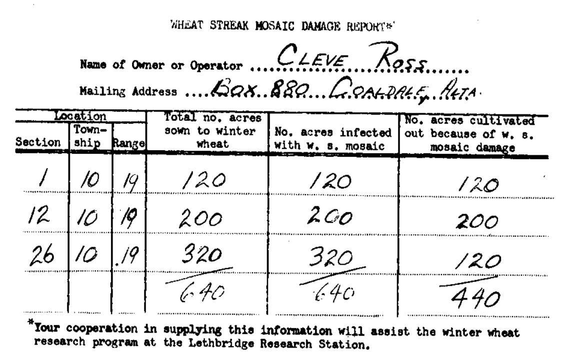

WHEAT STREAK MOSAIC DAMAGE REPORT*

Name of Owner or Operator ....Cleve Ross.......

Mailing Address ....Box 880...Coaldale, Alta.

Location			Total no. acres sown to winter wheat	No. acres infected with w. s. mosaic	No. acres cultivated out because of w. s. mosaic damage
Section	Township	Range			
1	10	19	120	120	120
12	10	19	200	200	200
26	10	19	320	320	120
			640	640	440

*Your cooperation in supplying this information will assist the winter wheat research program at the Lethbridge Research Station.

Figure 4. Report form used to obtain acreage information on the severity of wheat streak mosaic.

THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: BARLEY YELLOW DWARF

C. C. Gill[1]

The barley yellow dwarf virus (BYDV) causes diseases of wheat, oats, barley, and other members of the Gramineae. The virus is transmitted by several species of aphids that infest cereal crops.

Until recently, little was known about the reaction of varieties of wheat, oats, and barley grown on the Canadian prairies to BYDV, and no attempts had been made to assess losses from the disease in this area.

It was decided, therefore, to test the susceptibility of some of the more important varieties of cereals to this virus by controlled inoculations of plants grown in the greenhouse and in the field. Viruliferous aphids were placed on seedlings, allowed to feed for a few days, and then killed with insecticide. The yield from inoculated plants was then compared with the yield from uninoculated plants. This method allows one to:

Study symptom expression as an aid to diagnosis in the field;

Determine varietal reactions to the virus;

Make reasonable estimates of losses in the field from natural epidemics.

Results

Oats

All the more widely grown varieties that have been tested are very susceptible. The typical "red leaf" symptoms caused by the disease were clearly visible on these varieties. Yield losses from two separate trials are shown in Table 1.

In 1965 there was a high incidence of barley yellow dwarf in a 900 square mile area east of Riding Mountain in Manitoba. A survey indicated that losses to oats in this area amounted to $2\frac{1}{4}$ million bushels.

Wheat

Preliminary trials with nine varieties of common wheat and four varieties of durum wheat were made in the greenhouse. Despite mild symptom expression, losses in yield were heavy in all varieties (Table 2).

[1] Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

Table 1. Losses in oats from barley yellow dwarf

Variety	Yield loss (%) Trial 1	Yield loss (%) Trial 2
Fulghum**	15	
Albion	52	
Albion x Clintland	62	
Coast Black		71
California Red	76	89
Rodney*	83	95
Russell*	85	91
Victory*	85	92
Clintland***	87	90
Garry*	95	96

* Varieties grown on the Canadian prairies.

** A variety with known tolerance.

*** A widely grown American variety regarded as very susceptible.

In 1966 a block of 'Manitou' wheat was sown at Glenlea, near Winnipeg. Eight-foot rows were inoculated with BYDV and yields were compared with those from similar but uninoculated rows. Losses of 64% and 40%, respectively, occurred when plots were inoculated 20 and 30 days after seeding. Symptom expression was slight, however, and it will be difficult to make accurate disease ratings in the field on this and other wheat varieties.

Barley

A block each of 'Parkland' and 'Conquest' barley was grown at Portage la Prairie in 1965, and eight-foot rows were inoculated at the 3-leaf stage. Yield losses were 80% in 'Parkland' and 67% in 'Conquest'. Yellowing of the leaves and stunting of the plants were obvious, but leaf symptoms may be easily confused with those from infection with aster yellows virus.

Table 2. Losses in varieties* of common and durum wheats from barley yellow dwarf

	Variety	Yield loss (%)
Common wheat	Thatcher	63
	Pembina	71
	Canthatch	73
	Selkirk	76
	Manitou	80
	Chinook	81
	Park	85
	Cypress	85
	Rescue	88
Durum wheat	Stewart 63	79
	Lakota	89
	Pelissier	95
	Ramsey	99

* All varieties except 'Lakota' are grown on the Canadian prairies.

DISCUSSION OF THE PAPER BY C. C. GILL

W. E. Sackston: An apparent correlation was mentioned between the susceptibility in barley to aster yellows infection and root rot. This is an interesting observation. Dr. Putt and I found a somewhat similar relationship between two diseases of sunflowers. We relied upon natural infections of sunflowers with aster yellows virus to determine varietal reactions. Then it was found that aster yellows susceptibility could be determined by checking the susceptibility of varieties to Verticillium, another root-infecting pathogen.

J. A. Hoes: I believe there has been a prior report that cereals infected with virus are more susceptible to root rots.

M. L. Kaufman: Some of the data would indicate a disparity between 'Thatcher' and 'Canthatch' wheats in their reaction to virus disease. Since 'Canthatch' was derived by a backcrossing program to 'Thatcher', one would expect smaller differences between these two than between either one of them and other varieties.

C. C. Gill: The varietal comparisons were made in the greenhouse in preliminary trials, and further work is necessary. Different figures have been obtained in the field. For example, in 'Manitou' wheat we recorded losses of 64% in the field and 80% in the greenhouse.

D. S. McBean: The suggested correlation between root rot and virus susceptibility in wheat is not strengthened by some of the data. 'Manitou' and 'Chinook', which are resistant and susceptible, respectively, to common root rot, showed similar losses from barley yellow dwarf. Are there other data for the correlation?

T. G. Atkinson: I noted that 'Thatcher', which is fairly resistant to root rot, incurred the least loss from BYD. The three sawfly-resistant wheats, which are all fairly susceptible to root rot, had high loss figures for BYD.

THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: ASTER YELLOWS IN BARLEY

P. H. Westdal[1]

In the field, a barley plant infected with aster yellows virus (AYV) is usually somewhat stunted and yellowed and is characterized by the formation of one or more "sterile" heads. Usually one or more heads that appear normal are also formed on the plant. The sterile heads produce no seed; the other heads produce fewer kernels than do those of healthy plants and the kernels are usually shrivelled and discolored.

The following is a summary of results obtained in an assessment of losses from a natural infection of AYV in barley in 1966. The details of this work will be published elsewhere.

A comparison of yields of paired samples of healthy and AYV-infected plants showed that healthy plants yielded almost three times as much as infected plants, although almost one-half of the heads from the infected plants appeared normal. In practice much of the seed of infected plants would be lost during harvest.

A comparison of yields of paired samples of barley from one foot of row in which one sample of each pair had an AYV-infected plant showed that there was no compensation in yield by adjacent plants. This is presumably because a barley plant infected with AYV continues to grow and utilize moisture and soil nutrients.

In two separate tests, in which percentage yield was plotted against percentage sterile heads, the regression of yield on disease intensity agreed closely with that expected on the basis of the other yield comparisons. In both tests the percentage loss in yield was almost twice the percentage of sterile heads in the samples. The fact that AYV-infected plants produce heads that appear normal but contribute little or nothing to yield explains earlier work where the percentage loss in yield was two to three times greater than the percentage of sterile heads.

More work is required to establish the validity of the relationship between percentage sterile heads and yield loss, but once established it should prove useful in surveys designed to determine loss in yield due to AYV. For example, a survey of commercial barley fields in Manitoba in 1966 showed that from a trace to 6.5% (mean 3.5%) of barley heads were sterile due to AYV infection. On the basis of the relationship between percentage sterile heads and loss in yield, involving a factor of 2, the loss in barley yield in 1966 would have ranged from trace to about 13%, with a mean of about 7%.

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