# LOSSES FROM CEREAL DISEASES AND VALUE OF DISEASE RESISTANCE IN MANITOBA IN 1969'

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Data on losses caused by plant diseases and on gains in productivity from the use of disease control measures developed through research are becoming increasingly important to agencies such as FAO, U.S.D.A. and C.D.A. for assessing research programs and setting priorities. The terms of reference of the C.D.A. Research Station, Winnipeg, include "to develop varieties of wheat, oats and barley suitable for production in the Prairie Provinces" and "to devise protective measures for the growing crops.. .against disease". To fulfill our objectives and assess the value of our research under these terms of reference we must have data showing the importance of various diseases and the gain in cereal production through the use of resistant varieties.

In the past, pathologists in Manitoba relied on limited field surveys and yield trials in experimental plots to assess the importance of the various diseases, This approach was successful and the most important diseases were given a high priority in establishing breeding programs for their control. However, except for rusts (2, 8, 13, 17), very little was published on the dollars or bushels lost on a provincial basis to justify the initiation of research on specific diseases.

Similarly, the obvious advantages of new, disease resistant varieties have been such that no need was felt-to provide extensive data on their value to growers or to those providing funds for research. Some data are available on the value of rust-resistance in new varieties of wheat and oats (2, 13) but, with current attitudes towards budgeting for research programs, more data of this type will have to be provided for all diseases.

This paper reports estimates of losses caused by major diseases of wheat, oats and barley and the value of disease resistance obtained from an extensive survey of Manitoba in 1969.

## Materials and methods

Six survey routes, two for each crop, were mapped to cover all of the crop districts in Manitoba (Fig. 1). The acreage of each crop in each crop district was obtained (3, 4, 5)

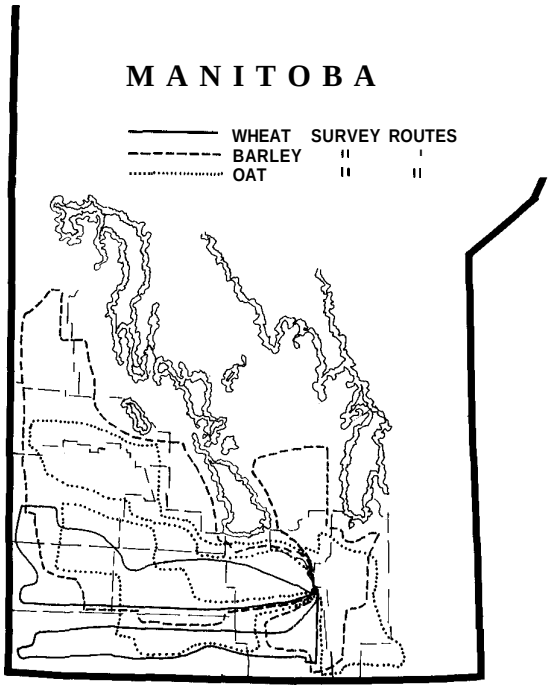


Figure 1. Map of the agricultural area of Manitoba showing survey routes.

and each pair of routes was designed to pass through the crop districts in which over 75% of the particular crop was grown. The length of the routes varied from 600 to 1100 miles.

The optimum number of survey sites in each crop district was arbitrarily set at 1%of the farms growing the specific crop (Table 1). The number of farms, rather than the number of acres in a district, was used because management practices such as seed treatment, crop rotation, and other disease control measures should be uniform on a particular farm regardless of the size of fields. It was assumed that a sample of this size would represent fields differing in variety, date of seeding, incidence of disease and environmental conditions. The sites were marked on the route maps at 15- to 20- mile intervals and the field closest to each site on the route was surveyed. Although each route was designed to survey a specific crop, some sites for the other two crops were also included. In districts where a specific crop was highly concentrated, the

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Table 1. Number of farms with specific crops, number of survey sites, and percentage of farms surveyed in Manitoba

| Area and crop district | Wheat | | | Oats | | | Barley | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of farms[1] | Farms surveyed | | No. of farms[1] | Farms surveyed | | No. of farms[1] | Farms surveyed | |
| | | Number | % | | Number | % | | Number | % |
| East | | | | | | | | | |
| 4 | 513 | 5 | | 605 | 10 | | 403 | 5 | |
| 5 | 1750 | 16 | | 1880 | 15 | | 843 | 11 | |
| 6 | 96 | 1 | | 189 | 1 | | 29 | 0 | |
| 12 | 600 | 3 | | 728 | 6 | | 321 | 3 | |
| Total | 2959 | 25 | 0.9 | 3402 | 32 | 0.9 | 1596 | 19 | 1.1 |
| Central | | | | | | | | | |
| 3 | 3723 | 23 | 0.6 | 3204 | 27 | 0.8 | 1649 | 16 | 1.1 |
| South-west | | | | | | | | | |
| 1 | 1544 | 13 | | 1207 | 10 | | 586 | 6 | |
| 2 | 2335 | 12 | | 1913 | 14 | | 994 | 11 | |
| 7 | 1422 | 11 | | 1299 | 13 | | 632 | 8 | |
| Total | 5301 | 36 | 0.7 | 4419 | 37 | 0.8 | 2212 | 25 | 1.1 |
| West-central | | | | | | | | | |
| 8 | 1541 | 15 | | 1427 | 14 | | 571 | 8 | |
| 9 | 1360 | 14 | | 1276 | 16 | | 571 | 10 | |
| 10 | 2543 | 19 | | 1852 | 18 | | 1465 | 15 | |
| 14 | 599 | 1 | | 630 | 2 | | 273 | 0 | |
| Total | 6043 | 49 | 0.8 | 5185 | 50 | 1.0 | 2880 | 33 | 1.1 |
| North-west | | | | | | | | | |
| 11 | 1818 | 11 | | 1489 | 10 | | 810 | 12 | |
| 13 | 932 | 6 | | 656 | 5 | | 702 | 6 | |
| Total | 2750 | 17 | 0.6 | 2145 | 15 | 0.7 | 1512 | 18 | 1.2 |
| Total | | 150 | | | 161 | | | 111 | |

[1] Yearbook of Manitoba Agriculture, 1968.

number of sites was less than 1% because disease incidence on cereals is fairly consistent over wide areas and it is unnecessary to select sites less than 15 miles apart. Disease incidence in each field was assessed on 25 plants, one collected every 2 paces along a traverse 50 yards long and 50 yards in from the edge of the field. Disease ratings and information on stage of growth, location, etc. were recorded on crop-specific survey forms.

The surveys were completed during the period of July 30 to Aug. 12 when most of the crop was in the soft dough stage. For the final analysis of the data, the 14 crop districts were grouped into five areas based on previous knowledge of the general distribution of diseases.

The range and mean percentage loss for each disease were determined and the potential average yield in each area was found by multiplying the average yield by 100 and dividing by 100 minus the percentage loss from all diseases. The loss in bushels from individual diseases was calculated by multiplying the mean percentage loss from a disease by the potential yield and by the acreage.

The methods of assessing losses from individual diseases were based on published data, where available:

Smuts - The percentage of main tillers destroyed was used as the percentage yield reduction (10). Where less than 1% of the crop was affected the incidence was rated as

trace and was not included in the estimate of loss. The value of smut resistance in cereals was calculated by multiplying the total actual production by the percentage of the acreage sown to resistant varieties and by the percentage smut in susceptible varieties. The percentage loose smut in common wheat was estimated at 1.3%, the average incidence of loose smut in susceptible durum wheat during the past 6 years. The percentage smut in oats and barley was estimated from data obtained in years prior to the widespread use of smut resistant varieties. In oats the average incidence of all smut was 1.2% during the 8 years, 1947-1954, and in barley it was 2.1% during the 16 years, 1951-1966.

Rusts - Losses from rust were estimated by relating the percentage infection observed in the field to yield losses sustained from similar levels of infection in experimental trials (6, 7, 15). The gain in wheat production from the use of stem- and leaf-rust resistant varieties was obtained by comparing the average yield of 'Manitou' (resistant to stem rust and leaf rust), 'Thatcher' (susceptible to leaf rust) and 'Marquis' (susceptible to stem rust and leaf rust) in the 1969 Western Wheat Co-operative Tests. The mean yields in cwt/acre from the four stations in the rust area of Manitoba (Winnipeg, Morden, Portage la Prairie and Brandon) were: 'Manitou', 24.0; 'Thatcher', 21.5; and 'Marquis', 18.1. The mean yields from the four stations in the adjoining rust-free area of Saskatchewan (Indian Bead, Yorkton, Melfort, and Regina) were: 'Manitou', 25.3; 'Thatcher', 25.3, and 'Marquis', 24.1 cwt/acre. The gain in production from leaf rust resistance was calculated from the difference in yield between 'Manitou' and 'Thatcher' as a percentage of the yield of 'Manitou'; and from stem rust resistance, the difference between 'Thatcher' and 'Marquis' yields as a percentage of 'Manitou' less 4.7%, the percentage yield advantage of 'Manitou' and 'Thatcher' under rust-free conditions. The acreage in the North-west area was not included in calculating the gain in production because of the low incidence of rust.

Leaf spots - Disease incidence was recorded on the flag and second leaves only and a formula developed for scald of barley (11) was used to calculate yield losses from all leaf spot diseases on all crops. Although assessment formulae have not been developed for all diseases, we believe that this formula gives a close approximation of losses from leaf spots on cereals based on previous observations (1, 9, 14, 19). Where possible, losses were attributed to specific diseases but, as they usually occurred as a complex, the total loss from all leaf spot diseases was used in the final estimation.

Virus diseases - By comparing the yield from individual plants that were moderately infected with barley yellow dwarf with that from adjacent apparently healthy plants of barley and oats, it was shown that the disease caused a 65% decrease in yield per plant (Gill and Martens, unpublished data). The percentage of infected plants observed in a field was multiplied by 65% to obtain the percentage yield loss from barley yellow dwarf.

Thrips - Infestations of thrips (Limothrips denticornis Hal.) were rated as severe, moderate or light and the yield loss was assessed at 10, 5, or 1%, respectively, based on results from North Dakota (18). In severe infestations, all plants in a crop exhibited complete chlorosis of the flag leaf and often also of the sheath. Mature thrips and larvae were abundant beneath the sheath.

## Results

### Wheat

Losses from the major diseases of wheat that occurred in Manitoba in 1969 amounted to 3.4 million bu or 5% of the potential yield without disease (Table 2); and the value of rust and smut resistance was estimated at 11.6 million bu or $16.3 million (Table 5).

Over 99% of the wheat acreage in Manitoba was sown to 'Manitou' or 'Selkirk' so that losses from stem rust caused by Puccinia graminis Pers. f. sp. tritici Eriks. & E. Henn. were practically nil, and losses from leaf rust caused by Puccinia recondita Rob. ex Desm. were mainly confined to late-sown fields of 'Selkirk' and to the few fields of susceptible varieties still grown. The potential severity of the leaf rust epidemic was shown by a field of 'Thatcher' in the West-central area in which a loss of 20% from leaf rust was estimated. A final yield of 18 bu/ac was reported by the grower of this crop compared to yields of over 30 bu/acre reported for 'Manitou' grown in adjacent fields.

All of the common wheat varieties grown in Manitoba are resistant to loose smut caused by Ustilago tritici (Pers.) Rostr., and only trace infections have been recorded for the past 5 years. The incidence of loose smut on susceptible durum varieties was 0.8%.

Leaf spots caused losses estimated as high as 26% in individual fields and they were the major factor contributing to the total yield loss. The results substantiate observations on the increased prevalence of these diseases in western Canada and North Dakota (16) during the past few years. It was difficult to distinguish in the field between symptoms caused by the three major leaf-spotting fungi, Drechslera tritici-repentis (Died.) Shoem., Bipolaris sorokiniana (Sacc. in Sorok.) Shoem. and Septoria avenae Frank f. sp. triticea T. Johnson. Collections of infected leaves were incubated in moist chambers and usually more than one of the pathogens were isolated.

Table 2. Yield losses from disease in wheat in Manitoba, 1969

| Area (Crop Dist.) | | Yield losses from Leaf rust | Leaf spot | BYDV | Total | Average yield[1] (bu/ac) | Potential av. yield (bu/ac) | Acres[1] (000) | Potential production (000 bu) |
|---|---|---|---|---|---|---|---|---|---|
| East (4, 5, 6, 12) | Range (%) | 0-10 | 0-20 | 0-3 | | 19.3 | 20.4 | 384 | 7833.6 |
| | Mean (%) | 3.33 | 2.08 | 0.25 | 5.66 | | | | |
| | bu (000) | 260.9 | 162.9 | 19.6 | 443.4 | | | | |
| Central (3) | Range (%) | T[2]-10 | 0-20 | 0-7 | | 18.4 | 19.4 | 395 | 7663.0 |
| | Mean (%) | 1.22 | 3.57 | 0.44 | 5.23 | | | | |
| | bu (000) | 93.5 | 273.6 | 33.7 | 400.8 | | | | |
| South-west (1, 2, 7) | Range (%) | 0-10 | 0-20 | 0-7 | | 27.6 | 28.8 | 732 | 21,081.6 |
| | Mean (%) | 1.42 | 2.28 | 0.39 | 4.09 | | | | |
| | bu (000) | 299.4 | 480.7 | 82.2 | 862.3 | | | | |
| West-central (8, 9, 10, 14) | Range (%) | 0-20 | 0-26 | 0-1 | | 28.3 | 29.7 | 692 | 20,552.4 |
| | Mean (%) | 2.37 | 2.29 | 0.12 | 4.78 | | | | |
| | bu (000) | 487.1 | 470.6 | 24.7 | 982.4 | | | | |
| North-west (11, 13) | Range (%) | 0-2 | T-15 | 0-3 | | 31.3 | 33.5 | 297 | 9949.5 |
| | Mean (%) | 0.47 | 5.94 | 0.18 | 6.59 | | | | |
| | bu (000) | 46.8 | 591.0 | 17.9 | 655.7 | | | | |
| Total (000 bu) | | 1187.7 | 1978.8 | 178.1 | 3344.6 | 25.5 | 26.8 | 2500 | 67080.1 |
| % of potential yield | | 1.77 | 2.95 | 0.27 | 4.99 | | | | |

[1] Personal communication, M. Daciw, Statistics Branch, Manitoba Department of Agriculture.

[2] T = trace.

Losses from barley yellow dwarf were not great except in late-sown fields in the southern part of the province.

A loss of 5% was estimated from root rot (*B. sorokiniana*) in the one field in which the incidence was recorded as being greater than trace.

## Oats

Losses from diseases in oats amounted to 5.3 million bu or 7% of the potential yield and was attributed mainly to an epidemic of crown rust (*Puccinia coronata* Cda.) that occurred on the one-third of the oat acreage that was sown late in the southern part of the province (Table 3). Smut-resistant varieties occupy 99% of the acreage of oats in Manitoba and the increase in production through their use amounted to 832,000 bu or $411,800 (Table 5).

Losses from barley yellow dwarf virus on late-sown oats were much less than on late-sown barley because the predominant virus strain in 1969 was carried by *Rhopalosiphum maidis* Fitch, which prefers barley to oats as a host.

Leaf spot diseases caused losses in individual fields but in most fields the incidence was rated as trace. *Drechslera avenacea* (Curt. ex Cke.) Shoem. and *Septoria avenae* Frank f. sp. *avenae* were isolated alone or in combination from infected leaves.

## Barley

Losses caused by the major diseases and by thrip damage in barley were estimated at: 4.1 million bu or 8.7% of the potential yield (Table 4) and the gain in production from the use of smut-resistant varieties amounted to 621,300 bu or $466,000 (Table 5). About one-

Table 3. Yield losses from disease in oats in Manitoba, 1969

| Area (Crop Dist.) | | Yield losses from Crown rust | Leaf spot | BYDV | Total | Average yield[1] (bu/ac) | Potential av. yield (bu/ac) | Acres[1] (000) | Potential production (000 bu) |
|---|---|---|---|---|---|---|---|---|---|
| East (4, 5, 6, 12) | Range (%) | T[2]-40 | 0-15 | 0-40 | | 37.8 | 41.3 | 367 | 15,157.1 |
| | Mean (%) | 3.13 | 1.75 | 3.72 | 8.60 | | | | |
| | bu (000) | 474.4 | 265.2 | 563.8 | 1303.4 | | | | |
| Central (3) | Range (%) | T-60 | 0-7 | 0-10 | | 38.8 | 44.4 | 291 | 12,920.4 |
| | Mean (%) | 10.56 | 1.22 | 0.78 | 12.56 | | | | |
| | bu (000) | 1364.4 | 157.5 | 100.8 | 1622.8 | | | | |
| South-west (1, 2, 7) | Range (%) | 0-40 | 0-14 | 0-10 | | 51.0 | 55.2 | 331 | 18,271.2 |
| | Mean (%) | 6.08 | 1.11 | 0.43 | 7.62 | | | | |
| | bu (000) | 1110.9 | 202.8 | 78.6 | 1392.3 | | | | |
| West-central (8, 9, 10, 14) | Range (%) | 0-20 | 0-20 | 0-7 | | 49.7 | 52.0 | 387 | 20,124.0 |
| | Mean (%) | 1.90 | 1.88 | 0.68 | 4.46 | | | | |
| | bu (000) | 382.4 | 378.3 | 136.8 | 897.5 | | | | |
| North-west (11, 13) | Range (%) | 0-5 | 0-2 | 0-1 | | 52.4 | 52.7 | 154 | 8115.8 |
| | Mean (%) | 0.33 | 0.13 | 0.07 | 0.53 | | | | |
| | bu (000) | 26.8 | 10.6 | 5.7 | 43.1 | | | | |
| Total (000 bu) | | 3358.9 | 1014.5 | 885.7 | 5259.1 | 45.3 | 48.8 | 1530 | 74,588.5 |
| % of potential yield | | 4.50 | 1.36 | 1.19 | 7.05 | | | | |

[1] Personal communication, M. Daciw, Statistics Branch, Manitoba Dept. of Agriculture.

[2] T = trace

third of the loss occurred in the eastern area, where a severe epidemic of barley yellow dwarf reduced yields of late-sown barley. Most of the loss from smut diseases occurred on susceptible 2-rowed varieties where the incidence of loose smut caused by Ustilago nuda (Jens.) Rostr. and of seedling-infecting smuts (U. nigra Tapke and U. hordei (Pers.) Lagerh.) as high as 9 and 12%, respectively. No loose smut and only a small percentage of seedling-infecting smuts was recorded on 6-rowed varieties. Leaf-spotting diseases were most severe on the late-sown crops in the eastern area where spot blotch (B. sorokiniana) and net blotch (Drechslera teres [Sacc.] Shoem.) predominated. Only trace infections of root rot (B. sorokiniana) were observed except in one field in the north-west area where the loss was estimated at 20%.

Damage from thrips was a major cause of yield losses in the western areas of the province where most of the crop was seeded early. Two factors contributed to the lower infection in the eastern and central areas. About one half of the barley acreage was sown late in these areas and Post (18) has reported that damage is less severe on late-sown crops. Also, 'Herta' barley was sown on over 35% of this acreage and it is resistant to thrip damage (H. P. Richardson, unpublished data).

## Discussion

The estimates of disease loss and the value of resistance, calculated from 1969 survey data are believed to be conservative, for several reasons. The estimates were based on the incidence of the major diseases of the three crops and only their effect on yield was considered. Decrease in the quality of diseased crops also has a significant bearing on their value but estimating this type of loss from disease, or the gain from resistance, was beyond the scope of a survey of this scale. Stem rust of wheat, which has the potential of causing major losses in the absence of resistant

Table 4. Yield losses due to diseases in barley in Manitoba, 1969

| Area (Crop Dist.) | | Yield losses from BYDV | Leaf spot | Leaf rust | Thrips | Smut | Total | Average yield[1] (bu/ac) | Potential av. yield (bu/ac) | Acres[1] (000) | Potential production (000 bu) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| East | Range (%) | T[2]-57 | 0-30 | 0-T | 0-10 | 0-9 | | | | | |
| (4, 5, 6, 12) | Mean (%) | 19.89 | 7.76 | 0 | 0.53 | 0.79 | 28.97 | 25.9 | 36. 5 | 204 | '7446.0 |
| | bu (000) | 1481.0 | 577.8 | 0 | 39.5 | 58.8 | 2157.1 | | | | |
| Central | Range (%) | 0-14 | T-15 | 0-17 | 0-T | 0-12 | | | | | |
| (3) | Mean (%) | 2.06 | 1.88 | 1.06 | 0 | 0.81 | 5. 81 | 26. 2 | 27. 8 | 217 | 6032.6 |
| | bu (000) | 124.3 | 113.4 | 63. 9 | 0 | 48. 9 | 350.5 | | | | |
| South-west | Range (%) | 0-3 | T-7 | 0-3 | 0-10 | 0-1 | | | | | |
| (1, 2, 7) | Mean (%) | 0.38 | 1.10 | 0.12 | 1.24 | 0.04 | 2. 88 | 40.5 | 41. 7 | 279 | 11,634. 3 |
| | bu (000) | 44.2 | 128.0 | 14.0 | 144.3 | 4.7 | 335.2 | | | | |
| West-central | Range (%) | 0-6 | 0-27 | 0-4 | 0-10 | 0-T | | | | | |
| (8, 9, 10, 14) | Mean (%) | 0. 39 | 3.36 | 0.73 | 2.46 | 0 | 6.94 | 41.2 | 44.3 | 329 | 14,574. 7 |
| | bu (000) | 56.8 | 489.7 | 106.4 | 358.5 | 0 | 1011.4 | | | | |
| North-west | Range (%) | 0-7 | 0-6 | 0 | 0-10 | 0-T | | | | | |
| (11, 13) | Mean (%) | 0.37 | 0.68 | 0 | 2.16 | 0 | 3. 21 | 38. 7 | 39.9 | 171 | 6822.9 |
| | bu (000) | 25. 2 | 46.4 | 0 | 147.4 | 0 | 219.0 | | | | |
| Total (000 bu) | | 1731.5 | 1355.3 | 184.3 | 689.7 | 112.4 | 4073. 2 | 35.4 | 38.8 | 1200 | 46510.5 |
| % of potential yield | | 3.72 | 2.91 | 0.40 | 0.48 | 0. 24 | 8.76 | | | | |

[1] Personal communication, M. Daciw, Statistics Branch, Manitoba Department of Agriculture.

[2] T = trace

varieties, did not appear in Manitoba until late in the season. It is difficult to place a true value on rust resistance today as practically all of the wheat crop in Manitoba and throughout the Mississippi Valley is resistant. Under these conditions the build-up of inoculum is severely restricted and reaches significant levels much later in the season than previously when only susceptible varieties were grown. Other diseases of major importance in some years, such as aster yellows (20), septoria leaf blotch (9), and stem rust of barley and oats were also absent. The relatively low average percentage of smut in susceptible varieties that was used to calculate the value of smut-resistant varieties does not give a true indication of the value of smut resistance. Seed-treatment fungicides also contribute to the control of smut and were responsible for the lower incidence of the disease recorded prior to the introduction of resistant varieties, compared to the levels reported in earlier years (10).

It should be emphasized that the value placed on new varieties reflects only the increased yield attributable to their resistance to specific diseases. It does not include the value of their increased productivity through improvements in yielding ability, adaptability, quality, resistance to lodging or other agronomic characteristics.

The methods used for this survey are open to criticism by those who desire greater statistical accuracy in data collecting. The size of the sample examined at each site was admittedly small but we believe that, as there is more variability in cereal crops as to variety, management and other factors between farms than there is between areas in a field, it is better to obtain smaller samples from many sites rather than larger samples from a few. The methods of relating disease intensity to yield losses were selected from published reports but differences in varieties or weather conditions as they affect disease development and plant maturation could change the intensity-loss ratios. A compromise is required between the degree of precision desired and tha availability of resources for surveying. We believe that the methods used were adequate for the purpose but admit that the total loss from diseases was underestimated. The use of Co-operative Test data to obtain yield comparisons of resistant and suceptible varieties gives an underestimate of the value of disease resistance in years when much of the crop is seeded late because of wet spring weather.

Table 5. Value of disease resistance in cereal varieties grown in Manitoba in 1969

| Crop | Disease | Loss on[1] susceptible vars. (%) | Acreage of[2] resistant vars. (%) | Total production[3] (000 bu) | Gain in production (000 bu) | Price[3] ($/bu) | Value ($000) |
|---|---|---|---|---|---|---|---|
| Wheat | Stem rust | 9.5 | 99.6 | 54,418.6 | 5169.8 | 1.40 | 7237.7 |
| | Leaf rust | 10.4 | 99.6 | 54,418.6 | 5659.5 | .40 | 7923.3 |
| | Loose smut | 1.3 | 95.5 | 63,704.8 | 790.9 | .40 | 1107.3 |
| | Total | | | | 11,620.2 | | 16,268.3 |
| Oats | Smut | 1.2 | 99.0 | 69,327.5 | 823.6 | 0.50 | 411.8 |
| Barley | Smut | 2.1 | 69.7 | 42,447.5 | 621.3 | 0.75 | 466.0 |
| Total | | | | | 13,065.1 | | 17,146.1 |

1 See text for methods of determining loss on susceptible varieties.

2 Seedtime and Harvest, Nos. 74, 75, 76. Federal Grain Ltd., Winnipeg, Man.

3 Personal communication, M. Daciw, Statistics Branch, Manitoba Dept. of Agric.

As the Co-operative Tests are seeded as early as possible, there is less loss from disease than on crops that are planted later and are exposed to the full effects of late-season inoculum.

Despite these limitations, the data accumulated on disease losses are believed to be reasonably accurate although conservative, and indicate the importance of cereal diseases and the value of disease resistance in Manitoba in 1969.

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