IMPORTANCE OF FOLIAGE DISEASES OF WINTER WHEAT IN ONTARIO IN 1969 AND 1970[1]

W. C. James [2]

Abstract

Surveys of foliage diseases of winter wheat (Triticum aestivum L.) grown in Ontario were conducted in 1969 and 1970. Approximately 750 acres per annum, from 63 and 50 fields respectively, were sampled in proportion to the winter wheat acreage in twelve counties. The percentage leaf area affected by each disease was recorded for the top four leaves in May 1969 and the top two in June 1969 and June 1970. In May 1969 the average percentages of leaf area affected by powdery mildew on the top four leaves were 0 (flag leaf), 0.05, 0.41, and 1.14; corresponding percentages for leaf rust were 0, 0.01, 0.03, and 0.06. In June 1969, mildew affected 0.23% and 3.53% and leaf rust 0.46% and 1.08% of the areas of first (flag) and second leaves, respectively. In June 1970, the corresponding percentages for mildew were 1.47 and 3.27; and for leaf rust 3.27 and 3.53. Powdery mildew and leaf rust accounted for an average yield loss of approximately 1 to 2%. Septoria diseases were difficult to assess and consequently their importance could not be evaluated. Spindle streak mosaic decreased yield by approximately 3% and combined with barley yellow dwarf probably had the most significant effect on yield. The total loss in yield from powdery mildew, leaf rust, and spindle streak mosaic was approximately 5% per year which represents an average loss of 2 bushels/acre, worth $3.40. For the total acreage of 350,000 acres, this represents a loss of $1.25 million per annum.

Introduction

Creelman (4) concluded that most of the plant disease surveys conducted in Canada were qualitative and merely involved the collection, identification, and cataloguing of diseases occurring on plants. The results of these surveys, conducted from 1920 to 1960, have been summarized by Conners (3). However, there has been little emphasis on quantitative surveys designed to assess the incidence and severity of diseases on a particular crop with a view to estimating the consequent losses in yield.

This paper deals with a survey designed to assess the incidence and severity of foliage diseases of the winter wheat crop in Ontario in 1969 and 1970 and to determine the consequent economic loss. The crop occupied approximately 350,000 acres in 1969 and produced 15 million bushels, worth about $25 million (13). An effort was made to satisfy as many as possible of the requirements of a well conducted survey, within the practical limitations imposed, using the facilities available to the Canada Department of Agriculture.

[1] Contribution No. 263, Research Station, Canada Department of Agriculture, Ottawa, Ontario.

[2] Plant Pathologist.

Materials and methods

The number of segments selected per county was based on the acreage of winter wheat (Triticum aestivum L.) in the 1961 Census figures. The survey covered 12 counties (Fig. 1), in which approximately 70% of the winter wheat in Ontario is grown. The remainder of the winter wheat acreage is distributed in other counties, and it was considered that the enormous effort involved to survey this vast area was not justified. The survey area was divided into approximately 5,000 segments (each segment equivalent to approximately 1,000 acres) and segments were chosen from each county at random. A 1% sampling rate was attempted and the distribution of the 50 segments chosen was reported by James et al. (8). These segments were originally selected by the Dominion Bureau of Statistics (DBS) in 1967 to determine the yield per acre of winter wheat in Ontario. Each segment was divided into 4 approximate quarters in 1969 and one quarter was selected at random. Within the chosen quarter one field of winter wheat per farm was examined. The names and addresses of the farmers within the selected area were provided by DBS.

Aerial photographs of segments were used in conjunction with maps to increase survey efficiency by reducing the time spent in locating farms; the method is summarized below. The locations of the segments were marked on a small-scale map (Fig. 1) of the twelve counties and later transferred to a road map so that a route passing through all the segments could be scheduled. The road map was used to locate the area in the large-scale map (Fig. 2), which was then used to locate the exact position of the segment. Aerial photographs of the segments were obtained from the Canada Department of Energy, Mines and Resources and were used to identify farms and fields (Fig. 3). Fig. 3 represents the boxed area in Fig. 2. If it was difficult to establish the orientation of the aerial photograph, the position of a farm or any other physical feature was used as a guide to compare the photograph with the segment. Within the selected quarter of the segment, each of the farms (Fig. 3, No. 1,2,and 3) was visited and where possible one winter wheat field per farm was surveyed; if a farm had more than one field of winter wheat, one field was chosen at random. Successive quarters within segments were examined if a winter wheat field could not be found. In 1969, 63 fields were visited on two separate occasions approximately one month apart. The first sampling was conducted during the last week of May when the crops were at growth stages 8-9 (10) and the second during the last week of June when the crops were at growth stages 10.5.4-11.1 (grain milky ripe). In an effort to sample crops at the same growth stage, the earlier maturing crops in the southern counties were sampled first. In 1970 the survey was repeated, but due to shortage of time only 50 fields, on the same farms as 1969, were surveyed and only one visit was made, during the last week of June.

In 1969 the sampling system involved selecting 3 culms per acre up to a maximum of 25 culms per field; the culms were selected at equal intervals along a W pattern in the field, having chosen the site of the first sampling point using random numbers from 1 to 30; e.g. if 5 was the random number chosen, the first culm was picked 5 paces from the edge of the crop. During the May sampling, disease assessments were recorded for the laminae of the top four leaves on the culm (leaf 1 = flag leaf). For each leaf an assessment was made of the percentage of leaf area 'affected' by powdery mildew (Erysiphe graminis DC) ex Merat, spindle streak mosaic virus, and leaf rust (Puccinia recondita Rob. ex. Desm. f. sp. tritici). 'Affected' area in this context included the lesion and any yellowing associated with the disease. Any doubtful symptoms were checked by taking an infected leaf sample back to the laboratory for incubation and plating on agar to identify the causal organism. The percentage of leaf area remaining green was also assessed and a value was derived for the percentage leaf area dead due to causes other than disease. The premature chlorosis of leaves observed in some fields was recorded as dead leaf area. For the June sample only mildew and leaf rust were assessed because the symptom expression was poor for spindle streak mosaic. The assessments in June were made only for the flag and second leaves because leaves 3 and 4 were usually dead.

Standard area diagrams illustrating each disease were used to achieve consistency between assessments.

In 1970, 30 culms were chosen from each field at approximately equal intervals along one diagonal, having chosen the site of the first culm at random. The top two leaves on each culm were assessed for disease, using the method employed in 1969. One visit was made during the last week of June and the first few days of July when the crops were at growth stage 11.1 to 11.2 (milky - mealy ripe). The sampling method was changed in 1970 because the method used in 1969 was very time consuming and there was also evidence that sampling 30 tillers along one diagonal was adequate for our purpose.

In this paper a primary sampling unit represents all plants within one field; a secondary unit represents a plant within a field. The secondary units selected from one field constitute a subsample, and the aggregate of the primary units selected constitutes a sample. The disease assessments were recorded in the field on 80-column sheets and the computer cards were punched directly from these sheets to save time and to avoid transcribing errors. After the data had been analysed the necessary tables were prepared by Dr. C.S. Shih, Statistical Research Services, C.D.A., Ottawa. No attempt was made to assess any diseases except those which affected the foliage.

Results and discussion

Frequency of occurrence of diseases - The frequency of occurrence of diseases found in the samples is to some extent a measure of the distribution of the pathogen. A high occurrence reflects a wide distribution of the disease, and a low occurrence suggests that the converse is true. Powdery mildew and leaf rust were recorded in all subsamples during May and June 1969 and June 1970. Therefore, on the basis of frequency of occurrence in relation to subsamples, no differences in the distribution of these diseases were detected. However, the frequency of occurrence of diseases found on particular leaves (Table 1) showed that in May 1969 a higher percentage of leaves was infected with mildew than with leaf rust. Both diseases had affected a higher percentage of lower leaves; but this phenomenon was more marked for mildew, indicating that the crops had been infected with mildew earlier in the season. However in the June 1969 assessment a higher percentage of the top two leaves were infected with leaf rust than with mildew. Thus, a changeover had occurred concerning the relative importance of mildew and leaf rust between May and June 1969. This was probably due' to higher June temperatures which favored the development of leaf rust, coupled with the fact that the disease had

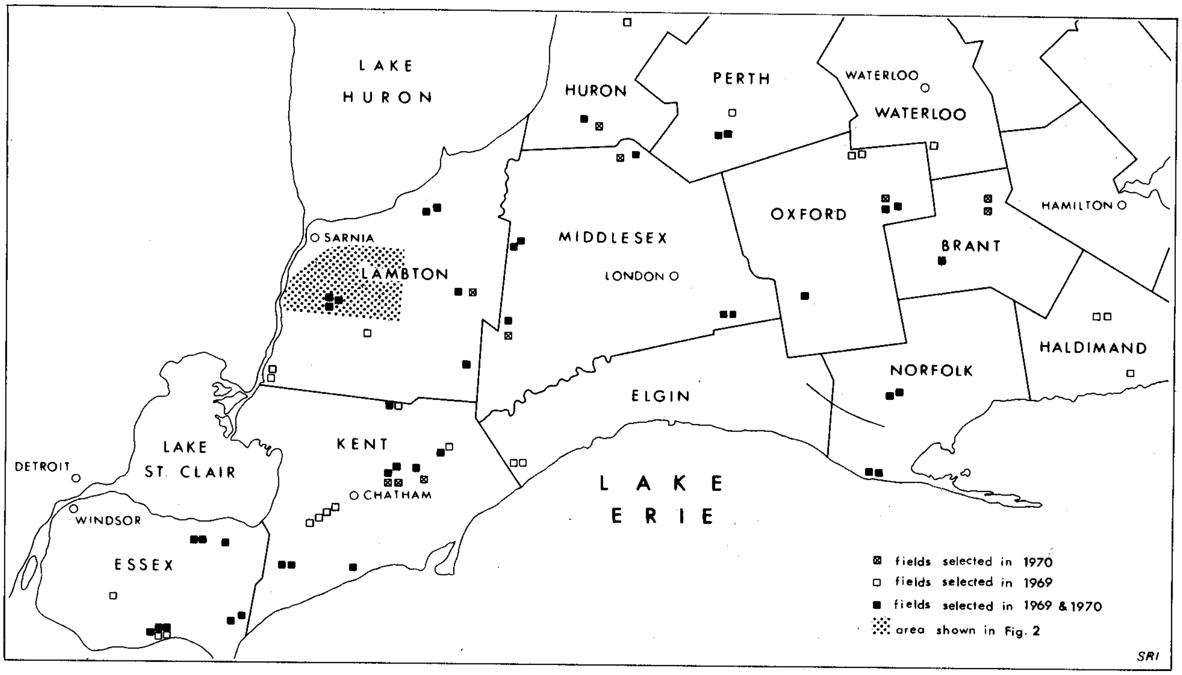

Figure 1. Location of winter wheat fields sampled in 1969 and 1970.

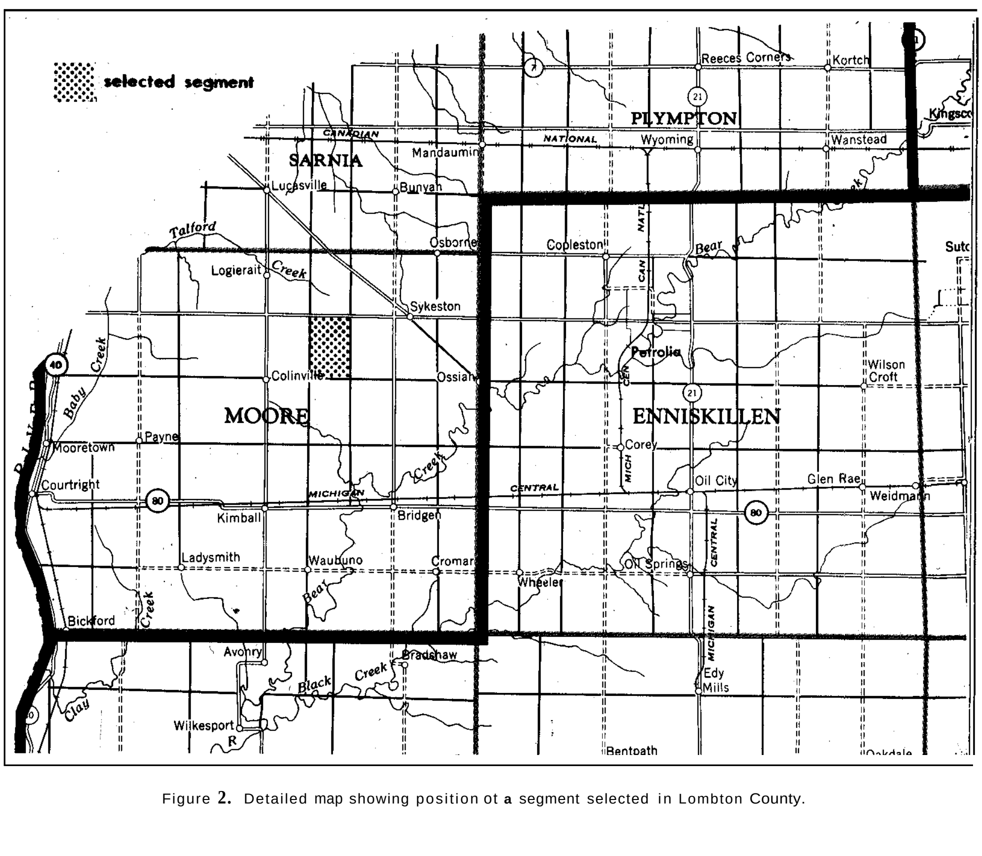

Figure 2. Detailed map showing position ot a segment selected in Lombton County.

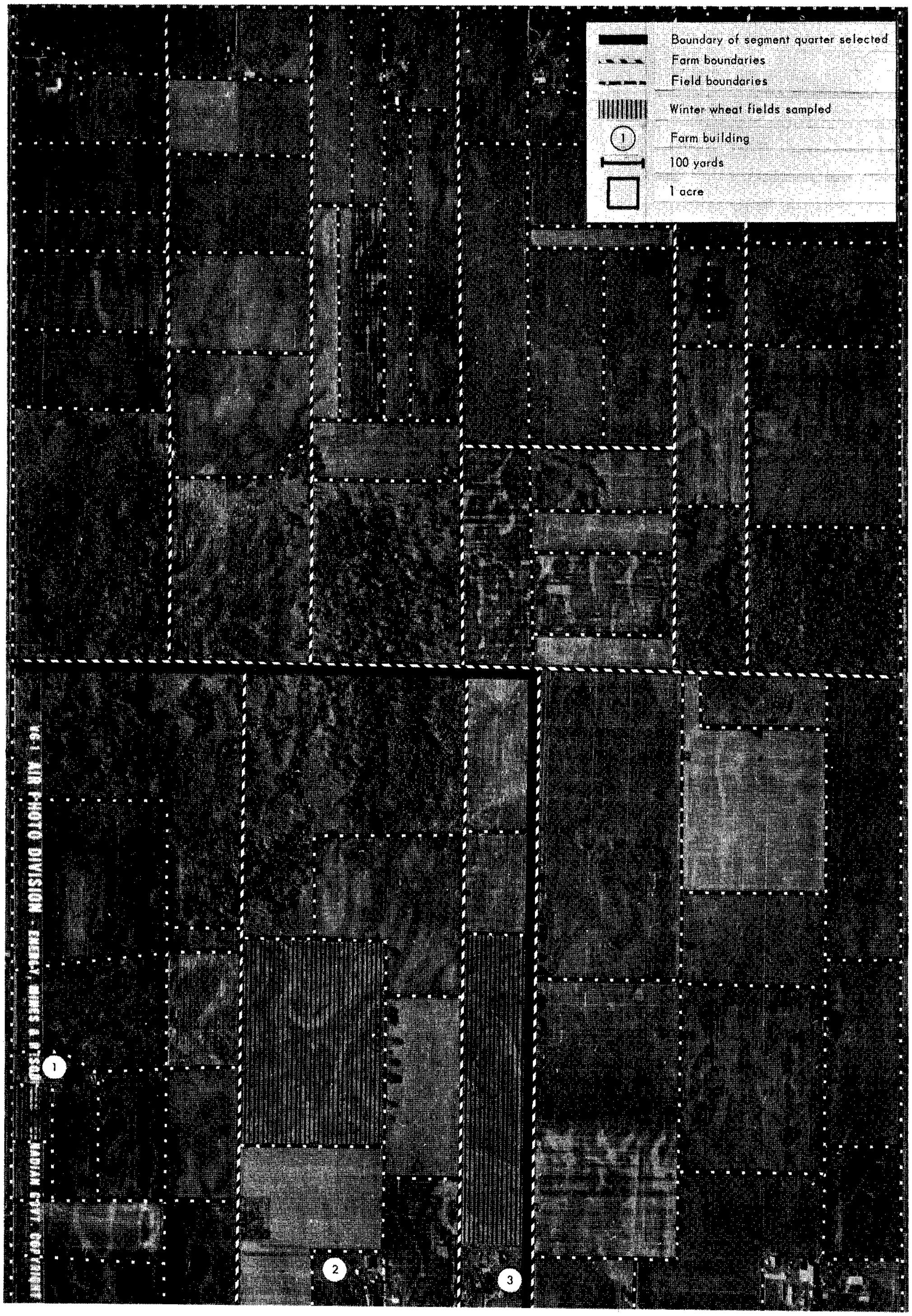

Figure 3. Aerial photograph of the segment shown in Figure 2, showing superimposed boundaries of farms and fields and the position of 'winter wheat fields sampled with the segment quarter selected.

Table 1. Percentage of leaves affected by disease

Disease	Leaf no.†	Date of assessment		
		May 1969	June 1969	June 1970
Powdery mildew	1	0	12	49
	2	5	16	53
	3	25		
	4	49		
Spindle streak mosaic	1	4		
	2	24		
	3	35		
	4	40		
Leaf rust	1	0	25	86
	2	1	25	79
	3	2		
	4	5		
Septoria spp.	1			13
	2			29

† Top or flag leaf = 1.

reached the logarithmic phase of development in the period between Clay and June. The figures for leaf rust and for mildew in June 1970 were higher than the corresponding percentages for 1969, and this suggests that the weather during 1970 was more favorable for the development of both diseases.

Wheat spindle streak mosaic virus was first reported on winter wheat in southwestern Ontario in 1957 (15), and since then (5,15) checks on the distribution of the pathogen have been made annually. Slykhuis (15) reported that 65% of the 96 fields inspected in 1968 contained plants infected with the virus, and Gates (5) reported that 74% of the 90 fields examined were infected; the mean percentages of plants infected were 47.4% and 44.2% respectively. Further work by Slykhuis and Polak (16) in 1969 showed that 58% of 107 fields examined contained infected plants, with a mean infection of 38%. In the May 1969 survey reported in this paper, 49% of the 63 fields contained infected plants and 33% of all plants examined were affected with spindle streak mosaic symptoms. These results are in close agreement with those quoted above (16). However, it should be noted that each of the surveys referred to were conducted in a different way. The survey reported here differs from the others because it allows for distribution of winter wheat acreage and uses a strictly defined sampling technique capable of repetition by other research workers.

Two other foliage diseases, leaf stripe incited by *Cephalosporium gramineum* Nisikado & Itaka and stem rust caused by *Puccinia graminis* Pers. f. sp. *tritici* Erikss. & Henn. were seen occasionally, but were not observed in any of the subsamples.

Table 2. Mean percentage leaf area affected by disease

Disease	Leaf no.†	Date of assessment		
		May 1969	June 1969	June 1970
Powdery mildew	1	0.00	0.23	1.47
	2	0.05	0.56	3.27
	3	0.41		
	4	1.14		
	Avg for 4 leaves	0.40		
Leaf rust	1	0.00	0.46	3.12
	2	0.01	1.08	3.53
	3	0.03		
	4	0.06		
	Avg for 4 leaves	0.03		
Spindle streak mosaic	1	0.08		
	2	0.68		
	3	1.75		
	4	3.07		
	Avg for 4 leaves	1.39		
Total diseases	1	0.08	0.69	4.59
	2	0.73	1.65	6.80
	3	2.18		
	4	4.27		
	Avg for 4 leaves	1.82		
Green tissue remaining	1		78.98	92.07
	2		37.46	34.95
Dead tissue	1		20.33	3.34
	2		60.90	58.25

† Top or flag leaf = 1.

Severity of infection - All the diseases were assessed in a similar manner by assessing the percentage leaf area (lamina) damaged by disease. The mean infections in Table 2 relate to the top four leaves for the May 1969 assessment and to the top two leaves for the June 1969 and 1970 assessments. For convenience the arithmetic means of the percentage area affected by disease on the top four leaves (where applicable) have been calculated so that one value can be used as a reference.

In May 1969 mildew covered a larger leaf area than rust, but by June this situation was reversed in considering the area occupied by disease on the top two leaves in June; reasons for this changeover have already been discussed. For the May 1969 assessment the ratio of infection on leaves 4:2, 3:2, and 4:3 for mildew were 22.6, 8.2, and 2.8; whereas the corresponding ratios for rust were 6.0, 3.0, and 2.0. The mildew had higher ratios than rust, although the absolute level of mildew was higher than rust. This indicates that the two diseases differ epidemiologically and points to the earlier and more severe mildew infection on the lower leaves compared with the later infection on the upper leaves with leaf rust. The same phenomenon was noted in England and Wales for mildew and leaf rust of barley (7), although the values of the ratio for barley differed from those reported here. Leaf rust and mildew increased between May and June 1969 (Table 2), but the levels of disease on both occasions were quite low.

The data on spindle streak mosaic refer only to the 1969 May assessment because in June it was difficult to diagnose the disease satisfactorily. Consequently, it was not possible to estimate the increase in virus disease, if any, in the period between May and June 1969; and it also precluded an assessment in June 1970. The assessments reported here were the best possible considering the difficulty in visually assessing a mosaic symptom; a disease assessment key was used for this purpose. However, there was a definite trend for the lower leaves to exhibit more symptoms than the top leaves, but this may or may not represent the total effects of the disease. Other workers (5,15,16) have used the percentage of plants infected as the sole indicator of disease level, whereas the method reported here incorporates an extra measurement of the severity of the disease by assessing the percentage leaf area visibly affected by the disease.

The assessments for glume blotch incited by Septoria nodorum Berk., speckled leaf blotch caused by Septoria tritici Rob. ex Desm., and lesions caused by Septoria avenae Frank f. sp. triticea T. Johnson (stat perf. Leptosphaeria avenaria Weber f. sp. triticea T. Johnson) are qualitative and should not be regarded as a measure of the effect of these diseases on the winter wheat crop. In 1969 several lesions typical of Septoria, but without pycnidia, were noted and assessed in the field. Samples were cultured under varying conditions in the laboratory, but no Septoria spp. were isolated. During the 1970 survey, well defined lesions were assessed in the field, but only a few contained pycnidia. Sample lesions were examined in the laboratory and efforts were made to isolate and identify the pathogens involved. In all cases where pycnidia had been observed in the field a Septoria sp. was positively identified as the pathogen. Some of the lesions which had no pycnidia in the field produced pycnidia in the laboratory and were identified as Septoria sp., but other similar lesions did not produce pycnidia and no other pathogens were isolated. A similar situation was observed for extensive dead areas on the leaves. Furthermore, three species of Septoria, viz. nodorum, tritici and avenae f. sp. triticea, were isolated and it was not possible to correlate a lesion type with any of these species; this has also been noted by other workers (9). The assessment of Septoria is problematic because no typical symptoms can be used as a reliable guide in the field, except when pycnidia are observed. However, since most of the lesions which produced Septoria pycnidia in the laboratory did not contain pycnidia in the field, the only way to check the presence of the pathogen is to sample the individual lesions. The logistics involved in checking a meaningful and reliable sample from any large-scale survey makes the task impractical. Furthermore, if the species of the pathogen is to be identified, a sample of the pycnidiospores must be measured. In this survey Septoria nodorum was isolated more frequently than the other species. It is for the above reasons that it is felt that the data presented in this paper on Septoria species is strictly qualitative.

A large percentage of the leaf area was dead (Table 2), particularly of the flag leaf in 1969. Dead tissue may be due to several factors, including senescence, disease, and soil and nutritive effects.

Differences in disease level between counties or groups of counties were not detected and since the variety Genesee comprised 67% of the crops sampled, it was not possible to make any meaningful varietal comparison concerning disease susceptibility. The varieties Talbot and Yorkstar constituted 19% and 2% of the sample respectively, and in 12% of the fields it was not possible to verify the name of the variety.

Effect of diseases on yield - Usually one of the primary reasons for conducting any survey on plant diseases is to establish the approximate losses in yield caused by the individual diseases and also the total loss caused by all the diseases. However, in order to be able to compute the above losses, a knowledge of the relationship between disease and yield loss is imperative. This relationship may differ under varying environmental conditions and therefore methods developed for a paxticular region or country may not be applicable elsewhere. Because of lack of knowledge in this sphere of plant pathology, it is usually difficult to derive accurate estimates of losses in yield. Consequently, some degree of extrapolation has to be resorted to in most cases; and this should be noted whenever the estimates of loss are used.

A prediction method has been reported (11,12) for estimating the loss in yield in winter wheat due to mildew, using an assessment key which accounted for the percentage of leaf area affected by mildew on the top four leaves at growth stage 10.5

(11,12). Using this key, yield losses were calculated using the formula 2 x $\sqrt{\text{mildew \%}}$. This method was shown to be consistent and reliable over a period of 3 years in Great Britain. In the survey reported here, two visits were made to the same fields in 1969 so that information was available on the progress of the disease between growth stages 8-9 and 10.5.4-11.1. The 10.5 growth stage used in the prediction method probably occurred, on average, at the midpoint between the two assessments. It is estimated that the average mildew level in 1969 was less than 1% at growth stage 10.5 (according to the Large and Doling key [11]). The loss in grain yield would therefore be equivalent to less than 1%. The corresponding figures for mildew in 1970 are estimated at between 2% and 3% mildew, representing an average loss in yield of between 1% and 2%. Even allowing for considerable error in estimating the losses using this method, which has not been proven in Ontario, it is almost certain that losses due to mildew in winter wheat in Ontario are negligible. The magnitude of the loss could warrant a disease control programme only through breeding efforts and cultural practice rather than control by fungicides.

The level of leaf rust in 1969 and 1970 was very low. Greaney (6) established that the yield loss due to stem rust and leaf rust was equivalent to approximately half the percentage of rust (according to the Cobb Scale) recorded just before ripening. On this basis the loss due to leaf rust in winter wheat in Ontario in 1969 and 1970 is estimated at approximately 1%.

Gates (5) estimated the yield losses due to spindle streak mosaic and suggested that the yield loss was equivalent to 10% when all the plants were infected, however this estimate did not take into account the severity of infection .on the individual plants. In the survey reported here 33% of all the plants examined were infected; and on this basis the yield loss in 1969 is estimated at 3%. Because most of the fields affected had approximately 100% plant infected there was no need to extrapolate for lower levels of infection.

Losses in yield due to Septoria spp. have been reported by several workers. In Australia, Shipton (14) showed that they can be as high as 29%, and this was probably an underestimate because the. disease was not completely controlled in the fungicide sprayed plots. In the U.S.A., estimates of loss from Septoria diseases ranged from 10.5 to 27.6% (2); and in Switzerland where artificial inoculum was applied, losses of up to 65% were recorded (1). More recently, in the United Kingdom (9), a mixed infection with S. nodorum and S. tritici caused a yield loss of 26%, and an effort was also made to relate the amount of infection to yield loss, but no prediction method was proposed. Because the results for Septoria on winter wheat in Ontario are considered qualitative, it is not possible to estimate yield loss. However, the above losses show that the decrease in yield can be considerable when severe attacks of Septoria occur.

No estimate of the loss due to dead tissue can be made because there is no published method to transform percentage dead tissue to loss in yield. However the losses were probably higher in 1969 than in 1970, because of the higher percentage dead tissue on the flag leaves.

The effect of barley yellow dwarf virus on yield of winter wheat in Ontario in 1969 has been discussed elsewhere (8). It is not possible to predict the losses due to this disease, but it may well be that the virus diseases spindle streak mosaic and barley yellow dwarf represent the most important diseases affecting winter wheat in Ontario.

In 1969 the average yield/acre was 39.8 bushels, and this sold at an average price of $1.71/bushel, giving an average price per acre of $68.00 (13). Using the extrapolated methods discussed above, the total loss in yield caused by mildew, leaf rust, and spindle streak mosaic virus during 1969 and 1970 was approximately 5% per year, which represents an average loss of 2 bushels/acre, worth $3.40. For the total acreage of 350,000 acres, this represented a loss of $1.25 million per annum. In conclusion it can be said that fungal leaf pathogens are probably not important enough on winter wheat to warrant the development of control measures other than the introduction of resistant varieties through breeding programs already in existence.

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