THE EXPERIMENTAL APPROACH IN ASSESSING DISEASE LOSSES IN CEREALS: ROOT DISEASES'

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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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.

Literature cited

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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.