Assessment of severity of foliage diseases of cereals in cooperative evaluation tests[1]

Luc Couture

Percentage evaluations of foliage diseases in cereal crops are fairly accurate if a minimum of ten leaves is examined in each plot of a test, a process that takes time. Scoring each plot as a whole on a defined 0-9 scale appears more practical for cooperative tests. Examples of the reaction of oat cultivars to speckled leaf blotch caused by ***Septoria avenae*** in Quebec are presented following the 0-9 scale.

Can. Plant Dis. Surv. 60:1, 8-10, 1980.

Les notations en pourcentage des maladies du feuillage chez les cereales sont passablement precises lorsque l'on examine un minimum de dix feuilles par parcelle dans une experience, ce qui requiert beaucoup de temps. L'évaluation globale de chaque parcelle au moyen d'une echelle definie de 0 a 9 apparaît plus pratique dans les tests cooperatifs. On presente des exemples de notations de tache septorienne causee par ***Septoria avenae*** chez des cultivars d'avoine au Quebec, suivant l'échelle 0-9.

Introduction

In assessing the reaction of lines or cultivars of cereals to foliage diseases in evaluation tests, plant pathologists are faced with the problem of selecting the correct method to achieve their goal. The ideal method ought to be reliable, consistent and reproducible, rapid and easy to use, differential, and applicable to all diseases. Basically there are two different approaches to assessment of foliage diseases of cereals: the percentage scales and the arbitrary scales. To preclude repeated mistakes in this matter and to promote more uniformity in cooperative tests, features distinctive of each of these procedures are displayed hereunder.

Discussion

Percentage scales

The percentage procedure can be applied to indicate the proportion of diseased plants in a stand; this is appropriate for diseases which kill plants rather quickly or which cause about the same amount of damage to all the infected plants (Tarr, 1972). Examples are smut diseases. It cannot relate to diseases in which different plants or plant organs show markedly different amounts of infection, such as rusts, powdery mildews and leaf spots.

With reference to leaf diseases of cereals the percentage scale must therefore pertain to disease intensity in individual plants and preferably on a particular leaf level. The percentage figure can be assessed directly by comparing the discoloured area of single leaves with standardized charts such as Cobb's (1892) or its various modifications and James' (1971). It can also be derived by transformation of data from the 0-11 scale of Horsfall and Barratt (1945) which is outlined in Table 1. Starting at 50%, the grades in percentage are altered by a factor of two in either direction, based on diseased tissue below 50 and on healthy tissue above 50. Many users of the latter scale are not aware that one is not allowed to average scores on the 0-11 scale because each category does not correspond to an arithmetic span but rather to a logarithmic span. To average these data it is necessary to transform each individual score beforehand to its corresponding mid-percentage value as given in Table 1 and to process the transformed data. Conversion tables have been prepared to facilitate this operation with all possible combinations of up to five scores (Redman *et al.*).

Table 1. Disease categories of the Horsfall and Barratt rating system

Score	Disease percentage limits*	Disease-free percentage limits*	Disease mid-percentage value**
0	0	100	0
1	0-3	97-100	2,34
2	3-6	94-97	4,69
3	6-12	88-94	9,38
4	12-25	75-88	18,75
5	25-50	50-75	37,50
6	50-75	25-50	62,50
7	75-88	12-25	81,25
8	88-94	6-12	90,62
9	94-97	3-6	95,31
10	97-100	0-3	97,66
11	100	0	100

* In rounded numbers

**Differences between adjoining mid-percentage values unfold by a factor of two in either dlirection from 50% disease, with exceptions for 0 and 100%.

[1] ***Contribution No. 147, Station de Recherches, Agriculture Canada, 2560 boulevard Hochelaga, Sainte-Foy (Quebec), G1V 2J6***

Accepted for publication October 11, 1979

In both instances, direct percentage evaluation or 0-11 scale, it is imperative to examine a minimum of ten leaves in each plot to make the survey fairly accurate. Sampling has to be representative. The same leaf level has to be used consistently as disease intensity varies greatly with leaf position. The penultimate leaf is often selected for such assessments.

Arbitrary scales

Arbitrary scales range from no symptoms (usually score 0 or 1) to very severe symptoms (score 5, 10, etc...) with intermediate categories in various numbers corresponding to scores falling between the determined limits. It is agreed that they are usually quite adequate for ranking a series of test plants or plots in order of increasing severity of symptoms when used by competent observers (Russell, 1978).

Arbitrary scales are used to assess the reaction of a whole plant or more simply of a particular leaf or set of leaves. The disease situation of a whole plot can also be integrated in one score; in this perspective we favour the 0-9 scale presented by Saari and Prescott (1975), originally designed for individual plants in wheat. In this instance the level reached by the disease on the foliage as well as the relative disease intensity on each level are taken into consideration in the grading process. Scoring the plot as a whole appears to be as accurate as more detailed methods for determining the amount of disease present (Townsend and Heuberger, 1943).

It is this latest scale that we have been following in our disease survey in evaluation tests of oat cultivars for recommendation to growers in the province of Quebec. Results of surveys performed in 1978 and 1979 are presented in Table 2 to illustrate the reaction of oat cultivars to the speckled leaf blotch caused by ***Septoria avenae*** Frank f. sp. *avenae.* Most oat cultivars show little variation in their response to speckled leaf blotch (Couture and Pelletier, 1975) but one can still segregate the most and/or the least susceptible lines from the others with the 0-9 scale (Table 2).

The principle of the 0-9 scale is the fact that foliar diseases of cereals tend to develop as a disease pyramid, where the lower and oldest leaves are the first and most severely infected. It is particularly useful for those situations where disease is absent or very limited on the upper leaves because of the growth stage of the crop or the particular environment for a given site or a given year as is the case at Macdonald College (Table 2). By assessing those very leaves (usually the penultimate as previously mentioned) on a percentage scale one should not derive the best differential information possible from the test. But by taking into consideration the disease reaction of the whole plant with the 0-9 scale, one may still have a fair evaluation of the relative susceptibility of different lines.

The 0-9 scale has the advantage to require only one column in computer data processing which becomes more and more widespread, making it more desirable than a scale calling for two columns such as 0-10 for instance. Some workers are also tempted to use a scale similar to one often used for lodging, where 1 corresponds to no disease and 5 (or 9, etc...) to maximum disease. This is not acceptable because each assessment is distorted on account of the arithmetic value 1 standing for absence of symptoms (the lowest score). Distortion is a weakness of several assessment scales (Desaymard, 1968). In our opinion it makes it impossible to average such data.

Furthermore, another sizeable advantage of the 0-9 scale over the percentage approach is its adaptability to virus diseases such as yellow dwarf caused by BYDV that gives a disease picture completely different of the conventional rust pustules or leaf spots. Evaluation of this disease in percentage does not reflect the reaction of the plant as the balancing of disease severity on all leaf levels is not respected by a straight percentage. We stress the desirability to evaluate **all** leaf diseases present in a test with the same scale.

The 0-9 scale of Saari and Prescott (1975) has been adopted by CIMMYT for its international wheat and

Table 2. Disease reaction (0-9) of oat cultivars to speckled leaf blotch in evaluation plots grown at seven locations in Québec in 1978 and 1979.

Cultivars	Disease severity																
	Macdonald College		Saint-Hyacinthe		Lennoxville		Deschambault		Pintendre		La Pocatière		Normandin		Averages		
	1978 g.s.76*	1979 g.s.80	1978 g.s.77	1979 g.s.78	1978 g.s.76	1979 g.s.84	1978 g.s.73	1979 g.s.76	1978 g.s.79	1979 g.s.81	1978 g.s.77	1979 g.s.80	1978 g.s.80	1979 g.s.80	1978	1979	78-79
Ajax	1,5**	---	5.8	---	5.5	---	5.8		6.3		4.8	---	6.3	---	5.1	---	
Garry	2.5	2.8	5.5	5.0	5.3	6.3	5.3	7,3	5.0	6,3	4.0	3.3	5.5	5.0	4.7	5.1	4,9
Dorval	3.5	2.5	4.8	5.8	6.0	5.0	6.0	6.5	6.0	6,0	5.0	3.3	5.8	5,3	5.3	4.9	5.1
Yamaska	2,8	3.0	5.0	6.3	6.3	7.8	5.8	8.0	6.8	7.3	5.8	3.3	6,8	5.8	5.6	5.9	5.8
Scott	2.0	3.0	4.8	4.5	5.3	7.8	5.3	7.5	5.0	6.8	3.5	3.0	4.8	5.0	4.4	5.4	4.9
Alma	2.3	2.8	5.3	5.0	5.8	7.8	5.3	6.8	5.8	5.3	3.8	3.8	5.5	3.8	4.8	5.0	4.9
Laurent	2.5	2.5	6.0	5.5	5.3	5,3	5.0	7,8	6.0	6.5	4.0	3.8	5.3	4.5	4.9	5.1	5.0
Oxford	1.5	2.0	5.0	5.0	4.8	5.3	4.3	6.0	5.0	4.8	3.5	3.5	5.0	4.8	4.2	4.5	4.3
Sentinel	1,5	3.3	5.3	5.3	5.5	6.5	5,3	5.5	5.5	5.0	3.8	3.0	5.3	4.8	4.6	4.8	4.7
Manic	3.5	2.3	5.5	5.8	6.0	7.0	5.0	6.0	5.5	5.3	4.3	2.8	5,3	4.5	5.0	4.8	4.9
Foothill	2.3	---	4.8	---	4.3	---	5.3		4.8		4.3	---	4.5	---	4.3	---	
Athabasca	4.0	---	6.8	---	6,3	---	6.5		7.0		6.3	---	7.0	---	6.3	---	
Lamar	2.3	2.0	4.3	4.0	3.3	4.0	3.3	6.3	4.8	4.3	3.3	2.8	3.8	3.5	3.6	3.8	3,7
Q.O.75.7		3.0	---	5.5	---	6.0	---	6.5		5.5		3.3	---	3.8	---	4.8	---
Cascade		4.0	---	6.0	---	7.0		8.0		7.0		5.3	---	6,8	---	6.3	---

* average growth stage (g.s.) of cultivars following the scale of Zadoks *et al.* (1974)
** each assessment is the average of four replicates

barley nurseries (Anonymous). Since descriptive scales are of little use to workers unless they are precisely defined (Tarr, 1972), we should like to add some more precision and modification to the outline of Saari and Prescott (1975). We summarize our considerations in Table 3. The terms free, isolated, scattered, light, moderate and severe are defined in percentage and disease severity is described on all leaf levels for each score. Furthermore, scores are not labeled with a name related to the degree of resistance or susceptibility of the plants in absolute terms such as resistant for 2, intermediate for 5 and susceptible for 8 in Saari and Prescott (1975). These names reflect the reaction prevailing under maximum disease conditions only, which is uncommon. The scale is intended to grade the relative disease severity in plants, not the absolute degree of susceptibility. It is clear that a cultivar with an average score of 6 in Table 2 is definitely susceptible while it would be declared as high intermediate following the terminology of Saari and Prescott (1975).

The use of the 0-9 scale allows one to assess each plot of each replicate of a test within a reasonable period of time to give a fair evaluation of the reaction of each entry. All the plants in a plot are considered as one unit. In the grading process, one can also resort to intermediate values between scores in cases of hesitation.

Growth stages

Whatever method is used, care should be taken to evaluate a test between the medium milk and the soft dough stages of development of the grain. A record of the crop growth stage should be taken accordingly. To determine growth stages of cereals the Feekes scale (Large, 1954) is probably the best known and most widely used but it has the definite weakness of lacking detail in the post-anthesis stages which are the important ones in many cereal disease epidemics. More recently Zadoks *et al.* (1974) developed a decimal code that is more detailed and consequently more accurate than the Feekes scale. It has now been widely recognized as the best scale available and we should recommend it to be used jointly with the 0-9 disease assessment scale. In Table 2, all but one assessments were made between stage 75 (medium milk) and stage 85 (soft dough) of the crop with reference to the scale of Zadoks *et al.* (1974).

Conclusion

In single experiments, the percentage scale is preferred because it can give high accuracy with a sufficient number of leaves. Furthermore the leaf level position can be adjusted to match the particular disease situation in the experimental plots.

But since time is limited to the one pathologist having to survey several or many sites and that all data collected in different tests and/or by different pathologists have to be comparable in cooperative tests, the answer to the initial question raised in the introduction is the extensive use of the 0-9 scale in cereal evaluation tests. It should prove especially useful for large tests with many locations and treatments.

Table 3. Adjustment of the 0-9 assessment scale to defined degrees of disease intensity on various leaf levels of cereals.

Leaf level	Intensity of symptoms* on leaves for each score									
	0	1	2	3	4	5	6	7	8	9
Upper leaves	free	free	free	free	free	free	scattered	light to moderate	moderate to severe	severe
Middle leaves	free	free	free	free	scattered to light	light to moderate	moderate	severe	severe	severe
Lower leaves	free	isolated	scattered	light	moderate to severe	severe	severe	severe	severe	severe

'Free: 0%. isolated: 1%, scattered: 5%, light: 10%, moderate: 25%. severe: 50%.

Literature cited

1. Anonymous. Instructions for the management and reporting of results for all international yield nurseries and screening nurseries. CIMMYT Inf. Bull. No. 38, 17 pp.
2. Cobb, N.A. 1892. Contributions to an economic knowledge of the Australian rusts (*Uredineae*). Appendix B: Report on the rustiness of wheats examined at Lambrigg. Agric. Gaz. N.S.W. 3: 60-68.
3. Couture, L. and G.J. Pelletier. 1975. Utilisation d'explantats pour evaluation de la susceptibilite de cultivars d'avoine a *Septoria avenae* f. sp. *avenae.* Phytoprotection 56(3): 148-154.
4. Desaymard, P. 1968. Notations et methodes de notations en phytopharmacie. Phytiatrie-Phytopharm. 17(2): 163-173.
5. Horsfall, J.G. and R.W. Barratt. 1945. An improved grading system for measuring plant diseases. Phytopathology 35(8): 655. (Abstr.).
6. James, W.C. 1971. An illustrated series of assessment keys for plant diseases, their preparation and usage. Can. Plant Dis. Surv. 51(2): 39-65.
7. Large, E.C. 1954. Growth stages in cereals: illustration of the Feekes scale. Plant Pathol. 3(4): 128-129.
8. Redman, C.E., E.P. King and I.F. Brown. Tables for converting Barratt and Horsfall rating scores to estimated mean percentages. Elanco Products Company, Indianapolis.
9. Russell, G.E. 1978. Plant breeding for pest and disease resistance. Butterworths, London. 485 pp.
10. Saari, E.E. and J.M. Prescott. 1975. A scale for appraising the foliar intensity of wheat diseases. Plant Dis. Rep. 59(5): 377-380.
11. Tarr, S.A.J. 1972. Principles of plant pathology. Winchester Press, New York. 632 pp.
12. Townsend, G.R. and J.W. Heuberger. 1943. Methods for estimating losses caused by diseases in fungicide experiments. Plant Dis. Rep. 27(17): 340-343.
13. Zadoks, J.C., T.T. Chang and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. Weed Res. 14(6): 415-421.