

Rating General Resistance on a Single-Plant Basis

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ABSTRACT

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A method of rating single plants for general resistance was devised which directly compares, over time, the relative amount of disease on a single plant with all other plants in the test. The method is simple and rapid and has been found to be reproducible between 2 years and among seven judges. It involves taking notes many times (7-14) throughout the disease cycle on the basis of S = standard for the most disease

as observed from a standing position on each day notes are taken, and L = less than standard. The number of times during the season that a plant is rated S is the disease index. If the ratings obtained with the method correlate with relative disease incidence in populations, it would make possible selecting for general resistance on a single-plant basis in a breeding program.

General resistance (GR) of plants to pathogens was suggested over 40 years ago (3) as a potential means of reducing damage from plant diseases. General resistance is used in the sense suggested by Caldwell (1). It is likely that agriculturists long ago used empirical methods for selecting for GR in some crops to some pathogens. In recent years, many workers have recommended that GR be utilized in planting breeding. Although GR is relatively easy to demonstrate in populations, it is extremely difficult to select for on a single-plant basis. In some clonally propagated crops, such as potatoes and fruit trees, selection for GR has been successful because clones can be grown as populations. It is also found in some self-fertilized and controlled hybrid plant cultivars. Examples are the GR of some winter wheat cultivars to *Puccinia recondita* Rob. ex Desm. (6) and corn hybrids to *Puccinia sorghi* Schw. (4). To a large extent these cultivars and hybrids resulted from accidental or empirical selection.

The major obstacle to breeding for GR is the need for a method of selection on a single-plant basis. We attempted to develop such a method and tested its reproducibility among years and judges.

MATERIALS, METHODS, AND RESULTS

The *Dactylis glomerata* L.: *Puccinia graminis* Pers. f. sp. *dactylidis* Guyot et Massinot (2) association (stem rust of orchardgrass) was used in these studies since both organisms can be propagated clonally, thus making it possible to repeat experiments. In this association GR might be the result of what is often referred to as "slow

rusting." Orchardgrass usually is cross-pollinated and populations usually are heterogeneous. Seeds of *D. glomerata* from diverse sources were sown in pots in the greenhouse, transplanted as single plants, and each plant was hypodermically inoculated at the six- to seven-leaf stage with a urediospore suspension of *P. graminis dactylidis*. Only plants with high infection type were kept since the study of GR in the association would not be complicated by the presence of corresponding gene pairs which result in low infection type. Selected plants were transplanted to the field in the spring as spaced plants on 1 m centers. An inoculated spreader clone was the center plant of each 3 × 3 group. The culture of *P. graminis dactylidis* (Pga 1) used in these studies was collected on orchardgrass at the Southwest Center, Mount Vernon, Missouri, in the fall of 1972. It is maintained in liquid nitrogen as a clonal line and was used throughout these studies for both greenhouse and field work.

Method of taking notes.—Most systems of taking plant disease data are based on predetermined scales. Generally these are descriptive scales against which are compared what is seen in the field or greenhouse. Usually such comparisons are detailed and time consuming and are made once during a season at the apparent height of an epidemic. General resistance perhaps is measured best by making many readings during the entire time disease is present and should indicate recognizably less disease on one plant than another. Such data, if plotted against time, should show a difference among plants in rate of disease development. One system that was devised for this purpose uses a calculation of the area under a disease-progress curve, but this must be done with populations of the host. Conventional systems of taking plant disease data are difficult to use in rating single plants since they

do not directly compare amount of disease on two plants. Instead they make the comparisons via a mental standard, and usually are too time consuming to use in scoring many times in a season. To avoid these difficulties, the following system was devised and tested for reproducibility.

The first notes on a plot were taken as soon as rust was observed on orchardgrass in the field. The experimental plot was examined for 5-10 minutes to develop a mental image of the maximum amount of disease on individual plants as seen from a standing position. This was designated as the disease standard for that day. Notes then were recorded on a tape recorder for each plant as standard (S) or less (L) than standard, while walking slowly through the plots. Thus S represents relatively narrow variability whereas L may range from slightly less stem rust than standard to complete absence of the disease.

This procedure was used to take notes on stem rust of orchardgrass at 1- to 3-week intervals so that at the end of the season seven or more sets of data had been taken. Each time notes were taken the criteria for S changes and, as a consequence, for L as well. The amount of disease designated S at one note-taking time may be L at another. This is the basic principle of the method since we are interested in the relative amount of disease on individual plants at a given time, not the absolute amount of disease.

The criteria for S may be different each time notes are taken. For example, in 1975 the following notes were made:

- 20 June—Uredia evident = S, no uredia evident = L.
- 17 July—Good rust development, notes taken on relative amount of rust.
- 8 September—Notes taken mainly on relative amount of leaf drying, as the preceding 7 weeks were hot and dry.
- 18 September—Poor data, taken mainly on relative amount of leaf drying.
- 8 October—New rust coming on, notes taken on relative amount of rust.
- 13 October—Fair rust development, notes taken on relative amount of rust.
- 21 October—Good rust development, notes taken on relative amount of rust.

At the end of the season each plant is characterized by the number of times it was rated as S. Thus, if notes were taken seven times, a plant designated as 7 means that it was rated as S each time, and 0 means it was never rated S. This number represents the disease index. For seven sets of notes, an index of 0 or 1 is suggested to indicate useful GR, 2 to 5 questionable GR, and 6 or 7 not useful GR (5). This classification is based on the assumption that a plant always rated L has less rust and, therefore, better GR than a plant which is sometimes rated L and sometimes S. It should be noted also that the difference between 1 and 2 is less significant than a difference between 1 and 5.

Taking notes and characterizing individual plants in this manner is a very rapid procedure. In 1974, it required 30 minutes to examine the field to establish the S standard and then take the notes on 760 plants. Another 30 minutes were required in the office to transfer the notes from the tape to data sheets.

Tests of the note-taking method.—In 1974, seven sets of data were taken between June and October on 760 single orchardgrass plants. Eight of these plants were selected which had disease indexes of 0 to 7, respectively. Each plant was divided into 7 to 10 vegetative propagules and transplanted to the field in the spring of 1975. A total of 63 readings were made on each plant by seven judges. Thus, the 1974 indexes for each clone were based on only seven readings whereas the 1975 indexes were based on 441 to 630 readings. The results (Fig. 1) indicate a good correlation (0.89) between data for the 2 years. Indexes

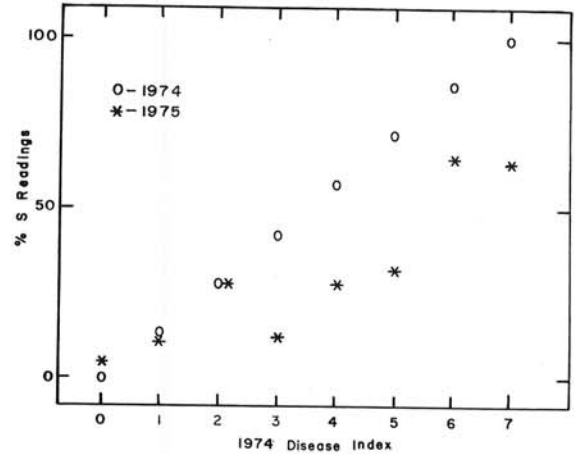


Fig. 1. Comparison between the disease index of orchardgrass clones for 2 years. The 1974 data are based on seven readings on one plant of each clone, and the 1975 data are based on 63 readings made on each of seven to ten plants of each clone. The correlation coefficient is 0.89, which is significant at $P = 0.01$.

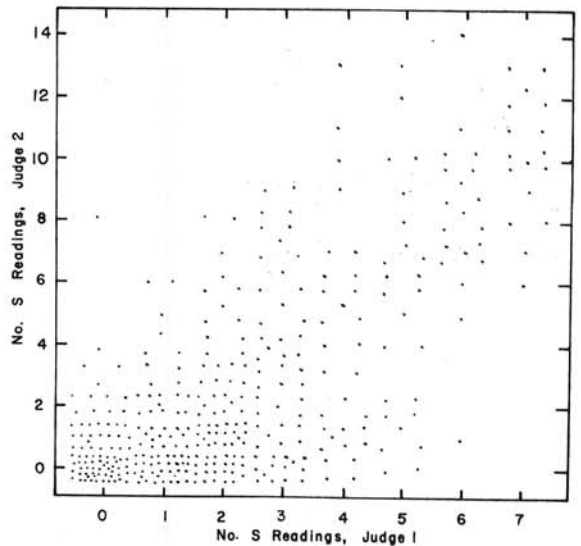


Fig. 2. Correlation between the disease indexes developed by two judges in 1975 for stem rust on 368 clones of orchardgrass. Judge 1 took seven sets of notes and judge 2 took 14 sets of notes. The correlation coefficient is 0.69, which is significant at $P = 0.01$.

for the plants rated 0, 1, and 2 in 1974 were almost the same in 1975, whereas for the other five clones the indexes were much higher in 1974 than 1975. This might have been the result of a lighter rust epidemic in 1975. It also indicates the expected variability in the disease index from year to year for plants with indexes in the middle and upper ranges. We should expect the lower indexes to be more consistent and plants rated 0 or 1 are those one would want to select in a breeding program.

In a second study made in 1975, two judges took seven and 14 sets of notes, respectively, on 368 plants at intervals from June through October. In June, the two judges met to discuss methods and establish guidelines. There was no further communication between them until the end of the season when the two sets of data were compared (Fig. 2). The correlation coefficient between the two judges was 0.69. It is apparent from Fig. 2 that judge 1 recorded more plants as "S" than judge 2, which indicates that they used slightly different criteria for the disease standard. Such variation would have little effect on selection of plants with a useful GR.

In a third study, made in 1975 to determine consistency among judges, seven judges rated 227 random orchardgrass plants for stem rust six times within 1 week by the S-L system. Two of the judges (judges 1 and 2) were experienced in taking notes in this manner; the others (judges 3 to 7) had never done so and were given 10 minutes of instruction as a group. Correlation coefficients between each pair of judges were calculated (Table 1) and ranged from 0.59 to 0.85. The highest correlation was between the two experienced judges. The lowest correlation was between two inexperienced judges who had not discriminated between stem rust and a leaf spot of undetermined cause. Among the 227 plants, 12 had obvious heavy spotting. Data on these 12 plants were

TABLE 1. Correlation coefficients among seven judges, each making six S-L ratings for general resistance to stem rust on each of 227 orchardgrass plants, before and after deleting data for 12 plants with leaf spots of undetermined cause

Judges	Correlation coefficients		Difference in c.c. + or (-)
	227 plants	215 plants	
2 and 5	0.85	0.85	0.00
1 and 4	0.81	0.82	0.01
2 and 3	0.78	0.79	0.01
2 and 4	0.76	0.77	0.01
3 and 4	0.81	0.82	0.01
3 and 5	0.76	0.77	0.01
1 and 2	0.85	0.87	0.02
1 and 3	0.80	0.82	0.02
1 and 5	0.80	0.82	0.02
4 and 5	0.78	0.80	0.02
1 and 7	0.70	0.72	0.02
4 and 7	0.75	0.78	0.03
1 and 6	0.67	0.72	0.05
2 and 7	0.60	0.65	0.05
3 and 7	0.67	0.72	0.05
4 and 6	0.69	0.74	0.05
5 and 7	0.61	0.68	0.07
2 and 6	0.59	0.68	0.09
3 and 6	0.63	0.72	0.09
5 and 6	0.61	0.72	0.11
6 and 7	0.74	0.73	(0.01)

eliminated from the study and the correlation coefficients were recalculated (Table 1). There was little change in the coefficients among judges 1 to 5; however, the correlation between these five judges and judges 6 and 7 improved. There was little change in the coefficient between judges 6 and 7. It seems likely that judges 6 and 7 not only erred with respect to the 12 plants with leaf spots, but also with respect to other plants that appeared diseased but not by stem rust. From the plant breeding standpoint this was valid, but it was inconsistent with the objectives of this experiment which was designed to test the degree of uniformity among inexperienced judges judging stem rust.

DISCUSSION

A method based on certain theoretical and practical considerations was devised for rating single plants for general resistance to pathogens. The method was tested using the *D. glomerata*: *Puccinia graminis dactylidis* association as a model. In all studies, only plants with high infection type resulting from greenhouse inoculation were used to avoid the complications of low infection types resulting from corresponding gene pairs for low reaction and pathogenicity. The method uses a monocyclic plot design but evaluates the plants in a polycyclic test (7) because each time notes are taken new criteria are used in the evaluation. The method is intended to measure relative amounts of disease among single plants over time as an indication of their relative general resistance to a disease. This would then permit selection for this character on a single-plant basis in a breeding program. The method requires relatively little time even though data are taken many times during a season.

High correlations between years and among judges indicated that the method is reproducible. At present, it should not be assumed that data taken by this method will correlate with differences in amount of damage from a disease on populations of the clones, although initial observations appear promising.

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