Relationship Between Yield Loss and Area Under the Wheat Stem Rust and Leaf Rust Progress Curves

G. W. Buchenau

Associate Professor, Plant Science Department, South Dakota State University, Brookings 57006.

Contribution 1341, Plant Science Dept., South Dakota Agricultural Experiment Station, Brookings.

ABSTRACT

Whole-culm area under wheat stem rust and leaf rust curves (AUC) was determined by plotting rust as logits from +5 to −5 versus time for each of the top three leaves and the stem. The 40-day time interval was standardized for each organ; flag leaf–10 days before, to 30 days after heading; 2nd (penultimate) leaf–17 days before, to 23 days after heading; 3rd (antipenultimate) leaf–24 days before, to 16 days after heading; stem–heading to 40 days thereafter. Whole-culm AUC was defined as the sum of the top three-leaf average + stem areas under the curve, expressed in percent. Yield and percent yield loss were correlated with, and regressed respectively on, AUC in 13 fungicide tests covering an 8-year period. Correlation coefficients (r) varied from −0.69 to −0.99, were not significantly different among tests, and the estimate of a common r was −0.93. The null hypothesis that regression coefficients (b) = 1% loss of yield for each percent area under the curve was rejected in 2 of 13 tests.

Phytopathology 65:1317-1318

Additional key words: Puccinia graminis tritici, Puccinia recondita tritici, epidemiology.

Three basic models have been developed that relate severity of wheat stem and leaf rust [*Puccinia graminis* (Pers.) f. sp. *tritici* Eriks. and Henn. and *Puccinia recondita* Rob. ex Desm. f. sp. *tritici*] to yield: (i) the critical-point model; (ii) the multiple-point model, and (iii) the area-under-the-rust-progress-curve model (3, 4, 5, 7, 10). The relative merits of each model depend on the view of the user. The area-under-the-curve model has received little experimental support (7).

I have previously described a method of rust loss prediction based on model iii, and proposed that parameters can be established to stabilize the regression of percent yield loss on area under the rust progress curve at 1; i.e., a 1:1 relationship (1). This paper evaluates the relationship between area under the stem and leaf rust progress curves to yield loss of spring and winter wheat (*Triticum aestivum* L.) in South Dakota.

MATERIALS AND METHODS.—The data were obtained from replicated fungicide tests conducted at several locations in South Dakota between 1965 and 1972 on hard red winter wheat and hard red spring wheat cultivars adapted to the area. Plots 2.14 × 9.15 m were separated from one another by 1.53 m alleyways of spring-sown winter wheat or by fall-sown winter wheat mowed at growth stage 5-6 on the Feekes scale (6). Variations in epidemic development were induced by season, fungicide treatment, and location. Only those tests in which yield was significantly affected ($P < 0.05$) by fungicide treatments are reported herein.

Ten leafy culms were removed at random from each plot at approximately 10-day intervals following the initiation of spraying. Each of the top three leaf blades and the stem (including leaf sheaths) were rated for rust by pustule counts up to a level of 25 pustules per leaf or stem, and by visual estimates according to the modified Cobb scale thereafter. The ten-culm means were converted to logits on the assumption that 100% severity = 1,000 pustules per leaf or stem and then plotted on graph paper with the following dimensions: y-axis (rust)–logit units at 25 mm intervals from +5 to −5, x-axis (time)–day units at 2.5 mm intervals over a 40-day leaf or stem life-span. The 40-day life-spans for each leaf and the stem were standardized in relation to heading (awns visible on 50% of the culms) as follows: flag leaf–10 days before to 30 days after heading; 2nd leaf (penultimate)–17 days before heading to 23 days after heading; 3rd leaf (antipenultimate–24 days before to 16 days after heading; stem–heading to 40 days thereafter.

The area under the curve (AUC) was then determined for each of the top three leaf blades and the stem by planimeter or trigonometric methods, usually the latter, and expressed as percent of the total area of the rectangle formed by the logit and time parameters. This rectangle represented the photosynthetic potential of a given leaf blade or stem; the area under the curve represented that portion of the potential destroyed by rust.

Whole-culm AUC (in percent) was calculated as the sum of the three-leaf blade average AUC + stem AUC. Linear correlations between whole-culm AUC and yield were then determined for each experiment, and homogeneity of correlation coefficients was evaluated according to the Z-test (8).

Yield loss expressed as percent, a useful value for predictions under varying cultural conditions, was determined for each fungicide treatment within a test as follows: (i) Determine the regression coefficient of yield (y) on whole-culm AUC (x) for each experiment. (ii) Determine the "a" intercept where $a = \bar{y} - b\bar{x}$. This is the yield potential if rusts were perfectly controlled, and is necessarily an extrapolation in these tests. (iii) Percent yield loss = (potential yield-treatment yield/potential yield) × 100.

RESULTS.—Whole-culm area under the curve was highly correlated with yield in every test where treatments affected yield; r values ranged from −0.69 to −0.99 (Table 1). The hypothesis that the correlations were from the same population was not rejected by the Z-test ($P = 0.15$), and the estimate of a common correlation coefficient was −0.93.

Regression coefficients of percent yield loss on whole-culm AUC were estimated for each experiment. These ranged from b = 0.68 to 1.69 percent yield loss for each percent AUC. An F-test of regression homogeneity indicated that regression coefficients differed significantly among tests (9). Regression coefficients were significantly different from 1 ($P < 0.05$) in only two of the 13 tests, 65-8 and 70-13.

DISCUSSION.—The results verify the close relationship between whole-culm area under the rust progress curve and yield.

The hypothesis that the parameters of 40-day leaf and stem life-spans over logit values of +5 to −5 provide a 1:1 relationship between percent yield loss and AUC was rejected in two of 13 tests. I consider this level of dependability acceptable for loss prediction though

TABLE 1. Range of areas under stem rust and leaf rust progress curves and the association of whole-culm AUC with yield and yield loss in 13 South Dakota fungicide tests

Test no.	Cultivars	Range of areas under rust progress curve: Three-leaf av. (%)	Stem (%)	Whole-culm (%)	Yield: Range (g/m^2)	Potential (g/m^2)	Correlation (r) and regression (b) coefficients[a]: (r)	(b)
65-7	Nebred W[b]	12-35	5-33	17-68	121-249	296	−0.98	0.85 ± .15
65-8	Omaha W	5-27	1-26	6-53	202-329	343	−0.94	0.68 ± .16
67-7	Nebred W	4-13	3-10	7-23	249-296	309	−0.98	0.85 ± .19
68-2	Lancer W	14-29	0	14-29	208-262	309	−0.99	1.12 ± .18
68-10	Hume W	15-29	0	15-29	363-450	538	−0.96	1.12 ± .22
68-12	Ceres S	10-17	0	10-17	175-215	249	−0.60	1.69 ± 1.10
69-1	Nebred W	8-23	7-18	15-41	168-229	303	−0.91	0.86 ± .37
69-11	Ceres S	28-35	9-16	40-50	94-148	383	−0.92	1.47 ± .62
70-2	Nebred W	3-29	15-22	19-50	229-370	444	−0.94	0.91 ± .25
70-11	Ceres S	23-46	10-18	37-63	128-249	410	−0.98	1.14 ± .34
70-13	Crim S	15-36	0	15-36	188-309	397	−0.86	1.52 ± .47
71-2	Nebred W	3-12	7-21	10-29	329-403	450	−0.92	0.89 ± .38
72-2	Ceres S	22-33	9-34	31-60	215-296	376	−0.98	0.74 ± .31

[a]Correlation between percent whole-culm area under curve and yield. Estimate of common r = −0.93. Regression of percent yield loss on percent whole-culm area under curve with 95% confidence limits.

[b]Winter (W) or spring (S) growth habit.

perhaps not as suitable as other methods for loss evaluation.

Whether the parameters used herein present a realistic concept of whole-plant loss is moot. This integration of disease loss into the "leaf area-duration" concept of Watson et al. (11, 12) assumes that the top three leaves are of equal size and that leaf-blade and stem destruction are independent and additive. The top three leaves are not always of equal size although they may be comparable under favorable growth conditions (2). Generally flag leaves are largest, but they are often small under stress conditions.

The 40-day "normal" leaf-life span for each of the top three leaves and stem was derived from studies on South Dakota winter wheat under good growth conditions. Shorter and longer life-spans were observed when growth conditions were poor and excellent, respectively. In other environments a 40-day life-span may be unrealistic.

The range of logit values of +5 to −5 was chosen for convenience, and does not necessarily reflect natural boundaries of the rust level-yield complex.

LITERATURE CITED

1. BUCHENAU, G. W. 1970. Forecasting profits from spraying for wheat rusts. S. D. Farm Home Res. 21:31-34.
2. BUCHENAU, G. W., and F. BODE. 1973. Comparison of leaf size and leaf life-span among selected tall and semidwarf spring wheat cultivars. Proc. S.D. Acad. Sci. 52:72-77.
3. BURLEIGH, J. R., A. P. ROELFS, and M. G. EVERSMEYER. 1972. Estimating damage to wheat caused by Puccinia recondita tritici. Phytopathology 62:944-946.
4. JAMES, W. C. 1974. Assessment of plant diseases and losses. Annu. Rev. Phytopathol. 12:27-48.
5. KINGSOLVER, C. H., C. G. SCHMITT, C. E. PEET, and K. R. BROMFIELD. 1959. Epidemiology of stem rust: II. Relation of quantity of inoculum and growth stage of wheat and rye at infection to yield reduction by stem rust. Plant Dis. Rep. 43:855-862.
6. LARGE, E. C. 1954. Growth stages in cereals. Plant Pathol. 3:138-129.
7. ROMIG, R. W., and L. CALPOUZOS. 1970. The relationship between stem rust and loss in yield of spring wheat. Phytopathology 60:1801-1805.
8. SNEDECOR, G. W. 1956. Pages 178-179 *in* Statistical methods, 5th ed. Iowa State College Press, Ames. 534 p.
9. STEEL, R. G. D., and J. H. TORRIE. 1960. Pages 171 and 319 *in* Principles and procedures of statistics. McGraw-Hill, New York. 481 p.
10. VAN DER PLANK, J. E. 1963. Plant diseases: epidemics and control. Academic Press, New York. 349 p.
11. WATSON, D. J., G. N. THORNE, and S. A. W. FRENCH. 1963. Analysis of growth and yield of winter and spring wheats. Ann. Bot. 27:1-22.
12. WELBANK, P. J., S. A. W. FRENCH, and K. J. WITTS. 1966. Dependence of yields of wheat varieties on their leaf area durations. Ann. Bot. 30:291-299.