Chloride Fertilizer Effects on Stripe Rust Development and Grain Yield of Winter Wheat

J. M. SCHEYER, Graduate Assistant, and N. W. CHRISTENSEN, Associate Professor, Department of Soil Science, and R. L. POWELSON, Professor, Department of Botany and Plant Pathology, Oregon State University, Corvallis 97331

ABSTRACT

Scheyer, J. M., Christensen, N. W., and Powelson, R. L. 1987. Chloride fertilizer effects on stripe rust development and grain yield of winter wheat. Plant Disease 71:54-57.

Seven winter wheat cultivars grown in the field on an Aquultic Argixeroll (pH 5.5) were spring topdressed with $(NH_4)_2SO_4$ or NH_4Cl to determine the effect of chloride (Cl) on the progress of stripe rust disease. Choride rates of 0, 76, 152, and 304 kg ha^{-1} were applied at a constant N rate of 120 kg ha^{-1}. Plots were inoculated with *Puccinia striiformis*, using a composite spore collection representing races common in the Willamette Valley of Oregon. Stripe rust severity was determined weekly, and disease progress curves were generated for each Cl treatment on the four cultivars developing the disease. Chloride reduced the apparent infection rate on Purplestraw, Yamhill, and Rew cultivars in one year but increased the apparent infection rate on Rew in another year. Results confirm that Cl-containing fertilizers can influence stripe rust development, but the effects are small and of questionable practical value. Chloride applied at 76 kg ha^{-1} significantly increased grain yield by an average of 0.50 Mg ha^{-1}, possibly by reducing stress from take-all root rot caused by *Gaeumannomyces graminis* var. *tritici.*

Stripe rust of winter wheat (*Triticum aestivum* L.) caused by *Puccinia striiformis* West. has been reduced by chloride (Cl) salts (2,3,5). In both glasshouse and field experiments at two locations in three successive years, Russell (5) found that soil, but not foliar, applications of NaCl or KCl reduced stripe rust severity on all nine winter wheat cultivars examined. Chloride applied to the soil as NaCl, KCl, or NaCl + KCl at rates ranging from 226 to 1,356 kg Cl ha^{-1} did not adversely affect growth or yield of field-grown wheat in the absence of the disease. Because sodium nitrate and sodium phosphate did not reduce stripe rust, Cl appeared to be responsible for disease suppression.

Christensen et al (2) observed less stripe rust on Stephens and Yamhill wheats when they were fertilized with NH_4Cl than with $(NH_4)_2SO_4$ at an equivalent rate of N. To evaluate Cl effects on stripe rust across a wide range of cultivars, Christensen et al (3) superimposed a Cl variable on the 1981 International Winter Wheat Rust Nursery. Fertilizer treatments [NH_4Cl or $(NH_4)_2SO_4$] were topdressed such that one-half of each single-row entry received 340 kg Cl ha^{-1}. Paired *t* test analyses indicated that Cl significantly ($P = 0.001$) reduced the percentage of leaf area attacked by stripe rust but had no effect on infection type.

Objectives of this study were to 1) evaluate the impact of Cl rates on stripe rust epidemiology, 2) measure Cl rate effects on grain yield and kernel weight, and 3) determine if resistant and susceptible cultivars differ in yield and disease development response to Cl.

MATERIALS AND METHODS

Field experiments were conducted in the Willamette Valley of western Oregon in 1981–1982 and 1982–1983 at a site near Corvallis. The soil type is a Woodburn silt loam (fine-silty, mixed, mesic Aquultic Argixeroll), pH 5.5, with 86 mg dilute acid-fluoride-extractable P, 235 mg ammonium acetate-extractable K, and 25 g soil organic matter per kilogram of soil in the surface 15 cm. Wheat followed fallow in 1981–1982 and followed oats infested with grassy weeds in 1982–1983.

Experimental design. Five winter wheat cultivars differing in resistance to *P. striiformis* were planted each season, using a split-plot experimental design with cultivars as main plots and four Cl rates as subplots (Table 1). Subplots were 1.38 × 11 m and treatments were replicated four times. Leaves of cultivars with a resistant infection type generally show necrotic and/or chlorotic areas and little or no sporulation when infected by *P. striiformis* races common in the Willamette Valley. Susceptible cultivars generally show abundant sporulation and may or may not show necrosis or chlorosis. Three of the seven cultivars were grown during both cropping seasons. Chloride rates ranged from 0 to 304 kg ha^{-1} with intermediate rates (76 and 152 kg ha^{-1}) obtained by applying a mixture of NH_4Cl and $(NH_4)_2SO_4$.

Agronomic practices. Plots were sown on 23 October 1981 and 3 November 1982 with a double-disc drill at 100 kg seed ha^{-1} in six rows spaced 23 cm apart. Fall fertilization included 22 kg N, 20 kg

Table 1. Winter wheat cultivar and chloride rate treatments

			Cropping season	
Treatments			**1981-1982**	**1982-1983**
Cultivars	**Infection type**[a]			
Hill 81	Resistant		+	...
Hyslop	Resistant		...	+
OR-67-237	Susceptible		+	...
Purplestraw	Susceptible		...	+
Rew	Resistant		+	+
Stephens	Resistant (adult)		+	+
Yamhill	Resistant (seedling)		+	+
	Nitrogen applied as:[b]			
Cl rate (kg ha^{-1})	**$(NH_4)_2SO_4$ (%)**	**NH_4Cl (%)**		
0	100	0	+	+
76	75	25	+	+
152	50	50	+	+
304	0	100	+	+

[a] Cultivar reactions to *Puccinia striiformis* races dominant in the Willamette Valley.
[b] Nitrogen topdressed at a rate of 120 kg ha^{-1} on 16 March 1982 and 15 March 1983.

Oregon Agricultural Experiment Station Technical Paper 7795.

Accepted for publication 19 May 1986.

P, 41 kg K, 9 kg S, and 37 kg Cl ha^{-1} applied in a band with the seed, using Unipel 10-20-22 fertilizer. No herbicides were applied to the 1981–1982 crop. Benomyl was applied at 230 g a.i. ha^{-1} on 9 March 1982 to protect against *Pseudocercosporella herpotrichoides*. Herbicides applied to the 1982–1983 crop on 12 December 1982 included 590 g a.i. ha^{-1} diuron and 6.2 g a.i. ha^{-1} chlorsulfuron.

The number of heads per square meter was determined before harvesting the entire plot area (15 m^2) with a small-plot combine on 28 July 1982 and 1 August 1983. Total grain weight and weight of 500 kernels were determined.

Inoculation. A mixture of susceptible cultivars was sown at the ends and in the middle of each subplot in a single row perpendicular to the long axis of the plot. Rows of susceptible plants were inoculated with *P. striiformis* spores and were intended to serve as line sources of stripe rust inoculum. Plants were inoculated at growth stage 30 (leaf sheath erect) (8) on 6 March 1982 and 31 March 1983 with spores of a composite collection containing *P. striiformis* races prevalent in the Willamette Valley. Preservation and rehydration of spores followed the procedures used by Shaner (6). Vials of spores collected the previous growing season and stored in liquid N_2 were heat-treated in water at 40 C for 10 min. Vials were then opened and placed on wet paper towels in a beaker covered with plastic. After 3 hr of hydration, spores were removed from the vial and mixed in a 1:5 ratio with sterile talc. The mixture of spores and sterile talc was shaken onto plants from a cloth bag held about 0.25 m above the ground.

In 1982, stripe rust was not observed through the month of April. Consequently, plants with sporulating stripe rust lesions were transplanted on 4 May from a nearby stripe rust nursery to serve as a source of inoculum. A single sporulating plant was transplanted into the center of each line of spreader plants in each subplot.

Stripe rust assessment. Infection type and stripe rust severity were recorded for each subplot from the time disease symptoms first became visible. Stripe rust severity was rated by assigning a number (0.1, 1, 5, 10, 25, 50, 75, 90, 95, 99) corresponding to the percentage of total leaf area showing sporulation and/or chlorotic/necrotic symptoms attributable to *P. striiformis* infection. In 1982, stripe rust was assessed on 26 May and 2, 10, 16, and 22 June. At four positions within each subplot, disease readings were taken on single plants adjacent to and 30, 60, and 120 cm from the transplanted sporulating plants for a total of 16 disease readings per subplot on each date. In 1983, stripe rust was assessed every 7 days from 19 April through 22 June (growth stage 80) by taking readings at three positions within each subplot adjacent to and 60 and 120 cm from the inoculated row of sporulating plants for a total of nine disease readings per subplot on each date.

Analysis of data. Head count, kernel weight, and grain yield data were subjected to an analysis of variance consistent with the experimental design. An analysis of variance of the disease readings revealed that distance from the source of inoculum (0–120 cm) had no significant effect on stripe rust severity. Consequently, the mean disease reading for each subplot was used as a measure of stripe rust severity on each sampling date. Percent attack (PA) data were transformed to logit values ($\ln[PA(100-PA)^{-1}]$) and regressed on time after inoculation. Slope of the regression line was taken as the apparent infection rate (7). Within cultivars, linear regression coefficients for treatments receiving Cl were statistically compared with the coefficients for the nil Cl treatment.

RESULTS

Chloride effects on stripe rust. Stripe rust epidemics occurred on only one cultivar (Rew) in 1982 and on three cultivars (Purplestraw, Rew, and Yamhill) in 1983. Least squares lines for the regression of logits on time after inoculation are shown in Figures 1–3 for the cultivars Purplestraw, Yamhill, and Rew, respectively. Coefficients of determination (R^2) ranged from 0.90 to 1.00. Linear regression coefficients for these lines are given in Table 2.

Chloride application reduced stripe rust severity on Purplestraw on all assessment dates (Fig. 1). Regression coefficients (Table 2) show that the apparent infection rate was significantly ($P = 0.01$) reduced by all rates of Cl and that 76 kg Cl ha^{-1} was as effective in slowing disease progression as were higher rates. The apparent infection rate on Yamhill was also significantly reduced by Cl application (Fig. 2, Table 2). In contrast to the results obtained with Purplestraw, stripe rust on Yamhill was more severe up to 65 days after inoculation in treatments receiving 76 or 152 kg Cl ha^{-1}. Between 65 and 80 days after inoculation, stripe rust on Yamhill was less severe where Cl had been applied. The effects of Cl on stripe rust development on Rew were different in 1982 compared with 1983 (Fig. 3). In 1982, 76 and 152 kg Cl ha^{-1} significantly increased the apparent infection rate, whereas in 1983, these same Cl rates significantly reduced the apparent infection rate (Table 2). In 1983, Cl effects on stripe rust development were similar for Rew and Yamhill wheats

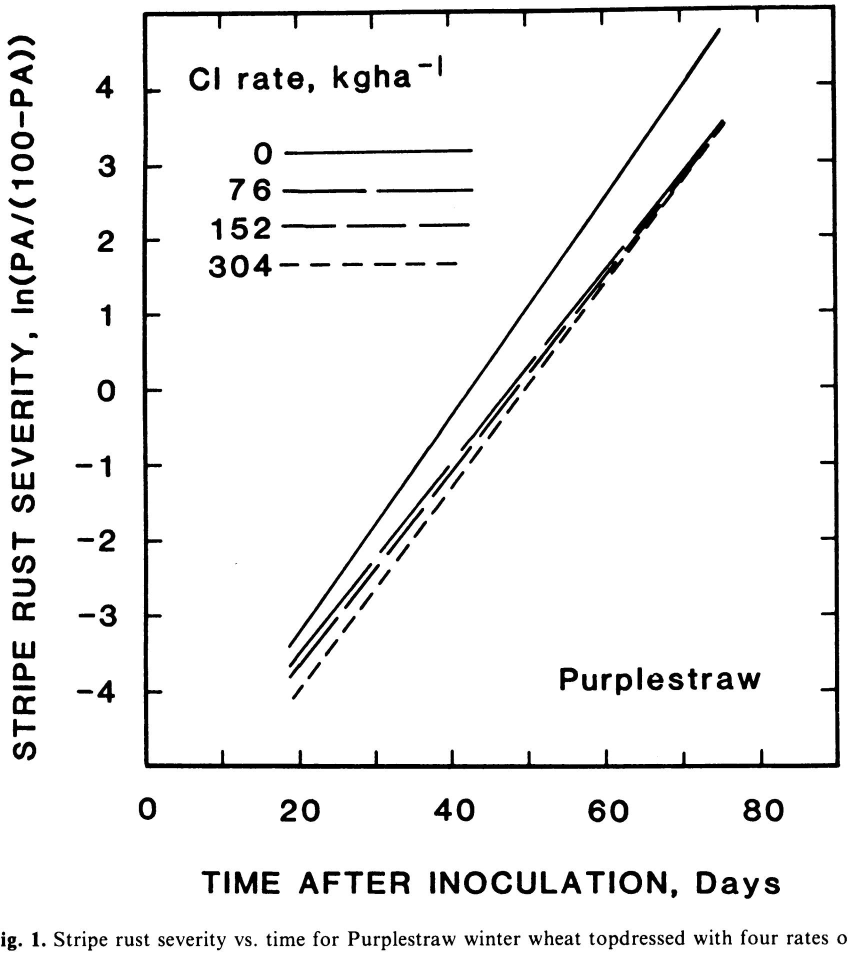

Fig. 1. Stripe rust severity vs. time for Purplestraw winter wheat topdressed with four rates of chloride.

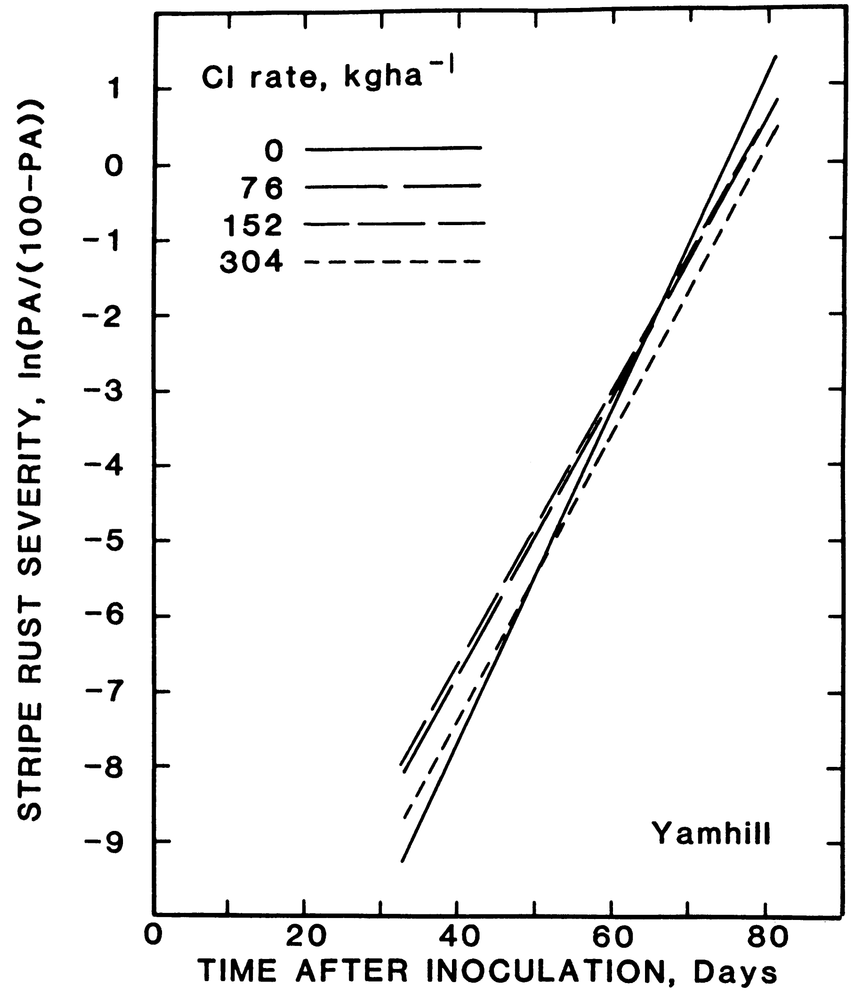

Fig. 2. Stripe rust severity vs. time for Yamhill winter wheat topdressed with four rates of chloride.

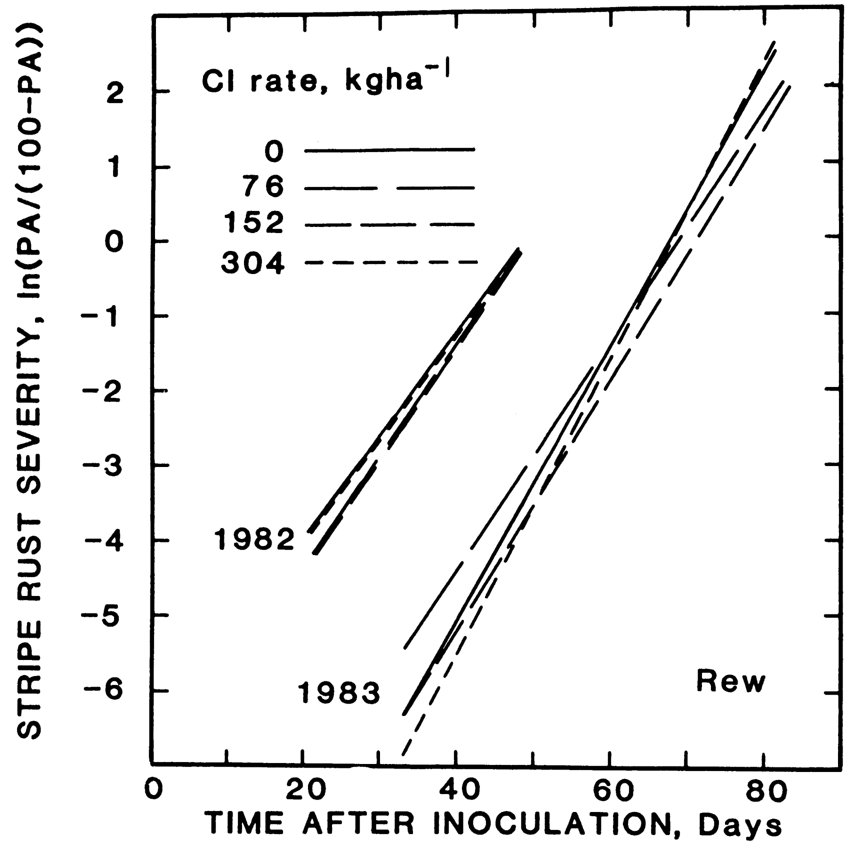

Fig. 3. Stripe rust severity vs. time for Rew winter wheat topdressed with four rates of chloride.

receiving 76 and 76 or 152 kg Cl ha^{-1}, respectively (Figs. 2 and 3).

Chloride effects on grain yield and yield components. Chloride application significantly ($P = 0.05$) increased grain yield of all seven cultivars (Table 3). There was no significant Cl rate × cultivar interaction effect on grain yield in either cropping season. In 1982, 76 kg Cl ha^{-1} significantly increased average grain yield by 0.47 Mg ha^{-1}. Increasing Cl rate from 76 to 304 kg Cl ha^{-1} reduced average grain yield to the level measured on the nil Cl treatments. In contrast, 76 kg Cl ha^{-1} increased average grain yield by 0.52 Mg ha^{-1} in 1983, but yields were not reduced with higher rates of Cl. Grain yield averaged 7.30 Mg ha^{-1} in 1982 and 3.67 Mg ha^{-1} in 1983.

The number of heads per square meter was unaffected by Cl in either year. Chloride significantly ($P = 0.05$) increased kernel weight from 44.4 to 45.2 mg per kernel in 1982 and from 39.4 to 41.6 mg per kernel in 1983.

DISCUSSION

Results confirm that Cl-containing fertilizers can, under some conditions, slow the progress of stripe rust epidemics on both resistant and susceptible winter wheat cultivars. Data from 1983 are consistent with results of the preliminary Oregon study (2) and those of Russell (5). In contrast, Cl application in 1982 increased the apparent rate of infection by an average of 7% over the nil Cl treatment. Differences between years may be related to differences in method of plot inoculation. Not all transplants with sporulating lesions survived in 1982, which may have resulted in different levels of inoculum across Cl rate treatments. Use of transplants as an inoculum source may have resulted in inadvertent selection for specific races of *P. striiformis* and may account for the fact that stripe rust developed only on the cultivar Rew in 1982.

Reduction in stripe rust severity with Cl was most obvious on the susceptible cultivar Purplestraw. The decrease in apparent infection rate on Purplestraw, Yamhill, and Rew wheats in 1983 suggests that the Cl treatment may have lengthened the latent period and/or reduced the effectiveness of secondary inoculum. These effects may be related to previously measured Cl effects on osmotic and turgor potentials in wheat leaves (3), Cl effects on leaf habit (erectness) (3), or Cl effects on the relative proportion and concentration of NH_4 and NO_3 in moderately acid soils (1,4). Despite the fact that Cl suppression of stripe rust was statistically significant, the degree of control obtained was small and probably of limited value as an effective means of disease control.

Grain yield responses to Cl application were probably not the result of stripe rust suppression. All seven cultivars responded

Table 2. Coefficients for regression of stripe rust severity ($\ln[PA(100 - PA)^{-1}]$) on time (days) as influenced by chloride rate

Cl rate (kg ha^{-1})	Cultivar			
	Purplestraw	**Rew (1982)**	**Rew (1983)**	**Yamhill**
		***b*₁ (Apparent infection rate)**		
0	0.144	0.136	0.182	0.221
76	0.128**[a]	0.147*	0.152**	0.183*
152	0.128**	0.151**	0.167**	0.172**
304	0.136**	0.139	0.196	0.198**
		***b*₀ (Intercept)**		
0	−6.135	−6.695	−12.330	−16.574
76	−6.093	−7.268	−10.451	−14.100
152	−6.183	−7.377**	−11.858	−13.562**
304	−6.715**	−6.807	−13.320	−15.157**

[a] Significantly different from zero chloride treatment: (* = $P = 0.05$ and ** = $P = 0.01$).

Table 3. Chloride treatment effects on grain yield of winter wheat cultivars inoculated with *Puccinia striiformis*

Cl rate (kg ha^{-1})	1982 Cultivars (Mg ha^{-1})					Cl mean
	Hill 81	**OR-67-237**	**Rew**	**Stephens**	**Yamhill**	
0	7.75	6.88	6.35	7.22	7.32	7.10
76	8.02	7.47	6.55	7.84	7.95	7.57
152	7.81	7.51	6.45	7.56	7.36	7.34
304	7.68	6.76	6.20	7.59	7.62	7.17
LSD ($P = 0.05$)	0.54	0.54	0.54	0.54	0.54	0.24
	1983 Cultivars (Mg ha^{-1})					
	Hyslop	**Purplestraw**	**Rew**	**Stephens**	**Yamhill**	
0	3.50	2.33	4.27	3.13	2.80	3.21
76	4.11	2.86	4.50	3.84	3.36	3.73
152	4.09	2.98	4.49	4.29	3.50	3.87
304	4.07	2.94	4.67	4.12	3.56	3.87
LSD ($P = 0.05$)	0.54	0.54	0.54	0.54	0.54	0.24

positively (average 0.50 Mg ha^{-1}) to an application of 76 kg Cl ha^{-1} even though only four of the cultivars were measurably attacked by stripe rust. Given the range in stripe rust severity across cultivars, one would expect to find evidence for a Cl rate × cultivar interaction if yield and kernel weight responses to Cl were the result of stripe rust suppression.

Yield responses to Cl may have resulted from a reduction in take-all root rot caused by *Gaeumannomyces graminis* var. *tritici* and/or higher NH_4:NO_3 ratios and total inorganic N in soils fertilized with NH_4Cl. In a subsequent year at this same site, Christensen and Brett (1) found that Cl application on pH 5.5 soil slowed the rate of nitrification and reduced the severity of take-all. Severe take-all was not expected in 1981–1982 or 1982–1983 because wheat followed fallow and oats, respectively. Nevertheless, the presence of stunted plants scattered throughout the experimental area suggested that take-all was present. Low yields measured in 1983 (3.67 Mg ha^{-1}) relative to 1982 (7.30 Mg ha^{-1}) are, in part, the result of poor drainage and an inadequate rate of N to compensate for N immobilized during oat straw decomposition.

ACKNOWLEDGMENTS

We thank the Oregon Wheat Commission and the Potash & Phosphate Institute for their financial support of this research.

LITERATURE CITED

1. Christensen, N. W., and Brett, M. 1985. Chloride and liming effects on soil nitrogen form and take-all of wheat. Agron. J. 77:157-163.
2. Christensen, N. W., Jackson, T. L., and Powelson, R. L. 1982. Suppression of take-all root rot and stripe rust diseases of wheat with chloride fertilizers. Plant Nutrition 1982: Proc. Int. Plant Nutr. Colloq., 9th 1:111-116.
3. Christensen, N. W., Taylor, R. G., Jackson, T. L., and Mitchell, B. L. 1981. Chloride effects on water potentials and yield of winter wheat infected with take-all root rot. Agron. J. 73:1053-1058.
4. Huber, D. M., and Watson, R. D. 1974. Nitrogen form and plant disease. Annu. Rev. Phytopathol. 12:139-165.
5. Russell, G. E. 1978. Some effects of applied sodium and potassium chlorides on yellow rust in winter wheat. Ann. Appl. Biol. 90:163-168.
6. Shaner, G. E. 1969. Epidemiology of stripe rust (*Puccinia striiformis* West.) of wheat in western Oregon. Ph.D. thesis. Oregon State University, Corvallis.
7. Vanderplank, J. E. 1963. Plant Diseases: Epidemics and Control. Academic Press, New York.
8. Zadoks, J. C., Chang, T. T., and Konzak, C. F. 1974. A decimal code for the growth stages of cereals. Weed Res. 14:415-421.