Common Root Rot and Yield Responses in Spring Wheat From Chloride Application to Soil in Northwestern Minnesota

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ABSTRACT

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Plots were established at five locations in northwestern Minnesota during 1986–1989 and fertilized with five rates of chloride (0, 13, 27, 40, and 54 kg/ha) using two sources ($CaCl_2$ and KCl) to determine if Cl affected the incidence and severity of common root rot and grain yield. Locations differed for all variables measured, but there were no significant interactions ($P = 0.05$) between the rate of Cl fertilization and location. Ratings for common root rot (0–100 scale) for each location during 1986–1989 averaged 81.9, 42.9, 60.2, 51.2, and 73.3 for control plots, respectively, and 74.3, 41.9, 59.5, 49.9, and 66.6 for combined Cl plots, respectively. There were no significant differences in plant populations, whole-plant uptake of Ca or K, or grain yield for Cl-fertilized plots compared with control plots. Fertilization with Cl tended to increase forage yield and decrease grain protein concentration. Test weight of grain was significantly increased by 6–11 g/L for Cl-fertilized plots compared with controls. Overall, soil supplemented with Cl was not effective in significantly decreasing common root rot or in increasing grain yield.

Additional keywords: *Bipolaris sorokiniana, Cochliobolus sativus*

Common root rot of wheat (*Triticum aestivum* L.) is endemic to the Northern Great Plains of the United States and Canada. The disease is caused by *Bipolaris sorokiniana* (Sacc.) Shoemaker (syns. *Helminthosporium sativum* Pammel, C. M. King, & Bakke, *H. sorokinianum* Sacc. in Sorokin; teleomorph *Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur) (22). *Fusarium graminearum* Schwabe and *F. culmorum* (Wm. G. Sm.) Sacc., either singly or in combination with *B. sorokiniana*, also contribute to the disease complex. These pathogens can cause severe symptoms on seedlings (stunting, necrosis, and death) and mature plants (stunting; necrotic lesions on seminal and crown roots, subcrown internodes, and basal stem tissues) of wheat (22).

Soil application of Cl to fields in northwestern Minnesota is being promoted because reports from other states have shown that the practice reduces disease and increases grain yield. Fertilizers containing Cl increased grain yields of wheat (2,19) and barley (8,9,20) in the Pacific Northwest and Great Plains of North America. Some of these yield increases have been attributed to decreases in take-all of wheat in Oregon (2,19) and common root rot in North Dakota (8,9,20) and Montana (18). Additionally, aboveground pathogens of cereals have been suppressed by soil-applied Cl, including powdery mildew (10) and stripe rust (16) of winter wheat; tan spot, Septoria leaf spot, and leaf rust of spring wheat (5); and spot blotch of barley (20). Fertilizers containing the Cl anion also have suppressed diseases caused by *Fusarium* species on asparagus (3), celery (17), and corn (24).

In 1989, 662,000 ha of spring wheat, comprising nearly 63% of the crop produced in the state, were planted in northwestern Minnesota (Minnesota Agricultural Statistics Service, St. Paul). No studies showing the effect of Cl fertilization on spring wheat in the area are available. Thus, the objectives of our study were to evaluate the effects of several rates of two forms of Cl fertilizer on common root rot, plant population, forage yield, uptake of calcium and potassium, grain yield, and grain protein of hard red spring wheat at various locations in northwestern Minnesota. A brief report has been published (11).

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MATERIALS AND METHODS

Plot preparation. Plots were established at five field sites during 1986–1989 that varied in soil characteristics and ranged in amounts of soil Cl from 30 to 80 kg/ha at a depth of 0–60 cm (Table 1). Five rates (Cl at 0, 13, 27, 40, and 54 kg/ha) were applied using two sources ($CaCl_2$ and KCl). Plots were fertilized according to soil test recommendations (14) for all nutrients but Cl. Only nitrogen and phosphorus were needed and were added as urea (46-0-0) and triple super phosphate (0-44-0), respectively. Specific amounts of Cl fertilizers were broadcast-applied to each plot in mid- to late April and incorporated with a multiweeder. Plots then were seeded with the hard red spring wheat cultivar Marshall (100.8 kg of seed per hectare), using a double-disk press wheel drill, at a 15-cm row spacing. Research in South Dakota has shown that among several cultivars tested, Marshall was most affected by Cl fertilization (P. E. Fixen, *personal communication*). The factorial combination of these treatments was arranged in a randomized complete block design with four replicates. Each plot measured 2.4 × 9.1 m.

Plant population and forage measurements. Stands were determined in a 1-m^2 area of each plot in 1986, 1987, and 1989 before plants were tillered. Aboveground biomass was collected from a 1.2 × 1.5 m area within each plot when grain was in the medium dough stage (Zadoks scale = 86) (25). Forage was dried at 43 C for 1 wk. Calcium and potassium were determined at the Research Analytical Laboratory, University of Minnesota, using procedures outlined by Munter and Grande (12). Plant uptake of calcium and potassium were calculated from oven-dry forage yields and nutrient concentrations.

Root rot evaluations. Plants were sampled in the hard dough to ripening stages (Zadoks scale = 87–90) (25). Plants were selected randomly from the remaining plot, except from the middle 1.5 m, which was harvested. Fifty subcrown internodes per plot were rated for severity of discoloration on a 0–3 scale where 0 = healthy, 1 = 1–25% of the area discolored (mild infection), 2 = 26–50% discolored (moderate), and 3 = >50% discolored (severe) (21). A root rot index was calculated (21) as follows: sum of (category value × number of plants in category) × 100/(number of plants rated × 3).

Grain yield measurements. Grain was harvested when ripe from a 1.5 × 7.6 m area of each plot using a small plot combine. Harvest date varied from late July through mid-August. Grain moistures were determined and yields were adjusted to 13.5% moisture. Total grain nitrogen was determined (13), and grain protein was calculated.

Data analysis. Statistical analyses were computed with the general linear model and ANOVA procedures from the Statistical Analysis System (15).

RESULTS

Variables measured. There were significant differences ($P = 0.01$) among locations for all variables measured, except plant populations, which were not different (Table 2). There were no significant interactions ($P = 0.05$) between rate of Cl fertilization and location for any variable except grain yield, which was significant at $P = 0.10$ (Table 2). Therefore, data will be presented for the combined analyses of the five locations. Data were not collected on leaf spots because foliar diseases were not observed in the upper canopy.

Forage measurements. Source of Cl ($CaCl_2$ vs. KCl) had no effect on forage weight or uptake of Ca or K in the plant at the medium dough stage (Table 2). Rate of Cl fertilization significantly ($P = 0.05$) affected forage yield, which increased at 13, 27, and 54 kg of Cl per hectare (Table 3). Uptakes of Ca and K by the plant were less in the Cl-fertilized plots than in the control plots, but these differences were not significant (Table 3).

Root rot evaluations. Rate of Cl fertilization had no effect on root rot (Table 2), but there was a trend toward lower root rot ratings for plants in Cl-fertilized plots compared with control plots (Table 3). Root rot values for each location during 1986–1989 averaged 74.3, 41.9, 59.5, 49.9, and 66.6 for the combined Cl plots, respectively, and 81.9, 42.9, 60.2, 51.2, and 73.3 for control plots, respectively (*data not shown*). The source of Cl affected common root rot at $P = 0.10$ (Table 2); the average root rot rating when $CaCl_2$ was applied was 59.6 compared with KCl, which was 57.3 (*data not shown*).

Grain yield measurements. Yields varied considerably among locations (Fig. 1) and were particularly low in 1988 at Mahnomen because of drought. There was a small but nonsignificant increase in yield with 13, 27, and 54 kg of Cl per hectare compared with the control (Table 3). Test weight of grain averaged 6–11 g/L greater for Cl-fertilized plots than for control plots and was significant at $P = 0.05$ (Table 3). Grain protein was slightly lower in plots treated with Cl than in untreated plots, and these differences were significant at $P = 0.10$ (Table 3). The source of Cl had no affect on

Table 1. Selected soil characteristics for five sites in northwestern Minnesota before fertilization with chloride

			Amount of soil nutrient (kg/ha)						
Year[a]	Location	Soil series[b]	Chloride	Nitrate-Nitrogen	Phosphorus	Potassium	Soluble salts (mmhos/cm)	Organic matter (%)	pH
1986	Eldred	Colvin Perela Complex	80	155	55	818	0.7	4.4	8.0
1987	Georgetown	Fargo silty clay	73	116	37	930	NA[c]	3.2	7.9
1988	Georgetown	Fargo silty clay	53	241	54	918	0.4	4.2	7.4
1988	Mahnomen	Vallers silty clay loam	31	56	8	235	0.3	4.4	8.0
1989	Crookston	Wheatville loam	30	87	10	330	NA	3.6	7.9

[a]Soil samples were collected in the spring before wheat was planted; analyses were done by the Soil Testing Laboratory, North Dakota State University, Fargo (1). Samples for analysis of chloride and nitrate-nitrogen were collected at a 0- to 60-cm depth; other analyses were done for samples collected at a 0- to 15-cm depth.

[b]Colvin Perela Complex = mixed frigid, Typic Calciaquolls, Typic Haplaquolls; Fargo silty clay = fine, montmorillonitic, noncalcareous, frigid Vertic Haplaquolls; Vallers silty clay loam = fine-loamy, frigid Typic Calciaquoll; Wheatville loam = coarse-silty over clayey, frigid Aeric Calciaquoll.

[c]Analysis not available.

Table 2. Statistical analyses for chloride application on hard red spring wheat Marshall for plant population, forage yield, calcium (Ca) and potassium (K) uptake, root rot index, grain yield, test weight, and grain protein in northwestern Minnesota, 1986–1989

Factor	df	Plant population	Forage yield	Plant uptake Ca	Plant uptake K	Root rot index	Grain yield	Test weight	Grain protein
Location	4	NS[a]	**	**	**	**	**	**	**
Rate	4	NS	*	NS	NS	NS	NS	*	++
Linear	1	NS	NS	NS	NS	NS	NS	**	*
Quadratic	1	NS	NS	NS	NS	++	NS	NS	NS
Source (Ca vs. K)	1	NS	NS	NS	NS	++	NS	NS	NS
Rate × source	4	NS	NS	NS	NS	NS	NS	NS	NS
Location × rate	16	NS	NS	NS	NS	NS	++	NS	NS
Location × source	4	NS	NS	NS	NS	NS	NS	NS	NS
Location × rate × source	16	NS	NS	NS	NS	NS	NS	NS	NS
C.V. (%)		15.8	22.6	40.3	33.7	12.7	14.1	2.36	3.6

[a]++, *, and ** = Significant at $P = 0.10$, $P = 0.05$, $P = 0.01$, respectively; NS = not significant.

Table 3. Effect of chloride fertilization on common root rot and several parameters of spring wheat averaged across five locations during 1986–1989

Cl rate (kg/ha)	Plant population (m^2)	Forage yield (Mg/ha)	Plant uptake (mg/g) Calcium	Plant uptake (mg/g) Potassium	Root rot index[a]	Grain yield[b] (Mg/ha)	Test weight (g/L)	Grain protein[b] (%)
0	209	5.3	1,300	13,415	61.9	2.5	729	14.7
13	220	5.6	1,190	12,645	57.7	2.6	735	14.6
27	216	6.0	1,149	12,346	58.2	2.7	739	14.6
40	226	5.2	1,164	12,531	58.9	2.5	736	14.5
54	206	5.7	1,197	13,173	59.0	2.6	740	14.5
P Value[c]	NS	*	NS	NS	NS	NS	*	++

[a]Root rot index based on a 0–100 scale where 0 = no root rot and 100 = all subcrown internodes >50% lesioned.

[b]Adjusted to 13.5% moisture content.

[c]++ and * = Significant at $P = 0.10$ and $P = 0.05$, respectively.

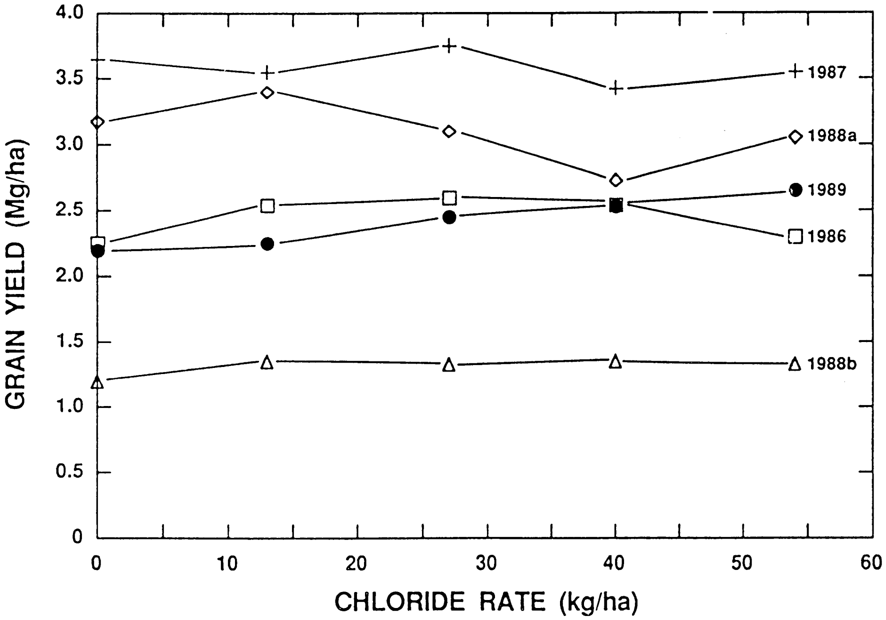

Fig. 1. Yield of wheat at five Minnesota locations. 1986 = Eldred, 1987 = Georgetown, 1988a = Georgetown, 1988b = Mahnomen, and 1989 = Crookston.

grain yield, test weight, or protein concentration (Table 2).

DISCUSSION

A slight but nonsignificant reduction in common root rot with Cl fertilization was shown for all five sites during 1986–1989. The source of Cl applied to soil also affected root rot ($P = 0.10$), but the differences were too small to be of practical significance. Ratings of naturally occurring disease intensity in this study were comparable to those of field studies reported in North Dakota (8,9,20) and Montana (18). *B. sorokiniana* is the primary component in the common root rot complex in northwestern Minnesota (23), as it is in North Dakota and Montana. Despite the reported benefits from Cl fertilization, it has been noted that the practice reduces root rot in some, but not necessarily all, field sites (9,20).

Grain yields varied considerably among fields and, in general, were slightly greater with some rates of Cl fertilization. Other studies have shown increases in grain yield, even when there was no suppression of common root rot and when Cl concentrations in soil were adequate (5,9). Fixen et al (7) reported that soil Cl amounts should be at 67 kg/ha (60 cm depth) for near-maximum yield potential and that at soil test values between 43 and 67 kg/ha, grain increases would occur in 33% of the fields. Two of five sites in this study were below 43 kg of Cl per hectare, yet none responded to the addition of soil-applied Cl. Chloride fertilizers were broadcast-applied to avoid possible adverse salt effects, which can occur when high rates of Cl are placed in direct contact with seed at planting (6).

The series and classification of soils tested in northwestern Minnesota (Table 1) were different from those reported in the Dakotas (5,6,8,9,20) and Montana (18). Soils in our trials were formed in lacustrine deposits (lake bed), whereas North Dakota soils are glacial till. It is unknown if soil pH affected our results. In North Dakota, responses of barley to common root rot and yield when fertilized with Cl were not related to soil pH, which ranged from 5.9 to 8.3 (8,9,20). It is not known if other characteristics of these soils could account for variation in common root rot and responses of wheat growth to Cl applications.

There were no differences in uptake of the two Cl sources (Ca and K) by spring wheat. Some researchers have noted that plant concentrations of K were not significantly affected by the addition of KCl to soil (6,8) but that concentrations of Cl increased in plants with increasing soil quantities of KCl (5,8,9,20). Engel and Grey (4) reported that whole-plant concentrations of Cl increased at a rate that was approximately linear with soil-applied Cl but that concentrations were not reliable predictors of grain yield response. Others have determined that as amounts of Cl applied to soil increase, there is an increase in uptake of Cl and a decrease in nitrate-nitrogen in barley (8,9,20). The trend of lower grain protein observed in this study may be explained by lowered uptake of nitrate-nitrogen by the plant as the amounts of Cl applied to soil increased. However, neither Cl nor nitrate-nitrogen uptake by the plant were measured.

In this study, the effects of Cl fertilization on common root rot or on wheat yield and quality were minimal.

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