MT-10F Effect of chloride fertilization on yield and development rate of several winter wheat varieties in Montana, 1993.

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Both non-disease and disease related Cl yield responses by winter wheat are being studied in this project with a focus on non-disease leaf spotting that has been observed on certain winter wheat varieties. Yield response to Cl was measured in both experiments in 1993 with average responses of 6.3 and 9.0 Bu/A. At the more responsive site, Cl response only occurred when a fungicide was used. Yield responses appeared to be related more to improved plant nutrition than control of diseases or leaf spotting of certain varieties. Studies like this one support the concept that balanced nutrition for wheat should include Cl management.

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Effect of Cl fertilization on yield, kernel weight, and leaf spot in winter wheat cultivars

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ABSTRACT

In Montana a leaf spot disease of unknown etiology in 'Redwin' winter wheat has been observed to be suppressed by Cl application. A research investigation was initiated to learn more about the origin of these leaf spots; to determine if leaf spot suppression by Cl extended to other cultivars with a history of leaf spot; and to determine if leaf spot suppression by Cl results in a yield and/or kernel weight response. Two studies were established near Lodgegrass, Montana at low Cl testing sites, 12.1 (Experiment 1) and 6.5 (Experiment 2) kg/ha in 0-120 cm depth. Experiment 1 consisted of five cultivars ('Redwin', 'Tiber', 'Manning', 'Kestrel', and 'Stephens') a foliar fungicide (propiconazole) and control, and two Cl levels (0 and 67 kg/ha, or -Cl and +Cl) in factorial arrangement. Experiment 2 consisted of 8 treatments seeded to 'Redwin' winter wheat, including a propiconazole and control, and four Cl levels (0, 22.5, 45, 90 kg/ha) in factorial arrangement. Experiment 1 and 2 results indicated that Cl suppressed leaf spot in 'Kestrel', 'Redwin', and 'Manning'. Leaf spot severity was greatest in 'Kestrel', followed by 'Redwin' and 'Manning'. Leaf spots were not present in 'Tiber', a 'Redwin' selection with leaf spot tolerance. 'Stephens' was also not affected by leaf spots. In affected cultivars propiconazole fungicide had no effect on leaf spot severity in and a causal organism could not be identified on necrotic areas of leaf blades. The results indicate that leaf spot occurrence has a genetic or physiologic basis, rather than being caused by a microbial infection. Winter wheat yield and thousand kernel weight were increased by Cl fertilizer in Experiment 1, and were not affected by cultivar selection or propiconazole. Yield and thousand kernel weight responses averaged 423 kg/ha or 8.7%, and 1.6 g or 4.7% over the -Cl, respectively. In Experiment 2 yield was increased only where propiconazole was applied. Yield response over the -Cl averaged (mean of 22, 45, and 90 kg Cl/ha) 609 kg/ha or 14.9%. Yield responses to Cl in Experiment 1 and 2 appeared to be related more to improved plant nutrition rather than control of diseases and/or physiologic or genetic leaf spot. Results from the Cl rate study indicate that a comparatively low available soil Cl level, perhaps <33 kg/ha, is needed to ensure adequate plant nutrition. Plant tissue analyses revealed that Cl concentration decreased between GS 8 to GS 11.3 due to an increase in plant biomass without a proportionate increase in Cl uptake. Plant Cl uptake reached a maximum at GS 10 to GS 10.5.1. Thereafter, plant Cl content was comparatively stable.

→ 6.3 bu/A
5% ↑ in kern wt

→ 9.0 bu/A
↳ only with tilt

INTRODUCTION

In Montana a leaf spot disease of unknown etiology is frequently observed in selected hard red winter wheat cultivars. Typically, symptoms first become visible on the older leaves at flag leaf emergence to boot stage and then advance to younger leaves after they become fully-emerged. Symptoms have been described as being similar to tan spot and Septoria leaf blotch, but plant pathogens responsible for these diseases, i.e. *Septoria tritic* and *Pyrenophora tritici* f. sp. *repentis,* are often not found on affected tissue. Leaf spot appearance and severity varies greatly with plant genotype and growing season environment. Leaf spot severity and progression to younger leaves is favored by cool, wet, and humid growing conditions. Among commonly grown winter wheat cultivars in Montana, 'Redwin' is probable the most susceptible to leaf spot. Recent investigations have revealed that on soils with extremely low Cl levels, < 10 kg ha^{-1} in 0-60 cm depth, Cl fertilizer greatly suppresses the appearance and severity of leaf spots in susceptible winter wheat cultivars.

Whether the origin of winter wheat leaf spots in Montana is physiologic or microbial is still unclear. In Oregon, a leaf spot with similar symptoms has been observed in soft winter wheat and described as physiological in nature (Smiley et al., 1993a). In South Dakota, reports that Cl suppresses foliar leaf diseases, including tan spot and septoria, in spring wheat (Fixen et al., 1986) suggest that plant pathogen(s) may be responsible for the observed leaf spots. Field studies were initiated to identify the origin of the leaf spots in winter wheat as physiologic or microbial. As previous research indicated Cl had a dramatic affect on leaf spot suppression in 'Redwin', we were interested in learning if this effect extended to other cultivars with a history of leaf spot; and if leaf spot suppression by Cl results in a yield and/or kernel weight response at harvest. Four hard red winter wheat cultivars, 'Redwin', 'Tiber', 'Manning', and 'Kestrel'; and a soft white winter wheat, 'Stephens', were selected for this investigation. 'Redwin', 'Manning', and 'Kestrel' were included because of their previous history of producing leaf spots in Montana agronomic trials. 'Tiber' was included because this cultivar was developed from a 'Redwin' population based on its tolerance to leaf spot disease. 'Stephens' was included because of its high susceptibility to physiologic leaf spot, and because foliar applications of urea + $CaCl_2$ were reported to affect leaf spot severity (Smiley et al., 1993b). Other objectives included: to determine the available Cl (soil + fertilizer) requirement for maximum yield and economic return; and to determine Cl concentration and uptake in winter wheat at several growth stages and as affected by fertilizer Cl application.

MATERIALS AND METHODS

Two field experiments were established on the farm of Gary and Allen Graham south of Lodgegrass, Montana at the base of the Bighorn Mountains. The farm is located in a high-precipitation and high-elevation (1340 m) area. Experiment 1 consisted of 20 treatments including five cultivars ('Redwin', 'Tiber', 'Manning', 'Kestrel', and 'Stephens') a foliar fungicide and control, and two Cl levels (0 and 67 kg/ha, or -Cl and +Cl) in factorial arrangement. Treatments were replicated six times. The study was arranged as a strip-split-block design with cultivars and foliar fungicide-control treatments oriented in perpendicular strips and Cl level sub-splots. Experiment 2 consisted of 8 treatments seeded to 'Redwin' winter wheat, including a foliar fungicide and control, and four Cl levels (0, 22.5, 45, 90 kg/ha) in factorial arrangement. Treatments were replicated four time and arranged as a split-splot design with foliar fungicide-control treatment main-plots, and Cl level sub-plots. Individual sub-plots were 2.4 m wide and 9 m long in both studies. Background soil Cl levels determined prior to seeding (Table 1) indicated 12.1 and 6.5 kg/ha available Cl (0-120 cm) at Experiment 1 and 2, respectively.

Table 1. Soil series and Cl levels for Experiments 1 and 2.

Experiment	Soil series	Soil depth (cm) and Cl level 0-30	 30-60	 60-90	 90-120
			mg/kg		
1	Korchea silt loam (Ustic torriorthents)	0.88†	0.88	0.44	0.49
2	Shaak silty clay loam (Abruptic agriborolls)	0.20	0.39	0.39	0.49

† Soil Cl levels determined by potentiometric titration with .005 N $AgNO_3$.

Winter wheat was seeded on 23 September 1992 in a 30-cm row spacing at 60 pure-live seeds per m. In Experiment 1, Cl was broadcast applied as KCl on 20 November. An equivalent K rate was maintained by broadcast applying K_2SO_4 to -Cl. In Experiment 2, Cl was broadcast applied as $CaCl_2$ on 25 March. A total of 100 kg/ha N was applied to both studies, 45 kg N/ha preplant as anhydrous ammonia plus 55 kg/ha N as urea on 25 March. Foliar fungicide treatments consisted of three propiconazole (Tilt) {1-[[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole} applications at a rate of 74 ml ha^{-1} on 4 May, 23 May, and 21 June or at Feekes growth stage 5, 8, and 9 (Large, 1954), respectively. Weed control was achieved by application of 2,4-Dichlorophenoxyacetic acid prior to the boot stage.

Whole plant tissue samples from Experiment 2 were collected from 0.4 m row on 23 May, 2 June, 13 June, 6 July, 20 July, and 13 August, or at Feekes growth stage 8, 9, 10-10.1, 10.5.1, 10.5.4, 11.1, and 11.3. Whole plant samples from Experiment 1 were collected from the control plots on 13 June or Feekes growth stage 10-10.1. Physiological leaf spot and leaf rust (*Puccinia recondita*) were evaluated by visually rating the percentage of the leaf area affected. Flag leaves on 15 to 20 culms were evaluated for physiological leaf spot on 27 June from 4 replications in Experiment 1, and on 23 June in Experiment 2. Flag leaves on 15 to 20 culms were evaluated for leaf rust in the propiconazole treatment on 1 August at Experiment 1.

Grain harvest was performed on 30 and 31 August by harvesting two and four center-rows in Experiments 1 and 2, respectively. Samples were dried at (50 °C) and subsamples were separated for test weight and thousand kernel weight determinations. Whole plant samples were dried (65 °C), ground, and analyzed for Cl by potentiometric titration (LaCroix et al., 1970).

RESULT AND DISCUSSION

Leaf spots

Leaf spot symptoms were apparent in 'Kestrel', 'Redwin' and 'Manning' at Experiment 1 and in 'Redwin' at Experiment 2. Symptoms became apparent at flag leaf emergence. Lesion numbers per leaf increased through flowering. Thereafter, lesion numbers remained stable but the level of necrosis or discoloration within the lesion increased. At Experiment 1 leaf spot severity was most severe in 'Kestrel', followed by 'Redwin' and 'Manning' winter wheat (Table 2). Absence of appreciable leaf spot symptoms in 'Stephens' suggest this cultivar is less susceptible to leaf spot than 'Kestrel', 'Redwin', and 'Manning' winter wheats. An Oregon study (Smiley et al., 1993b) found 'Stephens' to be the most susceptible winter wheat among 25 cultivars tested. It is possible the mechanism responsible for leaf spotting in Oregon are very different from the processes observed here, or 'Kestrel', 'Redwin', and 'Manning' winter wheat cultivars are more susceptible to leaf spot than 'Stephens'. Application of propiconazole fungicide had no effect on leaf spot severity and a causal organism could not be identified from affected areas of leaf blades. Leaf spots were not present in 'Tiber', a leaf spot tolerant 'Redwin' selection. These results indicate that leaf spots are most likely a result of a cultivar's specific genetic background. The term 'physiologic' or 'genetic' leaf spot is probably more appropriate to describe their origin.

Application of Cl fertilizer reduced leaf spot severity in affected cultivars. Leaf spot percentage in 'Redwin' 0 Cl treatments was less severe in Experiment 1 than 2, probably because background soil Cl levels were slightly higher. Evidence that only small amounts of Cl can greatly reduced leaf spot severity was apparent at Experiment 2 (Figure 1). This is consistent with results from previous years and indicates that physiological leaf spot in specific winter wheat cultivars is associated with extremely low soil Cl levels.

Yield and kernel weight

Due to abundant rainfall and cool temperatures winter wheat yields were extremely high. Rainfall amounts totaled 36.6 cm from 25 March to 31 August. The cool, wet weather made conditions ideal for severe powdery mildew (*Erysiphe graminis* f. sp. *tritic*) and leaf rust (*Puccinia recondita* f. sp. *tritici*) diseases infestation. Propiconazole applications greatly suppressed these diseases. Consequently, winter wheat yields in Experiment 1 were increased 1347 kg/ha, or 31%, on average over the control (Table 3). Disease infestation in the control was particularly high in 'Manning' perhaps explaining the large response to the foliar fungicide applications. Chloride increased yield in Experiment 1 by an average of 8.7%, or 423 kg/ha. The response to Cl was not affected by propiconazole and cultivar selection. The results indicate the yield response to Cl was related more to improved plant nutrition rather than control of foliar diseases.

In Experiment 1 mature kernel weight was increased by propiconazole due to Powdery mildew and leaf rust disease suppression (Table 3). Chloride application increased thousand kernel weight by an average of 4.7%. As yield response to Cl averaged 8.7%, the increase in mature kernel size was the most important yield component affected by Cl.

Table 2. Percentage of flag leaf affected by physiological leaf spot in several winter wheat cultivars as affected by Cl and propiconazole. Experiment 1. 1993.

Cultivar	Leaf spot					
	Control		Propiconazole		Mean	
	-Cl	+Cl	-Cl	+Cl	-Cl	+Cl
	%					
Kestrel	23.7	3.7	26.5	2.3	25.1	3.0
Manning	1.2	0.2	3.1	0.2	2.1	0.2
Redwin	7.0	0.3	5.2	0.1	6.1	0.2
Stephens	1.1	0.5	1.8	1.2	1.4	0.0
Tiber	0.2	0.1	0.0	0.0	0.1	0.0

Analysis of variance summary

Source	df	F test
Cultivar	4	.0001
Propiconazole	1	.7843
Cultivar x Propiconazole	4	.6942
Cl	1	.0001
Propiconazole x Cl	1	.5699
Cultivar x Cl	4	.0001
'Redwin' vs. 'Tiber' x Cl	1	.0226
Propiconazole x Cultivar x Cl	4	.7920

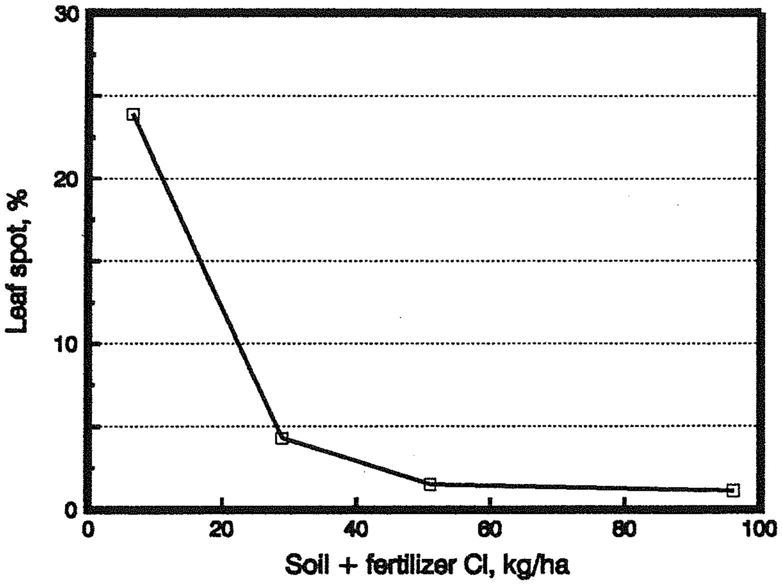

Figure 1. Effect of available Cl, soil Cl (0-120 cm) + fertilizer Cl, on physiological leaf spot severity in 'Redwin' winter wheat. Experiment 2. 1993.

Table 3. Winter wheat yield and thousand kernel weight in several winter wheat cultivars as affected by Cl and propiconazole. Experiment 1. 1993.

Yield results:

Cultivar	Control		resp.	Propiconazole		Mean	
	-Cl	+Cl	bu/A	-Cl	+Cl	-Cl	+Cl
	kg/ha						
Kestrel	3810	4354	8,1	4865	5127	4336	4739
Manning	2950	3178	3,4	4267	4918	3609	4050
Redwin	4179	4764	8,7	5368	5819	4774	5291
Stephens	6396	6907	7,6	7962	8567	7178	7734
Tiber	3548	3850	4,5	5153	5248	4351	4484
Average	**4179**	**4609**		**5523**	**5960**	**4850**	**5273**

Analysis of variance summary

Source	df	F test
Cultivar	4	.0001
Propiconazole	1	.0001
Cultivar x Propiconazole	4	.0184
Cl	1	.0001
Propiconazole x Cl	1	.8487
Cultivar x Cl	4	.6917
'Redwin' vs 'Tiber' x Cl	1	.1767
Propiconazole x Cultivar x Cl	4	.6962

Thousand kernel weight results:

Cultivar	Control		Propiconazole		Mean	
	Cl	+Cl	-Cl	+Cl	-Cl	+Cl
	grams					
Kestrel	29.3	30.6	31.7	32.0	30.5	31.3
Manning	26.6	28.3	30.6	32.3	28.6	30.3
Redwin	31.1	33.2	33.6	34.5	32.4	33.8
Stephens	41.2	43.3	46.3	49.4	43.7	46.4
Tiber	31.0	32.4	34.9	36.2	33.0	34.3
Average	**31.8**	**33.6**	**35.4**	**36.9**	**33.6**	**35.2**

Analysis of variance summary

Source	df	F test
Cultivar	4	.0001
Propiconazole	1	.0002
Cultivar x Propiconazole	4	.0005
Cl	1	.0001
Propiconazole x Cl	1	.5507
Cultivar x Cl	4	.1988
'Redwin' vs 'Tiber' x Cl	1	.8616
Propiconazole x Cultivarx Cl	4	.6294

'Redwin' winter wheat yield was affected by Cephalosporium stripe (*Cephalosporium gramineum*) in Experiment 2. Disease symptoms were present in at least 50% of the plants. Powdery mildew disease was present at this site, however, disease severity was considerable less than at Experiment 1. Propiconazole had no effect on Cephalosporium stripe, but did suppress Powdery mildew. Yield was increased by propiconazole but the response was not as great as Experiment 1 (Table 4). Economic yield response to Cl occurred only where propiconazole was applied. Without propiconazole yield was not appreciably improved by Cl. The reason for this significant interaction is not known. However, the results are consistent with conclusions from Experiment 1 and indicate that Cl yield responses are related more to improved plant nutrition than control of foliar diseases. Thousand kernel weight in the control and propiconazole plots were increased similarly by Cl. Hence, spike density and/or kernel per spike numbers must have been affected differently by Cl in the control and propiconazole treatments.

In Experiments 1 and 2 Cl application resulted in a greater economic return to the grower via increased yield. Maximum yield from Cl with propiconazole occurred at the lowest Cl application rate in Experiment 2. This is consistent with results from previous studies which suggest the available Cl requirement for maximum return may be only 33 kg/ha (Engel, 1993).

Table 4. 'Redwin' winter wheat yield, thousand kernel weight, and test weight as affected by several Cl fertilizer rates and propiconazole. Experiment 2. 1993.

Cl fertilizer	Propiconazole	Yield	1000 kernel wgt
kg/ha		kg/ha	gram
0	-	4003	33.3
22	-	4110	35.5
45	-	4193	34.4
90	-	4058	35.6
0	+	4097	34.7
22	+	4744	36.5
45	+	4787	35.8
90	+	4588	37.0

Analysis of variance summary

Source	df	F test	
Propiconazole (Pr)	1	.0269	.0271
Cl rate	3	.0959	.0028
0 vs 20,40,80	1	.0271	.0009
Pr x Cl rate	3	.2159	.9702
Pr x 0 vs 20,40,80	1	.0411	.9792

Plant Cl concentration and uptake

As expected whole plant Cl concentration were increased by fertilizer Cl application. In Experiment 1 whole plant Cl concentration at GS 10-10.1 were 1.7 and 5.6 mg/kg for the -Cl and +Cl treatments, respectively. Plant Cl concentrations in -Cl were higher than in Experiment 2 reflecting the higher background soil Cl levels. At Experiment 2 whole plant Cl concentrations decreased with plant development from GS 8 to GS 11.3 (Figure 2). The decrease in Cl concentration was approximately linear over GS 8 to GS 11.1 for fertilizer Cl levels 22, 45, and 90 kg/ha. The decrease in plant Cl concentration over time results because plant biomass is increasing without a proportionate increase in Cl uptake.

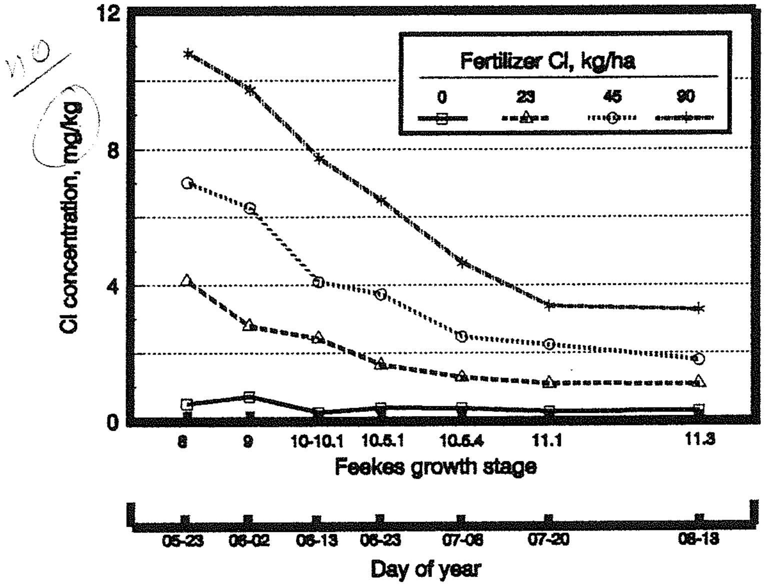

Figure 2. Effect of fertilizer Cl on whole plant Cl concentrations in winter wheat at several growth stages. Experiment 2. 1993.

Whole plant Cl uptake reached a maximum at GS 10 to GS 10.5.1 (Figure 3). During the ripening stages Cl uptake in the plant remained fairly stable at the lower Cl application rates, i.e. 0 and 22 kg/ha. At the higher Cl application rates there was a decrease in plant Cl at the last sampling date. It is possible that some Cl was leached during plant senescence by rain, or loss of Cl through the plant roots.

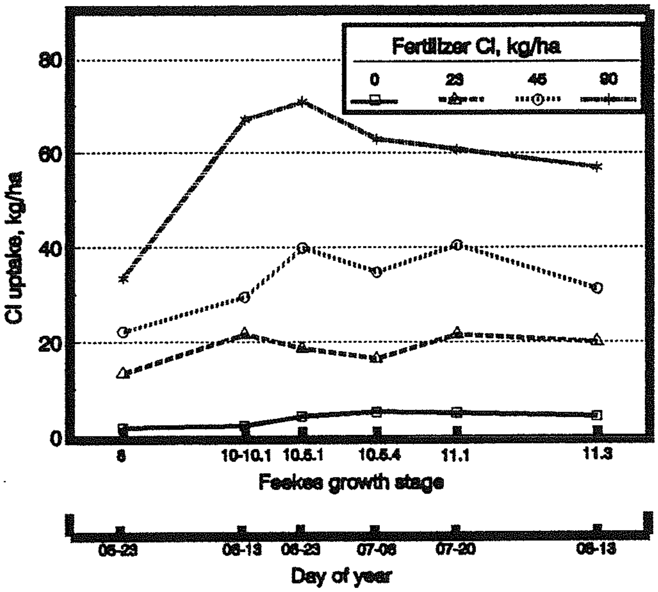

Figure 3. Effect of fertilizer Cl on whole plant Cl uptake in winter wheat at several growth stages. Experiment 2. 1993.

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