MT-10F Effect of chloride fertilization on yield and development rate of several winter wheat varieties in Montana, 1992.

Project Leader:

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Both non-disease and disease related Cl yield responses by winter wheat are being studied in this project. From 1988 to 1992, Cl increased winter wheat yield at 7 of 9 sites. The average Cl response at responsive sites was 4 bu/A but was as high as 9.1 bu/A. Chloride response for the variety Cree was 18 bu/A at one site in 1992. At several sites, Cl enhanced plant development and accelerated kernel growth rates. Both plant analysis and soil testing appear to be useful guides for identifying Cl responsive sites. These data are currently being used to help develop the potash market in the northern Great Plains.

REPORT TO POTASH AND PHOSPHATE INSTITUTE-1992

Effect of Cl fertilization on yield and kernel development of several winter wheat cultivars

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ABSTRACT

Fertilizer research in the Great Plains indicates that wheat yields are frequently improved by potash (0-0-60) on soils with seemingly abundant supplies of available K. The Cl component in this fertilizer may explain many of the observed yield responses. The objectives of this study were to determine the effect of Cl on yield, physiological development, kernel size and growth rate, foliar disease and/or disease-like symptoms in winter wheat. Fertilizer studies conducted from 1988-1992 indicate that Cl increased wheat yield at 7 of 9 sites. Yield increases averaged 267 kg/ha at responsive sites, but were as high as 611 kg/ha at one site. Overall, yield response size was affected more by site factors than cultivar selection. At several locations Cl enhanced plant development and accelerated kernel growth rates. Mature kernels sizes were increased by Cl, up to 17%, at 8 of 9 sites. Kernel size appears to be the most important yield component affected by Cl. Chloride reduced physiological leaf spot severity at 3 sites, particularly in 'Redwin' winter wheat. At 1 site powdery mildew (*Erysiphe graminis* f. sp. *tritic*), leaf rust (*Puccinia recondita* f. sp. *tritici*), and discoloration and/or bronzing in 'Weston' and 'QT542' flag leaves were suppressed by applied Cl. Plant analysis data from this study and a recent Great Plains survey indicates that a Cl concentration of 4.0 g/kg will ensure adequate Cl nutrition. Using this value a critical soil Cl level of 34 kg/ha (0-60 cm) was found to be necessary for adequate Cl nutrition.

INTRODUCTION

Chloride has been recognized as an essential plant nutrient since 1954 (Broyer et al., 1954). Initially it was classified as a micronutrient with plants requiring only trace amounts for their physiological functions. As soil Cl levels and inputs from rain were considered adequate to meet this requirement, until recently there was comparatively little attention given to Cl as a fertilizer. During the mid-1980's investigators in the Great Plains became interested in Cl fertilizers. This interest can be attributed to two factors: 1) studies in the Pacific Northwest indicating that Cl in fertilizers increased yield and suppressed take-all root rot in winter wheat caused by *Gaeumannomyces graminis* var. *tritici* (Taylor et al., 1981; Christensen et al., 1981); and 2) previous studies in the region documenting significant yield and quality responses by wheat and barley to potassium chloride, 0-0-60, on soils with seemingly abundant supplies of available K (Zubriski et al., 1970; Skogley, 1976; Schaff and Skogley, 1982).

Potassium chloride accounts for 95% of all K_2O fertilizer used. Hence when a grower applies K_2O fertilizer, either alone or in a blend, Cl is typically applied. In the Great Plains responses to the Cl component in KCl may be more common than previously believed. A review of small grain Cl research in the Great Plains indicated significant yield responses occurred in 42% of 166 cultivar x site x year episodes (Engel et al., 1992). Yield responses at significant episodes averaged 304 kg/ha.

South Dakota research indicates that return from Cl fertilization is potentially economical provided responses can be predicted (Fixen et al., 1986). Currently, South Dakota is the only state to have developed a soil Cl test recommendation (Fixen et al., 1987). Their calibration data for spring wheat indicates a response frequency to Cl applications of

69, 31, and 0% where soil Cl levels (0-60 cm depth) are 0-33, 33-66, and >67 kg/ha, respectively. Other states have found these guideline to be unreliable. Many investigators have expressed some difficulty and frustration in predicting responses. This difficulty may result because responses are often small, and because environmental factors beyond soil and plant Cl status appear to influence the probability of a response. Also, there is a lack of understanding of how Cl increases yield and affects crop growth.

In Montana studies were initiated in 1988 to determine i) if winter wheat would respond to Cl, ii) the processes involved and yield components affected, and iii) to generate a database that could be used to develop a soil Cl test and fertilizer recommendation program. This report provides an update and interpretation of research results from this study.

OBJECTIVES

- To determine the effect of chloride fertilization on grain yield, kernel weight, rate of kernel-filling, and grain-fill duration in several winter wheat cultivars.
- To determine if Cl fertilizer responses in winter wheat are affected by cultivar selection.
- To increase existing knowledge on the mechanism by which Cl improves small grain yields.
- To determine the effect of Cl on foliar diseases and disease-like symptoms in winter wheat when present.

METHODS

Field studies were conducted in south central Montana between 1988 to 1992 at 9 locations (Table 1). At all locations, except site 5, soil tested in the low category (0-60 cm) according to the calibration data of Fixen et al. (1987). Sites 1-7 and 9 were dryland, and site 8 was irrigated. Wheat was seeded in 30 cm rows at a rate of 72 kg/ha. Fertilizer KCl and K_2SO_4 were applied at seeding in a band located approximately 5 cm below and 7.6 cm to the side of the seed row. Sufficient fertilizer N and P were applied to ensure adequate nutrition of these nutrients according to soil test recommendations.

Sites 1-2

Factorial studies consisting of two winter wheat cultivars ('Cree' and 'Redwin'), five K levels (0, 24, 48, 96, and 144 kg/ha), two K sources (KCl and K_2SO_4), and six replications were established. Treatments were arranged as a RCB, split-split-plot design with cultivar as main-plot, K rates as sub-plots, and K source as sub-sub-plots. Plots receiving KCl were located adjacent to control or K_2SO_4 plot receiving an identical rate of K rate.

Table 1. Location, soil type, and background soil Cl level at study sites.

Site	Location	Year	Soil series	Taxonomic description	Soil Cl level	
					Soil depth (cm)	
					0-60	60-120
					——— kg/ha ———	
1	Forsyth	1988	Fort Collins, loam	fine-loamy, mixed, mesic Ustollic Haplargids	6.9	9.0
2	Forsyth	1988	Fort Collins, loam	fine-loamy, mixed, mesic Ustollic Haplargids	3.9	3.6
3	Garryowen	1991	Richfield silty clay loam	montmorillontic, mesic Aridic Agriustolls	4.4	5.6
4	Lodgegrass	1991	Farnuf loam	fine-loamy, mixed, Typic Agriborolls	3.5	19.5
5	Huntley	1991	Lohmiller silty clay loam	fine, montmorillontic, calcareous mesic, Ustollic Torrifluvents	34.0	45.5
6	Bighorn Mtn	1992	Judith clay loam	fine-loamy, carbonatic, Typic calciborolls	3.7	5.2
7	Lodgegrass	1992	Richfield silty clay loam	fine, montmorillontic, mesic Aridic Agriustolls	6.1	10.0
8	Huntley	1992	Fort Collins, clay loam	fine-loamy, mixed, mesic Ustollic Haplargids	17.7	6.9
9	Huntley	1992	Fort Collins, clay loam	fine-loamy, mixed, mesic Ustollic Haplargids	15.8	3.9

Sites 3-9

Factorial studies consisting of six winter wheat cultivars ('Cree', 'Manning', 'Neeley', 'QT542', 'Redwin', and 'Weston'), two Cl levels (0, 45 kg/ha), and four replications were established. Treatments were arranged as RCB, split-plot design with cultivar as main-plots and Cl level as sub-plots. Control and Cl plots were located side-by-side. Chloride was applied as Kcl in all studies. An equivalent rate of K was maintained by applying K_2SO_4 to the control plots. At site 3 an additional Cl rate study was included. 'Redwin' winter wheat was grown at five Cl fertilizer levels (0, 22, 45, 67, and 90 kg/ha) using a RCBD with six replications. Chloride and K were applied as Kcl and K_2SO_4 in appropriate amounts to achieve the desired Cl level and maintain a K level of 97 kg/ha.

DISCUSSION

Physiological development

Small differences in physiological development were apparent at several sites between Cl and control treatments. Chloride appears to accelerate plant growth during the vegetative stages. Visual differences were most obvious between the boot and flowering stages (Photograph 1). Though accurate measurements of plant development differences were not made, the effects appeared to be greatest at sites where drought and heat stress were low.

Photograph 1. Plant development differences in 'Cree' winter wheat at site 8. Control in front and Cl behind blue marker.

Winter wheat yield and factors affecting yield response

Chloride increased winter wheat grain yield (significance level <.05) at 7 of 9 sites (Table 2). At 6 of the 7 responsive sites yield improvement was great enough to cover the Kcl material cost of application assuming $.37/kg Cl and $.11/kg grain ($ 3.00/bu grain). A 300 mg/kg plant Cl level separated Cl responsive from non-responsive sites. However, below this level tissue Cl concentration was not a reliable predictor of yield response size. Apparently, environmental, soil, and/or plant factors beyond plant Cl status strongly interact with Cl and affect the magnitude of response at a specific location. This is consistent with a recent review of Cl research in the Great Plains (Engel et al., 1992).

Largest yield responses to Cl occurred at sites 2 and 6. Yield potential and growing season (1 March - maturity) environment differed greatly at these sites. Site 2 was characterized by extreme water (< 5.0 cm growing season precipitation) and heat stress. Site 6 was characterized by high-rainfall (42 cm growing season precipitation), extremely cool temperatures during grain-filling, and high foliar disease pressure (see plant disease section). Hence, it appears that Cl responses can occur over a wide range of environments and crop yield potentials (high vs. low).

Overall, cultivar selection did not appear to influence Cl response as much as site factors. In only two cases, sites 6 & 7, was the cultivar * chloride interaction significant ≤ 0.10 level. Anova across responsive sites indicated that cultivar selection did not significantly effect Cl yield response size (Cl yield - control yield) (Table 3). Although we suspect cultivars may differ in their responsiveness to Cl, the effects appear to be secondary or considerable less important than site factors.

Kernel growth rate and mature kernel weights

Chloride has frequently been observed to increase mature kernel weight and volume in wheat and barley (Engel et al., 1992). Larger mature kernels can be attributed to: 1) a prolonged grain-fill period (i.e. flower initiation to maturity), or 2) an accelerated kernel growth rate. To determine which process(s) might be involved we sampled and hand-threshed immature spikes periodically (3-5 times) during grain-fill at sites 3, 4, 6, 8, and 9. At sites 3,4,6, and 9 (Cl yield responsive sites) immature kernel weights were increased by Cl at every sampling date. At site 8 (no yield response to Cl) kernel weights were generally not affected by Cl. Regression analysis of kernel weight vs. time indicated that kernel growth rates were accelerated by Cl at sites 3, 4, and 6 (site 9 data has not been analyzed). Chloride accelerated kernel growth rates by 7% and 10% at sites 3 and 6, respectively (Figure 1). Precise dates of physiological maturity were not determined, however, the pattern of kernel growth vs. time, and mature kernel weights suggests that grain-fill duration did not differ greatly between the control and Cl plots (≈1 day).

Mature kernel weights were increased by Cl at 8 of 9 sites (Table 2). At the 8 responsive sites Cl increased mature 1000 kernel weights by an average of 2.0 g, or 6.5%. At 6 locations Cl increased kernel weight in similar proportion to, or at a proportionately greater rate than yield. Only at sites 2 and 6 was the Cl yield response size proportionately greater

Table 2. Winter wheat yield and mature kernel weight as affected by Cl. Control plant Cl concentration. Sites 1-9.

Site	Cultivars	Yield				1000 Kernel weight				Plant Cl conc.¶
		Control ‡	Cl§	Response	Prob > F	Control	Cl	Response	Prob > F	Control
		--------------- kg/ha ---------------				----------------- g -----------------				mg/kg
1	R,C	1831	1888	57*	.0095	20.6	23.0	2.4*	.0001	1050
2	R,C	962	1373	411*	.0001	15.0	16.8	1.8*	.0001	459
3	R,C,W,M,Q,N	3261	3378	117*	.0471	30.6	33.2	2.6*	.0001	640
4	R,C,W,M,Q,N	5214	5416	202*	.0051	36.6	38.1	1.5*	.0005	1330
5	R,C,W,M,Q,N	3941	4047	105..	.3027	34.2	34.2	0.0..	9289	3600
6	R,C,W,M,Q,N	5192	5803	611*	.0001	34.2	36.6	2.4*	.0001	265
7	R,C,W,M,Q,N	4314	4554	241*	.0034	36.2	38.9	2.6*	.0001	255
8	R,C,W,M,Q,N	6068	6157	89..	.5676	35.3	36.5	1.2*	.0173	3320
9	R,C,W,M,Q,N	5827	6058	230*	.0365	39.3	40.8	1.5*	.0001	2970
Mean over * sites =		3800	4067	267		31.0	33.0	2.0		

† R='Redwin'; C='Cree'; W='Weston'; M='Manning; Q='QT542; N='Neeley'

* Control = K2SO4; site 1 & 2 (mean of 24,48,96, & 144 kg/ha K); sites 3-9 (48 kg/ha K).

§ Cl = KCl; site 1 (mean of 24,48,96, & 144 kg/ha K); site 2 (96 kg/ha K); sites 3-9 (48 kg/ha K or 44 kg/ha Cl).

¶ Plant in boot stage at sites 3-9, and late-flowering at sites 1-2.

Table 3. Effect of cultivar selection on magnitude of Cl yield response at sites where Cl significantly (P < 0.10) increased yield.

Cultivar	Yield										
	Site 3		Site 4		Site 6		Site 7		Site 9		Mean
	Control	Cl respons	Control	Cl respons	Control	Cl respons	Control	Cl respons	Control	Cl respons	Cl respons
	kg/ha										
Cree	2957	183	4460	290	4163	1242	4066	179	5617	261	431
Manning	3327	143	5077	360	5233	396	4687	446	6130	226	314
Neeley	3298	237	5442	215	5663	125	4654	60	6493	87	145
QT542	3652	-21	5835	-124	5624	701	4495	556	6121	387	300
Redwin	3159	170	5157	219	5511	822	3821	396	5129	345	390
Weston	3173	-12	5302	251	4957	378	4160	-195	5545	119	108

Anova summary of Cl response

Source	df	Sum Squares	F value	Prob > F
Site	4	3485820	4.26	0.0118
Cultivar	5	1686984	1.65	0.1931
Site x Cultivar	20	4092525		

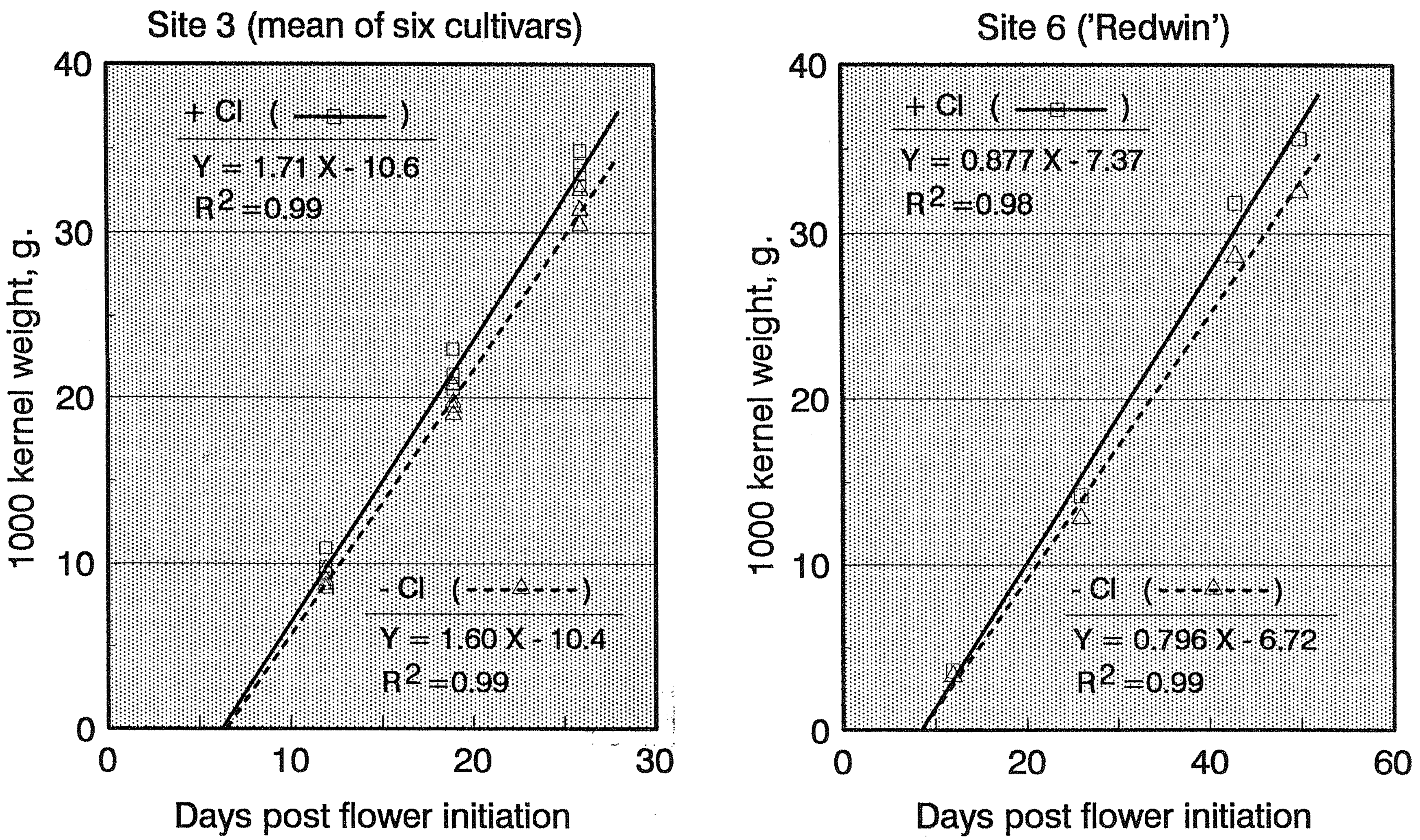


Figure 1. Effect of applied Cl on kernel growth in winter wheat. Sites 3 and 6. Note differences between slopes of +Cl and -Cl lines.

than the kernel weight response. At sites 1,3,7, and 8 kernel weights increased proportionately more than yield.

Spike or tiller density was not affected by Cl at sites were this yield component was measured, i.e. sites 3, 6, 8, and 9. However, variability within plots and the comparatively small area measured made it unlikely that we would fine small differences had they existed. At sites 4, 8, and 9 Cl caused a small decrease in kernel numbers in the larger more prominent spikes. Kernels per spike were not affected by Cl at site 6. In general, kernel size was the yield component most frequently increased by Cl.

The largest kernel weight response from Cl occurred at site 2 in 'Redwin' winter wheat. At this site a step-wise increase in kernel weight, up to 135 kg/ha Cl (144 kg/ha K), occurred from application of KCl (Figure 2). No response was observed from application of K_2SO_4. Kernel weight at 135 kg/ha Cl was 17% greater than at 0 Cl. Growing season conditions at this site were characterized by extreme drought and heat. Grain yield increased with kernel weights though at a proportionately greater rate. Yield at 0, 22.5, 45, 90, and 135 kg/ha was 1084, 1265, 1317, 1381, and 1441 kg/ha, respectively. Yield was not increased by K_2SO_4.

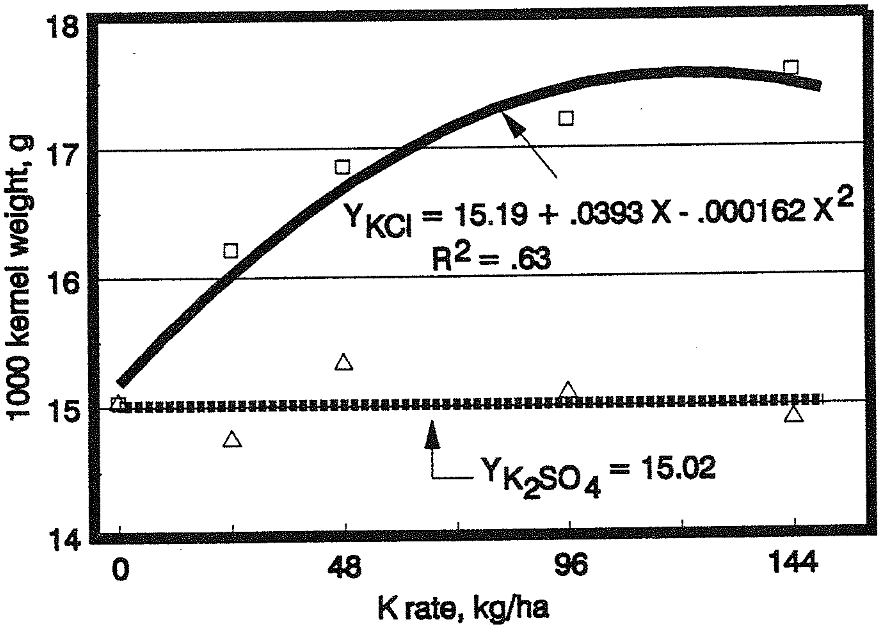


Figure 2. 'Redwin' winter wheat kernel weight as affected by KCl and K_2SO_4 rates. Site 3.

Physiological leaf spot and plant diseases

Winter wheat was affected by leaf spots of unknown origin at sites 3, 6, and 7. Symptoms initially appeared at flag leaf emergence to boot stage in the cultivars 'Redwin' and 'Manning'. Visual symptoms were similar to tanspot (*pyrenophora tritici repentis*). Spotting appeared first in the older leaves and advanced to younger leaves after they became fully emerged. In the early stages the lesions were circular to oblong in shape (1-10 mm diameter) with distinct margins. The interior contained a darker orange to brown center, surrounded by a yellow halo. During grain ripening, spots became necrotic and were bleached white or gray in color. In severely affected plants, spots coalesced and resulted in the premature senescence of the leaf.

Attempts to isolate a causal organism from affected areas of leaf blades produced inconsistent results. In some cases no organism could be identified. In other cases *Pyrenophora tritici repentis* was isolated from affected portions of the plant tissue. In Montana 'Redwin' winter wheat has a history of producing a physiological leaf spot, or a leaf spot that cannot be attributed to a biological pathogen. This may have been the phenomena observed in this study. Until conclusive evidence as to the etiology of these spots becomes available, they are probably best referred to as a physiological spotting.

Chloride fertilization reduced the severity of physiological leaf spots in 'Redwin' and 'Manning' (Table 4). The responses, particularly at sites 3 and 6, were dramatic and visually obvious. Occurrence and severity of leaf spots appeared to be affected by plant Cl levels, cultivar selection, and environmental conditions during the growing season. Leaf spotting was most severe in 'Redwin' followed by 'Manning'. Spotting was either absent or much less severe in the other cultivars tested. Leaf spotting occurred at locations where plant Cl levels in the control treatments were less than 0.7 g/kg. Cool, wet and humid growing conditions seemed to favor the occurrence, severity, and progression of leaf spots. Site 6, by far the wettest and most humid location, had the most severe leaf spotting. At sites 3 and 7 leaf spotting was less severe and more droughty than site 6. Leaf spots did not appear in 'Redwin' at site 2 though control plant Cl was < 0.7 g/kg. Growing conditions at this site were characterized by extreme heat and drought. Leaf spot suppression by Cl was particularly impressive at site 6. Flag leaves remained relatively free of spots (< 1.0%) thru maturity at this site. Chloride rate studies at site 3 indicate no difference in leaf spot severity over 22, 45, 67, and 90 kg/ha applied Cl (Table 5). The results suggest only small amount of Cl are required to maximize leaf spot suppression.

Powdery mildew (*Erysiphe graminis* f. sp. *tritic*) and leaf rust (*Puccinia recondita* f. sp. *tritici*) infection was apparent at sites 6 and 8. Symptoms were apparent at flowering and became progressively more severe to maturity due to high moisture and humidity conditions. With the exception of 'Redwin', it was difficult to make disease assessment comparisons between treatments due to lodging at both sites. Leaf diseases were affected by Cl at site 6, but not site 8, perhaps because of the lower plant Cl levels in the control. At site 6 (24 July) flag leaf area affected by powdery mildew was reduced ($P < .0760$) from 4.8% to 2.3% in control and Cl treatments, respectively. In flag-1 leaf affected area was reduced ($P < .0096$) from 45.9% to 25.7% in control and Cl treatments, respectively. Leaf rust in flag leaves (14 July) was reduced from 18% to < 1% in control and Cl treatments, respectively.

Table 4. Effect of chloride on physiological leaf spot (% necrotic and chlorotic area) in leaves of winter wheat.

Site	Cultivar	Leaf position	Head emergence			Anthesis			Milk stage		
			Control	Cl	Prob > F	Control	Cl	Prob > F	Control	Cl	Prob > F
			------- % -------			------- % -------			------- % -------		
3	Redwin	Flag	1.3	0.2	.0182	8.2	2.8	.0095			
		Flag-1	5.1	1.0	.0171	10.7	3.2	.0001			
		Flag-2	10.3	1.6	.0294						
	Manning	Flag	0.5	0.4	NS	2.9	1.6	NS†			
		Flag-1	1.5	2.2	NS	8.4	5.0	.0336			
		Flag-2	4.7	4.3	NS						
6	Redwin	Flag				25.1	1.6	.0001	27.3	0.8	.0001
		Flag-1				30.3	1.6	.0001	24.4	1.0	.0001
	Manning	Flag				10.7	0.0	.0001	10.2	0.2	.0001
		Flag-1				21.1	0.1	.0001	23.3	1.4	.0001
7	Redwin	Flag				13.0	0.3	.0001			
		Flag -1				16.0	0.3	.0001			
	Manning	Flag				1.2	0.1	NS			
		Flag-1				4.5	0.6	.0083			

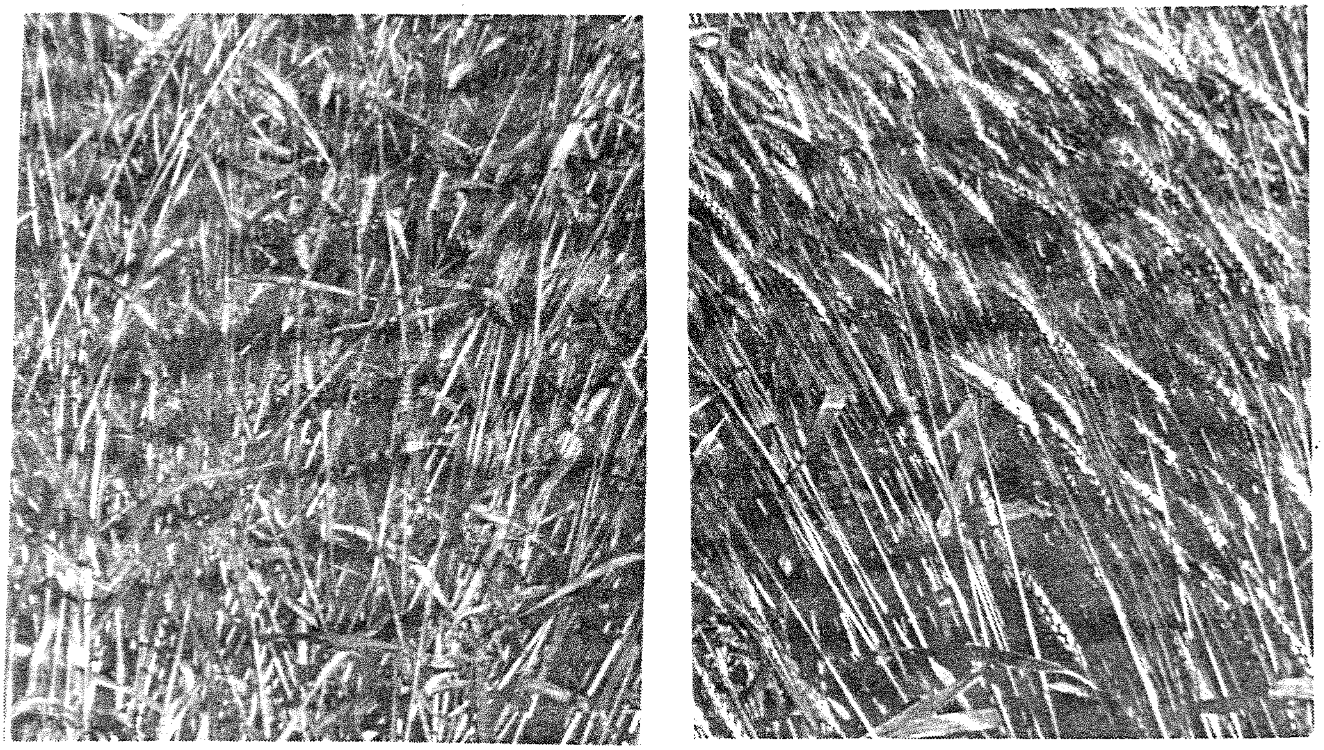
† NS = not significant at or below 0.10 level.

Table 5. Effect of Cl application rate on physiological leaf spot severity in 'Redwin' winter wheat at head emergence. Site 3. Mean of 3 replications only.

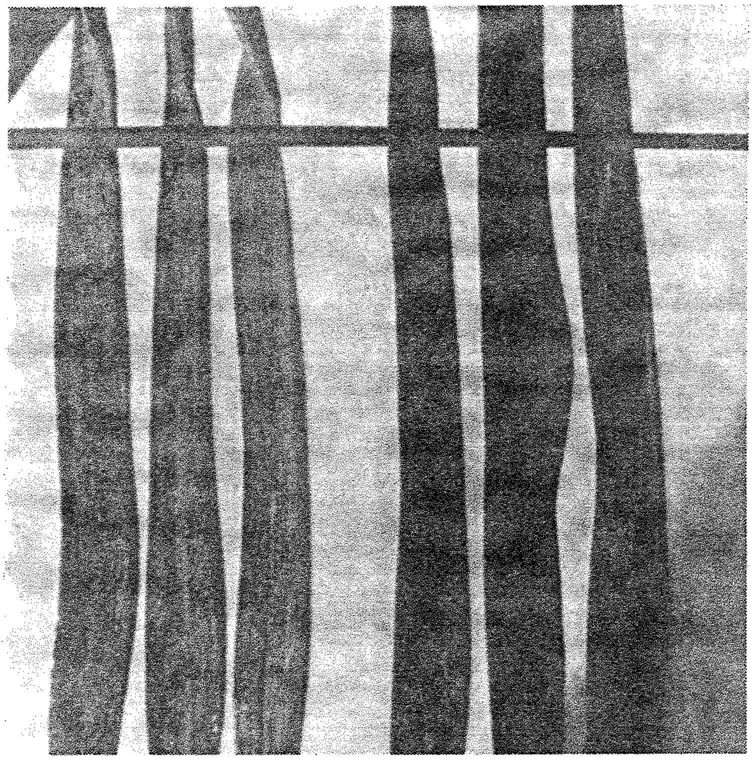
Applied Cl rate	Leaf position Flag	 Flag-1	 Flag-2	 Flag-3
kg/ha	%			
0	0.53	3.68	5.54	12.47
22	0.36	0.42	1.33	3.32
45	0.20	0.14	0.63	2.26
67	0.18	0.24	1.21	2.21
90	0.22	0.50	0.42	2.35
0 vs. rest	*	***	***	***
LSD(.05)	0.26	1.52	1.53	2.77

*, *** single df contrast significant < .05, 0.001 levels.

Approximately 26 day after anthesis (7 July) initiation a marked difference in discoloration appeared at site 6 between the control and Cl treatments in 'QT542' and 'Weston'(Photograph 2a and 2b). Chloride plots were greener and easily distinquished from adjacent control plots based on the amount of necrosis in the upper leaves (Photograph 3), and in some cases chlorosis of the stems. As with the leaf spotting the cause of this discoloration difference is not known. Analyses of 'QT542' flag leaf blades at this date revealed a Cl concentration of .177 g/kg and 1.19 g/kg in the control and Cl plots, respectively. A critical leaf Cl concentration of .250 g/kg was reported by Broyer et al. (1954) for tomato plants. Below this concentration tomato pant suffered from Cl deficiency disease, which was characterized by wilting of leaf blade tips; followed by, chlorosis, bronzing and necrosis. Curiously, the control plants in this study exhibited many of these symptoms. A discoloration index (i.e chlorosis and necrosis) was used to evaluate flag leaves on July 14, where 0=slight or no discoloration, leaves green; 1=moderate, some discoloration of leaf blade but primarily in isolated patches; 2=severe, discoloration over much of leaf blade; and 3=very severe, similar to 2 but greater than 50% of leaf blade necrotic. Results showed that Cl significantly (P <.0001) reduced the severity of flag leaf blade discoloration from an index of 2.0 to 0.5 in control and Cl treatments, respectively.



Photograph 2a (left) and 2b (right). Coloration differences in 'QT542' winter wheat between control (a) and Cl (b). Considerable lodging had occurred by this growth stage.



Photograph 3. Close-up of flag leaves from plants in photograph 2. Note necrosis and bronzing near tips. 'QT542' winter wheat, Site 6. Control (left), chloride (right).

Plant Cl levels and soil Cl test recommendation

Plant Cl levels at the boot stage appear to be useful in diagnosising potentially yield responsive from non-responsive sites to Cl fertilizer. Data from the present study is included with a recent four state Great Plains survey (Engel et al., 1992). Three zones of differing Cl status can be distinguished: a low range, ≤ 1.2 g/kg Cl, where Cl yield responses are observed approximately 80% of the time; a transition range (>1.2 - 4.0 g/kg Cl), containing an approximately equal mix of responsive and non-responsive episodes; and an adequate range (>4.0 g/kg Cl) where few significant responses to Cl are observed (Figure 3).

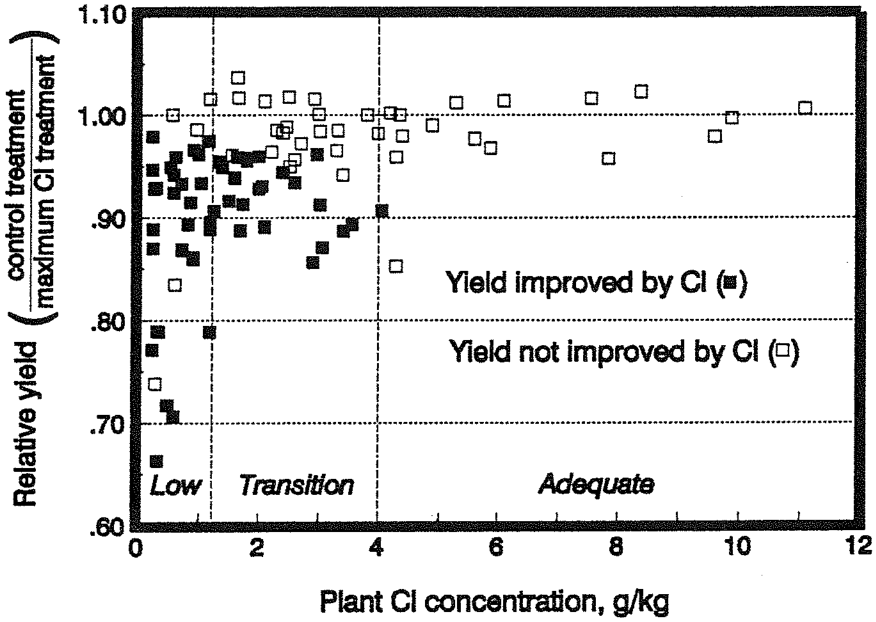


Figure 3. Plant Cl concentration in control treatments vs. relative yield in wheat and barley. 96 variety x site episodes over four Great Plain states.

Wheat Cl uptake and concentration was sensitive to the amount of soil Cl and fertilizer Cl applied. Plant Cl concentration increased with soil Cl (0-60 cm depth) in this study according to the relationship in Figure 3. Assuming a plant Cl level of 4.0 g/kg will ensure adequate Cl nutrition a critical soil Cl level of 34 kg/ha Cl (0-60 cm) can be defined from the curve. Application of Cl fertilizer should be made according to the following guideline:

Fertilizer Cl (kg/ha) = 34 - soil Cl (0-60 cm depth)

Though the relationship between soil and plant Cl was not precise, e.g. there were two data-points which are located well above the curve, the above guideline provides a estimate of Cl requirements by winter wheat based on interpretation of our current data-base. Plant Cl concentrations are affected by other factors including soil Cl below 60 cm in the profile, available water-plant relations, plant development stage, and soil nitrates. This factors may need to be considered in future updates.

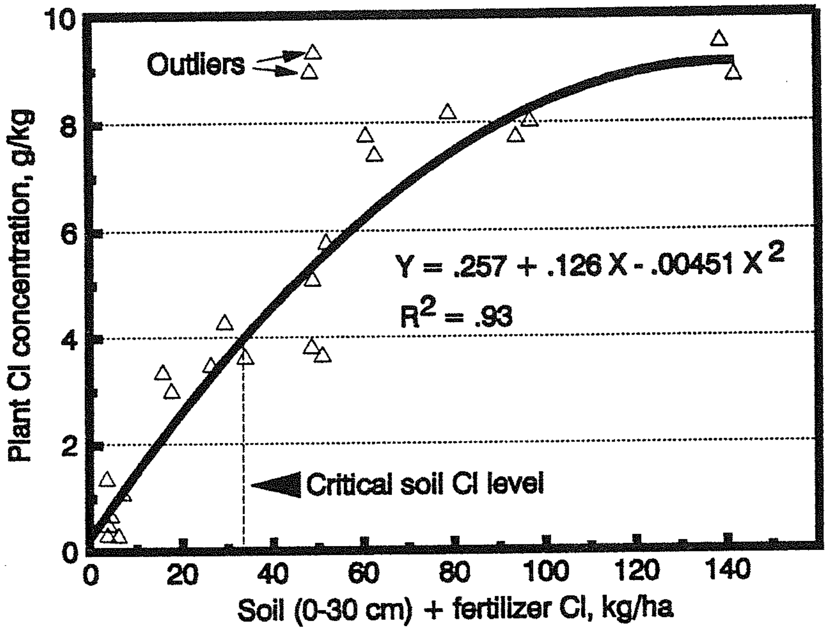


Figure 4. Effect of soil + fertilizer Cl on plant Cl concentration.

Although, plant Cl and/or soil Cl levels were not reliable predictors of yield response size, in most instances (7 of 8 sites, or 88% of locations) use of the fertilizer guideline above would have improved economic return to the grower. Chloride fertilizer, sold as 0-0-62, is currently priced at \$.37/kg Cl (\$16.80/cwt). Hence, the material cost of application using the above guideline is comparatively small. In addition, a large percentage of applied fertilizer Cl may be available to succeeding wheat crops under dryland conditions. Only small amounts of Cl are removed in the grain, i.e. < 3 kg/ha. Chloride in the wheat straw should be recycled and released to the soil as the residue decomposes. Also, as rainfall is comparatively low in Montana, leaching events are infrequent even though Cl is mobile in soils.

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Effect of Cl fertilization on yield and kernel development of several winter wheat cultivars

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INTERPRETATIVE SUMMARY

Fertilizer research in the Great Plains indicates that wheat yields are frequently improved by potash (0-0-60) on soils with seemingly abundant supplies of available K. The Cl component in this fertilizer may explain many of the observed yield responses. The objectives of this study were to determine the effect of Cl on yield, physiological development, kernel size and growth rate, foliar disease and/or disease-like symptoms in winter wheat. Fertilizer studies conducted from 1988-1992 indicate that Cl increased wheat yield at 7 of 9 sites. Yield increases averaged 4.0 bu/acre at responsive sites, but were as high as 9.1 bu/acre. At 6 of 7 responsive sites application of Cl improved economic return. Overall, yield response size was affected more by site factors than cultivar selection. At several locations Cl enhanced plant development and accelerated kernel growth rates. Mature kernels sizes were increased by Cl, up to 17%, at 8 of 9 sites. Kernel size appears to be the most important yield component affected by Cl. Chloride reduced physiological leaf spot severity at three sites, particularly in 'Redwin' winter wheat. At one site powdery mildew (*Erysiphe graminis* f. sp. *tritic*), leaf rust (*Puccinia recondita* f. sp. *tritici*), and discoloration and/or bronzing in 'Weston' and 'QT542' flag leaves were suppressed by applied Cl. Plant analysis data from this study and a recent Great Plains survey indicates that a Cl concentration of 0.40 % will ensure adequate Cl nutrition. Soil (0-24" depth) + fertilizer Cl levels of 30 lbs/a are required for adequate Cl nutrition and maximim grower return.