CHLORIDE FERTILIZATION ON WHEAT, CORN, AND GRAIN SORGHUM

Ray E. Lamond, David D. Roberson, Kirby Rector, and Brian H. Marsh[1]

ABSTRACT

Research in the Pacific Northwest and the Northern Great Plains has documented positive cereal grain responses to chloride (Cl) fertilization. Field research was conducted in Kansas evaluating Cl fertilization on winter wheat, corn, and grain sorghum. Chloride fertilization consistently and significantly increased plant Cl concentrations in all crops. Chloride fertilization increased grain yields or one or more winter wheat cultivars at 3 of 4 sites. The most dramatic yield increases were at the site having the lowest soil Cl level. One cultivar showed Cl deficiency symptoms at this site, which were eliminated with Cl application, and had a 23 bu/A response to Cl. The effects of Cl fertilization on corn and grain sorghum were less consistent, though several significant grain yield increases with Cl were noted. Responses to Cl fertilization appear to be most likely when soil Cl levels (0-24") are less than 20 lb/A and/or plant Cl concentrations are less than 0.10%. All chloride sources evaluated performed similarly.

INTRODUCTION

Chlorine, or more correctly, chloride (Cl) was determined to be an essential nutrient in 1954 by Broyer et al. Specific metabolic roles for Cl include functions in noncyclic photo-phosphorylation and in the riboflavin phosphate pathway of cyclic photophosphorylation reactions in photosynthesis. These reactions are responsible for the capture and storage of light energy in the form of high-energy phosphate bonds.

Chloride deficiency symptoms for crops are hard to describe as very few have been observed under field conditions. Plants suffering from severe deficiency of Cl have demonstrated chlorosis and necrosis of leaf areas. Leaf tips wilt followed by development of bronze coloration followed by necrosis. Engel et al., 1996, described a leaf spot complex, commonly called "physiological leaf spot", that results in leaf tissue necrosis in selected winter wheat cultivars in Montana. Their research indicates this problem results from inadequate chloride nutrition. They found the leaf spot where soils were < 1 ppm Cl and also determined that leaf spot damage was minimal when whole plant Cl at heading is > 0.10%.

Several researchers (Christensen et al., 1981; Powelson and Jackson, 1978; Fixen et al., 1986; and Goos, 1984) have documented positive yield responses of wheat and barley to Cl fertilization. Some of these responses were attributed to disease suppression with Cl fertilization while other responses appeared to be nutritional. Earlier work in Kansas (Bonczkowski, 1989) documented positive yield effects with Cl fertilization.

Many of the studies with cereal crops indicated that cultivars responded differently. In addition, much less work has been done with Cl fertilization on corn and grain sorghum. With this in mind research was conducted in Kansas to evaluate 1) Cl fertilization/wheat cultivar interactions and 2)

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[1] R.E. Lamond and B.H. Marsh are professor and assistant professor and D.D. Roberson is a graduate student in the Department of Agronomy, Kansas State University, Manhattan, KS., 66506; and K. Rector is a field agronomist for Ag. Services, Hillsboro, KS.

Cl fertilization of corn and grain sorghum.

MATERIALS AND METHODS

Wheat Studies

Field studies were conducted in Marion (MN 96, MN 97) and Saline (SA 96, SA 97) counties in 1996 and 1997. Soil test values for the sites are summarized in Table 1. Sixteen commonly grown winter wheat cultivars were seeded in early October each year. Seeding rate was 75 lb/A for all cultivars. Nitrogen and other needed nutrients were balanced and applied at levels sufficient for optimum wheat production. Treatments included a factorial arrangement of sixteen wheat cultivars and two Cl rates in a split plot design with six replications with cultivars as main plots and Cl rate as split plots. Chloride was applied as potassium chloride on half of each cultivar at 40 lb Cl/A as a February topdress. The other half of each main plot (cultivar) received no Cl. Whole plant samples were taken at boot stage and analyzed for Cl by potentiometric titration (LaCroix et al., 1970). Yields were determined by harvesting the center three rows of each plot with a binder and threshing. Yields were corrected to 13% moisture.

Table 1. Field studies site information.

Site[1]	Crop	Soil Type	pH	Bray-1 P	K	Cl[2]
				- - - - - ppm - - - - -		
MN 96	Wheat	sil	7.5	90	290	13
MN 97	Wheat	sil	5.8	118	321	7
SA 96	Wheat	sil	6.0	41	670	18
SA 97	Wheat	sil	5.9	62	704	22
RL 95, 96	Corn	sil	6.9	68	640	12
MN 95, 96	Grain Sorghum	sicl	6.1	47	340	13
BR 96	Corn	sicl	5.8	57	310	12
BR 96	Grain Sorghum	sicl	6.1	39	290	14

[1] MN, SA, RL, and BR are Marion, Saline, Riley, and Brown Counties.
[2] All soil test values are 0-6", except Cl which is 0-24".

Corn and Grain Sorghum Studies

Field studies were conducted in 1995 and 1996 in Riley (RL 95, RL 96), Marion (MN 95, MN 96), and Brown (BR 96) Counties. Soil test values for experimental sites are summarized in Table 1. Over the course of this work Cl sources including potassium chloride (KCl), ammonium chloride (NH_4Cl) and an experimental material (24-0-0-9.5 Cl) were evaluated (not necessarily at every site). Chloride rates (0, 10, 20, 30, 40 lb/A) were also evaluated (rates varied depending on location). All chloride treatments were applied at planting time (surface broadcast). Nitrogen and other needed nutrients were balanced on all treatments. Leaf samples were taken at V-6 and/or tassel/boot stages for Cl analysis by potentiometric titration. Grain yields were determined either by hand or machine harvest, depending on location. Yields were corrected to 15.5% moisture for corn and 14% moisture for grain sorghum.

RESULTS AND DISCUSSION

Wheat Studies

Effects of chloride fertilization and cultivar on plant Cl are summarized in Table 2. Chloride fertilization significantly increased plant Cl concentrations at both sites each year for all sixteen cultivars. Significant differences in plant Cl were noted between cultivars both in the absence or presence of Cl fertilization; suggesting different cultivars take up Cl differently. The site with the lowest soil Cl level (MN 97) had the lowest plant Cl concentrations as all 16 cultivars were less than 0.10% Cl without Cl fertilization.

Table 2. Wheat cultivar plant Cl concentrations as affected by Cl fertilization.

		Whole plant Cl concentrations							
		MN 96		MN 97		SA 96		SA 97	
Cultivar		-Cl	+Cl	-Cl	+Cl	-Cl	+Cl	-Cl	+Cl
		- - - - - - - - - - % - - - - - - - - - -							
AP 7510		.20	.49	.07	.50	.49	.60	.40	.60
Cimarron		.30	.55	.06	.40	.53	.64	.36	.49
Coronado		.26	.53	.07	.44	.49	.61	.35	.59
Custer		.28	.60	.06	.39	.57	.64	.36	.50
Jagger		.32	.56	.06	.48	.53	.60	.35	.55
Karl 92		.23	.50	.06	.41	.39	.51	.32	.48
Ogallala		.23	.38	.06	.31	.43	.52	.29	.41
Pecos		.24	.60	.05	.46	.49	.60	.33	.57
Rowdy		.30	.47	.07	.35	.50	.59	.34	.50
Tam 107		.24	.51	.06	.44	.47	.54	.33	.48
Tam 200		.32	.59	.06	.47	.60	.67	.36	.57
Tomahawk		.23	.54	.05	.45	.44	.55	.31	.53
2137		.25	.59	.07	.47	.39	.55	.33	.52
2163		.27	.66	.06	.52	.47	.68	.41	.64
2180		.26	.57	.07	.39	.48	.60	.35	.52
7853		.24	.45	.07	.36	.40	.51	.32	.45
LSD (0.10)	Between Columns	.02		.01		.02		.02	
	Cultivar x Cl	NS		NS		NS		NS	

At this location, the cultivar 'Cimarron' showed classic leaf spotting without Cl and these symptoms totally disappeared when Cl was applied. This cultivar has a history of occasionally showing leaf spotting and this research shows the leaf spotting is actually Cl deficiency. These data show an excellent relationship between soil and plant Cl levels.

Chloride fertilization significantly ($P < 0.10$) increased wheat yields of one or more varieties at 3 of 4 sites over two years (Table 3). The positive yield impact of Cl fertilization appears to be a nutrient

Table 3. Wheat cultivar yields as affected by Cl fertilization.

		Grain Yield							
		MN 96		MN 97		SA 96		SA 97	
Cultivar		-Cl	+Cl	-Cl	+Cl	-Cl	+Cl	-Cl	+Cl
		- - - - - - - - - - bu/A - - - - - - - - - -							
AP 7510		46	52	82	86	63	66	96	96
Cimarron		39	40	50	73	36	37	79	80
Coronado		32	34	79	83	45	43	87	80
Custer		46	48	82	87	56	57	100	95
Jagger		39	41	88	90	53	57	98	89
Karl 92		55	54	77	87	51	53	87	82
Ogallala		52	50	82	81	57	55	89	90
Pecos		50	48	85	91	57	55	92	94
Rowdy		26	27	82	85	31	34	91	88
Tam 107		26	56	83	87	64	64	82	88
Tam 200		20	20	69	77	36	38	81	81
Tomahawk		52	53	84	83	60	64	87	83
2137		63	63	89	91	65	67	100	99
2163		55	58	87	97	57	60	99	93
2180		43	44	80	79	37	44	79	85
7853		50	49	73	71	50	54	82	89
LSD (0.10)	Between Columns	2		2		2		NS	
	Cultivar x Cl	NS		NS		NS		NS	

response as leaf disease pressure was very low at every site. Yield responses were particularly impressive at MN 97 where 'Cimarron' produced an additional 23 bu/A with Cl fertilization. This site had a very low soil Cl level (7 lb/A, 0-24") and this cultivar showed Cl deficiency symptoms without Cl. Twelve of the sixteen cultivars significantly responded to Cl fertilization at this site. The site where Cl fertilization had no effect on yields (SA 97) had the highest soil test Cl level (22 lb/A) of all sites and had plant Cl concentrations of 0.29% or higher without Cl.

Evaluation of the data clearly suggests cultivar differences in response to Cl fertilization. Several cultivars consistently responded, however, the cultivar 'Ogallala' did not respond to Cl fertilization at any site. Further evaluation of wheat cultivars is needed. This work is being repeated in 1998 and several other cultivars which tend to occasionally show leaf spotting are being included.

Corn and Grain Sorghum Studies

Results of Cl fertilization work on corn and grain sorghum are summarized in Tables 4, 5, 6 and 7. All of these sites were in dryland production. Chloride fertilization, regardless of source, consistently and significantly increased leaf Cl concentrations at V-6 and/or tassel/boot stage.

The effects of Cl fertilization on grain yields were inconsistent. Significant yield increases were noted at 2 of 3 corn sites and 2 of 3 grain sorghum sites, although not all Cl treatments were better than the no Cl check. Interestingly, the leaf Cl concentrations (tassel or boot stage) of the no Cl treatments at responsive sites were 0.14% or less and the non-responsive sites were 0.20% or higher. Chloride sources performed similarly.

We have several studies out in 1997 on both corn and grain sorghum.

CONCLUSIONS

Chloride fertilization increased yields of some wheat cultivars. Yield increases were most consistent when soil Cl levels are < 20 lb/A (0-24") and when plant Cl concentrations are < 0.10%. Some wheat cultivar yields were unaffected, regardless of soil Cl level. Chloride fertilization consistently increases plant Cl concentrations, regardless of soil Cl level. At low soil Cl levels, Cl deficiency symptoms were noted on 'Cimarron' which were corrected by Cl fertilization. Chloride fertilization on corn and grain sorghum has produced inconsistent yield effects, though some positive responses have been observed. Both soil and plant analyses appear to be good predictors of potential Cl responses, however the possibility of a Cl nutrition/plant disease interaction can also be a factor.

Table 4. Chloride fertilization on corn and grain sorghum, eastern and central Kansas, 1995.

Cl Rate	Cl Source	Corn, Riley Co.			Grain Sorghum, Marion Co.		
			Leaf Cl			Leaf Cl	
		Yield	6-Leaf	Tassel	Yield	6-Leaf	Boot
lb/A		bu/A	- - - % - - -		bu/A	- - - % - - -	
0	--	70	0.12	0.09	87	0.15	0.13
20	24-0-0-9.5 Cl	94	0.73	0.18	94	0.44	0.18
40	24-0-0-9.5 Cl	83	1.05	0.25	102	0.75	0.26
20	KCl	84	0.62	0.20	97	0.56	0.22
40	KCl	88	0.74	0.23	96	0.80	0.30
LSD (0.10)		16	0.20	0.06	11	0.14	0.04

Table 5. Chloride fertilization on corn, 1996.

Cl Rate	Cl Source	Riley Co.			Brown Co.		
			Leaf Cl			Leaf Cl	
		Yield	6-leaf	Tassel	Yield	6-leaf	Tassel
lb/a		bu/a	- - - % - - -		bu/a	- - - % - - -	
0	--	127	0.18	0.23	108	0.50	0.14
20	NH_4Cl	130	0.21	0.28	118	1.39	0.19
40	NH_4Cl	136	0.47	0.39	113	1.35	0.29
20	KCl	128	0.32	0.30	123	1.42	0.22
40	KCl	137	0.54	0.38	130	1.49	0.31
LSD (0.05)		NS	0.07	0.06	11	0.44	0.12
Mean Values:							
Cl	20	129	0.27	0.28	120	1.41	0.20
Rate	40	137	0.51	0.37	122	1.42	0.30
LSD (0.05)		NS	0.04	0.03	NS	NS	0.06
Cl	NH_4Cl	133	0.34	0.34	116	1.37	0.24
Source	KCl	133	0.43	0.32	127	1.46	0.27
LSD (0.05)		NS	NS	NS	7	NS	NS

Table 6. Chloride fertilization on grain sorghum, Cornbelt Experiment Field, Brown Co., KS, 1996.

Cl Rate	Cl Source	Yield	Leaf Cl	
			6-leaf	Boot
lb/a		bu/a	- - - % - - -	
0	--	119	0.82	0.08
20	NH_4Cl	127	1.17	0.27
40	NH_4Cl	121	1.20	0.41
20	KCl	123	0.90	0.24
40	KCl	130	1.28	0.36
LSD (0.05)		10	0.38	0.09
Mean Values:				
Cl	20	125	1.03	0.25
Rate	40	125	1.24	0.38
LSD (0.05)		NS	0.17	0.05
Cl	NH_4Cl	123	1.19	0.34
Source	KCl	127	1.09	0.30
LSD (0.05)		NS	NS	NS

Table 7. Chloride fertilization on grain sorghum and soybeans, Marion Co., KS, 1996.

Cl Rate*	Grain Sorghum Yield
lb/a	bu/a
0	106
10	106
20	120
30	108
40	103
LSD (0.05)	NS

* Cl applied as KCl, broadcast after planting.

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Dr. Gary Hergert
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West Central Research & Extension Center
Route 4, Box 46A
North Platte, NE 69101