Response of Spring Wheat to Chloride Fertilization at Craik, Saskatchewan

J.J. Schoenau, V. Jowkin, C. MacLeod, *M. Ruszkowski

Department of Soil Science, University of Saskatchewan
* SAF Extension Agrologist, Davidson, Saskatchewan

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Introduction

Investigations into cereal yield responses to chloride began in the late 1970's. Christensen et al. (198l) and others working in the U.S. Pacific Northwest showed significant yield increases from chloride applied to winter wheat affected by take-all root rot. Since then other studies have been conducted in the Northern Great Plains of the U.S. (e.g. Fixen et al., 1986; Engel et al., 1994) as well as in Saskatchewan (Wang, 1987) which demonstrated root rot suppression and occasional yield response to chloride fertilization of wheat. Chloride plays a role in plant nutrition in certain physiological functions including maintaining cell water balance, but particular benefits can also be attributed to its role in suppressing plant diseases like root rot and leaf spot. In a recent review of chloride nutrition of wheat in the Great Plains, Engel (1995) describes research work in Montana directed towards broadening the wheat chloride fertility data-base. Research into chloride response in Western Canada is also being conducted by Grant and co-workers at AAFC Brandon who are examining varietal differences in chloride response and also by Fowler at the Crop Development Centre in Saskatoon, working with winter wheat.

To date, studies on chloride response such as those in Montana have been based on replicated small plot experimental designs. Franzen (1996) has recently reported significant variability in chloride content across grid-sampled fields in North Dakota Such variability may be partly explained by topography, as chloride is a mobile ion and therefore is susceptible to greater leaching losses in depressions where runoff water accumulates. To address the issue of possible spatial controls on soil chloride levels and Cl fertilizer response in Saskatchewan, a landscape-scale study of spring wheat response to KC1 fertilization was conducted in 1996. The site was a field on the District 15 ADD Board Demonstration Farm south of Craik, Saskatchewan that had been identified as chloride deficient based on soil tests taken in the fall of 1995.

Methodology

In the spring of 1996, ten shoulder and ten footslope landscape positions were identified and marked on both the left (west) and right (east) sides of a twenty acre field (plot 6) on the District 15 ADD demonstration farm at Craik. The field is typical of the area: gently undulating Weybum association which had been in fallow the previous year. In late April before seeding, soil cores (O-60 cm) were taken at each of the ten shoulder and ten footslope sampling points on the two sides of the field. The cores were segmented into 0 - 15, 15 - 30 cm and 30 - 60 cm increments and available Cl determined by extraction of 10 g of soil with 20 mL of 0.004M $CaSO_4$. Soil Cl below 60 cm is considered to be of limited availability to wheat as compared to Cl in the upper 60 cm (Fixen et al., 1986).

The field was seeded to hard red spring wheat (var. Columbus) in mid May using an air-seeder. The left side of the field received 40 lb/ac KC1 (potash O-0-60) seed-placed as a chloride source while the right side received no KCl.

When the spring wheat crop was near the heading stage (July 23), whole above-ground plant samples were taken from each of sampling points. The plant sample from each sampling point was then dried, ground and extracted with deionized water to determine tissue Cl concentration using automated calorimetry. The potassium (K) concentration in the plant samples was determined by acid digestion and flame emission spectrophotometry.

At maturity (August 22), square meter samples at each sampling point were used to determine grain and straw yields.

Results and Discussion

The mean spring pre-plant soil profile chloride levels (lb Cl / ac) on the left and right sides of the field before KC1 fertilization are shown in Table 1. On the two sides of the field, the landscape positions selected were a good match in spring profile (O-60 cm) Cl levels: 47 lb/ac vs 50 lb/ac in shoulders; 32 lb/ac vs 29 Ib/ac in footslopes.

Table 1. Pre-plant , pre-fertilization soil profile Cl contents (lb Cl / ac) on the left (L) and right sides (R) of a 20 acre gently undulating Weybum loam field near Craik, Saskatchewan. Values presented are means of 10 shoulder and 10 footslope landscape positions sampled on each side of the field in late April, 1996. Standard deviations are given in parenthesis.

	Pre-plant spring soil Cl: lb/ac							
	0-15 cm		15-30 cm		30-60 cm		0-60 cm	
	L	R	L	R	L	R	L	R
Shoulders (n= 10)	13	14	13	8	21	28	47 (12)	50 (25)
Footslopes (n=10)	9	10	3	8	20	11	32 (20)	29 (14)

On average, the footslopes had about 15 - 20 lb/ac less chloride in the top 60 cm compared to the shoulders, although the difference was not statistically significant at the 0.05 level. The trend towards lower chloride content in soil profiles of footslope positions in the landscape may be explained by greater leaching and crop removal of chloride in these landscape positions. However, it is important to note that grain removal of chloride is only in the order of l-3 lb Cl / ac (Engel, 1995), with upwards of 80 - 90 % of the total Cl in the plant remaining in the straw. The Cl in straw will be readily returned to the soil after harvest by leaching from the residue. As chloride is highly mobile in the soil, it seems likely that the accumulation of run-off water in depressions and subsequent leaching, especially in early spring, would be a more important factor contributing to a lower soil Cl content in the footslopes. In general, in Western Canada the yearly inputs of available Cl (atmospheric accession and mineral weathering) are small relative to the potential losses by leaching that could occur in wet years in well-drained depressions of undulating landscapes.

Proposed fertilizer Cl guidelines for Montana for wheat are to bring plant available Cl (fertilizer + soil Cl) to 32 lbs/ac (Engel, 1995). Using these guidelines, one would expect to see no yield response to fertilizer Cl on the shoulders (-50 lb available soil Cl / ac O-60 cm), but possibly encounter a response in the footslopes (-30 lb available soil Cl / ac O-60 cm). Guidelines for Saskatchewan (1994 Farm Facts: Potassium and Chloride Fertilization in Crop Production) as published indicate that > 30 lb Cl / ac (O-60 cm) and > 10 lb Cl / ac (0 - 30 cm) is adequate. Based on the Farm Facts guidelines, no response would be expected on the shoulders with a possible response on the footslopes.

The plant response data for tissue concentrations of Cl, K and grain and straw yield are provided in Table 2. Addition of 40 lb KC1 / ac resulted in significantly higher mid-season wheat tissue Cl concentrations in both shoulders and foot-slopes, with the largest difference observed in the footslopes. Engel (1995) has proposed that the desired critical wheat tissue Cl concentration at head emergence is 0.40%. Shoulder positions without KC1 added had tissue concentrations which on average exceeded this value while footslopes had average tissue Cl near the critical value. Tissue Cl concentration at two of the sampling points in the control (no KCl) footslopes was below 0.3%. Fertilization with KC1 at 40 lb/ac increased the tissue Cl concentrations well above the critical level, with wheat tissue in fertilized footslopes having an average of 1.0% Cl.

Table 2. Wheat tissue Cl and K concentrations (heading) and grain and straw yields in KC1 fertilized (left side) and unfertilized (right side) treatments in a 20 acre gently undulating Weybum loam at Craik, Saskatchewan in 1596. Values presented are means of ten shoulder and ten footslope landscape positions in each of the two treatments. Standard deviations are in parenthesis below the means.

	Tissue Cl (heading) %		Tissue K (heading) %		Grain Yield kg/ha		Straw Yield kg/ha	
	KCl	no KC1	no KCl		KClo	KCl	KClo	KCl
Shoulders **(n=10)**	0.80	0.52	2.52	2.56	2340	2010	4730	4880
	(0.10)	**(0.16)**	**(0.41)**	**(033)**	**(383)**	**(242)**	**(830)**	**(530)**
Footslopes **(n=10)**	1.01	0.43	2.82	3.00	2410	1140	5410	5600
	(0.22)	**(0.14)**	**(0.14)**	**(0.14)**	**(728)**	**(428)**	**(990)**	**(1390)**

When KC1 is used as the chloride source, the question arises as to whether a yield response is attributable to the chloride or whether it is due to the added potassium. The available potassium concentration as determined on a composite soil sample taken from the field in the fall of 1995 revealed a concentration of 390 lb available K / ac O-15 cm, which is considered sufficient for wheat production. Mid-season tissue K concentrations were in the range of 2.5 to 3.0% K, above the critical levels normally reported for wheat at heading (1.5 to 2.0%) and were not significantly different between KC1 and control (no KCI) treatments. These results indicate that the wheat is sufficiently supplied with potassium in the control treatment and a yield response attributable to the K in the KC1 is unlikely.

Final grain and straw yield data in Table 2 revealed a significant yield response to application of the KC1 fertilizer in the footslope positions. Mean grain yield was increased by over 100% (1270 kg/ha) in the footslopes where KC1 was applied. Grain yields were low (1140 kg/ha) in the control footslopes compared to the shoulders. Grain yield response to KC1 on the shoulders was limited and not significant at $p=0.05$. Straw yields were unaffected by KC1 addition on both footslopes and shoulders. The low grain yields in the control footslopes and the observed large grain yield response to KC1 addition may reflect increased incidence of root rot and leaf diseases in the footslopes under low soil chloride status which influenced grain filling and kernel size. Engel (1995) reported that kernel size was the yield component most frequently affected by Cl fertilization. Although no systematic measure of disease incidence was made at the Craik site, visual observations did not reveal any large differences in disease incidence in KC1 versus control treatments. Engel (1995) identified a physiological leaf spot symptom that was not disease related but was associated with low soil Cl and prolonged wet, cool weather during vegetative growth. Evidently, the mechanisms through which Cl influences plant physiology, pathology and ultimately yield require more clarification.

Conclusions

Soil chloride levels and chloride fertilizer response appears to be landscape-dependent, with greater potential for Cl fertilizer response in the more highly leached footslopes and depressional areas of fields. In southern Saskatchewan, the low-lying areas of a field typically exhibit the most rank growth due to high moisture and nitrogen availability. As such, they are also the locations where root and leaf diseases of cereals are often most prevalent and where one might expect Cl to have the greatest positive influence. Precision Cl fertilization involving selective application of KC1 to footslopes and depressions in farm fields would lead to substantial economic gains if the high yield response (-16 bu/ac) observed in this single site - year experiment was reasonably consistent over time. However, much of the past Cl fertilizer research work has shown that Cl responses are variable and difficult to predict because environmental conditions appear to play such a large role in the response. The soil and plant diagnostic tools and guidelines, although conservative given the large response observed at this location, appeared to work well in showing response differences in the field.

More site-years of data on landscape-based Cl response is required to be definitive in yield response prediction. As well, more information is needed on the effectiveness of a single application of KC1 in supplying Cl in subsequent years. It seems likely that recycling of Cl through the straw should be relatively effective in maintaining Cl for some time in the future.

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