Chloride in Kansas: Plant, Soil, and Fertilizer Considerations

Department of Agronomy MF-2570 Soil Fertility

Chloride (Cl) is one of 16 elements essential for crop growth. Because it is needed in small quantities, chloride is considered a micronutrient. Chloride deficiencies in crops in Kansas and the Great Plains have been identified and confirmed. The purpose of this publication is to discuss chloride in terms of plant, soil, and fertilizer considerations.

Plant Considerations

Chloride is taken up by plants as the Cl^- ion. A major function of chloride in plants is as a counterion for cation (Ca^+, K^+, Mg^+, NH_4^+) transport and as an osmotic solute. As a counterion, chloride maintains electrical charge balance for the uptake of essential cations. In addition, chloride serves an essential role in maintaining cell hydration and turgor. A critical role of chloride is as a cofactor in the oxidation of water in photosynthesis and as an activator of several enzymes. Although some chlorinated organic compounds exist in plants, no evidence exists that these compounds are essential.

Even though research in 1954 identified chloride as an essential plant nutrient, little concern existed about supplying this element as part of a complete fertilization program. However, by the early 1980s, research conducted in several states indicated responses to chloride fertilization when soil chloride levels were low. In addition, chloride application has been shown to suppress or reduce the effects of numerous diseases on a variety of crops. The exact mechanism of this effect is not well defined, but may be related to the role of chloride in osmotic regulation. In wheat, chloride has been shown to suppress take-all root rot, tan spot, stripe rust, leaf rust, and Septoria, while in corn and grain sorghum it has suppressed stalk rot.

Physical symptoms of chloride deficiency on plants vary and are not always consistent. In wheat, some varieties show a characteristic leaf spotting, best described as random chlorotic spots on the leaves. The spots resemble tan spot lesions, but are smaller and do not have the characteristic “halo” at the edge of the spot. In Kansas work on low chloride soils, some varieties consistently show the leaf spotting, while other varieties never spot. Montana research also verified variety differences. Other Kansas research indicates no obvious visual deficiency symptoms occurred on corn or grain sorghum, even where chloride fertilization increased yields.

Excessive levels of chloride in the soil can result in chloride sensitive crops accumulating excessive amounts of Cl^-, which can be toxic. For example, in the southeastern United States where large amounts of potassium chloride have been applied to supply needed potassium, high soil chloride levels exist. Chloride sensitive soybean varieties can show toxicity on these soils. In Kansas, the only situation where chloride toxicity may be a factor is on saline soils. In this case, the major detrimental effect of chloride results from its contribution to osmotic stress caused by excessive salts in the root zone.

Soil Considerations

Chloride is normally present in the soil in sizeable quantities, particularly in U.S. coastal areas where chloride deposition is high. Estimates of chloride levels in soils range from near zero to more than 1,000 pounds per acre. Limited evaluation in Kansas indicates fairly low soil chloride levels. This could be due to low chloride deposition (distance from oceans) and the relatively high indigenous potassium levels of the majority of Kansas soils, which means very little potassium chloride fertilizer has been applied. Summaries of soil test data in Kansas show a majority of the samples had chloride levels below 40 pounds per acre, with a significant number of samples less than 10 pounds per acre (on 0- to 24-inch samples).

As an anion, chloride is not readily adsorbed on the soils exchange complex and is subsequently not attached. Because of this, chloride moves readily with soil water. Chloride is quite leachable, even more so than nitrate. In fact, leaching of chloride is often used as a tracer for movement of other soluble anions such as nitrate or sulfate. The oxidation state of chloride in the soil is not changed by soil microorganisms.

The Kansas State University Soil Testing Laboratory and most commercial labs offer a chloride soil test. Because of the leaching potential of chloride, we recommend sampling to a depth of 24 inches to best assess soil chloride status (just like nitrogen and sulfur). When testing for pH, P, K, organic matter, and Zn, a 0- to 6-inch sample is recommended. When testing for the mobile nutrients (N, S, or Cl) a 0- to 24-inch sample is recommended.

Fertilizer Considerations

Several potential sources of chloride exist, including man-made fertilizers, atmospheric deposition, and naturally occurring chloride already in the soil. The atmospheric deposition of chloride in Kansas is quite low, and many Kansas soils are low in naturally occurring chloride. Thus, fertilizers become an important chloride source.

Potassium chloride (KCl) or muriate of potash is the most common and readily available chloride containing fertilizer in Kansas. On an elemental basis, potassium chloride fertilizer is 53 percent potassium and 47 percent chloride. For ease of calculating, we assume it to be roughly 50 to 50 potassium to chloride. For example, if 50 pounds of potassium chloride fertilizer is applied, about 25 pounds of chloride would be furnished. Since phosphorus and potassium in fertilizer are reported on an oxide basis (P_2O_5 and K_2O), it can be confusing because many fertilizer dealers know potassium chloride or muriate of potash fertilizer as 0-0-60 or 0-0-62. For ease of calculating chloride application, just remember the product is about 50 percent chloride.

Other chloride-containing fertilizers include: ammonium chloride (NH_4Cl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and sodium chloride (NaCl). These fertilizers contain 66 percent, 65 percent, 74 percent, and 60 percent chloride, respectively. Calcium chloride, ammonium chloride, and magnesium chloride are sometimes available as liquid fertilizer.

Research in Kansas has evaluated all of these sources of chloride. Results show all of these fertilizers to be equally effective in supplying chloride.

Chloride Research in Kansas

In the past 15 to 20 years, considerable research with chloride fertilization has been conducted in Kansas on wheat, corn, and grain sorghum. Positive yield responses have been noted on these crops. To date, chloride fertilization on other crops has been limited.

Wheat

Chloride research on wheat in Kansas has been ongoing for 20 years. Early work clearly showed that chloride fertilization not only increased wheat grain yields on low chloride soils, but also suppressed the progression of leaf rust. Research has also clearly shown that differences exist among wheat varieties in terms of responsiveness to chloride fertilization. For example the variety Cimarron, which consistently exhibits leaf spotting on low chloride soils, averaged 16 bushels per acre response to chloride fertilization at five sites that had soil chloride levels below 20 pounds per acre. At the same sites, the variety Ogallala yielded exactly the same with or without chloride fertilizer. Table 1 summarizes this chloride fertilization/wheat variety research. Averaged across all seven varieties, chloride fertilization increased grain yields by 8 bushels per acre. An 8-bushel-per-acre yield response to a micronutrient is quite impressive, but this was with outstanding wheat yields (70 to 90 bushels per acre). Yield responses of this magnitude would not be expected at lower overall yields, though research has shown a 7 to 10 percent yield increase on low chloride soils, regardless of yield level. Chloride application consistently and dramatically increased leaf tissue chloride concentrations on all varieties.

Table 2 summarizes many site-years of wheat data and shows the relationship between yield response to chloride and soil chloride levels. All sites below 20 pounds per acre soil chloride responded to the application of chloride fertilizer.

Table 1. *Chloride fertilization on wheat varieties in Kansas.**

	Grain Yield		Leaf Cl	
Variety	+ Cl	- Cl	+ Cl	- Cl
	- - - - - - bu/a - - - - - -		- - - - - - % - - - - - -	
Cimarron	75	59	0.44	0.10
Jagger	89	81	0.44	0.10
Karl 92	85	76	0.42	0.11
Ogallala	77	77	0.32	0.12
Tam 107	89	82	0.40	0.10
2137	90	84	0.42	0.11
2163	80	75	0.46	0.11
Average (all varieties)	84	76	0.42	0.11

**Average of five sites, all less than 20 lb/a soil Cl (0-24"), +Cl received 20 lb Cl/a as KCl fertilizer topdressed in February.*

Corn and Grain Sorghum

Tables 3 and 4 provide summaries of several site-years of chloride research on corn and grain sorghum. Overall, results are very similar to wheat results. All sites with low soil chloride levels (less than 25 to 30 pounds chloride per acre) responded to chloride application. The nonresponsive sites had soil chloride levels of 40 pounds chloride per acre or higher. As with wheat, leaf tissue chloride concentrations of the check (no chloride added) treatments at responsive sites were generally 0.15 percent or lower. Chloride fertilization always significantly increased leaf tissue chloride concentrations (data not shown).

Over the many years of work on chloride fertilization, several chloride rates and sources were evaluated. In most cases application of 10 to 20 pounds chloride per acre was sufficient to achieve optimum response. Ammonium chloride, magnesium chloride, calcium chloride, potassium chloride, and even sodium chloride as sources were evaluated. All chloride sources performed equally. Potassium chloride is the most readily available source. When potassium chloride is used as a chloride source, there is the possibility that the potassium could be the cause of any response. This research was conducted on sites with high soil potassium levels and potassium concentrations in leaf tissue samples were measured. The researchers are convinced the responses noted are due to chloride, particularly since other chloride sources also provided yield increases. The researchers have not evaluated chloride fertilization on other Kansas crops.

Chloride Soil Test Interpretation and Fertilizer Recommendations

Our research clearly indicates the likelihood of a response to chloride fertilizer is directly related to soil chloride levels. Chloride levels in Kansas soils vary, but levels below 25 pounds per acre are not uncommon, particularly where potassium chloride fertilizer is

Table 2. *Chloride fertilization on wheat.*

	Grain Yield*								
Chloride	Marion Co.		Saline Co				Stafford Co.		
Rate	Site A	Site B	Site A	Site B	Site C	Site D	Site A	Site B	Avg.
lb/a					bu/a				
0	45	80	51	89	83	70	73	64	69
20	47	85	54	89	90	75	80	70	74
Soil test Cl lb/a (0-24")	7	7	14	22	7	14	7	15	12

**Average over either 12 or 16 varieties.*

Table 3. *Chloride fertilization on corn in Kansas.*

	Grain Yield							
Chloride	Riley Co.			Brown Co.			Osage Co.	
Rate	Site A	Site B	Site C	Site A	Site B	Site C	Site A	Site B
lb/a					bu/a			
0	70	64	107	188	123	87	133	79
20	84	69	111	191	130	93	133	81
Soil test Cl lb/a (0-24")	9	16	24	28	14	28	40	61

Table 4. *Chloride fertilization on grain sorghum in Kansas*

	Grain Yield							
Chloride	Marion Co.				Brown Co.		Osage Co.	
Rate	Site A	Site B	Site C	Site D	Site A	Site B	Site A	Site B
lb/a					bu/a			
0	87	117	63	92	102	87	125	88
10	94	139	71	113	106	95	126	92
20	97	135	72	126	111	96	125	96
Soil test Cl lb/a (0-24")	9	7	9	43	7	9	52	29

Table 5. *Soil test chloride interpretation and fertilizer recommendation.*

Category	Soil Chloride* lb/a	Soil Chloride* ppm	Cl Recommended lb/a
Low	< 30	< 4	20
Medium	30-45	4-6	10
High	> 45	> 6	0

**Interpretations valid for 0-24 inch samples on wheat, corn and grain sorghum.*

not normally used. Since most central and western Kansas soils are high in potassium, use of potassium chloride fertilizer has been limited, and low soil chloride levels are often found. In southeast Kansas, however, where potassium chloride is routinely applied, low soil chloride levels are not widespread. On soils low in chloride, optimum yields of crops may require addition of chloride fertilizer. The information in Table 5 summarizes our interpretation of soil test chloride information.

Plant tissue analysis also has proven valuable in assessing a potential need for chloride. Research has shown that whenever leaf chloride concentrations are in the 0.10 to 0.12 percent range or less, this is a good indicator of low soil chloride levels. Again, research has been limited to wheat, corn, and grain sorghum. Research with wheat used leaf samples taken at boot stage, while corn and grain sorghum leaf samples were taken at the 6 to 8 leaf stage by taking the most recent fully emerged leaf.

When soil tests indicate a need for chloride, the authors' recommendation is to apply 10 to 20 pounds of actual chloride per acre, depending on soil test chloride level. For example, if potassium chloride is being used, application of 30 pounds per acre of potassium chloride would supply about 15 pounds per acre of actual chloride. Research has shown equal performance of chloride applied either preplant or topdress (November through early March) for wheat. On corn and grain sorghum, preplant or planting time applications are preferred. With the good solubility of all chloride fertilizers, surface broadcast applications work well with sufficient rainfall or irrigation after application.

Remember, response at any given soil chloride level in a specific year may vary with several factors, including variety, disease pressure, timing of moisture or temperature stress relative to the effect of chloride on plant development, and soil chloride distribution relative to crop root distribution.

Summary

Chloride, an often-overlooked nutrient, is essential for plant growth. Deficiencies of this nutrient have been verified in Kansas. Chloride is essential for photosynthesis and serves other critical roles in plants. Plants take up chloride as the Cl^- ion. This ion is very mobile in the soil and is subject to leaching.

Soil testing and plant analyses have proven useful in identifying potential deficiencies of chloride. Recent Kansas research has verified a need for chloride fertilization on some soils. Chloride recommendations are based on soil test chloride levels. If supplemental chloride is needed, several sources of chloride fertilizers are available, but potassium chloride is the most readily available.

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Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-2570 December 2002