Chloride

ESSENTIAL ELEMENTS

THE FERTILIZER INSTITUTE

Chloride is commonly found in nature—from seas, to soils, to the air—it's everywhere. It is a monovalent anion, having a single negative charge (Cl-). Plants take up the element chlorine in this anionic form. Under standard conditions chlorine (Cl) is an unstable, yellow-green gas. Unlike Cl- , free Cl rarely occurs in nature.

Chloride was first generally recognized as a plant nutrient in the mid 1950s. However, its value as a fertilizer supplement was not appreciated until the 1970s when work in the northwestern U.S. and elsewhere showed that some crops may indeed respond to Cl- fertilizer application. Since that time there has been a great deal of work investigating crop response to the addition of Cl-, and determining optimal management practices for Cl- fertilization.

Chloride in Plants

Chloride fulfills many important functions in plants. Some of the roles of Cl- in plants are:

- Photosynthesis and enzyme activation. Some of the enzymes activated are involved in starch utilization, which affects germination and energy transfer.
- Transport of other nutrients. Chloride aids in the transport of nutrients such as potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), since it acts as a counterion to maintain electrical balance.
- Water movement in cells. Cellular Cl- helps water move into cells and also aids in water retention in cells, thereby impacting cell hydration and turgor.
- Stomatal activity. Both K and Cl- are involved in the movement of guard cells that control the opening and closing of leaf pores or stomata.
- Accelerated plant development. Adequate Cl- in small grain production results in earlier head formation and emergence than where Cl- is deficient. In winter wheat production maturity advances of five to seven days have been observed.
- Reduced lodging. Chloride strengthens stems, helping to reduce lodging later in the season.

Among the most notable impacts of Cl- is its role in reducing the effects of numerous plant diseases. This effect may be related to its function in osmotic regulation. In wheat, Cl- 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 been shown to suppress stalk rot.

Chloride in Soils

Nearly all Cl- in soils exists in soil solution. Chloride, like nitrate (NO^3), is mobile in soils and moves freely with soil water. Thus, under certain conditions it can be readily leached from the root zone. There are several potential sources of Cl- in crop production systems, including rainfall, marine aerosols, volcanic emissions, irrigation water, and fertilizer. Some irrigation water contains substantial amounts of Cl-—often enough to meet or exceed crop needs. Atmospheric deposition can be particularly high in coastal areas. But regions further inland, such as the Great Plains of the U.S., have much lower atmospheric deposition of Cl- making the likelihood of response to Cl- fertilizer higher. Where there is a history of Cl---containing fertilizer application (such as muriate of potash; also known as MOP, potassium chloride, or KCl) it is not likely that Cl- will be limiting for crops.

Fertilizing with Chloride

There are several fertilizer sources of Cl-, but the most common and readily available is KCl (**Table 1**). All sources perform similarly—one is not superior to another when strictly considering Cl-. Since Cl- is soluble and moves readily with soil water, placement is not as great an issue as with more immobile.

Table 1. Chloride fertilizer sources and percent of nutrient.

Fertilizer Name	Formula	% Cl^-
Potassium Chloride	KCl	47
Magnesium Chloride	$MgCl_2$	74 (dry) 22 (liq.)
Ammonium Chloride	NH_4Cl	66
Calcium Chloride	$CaCl_2$	65

Some laboratories make fertilizer recommendations for Cl- based on soil and/or tissue analysis. It is usually recommended that soil samples be taken from a depth of 0 to 24 inches since Cl- is mobile. The Kansas State University soil testing lab recommends application of 20 lb Cl-/A to corn, wheat and grain sorghum when soil test level in the upper 24 inches is less than 30 lb Cl-/A[1].

Chloride Deficiency Symptoms

Chloride deficiency symptoms have been observed and characterized in several crops and can vary, but the two most common symptoms are chlorosis in the younger leaves and an overall wilting. Necrosis of some parts of the plant, leaf bronzing, and reduction in root and leaf growth may also occur. Increased susceptibility to infection of various diseases may result from Cldeficiency as well.

In the early 1990s, physiological leaf spot syndrome was first observed in certain winter wheat varieties in Montana. These symptoms are similar in appearance to tan spot and Septoria leaf blotch diseases, but are not associated with pathogens. Research has shown that this spotting is the result of Cl- deficiency.

This information was originally developed by the International Plant Nutrition Institute.

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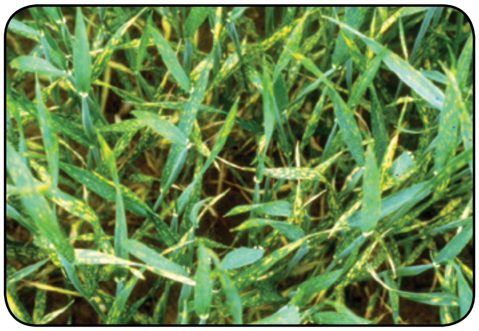

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Chloride deficiency observed as physiological leaf spot in winter wheat (left). Photo on the right shows wheat that received Cl- fertilizer application.

Crop Response to Chloride

There has been a great deal of research done on Cl- nutrition of crops on the Great Plains, mostly with winter wheat but some on other crops as well. **Table 2** shows grain yields and tissue Clconcentrations from multiple site years for dryland winter wheat, corn and grain sorghum receiving Cl- in Kansas.

In a recent meta-analysis of Cl- response data with winter wheat collected from 1990 to 2006 at 53 locations across Kansas, it was concluded that application of Cl- fertilizer generated an average yield increase of approximately 8 percent, and that application rates greater than about 20 lb Cl-/A would seldom result in further yield increases[2].

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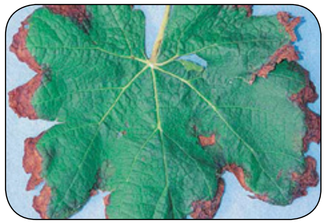

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Some plants are sensitive to high Cl- concentrations. Symptoms of excessive Cl- (clockwise starting top-left: grape, almond, walnut, strawberry) usually appear first at the tips and edges of older leaves.

Circumstances that favor response to Cl--containing fertilizer are low soil and/or plant tissue levels, high foliar and or root fungal disease pressure, responsive cultivar, and where KCl fertilization is minimal in non-coastal areas.

Chloride Sensitivity

Plants growing in salt-affected soils or irrigated with high-Cl- water can be negatively impacted by additional Cl- fertilization. Leaf damage can also result from excessive Cl- deposited on foliage during irrigation. Careful fertilizer and water management is needed to manage Cl- in these situations. Some crops are reported to be sensitive to elevated Cl- (e.g., tobacco, potato, a number of fruit, berry, and vegetables, some tree crops, and some soybean varieties) although this sensitivity varies depending on the growing conditions.

References

1. Leikam, D.F., R.E. Lamond and D.B. Mengel. 2003. Kansas State Univ. Ag. Exp. Station. MF-2586.
2. Ruiz Diaz, D.A. et al. 2012. Comm. in Soil Sci. and Plant Analysis. 43:2437- 2447.
3. Mengel, D.B. et al. 2009. Better Crops with Plant Food. Vol. 78:20-23.

Further Reading

Engel, R.E. and P.E. Fixen. 1994. Better Crops with Plant Food. 78:20-23.

Havlin, J.L. et al. 2005. Soil Fertility and Fertilizers. Pearson Prentice Hall. Upper Saddle River, NJ.

Lamond, R.E. and D.F. Leikam. 2002. Kansas State Univ. Ag. Exp. Station. MF-2570.

Table 2. Yield and tissue response to 20 lb Cl-/A for wheat, corn and grain sorghum in Kansas[3].

Crop	Grain Yield, bu/A			Leaf Cl-, %		Site Years
	Control	20 lb Cl-/A	Response	Control	20 lb Cl-/A	
Winter Wheat	48.4	52.5	4.1	0.29	0.43	34
Corn	104.4	108.9	4.5	0.17	0.27	11
Grain Sorghum	98.5	108.2	9.7	0.10	0.24	20

Plant tissue for wheat and grain sorghum sampled at boot, corn taken at tassel.

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