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Societies**

# **Chloride deficiency and toxicity can be a real problem**

By Susan Winsor

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*Opposite page: Plants with insufficient chloride show chlorotic and necrotic spotting along leaves with abrupt boundaries between dead and live tissue. Leaves wilting at margins and highly branched root systems are also typical chloride deficient symptoms, found mainly in cereal crops (Mengel & Kirkby, 2001). Chloride deficiencies are highly cultivar-specific and can be easily mistaken for leaf diseases.*

The micronutrient chloride ( $\text{Cl}^-$ ) is one of 17 essential nutrients for plant survival. Chloride deficiency can be an issue in wheat, barley, oat, corn, and grain sorghum. In other species, like soybeans and rice, too much chloride can hurt yields. This article will cover deficiency symptoms, fertilizer tips and reported yield responses, and chloride toxicity.

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The micronutrient chloride ( $\text{Cl}^-$ ) is one of 17 essential nutrients for plant survival. Chloride is required for cell turgor, enzyme activation, nutrient transport, water and ion movement in cell vacuoles, and stomata regulation of plant moisture content. It even helps split water molecules to liberate oxygen during photosynthesis.

Chloride deficiency can be an issue in wheat, barley, oat, corn, and grain sorghum. In other species, like soybeans and rice, too much chloride can hurt yields. Most soils have enough chloride. Chloride levels are high near soils derived from marine geologic deposits, saline soils, soils with a shallow water table in low spots below long slopes, and near coastal areas.

Chloride deficiency is most common in Kansas, Montana, Wyoming, western North Dakota, and South Dakota where chloride soil levels can be naturally low and/or where limited potash (KCl) was historically applied, until recently. Because chloride is the most leachable nutrient, you also see deficiencies in areas with high fall and winter precipitation.

The average dryland winter wheat yield increase from chloride supplementation was 8%, in deficient soils, but has been as high as 20%. Corn yields increased by an average 6 bu/ac from supplemental chloride, and grain sorghum yields increased an average 11 bu/ac from chloride supplementation in low-chloride soils.

As an anion,  $\text{Cl}^-$  is not readily adsorbed on the soils exchange complex and vulnerable to leaching, says Dorivar Ruiz Diaz, Kansas State University (K-State) professor of Soil Fertility and Nutrient Management. "Because of this,  $\text{Cl}^-$  moves readily with soil water and is quite leachable, more so than nitrate. In fact,  $\text{Cl}^-$  is often used as a tracer for the movement of soluble anions such as nitrate or sulfate."

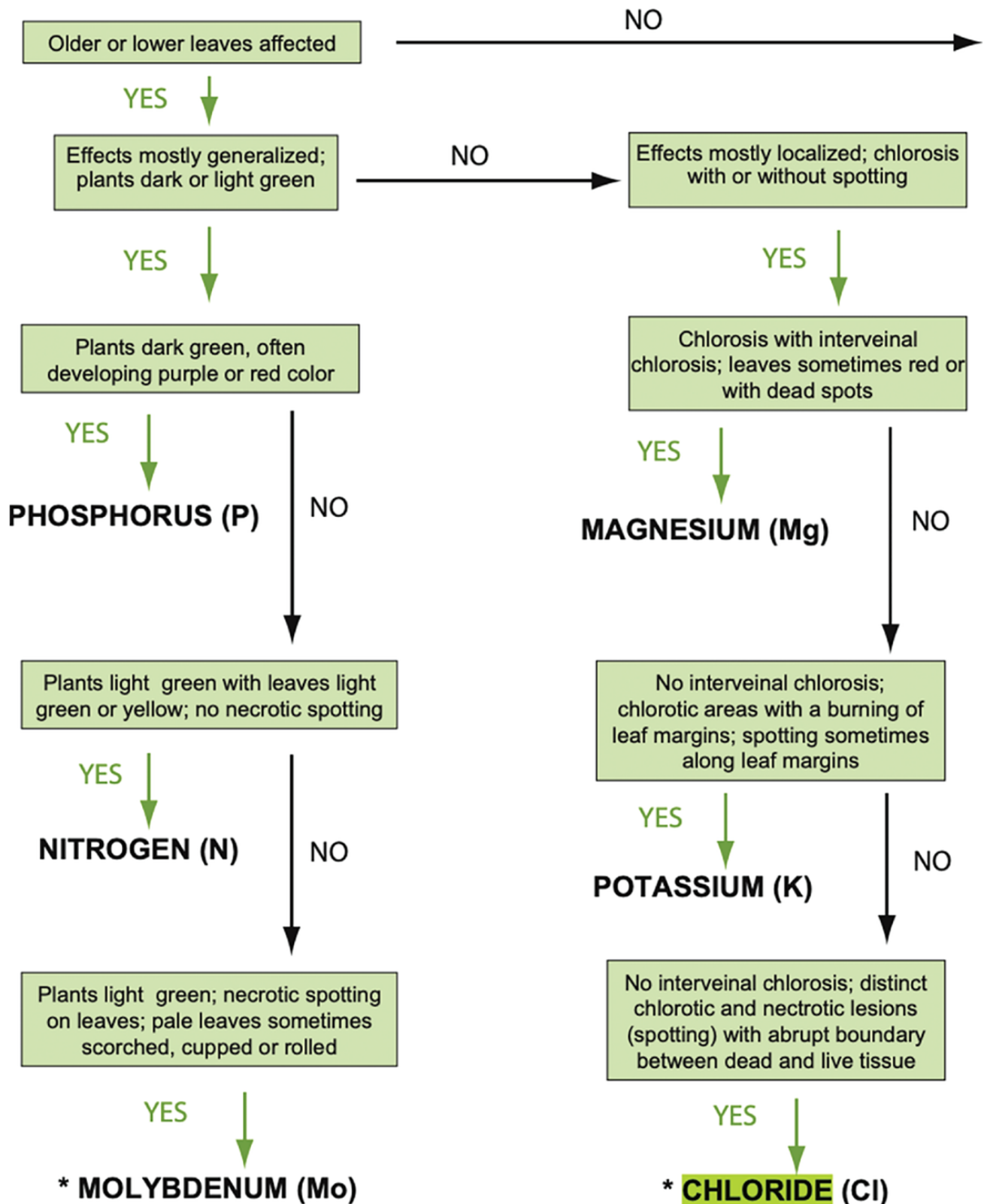
"Chloride is a component of many soluble salts," adds Nathan Slaton, a CCA and University of Arkansas professor of soil testing. "Any time you talk about salinity, it affects plant–water relations. Most soil labs may not include chloride testing in a regular soil testing or plant analysis packages; chloride requires different testing procedures."

Soil test samples for chloride must be taken 24 inches deep in the soil to account for leaching.

"In the Northern Great Plains, its correlation with soil test potassium (K) goes two ways," says John Breker, CCA and soil scientist, Agvise Laboratories, Northwood, ND. "Soils with low soil test K are often coarse textured and well drained. They often leach

chloride, especially if irrigated. At the opposite end of the spectrum, chloride-deficient soils with high soil test K do not warrant potash application (KCl, 0-0-60) to meet crop K requirements. They are often naturally low in chloride and, without potash application, do not receive any chloride. Therefore, these soils stay low in chloride. This is the story across much of the Northern Great Plains where small grains could benefit from a modest application of 10 to 20 lb/ac chloride."

## MOBILE NUTRIENTS



\*If symptoms don't meet any of the key descriptions, either go back through the key another time or refer to text for more specific symptom descriptions.

*This “key” can be used for identifying nutrient deficiencies for mobile nutrients based on common symptoms. It consists of different alternative statements about plant structures and their appearance. Beginning at the top of the key, read the first statement and determine whether it applies to the plant(s) being evaluated. If the statement describes the plant’s symptoms, proceed along the “YES” arrow to the next statement. If not, follow the “NO” arrow to an alternative statement. Continue this process until the probable nutrient responsible for the deficiency is identified. Source: Nutrient Management Module 9: “Plant Nutrient Functions and Deficiency and Toxicity Symptoms,” published by Montana State University Extension.*

## **Deficiency Symptoms**

Chloride-deficient leaf spot syndrome—random tan to yellow leaf spots in wheat, barley, grain sorghum, and corn (not oats)—has been noted in the U.S. since the 1940s. The spots in wheat resemble tan spot lesions but are smaller and do not have the halo at the spot edge, says K-State’s Ruiz Diaz.

These spots were first thought to be a metabolic or genetic dysfunction since pathogens weren’t present. But research found that spots only appeared on specific varieties when tissue Cl concentration fell below 0.1% (0.09% for barley). Knowing this may save unnecessary fungicide applications.

Chloride deficiency caused leaf necrosis (evident as spots) in winter and durum wheat, according to 1998 Montana research by Richard Engel. This may be due to low rainwater chloride concentrations and potash fertilizer being seldomly applied because soil K levels are adequate. This leaf-spot phenomenon in wheat resembles tan spot caused by *Pyrenophora tritici-repentis*.

The lesion margins have a distinct boundary between healthy and affected leaf tissue compared with tan spot where the boundary is diffuse.

## **Fertilizer Responses**

## Wheat and Barley

More than 200 trials in seven North American states have evaluated chloride fertilizer response in wheat and barley. Yield responses occurred in 48% of trials. There was a 70% likelihood of yield response to chloride fertilizer if the soil test chloride was less than 30 lb/ac (34 kg Cl/ha) to a depth of 24 inches. Depending upon soil type and crop variety, the chloride-deficiency threshold may range from 5–30 lb/ac chloride, says K-State's Ruiz Diaz.

At responsive research sites, chloride-treated plants were more erect at midday, developed faster, and had less disease and lodging and higher kernel weight. Supplemental chloride in deficient settings suppressed take-all root rot, tan spot, stripe rust, leaf rust, and Septoria leaf spot in wheat; as well as stalk rot in sorghum and corn.

This mechanism is not well defined but possibly related to chloride's role in osmotic regulation, Ruiz Diaz says. Research confirms "improved wheat overall disease resistance, improved color, fungal disease suppression, and increased yield."

A K-State agronomy reference notes that, "It is difficult to predict whether chloride would significantly increase wheat yields unless there's been a recent soil test analysis. Chloride fertilization based on soil testing is becoming more common in Kansas." Most Kansas soils sampled had chloride levels below 40 lb/ac with many samples below 10 lb/ac, using 0- to 24-inch samples.

| Category | Soil chloride <sup>a</sup> |     | Chloride recommended |
|----------|----------------------------|-----|----------------------|
|          | lb/ac                      | ppm | lb/ac                |
| Low      | <30                        | <4  | 20                   |
| Medium   | 30–45                      | 4–6 | 10                   |
| High     | >45                        | >6  | 0                    |

<sup>a</sup>Interpretations valid for 0- to 24-inch samples on wheat, corn, and grain sorghum.

Montana research results from 32 field studies suggest a yield response to chloride is likely if soil tests below 30 lb/ac chloride in the top 2 ft, or plant-tissue chloride levels in

wheat at the boot stage are less than 0.10% chloride (Engel et al., 1998). The average yield response was 7%. Durum wheat grown in fields with 7 lb/ac chloride in the upper 3 ft had 87% flag leaf spot damage. In contrast, fields that received 40 lb/ac chloride (as KCl) had only 6% leaf spot damage and a 22% yield increase (Engel et al., 2001).

Although leaf spots from chloride deficiency are variety dependent, yields still increase in non-spotted deficient crops after 5–15 lb/ac supplemental chloride in deficient soils. Leaf tissue chloride levels of 0.1–0.12% and below, taken at the six- to eight-leaf stage, are a good indicator of low soil chloride levels although a soil test is the standard testing method.

The remedy is to apply 10 to 20 lb/ac actual chloride (Table 1), depending on soil chloride level, either preplant, banded, or topdressed from November through early March for wheat. Placing fertilizer with the seed may reduce germination and delay emergence due to high salts. The effect is highly dependent on the specific fertilizer's salt index. For example, the high salt index of KCl (0–0–60) means a high potential to impede germination if placed with the seed.

**Table 1.** Soil test interpretation and fertilizer recommendation. Source: Kansas State University



*Chloride toxicity, not deficiency, is a problem with soybeans and sometimes rice. Soybean leaf scorching and desiccation increased as tissue chloride concentrations increased, after the R5.5 stage, in Nathan Slaton's University of Arkansas research. Leaf scorch has also been observed elsewhere in chloride-sensitive cultivars during pod development, and yields were 37% less compared with tolerant cultivars in high-chloride soil. Chloride toxicity yield loss can occur without visible season-long symptoms—symptoms may not appear until very late in the growing season. Photo by Nathan Slaton, University of Arkansas.*

[https://bit.ly/Cl\\_research.\)](https://bit.ly/Cl_research.)

## **Soybean Chloride Toxicity**

Chloride-sensitive crops such as soybeans can accumulate excessive chloride, which can be toxic and lower yields slightly, says Dan Kaiser, University of Minnesota Extension nutrient management specialist. "While soybean's exact chloride tolerance is not known, its effect is worse on poorly drained soils with low rainfall because chloride won't move out of the root zone," he says.

In his three-year, four-location, four-variety Minnesota soybean chloride study, yield reductions were mostly about 1 bu/ac (see [https://bit.ly/SB\\_CI](https://bit.ly/SB_CI) for details).

## **Corn and Grain Sorghum**

Chloride yield responses have also been measured in corn and sorghum. Corn yields increased by an average 6 bu/ac from supplemental chloride where soil levels were below 20 lb/ac soil test in 1999 Kansas research. Grain sorghum yields increased an average 11 bu/ac from chloride supplementation in soils having chloride levels below 20 lb/ac at a 24-inch depth in Kansas research. Yield increases occurred regardless of chloride source (KCl, CaCl<sub>2</sub>, and NaCl). The response appears to have been a nutrient response as disease pressures were low. (Research details are at

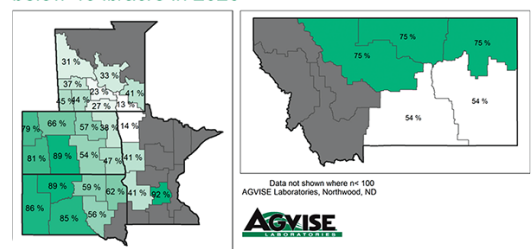
“Soybean chloride toxicity varies by variety,” Kaiser says. “Most northern soybean varieties are susceptible to yield loss from chloride overapplication—we call these ‘includer’ varieties.”

Soybean “excluder” varieties suffer less yield loss from high-chloride environments and are more tolerant of saline conditions. They accumulate less chloride in the plants’ aboveground portion than “includer” cultivars (Abel & MacKenzie, 1964; Parker et al., 1983). Despite chloride exclusion being a dominant genetic trait, only about 20% of late Maturity Group IV and 30% of early Maturity Group V cultivars are excluders (Green & Conatser, 2017).

Knowing whether your varieties are includers or excluders is the vital first step in managing potential chloride toxicity, Slaton says. Additionally, it’s important to know the chloride content of your irrigation or surface waters. “Arkansas thresholds are about 100 ppm  $\text{Cl}^-$  to avoid problems,” he says. “I see farmers really struggle when water  $\text{Cl}^-$  levels reach 400–500 ppm.”

In the South, “Potential yield loss from chloride toxicity can be detected at the R3 or R4 stage before symptoms are expressed using soybean leaf analysis,” Arkansas’ Slaton says. These symptoms were “similar to what you’d expect in salinity-related problems.” Slaton researched the impact of soybean excluder and includer varieties on soybean chloride toxicity. (See <https://bit.ly/3Dg8J80> for research details.)

Soil samples with soil test chloride below 40 lb/acre in 2020



To help manage soybean chloride toxicity, apply K fertilizer only where it is needed,” Kaiser says. “If K needs to be applied ahead of the soybean crop, keep the rate low. Our University of Minnesota [soybean fertilizer recommendations](#) suggest no more than 100 lb/ac of potassium chloride be applied ahead of the soybean crop, but the actual tolerable rate can vary from one field to another. We have encountered yield reductions in sandy soils, so no field is immune to these issues.”

*Soils potentially requiring chloride for small grains in the Northern Great Plains. The percentage of soil samples with soil test chloride below 40 lb/ac (0- to 24-inch soil profile) are shown for Minnesota, Montana, North Dakota, South Dakota, and Manitoba. Source: AGVISE Laboratories, Northwood, ND.*

Soybean leaf scorching and dessication increased as tissue chloride concentrations increased, after the R5.5 stage, in Slaton’s research. Parker et al. (1983) also noted chloride-sensitive cultivars developed leaf scorch during pod development, and yields were 37% less compared with tolerant cultivars in soil with naturally high chloride concentrations. “Yield loss from chloride toxicity can occur without visible season-long symptoms—symptoms may not appear until very late in the growing season, presumably due to chronic chloride accumulation from applied irrigation water,” Slaton says. “Symptoms’ late appearance is an important aspect of chloride toxicity and highlights the need for diagnostic information that would aid in early toxicity detection.”

Rice can also be somewhat sensitive to excess soil chloride, Slaton says.

“It’s important for CCAs to do their homework,” Arkansas’ Slaton says. “It’s easy to forget about chloride since it’s not a macro- or micronutrient that we commonly consider. But in some geographies, it can be important.”

#### **A Note about Cadmium**



*Surface-broadcast KCl is ideally incorporated with irrigation or rain after application. Photo by Mike Staton, Michigan State University Extension.*

High soil chloride levels have been linked to increased cadmium uptake in cadmium-accumulating crops like sunflower, durum wheat, and flax. Research in the *Soil Science Society of America Journal* (<https://bit.ly/3rtDofA>) notes that “Cadmium (Cd) is a potentially toxic heavy metal with no known human benefit. Plant foods are the predominant Cd sources in human diets. A

durum wheat study in northeastern North Dakota with a range in soil pH and salinity found grain Cd accumulation to be strongly and positively associated with soil salinity as represented by soluble chloride, soluble sulfate, or extractable sodium, and chelate-extractable Cd. ... Although the mechanism is not clear, it is likely to involve increased solubility or availability of soil Cd resulting from the formation of chloro-complexes in soil solution.”

### **Chloride Fertilizer Tips**

- A rescue treatment for chloride deficiency is approximately 5–20 lb/ac chloride as liquid or granular KCl. Surface-broadcast KCl is ideally incorporated with irrigation or rain after application. A large percentage of in-season applied chloride may be available to subsequent crops, especially in dryland conditions because little is removed by the crop and leaching is generally infrequent in dry High Plains climates where chloride deficiencies are more common.
- Because it is the most leachable essential nutrient, supplemental chloride placement is “likely not important, except due to its harmful negative effect on germination,” according to the Montana State University fertilizer manual ([https://bit.ly/MT\\_fert\\_guide](https://bit.ly/MT_fert_guide)).

- All chloride-containing fertilizers are equally effective in delivering chloride: ammonium chloride, calcium chloride, magnesium chloride, and sodium chloride. In Northern Great Plain regions where K is abundant,  $\text{CaCl}_2$  or  $\text{MgCl}_2$  might be best, says Clain Jones, Montana Extension fertility specialist. “NaCl, while cheap, will eventually cause soil dispersion.”
- “I would go with whatever source is more economical,” says K-State’s Ruiz Diaz. “The concept of K impeding Mg uptake is not conclusive to my knowledge under field conditions. We do have a lot of high-testing K soils in the Great Plains.”
- The vast majority of applied chloride is available to plants, absorbed through roots and leaves.
- Chloride availability is independent of soil pH.
- Uptake can be decreased by high concentrations of  $\text{NO}_3^-$  or  $\text{SO}_4^{2-}$  due to competition for negatively charged ions at roots’ surface.
- To avoid chloride toxicity in soybeans where chloride toxicity is a problem, variety selection (chloride includer or excluder variety) is very important and is really the only management option available to growers, says Arkansas’ Slaton.

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