Agdex 531-1

Micronutrient Requirements of Crops

Crops require 16 essential elements to grow properly. The elements include carbon (C), hydrogen (H) and oxygen (0_2), which are derived from air and water. All the remaining nutrients used by plants come from soil in the form of inorganic salts. Legumes are an exception because they can also fix nitrogen from the air.

The ***macronutrients*** obtained from the soil include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S). The remaining essential elements needed by plants are known as ***micronutrients*** because plants use them in relatively small amounts. They include: boron (B), chlorine (Cl), copper (Cu), iron (Fe) manganese (Mn), molybdenum (Mo) and zinc (Zn). Carbon, hydrogen and oxygen comprise from 94.0 to 99.5 per cent of fresh plant tissue. The remaining nutrients, which come from the soil, make up the balance of the tissue.

The term micronutrient refers to the relative quantity of a nutrient that is required for plant growth. It does not mean that they are less important to plants than other nutrients. Table 1 lists amounts of micronutrients removed from the soil by several crops. Plant growth and development may be retarded if any of these elements is lacking in the soil or is not adequately balanced with other nutrients. This fact sheet describes where potential micronutrient deficiencies may occur in Alberta, how to determine if a micronutrient is deficient and how to correct the deficiency.

Table 1. Amounts of some micronutrients removed by good yields of various crops.

Crops harvested and portion used for analysis	Yield level t/ha	Micronutrients removed (kg/ha)					
		Chlorine (Cl)	Boron (B)	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)
Alfalfa - hay	1.3	6	0.10	<0.1	0.20	0.70	0.70
Barley - grain	4.0	8	0.10	<0.1	0.30	0.10	0.10
- straw	-	1	0.02	<0.1	0.01	0.70	0.10
Corn - grain	9.5	2	0.70	<0.1	0.20	0.10	0.20
- stover	-	1	0.06	<0.1	1.00	1.70	0.30
Oats - grain	4.0	1	-	<0.1	1.00	0.20	0.10
- straw	-	1	-	<0.1	0.20	0.20	0.40
Peas - vines & pods	-	-	0.07	<0.1	0.70	0.50	0.10
Potatoes - white, tubers	40	27	0.07	<0.1	0.90	0.20	0.10
Wheat - grain	4.0	6	0.06	<0.1	0.50	0.20	0.20
- straw	-	2	0.02	<0.1	0.20	0.30	0.10

Data compiled from several sources.

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Sources of micronutrients in soils

Inorganic micronutrients occur naturally in soil minerals. The parent material from which the soil developed and soil forming processes determine what the micronutrient content of the soil will be. As minerals break down during soil formation, micronutrients are gradually released in a form that is available to plants. Two sources of readily available micronutrients exist in soil: nutrients that are adsorbed onto soil colloids (very small soil particles) and nutrients that are in the form of salts dissolved in the soil solution.

Organic matter is an important secondary source of some micronutrients. Most micronutrients are held tightly in complex organic compounds and may not be readily available to plants. However, they can be an important source of micronutrients when they are slowly released into a plant available form as organic matter decomposes.

Soil factors that affect micronutrient availability

Physical and chemical characteristics of soil affect the availability and uptake of micronutrients:

- Soils low in organic matter (less than 2.0 per cent) may have lower micronutrient availability.
- Soils with higher amounts of clay (fine texture) are less likely to be low in plant available micronutrients. Sandy soils (course texture) are more likely to be low in micronutrients.
- Soils that have very high levels of organic matter (greater than 30 per cent organic matter to a depth of 30 cm) often have low micronutrient availability.
- Soil temperature and moisture are important factors. Cool, wet soils reduce the rate and amount of micronutrients that may be taken up by crops.
- As soil pH increases the availability of micronutrients decreases, with the exception of molybdenum.

Determining the need for micronutrients

Diagnosing a micronutrient deficiency can be a difficult and time consuming process. To identify a micronutrient deficiency follow these steps:

1. Ensure that poor crop growth is not the result of a macronutrient deficiency, drought, salinity, disease or insect problem, herbicide injury or some physiological problem.
2. Find out if a micronutrient deficiency has been identified before in a particular crop or soil type in the area.
3. Examine the affected crop for specific micronutrient deficiency symptoms.
4. Take separate soil samples from both the affected and unaffected areas for complete analysis, including micronutrients.
5. Send plant tissue samples from both the affected and unaffected areas for complete analysis that includes tests for micronutrient levels.
6. If all indications point to a micronutrient deficiency, apply the micronutrient to a specific, clearly marked out affected area of land to observe results in subsequent seasons.

Potential micronutrient deficient areas in Alberta

While Alberta soils generally contain adequate amounts of micronutrients, some micronutrient deficiencies have been documented. As soils continue to be cropped, micronutrient deficiencies may become more common as available levels of some elements are depleted.

Boron

Boron deficiencies have been suspected in canola and alfalfa grown on sandy-textured Grey Wooded soils. However, research specifically documenting the response to added boron is limited.

Brown and Dark Brown irrigated soils in southern Alberta will frequently test deficient for boron. However, cereal crops do not respond to additions of boron. Canola, pea and bean yields have declined by 10 to 20 per cent due to boron toxicity after a 2 lb/ac application of boron.

Chlorine

Chlorine is not known to be deficient in Alberta soils from a nutritional standpoint. The requirement of plants for chlorine is satisfied by the chlorine found in the soil and received from rainfall. Chloride is also added to soil in potash fertilizer (KCI). Research has shown that chloride added at rates higher than required to meet nutritional needs is associated with suppression of root and leaf diseases in some cereal crops. The reasons for disease suppression in some soils are poorly understood.

Copper

Research has shown that cereal crops grown on organic soils (greater than 30 per cent organic matter to a depth of 30 cm) often respond to copper fertilization. More recently, copper deficiency has been identified in wheat, barley and oats grown on mineral soils in the Black and Grey-Black soil zones of Alberta. Copper deficient soils tend to be either sandy or light loam soils with relatively high levels of organic matter (6-10 per cent). High levels of soil phosphorus or heavy applications of manure are often associated with a copper deficiency on these soils.

Wheat, barley and oats are the most sensitive to a copper deficiency. Park spring wheat and Condor barley are the varieties that are the most sensitive to copper deficiency and show the most obvious disease symptoms. Rye and canola are relatively tolerant to a copper deficiency.

Iron

Iron deficiencies have not been observed in field crops in Alberta. However, iron deficiency symptoms such as leaf yellowing are common among various trees, shrubs and ornamentals on high pH soils because lime reduces the availability of iron.

Manganese

Manganese deficiencies are most common on organic soils and high pH mineral soils. Deficiency symptoms are commonly observed following cool wet conditions in spring. Oats are more susceptible to a manganese deficiency than other cereal crops. Organic soils with a high pH are the most likely to respond to manganese fertilizer.

Molybdenum

Molybdenum deficiencies have not been diagnosed in field crops in Alberta. However, isolated deficiencies have been observed in vegetable crops such as cauliflower.

Zinc

Zinc deficiencies tend to occur on calcareous, high pH soils that have been machine levelled, are sandy in texture or have relatively high soil phosphorus levels. Deficiencies are most common in spring when conditions are cool and wet. In southern Alberta, irrigated field beans have responded to applications of zinc. Zinc deficiencies have been suspected in some irrigated corn fields in southern Alberta, but research trials have not confirmed this.

A response to added zinc may occur on badly eroded soils or soils that have had large amounts of added phosphate fertilizer.

Micronutrient deficiency symptoms

Some micronutrients have characteristic deficiency symptoms. However, symptoms can be easily confused with other nutrient deficiencies, salinity, disease, drought, herbicide injury or other physiological problems. Visual symptoms alone are not a reliable method of determining a micronutrient, problem, but they are useful indicators when used with other diagnostic tools.

Boron

This deficiency results in stunted growth of young plants. The youngest leaves are affected first. They will be misshapen, thick, brittle and small. Because boron is not easily transferred from old to young leaves, older leaves usually remain green and appear healthy. Often dark brown, irregular lesions appear, followed by pale yellow chlorosis of young leaves. Stems are short and growing points may die. In canola, the symptoms of a boron deficiency can be confused with a sulphur deficiency. In alfalfa, boron deficiency symptoms include death of the terminal bud, rosetting, yellowtop and poor flowering.

When a boron deficiency is moderate, seed yield is often reduced without any evidence of severe deficiency symptoms during vegetative growth.

Chlorine

Chlorine deficiencies are very rare; therefore, symptoms are seldom observed. Symptoms may include stubby roots, some chlorosis of new leaves and plant wilting.

Copper

Copper is not readily transferred from old to young leaves, so older leaves remain darker and relatively healthy and the deficiency symptoms develop on younger leaves. The visual symptoms of a copper deficiency in wheat include yellowing of younger leaves, limpness, wilting, pigtailing (whip tailing or curling) of the upper leaves and kinking of the leaf tips. Other signs include excessive tillering, aborted heads, delayed maturity and poor grain filling resulting in a high straw to grain ratio. On copper deficient soils these symptoms tend to occur in irregular patches. Copper deficiency is often associated with the disease stem or head melanosis and an increased incidence of ergot. For barley, the symptoms of a copper deficiency include yellowing, pigtailing, awn kinking, excessive tillering and weak straw. Oats will also show pigtailing. Copper deficiency symptoms have not been well documented for canola or alfalfa.

Iron

Chlorosis of the younger leaves characterizes an iron deficiency. The tissue between the veins gradually turns yellow, while the veins tend to stay green. The tips and margins of some leaves may turn brown and become dry and brittle.

Manganese

In legumes, deficiency symptoms include pale green young leaves and a pale yellow mottling develops in interveinal areas, while the veins remain green. Oats are an excellent indicator crop. Manganese is partly mobile in oats. White to grey flecks or specks first appear and become more severe on mature leaves about halfway up the shoot. If a deficiency persists, symptoms spread to old leaves then to the youngest leaves. The specked condition is referred to as “grey speck” and will appear in the interveinal area of the lower half of older leaves and extend toward the tip as symptoms develop.

Manganese is not readily transferred from old to young leaves in wheat and barely. In wheat and barley, affected young leaves frequently turn pale green and have a limp or wilted appearance. A mild interveinal chlorosis develops in the mid-section of the leaf and spreads rapidly becoming pale yellow-green. Small white to grey spots, specks or strips appear a short distance from the end of the leaf tip on young leaves.

Molybdenum

Molybdenum deficiency symptoms are similar to those of nitrogen. Since molybdenum deficiencies are very uncommon symptoms are rarely seen.

Zinc

Zinc is partly mobile in wheat and barley. In these crops pale yellow chlorotic areas appear on middle leaves, halfway up the stem. Chlorotic symptoms first develop in the lower half or mid-section of the leaf followed by grey or dark brown necrosis of the leaf. Generally, stems are very short and often fan-shaped with leaves crowded together at the top.

Zinc deficient beans are stunted and older leaves are smaller and narrower. The older leaves may have light blotches between the veins. Younger leaves will have a more normal healthy green color but may be smaller.

In flax, a zinc deficiency can cause grayish-brown spots in the younger leaves with shortened internode spaces and stunted appearance.

In corn, symptoms occur within a few weeks of emergence as light yellow bands on the youngest leaves. The most severe symptoms occur on the youngest leaves from the unfolding bud, referred to as “white-bud”. Old leaves remain dark green and appear healthy. In a prolonged case of deficiency the middle leaves develop pale yellow interveinal chlorosis near the tips. A zinc deficiency prevents the elongation of internodes and leaves, which results in short stems with the leaves crowded together at the top in a fan-shaped appearance.

Note that zinc deficiency symptoms are similar to those of manganese and iron in some crops.

Soil sampling and testing

Soil tests aid in determining whether a particular nutrient is responsible for poor production and provides the basis for deciding the type and amount of fertilizer needed to correct a nutrient shortage. A soil sample used for laboratory analysis must consist of a composite of a number of samples taken from the field.

The DTPA (diethylenetriamine pentaacetic acid) method is used to extract the metal micronutrients. Hot water is used to extract boron. Either water or sodium nitrate is used to extract chlorine. Analytical results are usually given in parts per million (ppm). No soil test has proven particularly useful in predicting the availability of molybdenum. The micronutrients that are normally tested for are boron, copper, iron, manganese, and zinc.

Surface soil samples (0-15 cm) should be taken from both the affected area and an adjacent area of good crop growth for comparison. The general range levels used for determining when to add micronutrients for improving crop production are shown in table 2. When a soil sample tests low in a micronutrient, a potential micronutrient deficiency may occur. Some soils with low micronutrient levels at the surface (0-15 cm) do not respond to fertilization because they have higher levels of the nutrient in the subsoil.

Table 2. Range levels of micronutrients in soils.			
	Deficient	**Medium**	**Adequate**
Boron (Hot Water Extracatable - ppm)	0.0 - 0.4	0.5 - 1.2	>1.2
Chlorine (Water Extractable - ppm)	0.0 - 8.0[a]	-	-
Copper (DTPA Extractable - ppm)	0.0 - 0.2[b]	0.3 - 1.0	>1.0
	0.0 - 0.5[c]	0.6 - 1.0	>1.0
	0.0 - 2.5[d]	-	>2.5
Iron (DTPA Extractable - ppm)	0.0 - 2.0	2.0 - 4.5	>4.5
Manganese (DTPA Extractable - ppm)	0.0 - 1.0	-	>1.0
Zinc (DTPA Extractable - ppm)	0.0 - 0.5	0.5 - 1.0	>1.0

[a] This level is used by some labs as a critical level for recommending Cl for disease suppression in cereals.
[b] Brown and Dark Brown soil areas.
[c] Black and Grey Wooded soil areas.
[d] Organic soils.

Tissue sampling and testing

Plant tissue tests can aid in determining if a particular nutrient is responsible for poor crop growth. When a deficiency is detected by tissue sampling, a reduction in yield due to restricted crop growth has already occurred.

As with soil analysis, tests involving plant tissue must be calibrated with field fertilizer trials. Calibration in this case is far more complex than for soil tests. The reason is that measured nutrient concentration, which is the basis of the tests, varies considerably with the stage of plant development and the portion of the plant sampled.

Special care is required intaking plant tissue samples. Representative plant tissue samples can be taken early inthe growing season to assist in the interpretation of siol tests. For small grain crops all the above ground portion should be sampled. For alfalfa or other forage legumes, the top 6 inches (15 cm) should consist of the first fully mature leaves. Normally, 25 plants should be sampled to provide agood representation of the field and ensure a sufficient quantity of the sample for complete analysis. The fresh samples should be air-dried to remove excess moisture before they are shipped to a lab.

Plant tissue samples should be taken from bothan affected area and an adjacent area of good crops growth for comparison. Takingsoil and plant tissue samples at the same time wil aid in determing if a micronutrient is deficient. A range of levels of micronutients has been established for a number of crops at various stages of growth. Table 3 gives typical values for alfalfa, cereals and canola.

Table 3. Typical micronutrient levels in parts per million(ppm).

Alfalfa: upper 15 cm at 10% bloom

Nutrient	Low	Marginal	Sufficient
Boron	<20	20 - 30	30
Copper	<4	4 - 8	8
Iron	<20	20 - 30	30
Maganese	<15	15 - 25	25
Molybdenum	<0.5	0.5 - 1.0	1.0
Zinc	<12	12 - 20	20

Cereals: whole plant prior to filling

Nutrient		Low	Marginal	Sufficient
Boron		3	3 - 5	5
Copper	- barley	<2.3	2.3 - 3.7	3.7
	- wheat	<3	3 - 4.5	4.5
	- oats	<1.7	1.7 - 2.5	2.5
Iron		<15	15 - 20	20
Maganese		<10	10 - 15	15
Molybdenum		<0.01	0.01 - 0.02	0.02
Zinc		<10	10 - 15	15

Canola: at Flowering

Nutrient	Low	Marginal	Sufficient
Boron	<20	20 - 30	30
Copper	<1.7	1.7 - 2.7	2.7
Iron	<15	15 - 20	20
Manganese	<10	10 - 15	15
Molybdenum	-	-	-
Zinc	<12	12 - 15	15

Critical levels have not been established for chlorine.
Source: Alberta Agriculture data and the former Manitoba Provincial Soil Testing Laboratory

Micronutrient application in test strips

Even after observing micronutrient deficiency symptoms and conducting soil and plant tissue analyses it still can be difficult to predict if a profitable yield response will occur. Therefore, the micronutrient suspected of being deficient should be applied to a small affected area of the field in a carefully marked test strip. Visual observations and yields from the treated and untreated reas should be taken to determine if a measurable response occurred.

Micronutrient fertilizers

For the most current information on micronutrient recommendations, sources and methods of application for specific crops on problem soils, a regional soil or crop production specialist should be consulted.

Micronutrient fertilizers are either in inorganic form (readily soluble inorganic salt) or organic form. Table 4 lists some common inorganic micronutrient fertilizers. The inorganic forms are the most economical. The organic sources are synthetic chelates which are considered to be more available in some soil types.

Table 4. Some common inorganic micronutrient fertilizers.

Nutrient	Form	% of nutrient in product
Boron	Borate	14 - 20
	Borax	11
Copper	Copper sulphate	25
Iron	Iron sulphate	19
Manganese	Manganese sulphate	26
Zinc	Zinc sulphate	18 - 23

Boron

Application of borate or borax can be either broadcast and incoprorated or banded. Boron containing fertilizers should not come into contact with the seed at planting time. For permanent crops such as alfalfa, boron should be used as a topdressing. Soil application rates should not exceed 1.5 lb/ac on soils with a pH less than 6.5 to avoid boron toxicity problems. Foliar applications should not exceed 0.3 lb/ac to avoid toxicity problems. For all types of applications, extreme care must be taken to apply the correct amount and to apply it uniformly to avoid toxicity problems.

Copper

Broadcast and incorporated rates of 3 to 7 lb/ac of copper in the form of copper sulphate or copper oxide is recommended for deficient mineral soils. On organic soils, broadcast and incorporated rates of 10 to 15 lb/ac are required. Soil application rates should be effective for up to 10 years. Chelated forms of copper are also very effective in the year of application but little is known about the residual effects in Alberta soils. Foliar application on mineral and organic soils is not as consistent but can be used after deficiency symptoms appear. Foliar applications are required annually and are most effective at the late tillering stage. If the deficiency is severe, two applications (mid-tillering and boot stage) are necessary. Foliar rates of between 0.1 to 0.3 lb/ac are recommended.

Manganese

Only limited information is available on manganese fertilization in Alberta. As a rule, broadcast applications are seldom effective. For cereals, a seed placed treatment of manganese sulphate should be most effective. Foliar application can also be used if deficiency symptoms develop during the growing season.

Zinc

For treatment of a zinc deficient soil where a sensitive crop such as beans or corn is grown, a band application of 2 to 5 lb/ac of zinc sulphate or 0.5 to 1.0 lb/ac of a chelated zinc is recommended. When zinc deficiencies are suspected early in the growing season, a foliar application of 0.5 lb/ac of zinc sulphate can be used. Severely, deficient beans may require two applications. On eroded soils a 5 lb/ac broadcast and incorporated application of zinc sulphate can be tried.

Conclusions

The need for micronutrients in crop production have long been recognized in Alberta. Zinc deficiencies in irrigated beans in southern Alberta were detected in the early 1980s. Research by Alberta Agriculture and Agriculture Canada has clearly shown the need for copper fertilizer particularly for wheat grown on organic soils and on some Black and Grey-Black soils in central Alberta. One million acres may be copper deficient in central Alberta. Some suspected manganese deficiencies are presently being investigated. Continued research and testing is required to identify when various crops will give economic yield increases to additions of micronutrient fertilizers.

It is important to keep the need for micronutrient fertilizers in perspective. Over-promotion of micronutrients has occurred on occasion. Some farmers have applied micronutrients in the hope of increasing crop yields even though there is little evidence to suggest a deficiency exists.

Farmers who are concerned about micronutrient deficiencies are encouraged to investigate the need thoroughly and apply the nutrients in test strips if necessary. The test strip areas must be carefully marked out for comparison to areas where micronutrients were not used. Visual and qualitative comparisons should be made on these test strips.

There is no question that micronutrient levels will gradually decline in soils over time as cropping continues. However, most Alberta soils are currently well supplied with micronutrients. Soils and crops in Alberta that require micronutrient fertilizers are the exception not the rule. Care must be taken to keep the need for micronutrient fertilizers in perspective and not to promote them beyond their true significance.

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