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Minerals for Plants, Animals and Man

Twenty five elements are recognized as essential components of plants, animals and man. Because these elements are considered essential to life, they could be called “bioessential.” A few others, such as cobalt and the rare earth elements, could be included, but information on their roles is less exact. Carbon (C), Nitrogen (N), Oxygen (O) and Hydrogen (H) are primarily derived from air and water and are not discussed; the other 21 elements, listed in alphabetical order, occur as minerals in the soil.

Phosphorus, potassium and sulphur are regarded as macronutrients in all living systems. Calcium and magnesium are required in relatively large quantities while living organisms need the remaining 16 minerals in trace to minor amounts. Of the trace elements required for normal plant growth, referred to as micronutrients, Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn), and Molybdenum (Mo) are the most important and best understood. The remaining micronutrients play definitive roles in the metabolism of animals and man, but only a few, such as chloride and sodium, are known to have plant growth functions.

The more understood essential micronutrients are commonly found in mineral soils in the following ranges in parts per million or ppm.

Parts Per Million (ppm)

Boron	0.1 to 5	Manganese	1 to 100
Copper	0.1 to 4	Molybdenum	0.05 to 0.5
Iron	2 to 150	Zinc	1 to 20

Factors affecting deficiencies of these and other micronutrients include crop removal; leaching; extremes of soil pH; soil liming; land leveling; high soil phosphate; soil compaction; cool, wet growing conditions; tie-up in high organic soils or by manure amendments. In copper deficient soils, wheat is highly inefficient at extracting copper whereas rye or canola are considered to be very efficient at extracting this element. Micronutrient deficiency can, therefore, be very crop specific.

Table 1 below is intended to interrelate these essential minerals with brief descriptions of their roles, where known, in plants, animals and man. Deficient or adequate levels are provided only for plant growth. Such mineral nutrient parameters for animals and man are best left to veterinary or medical experts in this field.

Table 1.

Soil Minerals	Plants (P)	Animals (A)	Man (M)	Comments
***Boron* (B)** Micronutrient Deficient* 0.0 - 0.3 Adequate** 1.2 High 2.0 Hot water extraction (ppm)	Essential for normal plant growth (1923)***, canola and legume crops in particular. Promotes crop maturity, water balance, flower set and yield.	Stunted growth when deficient (1985).	Helps build and maintain healthy bones.	Toxic at anything more than low levels to plants **(P)**, animals **(A)**, and man **(M)**. Boron toxic soils occur on the prairies. Cole crops are most tolerant of high levels.
***Calcium* (Ca)** Macronutrient Ca, Mg, K and H cation ratio’s important	Cell wall structure component. No specific recommendation other than liming low pH soils, 5.5 or less.	The 5th most abundant body mineral.	The primary structural bone mineral.	Major soil pH regulator for plants. “Ideal” cation saturation in soil for Alfalfa would be 65% Ca, 10% Mg, 5% K and 20% H.
***Chlorine* (Cl)** Micronutrient Deficient <- 8.0 Adequate unknown	Trace levels seem beneficial in root rot control in wheat and barley. Potash fertilizer is KCl.	Essential for body fluid regulation.	Essential for body fluid regulation.	Excessive intake as NaCl can lead to health problems in animals and man.

Table 1. Soil Minerals	Plants (P)	Animals (A)	Man (M)	Comments
Chromium **(Cr)** Micronutrient Deficient unknown Adequate unknown	Unknown	Blood sugar regulation and can enhance weight gain in livestock (1950).	Deficiency causes diabetes like illness.	Toxicity rate.
Copper **(Cu)** Micronutrient Deficient <- 0.6 Adequate 0.9 - 2 High 2.5 + DTPA extraction (ppm)	Wheat, barley and flax crops are very sensitive to deficient Cu levels. Very important in plants reproductive growth stage and indirect role in chlorophyll production. Deficiency results in major yield and quality losses.	Red blood cells and skin pigments (1966). Up to 70% of cattle in Western Canada have been diagnosed as being deficient to some degree (blood copper levels). In nature, migrating animals may move from low copper to high copper areas.	Emphysema, high cholesterol, heart and muscle damage when deficient.	Molybdenum (Mo) interferes with Cu metabolism in **(P)**, **(A)** and **(M)**. Cu levels fed to cattle may be toxic to sheep. Copper toxicity occurs in some soils with history of prolonged copper pesticide applications, such as citrus groves in Florida.
Fluorine **(F)** Micronutrient Deficient unknown Adequate unknown	No known role in plants.	No deficiency identified in animals.	Prevention of dental cavities (1940). Important for hardness of bones and teeth.	Only in trace amounts.
Iodine **(I)** Micronutrient Deficient unknown Adequate unknown	Some plant species reputed to accumulate this element.	Major role in thyroid function.	Lack of iodine, a cause of a thyroid disease, goitre.	Commercial table salt is always iodized, i.e. trace levels of iodine.
Iron **(Fe)** Micronutrient Deficient 5.0 Adequate 11 - 16 High 25 + DTPA extraction (ppm)	Critical for cholorphyll formation and photosynthesis. Important in enzyme systems and respiration in plants.	The oxygen transporter in red blood cells and the red color in muscles.	Lack of iron causes anaemia and failure to produce red blood cells. Iron is also necessary for white blood cells in disease immunity responses.	Iron competes with zinc and copper in their ionic forms. High pH soils (8 or greater) are likely to be iron deficient for many plant species.
Magnesium **(Mg)** Macronutrient	The key element in the chlorophyll molecule. There would be no greening in the absence of Mg. First shows up as yellowing on older leaves.	Present in the body skeleton and a co-factor in many enzyme reactions.	Involved in protein synthesis DNA and RNA. Present in all green plant parts that are consumed as food.	Calcium and potassium interfere with Mg absorption in plants. Mg levels in soil should be greater than that of K.
Manganese **(Mn)** Micronutrient Deficient <- 4.0 Adequate 9 - 12 High 30 +	Important for all cereals on high pH mineral (alkaline) and organic soils. Enzyme systems involved with carbohydrate and nitrogen metabolism.	Bones, connective tissue and genetic proteins.	As for animals, including fat metabolism (1970).	Iron interferes with Mn uptake. Toxicity can occur with high intake levels of Mn in **(P)**, **(A)** and **(M)**. Grey speck disease of oats and barley (manganese deficiency) is common in Alberta.
Molybdenum **(Mo)** Micronutrient Deficient <- 0.05 Adequate 0.11 - 0.2 High 0.40 + Hot water extraction (ppm)	Essential for nitrogen fixation in legumes and nitrogen metabolism in crucifers (canola). Mo deficiency resembles iron chlorosis. Forages range from 0.1 to 3 ppm/kg of dry matter.	Involved in iron metabolism and enzyme reactions.	Available in grain seeds and animal livers. Seems to be involved in gout and sexual impotence.	Can seriously and lethally interfere with Cu metabolism in cattle. Food and drinking water are sources of Mo. Soil availability increases as pH rises.
Nickel **(Ni)** Micronutrient Deficient unknown Adequate unknown	Role in plants unknown. Present in nuts, beans and peas.	Co-factor for certain enzyme systems.	In the 1970's, evidence that high iron intake increased the need for nickel.	Some people are allergic to nickel jewelry.
Phosphorus **(P)** Macronutrient	Essential for all plant growth, i.e. energy transfer.	Present in bones, teeth and numerous metabolic reactions.	Average person eats 7 to 10 times the adult requirement for P.	High phosphorus dietary levels can lead to calcium imbalance (bone loss-osteoporosis).

Table 1. Soil Minerals	Plants (P)	Animals (A)	Man (M)	Comments
***Potassium* (K)** Macronutrient	The major ion inside every living plant and animal cell.	Involved in nerve impulses and muscle contraction, including the heart muscle.	With extreme sweating or diarrhea, potassium deficiency can occur (over-use of diuretic medications).	Potassium is universally present in all foods.
***Selenium* (Se)** Micronutrient	No known function but this mineral can accumulate in some plant species. Sulphur may interfere with selenium uptake in crop production.	Selenium first recorded as a poison in cattle grazing on high Se soils in 1930's. Deficiency causes white muscle disease in animals.	Deficiency known to be responsible for a heart weakening disease (1979). Vitamin E and selenium interact to form free radical scavengers.	Pastures in Alberta may be deficient in or occasionally contain toxic levels of available Se. S may interfere with Se plant uptake and animal metabolism.
***Silicon* (Si)** Micronutrient Deficient unknown Adequate unknown	The most abundant element on earth. Plays a role in disease resistance in crop plants. A structural component of some plant species.	Believed to hook fibrous body tissues, collagen and elastin tightly together. Possible role in bone calcification.	Not until 1972 was Si shown to have a role in animal and human health.	Non-toxic.
***Sodium* (Na)** Micronutrient Deficient unknown Adequate unknown	Many cultivated crops, such as beets, were originally sea shore plants. Sugar beets will respond to sodium fertilization.	Major ion in the fluids of the body outside the cells. Present usually as sodium chloride (NaCl).	Sodium controls body water balance and has a role in muscle contraction.	A diet high in calcium and magnesium can lead to sodium loss. Deficiency or excess may cause congestive heart failure.
***Sulphur* (S)** Macronutrient	Absolutely essential for plant growth. Deficiency causes yield loss in all crops, especially canola.	Plays a role in most body functions. Component of DNA.	Universally required for the enzymes that speed body chemicals reactions.	No symptoms of toxicity have been documented. High levels can interfere with selenium availability.
***Tin* (Sn)** Micronutrient Deficient unknown Adequate unknown	Role not defined.	Role unclear.	Thought to be essential. An ingredient in mineral supplement health tablets.	Tin is used extensively in cans, mugs and other food containers.
***Vanadium* (V)** Micronutrient Deficient unknown Adequate unknown	Present in plants such as dill, parsley and corn – role unknown.	Vanadium active in a number of body chemical reactions (1974). A co-factor in blood sugar and fat metabolism.	Important in building bones and teeth.	Toxic to health of man (1876). No dietary recommendations.
***Zinc* (Zn)** Micronutrient Deficient <- 0.5 Adequate 1.0 - 3.0 High 6.0 + DTPA extraction (ppm)	Very important in corn and bean production. Deficiencies usually occur on eroded soils low in organic matter with high pH. Essential for sugar regulation and enzymes that control plant growth.	Important for growth of hair, healing wounds and cell division (1934).	Important in taste and as an enzyme detoxifier component for alcohol.	High phosphate levels interfere with zinc uptake. Deficiencies have been recorded in beans, wheat and barley in Alberta.

* 1 Deficient – in parts per million (ppm).

** 2 Adequate – in ppm that are generally sufficient to meet most normal crop requirements. Insufficient under higher fertility conditions.

*** 3 Dates in parentheses indicate when the essential role of the mineral was first established.

4 To convert ppm (parts per million) into lbs per acre, multiply by 2, i.e. 5 ppm iron (Fe) equates to 10 lbs per acre. This fact is based on the rough assumption that 1 acre of soil to 6 inches deep weighs, on average, 2 million pounds. Peat and heavy clay soils would weight much less and much more, respectively.

5 In calculating the needs of a 60 bushel crop of wheat (Table 2), you need a SOIL TEST – soil available N and the organic fraction of the soil contribute N – may be 50 lbs per acre! But a 60 bushel crop needs 105 lbs per acre plus extra N for the inefficiency of the roots; therefore, you would need 55 lbs plus an extra 20 lbs to a total of at least 75 lbs of actual N per acre.

6 What does 1 per cent organic and 10 per cent organic mean? It means that in the top 6 inches of your soil stored in the 1 per cent organic fraction, there are 10,000 lbs of carbon, 1,000 lbs of nitrogen, 100 lbs of sulphur and small amounts of boron per acre. In a 10 per cent organic soil, there are ten times these amounts. Over the course of a year, cultivated (or fallowed) soil will release about .01 per of its nutrients. For 1 per cent O.M., that means 10 lbs of nitrogen and 1 lb of sulphur are released per acre in a form available to growing plants. Similarly, a 10 per cent organic matter content could release up to 10 times more nitrogen and sulphur. If you take out these nutrients without replacement, your soils will gradually lose its organic component. Hence, most prairie soils have lost 30 to 50 per cent of their original organic matter (fertility).

In drawing down the fertility of your soil, you are depleting the nitrogen, phosphate, potash, mineral sulphur and micronutrient reserves as well. Soil reserves of nutrients are not limitless, but some soils contain more than other.

Table 2. *

Nutrients removed by different crops and yield components

			Plant nutrients removed by crops (lbs/acre)										
Crop	**Yield per acre**	**Yield component**	**Nitrogen N**	**Phosphate P_2O_5**	**Potash K_2O**	**Sulphur S**	**Calcium Ca**	**Magnesium Mg**	**Boron B**	**Copper Cu**	**Iron Fe**	**Manganese Mn**	**Zinc Zn**
Alfalfa	4 t	all	175	39	175	20	112	21	.06	.06	.8	.4	.4
Barley	80 bu	grain	78	34	25	7	2	4	.09	.09	.27	.09	.09
Barley	2 t	straw	28	9	68	5	15	4	.02	.03	.01	.62	.09
Beans	40 bu	all	100	31	31	7	3	3	–	.03	.04	.04	.08
Canola	35 bu	seed	66	32	16	12	–	–	.1	.02	.41	.15	.22
Canola	–	residue	39	14	67	9	–	–	.1	.02	.3	.16	.07
Corn	100 bu	seed	97	44	28	7	–	–	.41	.05	.12	.05	.12
Corn	3 t	residue	56	19	101	8	10	14	.07	.05	.06	1.0	.2
Cotton	1500 lb	lint/sd	105	40	45	7	18	12	–	–	–	–	–
Cotton	–	residue	95	30	85	25	9	12	–	–	–	–	–
Flax	24 bu	seed	51	15	15	5	70	24	–	–	–	–	–
Flax	–	straw	14	3	20	4			–	–	–	–	–
Oats	100 bu	grain	61	26	18	5	3	4	–	.09	.9	.18	.09
Oats	2.5 t	straw	45	15	127	8	10	10	–	.09	.18	.18	.36
Peas	50 bu	all	153	43	137	13	175	15	.06	.09	.63	.45	.09
Peanut	5000 lb	nuts	175	33	41	13	12	17	–	–	–	–	–
Peanut	–	residue	95	30	85	25	90	24	–	–	–	–	–
Potatoes	20 t	tubers	228	66	298	18	6	10	.06	.09	.8	.18	.09
Soybean	60 bu	bean	250	50	86	12	9	9	.07	.06	.6	.07	.06
Soybean	–	residue	80	20	60	14	56	25	.04	.02	1.2	.6	.35
Sugarbeets	15 t	roots	65	24	65	9	30	24	–	–	–	.70	.20
Wheat	60 bu	grain	75	39	24	5	2	9	.06	.05	.45	.14	.2
Wheat	2 t	straw	30	9	65	7	9	5	.02	.03	.15	.26	.08

Metric conversion

1 lb/acre = 1.12 kg/ha; 1 ton/acre = 2.244 kg/ha; ton (t) = 2000 lbs (U.K. ton = 2240 lbs);

wheat and peas: 1 bu/acre (60 lb) = 67.20 kg/ha; barley and canola: 1 bu/acre (50 lb) = 56 kg/ha; oats and light barley: 1 bu/acre (34 - 48 lb) = 38 - 53.80 kg/ha

* Data collected from many sources.

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