Chapter 1. The functions and critical concentrations of micronutrients in crop production

FUNCTION AND ROLE OF MICRONUTRIENTS

The seven micronutrients or trace elements discussed in this book are as important to plant growth as the levels of macronutrients in the soil. Micronutrients are required only in very small quantities. Their concentrations in plant tissues are only a small proportion of the concentrations of macronutrients.

The functions of soil micronutrients for crops are listed in Table 1 (from Brady and Weil 1999). Micronutrients play many complex roles in plant nutrition, but most of them are used in the functioning of a number of enzyme systems. However, there is considerable variation in the specific functions of the various micronutrients in plants and in microbial growth processes. For example, copper, iron, and molybdenum are an essential part of the complex reactions which make up photosynthesis and many other metabolic processes. Zinc and manganese function in many plant enzyme systems as bridges. They connect the enzyme with the substrate upon which it is meant to act.

Since most micronutrients are relatively immobile in the plant, they are not readily transferred from older leaves to younger ones. Therefore the concentration of the nutrient tends to be lowest in younger leaves. Symptoms of deficiency are most pronounced in young leaves which develop after the supply of the nutrient has run low.

SOURCES OF MICRONUTRIENTS

Sources of the seven micronutrients vary markedly from one area to another. The wide variability in the content of these elements in soils is shown in Table 2 (Brady and Weil 1999).

All of the micronutrients are found in varying quantities in igneous (volcanic) rocks. Two of them, iron and manganese, are common in silicate minerals, such as biotite and hornblende. Others, such as zinc, may also replace some of the major constituents of silicate minerals, including clays.

Chlorine, by far the most soluble of the group, is added to soils in considerable quantities each year through rainwater. It is also added to soil in fertilizers and in other ways. These natural sources help prevent chlorine deficiency under field conditions.

Organic matter is an important secondary source of some trace elements. Several tend to be present as complex combinations in humus. Copper, in particular, is often tightly held by organic matter, to the extent that its availability can be very low in organic peat soils (Histosols). Soil profiles of uncultivated soil tend to have higher concentrations of micronutrients in the surface soil, much of them presumably in the organic matter. There is a certain connection between levels of soil organic matter and the content of copper, molybdenum, and zinc. Although the elements present in the organic matter are not always readily available to plants, their release through decomposition is undoubtedly an important fertility factor. Animal manure is a good source of micronutrients, many of them being present in organic forms.

Table 1. The functions of micronutrients

Elements	Functions
Zinc (Zn)	Present in a number of enzymes. Promotes the formation of growth hormones and starch, promotes seed development.
Iron (Fe)	Present in several important enzymes. Important in chlorophyll formation.
Copper (Cu)	Present in several enzymes. Important in photosynthesis, protein and carbohydrate metabolism, and probably nitrogen fixation.
Manganese (Mn)	Activates a number of important enzymes Important in photosynthesis and nitrogen metabolism.
Boron (B)	Activates certain dehydrogenase enzymes. Facilitates translocation of sugar in the plant, and the synthesis of nucleic acids and plant hormones. Eessential for cell division and development.
Molybdenum (Mo)	Present in various enzymes. Essential for nitrogen fixation and nitrogen assimilation.
Chlorine (cl)	Plays a role in photosynthesis and enzyme activation. Regulates the openning of the leaf stomata.

Table 2. Major sources of seven micronutrients, and usual content of these nutrients in soils, and in harvested crops

Element	Levels usually found in		Soil/crop ratio
	Soils* (kg/ha)	Crops (mg/kg)	
Iron (Fe)	56,000	2	1:28,000
Manganese (Mn)	2,200	0.5	1:4,400
Zinc (Zn)	110	0.3	1:366
Copper (Cu)	45	0.1	1:450
Boron (B)	22	0.2	1:110
Molybdenum (Mo)	5	0.02	1:250
Chlorine (Cl)	22	2.5	1:0.9

* In 15 cm of topsoil

DEFICIENCIES AND TOXIC CONCENTRATIONS OF MICRONUTRIENTS IN SOILS AND PLANTS

Research has indicated that background levels of micronutrients in soils and plants vary widely. So do the levels likely to cause symptoms of deficiency or toxicity, as shown in Table 3 and Table 4.

Table 3. Concentration of micronutrients in soils and plants

Element	Normal range found in soils[1]	Critical total concentration in soil[2]	Normal range in plants[1]	Critical concentration in plants[3]	
				Upper	Lower
	mg/kg				
Copper (Cu)	N2 - 250	60 - 125	5 - 20	20 - 100	5 - 64
Molybdenum (Mo)	0.1 - 40	2 - 10	0.03 - 5	10 - 50	--
Manganese (Mn)	20 - 10,000	1500 - 3,000	20 - 1,000	300 - 500	100 - 7,000
Zinc (Zn)	1 - 900	70 - 400	1 - 400	100 - 400	100 - 900

1: Bowen (1979)
2: Kabata-Pendias and Pendias (1992)
3: Critical concentration. Upper = levels above which toxicity effects are likely, data from Kabata-Pendias and Pendias (1992). Lower = Values likely to cause 10% depression in yield, data from McNichol and Beckett (1985).

Source: Alloway 1990

Table 4. Deficiency, normal, and critical toxicity levels of micronutrient elements in plants

Elements	Deficiency	Normal	Toxicity
	mg/kg		
Iron (Fe)	Less than 20	20-1000	2000 and above
Manganese (Mn)	Less than 90	90-200	200 and avove
Copper (Cu)	Less than 10	10-25	25 and above
Zinc (Zn)	Less than 10	10-120	120 and above
Boron (B)	Less than 10	10-80	80 and above
Molybdenum (Mo)	Less than 0.1	0.1-90	90 and aabove