Chapter 1
Micronutrients and Crop Production:
An Introduction

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Abstract Eight trace elements are essential for higher plants: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn). Whenever the supply of one or more of these elements is inadequate, yields will be reduced and the quality of crop products impaired, but crop species and cultivars vary considerably in their susceptibility to deficiencies. Zinc deficiency is the most ubiquitous micronutrient problem throughout the world affecting many crops including the staples maize, rice and wheat. Boron deficiency is the second most widespread micronutrient problem and dicotyledon species tend to be more sensitive to B deficiency than graminaceous crops. Iron deficiency is important in some regions, especially those with a Mediterranean climate and calcareous soils. Copper deficiency is important in some parts of the world, such as Europe and Australia where cereals are most affected. Likewise, Mn and Mo deficiencies vary in importance around the world. Acute micronutrient deficiencies in plants are accompanied by distinct symptoms, but hidden deficiencies without obvious symptoms are generally more widespread.

1.1 Introduction

Micronutrients are those trace elements which are essential for the normal healthy growth and reproduction of plants and animals. The trace elements essential for plants are: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn). Although, cobalt (Co) is known to be essential for the bacterial fixation of atmospheric nitrogen (N) in leguminous plants, it is not considered to be essential for all higher plants. Nevertheless, it has been shown to have beneficial effects on crops in other plant families, such as the Graminae (e.g., wheat, Triticum spp.) (Asher, 1991) and is referred to as a “beneficial” element. Other beneficial elements, which have not yet been proved to be “essential”, include silicon (Si), sodium (Na), selenium (Se), vanadium (Va) and aluminium (Al) (Barker and Pilbeam, 2007).

The trace elements recognised as being essential for animals are: Co, Cu, chromium (Cr), fluorine (F), iodine (I), Fe, Mn, Mo, Se and Zn. However, an additional
seven elements are also regarded as being essential for humans (see Graham, Chap. 2 and Welch, Chap. 12).

For a trace element to be essential for either plants or animals (i.e., a micronutrient), it needs to satisfy three criteria: (1) the organism cannot grow and reproduce normally without the element, (2) its action must be specific and unable to be replaced by any other element, and (3) its action must be direct (Arnon and Stout, 1939). However, Epstein (1965) advocated that an element can also be regarded as essential if it is a component of a molecule known to be an essential metabolite, even if it cannot be demonstrated that it fulfils all of the criteria proposed by Arnon and Stout.

In geochemistry, the term “trace element” is given to elements which normally occur in trace amounts (usually <1,000 mg kg\(^{-1}\)) in rocks and soils. However, the biological use of the term “trace element” applies to elements occurring at relatively low concentrations (usually <100 mg kg\(^{-1}\)) in the dry matter of living organisms.

The macro elements carbon (C), hydrogen (H), oxygen (O) and N, which form the main organic compounds in plants and animals, are present in the highest concentrations (at percentage levels). Potassium (K) tends to be present in similar concentrations to N (1.4–5.6%) but phosphorus (P), calcium (Ca), magnesium (Mg), Na and Cl are present in intermediate concentrations (0.1–2.5%) (Wild and Jones, 1988; Marschner, 1995).

It is very important that the micronutrient element requirements of crops are met as well as their macronutrient needs if they are to yield satisfactorily and bear products (e.g., grains and fruits) of acceptable quality. The dose response curves for all micronutrients show that, just as yields can be affected by deficiencies, they can also be reduced by toxicity due to excessive concentrations of the same elements. It is therefore important that soils and/or crops are monitored to ensure that the available micronutrient concentrations in soils are in the optimum range, being neither too low, nor too high. Typical dose–response graphs for micronutrients and non-essential elements are shown in Fig. 1.1.

It is only during the last 70 years that most micronutrient deficiency problems have been widely recognised and treated in the field. This has been largely due to the increased intensification of arable farming in many parts of the world and also to the cultivation of virgin and/or reclaimed land. Intensification involves the increased use of N, P, K and other fertilisers, growing new and higher yielding crop cultivars, liming to create more optimal soil pH conditions, increased use of agrichemicals to control pests and diseases and, in more arid areas, increased use of irrigation. Prior to this intensification, much lower crop yields were usually accepted as the norm in many parts of the world and the crop cultivars grown were generally well adapted to local soil and climatic conditions.

With the adoption of more intensive methods of crop husbandry, it was frequently found that crops began to exhibit various symptoms of stress which had not previously been known on the same area of land. Many of these micronutrient deficiencies were brought about by the increased demands of more rapidly growing crops for available forms of micronutrients. In some cases, several of the elements were rendered less available due to changes in soil conditions, such as increased pH through liming. Perhaps the most important and ubiquitous cause has been the