# PREFACE

Crop production depends on a complex interaction among soil, water, climate, plants, microorganisms, and essential nutrients. Among the various elements present in agricultural systems, **metals and metalloids** have a special significance because many of them are directly involved in plant growth, development, metabolism, enzyme activity, photosynthesis, respiration, nitrogen fixation, and reproductive processes. Elements such as iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), and nickel (Ni) are recognized as essential micronutrients for higher plants, while elements such as boron (B) and silicon (Si) are commonly classified as metalloids and play important beneficial or essential roles in particular plant species and physiological processes.

Although these elements are required in very small quantities, their importance in crop production is disproportionately high. **Iron** is essential for chlorophyll formation and electron transport, **zinc** contributes to

enzyme activity, protein synthesis, and growth regulation, while **copper** is involved in photosynthesis, respiration, and several enzymatic reactions. **Manganese** participates in photosynthetic water splitting and activates numerous enzymes. **Molybdenum** is particularly important for nitrate reduction and biological nitrogen fixation, whereas **nickel** is required for the activity of urease and is therefore associated with nitrogen metabolism. **Boron** contributes to cell wall formation, reproductive development, pollen germination, and seed production. **Silicon**, although not universally considered an essential nutrient, can improve plant strength and enhance tolerance to several environmental and biotic stresses.

The availability of metals and metalloids in soil is influenced by **soil pH, organic matter, moisture, texture, redox conditions, temperature, and interactions with other nutrients**. Therefore, the total concentration of an element in soil does not necessarily indicate its availability to plants. Deficiency of these elements can result in characteristic symptoms, reduced growth, poor flowering and fruiting, lower yield, and

deterioration in crop quality. On the other hand, excessive accumulation of certain metals and metalloids may become toxic to plants, disturb nutrient balance, inhibit root growth, reduce photosynthesis, and pose risks to food safety and human health.

Modern intensive agriculture has increased the importance of balanced micronutrient management. Continuous cultivation, removal of crop residues, high-yielding varieties, imbalanced fertilizer use, and declining soil organic matter can contribute to micronutrient deficiencies. At the same time, industrial activities, contaminated irrigation water, sewage, certain fertilizers, and other anthropogenic sources may increase the concentration of potentially toxic elements such as cadmium, lead, chromium, and arsenic in agricultural soils.

Thus, understanding the **role, availability, deficiency, toxicity, uptake, and management of metals and metalloids** is essential for sustainable crop production. Proper soil testing, balanced fertilization,

selection of suitable nutrient sources, efficient application methods, and regular monitoring can help maintain an appropriate nutrient balance. This knowledge not only supports higher crop productivity but also contributes to improved nutritional quality, soil health, environmental protection, and safe food production. The study of metals and metalloids therefore forms an important component of modern plant nutrition and sustainable agricultural management.

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