

Table 3.6

ESSENTIAL PLANT NUTRIENTS

Element	Chemical symbol by crop plants	Chemical forms absorbed	Source
carbon	C	CO ₂	air
hydrogen	H	H ₂ O	water
oxygen	O	O ₂ , H ₂ O	air, water
PRIMARY NUTRIENTS			
nitrogen	N	NO ₃ ⁻ , NH ₄ ⁺	soil solids*
potassium	K	K ⁺	soil solids
phosphorus	P	H ₂ PO ₄ ⁻ , HPO ₄ ²⁻ , PO ₄ ³⁻	soil solids
SECONDARY NUTRIENTS			
calcium	Ca	Ca ²⁺	soil solids
magnesium	Mg	Mg ²⁺	soil solids
sulfur	S	SO ₄ ²⁻	soil solids
MICRONUTRIENTS [†]			
boron	B	BO ₃ ³⁻	soil solids
chlorine	Cl	Cl ⁻	soil solids
copper	Cu	Cu ⁺ , Cu ²⁺	soil solids
iron	Fe	Fe ³⁺	soil solids
manganese	Mn	Mn ²⁺	soil solids
molybdenum	Mo	MoO ₄ ²⁻	soil solids
nickel	Ni	Ni ²⁺	soil solids
zinc	Zn	Zn ²⁺	soil solids

Notes:

*Some microorganisms that live in association with legume plant roots (*Rhizobia*, for example) can fix atmospheric nitrogen (N₂), converting it to inorganic forms, including ammonium ions (NH₄⁺), which crop plants can absorb. In this case, it can be said that some plants obtain their essential nitrogen from the air in symbiotic relationship with soil microorganisms.

†The term *micronutrient* has been restricted to mean those elements known to be essential for the growth of higher plants that are needed in minute or trace quantities (ppm or ppb). Although the term *trace elements* is often used interchangeably with micronutrients, it has been used rather loosely in the scientific literature to describe elements with no known physiological function that may be toxic to plants and animals. Unfortunately, the terms *micronutrients*, *trace elements*, *microelements*, *heavy metals*, *trace metals*, and *trace inorganics* are used interchangeably. To avoid confusion, it is best to use the term micronutrients to refer to mineral elements that are essential for plant growth in trace quantities.