

An Effective Role of Soil Minerals in Plant Nutrition

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Abstract

Soil mineral nutrient required by plants is an essential for its survival without availability it can't be survived. A various way of transportation of nutrients through different phenomenon's involved in its activity. Although, 17 essential elements are required by plants in which Carbon, Hydrogen and Oxygen is freely available in the atmosphere whereas other nutrients are available through soil. Uptake of nutrients by plants in ionic (both cationic and anionic) form. Plant absorbed nutrients in single ionic form (K^+ , Ca^{2+} , Mg^{2+} , Fe^{2+} , Mn^{2+} , Cu^+ , Zn^{2+} , Cl^- , Na^+) and combined ionic form (NH_4^+ , HPO_4^{2-} , SO_4^{2-} , H_3BO_3 , MoO_4^{2-}). Each and every nutrient play a significant role of functions in plants and deficiency of any nutrient occur leads to reducing the growth and development of yield. So, a sufficient knowledge about nutrients must be known and its deficiency must be enhanced it through fertilizers use, manure, organic amendments, etc.

Keywords: Essential elements, nutrients, ionic form, N-P-K uptake, Oxygen.

INTRODUCTION

Although plant physiologists generally scan a soil as merely a source of nutrients to plants [1]. Soil nutrient fluxes additionally play a job in additional international situations. Soil-plant nutrients are supported the principle that nutrient uptake rate is controlled by specialized transporter enzymes [2]. At least 17 elements are well known to be essential nutrients for plants to complete their life cycle. Plant growth and development primarily rely upon the mixture and concentration of mineral nutrients obtainable within the soil. A plant primarily faces a serious defiance in obtaining an adequate supply of essential nutrients to fulfill the demand of basic cellular processes because of their relative immobility. An inadequacy of any one of nutrient might lead to reduce in plant fertility.

Plants nutrient is particularly classified into two categories of nutrients are thought of a vital for plants: Macro and Micro nutrients. Macronutrients are the building blocks of crucial cellular elements like proteins and nucleic acids. They are needed by plants in concentrations more than 1 ppm is taken into an account as a large quantity. C, H, O, N, P, K, Ca, Mg and S are a number of the foremost necessary macronutrients. However, micronutrients (Oligo/ trace elements) are needed by plants in

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concentration less than 1 ppm is taken into an account as a minute quantity. Fe, Mn, Zn, Cu, Bo, Cl, Mo and Ni are remaining micronutrients. Micronutrients are usually needed as cofactors for enzyme activity [3]. With the exception of Carbon, Hydrogen, and Oxygen, that plant get from air and water, whereas the remaining 14 elements absorbed from the soil or through fertilizers, manures, and amendments [4].

Plants are well-known to indicate totally different responses to different specific nutrient deficiencies and therefore the responses will vary between species. As shown in Figure 1, the foremost common changes are inhibition of primary root

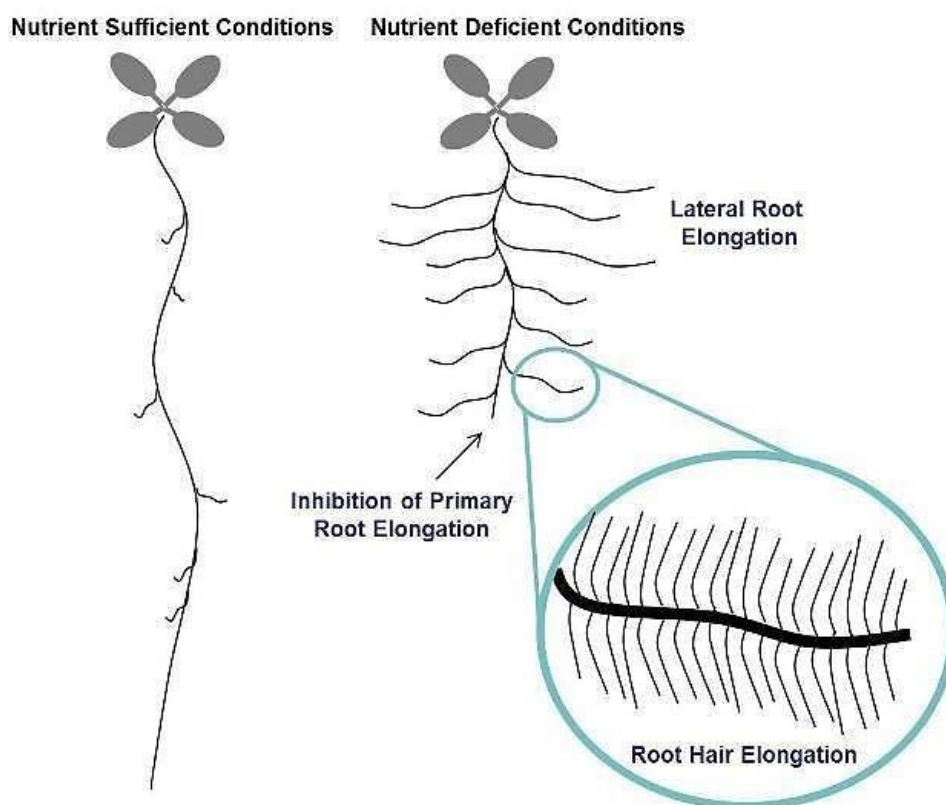


Figure 1. Overview of root architecture changes in response to nutrient deficiency.

growth (often associated with P deficiency), increase in lateral root growth and density (often associated with N, P, Fe, and S deficiency) and increase in root hair growth and density (often related to P and Fe deficiency).

While nutrient deficiencies will cause serious threats to plant productivity, nutrients will become noxious in excess that is additionally problematic. Some extremely noxious components like lead and cadmium element cannot be distinguished from essential nutrients by the nutrient uptake systems within the plant root, which suggests that in contaminated soils, noxious components might enter via nutrient uptake systems, inflicting reduced uptake of the essential nutrient and considerably reduced plant growth and quality.

In order to keep up nutrient physiological state, plants should regulate nutrient uptake and should reply to changes within the soil yet as among the plant. Thus, plant species utilize varied methods for mobilization and uptake of nutrients yet as chelation, transport between the various cells and organs of the plant and storage to realize whole-plant nutrient physiological state. We will discuss soil mineral nutrients and its form of uptake with their deficiency symptoms in plant.

PRIMARY MINERALS AND ITS INFLUENCE ON SOIL FERTILITY

Soil parent material contains a vital direct influence on the nutrient element part contents of the soil; this influence may be a lot of pronounced in young soils and diminishes somewhat with increasing soil age and soil weathering. So as to perceive the result of soil parent materials on the soil elemental composition, it is helpful to review the mineralogical composition of common rocks that structure the soil parent material (Table 1). Primary minerals kind at elevated temperatures from cooling magma throughout the primarily activity of rock or throughout geological process, and that they are sometimes derived from igneous and metamorphic rocks in soil [5]. In most soils, feldspars, micas, and quartz are the main primary mineral constituents, and pyroxenes and hornblendes are present in smaller amounts.

Table 1. Average mineralogical and nutrient element composition of common rocks on the Earth's land surface (Klein & Hurlbut 1999, based on data of F. W. Clarke) [6].

Mineral constituents	Igneous rock (%)	Shale (%)	Sandstone (%)	Nutrient element constituents	
				Major	Minor
Feldspars	59.5	30.0	11.5	K, Ca, Na	Cu, Mn
Amphiboles and Pyroxene	16.8	-	11.5	Mg, Fe, Ca	Ni, Co, Cu, Mn, Zn, Mo
Micas	3.8	-	11.5	K, Ca, Na, Mg, Fe	Ni, Mn, Co, Zn, Cu
Titanium minerals	1.5	-	11.5	Ti, Fe, Ca	Co, Ni
Apatite	0.6	-	11.5	Ca, P	-
Clay	-	25.0	6.6	K, Mg, Fe, Ca, Na	-
Iron Oxides	-	5.6	1.8	Fe	Mn, Zn, Ni, Co
Carbonates	-	5.7	11.1	Ca, Mg, Fe	-
Other minerals	-	11.4	2.2	-	-

The physical, chemical, and biological weathering of primary minerals releases variety of nutrient elements into the soil solution. Weathering rates and pathways of primary minerals are extremely variable and rely upon many factors, together with mineral properties and atmospheric condition. Although the weathering rates of primary minerals for certain elements might not be quick enough to fulfill plant nutrient. Mineral weathering is a very important and long-run supply of many geochemically derived nutrients. The nutrient offer capability of a soil through weathering of primary minerals diminishes because the extent of soil weathering will increase.

SECONDARY MINERALS AND ITS INFLUENCE ON SOIL FERTILITY

Secondary minerals in soils are typically formed by low-temperature reactions throughout the weathering of primary minerals within the aqueous atmosphere at the surface. Secondary minerals primarily manage nutrients through adsorption-desorption, dissolution-precipitation, and oxidation-reduction reactions.

Adsorption reactions involving minerals are usually a lot of necessities in dominant plant nutrient element convenience than the discharge of nutrient elements by mineral weathering. Phyllosilicates with a permanent charge (e.g., vermiculite and smectite) provide exchange sites that hold a variety of essential nutrients in their cationic type (cation exchange capacity), like Ca^{2+} , Mg^{2+} , K^{+} , and Na^{+} ; the nutrients are preserved by outer-sphere advanced formation and will be simply taken up by plant roots.

ESSENTIAL ELEMENTS AND THEIR FORMS OF AVAILABILITY

Plants absorb nutrients from the soil as in ionic forms given in the Table 2.

Table 2. Availability of Macronutrients and Micronutrients [7]

S.N.	Elements	Concentration in plants	Forms of uptake
1.	Major Elements		
	Carbon (C)	45%	CO_2
	Hydrogen (H)	6%	H_2O
	Oxygen (O)	45%	H_2O , O_2
A.	Primary nutrients		
	Nitrogen (N)	1.5%	NH_4^+ , NO_3^-
	Phosphorus (P)	0.2%	H_2PO_4^- , HPO_4^{2-}
	Potassium (K)	1.0%	K^+
B.	Secondary nutrients		
	Calcium (Ca)	0.5%	Ca^{2+}
	Magnesium (Mg)	0.2%	Mg^{2+}
	Sulphur (S)	0.1%	SO_4^{2-} , SO_2

2.	<i>Micronutrients</i>		
	Iron (Fe)	100 ppm	Fe^{2+} , Fe^{3+}
	Zinc (Zn)	20 ppm	Zn^{2+}
	Manganese (Mn)	50 ppm	Mn^{2+}
	Boron (B)	20 ppm	H_3BO_3
	Copper (Cu)	6 ppm	Cu^{2+} , Cu^+
	Molybdenum (Mo)	0.1 ppm	MoO_4^{-2}
	Chlorine (Cl)	100 ppm	Cl^-
	Nickel (Ni)	0.1–1.0 ppm	Ni^{2+}

ROLE AND DEFICIENCY SYMPTOMS OF PLANT NUTRIENTS

Primary Nutrients

Nitrogen

It is a significant element of proteins, hormones, chlorophyll, vitamins and enzymes essential for flora. An excessive amount of N will delay in flowering and maturity. Plants typically take up the nitrate (NO_3^-) and ammonium ion (NH_4^+) forms of soil nitrogen. In soils, N applied through fertilizers and mineralized N from organic matter largely finished up within the NO_3^- form. The geology of oxisols and ultisols is dominated by minerals with variable surface charge, mainly kaolinite and Fe and Al oxides, which offer these soils with the capability to retain massive amounts of NO_3^- -N, significantly within the subsoil horizons. For instance, [8] estimated between 17,000– 32,000 kg NO_3^- -N ha^{-1} to a depth of 10 m beneath totally different land uses in oxisols from northern Queensland in Australia. The adsorbate nitrate is just too deep and is probably going inaccessible to most field crops; nevertheless, it doesn't leach into groundwater. Deficiency of N will reduce yields, caused yellowing at tip of the leaves and stunt growth (Figure 2).

Phosphorus

It is necessary for seed germination, photosynthesis, protein formation and the majority aspects of growth and metabolism in plants. It's known as "key of life". P is primarily haunted by plants within the sort of phosphate ions (HPO_4^{2-} and H_2PO_4^-) from the soil solution. The concentration of P in soil water is usually very low (< 0.01% of the total soil P), with the majority of the soil P existing as organic P, insoluble compounds of P with Al, Fe, and Ca, and phosphate adsorbate to Fe and Al oxides and phyllosilicates [9, 10]. Phosphate ions from dissolved chemical fertilizers react rapidly in most soils, leading to P fixation within the soil. Deficiency in P imparts purple stems and leaves, bronzing look on older leaves and later develops into red purple coloration (Figure 3). Yields of fruit and flowers are poor.



Figure 2. Nitrogen deficiency symptom showing in leaf



Figure 3. Phosphorus deficiency symptom showing in leaf

Potassium

Among the essential elements, K is typically the foremost abundant in soils. Total K in soils varies from 0.5–2.5% of the soil mass, and most of the K exists in mineral form (K-feldspars and micas). Potassium is essential for control of stomatal opening or closing and serving as an osmotic for cellular growth. Under conditions of potassium limitation, plants typically induce high affinity K^+ transport systems. There are seemingly several proteins concerned in high affinity potassium transport, however in genus *Arabidopsis*, two proteins are known because the most vital transporters during this method. Interestingly, one in all these transporters, AtHAK5, could be a carrier protein and thought to mediate active transport of potassium into plant roots, whereas the other protein, AKT1, could be a channel protein and sure mediates a passive transport mechanism with associate in magnified affinity for K^+ beneath conditions of potassium limitation [11]. It is clear that the mechanisms involved are advanced and tightly controlled to permit the plant to acquire enough amounts of potassium from the soil beneath variable conditions.

Potassium deficiency often happens in plants full grown on sandy soils leading to variety of symptoms as well as browning of leaves, mottled, spotted or curled leaves, scorched and yellowing of leaves, as well as reduced growth and fertility (Figure 4).



Figure 4. Potassium deficiency symptom showing in leaf

Secondary Nutrients

Among the secondary nutrients, Ca and Mg are haunted by plants in their cationic forms, Ca^{2+} and Mg^{2+} . These cations are preserved at negatively charged sites of phyllosilicates via electrostatic attraction (outer-sphere complexation) (Figure 5). The precipitation of secondary carbonates, like calcite (CaCO_3), magnesium calcite ($\text{Ca}_{1-x}\text{Mg}_x\text{CO}_3$), and gypsum is common in soils of arid and semi-arid environments.

Ca influences water movement in cells and is additionally necessary for cell growth and division. Calcium is immobile in plants and its deficiency symptoms seem on meristem tip portion. The young leaves is also severely distorted with the tip hooked back and poorly roots developed with lack of fibers. Mainly two most typical diseases could found because of deficiency of Ca is Tip hooking (mainly found in cauliflower, beet and tobacco) and Blossom end rot commonly in tomato.

Mg is a vital structural component of the chlorophyll molecule and is critical for functioning of plant enzymes to supply carbohydrates, sugar and fats. Deficiency of Mg show yellowing between veins of older leaves and leaves might drop off. Defoliation is also quite severe. In Tobacco, sand drown disease is especially common because of Mg deficiency.

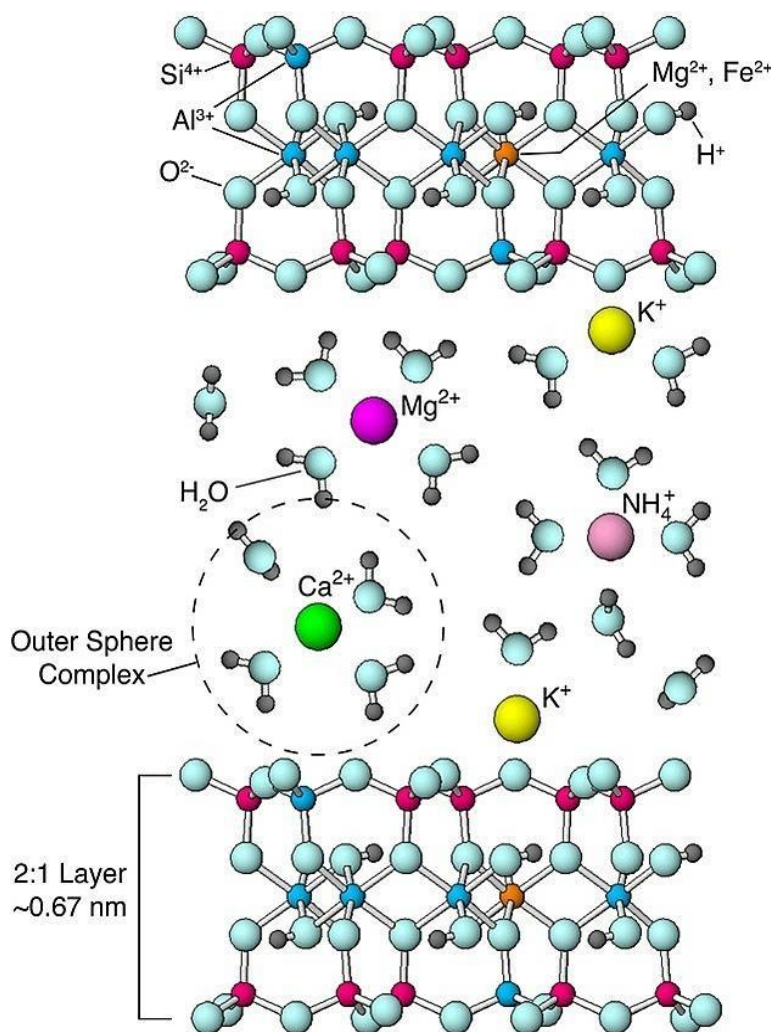


Figure 5. Hydrated exchangeable cations within the interlayer region of the clay mineral smectite [12]



Figure 6. Ca, Mg and S deficiency symptom showing in leaf

Sulphur is taken up by plants as sulphate (SO_4^{2-}), and this is often the foremost common inorganic S form in soils. Fe and Al oxides and kaolinite offer surface assimilation sites for SO_4^{2-} in most soils, even if these minerals are present in tiny amounts. In calcareous soils, SO_4^{2-} is also combined on CaCO_3 by forming a $\text{CaCO}_3\text{-CaSO}_4$ precipitate that renders SO_4^{2-} unavailable to plants. It is an essential structural component of amino acids, proteins, vitamins and volatile oils. The characteristic odour of cruciferous family plants is thanks to sulphur as a constituent of volatile oils. Its deficiency shows a light green leaves, necrosis of young leaf tips and die back occurs (Figure 6). The tea yellow disease in tea plants mainly due to growing in sulphur deficient soils.

Micronutrients

Among the micronutrients, Fe, Mn, Cu, Zn, and Ni are taken up by plants in their cationic forms, and B, Mo, and Cl are taken up by plants in their anionic forms. The two most stable Iron oxides, goethite and hematite, are famous to possess substantial structural substitution of trace elements, including Mn, Ni, Zn, and Cu. Manganese minerals exist in soils as mineral coatings or as finely dispersed particles within the soil matrix. Plant accessibility of both Fe and Mn is greatly reduced in calcareous soils due to the very low solubility of Fe and Mn oxides. In such things, plants induce biochemical responses, like release of reducing and chelating compounds and acidification of rhizosphere, which may increase the provision of Fe, Mn, and other micronutrients.

Copper, Zn, and Ni are adsorbed by Fe and Al oxides by forming inner-sphere complexes at low solution concentrations. However, at higher solution concentrations, precipitation of metal hydroxides happens [13]. Surface assimilation of Cu^{2+} , Zn^{2+} , and Ni^{2+} happens by outer-sphere complex formation on negatively charged surfaces of 2:1 phyllosilicates and maybe by inner-surface advanced formation on kaolinite surfaces. In alkaline soils, surface assimilation of Zn on calcite and co-precipitation of Cu in calcite can also occur.

B and Mo are taken up by plants as H_3BO_3 and MoO_4^{2-} . Restricted proof suggests that B species i.e., $\text{B}(\text{OH})_3$ and $\text{B}(\text{OH})_4^-$ in soils are adsorbable by forming inner-sphere complexes on the surfaces of Fe and Al oxides [12]. Similarly, MoO_4^{2-} is powerfully adsorbable by metal oxides. Chlorine is taken up by plants within the chloride (Cl^-) form. In certain soil environments, such as those with restricted action or those with low-lying areas in arid climates, Cl could exist in precipitated mineral forms, like NaCl , CaCl_2 , and MgCl_2 .

CONCLUSION

I would suggest to farmers that in order to get an optimum production of the crop, soil testing should be followed at specific area, which helps a farmer's to know about the fertility status which is beneficial

for diagnosing deficient and sufficient available nutrient status of soil in a field. Application of fertilizers should be performed to a particular crop as per according to a soil test report. Farmers will get a benefit if they know about the soil health card scheme in which an optimum level of nutrients is mentioned in the card of a specific field area which provides a farmer to adopt a crop suitable for his land to get a maximum output yield.

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