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Mineral Stresses and Crop Productivity

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1. Introduction

The 21st century, as a wealth and prosperity of human being all over the world, should be guaranteed by the sustainable food production through plant nutrition and agricultural development in Asia is the key issue for the sustainable future of human beings. Today, agricultural sector provides food to 6 billions people in the world. Of this nearly 4 billion people are living in Asia where the food scarcity, which was repeatedly claimed due to increasing population, has been evaded by the tremendous progress of agricultural technology particularly in India and China during the past four decades. The world population is predicted to become nearly 10 billions in next 25-30 years. Of this, more than 60 % people will be living in Asia where main agricultural products produced in this area are presently only 50 % of those of the world. Thus food shortage may become an important problem in future in Asia.

The science of plant nutrition has made a great progress during the 20th century. It became an established scientific discipline, defining the role of chemical elements supporting plant growth, and has contributed to improvement in plant production and environmental quality. In the present era, environment-harmonic agriculture is required where research on plant nutrition have a very important role to achieve this type of agriculture with no reduction of yield. Optimization of the mineral nutrition is the key way to optimize the production of recently released high yielding crop varieties with very high nutrient requirement. On contrary, the farmer use very less nutrient fertilizer and many a times only one or two nutrients resulting in poor yield due to inadequate and imbalance use of nutrients.

Thus, it is high time to re-look the various aspects of mineral stresses of crops for achieving high yield and advocate the suitable package of practices for it's improvement. The intervention of man is important and he must use the processes taking place in the soil and physiological process going on in the plant. The present chapter highlights some of the current views on the mineral stresses caused by their deficiencies and toxicities in crop plants to enhance the yield and quality.

2. Major causes of mineral stresses

Any type of stress in soil affects the mineral nutrient stresses in crop plants limiting its production. Under ideal conditions the plants mines all the essential nutrients in balanced proportions and deviation from this may results in mineral disorders, either due to deficiency or the toxicity of a single or multi-nutrients. Following are the major factors causing these nutritional deficiencies and toxicities in plants:

- Continuous withdrawal and inadequate supply of nutrients in the soil;
- Leaching , run off and nutrient fixation in the soil;
- Soil, water and environmental factors affecting absorption of nutrients by plants;
- Changes in soil physico-chemical conditions such as pH and EC;
- Imbalance use of fertilizers;
- Induced deficiency;
- Interaction between minerals during uptake;
- Antagonism and synersism;
- Use of intensive nutrient (response) requiring crops and nutrient in-efficient crops;
- Other biotic (Disease and pests) factors.

An early detection of nutritional stress is important as these might extend to the entire plant and might cause plant death. Some of these factors are discussed here in details.

2.1. Soils and pH

The acid soils, with pH less than 5.5, and calcareous soils with pH above 7, in their surface zones, are the two major soils causing mineral stresses in most of the crop plants. Word-wide these soils occupy about two third (each one third) of the land surface area. However, the optimum pH for growth and development of most of the plant species is below pH 7.0 and vary with plant species. Besides these the nutritional stresses in plants also occur in saline and sodic soils, sulphate soils, coastal and marshy soils.

Acid soils occupy approximately 30 % (3950 m ha) of the world's land area distributed mainly in two global belts America (41 %, 1616 m ha) and Asia (26.4% and 1044 m ha). Sixty seven percent of the acid soils support forest and woodlands, 18 % grasslands and only 4.5% (179 m ha) is used for arable crops (FAO, 1991). Humid tropics account for 60% of the acid soils of the world. India has nearly 145 million ha net cultivated area of these about 25 m ha are acid soils found mainly in high rainfall areas of hilly terrains in the Himalayan region, eastern and north-eastern plains, peninsular India and coastal plains and western ghats distributed in high rainfall areas of north eastern hills (NEH) and eastern (Orissa, Jharkhand and WB) regions, Tamil Nadu, Andhra pradesh, Konkan (Maharashtra), and Dang area of Gujarat, (Murthy et al, 1997; Singh, 2000; 2008). The acid soils are deficient in Ca, P and Mg, CEC below 25 %, but have excess Al, Mn and Fe causing poor crop growth. A combination of toxicities of Al, Fe and Mn and deficiencies of P, Ca, Mg and K of poor fertility, low water holding capacity, susceptible to crusting erosion and compaction making the acid soils of low productive. Liming is the solution, but cost effective. As these are not easily rectifiable the concepts of fitting plant to soil may be more economical than the soil rectification (Singh, 2000).

The calcareous soils accounts about one third of the area in the world, where P, Fe, Zn and Mn deficiencies and are most common problem. The plants that grow well on calcareous soil are called ′calcicoles’, and that those do not are ′calcifuge’. India has about 33 m ha of calcareous land, mostly spread in Gujarat, Maharashtra, Karnataka and Rajasthan, and in a limited area in Bihar, Tamil Nadu and Punjab. These soils are productive mainly due to high Ca and cation contents, but because of high Ca and Mg, the plant show multi-nutrient deficiencies (Singh and Joshi, 2000). The chlorosis due to iron and sulpur deficiencies is a major problem of calcareous and alkaline soils. Phosphorus availability is often low in calcareous soil and adsorption of added P depends on the number of weakly adsorbing sites. Thus utilization of P depends on plant tolerance to alkalinity. High HCO_3^- is associated with increased pH or CO_2 concentration in calcareous soil which directly affects the uptake of P and reduces the solubility of many nutrients particularly of Fe, Mn, P and Zn. Deep ploughing brings up carbonate of higher solubility to increase the amount in the surface layers and increases the soil pH.

2.2. Water and salinity

The favorable moisture condition influences soil nutrient availability and their movement in plant, but all these are overcome by fast growth and dry matter accumulation. The soil moisture, within the beneficial range between wilting and field capacity, stimulates the plant gowth and hence tends to lower the elemental concentration due to dilution effects. The humidity influences the rate of transpiration and thus indirectly affects the nutrient content in plants.

The flood irrigation aggravates problem of root aeration resulting in abnormal respiration, inhibiting root growth and altering metabolic functions. Because of this, plant becomes chlorotic due to multi-nutrient deficiencies mainly of N caused by inability of roots to take up these and ineffectiveness of Nitrogen-fixing bacteria, deficiency of S due to leaching in coarse textured soil and deficiency of Fe in calcareous soil due to conversion of ferrous to ferric form. Broad-bed furrow method helps to drain excess water improving the micro-environment especially aeration in the soil and hence is beneficial especially where water stagnation is a problem. Application of sand and FYM, fertilizers and ties (Calcium rich Murrhum) in the furrows makes the field fertile and airy (Singh et al., 1997).

Soil salinity, which is increasing due to non-scientific use of poor quality ground water in coastal and saline areas and salt accumulation in excessively irrigated areas and sodicity limit crop cultivation in India (Chhabra & Kamra, 2000). The salinity cause damage reducing germination, and growth, dry matter production and induces Ca, K and Fe deficiencies causing yield losses. However, there is an increasing pressure to make use of saline land through its management to bring more area under cultivation. Some efforts have been made on the salinity management through soil amelioration and installation of drainage, but very few studies on the genotype selection for saline areas.

2.3 Light and Temperature

The light intensities and its duration and extreme temperatures influence the concentrations of elements. The temperature influences the movements, translocation and utilization of elements by plants. There is optimal temperature for plant growth and development, which vary from species to species, and deviation from these causes abnormality in nutrient uptake. The elemental concentration at high temperature reduces, due to increase in the dry matter production and hence dilution effect. High temperature enhances respiration, depleting photosynthates allowing more absorption of elements from soil. However, the effect of temperature is masked by concomitant effects of light and moisture prevailing during the cropping season (Jones et al., 19991).

Light affect the photosynthesis, provide energy for active upkate of elements and enhancing concentration, but alter the ratio of element to dry matter due to dilution effects. Increasing light exposure reduces the N, P, K, concentration, but increases Ca concentration (Jones et al., 1991). While shading increases the P, K, Al, Ca, Fe, and Mn concentrations and decreases the Cu, Mg and Zn concentrations in leaves. The adverse effects of excess Na and K due to high salinity and low light can be partially corrected by high light.

2.4 Interaction of nutrients

Increasing the levels of any nutrient increases the concentration of that particular element in the plant tissue upto certain levels only, but low or excess of any element influence the uptake of other nutrients also that may be synergistic (beneficial) or antagonistic (detrimental) effects. For example application of N increases N as well P, K, Ca and Mg concentration, K decreased Ca and Mg, and Ca decreased K and Mg concentrations in plant tissues.

Mineral stress symptoms are many a time confused with damage caused by insect-pest, disease, salt stress, water stress, pollution, light and temperature injury and herbicide. Toxicity of Mo or Se is similar to P deficiency. Therefore, it is necessary to critically observe and define the deficiency and toxicity symptoms for individual crop based on the plant part showing symptoms, presence or absence of dead spots and entire leaf or interveinal chlorosis.

3. Mineral nutrients and their stresses

Presently, there are 17 essential mineral elements (three essential for some plants) required for growth and development of plants in addition to C, H, and O, although most plants require only 14 (Marschner, 1995). The essential elements are assimilated into plant through absorption by root or other plant parts as ions from the soil and hence described as mineral nutrients. Among these nutrients N, P, K, Ca, Mg, and S are considered major or macro-nutrients, because they are required in large quantities (1 to 150 g per kg of plant dry matter). The Fe, Zn, Mn, Cu, B, Mo and Cl are minor or micro-nutrients that are required at rates of 0.1 to 100 mg per kg of plant dry matter (Marschner, 1995). In addition nickel (Ni) and cobalt (Co) are also beneficial for legume crop and Si and Na beneficial for other crops.

The nutrient absorption and uptake in crop plants follow the growth pattern characterized by a lag phase in early growth, exponential increases from vegetative to flowering, a linear and maximum rate during late vegetative to early seed filling, and leveling during late seed filling stages. However, in tree once the full growth is achieved the maximum amount is needed every year. The biological limitations for low yields in oilseeds and pulses are due to conversion of photosynthates to lipids and protein which is less than 40 %.. As the oilseeds and pulses are much remunerative crop, the fertilizer response in these need not be compared with those of cereals. Unless these crops are provided with extra input, it is not expected to produce the same high yield as in case of cereals.

The nutrient requirement, the critical stages and tissues have been identified for assessing the nutrient status of crop plants. The concentration of a nutrient in tissues just below the level, which gives maximum growth, is the critical concentration. The growth falls off sharply below the critical concentration as the nutrient content becomes deficient. When the nutrient levels exceeds critical concentration, it is no longer limiting, however there is a limit for the adequacy and at sufficiently high level virtually all the nutrients become toxic.

In general the first fully developed leaves are the main indicator for assessing the nutrient status, however, for the plants storing their reserve food underground, the analysis of underground parts becomes essential. In macronutrients, the toxic levels are seldom achieved but are common in case of micronutrients. Hence there is no problem of macronutrient toxicity and as these are needed in high quantity deficiency is major problem. Besides these, heavy metals and pollutant cause their toxicity in plant.

The micronutrient deficiencies mainly of Fe Zn and Mn are major problem of calcareous soil which may cause mild yield reduction to complete crop failure (Singh et al. 1995). As the fertilizer management practices and their response vary considerably from situation to situation, the fertilizer management in sole crop, sequential crop, vary and need to be studied cautiously. Majority of the crop in the world are grown as sole crop, and most of the research work on fertilizer management have been dealt considering sole crop.

Each element has one or more specific structural or functional roles in the plant and absence of that the plant exhibits certain generalized morphological or biochemical symptoms, though not always common in all plants. The deficiency symptoms also depend on the mobility of the element in the plant. If the elements are mobilized within the plants and exported to the young developing tissues, the deficiency symptoms tend to occur first in the older tissues. On the other hand for immobile elements, once located in a tissues they are not readily mobilized for use elsewhere, the deficiency occurs first on the young tissues.

The most common mineral stress symptoms due to deficiencies are yellowing of old leaves (nitrogen and P) young leaves (Fe and S), deformed leaf tips (Ca and B), Older leaves with marginal yellow, chlorosis (K), young leaves with bands between the margins and purpling on lower side (Zn), interveinal and intercostal chlorosis (Mn), hollow-heart of kernel with depressed inner faces of the cotyledons (B). The minerals stresses limiting productivity in India are discussed here.

3.1. Macronutrients

Nitrogen

Nitrogen, which accounts for 1-6% of the dry matter in various plant parts with sufficiency values from 2.5-3.5% in leaf tissues, is a constituent of proteins, chlorophyll, hormones, vitamins and enzymes. It is required for the vegetative and reproductive growth, nutrient absorption, photosynthesis and production of assimilates for sink development. Nitrogen is most often limiting nutrient in agriculture and its deficiency causes slow, stunted growth and chlorosis of older leaves. Most plants absorb nitrogen from the soil primarily as nitrate ion (NO_3^-) and in a few cases as ammonium (NH_4^+) ion. But once entered into plant, the NO_3^- is reduced to NH_4^+ before incorporation into amino acids protein and other nitrogenous substances.

Most of the soils in Asian and African countries and particularly in India are deficient in nitrogen. Nitrogen deficiency accelerates the reproductive development causing low yield and protein levels. The nitrogen requirements of legumes are much higher than cereals because of their high protein content, but they are capable of meeting their nitrogen requirements both from symbiotic nitrogen fixation (60-80%) by root nodules and from soil nitrogen (20-40%). The recommended doses of nitrogen vary from crop to crop and place to place and hence range from 20-200 kg/ha. Though there is not a clear cut demarcation between the optimal and exces nitrogen supply, excess of nitrogen cause excessive vegetative growth resulting in high shoot/root ratio, delayed onset of flowering and low harvest index in agricultural crops. Plant with excess N are dark green in colour with succulent leaves and susceptible to water stress and diseases.

Phosphorus

Phosphorus is required for seed germination, photosynthesis, protein formation, overall growth and metabolism, flower and fruit formation. It accounts for 0.1-1.0% of the total dry matter of plant with a sufficiency range 0.20-0.40 % in leaves tissues. Phytin, which accounts for upto 80% of the total P in grain and seed is the form of P stored in plant.

P is the most deficient element on global level, and most of the Indian soils are either deficient in P or having medium P due to its fixation and low availability in the soil due to several factors. In soil, the P is present primarily as polyprotic phosphoric acid (H_3PO_4) and soil pH plays a major role in its availability. However this P is present either as Ca-, Fe- and Al-phosphate, and organic P. The mobility of P is highest at pH between 6.0 and 6.5. The monovalent $H_2PO_4^-$ is the predominant form of P in a soil having pH below 6.8, which is readily absorbed by plants, however, between pH 6.8-7.2 the HPO_4^{2-} is the predominant anion, which is less readily absorbed. In alkaline soil with pH more than 7.2, the predominant form of P is trivalent HPO_4^{3-} which is virtually unavailable for uptake by plants. Also, P tends to form an insoluble complex with Al and Fe in neutral pH while in basic soil Ca and Mg complexes precipitate the P. Thus P is always limiting factor in calcareous soils.

The P deficiency causes purpling of leaf margin and stunted growth but more dark green in colour. The leaves remain small, erect, unusually dark green with greenish red bluish green brown in sugarcane, but it takes minimum of 4 weeks to appear the deficiency symptoms on the plants. In legumes P limits N_2-fixation either directly by affecting nodule initiation, nodule development and N_2-fixation or indirectly by affecting plant growth. In general the P content less than 0.15% indicates lower concentration of P in most of the crop plants, however this value differs from crop to crop and species to species.

In present agriculture P is a key nutrient. It is valuable but scarce resource and need efficient management. But, there are number of reports about the non-responsiveness of P application even in apparently low available P mainly due to P-efficient crops. Many crops and tree forms symbiotic association with certain zygomycetous fungi known as vesicular arbuscular mycorrhiza (VAM) in their root augmenting phosphorus (P) uptake from soils deficient in this element. P deficiency is induced by Al-toxicity which vanish with application of lime. Heavy dressing of P fertilizer however, induces deficiencies of Fe and Zn and prevents toxicities of Al and heavy metals.

Potassium

Potassium is not a constituent of any compound, its concentration in plants vary from 0.5-6% in leaves. It activates a number of enzymes involved in photosynthesis, and respiration. It is required for translocation of assimilates, maintenance of water status of plant, opening and closing of stomata, increase availability of metabolic energy for the synthesis of starch and proteins and help in growth and filling of grain and pods (Mengel and Kirkby, 1987). Since high concentration of monovalent cations are needed to keep the active centers of enzymes free so that reaction can take place, the K is believed to be the only candidate for the same (Bergmann, 1992). The K deficiency occurs mostly on light textured sandy soils, acid soils with low CEC, due to its high solubility and frequent leaching. Though Indian soils are reported to be rich in K, its deficiency occur in almost all states and more frequently in Orissa, entire NEH region and part of A.P., U.P., Gujarat and Maharashtra mainly due to very little or no K application in the soil, during past.

Potassium is required in large amount by most of the plant and as long as other growth factors favour it increase the yield and quality. The saturation level of the CEC of the soil for K is 3-5 % and its deficiency occurs when the K levels goes down. The K^+ is highly mobile in both xylem and phloem which enables the plant to regulate their K budget easily. The K deficiency symptoms first appear in the older leaves characteristically developing mottling or chlorosis. Under potassium stress condition, yellowing of leaves starts from the tips or margins of leaves extending towards the center. These yellow parts become necrotic (dead spots) with leaf curling. There is a sharp difference between green, yellow and necrotic parts, stems shortened and weakened and susceptibility to disease increases. Even if there is no visible symptoms, plants lacking in K can be identified by their tendency to wilt more rapidly on dry, warm and sunny days than plants receiving sufficient K. The K deficiency reduced flowers, peg and kernels in groundnut (Singh, 1999).

The plants are highly efficient in obtaining K from the soil. In order to get high yield, there is need to maintain optimal N:K ratio when increasing the rates of N fertilizers. It should be about 1:1 but never more than 2:1. The adequate K contents in leaves have been reported to be in between 1.0-3.0 % for most of the crops (Jones et al., 1991). The recommended doses of K vary from 40-100 kg/ha K_2O depending upon the crop variety soil and types. The shelling, kernel weight and oil content increased with K application in groundnut (Singh, 2000b). Potassium is also known to increase frost resistance during winter. Thus, high yield of desired quality can be obtained by optimal supply of potassium.

Plants luxuriantly absorb the K and its uptake gradually increases with growth and development of plant. The excess of K fertilization rarely causes any toxic symptoms, because it is not absorbed in toxic concentration by plants, however ‘salt damage’ occurs and it induces Ca deficiency in various plants. High K levels in the soil depress the uptake of Mg, Ca and NH_4 first and then B, Zn, Mn inducing deficiencies of these elements (Jones et al, 1991). Excess K causes, scorching and scabbing in lemon, and delayed ripening in orange.

Calcium

Calcium activates a number of enzymes for cell division and is required for structural part of cell walls, influences water movement, cell growth and division enhances pollen germination, and takes part in protein synthesis and carbohydrate transfer. It is most important to dividing cells act as a second messenger in certain hormonal and environmental responses and regulating enzyme activities. In its physiological effects, Ca is usually regarded as counterpart to K. Calcium accounts for 0.2-3.0% of the dry matter with sufficiency range from 0.3-1.0%, however in most of the plant 0.5% Ca is adequate. The herbaceous plants, dicots and legumes need 5-6 times more Ca than the cereals and monocots.

The calcium is transported exclusively in xylem tissue upward with transpiration stream but its downward movement from the leaves through phloem is practically nil (Mengel and Kirkby, 1987). Since calcium plays a major role in cell division its deficiency appears in meristematic and growing region of plants and occurs on the fresh and emerging leaves. The leaf calcium deficiency is characterized by localized pitted area on its lower surface which later on converts into large necrotic spots. The Ca is taken up directly from the soil by groundnut pods, and inadequate supply results in pods without seeds called "Pops". Accumulation of Ca by groundnut pod is positively correlated with the pod surface area, days required to maturity, and negatively correlated with the pod thickness (Kvien et al.,1988).

In acid soil the lime has to be added in a manner to ensure that fine lime in the furrow below root zone (in the top 7 or 9 cm of soil). Lack of Ca in legume prevents the development of nodulation and nitrogen fixation, thus inducing N deficiency. Lack of Ca also inhibits the transport of carbohydrates. Both lime-stones and dolomites are useful as a Ca source in field crops and shallow incorporation of 1000 kg/ha lime stone (90 % CaCO3), before planting produced maximum yield. Excess liming or Ca causes imbalance between Ca and Mg and induce Mg deficiency. The ratio of exchangeable Ca^{2+} and Mg^{2+} therefore should not be higher than 6 (Jokinen,1981). The ratios between Ca:N in fruit crops and Ca:B is related to quality (Jones et al 1991). The excess calcium in the form of calcium carbonate increases the alkalinity and decreases the availability of Mn, Fe, Zn, Cu, B and P. Lime-induced chlorosis is the major problem commonly observed in the calcareous soil mainly due to deficiencies of Fe and Zn (Singh and Dayal, 1992; Singh and Joshi, 1997).

Sulphur

Sulphur is a part of amino acids, proteins, vitamins, enzymes. It is present in both organic and inorganic compounds and constitutes methionine, cysteine and cystine amino acids, coenzyme A and required for respiration and oil and fatty acid synthesis. As Fe-S protein it impart electron transfer reactions in both photosynthesis and nitrogen fixation. In plants, S accounts for 0.1-0.5% of the dry matter, however cabbage and crucifers some times contain higher than 1%. The available S consists of easily extractable SO_4-S which is the immediate supplier of SO_4^{2-} to root. The coarse-texture and low organic matter soil contains less available S. In well aerated soil, S is present as SO_4^{2-} and as component of organic matter, but in arid soil where sulphate concentration is high it occurs as gypsum ($CaSO_4.2H_2O$). The mineralization of S is fast in neutral to alkaline soils than acid soils.

The S-deficiency is reported to be very severe in Bihar, Gujarat, Punjab, M.P., U.P., Karnataka and A.P. mainly due to use of S-free NPK fertilizers, adoption of high yielding varieties and loss of S through leaching and erosion (Tandon, 1991, Singh 1999). The crop grown on coarse-textured sandy and calcareous soils generally suffers from S deficiency due to leaching of SO_4^{-}S. Sulphur increases chlorophyll nodulation, and pod yield besides reducing the incidence of diseases and is as important as phosphorus (Singh, 1999). The S deficiency is like nitrogen but occurs on young leaves. The Fe and S deficiency symptoms in appear together in most parts and distinction is not possible. Though S is mobile, unlike nitrogen, it is not readily mobilized in most of the crops and the symptoms occurr initially on young leaves extending towards middle showing pale yellow colour. The calcareous soil is a S deficient soil as their available sulphur (heat soluble S) level is in between 10-12 ppm.

Sulphur requirement of crop can be met through a number of S-containing materials such as gypsum, elemental S, pyrite and phosphogypsum. Generally 20-40 kg of S/ha is sufficient to meet the nutrient requirement of most of the crop (Tandon 1991). Pyrite is reported to be a good and cheap sulphur source for calcareous soil. The combined application of S with micronutrient is useful (Singh et al, 1990). Sulphur is synergistic with N, while antagonistic with B, Mo, Fe etc. (Jones et al. 1991). When the atmospheric concentration of SO_2 gas achieve 0.2-1.0 mg/m^3, in the industrial area and nearby the town, it cause damage to plant and crops due to SO_2 toxicity with acute and chronic symptoms.

Magnesium

Magnesium, accounting for 0.1-0.5% of plant DM, is the part of chlorophyll and required for functioning of enzymes for carbohydrates, sugars and fats, fruit and nut formation, germination of seeds. The deficiency of magnesium is also a problem of sandy and strongly acid soils as under high rainfall Mg is leached out more easily. In India, the Mg is deficient in acid soils particularly of Karnataka, Tamil Nadu, part of A.P. and Eastern and North Eastern Hill Regions. Magnesium is present as in the form of dolomite ($(CaMg)CO_3$) and magnesite in calcareous soils and is second in abundance to calcium, but with increase of pH in alkaline soils the Mg becomes non-exchangeable.

The Mg deficiency is induced by the high NH_4, K or Ca, as Mg is the poorest competitor among these. The most pronounced symptom of Mg is interveinal chlorosis due to breakdown of chlorophyll in the region that lies between the veins. The chloroplasts in the vein are less susceptible to Mg deficiency and retain their chlorophyll much longer. As Mg is mobile the basal leaves are first affected and the deficiency starts from leaf margin and advances towards midrib. The Mg deficiency is conducive to the occurrence of tikka disease in groundnut. The Mg content of legume is usually twice as high as of cereals and much higher in oil plants. The Mg concentration in grains and seeds are usually high (0.16-0.49%).

Most of the crops require Mg in high amount, but there are hardly reports available on its fertilization. In Mg-deficient soils 20-50 kg $MgSO_4$/ha is helpful in alleviating the deficiency and offsetting yield losses. In acid soils with high available Al^{3+} concentrations always need liming with dolomite to recover the Mg deficiency and Al-toxicity. The groundnuts are very efficient in extracting Mg from the soil, and rarely show its deficiency, however, Mg deficiency causes upto 25 % yield losses of groundnut in calcareous soil (Singh and Joshi, 2001). Under moderate soil Mg, heavy application of K fertilizers and liming reduce Mg uptake and induce deficiency due to their antagonistic effects. The ratio of K:Mg and Ca:Mg ions should not exceed 5 and 3.

3.2. Micronutrients

With introduction of high yielding crop varieties which draw more nutrient from soil, and constantly negligible use of micronutrients during the last three decades, the micronutrient efficiencies have wide-spread for the past one decade in all crops throughout India inspite of the fact that a considerable progress has been made about the delineation of deficient areas and diagnosis and rectification of disorders. Earlier, only Zn deficiency was observed in intensive cultivation of rice, wheat, maize as a result use of zinc sulphate has become a common practice in India. The micronutrient fertilizers are applied through broadcast, basal, top dressing, band or seed/seedling coating and foliar sprays but use of zinc in rainfed crops is very less than irrigated crops.

Zinc is a functional part of enzymes including auxins (growth hormones), and required for carbohydrate metabolism, protein synthesis, stem growth. Its deficiency cause mottled leaves, irregular yellow areas. Faint chlorosis of the lower leaves between the vein, leaf margin and tips are also observed. The Zn deficiency can be separated from Fe with its wider strip which may not run entire length of the leaflets.

Iron is an essential element for haem and ferredoxin and its deficiency is characterized by interveinal chlorosis of younger leaves. For the prevention, soil application of 10-25 kg Fe either as iron sulphate or as pyrite or 10 kg Fe as Fe-EDDHA is recommended. Spray of 0.5 % $FeSO_4$ + 0.02% citric acid thrice during cropping season, alleviate iron deficiency and increase pod yield. The iron sources such as iron sulphate, FeEDTA, iron citrate are available and all are equally well. The Fe containing ferilizer is most effective if applied along with drip.

Manganese governs the oxidation reduction process, photosynthesis and oxygen evolution and nitrogen metabolism. Its deficiency is observed on young leaves with a pale green veins similar to iron-deficiency but characterized by brown, black, or gray spots. Selection of efficient genotypes for Fe, Zn and Mn are the major solution for calcareous soil. Acid soils may increase uptake causing toxicity.

Boron affects flowering, pollen germination, fruiting, cell division, water relationships, facilitate calcium uptake, sugars translocation and fat synthesis. The B is transported primarily in xylem and is relatively immobile in phloem. The deficiency of B occur on the growing points, the terminal bud dies, causing rosette of thick, curled, brittle leaves or brown, discolored, cracked, fruits, tubers and roots and now-a-days are most common. The B deficiency and its the response is reported to occur in neutral to alkaline and highly weathered soils of Tamil Nadu, Gujarat, Karnataka, Maharashtra and Bihar. The critical limits in soil vary from 0.2-0.4 ppm B. The deficiency of B in groundnut causes low filling of pod, hollow darkening or off-colour area develop in the centre of the seed known as `hollow heart' symptom. Boron is important both at deficient as well as toxic level in soil. In B-deficient soils, application of 0.5-1 kg/ha B per crop recover the deficiency, however application of more than 5 kg/ha B show toxicity symptoms in leaves.

Copper, as a constituent of chloroplast protein, plastocyanin, and many enzymes, participate in the metabolism of protein and carbohydrate. The Cu deficiency is a major problem of organic and acid soils where the young leaves are curled, stunted, rosettes, interveinal crinkling and marginal wilting occur.

Molybdenum (Mo) is structural part of nitrogenase and nitrate reductase enzymes, essential for nitrogen-fixation and nitrates reduction to ammonia. Mo is needed in the least amount of all the micronutrients, but its deficiency disrupt nitrogen metabolism and the plant shows N deficiency. The Mo deficiency results in bright yellow, green interveinal chlorotic mottling, leaf margin curled and leave collapse completely at later. Synthesis of proteins is blocked, plant growth ceases. The deficiency has largely been reported in acid soils where seed may not form. Application of 0.4-1 kg/ha ammonium or sodium molybdate with seed or fertilizer or alleviate Mo deficiencies. Like B the excess of Mo also cause toxicity.

Chlorine and Sodium (Na) is involved in the movement of water or solutes in cells (osmosis), ionic balance necessary to take up mineral elements and photosynthesis. The Cl is leached by watering, its deficiency causes wilting, yellowing, bronzing decrease of scents.

Nickel (Ni) **is** recently added to the essential element required for urease enzyme to break down urea into usable nitrogen and for iron absorption. Seeds need nickel to germinate. Cobalt (Co) is required by nitrogen fixing bacteria and its deficiency result in nitrogen deficiency symptoms in legume crops.

Silicon (Si) is a component of cell walls. It creates mechanical barrier to piercing, sucking insects. Foliar sprays of Si reduce aphids' populations, enhance leaf presentation, improve heat and drought tolerance and reduce transpiration in plant. The deficiency of Si cause wilting, poor fruit and flower set, increased susceptibility to insects and disease.

The organic manures and mineral ores take care of micronutrient requirement of crops. Micronutrient chelates are efficient, but costly and rarely use by farmers. Soil application of zinc and boron and foliar sprays of iron and manganese are more economicaland widely practiced by the farmers. Single and multi-micronutrient mixtures are now approved in fertilizer control order (FCO). Multi-micronutrient mixtures are mainly used in sugarcane, grape, turmeric, groundnut, vegetable, fruit and plantation crops. Seed coating or foliar feeding needs systematic studies to control wide-spread hidden hunger. GIS information on micronutrient deficient areas and multi-micronutrients are emerging fast in areas brought under intensive cropping. Better quality material, technical know-how, mass awareness and better partnership among scientists industrialists-state governments and farmers are very much needed to curve micronutrient malnutrition, improve yield and quality of produce and sustain soil environment.

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4. Technological approaches and management strategies

4.1. Fertilizers and crop response

Borlaug has continually advocated increasing crop yields as a means to curb deforestation. The large role he has played in both increasing crop yields and promoting this view has led to it being called by agricultural economists the "Borlaug hypothesis", namely that increasing the productivity of agriculture on the best farmland can help control deforestation by reducing the demand for new farmland. The economic value of any crop is determined by its yield and quality, which are the resultant in part of the grower's ability to exploit the plant genetic make-up and part of less tractable components of the environment in which it is growing. If the growing conditions provide all that the plant needs for full expression of genetic potential, yield and quality will be maximized, but in practice due to environmental constraints and cultural shortcomings this objective is rarely achieved. However, within the constraints posed by site and climate the genetic potential of a crop can be exploited to a greater extent by maintaining adequate water and mineral supply which often becomes the limiting factors for most of the crop in the world. There are records for exceptionally high yield of 21 t/ha by ‘Melhite Kenye’, rice in Nagaland, India (Agricomplex Newsletter, 2001). The achievable yield potential for many crops has been worked out, which exceeds 7 t/ha for oil seeds, 10 t/ha for cereals, 20t/ha for maize and 80 t/ha for potatoes, but the average yield of these crops is only around one third of these achievable yield in most of the countries except a few developed one.

India is the third largest producer and consumer of fertilisers in the world after China and the USA and contributes about 12 per cent to the total world production as well as consumption of Nitrogen, Phosphate and Potash (NPK) nutrients. The unit area consumption of fertiliser nutrients in India, however is less than that of many developing countries. During 2005-06, the fertiliser consumption of NPK in India was 20.3 million tonnes, the highest ever achieved. The soil analysis provides a base but many a times mislead as the deficiency of the element, showing their adequate concentration in soil, occurs in plant. The cultivars are developed for ideal condition of soil fertility and pH, but when grown on soil even slightly different from those of originating centers developed mineral deficiency or toxicity problems which are corrected with soil amendment or foliar application of nutrient. Though the soil samples from various parts of the world have been analysed and sufficiency, deficiency and toxicity areas of certain elements have been worked out, these studies are based on the limited soil samples and crops and hence require location specific delineation of the nutrient deficiency and toxicity areas for various crops and their visual symptoms.

Inadequate and imbalance use of nutrient is one of the major factors responsible for low yields in crop plants worldwide. India is the world's largest producer of many crops and vegetables and depending upon the soil types, nutritional status of soil and crop varieties, the mineral disorders causes negligible to severe yield and quality losses, however there are very less report on the quantification of the same in the world. As most of these are location specific effort needs to be made to measure the yield losses due to mineral stresses in problem soils. Providing the adequate quantity of nutrients can double the production and thus meeting the challenges of the future.

The Government of India is promoting soil test-based balanced and judicious use of chemical fertilisers in conjunction with bio-fertilisers and organic manures to maintain soil health and its productivity under the programme of Integrated Nutrient Management through various schemes. Most of the fertilizer recommendations are for a particular crop on that particular soil, but, vary from variety to variety. Plant analyses data can be used to help guide future soil test calibration work and agronomic research. The responses of nutrients are very high on deficient and marginal soils. The soil and plant analysis can adequately meet the need of the crop growers by providing efficient and profitable site-specific fertilizer recommendation for increasing crop production. The desired yields only could be achieved with suitable fertilizer applied on soil test-crop response basis. This will enhance the fertilizer efficiency and overall productivity. Application of Soluble or liquid fertilizer through micro-irrigation system as fertigation substantially increases fertilizer use efficiency and yields. To safeguard the interest of farmers, bio-fertilisers and organic fertilisers have been brought under the statutory regulatory mechanism. A new provision has been made under the Fertilizer (Control) Order, 1985, for customized fertilisers to promote site-specific nutrient management.

Though nutrient deficiency and the responses of fertilizers are reported, no systematic approaches has been made to find out the yield losses either due to deficiency or toxicity of a particular element. There is also need to conduct multilocation yield targeting field experiments based on the soil test and crop response for all crops and advocate the strategies.

4.2. Selection of nutrient efficient crop genotypes

The nutrient efficiency is the ability of a system to convert inputs into desired outputs, or to minimize the conversion of inputs into waste. The supply or availability of the mineral nutrient is the input and plant growth, physiological activity and yield are the outputs. Thus the efficiency is the relationship of output to inputs and expressed as simple ratio, such as kg yield per kg fertilizer or kg dry weight per g of nutrient supply. However this efficiency depends upon the uptake efficiency (uptake of nutrient per unit supply of nutrients) and utilization efficiency (dry matter production per unit of nutrient taken up). The nutrient responsiveness is the capacity of a plant to increase uptake and yield as nutrient supply increases. The responsive plants are most desirable in fertilized high-input systems, while the nutrient efficient plants, which produce high yields at low levels of nutrients, are most valuable in low-fertility situations. However, if the responsiveness and efficiency are combined in one genotype through breeding programme or achieve through natural selection, it is the best and efforts needed in this direction in the present day modern agriculture.

It is difficult to devise the selection criteria for nutrient efficiency in plants as the definition, vary depending upon the situation in which plant is being grown. Gourley (1994) suggested comparisons of lines at non-limiting nutrient supply levels as well as under low-nutrient conditions. A ‘nutrient efficient’ genotype is the one that better converts nutrient inputs into desired outputs than other genotypes, which by comparison are ‘nutrient inefficient’ (Lynch, 1998). Lynch (1998) critically analyzed the role of nutrient efficient crops in the modern agriculture, and demonstrated three strategies for the improved nutrient efficiency. These were, improving yields response to high inputs, improving yield response to low nutrient availability and improving yield response to both low and high nutrient inputs.

When nutrient efficiency is defined as the function of desired output over nutrient input, an efficient genotype is the one that has greater output over some significant range of nutrient input. This was the basis for the ‘green revolution’ where short-stature high-yielding varieties of rice and wheat responsed to high rates of N fertilization without lodging. In contrast, traditional cultivars were adopted to low input conditions, and would lodge when excessively fertilized, therby-reducing yield. The role and value of the nutrient-efficient crops in the modern agriculture is clearly shown by the fact that the green revolution was basically an improvement in the nutrient efficiency of wheat and rice. However, the demerits and often–critised aspects of the green revolution varieties was that these new varieties were less efficient in low levels of nutrients. Thus, the green revolution technology disproportionally benefited larger or rich farmers.

An alternative approach to enhancing nutrient efficiency is the one where yield response to nutrients over the low range of nutrient availability is increased without affecting the response to high rates of nutrient uptakes. This type of nutrient efficiency is more useful in situations of low nutrient availability and also in low-input agriculture. The legume crops are the typical examples that are preferably grown on marginal soils. The ability to grow and yield at low nutrient availability has been called ‘efficiency’, while the capacity to respond to increasing levels of nutrients is called ‘responsiveness’ (Whiteaker et al., 1976).

The third type of nutrient efficiency is superior yield response at all levels of nutrient availability and genotypes showing this response are highly valued in selection and breeding programme. In modern agriculture, both the high and low input production systems are being given due importance. With the introduction of ‘organic agriculture’ there is preferably less use of nutrients as crop produced with high fertilization are less healthy and less nutritious than plants produced more naturally. In the poor and developing countries the most important role of nutrient efficient crops is the improvement of crop yield quality, or profitability, however, in the wealthy and developed countries such as USA, Canada, Western Europe, Australia, Newzealand, Japan and Israel, the most important role of nutrient efficient crops is the reduction of nutrient wastes.

In acid and alkali soils, causing mineral stresses in most of the crops, concepts of fitting plant to soil may be more economical than the soil rectification. In India, the Eastern and North Eastern parts of the country have acid soils where prospects are there for crop improvement as yield is very high due to high rainfall. However the crop faces Al-toxicity and Al-induced P, Ca, K and Mg deficiencies. In contrast the western part of India have calcareous soil which are rich in cations due to low rainfall but low organic matter, N, P and S and lime-induced Fe, P, S deficiencies are the main problems. Thus, as plant scientists, our strategy should be to screen crop genotypes for their tolerance to low P, K, Ca and Mg and Al and Fe toxicities for acid soil and for low P, S, Fe in calcareous soil.

In responses of plant adaptation in low pH soil, the native plant growing in acid soil requires Al for growth to a certain extent, however, the tolerance of the genotype differs among different species. The field experiment conducted by this center in collaboration with ICAR Res Complex in NEH Region report that, under low pH condition, the groundnut grow well and several varieties performed extraordinarily. Six hundred groundnut genotypes were screened at the hotspot and the Al toxicity and acid soils tolerant and sensitive genotypes identified. The 'Melhite Kenye', a rare paddy species, growing near Dimapur, Nagaland, India has been found to have 220 cm height, 30 cm panicle length with 510-570 grains/panicle and record yield of 21 t/ha (Agricomplex Newsletter, 2001).

In calcareous soil, efforts were made at NRCG, Junagadh to identify the groundnut genotypes having tolerance of lime-induced iron-chlorosis and the tolerant (Fe-efficient) and sensitive (Fe-inefficient) groundnut genotypes/cultivar (Singh and Chaudhari, 1993; Singh et al 2004). Some of the Fe-efficient genotypes are high yielding too and that may be grown in the areas where the problem of Fe-deficiency is very serious. The Fe-inefficient (sensitive) genotypes can be grown in Fe-toxic areas of acid soils. Similar efforts are needed for all the crops and the calcareous soils of Saurashtra serve as hot spot for such screening.

Alkaline and sodic soils also limit crop cultivation specially in coastal and highly irrigated areas where the salinity is building. Unfortunately less work has been done on these aspects as most of the crops are susceptible to salinity. Groundnut is sensitive to salinity and grows below 4 dS m^{-1}. Field screening of groundnut genotypes, indicated a clearcut demarcation between salinity tolerant and sensitive genotypes at 90 days and onwards and few genotypes with high plant stand seed yield were identified for their use in the area having salinity upto 3 dS m^{-1} (Singh et al. 2008). These studies need to be conducted for all crops.

In view of the increasing problems of the nutrition, time bound efforts needed to test the hypothesis that genetic manipulation can contribute significantly to mineral nutrition in plants and bring another green revolution. Further to achieve this a number of laboratories having expertise in various components of research should work with a consortium approach.

4.3. Optimization of nutrient and water use efficiency

The low-input agriculture system is prevalent in most part of the world where the nutrient efficient crops have an important role to improve the productivity (Lynch, 1998). The nutrients are absorbed by root in soluble form, in water, and distributed to various plant parts through transpiration stream. The water use efficiency (WUE), which is normally defined as: WUE= Y/ET (Y= yield of grain or biomass, and ET=evapotranspiration) is affected much due to fertilization as the photosynthesis and transpiration are controlled by nutrients. Thus all through the water is the main medium right from absorption to its transport and distribution and hence water and mineral nutrients go hand in hand and one system can not exist without other. The cultivars can be selected for traits that improve water use efficiency, and fertilizers and other nutrient sources also can be managed to optimize WUE of a crop. The nutritional effects on flower and seed development are either direct (deficiencies) or through influence on plant hormone and its impacts on plant reproduction influences yield and subsequently WUE. In cereal crops N application prior to flowering increases number of grain/seeds per plant. The deficiency or toxicity symptoms of nutrients appearing in the above ground parts influence the demand of water, thus nutrient can influence ET of the crop by altering the available water supply through root growth, and the demand of water. Further improving rooting volume and surface area and soil water balance can increase the water and nutrient supply. Rooting depth is an estimate of rooting volume at one point of time.

Nitrogen fertilization increases WUE, however increasing WUE may also be limited by N supply. Supply of P and K influences cytokinin levels and flower number in many plant species (Marschner, 1995). K deficiency elevates abscisic acid levels in the leaves, resulting in premature ripening and reduced size. As Ca plays a critical role in cell extension, cell wall structure its deficiency limits root extension. On the other hand, the nutrient starvation of P for a longer period increases the root surface areas. Fertilizer placement has marked effects on rooting pattern and subsurface fertilizer banding increases root mass and WUE. Increased rooting depth reduces the deep drainage of water out of the rooting zone increasing WUE. Improvement in the nutrient status of plant increases the leaf area index and influences transpiration rate. Leaf area duration influences transpiration differently throughout the growing season. Nitrogen and P-deficiencies caused smaller leaves thus reducing transpiration, however, application of these increases leaf area index and delays senescence, resulting in increased transpiration.

The K deficient plants are low tolerance for water stress. The stomatal functions are governed by K^+ balance in guard cells and nutritional effects on abscisic acid production. During water stress, the abscisic acid level in leaves increases, and stomatal closure occurs, thus reducing transpiration. Nitrogen deficiency causes more rapid closure of stomata and increases resistance to water vapor diffusion diminishing transpiration rates. The P-deficient plants also accumulate abscisic acid and closes stomata reducing transpiration. Increasing soil P increases photosynthetic rate/ transpiration rate (transpirational WUE).

In order to optimize WUE, the cultivar and nutrient decision should be made jointly. The cultivars tolerant to rooting limitations such as compaction, Al-toxicity, and salinity indirectly increase the available water supply and optimize the potential of a crop to respond to improved nutrition. As leaf senescence plays a major role in water use and is affected by fertilization, a cultivar with delayed senescence under drought condition may also delay senescence under nutrient-deficient conditions which prolong photosynthetic productivity and increase WUE. Specific leaf area (SLA) is positively correlated with WUE and negatively correlated with leaf N concentration (Nageswara-Rao and Wright, 1994). Within a cultivar, the leaf color and Light absorbance vary with nutrient status. The chlorophyll meter is used to determine the N status of the plant and recommendation of fertilizer. This need to be standardized across the crop species. The B, K and water stress interfere with grain filling.

4.4. Plant modifications and molecular aspects

Plant can increase their access to soil nutrient either by increasing the absorption areas or by modifying the rhizosphere to increase nutrient availability and absorption mechanism to increase the uptake from low nutrient containing soil. The modification in the absorption mechanism uptake requires modification in the genotypes. The absorption area can be increased either by increasing the total root surface area through root proliferation and root hair developments or by mycorrhizal associations which allows to capture nutrients beyond the rhizosphere region. The rhizosphere in the plant is modified through root exudates varying from protons to complex organic molecules, which influence the nutrient availabilities and uptake either directly, or through microbial inhabitants. Understanding genetic control of the nutrient acquisition mechanism may open new avenues for favourable genetic manipulation either through standard breeding procedures or through identifying and transferring genes controlling nutrient ion uptake and root exudation processes.

Problems of mineral stresses can be tackled through molecular biology. From the genetic improvement point of view, root exudates that could mobilize sparingly soluble soil nutrients especially P from Al-P, Fe-P, and Ca-P permit better use of less processed fertilizers and amendments in developing countries of tropical and subtropical regions. Exudation of pscidic acid by pigeon pea roots which release P from normally plant-unavailable Fe-P (Ae et al., 1991) is one such example. The molecular markers such as isozymes, restriction fragment length polymorphism (RFLP), and random amplified polymorphic DNA (RAPD) have an excellent potential as a tool for gene mapping of root characteristics or other traits associated with nutrient uptake. The each quantitative trait loci (QTL) can be studied as a discrete entity and its properties measured. Torres et al. (1993), in an attempt to develop a complete gene map for *Vicia faba*, found linkage relationship of 9 isozymes, 1 RFLP marker, and 43 RAPD markers. The RFLP has been also used to map QTL in tomato for WUE (Martin et al., 1989) and tolerance to low-P stress (Reiter, et al., 1991). Root colonization by indigenous VAM fungi differed among genotypes, biochemical activities such as acid phosphatase may be a potential criteria for high root colonization by VAM. The molecular structure of ion transport system in cell membranes suggests identifying gene sequences associated with proteins of the ion channels and H^+-ATPase (Smith et al. 1993,). However, very little is known about the genetic control of exudates.

4.5 Management of other stresses

To maintain a healthy crop proper nutrition is must. These nutrients help the crop to grow well and provide the resistance to sustain against the disease, pests and abiotic stresses. Application of gypsum helps the drought management by delaying the wilting and senescence of leaves (Singh and Chaudhari, 1995) thus establishing the role of Ca in drought management. Though, during drought the uptake of most of the mineral nutrients is restricted, application of Ca, K and S is beneficial. During winter season when the nutrient uptake and growth are reduced, application of N helps the crop to grow well. However, plants given abundant nutrients become susceptible to diseases, insects, and drought than the plants given adequate nutrition (Marschner, 1995).

The disease incidence during rainy season causes severe yield losses. Application of Fe reduces the incidence of tikka and rust diseases in groundnut (Singh, 1999). Generally, the disease incidence is comparatively higher in malnourished crop than the properly nourished crop. The chlorotic and dying leaves, while degradation, invite other microflora to develop and hence bringing new invasion to the plant. If such deficiencies are prevented or recovered timely such invasion could be avoided.

The role of K, Ca and S in disease management is well known and application of these reduces their occurrence. The elemental S or copper sulphate when mixed with the seed act as a seed dresser and hence seeds do not require additional treatment with fungicides. In general greater Ca and B is required for large seeded groundnut than the small seeded one and improper nutrition of these elements causes cracking of pods and seed inviting the soil fungi especially *Aspergillus flavus* to attack and develop aflatoxin. Ca increased the thickness of seed coat leading to decrease in seed infection by *Aspergillus* spp., *Penicillium* spp. and *Rhizopus* spp (Fernandez et al., 1997). Thus providing proper nutrition to the crop, most of the diseases could be prevented to occur in the field as prevention is better than cure.

5. Conclusions and recommendations

The stresses caused by various mineral deficiencies and toxicities leading to soil infertility, limit productivity in developing countries where, plant nutrition research can raise the productivity by diagnosis of these, their correction with minimal fertilizer and treatment costs, and development of cultivars with high nutrient efficiency in problem soils. In USA and other developed countries the sustainability has resulted in reduced fertilizer application rates, but in most of the developing country the fertilizer rates are much below the requirement and increasing the same will definitely improve the productivity. However, long-term sustainability must be kept in mind and it should not be disturbed for short-term benefit. A balance approach with long-term sustainability should be the main objective.

Once the breeders has essentially exhausted the possibilities for raising the genetic yield potential and farmers are using the most advanced agronomic practices, the yield potential of a crop, in a given country, is determined largely by the physical environment, soil moisture and nutrients, temperature, day length and solar intensity. The most promising areas in which manipulation of nutrient absorption could improve the efficiency of crop production in the near future are the absorption of nutrients under stress.

The informations on the available nutrient status and their critical levels for growing soils are limited. As the critical level vary from soil to soil and varieties an intensive delineation is needed on country wise and also at global level for problem soils and plant grown under stress conditions. There is an urgent need to workout the physiologically-based critical value for diagnosis of macronutrients in various plant parts and its correlation with agronomic yield and for making fertilizer recommendation. The informations on the rate, frequency, time, mode, source and method of nutrient application are differing which need to be standardized in concise form and recommended for particular soil, crop variety and area.

Diagnosis of deficiency in plants through visual symptoms, biochemical technique low-altitude aerial photography, offers a new avenue for detecting nutrient status. The new soil extractants should be used for predicting the nutritional status of acid and alkaline soils. The remote sensing technique can be a new nutritional diagnostic tool, if the satellite data used to estimate and improve the productivity by appropriate fertilization in crop. Screening of crop genotypes in acid soil for an Al-induced Ca and P deficiencies and in calcareous soil for tolerance of lime-induced deficiencies should be extensively done. The ameliorative effects of Ca, P on Al toxicity and molecular mechanism of Al toxicity and tolerance should be studied. Screening and identification of nutrient-efficient genotypes with special reference to P, Ca, Fe and Zn. Emphasis should be placed on efficient use of nutrient and yield targeting and seed quality under stress. Relationship between nutrient use efficiency and tolerance to water stress need to be studied.

Globally, most of the mineral nutritionists are working on only a few crops and only a few scientists are working on other important crops. Also most of the study is under refined condition and does not corroborate with the existing problem soils. As a result, most of the crop in most part of the world is grown under low fertility. A group of scientists should work in close collaboration to improve the nutrition of crops facing mineral stresses, particularly in acid and calcareous soils.

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