Role of Nutrients in Plants, its deficiency And Management

ABSTRACT

Like all living things, plants need food for their growth and development. Plants require 16 essential elements. Carbon, hydrogen, and oxygen are derived from the atmosphere and soil water. The remaining 13 essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine) are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers. Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients is important. Soil and plant tissue tests have been developed to assess the soil and plants' nutrient content. By analyzing this information, plant scientists can determine the nutrient need of a given plant in a given soil. In addition to the levels of plant-available nutrients in soils, soil pH plays an important role in nutrient availability and elemental toxicity. In the majority of the studies presented here, disease incidence in crop plants has been reduced by fertilization or the addition of nutrients. This is probably because the host plant's tolerance or resistance mechanisms involve these nutrients. When the plants were deficient, the application of nutrients significantly reduced disease.

Keywords Essential, Management, Nutrients

INTRODUCTION

Like all living things, plants need food for their growth and development. Plants require 16 essential elements. Carbon, hydrogen, and oxygen are derived from the atmosphere and soil water. The remaining 13 essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine) are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers. For plants to utilize these nutrients efficiently, light, heat, and water must be adequately supplied. Cultural practices and control of diseases and insects also play important roles in crop production. Each type of plant is unique and has an optimum nutrient range as well as a minimum required level.

Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients is important. Soil and plant tissue tests have been developed to assess the soil and plants' nutrient content. By analyzing this information, plant scientists can determine the nutrient need of a given plant in a given soil. In addition to the levels of plant-available nutrients in soils, soil pH plays an important role in nutrient availability and elemental toxicity. This chapter describes the essential nutrients, the chemical forms in which they are available to plants, their function in plants, symptoms of their deficiencies, and recommended nutrient levels in plant tissues of selected crops.

It is important to manage nutrient availability through fertilizers or change the soil environment to influence nutrient availability, and in that way to control plant disease in an integrated pest management system **(Huber and Graham, 1999 and Graham and Webb, 1991).** The use of fertilizers produces a more direct means of using nutrients to reduce the severity of many diseases and together with cultural practices can affect the control of diseases **(Marschner, 1995, Atkinson and McKinlay, 1997 and Oborn *et al.* 2003).**

Nitrogen

Nitrogen is the most important nutrient for plant growth and there is extensive literature about the effect of N on diseases because its role in disease resistance is quite easily demonstrated **(Engelhard, 1989 and Huber and Watson, 1974).** Despite the fact that N is one of the most important nutrients for plant growth and disease development, there are several reports of the effect of N on disease development that are inconsistent and contradict each other, and the real causes of this inconsistency are poorly understood **(Huber and Watson, 1974, Büschbell and Hoffmann, 1992, Marschner, 1999 and Hoffland *et al.* 2000).** These differences may be due to the form of N nutrition of the host and the type of pathogen: obligate vs. facultative parasites **(Büschbell and Hoffmann, 1992 and Marschner, 1995)** or the developmental stage of N application. Also, there are no systematic and thorough studies about the effect of N supply on disease resistance, on biocontrol agents' activity, and especially on the interaction among nutrient, pathogen, and biocontrol organisms **(Tziros *et al.* 2006).**

The form in which nitrogen is supplied has also been reported to affect the damage to plants. Thus plants grown with nitrate show more tolerance to photodamage than plants grown with ammonium as observed by **Zhu *et al.* (2000)** in bean plants. The plants grown with ammonium showed higher levels of lipid peroxidation. Nitrogen affects the biosynthesis of phenolic compounds and thus alters the oxidative status of the cell. Variations were observed in the antioxidant system in nitrogen-deficient plants which was also mediated by NO signaling **(Kovacik *et al.* 2009, 2014)** showed that the phenylpropanoid biosynthesis as well as the antioxidant status increased, to overcome oxidative stress under nitrogen deficiency.

Phosphorus

Phosphorus is the second most commonly applied nutrient in most crops and is part of many organic molecules of the cell (deoxyribonucleic acid (DNA), ribonucleic acid (RNA), adenosine triphosphate (ATP), and phospholipids) and is also involved in many metabolic processes in the plant and also in the pathogen. However, its role in resistance is variable and seemingly inconsistent. P has been shown to be most beneficial when it is applied to control seedlings and fungal diseases where vigorous root development permits plants to escape the disease. Phosphate fertilization of wheat can have a significant effect and almost eliminate economic losses from pythium root rot. Similarly, in corn P application can reduce root rot, especially when it is grown on soils deficient in P, and in other studies, it can reduce the incidence of soil smut in corn **(Huber and Graham, 1999; Potash and Phosphate Institute, 1988)**.

A number of other studies have shown that P application can reduce bacterial leaf blight in rice, downy mildew, blue mold, leaf curl virus disease in tobacco, pod and stem blight in soybean, yellow dwarf virus disease in barley, brown stripe disease in sugarcane and blast disease in rice. However, in other studies application of P may increase the severity of diseases caused by Sclerotinia in many garden plants, Bremia in lettuce, and flag smut in wheat (Huber, 1980). Foliar application of P can induce local and systemic protection against powdery mildew in cucumber, roses, wine grapes, mango, and nectarines **(Reuveni and Reuveni, 1998).**

Potassium

In potassium, there is increasing evidence that plants suffering from environmental stresses like drought have a larger internal requirement for K. Environmental stress factors that enhance the requirement for K also cause oxidative damage to cells by inducing the formation of ROS, especially during photosynthesis. The reason for the enhanced need for K by plants suffering from environmental stresses appears to be related to the fact that K is required for the maintenance of photosynthetic CO2 fixation. For example, drought stress is associated with stomatal closure and thereby with decreased CO2 fixation. The formation of ROS is intensified because of inhibited CO2 reduction by drought stress. Obviously, the formation of ROS under drought stress would be dramatic in plants exposed to high light intensity, with concomitant severe oxidative damage to chloroplasts. Increases in ROS production in drought-stressed plants are well-known and related to impairment in photosynthesis and associated disturbances in carbohydrate metabolism These results indicate that when plants are grown under a low supply of K, drought-stress-induced ROS production can be additionally enhanced, at least due to K-deficiency-induced disturbances in the stomatal opening, water relations, and photosynthesis **(Marschner, 1995; Mengel and Kirkby, 2001).** In addition, most importantly, under drought conditions, chloroplasts lose high amounts of K to further depress photosynthesis **(Sen Gupta and Berkowitz, 1987)** and induce further ROS formation. These results strongly support the idea that increases in the severity of drought stress result in corresponding increases in K demand to maintain photosynthesis and protect chloroplasts from oxidative damage. Alleviation of detrimental effects of drought stress, especially on photosynthesis, by sufficient K supply has also been shown in legumes **(Sangakkara *et al.*, 2000).** In field experiments conducted in Egypt, it was found that decreases in grain yield resulting from restricted irrigation could be greatly eliminated by increasing the K. In view of these results, it can be concluded that improvement of the K nutritional status of plants seems to be of great importance for sustaining high yields under rain-fed conditions.

Calcium

Calcium is a macronutrient for plants, yet it is actively excluded from plant cytoplasm Calcium has several distinct functions within higher plants. Inhibition of nodulation is a major limiting factor in the N2 fixation of many legume species grown in acid mineral soils. An increase in soil pH by Hming is therefore very effective in increasing nodule number, for example in common beans or alfalfa. Various factors are responsible for poor nodulation in acid mineral soils, high concentrations of protons and monomeric aluminum, and in particular, low calcium concentrations. With regard to legume plants under N2-fixing symbiosis, sub-clover plant chlorosis under Ca deficiency due to impaired N2 fixation has been described.

Calcium deficiency and decreased nitrogen fixation in nodules of T. subterraneum, G. Max, and M. Sativa, also affect the attachment of rhizobia to root hairs and nodulation and nodule development. Lastly, a calcium-spiking phenomenon is initiated in root-hair cells of legumes by nodulation actors and rhizobia.

Sulphur

Sulfur is an essential element for the growth and physiological functioning of plants. The sulfur containing amino acids cysteine and methionine plays a significant role in the structure, conformation, and function of proteins and enzymes in vegetative plant tissue. Although synthetic media for the growth of rhizobia commonly contain S, until recently little attempt has been made to define S requirements quantitatively. The S nutrition of two strains of B. japonicum and two strains of Brady rhizobium sp. using batch and chemostat cultures. High levels of contaminating S present in media components had to be removed before S limitation occurred in batch culture. Growth of the four Brady rhizobia strains became limited in chemostat culture when the concentrations of S in the inflowing media were less than 20M. Under S-deficiency cells derepressed an active S-uptake system and the enzyme alkaline sulfatase.

Sulfur deficiency leads to younger leaves being chlorotic with evenly, lightly colored veins. In some plants (e.g., citrus) the older leaves may show symptoms first. However, deficiency is not commonly found in most plants. The growth rate is retarded and maturity is delayed. Plant stems are stiff, thin, and woody. Symptoms may be similar to N deficiency and are most often found in sandy soils that are low in organic matter and receive moderate to heavy rainfall.

Magnesium

Even though abundant in soil solution, magnesium (Mg2+) is taken up by plant concentrations much lower than the other cationic macronutrients **(Wanli *et al.* 2016).** This is possible because of strong cation competition in uptake and a lack of magnesium transporters in plasmalemma. The uptake of Mg2+ is depressed by low pH and cations like K+, NH4 +, Ca2+, and Mn2+. The uptake rate is very slow and passive. Magnesium performs very diverse functions. The function of magnesium is related to its mobility within cells. The major function of magnesium stems from its being a central atom of the chlorophyll molecule. A central magnesium atom is coordinated with the nitrogen atoms of the four modified pyrrole rings forming a porphyrin-like structure. Chlorophyll magnesium may constitute 10% or more of the total leaf magnesium. The total protein (almost 25%) in leaf cells is localized in chloroplasts, and therefore magnesium deficiency results in poor chlorophyll content, the small size of the chloroplasts, and a reduction in electron transfer in photosystem II. Magnesium also helps to maintain the structural integrity of ribosomes and binding of the ribosomal aggregates to tRNA, a process necessary for protein synthesis **(Maathuis 2009).** Only a relatively small proportion of total plant Mg2+ (20%) is required for various functions in chloroplasts and cytoplasm. The rest of Mg2+ occurs as counterions for organic acid anions and inorganic anions in the vacuole and for pectates in the N. Pandey 63 middle lamella of cell walls. Like potassium, magnesium is also important in maintaining ionic balance and stabilizing pH. The vacuolar concentration of magnesium is particularly important for osmoregulation and turgor-driven cell growth **(Shaul 2002).** Starch is accumulated, and the rate of photosynthesis and respiration is low under magnesium deficiency.

Because Mg is a mobile element and part of the chlorophyll molecule, the deficiency symptom of interveinal chlorosis first appears in older leaves. Leaf tissue between the veins may be yellowish, bronze, or reddish, while the leaf veins remain green. Corn leaves appear yellow-striped with green veins, while crops such as potatoes, tomatoes, soybeans, and cabbage show orange-yellow color with green veins. In severe cases, symptoms may appear on younger leaves and cause premature leaf drop. Symptoms occur most frequently in acid soils and soils receiving high amounts of K fertilizer or Ca.

Iron

Iron is one of the most important micronutrients for animals and humans and the interaction between Fe nutrition and human or animal health has been well studied, as it is involved in the induction of anemia. However, the role of Fe in disease resistance is not well studied in plants. Several plant pathogens, e.g. Fusarium, have higher requirements for Fe or higher utilization efficiency compared with higher plants. Therefore, Fe differs from the other micronutrients such as Mn, Cu, and B, for which microbes have lower requirements. The addition of Cu, Mn, and B to deficient soils generally benefits the host, whereas the effect of Fe application is not as straightforward as it can have a positive or negative effect on the host. Fe can control or reduce the disease severity of several diseases such as rust in wheat leaves, smut in wheat, and Colletotrichum musae in bananas. Foliar application of Fe can increase the resistance of apples and pears to Sphaeropsis malorum and cabbage to Olpidium brassicas. Also, in cabbage, the addition of Fe overcame the fungus-induced Fe deficiency in the host but it did not affect the extent of infection. In other cases, Fe in nutrient solution did not suppress take-all of wheat and Colletotrichum spp. in beans. Application of Fe to disease-suppressive soils increased take-all of barley, and in soils with a high disease score, Fe had no effect. Iron can promote antimycotic or interfere with it. Fe does not seem to affect lignin synthesis, even though Fe is a component of peroxidase and stimulates other enzymes involved in the biosynthetic pathway. Fe can activate enzymes that are involved in the infection of the host by the pathogen or the defense, which is why opposite effects were found. Fe can promote the synthesis of fungal antibiotics by soil bacteria **(Graham and Webb, 1991).** Rhizosphere microorganisms can synthesize siderophores which can lower Fe levels in the soils. These siderophores can suppress the germination of chlamydospores of Fusarium oxysporum f.sp. cucumerinum in vitro. However, the production of siderophores and the antagonisms for Fe are not the only mechanisms to limit the growth of parasitic fungi.

Iron deficiency leads to interveinal chlorosis in younger leaves. The youngest leaves may be white, because Fe, like Mg, is involved in chlorophyll production. Usually observed in alkaline or over-limed soils.

Zinc

Zinc has a single valency state (Zn2+) which makes it different from the other redox-active micronutrients. The zinc ion (Zn2+) binds to nitrogen- and sulfur-containing ligands through ionic bonds forming a tetrahedral geometry. Zinc is stable in the 2 Roles of Plant Nutrients in Plant Growth and Physiology 72 biological medium since it is inert to oxidation-reduction, and therefore it has a number of structural and physiological roles in plants (Pandey 2010b). An important role of zinc is the maintenance of the structural integrity and permeability of plasma membranes. According to **Bettger and O'Dell (1981),** loss of membrane integrity is the earliest biochemical change caused by zinc deficiency. The involvement of zinc in the permeability of plant plasma membranes was first shown by **Welch *et al.* (1982).** In plants that are not adequately supplied with zinc, the root plasma membrane shows a loss of structural integrity and enhanced leakage of ions. This is attributed to the low concentration of phospholipids and thiol (-SH) groups in membranes of zinc-deficient plants **(Rengel 1995)**, possibly because of zinc involvement in the protection of thiol groups.

Zinc deficiency leads to interveinal chlorosis occurring on younger leaves, similar to Fe deficiency. However, Zn deficiency is more defined, appearing as banding at the basal part of the leaf, whereas Fe deficiency results in interveinal chlorosis along the entire length of the leaf. In vegetable crops, the color change appears in the younger leaves first. The new leaves are usually abnormally small, mottled, and chlorotic. In citrus, irregular interveinal chlorosis occurs with small, pointed, mottled leaves. Fruit formation is significantly reduced. In legumes, stunted growth with interveinal chlorosis appears on the older, lower leaves. Dead tissue drops out of the chlorotic spots.

Manganese

Manganese is probably the most studied micronutrient for its effects on disease and is important in the development of resistance in plants to both root and foliar diseases. Mn availability in the soil varies and depends on many environmental and soil biotic factors. Mn is required in much higher concentration by higher plants than by fungi and bacteria and there is an opportunity for the pathogen to exploit this difference in requirement **(Marschner, 1995)**. Manganese fertilization can control a number of pathogenic diseases such as powdery mildew, downy mildew, take-all, tan spot, and several others. Despite the fact that Mn application can affect disease resistance the use of Mn is limited, which is due to the ineffectiveness and poor residual effect of Mn fertilizers on most soils that need Mn supplements and because of the complex soil biochemistry of Mn.

In most soils that require the addition of Mn such as calcareous soils, 90–95% of added Mn is immobilized within a week. Mn has an important role in lignin biosynthesis, phenol biosynthesis, photosynthesis, and several other functions **(Marschner, 1995; Graham and Webb, 1991).** Mn inhibits the induction of aminopeptidase, an enzyme that supplies essential amino acids for fungal growth, and pectin methylesterase, a fungal enzyme that degrades host cell walls. Manganese controls lignin and suberin biosynthesis through the activation of several enzymes of the shikimic acid and phenylpropanoid pathways. Both lignin and suberin are important biochemical barriers to fungal pathogen invasion. since they are phenolic polymers resistant to enzymatic degradation. Lignin and suberin are believed to contribute to wheat resistance against powdery mildew and to all diseases caused by Gaeumanomyces graminis (Sacc.) It has also been shown that Mn soil applications reduce common scabs of potato, Fusarium spp. infections in cotton and Sclerotinia sclerotiorum (Lib. de Bary) in squash.

In Mn-deficient plants, dry matter production net photosynthesis and chlorophyll content decline rapidly, whereas rates of respiration and transpiration remain unaffected. Manganese-deficient plants are more susceptible to damage by freezing temperatures and a range of soil-borne root-rotting fungal diseases and require twice as long to reach the booting stage than Mn-sufficient plants. A decrease in grain number and grain yield in Mn-deficient plants is presumably a combination of low pollen fertility and a shortage of carbohydrate supply for grain filling.

Copper

Apart from its role in respiratory proteins that are required for N2 fixation in rhizobia. copper also plays a role in a protein that is expressed coordinately with the nifgenes and may affect the efficacy of bacteroid function. Several rhizobial strains, particularly R. *leguminosarum* bv. phaseoli, make the pigment melanin. The genes for melanin production are on the same large Sym plasmid as the nod and nef genes The meIA gene, specifying the copper-containing enzyme tyrosinase is expressed at high levels in bacteroids, this being under the control of the regulatory R. *leguminosarum* nifA gene. Lastly, there is increasing interest in the phenomenon whereby bacteria enter a state that is 'viable but non-culturable. There is a recent report that shows that for reasons that are not clear, adding Cu to Agrobacterium or R. *leguminosarum* cells sends them to this state.

Cu deficiency decreased nitrogen fixation in subterranean clover. Reduced growth, distortion of the younger leaves, and possible necrosis of the apical meristem. In trees, multiple sprouts occur at growing points, resulting in a bushy appearance. Young leaves become leached, and eventually, there is defoliation and dieback of twigs. In forage grasses, young leaf tips and growing points are affected first. The plant is stunted and chlorotic.

Boron

Boron (B) is one of the eight essential micronutrients, also called trace elements, required for the normal growth of most plants. Boron distribution in nitrogen-fixing pea plants. strong alterations in N2 fixation in soybean plants with a low B supply. The boron effect on Rhizobium-legume cell-surface interaction and nodule development in peas. In boron-deficient plants, the number of Rhizobia infecting the host cells and the number of infection threads were reduced and the infection threads developed morphological aberrations. The cell walls of root nodules of boron-deficient plants showing structural aberrations are reported to lack the covalently bound hydroxyproline/proline-rich proteins **(Bonila *et al.* 1997)** which contribute to an O2, barrier, preventing the inactivation of nitrogenase and associated decrease in N, fixation.

Generally, B deficiency causes stunted growth, first showing symptoms on the growing point and younger leaves. The leaves tend to be thickened and may curl and become brittle. In many crops, the symptoms are well-defined and crop-specific, such as:

- peanuts: hollow hearts
- celery: crooked and cracked stem
- beets: black hearts
- papaya: distorted and lumpy fruit
- carnation: the splitting of calyx
- Chinese cabbage: midribs crack, turn brown
- cabbage, broccoli, and cauliflower: pith in the hollow stem

Molybdenum

Molybdenum is a micronutrient specifically for plants that form root nodules with nitrogen-fixing bacteria, though plants that do not form nodules also use trace amounts of it in a protein involved with nitrogen metabolism and uptake. Its relevance to N2 fixation is clear, given that Mo in the 'FeMoCo' cofactor is at the heart of the nitrogen reduction process - at least for most nitrogenases. Mo–Fe protein contains two atoms of molybdenum and has oxidation–reduction centers of two distinct types: two iron–molybdenum cofactors called FeMoco and four Fe-S (4Fe-4S) centers. The Fe–Mo cofactor (FeMoco) of nitrogenase constitutes the active site of the molybdenum-containing nitrogenase protein in N2-fixing organisms. Although at low supply, molybdenum is preferentially transported into the nodules molybdenum deficiency-induced nitrogen deficiency in legumes relying on N2 fixation is widespread, particularly in acid mineral soils of the humid and subhumid tropics. There are reports that foliar applications of Mo to grain legumes in field conditions increase levels of N2 fixation and nodule mass, resulting in higher overall N content and seed yield. It is also reported that a B. japonicum strain deficient in molybdenum transport showed impaired nitrogen fixation activity when inoculated to soybean roots **(Delgado *et al.* 2006)**. In laboratory conditions, several different legumes that were severely starved of Mo showed more dramatic signs of deficiency.

Deficiency symptoms resemble those of N because the function of Mo is to assimilate N in the plant. Older and middle leaves become chlorotic, and the leaf margins roll inwards. In contrast to N deficiency, necrotic spots appear at the leaf margins because of nitrate accumulation. Deficient plants are stunted, and flower formation may be restricted. Mo deficiency can be common in nitrogen-fixing legumes.

Chlorine

Chlorine is required in very small amounts for plant growth and Cl deficiency has rarely been reported as a problem in agriculture. However, there are reports showing that Cl application can enhance host plants' resistance to disease in which fairly large amounts of Cl are required, which are much higher than those required to fulfill its role as a micronutrient but far less than those required to induce toxicity. It has also been suggested that Cl might interact with other nutrients such as Mn. Cl has been shown to control a number of diseases such as stalk rot in corn, stripe rust in wheat, take all in wheat, northern corn leaf blight and downy mildew of millet, and septoria in wheat **(Graham and Webb, 1991; Mann *et al*., 2004).** The mechanism of Cl's effect on resistance is not well understood. It appears to be non-toxic in vitro and does not stimulate lignin synthesis in wounded wheat leaves. It was suggested that Cl can compete with NO− 3 absorption and influences the rhizosphere pH: it can suppress nitrification and increase the availability of Mn. Furthermore, Cl ions can mediate the reduction of MnIII, and IV oxides and increase Mn for the plant, increasing the tolerance to pathogens.

Chlorosis of younger leaves and wilting of the plant. Deficiency seldom occurs because Cl is found in the atmosphere and rainwater.

MANAGEMENT

The nutritional status of the plant and factors that can influence the development of the illness, such as dense stands, changes in light interception, and humidity inside the crop stand, are directly impacted by fertilizer application on the development of plant disease under field settings. A balanced diet must be given at the right moment for the nutrient to be most effective in preventing disease and increasing yield. Anything that changes the soil environment, such as tillage, seedbed firmness, moisture control (irrigation or drainage), crop rotation, cover crops, green manures, manures, and intercropping, can influence disease development in addition to fertilizer application.

Changing either nutrient availability or nutrient uptake is one way that nutrient manipulation can be used to control the disease. There are a number of examples of this. Utilizing a fertilizer is the most common method for altering the availability of nutrients; however, modifying the environment through tillage, adjusting the firmness of the seedbed, controlling moisture (through irrigation or drainage), and using a particular crop sequence can have a significant impact on the availability of nutrients. In conditions of high leaching or denitrification, the application of nitrification inhibitors can boost the efficiency and availability of nitrogen. expansion of microorganisms, for example, microbes, growths that structure mycorrhizae, and any plant development advancing living beings can increment supplement take-up (P, Zn, Mn) by impacting minor component accessibility through their oxidation-decrease responses or siderophore discharge. In the case of Mn, Zn, and Fe in high pH soils with high concentrations of free CaCO3, or when Mn is made unavailable in the soil by rapid oxidation by microorganisms, the application of fertilizers to the soil may not always be effective. Mn is not well translocated in the phloem, so root tissues that are attacked by the pathogens remain Mn-deficient. Additionally, the addition of nitrification inhibitors to NH+ 4 fertilizers can suppress Mn oxidation as well as nitrification and increase the availability of Mn, P, and Zn for plant uptake. Foliar applications are frequently recommended to alleviate symptoms of aboveground deficiency. Increasing the nutrient content of grains was actively pursued as a means of improving human nutrition and may concurrently increase plant resistance to a variety of diseases. Nutrient uptake can be altered by altering root absorption, translocation, and metabolic efficiency. In some instances, it has been demonstrated that wheat seeds with a higher Mn content produced plants with less take-all compared to the same cultivars with a lower Mn concentration in the seed.

CONCLUSION

In the majority of the studies presented here, disease incidence in crop plants has been reduced by fertilization or the addition of nutrients. This is probably because the host plant's tolerance or resistance mechanisms involve these nutrients. When the plants were deficient, the application of nutrients significantly reduced disease.

Additionally, disease incidence can be reduced at supraoptimal rates of nutrients. It's possible that the disease has been exacerbated by toxicity rather than deficiency when a nutrient has been added; or, in other instances, the addition of a nutrient can make the primary shortage worse. In addition, a balanced diet is an essential part of any integrative crop protection program in sustainable agriculture because controlling plant disease with the right nutrients and no pesticides is typically more cost-effective and better for the environment. Nutrients can reduce disease to a level that is acceptable or, at the very least, at a level at which other cultural practices or conventional organic biocides are more effective and less expensive for further control.

REFERENCES

Atkinson D., McKinlay R.G. (1997) Crop protection and its integration within sustainable farming systems, Agr. Ecosyst. Environ. 64, 87– 93.

Bettger WJ, O’Dell BLA (1981) Critical physiological role of Zn in structure and function of biomembranes. Life Sci 28:1425–1438

Bonilla, I., Mergold-Villasefisor, C., Campos, M.E., Sanches, N., Perez, H., Lopez, L., Castrejon, L., Sanchez, F. and Cassab, G.I. (1997) The aberrant cell walls of boron-deficient bean root nodules have no covalently bound hydroxyproline-proline-rich proteins. Plant Physiol. 115: 1329-1340.

Buschbell T., Hoffmann G.M. (1992) The effects of different nitrogen regimes on the epidemiologic development of pathogens on winterwheat and their control, J. Plant Dis. Prot. 99, 381–403.

Delgado, M.J., Tresierra-Ayala, A., Talbi, C., Bedmar, E.J. (2006) Functional characterization of the Bradyrhizobium japonicum modA and modB genes involved in molybdenum transport. Microbiology. 152:199–207.

Engelhard A.W. (1989) Soilborne plant pathogens management of disease with macro and microelements, APS Press, St. Paul, Minn., USA.

Graham D.R., Webb M.J. (1991) Micronutrients and disease resistance and tolerance in plants, in Mortvedt J.J., Cox F.R., Shuman L.M., Welch R.M. (Eds.), Micronutrients in Agriculture, 2nd ed., Soil Science Society of America, Inc. Madison, Wisconsin, USA, pp. 329–370.

Hoffland E., Jegger M.J., van Beusichem M.L. (2000) Effect of nitrogen supply rate on disease resistance in tomato depends on the pathogen, Plant Soil 218, 239–247.

Huber D.M., Graham R.D. (1999) The role of nutrition in crop resistance and tolerance to disease, in Rengel Z. (Ed.), Mineral nutrition of crops fundamental mechanisms and implications, Food Product Press, New York, pp. 205–226

Huber D.M., Watson R.D. (1974) Nitrogen form and plant disease, Ann. Rev. Phytopathol. 12, 139–165.

Kovacik J, Klejdus B (2014) Induction of phenolic metabolites and physiological changes in chamomile plants in relation to nitrogen nutrition. Food Chem 142:334–341

Kovacik J, Klejdus B, Backor M (2009) Nitric oxide signals ROS scavenger-mediated enhancement of PAL activity in nitrogen deficient Matricaria chamomilla roots: side effects of scavengers. Free Radic Biol Med 46:1686–1693.

Maathuis FJ (2009) Physiological functions of mineral macronutrients. Curr Opin Plant Biol 12:250–258.

Mann R.L., Kettlewell P.S., Jenkinson P. (2004) Effect of foliar-applied potassium chloride on septoria leaf blotch of winter wheat, Plant Pathol. 53, 653–659.

Marschner H. (1995) Mineral Nutrition of Higher Plants, 2nd ed., Academic Press, London, p. 889.

Mengel K., Kirkby E.A. (2001) Principles of Plant Nutrition, 5th ed., Kluwer Academic Publishers, Amsterdam, Netherlands, p. 847.

Oborn I., Edwards A.C., Witter E., Oenema O., Ivarsson K., Withers P.J.A., Nilsson S.I., Richert Stinzing A. (2003) Element balances as a tool for sustainable nutrient management: a critical appraisal of their merits and limitations within an agronomic and environmental context, Eur. J. Agron. 20, 211–225.

Rengel Z (1995) Carbonic anhydrase activity in leaves of wheat genotypes differing in zinc deficiency. J Plant Physiol 147:251–256.

Reuveni R., Reuveni M. (1998) Foliar-Fertilizer therapy – a concept in integrated pest management, Crop Prot. 17, 111–118.

Sangakkara, U. R., Frehner, M., Nosberger, J. (2000) Effect of soil moisture and potassium fertilizer on shoot water potential, photosynthesis and partitioning of carbon in mungbean and cowpea. J. Agron. Crop Sci. 185, 201–207.

Sen Gupta, A., Berkowitz, G. A. (1987) Osmotic adjustment, symplast volume, and non-stomatally mediated water stress inhibition of photosynthesis in wheat. Plant Physiol. 85, 1040–1047.

Shaul O (2002) Magnesium transport and function in plants: the tip of the iceberg. Biometals 15:309–323.

Tziros G.T., Dordas C., Tzavella-Klonari K., Lagopodi A.L. (2006) Effect of two Pseudomonas strains and Fusarium wilt of watermelon under different nitrogen nutrition levels, Proceedings of the 12th Congress of Mediterranean Phytopathological Union, 11–15 June 2006, Rhodes Island Hellas, pp. 585–587

Wanli G, Nazimc H, Lianga Z, Dongfeng Yang D (2016) Magnesium deficiency in plants: an urgent problem. Crop J 4:83–91

Welch RM, Webb MJ, Loneragan JF (1982) Zinc in membrane function and its role in phosphorus toxicity. In: Scaife A (ed) Proceedings of the 9th plant nutrition colloquium, Warwick, England. Commonwealth Agricultural Bureaux, Farnham Royal, pp 710–715.

Zhu Z, Gerendas J, Bendixen R, Schinner K, Tabrizi H, Sattelmacher B, Hansen UP (2000) Different tolerance to light stress in No3 − and NH4 + grown Phaseolus vulgaris L. Plant Biol 2:558–570