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C Kashyap
Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

SP Bainade
Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

V Kumar
Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Anuraj Singh
Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author
C Kashyap
Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Foliar application of macro and micronutrient in field crops and their effect on growth, yield, quality and economics

C Kashyap, SP Bainade, V Kumar and Anuraj Singh

Abstract
Nutrients play a very important role in the proper growth and development of crops. The plant needs different types of nutrients for the different growth of plant parts. Both the macro and micronutrients are required for the proper functioning of the physiological functions of plants. The macronutrients are required in a large quantity whereas the micronutrients are required in a very small quantity. The macronutrients are used in percentage or Kg/ha and the micronutrients are used in parts per million (ppm). Different nutrients have different functions and sometimes one nutrient increases the effect of another nutrient. The quality of grain, fruit and flower depends upon the number of nutrients provided or uptake by the plant. Sometimes if any nutrient is deficient then this will cause deficiency symptoms which result in stunted growth, leaf curling etc. The deficiency symptoms depend upon the type of plant and nutrient. The deficiency of any nutrient causes loss in the yield and quality of the product. The excessive amount of nutrient uptake by the plant causes toxicity. The toxicity of nutrients causes toxicity symptoms also and this will cause the death of the plant. The application of nutrients is also very important. For different nutrients, different methods of application are used. The soil application and foliar application are the main types but the application of macronutrients is effective only when soil application is provided. The best method for the micronutrient application is through foliar application. The type of application of nutrients also decides the growth, quality and yield of the crops.

Keywords: Crop, deficiency, foliar, macronutrient, micronutrient, toxicity, yield

Introduction
For decades in India agriculture has been practised by many people, as it contributes to enhancing the Indian economy which is why agriculture is said to be the backbone of the Indian economy. About 17% of the world population cover 2.3% of the total geographical area along with 4.2% of water resources supported by agriculture (Zain *et al*., 2015) [69]. In the 1990s the economic reforms have been started which leads to an increase in the economy and push the growth trajectory. During the initial stage, the GDP was 6% after which it rise to more than 8%, due to the increase in the non-agriculture sector. From 1950 to 1951 there is only a 26% increase in the cropping intensity (Ejatz *et al*., 2011). From 2004 to 2005 the total sown area is 142mha, the net irrigated area is 58.87mha but at present, the net irrigated area is only 45.5% of the net sown area and the remaining area is rain-fed which is 54.5%. Today there is the contamination of land and water due to both biotic (insect and pest) and abiotic factors (salinity, drought and heat), but as the population is increasing agriculture fulfilled the need of people. the productivity in agriculture increased which lead to enhance the income of farmers, feeding to poor and provided various responsibilities and employment, when progress in agriculture has been initiated as a result people was introduced by technologies which helps in increase the productivity during the 70s and 80s also known as the era of "GREEN REVOLUTION" and this term coined by WILLIAM GAUD & NORMAN BORLAUG (Father of the green revolution) (Mondal *et al*., 2011) [38]. In the previous time before the green revolution, they have been using primitive techniques and practices as people were suffered from famines and starvation due to which there was pressure on the agriculture field as people started to prefer industrial fields and plantations. But today, farmers were introduced by seeds which give high yield and productivity and this is all due to the "GREEN REVOLUTION" era whose effect can be seen today also (Ali *et al*., 2014) [1]. In India with the help of M. S. Swaminathan (Father of the green revolution in India) this revolution was launched which leads to the drastic change in the yield, production and economy of our country. Various schemes like MIDH (Mission for Integrated Development of Horticulture), NFSM (National

Food Security Mission), NMSA (National Mission for Sustainable Agriculture), SAME (Submission on Agriculture Extension) etc. was introduced as shown in (figure 1). In this process, farmers used modern tools and equipment and converted primitive technology agriculture to modern agriculture (Grusak, M.A., 2001) [21]. If we talk about modern agriculture it plays an important role in the living standards of people, due to which there is an increase in productivity. As we all know our earth is full of resources (land, soil, water, sunlight, minerals, nutrients, raw material) but the user should be limited as we should save this for our future generation too, to handle this problem scientists overcome with the term modern agriculture which means high input along with high productivity and yield and it includes the use of modern techniques and equipment like inorganic or synthetic fertilizers, manipulation of seeds genetically or hybrid seeds (Fageria *et al*., 2008) [15].

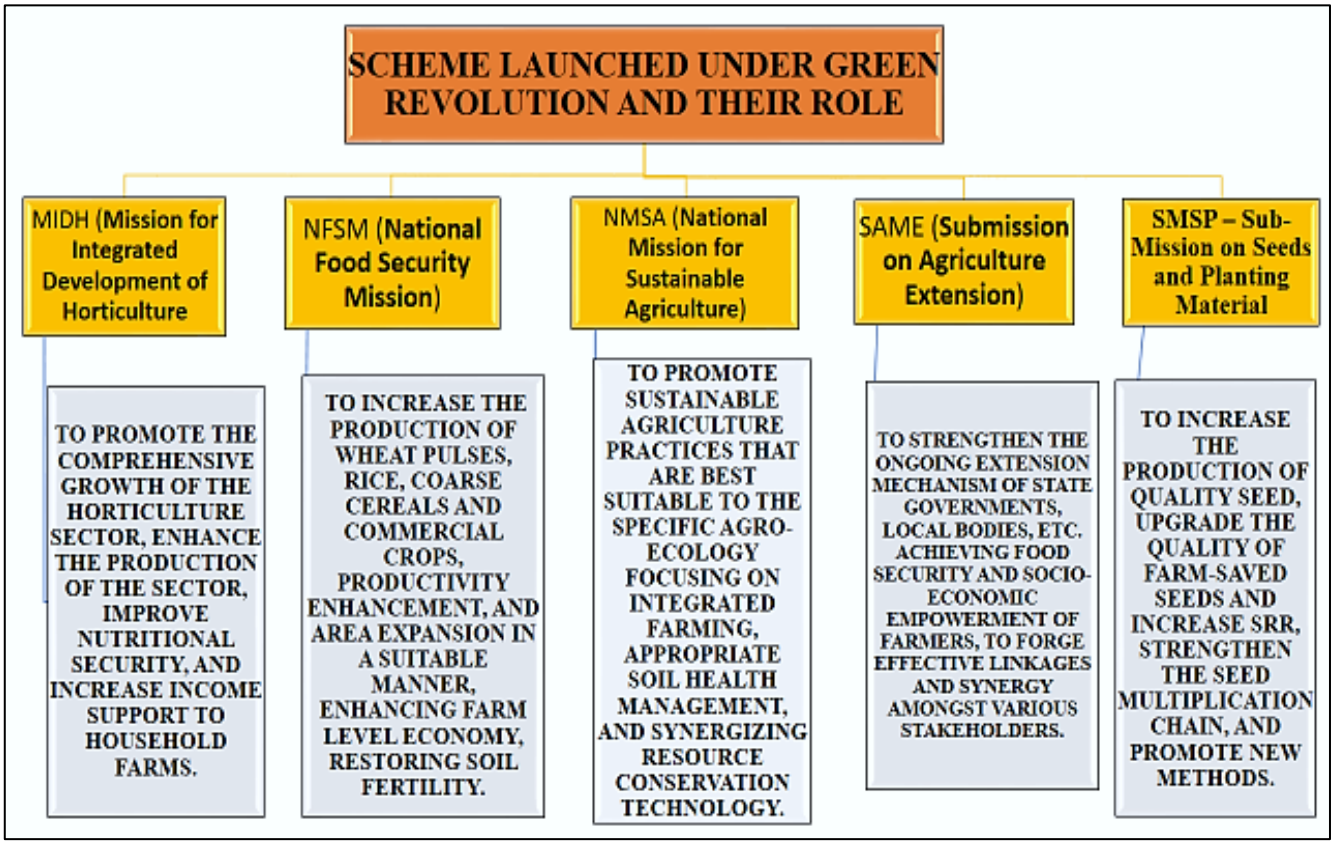

Fig 1: Schemes under green revolution and their role

As modern agriculture is useful but on the other hand there are some disadvantages too, rapid and continuous use of inorganic or synthetic products there will be degradation of soil to control this there should be proper management of both macro and micronutrient, but first, we should know about nutrient and its type there are two types of nutrient i.e. macro and micronutrient (Maathuis, F.J & Diatloff, E., 2013) [36]. Plants are also living organisms like us, in daily routine, we need food to do our work which provides us energy, in plants the process is same plants also need energy for various processes like photosynthesis, transpiration, opening and closing of stomata etc. and this energy is provided by macro and micronutrients (Shukla *et al*., 2009) [54]. The nutrients which are required in large amounts are macronutrients (carbon, hydrogen, oxygen, nitrogen, phosphorus, calcium, potassium, magnesium and sulphur) among the most important macronutrients are nitrogen, potassium and phosphorus. On the other hand, a nutrient that is required in less amount is known as micronutrient but these are important as a macronutrient, the nutrient which comes under micronutrient are iron, manganese, boron, molybdenum, copper, chlorine, zinc and nickel as shown in (figure 2). Both macro and micronutrients are very important for the growth and development of plants but the management of nutrients is also essential, but before this, we should know what nutrient management is. It is the process in which the nutrients are utilized very efficiently and to balance for further use too (Waraich *et al*., 2011) [67]. The main objective of this management is to provide nutrients to plant at right time, at the right quantity to increase crop productivity. These nutrients are provided to plants by foliar application and soil application, but the foliar application is mostly preferred by farmers as it is most effective than soil application (Ballabh *et al*., 2013) [10]. It is a technique in which nutrients are directly provided to plants in liquid form by the leaves, as the leaves of the plants readily absorb the nutrient and it is done by the stomata along with the epidermis. The application is in the foliage of the plant in the spray form that is why it is called foliar spray (Noreen *et al*., 2018) [44]. This method is beneficial than another method because in soil application the amount of fertilizer requirement is more but in foliar spray the amount needed is low and this method is used mostly for the micronutrient. In this paper, we will further discuss thoroughly the nutrients their role, importance, deficiency symptoms and how to manage them (Patil *et al*., 2018) [45].

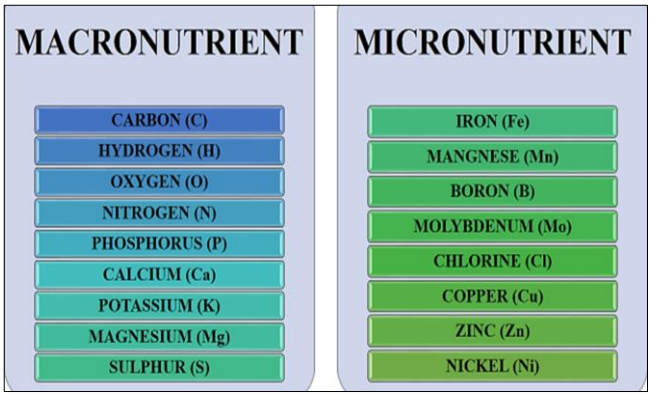

Fig 2: List of macro and micronutrients

As different nutrients have different symptoms according to their mobility, some symptoms occur in younger leaves and some occur in old leaves. The highly mobile nutrients are N, P, and K. The nutrient which is less mobile are S, Fe, Cu, Mn, Cl, and Mo. The moderately mobile nutrient is Zn and the nutrient which are immobile are immobile and according to their mobility there, symptoms occur in various parts of the plant (Fageria *et al*., 2009) [16].

For the proper growth and development of plants, plants need nutrients and the nutrients which are used by plants are in large numbers. Mainly two types of nutrients that are important for the proper growth and development of plants are Macronutrients and micronutrients. Macronutrients are the nutrients that are needed by the plants in a large amount for proper and complete development (Imtiaz *et al*., 2010) [23]. There are nine macronutrients which are Nitrogen (N), Phosphorus (P), Potassium (K), Carbon (C), Hydrogen (H), Oxygen (O), Sulphur (S), Calcium (Ca) and Magnesium (Mg). Among all these nine macronutrients three are Carbon, Hydrogen and Oxygen are not absorbed by the plants. Nitrogen, Phosphorus and Potassium are the primary macronutrients and Calcium, Magnesium and Sulphur are the secondary macronutrients. The primary macronutrients are required by the plants in large quantity whereas the secondary macronutrients are required in small quantities (Samota *et al*., 2017) [58]. Macronutrients are the nutrient elements that are required by the plants and present in the soil in a very low amount. They are eight in number that are Iron (Fe), Boron (B), Chlorine (Cl), Manganese (Mn), Zinc (Zn), Copper (Cu), Molybdenum (Mo) and Nickel (Ni) etc. The micronutrients are also called trace elements as they are required by the plant in a very less amount. The micronutrients are present in the plant tissues and are present in parts per million (ppm). All the macro elements are present under the soil in the form of salts and are absorbed by the plants in the form of ions (Nasin *et al*., 2010). The macronutrients are needed by the plant in a very large quantity. The 95% of plant biomass depends upon the dry weight accumulation. Both the macro and micronutrients are important for the proper development of plants. The role of macronutrients and micronutrients, their importance, deficiency symptom and their management through the foliar application is discussed below.

Nitrogen (N): Nitrogen is regarded as the most important primary macronutrient for the growth and development of plants. Nitrogen is also known as the building block of proteins because nitrogen helps in the synthesis of proteins and many enzymes. Nitrogen helps in the production of chlorophyll and amino acids. Mainly nitrogen increases the vegetative growth of plants, makes plants vigorous and succulent and also delays maturity. Due to the lack of nitrogen in the field crops, the chlorosis that is the yellowing of leaves occurs, cell division also get suppressed due to which the plant gets stunted (Khosa *et al*., 2011) [31]. The grains of the cereal crop started getting wrinkled and purple colour appears on the axis of shoots. With the decrease in nitrogen, the protein content in the grain also gets decreases and the starch content get increases. The foliar application of 1% urea is applied for the management of nitrogen deficiency on the yellow leaves (Mishra *et al*., 2013) [37].

Phosphorus (P): After Nitrogen, Phosphorus plays a major role in plant growth. The main role of phosphorus is the transfer of energy. Phosphorus enhances the early root growth and seedlings development. Phosphorus is a constituent of ATP, nucleic acid and amino acids etc. It also helps in early maturity, nodulation of legumes, formation of seeds and it maintains the effect of toxicity of nitrogen in the soi (Ejaz *et al*., 2011) [13]. The deficiency of Phosphorus causes early leaf fall, hinder seed germination. It affects the older leaves first and then affects the new young leaves. First, the leaves turn brown after that purple to red pigmentation occurs in the leaves. The foliar application of phosphate is applied for controlling phosphorus deficiency (Zain *et al*., 2015) [69].

Potassium (K): Potassium is a macronutrient that helps in the synthesis of proteins and chlorophyll so that photosynthesis occurs smoothly. Potassium has catalytic nature so it requires about 60+ enzymes for its activation. Potassium helps the plants in adverse climatic conditions and provides resistance from insect pests and diseases. It also plays an important role in maintaining the quality of food grains and vegetables (Grusak, M.A., 2001) [21]. The deficiency of macronutrient Potassium reduces the photosynthesis so that the growth and development of the plants reduces. Potassium deficiency also causes the dieback of plants and plants to get bent towards the ground. There is a loss of apical dominance and the plant get turned into a bush. Chlorosis and necrosis also occur which directly causes the death of the plants. The application of potash is provided for the management of potassium (Ali *et al*., 2014) [1].

Calcium (Ca): Calcium is a macronutrient that helps in many physiological reactions going in the plant. Calcium helps in the formation of nodules which helps in the fixation process also so that the rhizobium activity increases and also helps in the uptake of nitrogen to the plants. Calcium helps in the elongation of roots, cell division and also provides structure to the cell wall. Many physiological processes are going on in the plants so the main aim of calcium is the translocation of sugars in the plants. Calcium also maintains the pH of the soil and helps in the easy intake of many nutrients and acts as an activator of enzymes like lipase and amylase. The deficiency of Calcium causes dieback of plants. The growth of the plant get stopped and the roots become short. The leaves of the cereal crops start folded and get wrinkled (Mondal *et al*., 2011) [38].

Sulphur (S): The main aim of sulphur is to provide structure to the protein and it is a constituent of many enzymes like Cysteine, Vitamin, Methionine and Coenzyme A. In many vegetables and oils, the pungent smell is also due to the presence of sulphur. The deficiency of sulphur causes a

reduction in oil content, nitrogen fixation gets reduced and the fruit size or the grain size get distracted. The deficiency first appears on the young leaves. The yellow or red colour appears on the leaves of the crops (Nasin *et al*., 2010).

Magnesium (Mg): Magnesium is the main component of Chlorophyll. It helps in the production of proteins, vitamins and fats. Magnesium helps in the formation of oils, fats and chlorophyll which provides green colour to the plants. It also enhances the uptake of nitrogen and phosphorus from the soil. The deficiency of magnesium causes premature and defoliation of leaves. The leaves changes in yellow colour. The whole leaf gets chlorosis but the vein of the leaf remains green in colour. Magnesium sulphate is used for the management of magnesium deficiency (Shukla *et al*., 2009) [54].

Carbon, Hydrogen and Oxygen (C, H, O): These three elements are the building blocks of macronutrients. These are the framework elements. But these elements are the non-essential elements so that they are not absorbed by the plants and are not needed by the plants (Ali *et al*., 2014) [1].

Iron (Fe): iron comes under the micronutrient and its main role is to help the plant in chlorophyll synthesis and is also a little bit responsible for the green colour in a plant. The protein that resides in chlorophyll is synthesized by the iron, along with this it also acts as a catalyst and regulates the processes like respiration, photosynthesis, and nitrate/sulphate reduction. There are various deficiency symptoms is visible in plants if it is suffered by iron deficiency, in young plants the symptoms are visible it will turn green to yellow known as chlorosis, and pale white if the deficiency is visible (Imtiaz *et al*., 2010) [23]. If the deficiency is more severe than this the shoot will die and leaves will become dry. The deficiency of iron can be seen mostly in paddy and young leaves of sugarcane. If the plant is suffering from iron deficiency then we can opt for several methods like we can treat the soil with a combination of elemental sulphur and ferrous sulphate or by application of iron chelates and the other method is the foliar application, incorporation of ferrous sulphate or chelated iron, in trees we can inject ferric ammonium citrate in the trunk (Nasin *et al*., 2010).

Manganese (Mn): As it is a part of chlorophyll, it helps in the synthesis of chlorophyll too and in the reaction of oxidation and reduction it acts as a catalyst, in chloroplast it also helps in the synthesis of protein and along with this manganese also support mobilization of iron in the whole part of the plant. If the plant is suffering from manganese deficiency the symptoms can be visible in the younger leaves as it cause inter venial chlorosis (Khosa *et al*., 2011) [31]. In oats there will be grey spots, in sugar beet, there will be speckled yellow spots and in peas marsh type spots are visible. If the plant suffered from manganese deficiency then we can apply the inorganic or chelated form of manganese @0.5 – 1.0 lb Mn/acre+20 gallons of water (recommended) by foliar spray (Mishra *et al*., 2013) [37].

Zinc (Zn): It also contributes to the chlorophyll synthesis along with this in the synthesis of IAA (plant growth hormone) zinc is involved and in the process of photosynthesis and metabolism of N zinc has its special role. In the production of seed and synthesis of RNA, zinc is required. If the plant is suffered from a deficiency of zinc the symptoms will be visible like in foliage of crop interveinal chlorosis has been seen, mostly the suffered part of the plants is young leaves as the leaves size get reduced, the length of internodes get shortened and the growth of plants get stunted (Fageria *et al*., 2009) [16]. Zinc deficiency also affects the plant physiologically the maturity of flowers and fruit gets delayed. There is a disease named "white bud" in maize that occurred in new leaves and the most famous disease which occurs in rice is called "khaira disease". If the plant is suffering from zinc sulphate 36% then spray the plant with kelp extract or any micronutrient which contain zinc (Zain *et al*., 2015) [69].

Boron: For the differentiation and development of plant tissue boron is responsible along with the translocation of sugar and metabolism of carbohydrates, even if the plant is calcium deficient boron makeup for calcium up to some extent, the development of root, flower and formation of the pollen grain is due to boron too. If the plant is boron deficient then the tissue development will be slow, as a result, the colour of leaves will turn from green to yellow or red, and this deficiency also affect the sterility and reproductive organs. The growth of the plant will be abnormal like in Lucerne there will be yellow and resetting of plant, in walnut snakehead disease, and in fruit disease, there will be dieback. To overcome the boron deficiency application of nay boron supplements which are highly and easily soluble are preferred. As for foliar spray U. S. BOREX solution (containing 11% of boron) or boric acid (Ejaz *et al*., 2011) [13].

Copper: Copper is a very essential nutrient for the reproductive growth of the plant, it helps in root metabolism and make sure that proteins are utilized by plants appropriately. If the plant is copper-deficient then the symptoms can be seen in younger leaves it will distort and thus, the growth will be stunted, in the apical meristem, some type of necrosis can be seen also. From the same point, various sprouting can be seen especially in trees and the plant growth will be stunted and leaves were chlorotic. If the plant is copper-deficient then we can apply copper at 150 to 250gram per hectare+50 to 100litres of water as a foliar spray, but it should be applied at the cool condition when there is not much sunlight as it may cause burn-in leaves (Ballabh *et al*., 2013) [10].

Chlorine: For the photosynthesis process chlorine is very important, thus the evolution of oxygen is associated with chloride. If the plant is chlorine deficient then the chlorosis will occur on the younger leaves, the plant will suffer from chlorosis and overall wilting too. The tip of the margin will have burned like patches, bronzing, and leaves will have premature yellowing and due to chlorotic toxicity the leaves will fall (Waraich *et al*., 2011) [67]. If the plants are chlorine deficient then we can apply KCl (containing 47% of Cl), MgCl2 or CaCl2 (containing 64% Cl).

Molybdenum: The symbiotic nitrogen fixation and the synthesis of protein is due to molybdenum, it also regulates various enzymes in the plant. If the plant is Mo deficient it will cause whiptail disease in cauliflower, broccoli and other crops which belongs to the brassica family. Most horticulture crops have Mo deficiency, in reddish we can see cupping on the downward side, the formation of flowers will become slow or inhibit (Grusak, M. A., 2001) [21]. We can prevent the

plants from Mo deficiency by foliar spray of any Mo containing fertilizer (ammonium molybdate 54% & sodium molybdate 39%).

NICKEL: Recently a new micronutrient has been introduced i.e. Nickel is considered a micronutrient because it is utilized by the plant in a very small amount. Most of the leguminous plants require nickel for the nodulation and nitrogen fixation nickel is required. If the plant is nickel deficient then there will be poor shoot growth, the colour of leaves will become pale and leads to the death of the leaves. The flower will have a deformed structure. To prevent the plant from nickel deficiency we can foliar spray of a dilute solution (NiSO4 or any other nickel fertilizer which are water-soluble (Samota *et al*., 2017) [58].

Foliar application of macronutrient and micronutrient in agriculture and horticulture

The foliar application of macronutrient and micronutrients is very important in agricultural and horticultural crops. The macronutrients are applied as a soil application in both crops and horticultural crops. But the application of micronutrients is done mainly with the foliar application. Because they are applied directly to the foliage of leaves and is easily absorbed by the plant. There are different forms of nutrients out of which some specific forms are used for the uptake of nutrients (Mondal *et al*., 2011) [38]. The carbon is uptake by the plants in the form of CO_2, Hydrogen is uptake by the plant in the form of H_2O, Oxygen in the form of O_2, Nitrogen in the form of $N0^{3-}$, Phosphorus in the form of H_2PO^{4-}, Potassium in the form of K^+, Calcium in the form Ca^{2+}, Magnesium in the form of Mg^{2+}, Sulphur in the form of SO_2^{-4}, SO_2, Iron in the form Fe^{2+}, Zinc in the form of Zn^{2+}, Manganese in the form of Mn^{2+}, Boron in the form of H_3BO_3, Copper in the form of Cu^{2+}, Molybdenum in the form of MoO_4^{2-}, Chlorine in the form of Cl^-, Nickel in the form of Ni^{2+} (Samota *et al*., 2017) [58].

Conclusion

Macronutrients and micronutrients are very important for plant growth and development. Different nutrients have different functions and they function differently in different plants. The macronutrients like Nitrogen, Phosphorus, Potassium, Carbon, Hydrogen, Oxygen, Calcium, Magnesium and Sulphur are beneficial nutrients and are required in a large amount for plant growth. The deficiency and toxicity of the nutrients also hinder plant growth and causes loss in the yield and quality of the product. The application of macronutrients is mainly done as a soil application as basal application, deep placement, top dressing etc. because they are required in a large quantity as Kg/ha. The macronutrients are required by the plants in a very less amount because they are needed for the functioning of plant tissues. The micronutrients are needed in parts per million. The application of micronutrients is mainly through foliar application. The foliar application is regarded as best for the micronutrient application because in this the micronutrient is directly applied to the foliage of the plant so that it is directly absorbed by the plant. The soil application of micronutrients is also there but is not much effective as the foliar application because the soil application takes much time for the uptake of nutrients whereas the foliar application can directly absorb the nutrient and function more frequently than the soil application. This review paper shows the role and function of different macronutrient and micronutrients in plant growth, their deficiency symptoms and the type of application needed for macro and micronutrients and the effect of different nutrients on the growth, quality and economics of crops.

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