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A review on role of macro nutrients on production and quality of vegetables

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Abstract
Macronutrients play a very important role in plant growth and development. Three main elements are nitrogen, phosphorus, and potassium (N, P, K) and are required in abundance. They must be readily available through soil medium or fertilizer. The secondary elements are sulfur, calcium, and magnesium (S, Ca, Mg). The quantities required are much less than the macro elements but they are needed in reasonably large quantities. Vegetables are rich and comparatively cheaper source of vitamins and minerals. Their consumption in sufficient quantities provides taste, palatability and increase appetite and provides fair amount of fibres. Proper plant nutrition is essential for successful production of vegetable crops. Every macronutrient has its own character, and is therefore involved in different metabolic processes of plant life. The present review is an attempt to provide basic information about the role of macronutrients in the production and quality of vegetables.

Keywords: Macronutrients, vitamins, minerals, vegetables and nutrition

Introduction

Vegetables play an important role in the balanced diet of human beings by providing not only the energy rich food but also promise supply of vital protective nutrients like minerals and vitamins. They not only adorn the table, but also enrich health from the most nutritive menu and tone up the energy and vigor of man. Comparatively, vegetables are one of the cheapest source of natural nutritive foods. Some of the vegetables are good source of carbohydrates (Leguminous vegetables, tapioca, sweet potato, yams, colocasia, potato, garlic, onion, Brussels sprout, Methi), proteins (Leguminous vegetables like peas and beans, leafy vegetables, Garlic, Brussels sprouts), Vitamin A (Tomato, carrot, turnip, leafy vegetables, root vegetables like sweet potato, colocasia and pumpkin-yellow), Vitamin B (peas and beans, garlic, colocasia, tomato, asparagus), Vitamin C (green chilies, turnip, Brussels sprout, Drumstick leaves, cauliflower, cabbage, Knol khol, bitter gourd, radish leaves and leafy vegetables), calcium and iron (all green leafy vegetables, drumstick fruits). Vegetables neutralize substances and provide alkaline reactions for normal metabolism. Cellulose, pectin and other constituents present in the fibres of vegetables help to clear the bowels, reduce constipation and also promote digestion. Consumption of sufficient quantities of vegetables very much reduce the possibility of cancer in the intestine and colon, cancer specialists advocate consumption of sufficient vegetables, particularly, cabbage, cauliflower, carrot, hyacinth bean, sweet potato, green papaya and bottle gourd. It is now being apprehended that pointed gourd, carrot and bean have cancer protection properties.

India grows maximum number of vegetable crops due to diversity of agro climatic conditions. Nearly 60 kinds of fruit, leafy, root, bulb, starchy tuberous and other types of vegetables are cultivated in our country. The status of vegetable cultivation in India is unique, consisting of diverse kinds, such as, kitchen garden of urban areas, market gardens near big as well as metropolitan cities and truck farming of special crops in large quantities for distant market.

Vegetable cultivation in our country has received greater importance during the last decade. India has witnessed 2.6 percent increase in vegetable production per year in the past 10 years. India is the world's second largest producer of vegetables next to China. The estimated area under vegetable crops in India is 6.2 million hectares excluding potato. Low productivity is the main feature of vegetable cultivation in India. India share to the world's production is only 14 percent, while it is about 26 percent in case of China. The productivity gap is more conspicuous in tomato, cabbage, onion, chilli and peas.

Preponderance of hybrid varieties and protected cultivation are mainly responsible for higher productivity of these vegetables in the developed countries. On-farm yield of most of the vegetables in India is much lower than the average yield of world and developed countries. However, our on-farm yield levels of brinjal, onion, cauliflower and peas are higher than the average productivity of these crops in developing countries.

INM and vegetable cultivation

Limited availability of additional land for crop production, along with declining yield growth for major food crops, have heightened concerns about agricultures ability to feed a world population expected to exceed 7.5 billion by the year 2020. Decreasing soil fertility has also raised concern about the sustainability of agricultural production at current levels. Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively and sustainably than in the past. Integrated management of the nutrients needed for proper plant growth, together with effective crop, water, soil and land management will be critical for sustaining agriculture over the long term. Integrated nutrient management is an approach that seeks to both increase agricultural production and safeguard the environment for future generations. It is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation and thereby help meet future food supply needs. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants and the dissemination of knowledge between farmers and researches.

In crop production, plants synthesize nutrients in the soil such as nitrogen, phosphorus and potassium (NPK) with air, sunlight and water. Without proper management, continuous crop production can reduce nutrient reserves in the soil. As reserves get depleted, crop growth and productivity can be compromised. Over time, cumulative depletion can decrease agricultural production, crop yields, soil fertility and lead to soil degradation. Techniques to conserve and add nutrients to the soil through the application of organic and inorganic fertilizers can help to maintain and increase the nutrient reserves of the soil. But over supply of nutrients can also be a problem, causing economic inefficiency, damage to the environment and in certain situations, harm to the plants themselves, and to the animal and humans that consume them or products made from them. Over application of nutrients occurs chiefly in the developed world, where the relatively low cost of fertilizer leads some farmers to use it in amounts far in excess of plant needs and the capacity of soils to hold nutrients. Balance in the absolute and relative application of nutrients is a part of INM.

Nutrient removal for the range of crops listed varies between 60 and 370 kg N/ha, 25 and 100 kg P_2O_5/ha, and 80 and 350 kg K_2O/ha. On average, plant uptake of K is 1.4 times more than N uptake. (Table.1)

Fertilizers replace nutrients removed during harvest and allow growers to manage crop nutrition for maximum yield. Fertilization practices can also have significant impacts on harvested fruit quality and quality retention during packinghouse operations and distribution. These include physiological disorders, disease susceptibility and compositional and textural changes. A carefully planned and managed fertilizer program has many benefits.

Table 1: Nutrient removal by selected vegetable crops grown in India

Crop	Nutrient removal Kg/ha		
	N	**P_2O_5**	**K_2O**
Asparagus	120	60	150
Beans (Dry grains)	155	50	120
Brinjal	175	40	300
Cabbage	370	85	480
Cauliflower	250	100	350
Cassava	150	70	350
Celery	200	80	300
Cucumber	70	50	120
Green beans	130	40	160
Leek	120	45	280
Lettuce	90	35	160
Okra	60	25	90
Onion	120	50	160
Peas	125	35	80
Potato	175	80	310
Pumpkin	90	70	160
Radish	120	60	120
Spinach	120	45	200
Sweet potato	190	75	340
Tomato	140	65	190

(Tiwari and Gavin, 2004) [10]

Need of Nutrients in vegetable crops

Sixteen plant food nutrients are essential for proper crop development. Each is equally important to the plant, yet each is required in vastly different amounts. These differences have led to the grouping of these essential elements into three categories; primary (macro) nutrients, secondary nutrients, and micronutrients.

Primary (Macro) Nutrients

Primary (macro) nutrients are nitrogen, phosphorus, and potassium. They are the most frequently required in a crop fertilization program. Also, they are need in the greatest total quantity by plants as fertilizer.

Nitrogen

Nitrogen is available 79% in the air, but plant can only be used N in the form of nitrate (NO_3^-) and ammonium (NH_4^+). Nitrogen is also regarded as the essential component of all proteins and enzymes and further performs in various metabolic processes of energy transformation (Street and Kidder 1997). Therefore, sufficient amount of N availability in plants is required, because it is one of the major key factors of crop production (Nadeem *et al*. 2013) [7]. Rhizobium species of bacteria present in the roots of leguminous crops can convert atmospheric nitrogen into plant available compounds. Nitrogen is the most important nutrient and required by the plant in largest proportion. It is the important constituent of chlorophyll, protoplasm, protein and nucleic acids. Nitrogen gives dark-green colour to plants and increases the vegetative growth of crop-plants. It plays a key role in the preparation of starch in leaves and production of amino acids. It improves the quality of leafy vegetables and fodders and protein content of food-grains. Plants contain 1-5% nitrogen by weight. Excess of N leads to excessive succulent growth and susceptibility to pests and diseases.

Nitrogen related with:

- High photosynthetic activity
- Dark green color
- Vigorous growth
- Branching/tillering

- Leaf production and,
- Size enlargement.

Nitrogen is necessary for formation of amino acids, the building blocks of protein. Essential for plant cell division, vital for plant growth. Directly involved in photosynthesis. Necessary component of vitamins. Aids in production and use of carbohydrates. Affects energy reactions in the plant.

Deficiency Symptoms

- Lack of N causes the reduction in chlorophyll production resulting into yellowing of lower leaves.
- In case of severe deficiency, spots appear on the tips and edges of leaves towards midribs and cause stunting.
- Nitrogen deficient plants always remain small in size and early flowering and fruiting takes place which mean the plant goes early in the reproductive phase.
- In this situation, the plant-yield and quality affect negatively.

If crop-plants provide nitrogen in excess, it causes more vegetative growth and the crop plants must be lodged before seed-production. These plants will be more prone to the insect pests and diseases. It will increase the duration of reproductive period, delay the ripening of crops and also affect the quality of vegetables.

Phosphorus

Phosphorus is vital to plant growth and is found in every living plant cell. It is involved in photosynthesis, respiration, energy storage and transfer, cell division, and enlargement. Promotes early root formation and growth. Improves quality of fruits, vegetables, and grains. It has been well reported that P is a necessary component of photosynthetic processes which are systematically implicated in creation of sugars, oils, and starches and which further helps in the conversion of solar energy into chemical energy, proper plant maturation, and withstanding stress. It helps plants survive in harsh winter conditions, hastens maturity and increases water-use efficiency. It is the constituent of certain nucleic acids, phosphatides, chromosomes and coenzymes. It plays an important role in cell division, and also in seed and fruit-development. It stimulates the early root development, leaf size, tillering, flowering, grain-yield and hastens the maturity of crops. It establishes the plant roots and helps them to go deep for getting moisture and nutrients. Deep roots also firm the plant in soil and reduces the loss caused by lodging. It is not only helps in flowering and fruiting but also helpful in healthy fruit and seed-formation.

Deficiency Symptoms

- The leaves of plants turn blue or purple and stunting occurs due to deficiency of phosphorus.
- Root-development of crop-plants inhibits due to P deficiency.
- Its deficiency causes delay and reduction in flowering and fruiting.
- Crop takes much time to ripe.
- It affects the shape and size of fruits.

Table 2: Effect of fertilizers and micronutrients on plant growth and its parameters in brinjal

Treatment	Plant height at harvest (cm)	No. of leaves/ plant at harvest	No. of branches/plant at harvest	Days to 50% flowering
Fertilizers (F) (kg NPK/ha)				
F_1 – 125:100:50 (RDF)	77.03	74.53	24.27	42.25
F_2 – 100:100:50 + Azo	85.40	80.57	29.57	44.58
F_3 – 125:100*:50 + PSB	78.23	75.93	25.77	42.50
F_4 – 100:100*:50 + Azo + PSB	86.22	83.72	30.15	45.92
SEm$\pm$	0.83	0.90	0.47	0.66
CD (P=0.05)	2.41	2.59	1.35	1.90
Micronutrient spray (S)				
S_1 – Control	80.07	76.68	26.62	43.58
S – ZnSO (0.2%)	83.70	80.32	28.75	44.33
S_3^2 – $FeSO_4^4$ (0.5%)	82.37	79.35	27.77	43.58
S_4 – Borax (0.2%)	80.75	78.40	26.62	43.75
SEm$\pm$	0.83	0.90	0.47	0.66
CD (P=0.05)	2.41	2.59	1.35	NS

Azo: Azospirillum @ 250 g/ha PSB: Phosphate solubilizing bacteria @ 250 g/ha
Azo + PSB: Each @ 125 g/ha) DAT – Days after transplanting NS – non-significant
(Kiran *et al.,* 2010) [4]

Significant increase in growth parameters by plant due to increase in the fertilizer levels could be attributed to the increased uptake of nutrient in the plants leading to enhanced chlorophyll content and carbohydrate synthesis and increased activity of hormones produced by Azospirillum and phosphorus solubilizing bacteria (PSB) (Table.2). The PSB root dipping increased phosphate utilization by plants which in turn might have helped better proliferation of roots. Data on days to 50 per cent flowering was also significantly influenced by fertilizer levels Application of 125:100:50 kg NPK per ha (RDF) took significantly less number of days to 50 per cent flowering (42) than other treatments. Treatment with 100:100:50 kg NPK per ha + Azo + PSB (root dipping) each at 125 g per ha took longer period (46 days) for 50 per cent flowering. With the increase in the levels of fertilizer particularly, time taken for 50 per cent flowering showed decreasing trend.

Potassium

It plays an important role in the process of photosynthesis and food production. It controls the enzymatic activities of the plant body. It works as a catalyst in about 60 enzymatic systems of the plants. It regulates the water in plants and reduces the negative effects of salts in the plants. It is helpful in the transportation of prepared food from leaves to the rest of the plant parts. It also regulates water within plant cells and loss of water by transpiration. It increases resistance power against lodging and diseases. It is most connected with the quality of seeds and fruits. It converts the starch into sugar due to which sweetness of fruits sugar crops increases. It is necessary for early ripening of crops.is involved in Carbohydrate metabolism and the break down and translocation of starches. Its use improves the quality of fruits and vegetables and they can be stored for a longer period of time. Potassium strengthens the roots, stem and branches of plants and reduce lodging. It is mostly used in sugar crops and crops having starches, for example, sugar-beet, potato and musk melon, etc.

Deficiency Symptoms

- In deficient plants, the height of plant is negatively affected and plant remains short.
- Due to K deficiency the tips and edges of leaves become burned.
- There is a reduction in sweetness and juice of fruits occurs in K deficient plants.
- Lack of potassium causes the water stress in light drought conditions.
- Due to K deficiency breaking of branches and lodging of crop plants will takes place.

Increases photosynthesis. Increases water-use efficiency. Essential to protein synthesis. Important in fruit formation. Activates enzymes and controls their reaction rates. Improves quality of seeds and fruit, winter hardiness, Increases disease resistance.

Secondary nutrients

The secondary nutrients are calcium, magnesium, and sulphur. For most crops, these three are needed in lesser amounts that the primary nutrients. They are growing in importance in crop fertilization programs due to more stringent clean air standards and efforts to improve the environment.

Calcium

Calcium fertilization of many crops is frequently confused with lime or gypsum soil amendments. Many believe application of these minerals to soils sufficiently supplies the calcium requirement of crops. Unfortunately, the role of calcium in plant nutrition is often eclipsed by interest in macronutrients or specific micronutrients. Many Overlooked and is only considered when deficiency disorders influence the economic threshold of produce quality and value. Calcium boosts the nutrient uptake, improves the plant tissue's resistance, makes cell wall stronger, and contributes to normal root system development (Hirschi, 2004) [2]. It has been reported that Ca ions alleviate ionic stress in plants, and various feasible mechanisms have been briefly described by which Ca ions are able to prevent the subsequent damage (Plieth, 2005) [8]. Kochian (1995) [5] reported that, due to protective behavior of Ca ions, the plants were protected from the Al toxicity. However, we know that calcium

1) Is a multifunctional nutrient in the physiology of crop plants and
2) In the soluble form influences availability and uptake. Nitrogen-use efficiency of urea-containing fertilizers is also increased with soluble calcium sources such as calcium nitrate.

Classical visual symptoms in calcium deficient plants include

- Death of growing points,
- Abnormally dark green foliage,
- Premature shedding of blossoms and buds, and
- Weakened stems.

Calcium is Utilized for Continuous cell division and formation. Involved in nitrogen metabolism. Reduces plant respiration. Aids translocation of photosynthesis from leaves to fruiting organs. Increases fruit set. Stimulates microbial activity.

Magnesium

Magnesium is a key element of chlorophyll production, Improves utilization and mobility of phosphorus. Activator and component of many plant enzymes and increases iron utilization in plants. Influences earliness and uniformity of maturity. It is the constituent of chlorophyll molecule. It is very important in formation of seeds rich in oil. It helps in translocation of starches and regulates uptake of other nutrients. Mg concentration in plants ranges from 0.1-0.4 %. It acts as a catalyst in some enzymatic activities. Magnesium is a central atom of chlorophyll and therefore plays a major role in plant photosynthesis, and thus its deficiency degrades the chlorophyll content and leaves become yellowish in color, which is known as chlorosis; however, an adequate supply of Mg makes the plant healthy (Hermans *et al*., 2010) [1]. In most of soils Mg content is ranges from 0.05- 0.5%. It is the chemical constituent of different minerals so it is less available to the plants. It has been observed that soils have calcium in abundance also rich with magnesium.

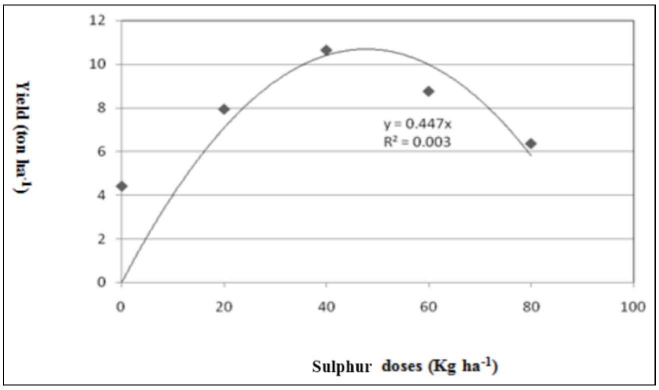
Sulphur

Sulphur is an integral part of amino acids. Helps develop enzymes and vitamins. It promotes nodule formation on legumes, aids in seed production and necessary in chlorophyll formation. Major role of S has been differently recognized, i.e., it plays a crucial role in the synthesis of chlorophyll, proteins, seeds oil content, as well as amino acids methionine and cysteine (Jamal *et al.*, 2010) [3]. These amino acids are involved in metabolic activities of vitamins, biotins, thiamine and coenzyme A. Crop-plants fulfill there all S requirements through soil in the form of sulfate (SO_4) which convert into organic matter after assimilation. Crops grown in industrial areas can absorb sulfur present in the air in the form of sulfur dioxide (SO_2). In our soils, sulfur is present in large amounts in the form of sulfate albeit in the mountainous areas; it dissolves and flows down with the water. In rice-crop, due to standing of water, it converts into sulfur oxide and causes its deficiency. Continuous use of sulfur free fertilizers like urea and DAP causes its deficiency in crop-plants. In nitrogen deficient plants, lower and upper all leaves shows symptoms whereas in S deficient plants it appear on the new leaves only. Removal of sulphur from certain vegetables are given below. (Tabl.4)

Table 4: Removal of sulphur from soil by some vegetable crops

Crop	Yield(t/ha)	Sulphur level (kg/ha)
Cabbage	70	80
Cauliflower	50	40
Tomato	50	30
Onion	35	30
Radish	20	40
Cassava	45	15

Effect of different doses of sulphur on yield, yield contributing characters and sulphur content of onion (Fig.1)



(Mishu *et al.*, 2013) [6]

Different doses of sulphur application had a significant variation on fresh and dry weight of individual onion. The maximum fresh weight was observed with the application of 40 kg S ha-^{1} followed by 20 and 60 kg S ha^{-1}. The maximum dry weight was observed where land was fertilized with 40 kg S ha^{-1} followed by 20 and 60 kg S ha^{-1} with same statistical rank. Control treatment showed the minimum fresh and dry weight. The highest bulb diameter was observed with 40 kg S ha^{-1}. The highest neck diameter was observed with 40 kg S ha^{-1} and the highest neck bulb ratio was observed with 40 kg S ha^{-1}. On the other hand, the highest number of split bulb was counted where 60 kg S ha^{-1} was added and the control showed the lowest value. A response curve on the effect of different doses of sulphur on yield of onion was constructed at final harvest. The sulphur dose at 40 kg ha^{-1} produced significantly highest yield and subsequently yield was reduced at 60 and 80 kg ha^{-1}

Physiological disorders

Physiological disorders are abiotic abnormalities in leaf and fruit and plant morphology which are not caused by infectious diseases or insects. These abnormalities occur as a result of genetic factors, environmental factors like temperature and relative humidity, unbalanced soil nutrients, moisture stress, poor drainage, improper planting time and harvesting time etc. These disorders decrease the yield in vegetable crops and quality of the produces becomes poor. Different disorders are found in vegetable crops and are as follows:

Tomato

Blossom-End Rot

Lesions appear at blossom end of the fruit while it is green. It begins with light tan, water-soaked areas that can enlarge and turn black and leathery in appearance. Most often the problem occurs at the blossom end of the fruit, but on occasion can occur on the side of the fruit. Many factors can influence this disorder like low soil Ca, high N rates, using ammonia sources of N, high concentrations of soluble K and Mg in the soil, high salinity, low humidity, inadequate soil moisture, excess soil moisture and damage to root system by nematodes etc. This disorder can be controlled by spraying the crop with calcium chloride @0.5% at fruit development stage. Apply recommended quantity of nitrogen and give light and frequent irrigations to maintain optimum soil moisture.

Cat face

The fruits with cat face are characterized by the distortion of blossom end of the fruit. Such fruits have ridges, furrows, indentations and blotches. It resembles blossom end rot but is distinct from it. Abnormal growing conditions during formation of blossom appear to cause distortion of growth of the cells of the pistil. As a result, the cells in the blossom end of the ovary die and turn dark to form a leathery blotchy at the end of the fruit without the progress of symptoms characteristic of blossom end rot. For less incidence of this disorder grow tomato crop under favorable climatic conditions.

Puffiness

As the fruit reaches about two third normal size, the outer wall continues to develop normally but remaining internal tissue growth is retarded. As a result, tomato fruits are light in weight, lack firmness and partially filled. This is due to non-fertilization of ovule, embryo abortion after normal fertilization and necrosis of vascular and placental tissue after the fruit is well developed. Causal factors are high or low temperature and low soil moisture. To control this disorder maintain the optimum soil moisture. Summer grown tomatoes have less incidence of this disorder.

Sunscald

Exposed fruits of tomato either green or nearing ripeness scald readily during extreme heat. The tissue has blistered water soaked appearance. Rapid desiccation leads to sunken areas which usually have white or grey colour in green fruit or yellowish in red fruits. The cultivar in which heavy foliage is characteristic and in which there is greater protection from sun rays usually have least damage. Avoid heavy training and pruning in summer months. Crop can be raised in higher density.

Fruit cracking

Cracking of the surface of the fruit at the stem end is a common occurrence and often results in large losses. The cracks are of two kinds, one which radiates from the stem end and other develops concentrically around the shoulder of the fruit. Radial cracking is more common and causes greater loss than concentric cracking. Besides these, cuticular cracking is also often found of the skin of fruits. Several environmental factors seem to be involved in the cracking. It is common during rainy season when temperature is high, especially when rains follows long dry spell. Radial cracking is more likely develop in full ripe fruit than in mature green or turning stage maturity. On other hand, concentric cracking is relatively low on ripe fruits than mature green. Fruits exposed to sun develop more concentric cracking than those which are covered with foliage. Cultivar Sioux is resistant to fruit cracking.

Gold fleck

Appearance of gold colour flecks on fruits is the main feature of this disorder and chlorophyll is not properly changed in carotenoids. A fine spotting affects the calyx ends of the fruits and sometimes extends over the whole skin. The affected fruits have a shorter shelf life than unaffected ones. This disorder is most commonly found in late crops in glasshouses with little or no heating. A high incidence of the disorder is associated with large differences in temperature and humidity during the day and night, a low K:Ca ratio, low Mg content and a low EC level. High Mg and low P concentrations in the nutrient solution with high EC value will reduce the severity of the disorder. Summer grown tomatoes have less incidence.

Capsicum

Blossom end rot

Disorder is characterized by appearance of water soaked spots on the blossom end of the fruit. They turn light brown and papery as they dry. Causes are Ca deficiency in the soil, moisture stress and heavy fertilization of nitrogen. This disorder can be controlled by spraying the crop with calcium chloride @ 0.5% at fruit development stage. Give light and frequent irrigations to maintain optimum soil moisture and apply recommended dose of nitrogen.

Sun scald

Soft, light coloured and slightly wrinkled areas appear on the fruit surface. Later these areas become sunken and papery. It is caused when fruits are exposed to intense light. Disorder can be controlled by transplanting the seedlings at closer spacing. Raise the crop in high density.

Onion

Bolting

It refers to the emergence of seed stalk prior to time of their formation and adversely affects the formation and development of bulbs. Bolting is an undesirable character because it directly affects the bulb yield of onion. Early transplanting and late transplanting induce bolting in kharif and rabi onion respectively. White cultivars are more sensitive to bolting.

Lettuce

Tip burn

Disorder is characterized by appearance of tip burning of margins of the inner leaves of mature heads. The disorder is common in greenhouse grown crop than open field crop. This is caused due to prevalence of high temperature, excess of nitrogen, calcium deficiency. Spray the crop with Calcium Chloride at rate of 0.5 percent and apply recommended dose of nitrogen.

Conclusion

In conclusion, macronutrients play a very important role in plant growth and development, and thus influence every stage of plant life. However, excess and/or deficit of macronutrients may adversely affect the overall growth and performance of plants. By managing the amount of particular macronutrient, the unwanted loss of crop productivity due to other stresses will also be minimized, which could help to feed the growing population.

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