# Plant Nutrient Balance for Robust Vegetable Cultivation and Healthier Human Nutrition

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**OPEN ACCESS**

**Keywords**

Malnutrition, Micro and Macro nutrients, Vegetables, Yield and Quality

*How to cite this article:*

Chandrasekaran, P., Ashokkumar, N. and Ashok, S. 2024. Plant Nutrient Balance for Robust Vegetable Cultivation and Healthier Human Nutrition. *Vigyan Varta* 5(6): 43-48.

**ABSTRACT**

Plant nutrient deficiency is the most serious problem in agriculture, particularly in vegetable cultivation. This results in lower crop yield and quality, which reduces the farmer's income. However, malnutrition arises as a result of the consumption of vegetables that are lacking of vital nutrients, resulting in around 1.7 million deaths every year. Eating nutrient-dense vegetables is the most cost-effective strategy to combat malnutrition. Malnutrition is major issue in the world and more than 60% of people are affected by iron, 30% zinc, 30% iodine, and 15% selenium. It is necessary to provide crops with micronutrients and macronutrients essential for plant growth in order to avoid malnutrition and hidden hunger in humans and yield loss in vegetables. The efficiency of inorganic micronutrients applied to soils is low as they become easily fixed to soil particles. Hence, applying a foliar spray of nutrients is an effective option to enhance plant nutrient use efficiency. In this review, we discussed about importance of nutrients in vegetable production and human health. Further, we make clear about importance of vegetables to overcome malnutrition, how to develop nutrient-rich vegetables, and finally how to plant response to applied nutrients.

## INTRODUCTION

The plant contains about 40 nutrients out of which 17 nutrients are classified as essential nutrients and three as beneficial nutrients (selenium [Se], silicon [Si], and sodium [Na]). Among the 17 essential nutrients 9 are major nutrients (Carbon, [C], Hydrogen [H], Oxygen [O], Nitrogen [N], Phosphorus [P] and potassium [K], Calcium [Ca], Magnesium [Mg] and Sulphur [S]) and 8 are micronutrients (Copper [Cu], Boron [B], Zinc [Zn], iron [Fe], Manganese [Mn], Molybdenum [Mo], Nickel [Ni] and Chlorine [Cl]. Agriculture production and productivity has increased that experienced the application of major nutrients. Addition to major nutrients, micronutrients application is essential to improve vegetable nutrient status. These nutrients also play crucial roles in human's diet, physical and mental development. Addition of macro nutrients with micronutrients viz., iron, zinc, boron, manganese, copper gives profound changes in various metabolic processes within the plant system, thereby influencing plant growth and yield considerably. In recent days, the multinutrient mixture application is raised due to combined nutrient stress and other biotic and abiotic stresses. These nutrient mixtures are enhancing the plant growth, productivity and quality of vegetables which overcome the malnutrition and hidden hunger in increased human populations worldwide. The major nutrients for human come from vegetables. Due to poor soil condition the plant unable to absorb nutrients from soil. Plant cultivate under low nutrient soil which leads to reduced uptake and accumulation of nutrients in the vegetables. Deficiency of nutrient status in vegetables is the foremost reason for high prevalence of nutrient deficiency in humans and this indicates the correlation between plants and human nutrition. Consumption of nutrient deficit vegetables for daily diet of humans leads to create malnutrition and hidden hunger. Maintaining a proper nutrient balance in the soil is crucial for robust vegetable cultivation and ensuring healthier human nutrition. Hence, this review explain about maintaining of balanced approach to soil health, crop management, and dietary habits, both plant cultivation and human nutrition can significantly benefit, leading to healthier produce and improved overall well-being (Bana *et al.*, 2022a).

### Importance of vegetable nutrient content for human health

India has slipped to the 107$^{th}$ position in global hunger index in 2022 out of 121 countries and it low compare to our neighbour's countries like Pakistan, Bangladesh and Nepal. This hunger index is based on two major factors of hunger and malnutrition. These two problems are majorly facing for developing countries. Approximately, 3.1 million peoples around the world are unaffordable to access to healthy diets.[9] The unequal income and income losses among the peoples due to COVID pandemic worsened the food security situation which already struggling to feed their families. Furthermore, the rapid climate change that affect the grain production. About 43.5 % children in India under the age of five years are chronically malnourished. Consumption of vegetables is generally considered to be associated with several positive effects on health. It has been shown that low consumption of fruits and vegetables is related to more cardiovascular disease and cancer.

The State of Food Security and Nutrition in the World 2022 reported 828 million people affected by malnutrition. Women and children are disproportionately affected by micronutrient deficiencies, which affect more than two thirds of the world's population overall. Two billion iron nutrient deficiency

peoples, 2 billion iodine nutrient deficiency peoples, 150 million vitamin A nutrient deficiency peoples and 3 million peoples are insufficiency of zinc nutrient in the world. Hence, providing good quality nutritious food to individuals is one of the important 17 sustainable development goals given by United Nations. The essentiality of nutrients for both plants and humans are given in the table 1. The reduced amount of essential nutrients in the food is main factor for hidden hunger.

**Table 1. Dry weight of nutrients (%) in plants and essentiality of nutrients for plants and animals**

| Sl. No | Nutrient | Nutrients (%) | Essentiality | |
|---|---|---|---|---|
| | | | Plant | Animal |
| 1 | Carbon | 45.0 | + | + |
| 2 | Hydrogen | 45.0 | + | + |
| 3 | Oxygen | 6.0 | + | + |
| 4 | Nitrogen | 1.5 | + | + |
| 5 | Phosphorus | 0.2 | + | + |
| 6 | Potassium | 1.0 | + | + |
| 7 | Calcium | 0.5 | + | + |
| 8 | Magnesium | 0.2 | + | + |
| 9 | Sulphur | 0.1 | + | + |
| 10 | Iron | 0.01 | + | + |
| 11 | Boron | 0.002 | + | +/- |
| 12 | Copper | 0.0001 | + | + |
| 13 | Chlorine | 0.01 | + | + |
| 14 | Manganese | 0.005 | + | + |
| 15 | Zinc | 0.002 | + | + |
| 16 | Molybdenum | 0.0001 | + | + |
| 17 | Nickel | Trace level | + | +/- |
| 18 | Sodium | Trace level | Beneficial | +/- |
| 19 | Selenium | Trace level | Beneficial | +/- |
| 20 | Cobalt | Trace level | Beneficial | +/- |

**+Essential, - Non essential, +/- Suggested**

Implementation of food security in India is really challenging one among Indian populations and failed to combat malnutrition that affect country social economic status. The typical vegetable yield is substantially below potential productivity, owing to abiotic and biotic plant stresses, as well as farmers' lack of knowledge about proper nutrition and other management measures. Vegetables are high nutrient exhausting crops due to their high biomass output and lengthy growing season. Approximately 89, 80 and 50% of the arable soils are deficient in N, P and K, respectively. Further, zinc (Zn), boron (B), iron (Fe), manganese (Mn), molybdenum (Mo), and copper (Cu) deficiencies have been reported in around 40, 33, 12, 5, 11 and 3% of Indian soils, respectively which paves the way for improvement of nutrient status in vegetables (Bana *et al.*, 2022b).

The global nutritional problem is characterized by deficiencies in essential nutrients affecting crop growth and yield. This issue is particularly prevalent in Asia, where nutrient deficiencies in nitrogen, potassium, zinc, boron, manganese, copper, iron, and molybdenum significantly impact vegetable crops. The Indian subcontinent, including India, faces specific challenges related to soil nutrient levels, affecting the uptake, translocation, and assimilation of nutrients by vegetables. Addressing these issues through effective nutrient management, particularly via foliar spray, is crucial for enhancing crop yield, quality, and nutritional value in the context of the Indian subcontinent.

## Improving the nutrient content of vegetables for healthy human's diet

Malnutrition problem is associated with inadequate uptake of healthy and quality food grains, fruits and vegetables which contain various nutrients, minerals, and vitamins. Vegetables are one of the important sources of nutrients, vitamins, minerals and phyochemical which protect the individuals from malnutrition. Therefore, the enrichment of nutrients is important in agriculture. It is also attraction of researchers to develop enriched or elevated level of phytonutrients in vegetables that overcome the malnutrition problem. There are several methods can be proposed to achieve better nutrient delivery

through plant-based products in vegetables, 1. Vegetables can be improved through conventional breeding 2. Transgenic method 3. Agronomic practices. However agronomic improvement of vegetable nutrients is the most convenient cost-effective and rapid method for bio-fortification and there are several approaches available viz., seed priming, seed treatment, foliar application and use of organic manures.

**Improving plant nutrient status for yield and sustainability**

The status of micronutrients is critical and deficiency in zinc, iron, boron and copper is noticed in many states of the country. The soil in world as well as in India is often low in nitrogen and potassium and rich in phosphorus. In India, vegetable cultivation is hampered by a lack of nitrogen, potassium, magnesium, boron, iron, and zinc based on the agro climatic zones and soil type. In other hand, vegetables are very sensitive to deficiencies of Magnesium (Mg), Boron (B), Iron (Fe) and Zinc (Zn) based on plant growth and development characters**.** The clay loam soil is deficient in phosphorus, potassium, molybdenum in the acidic condition and deficit in boron, manganese, and zinc in alkaline conditions. In the red sandy loam soils, Nitrogen, Potassium, Magnesium, Copper, Molybdenum deficiencies occur in Acidic soil nature and Nitrogen, Magnesium, Sulphur, Boron, Copper, Manganese, Zinc deficiencies occur at normal pH soil and Nitrogen Phosphorus, Magnesium, Sulphur, Boron, Copper, Iron, Manganese, Zinc deficiencies occur in Alkaline soil (Table 2, 3). These soil conditions affect nutrient uptake, plant growth and development, as well as crop production and quality, which affect farmer revenue.

**Table 2. The foliar recommendation and source of nutrients in crop plants**

| Nutrient | Source | Concentration |
|---|---|---|
| Nitrogen | Urea | < 2% |
| Phosphorus | Mono ammonium phosphate/ Single super phosphate (MAP/SSP) | < 2% |
| Potassium | Murate of potash/ Sulphate of potash (MOP/SOP) | < 2% |
| Calcium | Calcium chloride ($CaCl_2$) | < 0.5% |
| Magnesium | Magnesium sulphate ($MgSO_4$) | < 0.5% |
| Sulphur | Any Sulphur containing fertilizers | < 0.5% |
| Iron | Iron sulphate ($FeSO_4$) | < 0.5% |
| Boran | Borax ($Na_2B_4O_7.10H_2O$) | 0.3% |
| Copper | Copper sulphate ($CuSO_4$) | 0.1% |

Vegetables and vegetables-based cropping systems show that vegetable crops are well responsive to nutrient supply through organic manures and chemical fertilizers. Okra produces fruits for a long time and needs balanced and sufficient supply of nutrients for higher yield and better quality. Indiscriminate use of inorganic fertilizers has resulted in decreased nutrient uptake, poor quality of vegetables and deterioration of soil health. The country is now facing various problems like inadequate and imbalanced fertilizer use, distorted NPK consumption ratio and nutrient mining (export (loss) of a nutrient is greater than import (input)), leading to multi nutrient deficiency.

Watermelon is sensitive to deficiencies of Mg, Boron (B), Iron (Fe) and Zinc (Zn). Foliar sprays of these nutrients in some cases have proved useful in enhancing the sugar content of the fruit. Since watermelon yield and quality are so greatly influenced by production practices, it is important that watermelon varieties should be tested under conditions of adequate nutrition. Special attention should be given to Boron nutrition in areas with high

relative humidity. Boron deficiency symptoms gradually increase and become fully visible during flowering phase in watermelon.

**Table 3: Effect of soil characters antagonist and synergist of plant nutrients**

| Sl. No | Nutrient | Acid soil | Alkaline soil | Condition to reduce the availability | Antagonist | Synergist |
|---|---|---|---|---|---|---|
| 1 | Nitrogen | _ | _ | Water logged soil, Poor aeration | Potassium and Copper | Magnesium and Molybdenum |
| 2 | Phosphorus | _ | + | High clay content, High level of Calcium, Aluminium and Iron | Zinc, iron and Calcium | *Magnesium* |
| 3 | Potassium | + | + | Light sandy soil | Nitrogen and boron | Manganese and iron |
| 4 | Calcium | _ | ++ | Low pH soil | Boron, zinc, Iron and manganese | Nil |
| 5 | Magnesium | _ | ++ | Light soil, High rainfall | Nil | Nitrogen and Phosphorus |
| 6 | Sodium | _ | ++ | | Nitrogen | Nil |
| 7 | Copper | ++ | | High organic matter | zinc, Iron and manganese | Nil |
| 8 | Iron | ++ | + | High soil pH | Copper and Calcium | Potassium |
| 9 | Manganese | ++ | _ | High soil pH | Copper, iron and Calcium | Potassium |
| 10 | Zinc | ++ | _ | Low organic matter soil | Phosphorus, Calcium, Iron and Copper | Nil |

**++ More available, + moderately available, - Unavailable**

## Response of vegetables to nutrient application

Growth, yield and quality of vegetables can significantly be increased by increasing level of fertilizer application. The application of 1.0 kg of multi-micro nutrients booster along with recommended dose of fertilizer improves the fruit nutrient status of eggplant. In other hand multi-micro nutrients booster improves nutrients status of leaves and shoots of eggplant without recommended dose of fertilizer.

The combined application of multi-micro nutrients (either 0.75 or 1.0 kg $ha^{-1}$) with recommended dose of fertilizer enhances the brinjal yield upto 21 % and significantly increase the micronutrient status in fruits. This was also studied in potato plants by foliar application of Zinc nutrient and increment of Zn content. A study on biofortification of zinc through three foliar applications in capsicum, eggplant and tomato. The study resulted that the significant improvement of zinc 6.6% in capsicum, 7.10% in eggplant and 8.59% in tomato of zinc in the improved by foliar applied zinc. Selenium is the major nutrient for onion. And improvement of selenium in onion through foliar application and the study resulted that 99.7% of selenium was increased by 50 mg selenium is applied. The tomato iodine content was increased by biofortification through foliar application of 5mM iodide.

Iron fortification through foliar application improves the iron concentration in rice grains. Similarly in brown rice grains, foliar applied iron increase the iron content up to 15.6 times than untreated plants. Also reported that foliar application of zinc promotes the concentration and availability of zinc in rice plants. Essential nutrient selenium a potent antioxidant has been also improved in rice by fortification of selenate. Agronomic biofortification of zinc oxide/zinc sulphate and selenium increased the both the concentrations in potato tubers. Increased beta-carotenes were observed in sweet potato by application of chemical fertilizers. Application of Iodine and Selenium in carrot and lettuce improve the Iodine and Selenium content (Kumari *et al.*, 2022).

## CONCLUSION

This review highlights the importance of nutrient management in vegetable crops and the impact of nutrient deficiencies on plant growth and crop yield. Nutrients such as nitrogen, potassium, zinc, boron, manganese, copper, iron, and molybdenum play crucial roles in various physiological processes within plants, including photosynthesis and respiration. Nutrient deficiencies can disrupt these processes, leading to decreased crop yield and compromised quality. To address these deficiencies, the use of foliar spray is suggested as a cost-effective and efficient method. Foliar application involves spraying a nutrient solution directly onto the leaves of plants, allowing for quick absorption and utilization by the plant. This method is

advantageous in situations where soil nutrient levels are not optimal or when there are issues with nutrient uptake, translocation, or assimilation. Foliar spraying helps in bypassing potential soil-related limitations and ensures that plants receive the necessary nutrients directly. It can also be particularly useful during critical growth stages when nutrient demands are high. By addressing nutrient deficiencies through foliar spray, not only can the yield and quality of vegetables be improved, but the overall nutritional content of the crops may also be enhanced. This is crucial for reducing the risk of malnutrition in humans who consume these vegetables as part of their diet. In conclusion, nutrient management, especially through foliar spray, is a valuable approach to optimize the growth and development of vegetable crops, ultimately benefiting both farmers and consumers by improving yield, quality, and nutritional value.

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