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Integrated Nutrient Management in Pomegranate

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INTRODUCTION

Pomegranate (*Punica granatum* L.), is a native fruit of Iran. However, it is well suited to the tropical and sub-tropical regions of the world, but best thrives in hot arid, and semi-arid regions. In India, due to its wider adaptability to diverse climatic and soil conditions in arid and semi-arid regions, it has drawn a lot of attention in recent years and become a boon for Horticulture farmers. Irrespective of the amount required for macro and micronutrients, deficiency of all or even single elements will affect vegetative growth, flowering, fruiting, stress tolerance, and pest incidence. Earlier, the interest was to produce higher crop yield only, but now the scenario has changed from higher production to quality fruit production. The effect of plant nutrition on quality fruit production may be recognized by supplying nutrients in balanced proportion resulting in higher fruit yield with required quality standards. Also, the selection of soil is of much importance for the success of the pomegranate crop, because the crop cannot tolerate poor aeration and water logging condition in the root zone.

Soil Selection

Soils are classified based on their physicochemical properties such as origin, mineral or organic matter content, mechanical separation of soil as sand, silt, and clay percentage, soil reaction, water holding capacity, and cation exchange capacity. Generally, surface soils are more fertile than subsoils because of the accumulation of decomposed crop residues and organic and inorganic nutrition applied externally by the farmers.

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Pomegranate is a drought-tolerant and winter-hardy crop, so can thrive well under diverse climatic conditions and has the potential to grow on a variety of soils. The pomegranate crop thrives best in sandy loam soil having a very low water-holding capacity and faster water infiltration rate. The clayey soils are having more clay particles leading to compaction that inhibits root penetration and exploration so, the roots are unable to extract water and nutrients efficiently, even though present in adequate quantities. However, sandy soils have better tilth than clay soils but are usually less fertile due to low cation and anion exchange capacity and also require more frequent irrigations and fertilization than loamy soils. Due to these limitations, it is being promoted under watershed programmes in arid and semi-arid regions of Maharashtra, Andhra Pradesh, and Karnataka states of India. Soil reaction and nutrient availability On the basis of soil reactions i.e. soil pH, soils are categorized as acidic (pH < 6.5), neutral pH (6.5-7.5), and alkaline (pH > 7.5). The soil is able to buffer the soil solution because of the adsorption, precipitation, and cycling of organic matter. Soil pH also affects the extent to which most nutrients are bounded by the soil particles. However, the pH of the soil near the root is not the same as compared to the bulk because the roots of the plants exerted substances such as carbon dioxide, which forms carbonic acid in soil solution alters the soil pH adjacent to the roots and leads to increase the availability of nutrients to the plants, except in acid soil. The alkaline soil pH greatly limits the solubility of many elements including Zn, Cu, Mn, and Fe, and acidic soil pH may lead to deficiencies of Ca, Mg, P, and Mo, and result in excessive amounts of Mn, Fe, or Al in the solution. These problems may be overcome by the application of lime (for raising pH), sulfur or sulfuric acid or gypsum (for lowering pH), organic matter (to improve soil structure), or adding fertilizers in some instances. The different soil category affects the availability of nutrients in the soil.

- **Alkaline soils:** Zinc and copper are unavailable to plant.
- **Neutral to alkaline soils:** Calcium phosphate precipitates, and its solubility decreases with increasing alkalinity. Excessively alkaline soils are usually the results of the accumulation of sodium carbonate in the soil or Na replacement on a large percentage of the ion exchange sites, or both.
- **Under acidic to neutral conditions:** Phosphorus is specifically adsorbed onto the surface of iron oxide, aluminum oxide, and clay mineral particles, and is not displaced from these surfaces to any appreciable extent by other components of the soil solution. In addition to the specific adsorption of phosphate on the oxide surface, iron phosphates, and aluminum phosphates may precipitate. In too-acidic soils, aluminum oxide dissolves to create toxic levels of Al. The conversion of insoluble manganese dioxide to soluble Mn^{2+} also leads to toxic concentrations of Mn.

Functions of macro and micronutrients

There are numerous publications on the functions of mineral nutrients in fruit trees, which deal with growth and physiological aspects. Today, mineral nutrition has to be considered more in terms of fruit quality rather than yield. Fruits are regarded as healthy food and thus fertilization of pomegranate trees is not only a means of increasing the productivity of the plant but also of promoting the formation of valuable components within the fruit. Pomegranate fruit trees like other tree species also require seventeen elements for growth and development and the deficiency of one or more elements impairs the growth and development of the plant as well as fruit production and quality. These seventeen elements required for the growth and development of the fruit tree are known as essential elements. These are carbon (C), hydrogen (H), oxygen (O) nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), boron (B),

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zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), chloride (Cl), molybdenum (Mo) and nickel (Ni). Out of these seventeen essential elements C, H, and O are present in air and water and plant takes these three elements easily from air and water. The other six elements i.e. N, P, K, S, Ca, and Mg are required in large quantities by the plants, so-called macro-elements, and the rest of the nine elements i.e. B, Zn, Cu, Fe, Mn, Cl, Mo and Ni are required in much smaller amounts and are called as micro-elements. These macro and micro elements are either present in soil as inherent capacity of soil or have to applied externally as organic or inorganic source by the farmer in the soil. The important functions of these essential elements are discussed as follow:

Macro-elements

Nitrogen: is an important nutrient that governs the vegetative and generative development of the fruit tree, affects shoot growth, and is necessary for flower bud formation, fruit set, and fruit development. Nitrogen-deficient trees not only produce an insufficient number of fruits but also the individual fruits are small in size and poorly developed. However, nitrogen promotes the development of the ripening fruit, but the excessive nitrogen content in plants suppressed the formation of some vitamins, color pigments, aroma compounds, the optimum sugar-acid ratio, and fruit shelf life. Excessive application of nitrogen may also impart nutrient imbalances within the fruit may lead to the Ca deficiency symptom.

Phosphorus: is mostly governs the flowering and fruiting as well as energy metabolism of the tree. Phosphorus enhances the production by increasing the number of flowers, fruit set, and fruit size and regulates the meristematic activities and fruit quality parameters such as skin color and the formation of vital plant phosphorus-containing compounds such as phospholipids, nucleic acids, and adenosine triphosphate (ATP).

Potassium: is the most important nutrient for pomegranate, however, it is not directly involved in the structural growth of the tree but plays a major role in a number of physiological processes such as water retention, frost tolerance, and lowering the susceptibility to insects and diseases infestation as well as biochemical processes involved in the fruit development. Besides these potassium play a vital role in enzymatic reactions and is an important factor in the development of fruit color, total soluble sugar, and vitamin C content. Potassium is an important nutrient for osmoregulation and maintaining cell turgor. Fruits rich in potassium are more resistant to sunscald. However, excess potassium with calcium can induce fruit disorder.

Calcium: is the typical structural nutrient element in the tree and the fruit. Calcium transportation into fruits is very low because it is almost absent in the phloem and also depends on the water influx driven by transpiration, which is very low. However, calcium accumulates in very high amounts in leaves as virtually sucked away from fruits by the competing transpiring leaves. Calcium is crucial for fruit firmness because it forms bonds in the middle lamellae and the micro-fibrils of the fruit tissue and also has an important function in the maintenance of cell membrane integrity. Calcium deficiency causes cracking in fruits, which favours the disease infestation.

Magnesium: is the central atom of the chlorophyll molecule in the plant and is involved in numerous metabolic reactions. Magnesium plays a vital role in improving fruit quality such as fruit size and color, increases sugar content, and promotes the formation of aroma compounds and acidity. Fruit premature drop was found higher in the orchards where magnesium deficiency occurs in trees.

Sulphur: has not been considered an important element among pomegranate farmers, but there is a need for greater awareness regarding the importance of sulphur as significantly lowered industrial output and the consequent continuing falls of sulphur content in soils. Sulfur is essential for protein synthesis as well as for the formation of aromatic compounds in the fruit. Sulphur-containing substances enhance the plant's tolerance to diseases and insect-pest infestation and biotic and abiotic stresses (i.e., heat and cold stress).

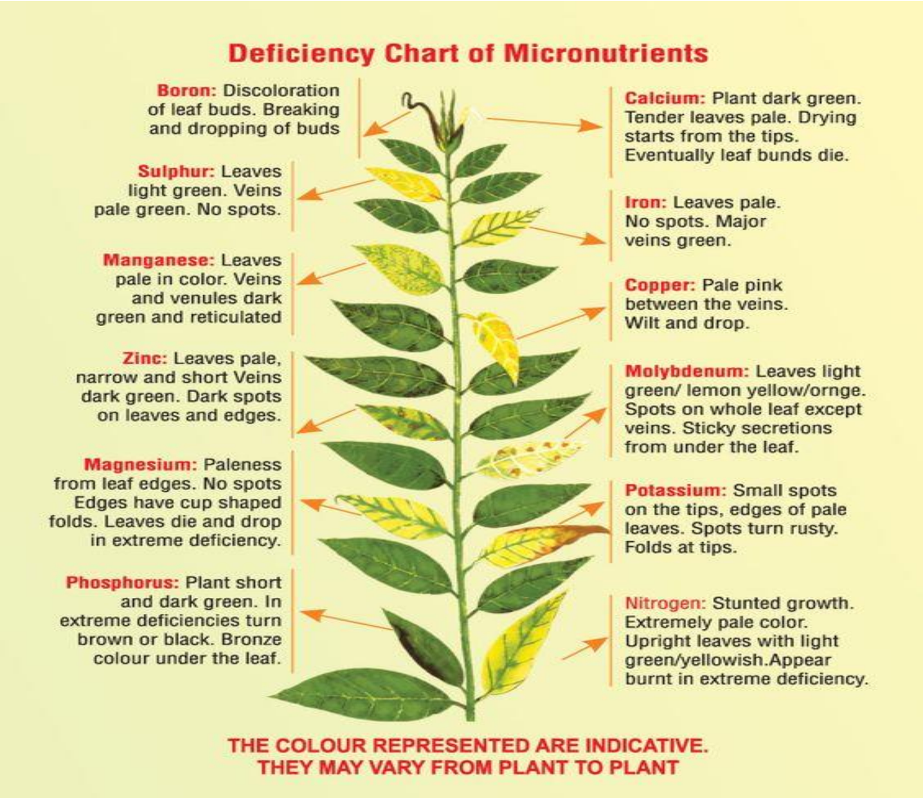

Chart showing nutrients deficiency symptoms

Micro-elements

In most of the literature published, the significance of micronutrients in terms of fruit quality has not been evaluated in detail. However, most of the physiological processes depend on the action of micronutrients such as iron, manganese, copper, zinc, and boron, which are involved in a number of enzymatic reactions. Micronutrient deficiencies appear mainly in soils with high pH, which governs the low availability and the deficient trees develop characteristic leaf symptoms.

Iron: is an important micro-element present in the soil as it oxidized from Fe^{3+}, but most plant species including pomegranate trees take the element when it is chemically reduced to Fe^{2+}. The maximum (up to 80%) of total iron content present in plants is localized in the chloroplasts and closely linked to CO_2-assimilation in the leaf. In many biochemical processes that occur within the plant's metabolism, the element iron plays a role of an activator such as the regulation of oxidation/reduction pathways. The iron mobility in the tree is very low, therefore plant young leaves and shoots show typical deficiency symptoms.

Manganese: This element plays an important role in nitrogen assimilation and magnesium uptake by plants and is also involved in carbon dioxide assimilation and respiratory pathways. As a micro-element, it requires in minute quantity by the plants, and at a very narrow concentration it favours the formation of green color pigments in fruits, but at excessive concentration, it can increase the problem of rusting depending on local weather conditions.

Zinc: is one of the important micro-elements required by plants including pomegranate trees and is found mostly deficient in soils

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worldwide, being prominent in many calcareous or alkaline soils. The element is very essential for the fruit set in pomegranate trees and it has a strong influence on the elongation and growth of fruit. The deficiency shows very short internodes in plants resulting in rosette-like, stunted shoots known as little leaves and it is related to the requirement of zinc for the synthesis of the growth hormone indole acetic acid (IAA).

Copper: is an important micro-element for growth-related processes in plants such as in meristematic tissues as well as in xylem development.

Boron: is an important micro-element that requires much during the reproductive phase of growth and imparts a beneficial effect on fruit set and yield. The element is beneficial in controlling post-harvest disorders and increases the calcium uptake to overcome the deficiency of the element. Boron plays an important role in alleviating water deficiency stress in plants and enhancing the frost resistance of trees.

Integrated nutrient management (INM)

INM is an approach that increases the quality of production as well as protects the environment for posterity. It includes nutrient application and conservation, new technologies to increase nutrient availability to plants, and also the dissemination of knowledge between farmers and researchers regarding nutrient application and management. A large number of fertilizers are used to supply nutrients to the pomegranate crop, according to the crop management and growth conditions in solid or liquid form applied as straight or complex fertilizer. Now a day the use of micronutrient fertilizers is very common in pomegranate production. On the basis of origin, the nutrient source can be classified as: -

1. 1. Organic fertilizer (composts and farmyard manure, residues from processing of organic materials)
2. Bio-fertilizers
3. Mineral fertilizers
4. Soil amendments and products with low nutrient contents (e.g. gypsum, lime, rock flour, etc.)

In the early days, it was believed that the mature pomegranate required only about 40 to 60 kg of nitrogen (N) annually and phosphorus (P) and potash (K) did not play any role in improving yield, size, and quality of fruit. At that time only 1.2 to 4.0 kg ammonium sulphate along with 15 to 40 kg FYM, 2.5 to 3.5 kg cake, sometimes 5.0 kg wood ash, and 1.0 kg lime were recommended to meet out the nutrient requirement of the crop in India. But now a day, with the commercialization of pomegranate cultivation and more research outcome, it was found that the availability of all three major nutrients N, P, and K are essential for the growth and development of the crop resulting in higher quality fruit production. Based on different fertilizers' responses to pomegranate crop growth and development, and fruit quality and production, several recommendations have been worked out for various soil and crop situations in India and abroad. Various scientists suggested 250-625 g N + 125-250 g P2O5 + 125 g K2O per plant for ‘Ganesh’ grown on black soils; 120 kg N + 90 kg P + 60 kg K ha-1 for ‘Kzyr anar’; 240 kg N + 160 kg P + 60 kg K ha-1 for ‘Jodhpur Red’ and 375 g N +375 g P + 375 g K per plant for ‘Dholka’. Generally, the pomegranate fruit crop responds very well to sulphate of potash rather muriate of potash. Also, the foliar application of potassium chloride or potassium sulfate at 0.5, 1.0, 1.5, and 2.0%, from bud to harvesting stage at 15-day intervals increased fruit quality in pomegranate crops. The results of a large number of experiments conducted on manures and fertilizers confirmed that neither chemical fertilizers nor organic sources of nutrition alone can achieve higher and quality fruit production sustainably. However, the integrated application of inorganic fertilizers along with organic nutrients (FYM at 25 kg/tree) increased tree spread and yield of pomegranate. It is also reported that the application of 10 kg FYM per plant alone or in combination with recommended NPK; poultry manure 5 kg and bone meal 1 kg along with recommended NPK were found effective to boost the vegetative growth of pomegranate plant. The application of compost (25 kg/ tree) or humic acid (25 g/ tree) accompanied with recommended NPK dose resulted in much higher quality fruit production from pomegranate trees. It was also observed that fifty percent supplementation of inorganic fertilizer along with cattle dung manure increased fruit yield and improved fruit quality parameters as compared to the application of organic alone. Similarly, supplementation of inorganic fertilizers with vermicompost in equal ratios increases plant height, canopy volume, and fruit yield in sandy soils of the hot arid region. An integrated approach consisting of 10 kg vermicomposting, 25 percent recommended dose of N-P-K, 5 kg neem cake, and 20 g phosphate solubilizing bacteria per plant was found to produce a large number of flowers, higher fruit setting, and fruit retention and ultimately higher yield as compared to yield obtained from recommended dose of NPK through inorganic fertilizers. The integrated supply approach not only increases fruit yield but also improves fruit quality such as TSS, TSS: acid ratio, ascorbic acid content, reducing and nonreducing sugar, and total sugar.

The role of micronutrients cannot be ignored in pomegranate as their application was found to improve fruit quality and other physiological activities. Foliar application of Macroliq micronutrient increased fruit size and juice percentage. The application of boron and zinc at the rate of 12.5 and 45 g per tree per year, respectively enhances the sugar content in pomegranate fruits. Similarly, the combined application of zinc, iron, manganese, and boric acid increased the juice content in the pomegranate crop. The TSS content in fruit can also be increased by the application of $ZnSO_4$ (0.4%) along with 0.2% boric acid. However, spraying of 0.3% $MnSO_4$ produced fruits with higher average weight and volume.

CONCLUSION

- Planning an orchard fertilization program should start long before the orchard plantation.
- The amount of material should be applied based on nutrients requirement and crop response throughout the field at least in the upper 40-50 cm soil layer.
- The additional nutrient elements requirement of the crop should be judged from the differences in nutrient requirement of the crop and the supplying capacity of field soil calibrated on the test basis, because when the orchard has been established it is very difficult to make rapid and large changes in soil supplying capacity of nutrient elements (macro and micronutrients), even by applying them to the surface.
- As micronutrients differ in their relative mobility in the soil, so should be applied with the most appropriate method. Therefore, the combination of soil and foliar application is considered to be the best approach.
- With the increasing trends towards intensified production systems using high-density plantations with canopy management, fertigation offers an effective means through the drip irrigation system and enhancing the efficiency of fertilizer use.

Future research needed

There are some key issues, which need to be addressed for future researches are as follows.

- The future approach should be based on the delineation of soil factors in relation to yield with the help of available information along with sustaining the soil fertility and health. This will also lead to the delineation of suitable soil areas free from soil constraints for establishing future pomegranate industries in potential areas with prolonged orchard life.

- Soil map showing agro-climatic zones of the potential areas for further expansion of pomegranate cultivation should be prepared with the help of available information.
- The computerized yield forecasting models capable of predicting the total fruit production should be prepared by using the data on the latest leaf nutrient status of pomegranate orchards.
- New models should be developed through nutrient diagnostic techniques capable of detecting early stages of deficiency.

Such an attempt would not only save the current season crop but simultaneously safeguard the future nutritional security of the orchard.