INTEGRATED NUTRIENT MANAGEMENT: KEY TO SUSTAINABLE QUALITY POMEGRANATE PRODUCTION

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INTRODUCTION

Pomegranate (*Punica granatum* L.) has gained tremendous impetus during recent past in dry lands and semi-arid tropics of India and around the globe due to its sustained profitability, versatile adaptability, export potential and nutraceutical properties. It is also referred as strategic crop in ensuring sustainable livelihood in climatically and edaphically challenged regions with limited irrigation resources. The health promoting benefits of this 'Super Fruit' has led to steep rise in demand and accelerated expansion of pomegranate cultivation around the globe. Further, magical therapeutic values and increasing demand for table and processed products in local and export markets have made pomegranate a popular fruit of tropical and sub-tropical regions in the recent time. It is widely cultivated in India, China, Iran, Israel, USA, Turkey, Spain, Tunisia, Morocco, Greece, Italy and South Africa. In present scenario, pomegranate cultivation provides livelihood to about 0.25 million farm families mostly in dry regions of India. India is the global leader in pomegranate acreage and production with around 2.83 lakh ha and production of 31.86 Lakh MT out of estimated global area of 5.6 lakh ha. and production of 63.0 Lakh MT. Although India is the largest producer of pomegranate, yet its export share in world trade of pomegranate is just 22.21% in comparison to China (30.34%) and Iran (26.21%) with respectively 57.6% and 73.50% less area under pomegranate cultivation than India.

There are many factors, including climate, soil, irrigation, varieties, pruning, insects, and tree nutrition which influence the growth and quality fruit production. Some of these factors can be controlled by growers; others cannot. Tree nutrition is probably the most important factor for a successful orchard operation as it can have significant influence on the post-harvest quality of the fruit, in particular its size, shape, shelf life and susceptibility to diseases and pests. It is a well-known fact that selection of proper soils is of paramount importance in the success or failure of a pomegranate crop. Soil properties viz. texture, structure, pH, EC, organic carbon and depth play important role in successful pomegranate cultivation. Though pomegranate can be cultivated on varied soil and climatic conditions, medium to deep and well-drained soil with pH ranges of 6.5 to 7.8 is considered ideal. The soil pH above or below this range is known to limit the availability of some nutrient elements and thus inhibit growth and development of plant. Since pomegranate is perennial crop, favorable rhizospheric environment and proper understanding of the phenology of the crop is essential to efficient nutrient management. Before going to the orchard management aspect, it is prerequisite to know the importance of nutrients on influencing various attributes of pomegranate tree.

Function of nutrients in pomegranate

There are numerous publications on the function of mineral nutrients in fruit trees, which deal mainly with growth and physiological aspects. Today, mineral nutrition has to be considered more in relation to aspects of fruit quality rather than to yield. Fruits are regarded as healthy food and thus fertilization of pomegranate trees is not only a means of increasing productivity of the plant, but also of promoting the formation of valuable components within the fruit.

Nitrogen (N) is the driving force for vegetative and generative development of the tree. Besides its promoting effects on shoot growth, N is absolutely necessary for flower bud formation, fruit set and fruit development. Nitrogen promotes the development of the ripening fruit Nitrate as an N source has been shown to be more effective than NH_4 or urea in maintaining a physiologically adequate level of Ca in fruits.

Phosphorus (P) is mostly related to flowering and fruiting as well as to the energy metabolism of the tree. Phosphorus promotes yield by increasing the number of flowers, fruit set and fruit size. A beneficial effect of P on fruit quality parameters such as fruit firmness and skin colour has also been shown.

Potassium (K) is the second most important nutrient for pomegranate trees in terms of requirement. Potassium participates in numerous enzymatic reactions and is an important factor in the development of fruit colour, TSS and vitamin C content. K is the key nutrient in osmoregulation and the maintenance of cell turgor and therefore closely related to firmness of the fruit.

Calcium (Ca) unlike K is the typical structural nutrient element in the tree and the fruit. Calcium forms bonds in the middle lamellae and the micro-fibrils of the fruit tissue, and is therefore crucial for fruit firmness. Ca has also an important function in maintenance of cell membrane integrity.

Magnesium (Mg) function as the central atom of the chlorophyll molecule in the plant however, its role in growth and development of pomegranate trees is often underestimated. More than 60% of Mg is located elsewhere in the cell and is involved in numerous metabolic reactions. In terms of fruit quality, Mg improves fruit size and colour, increases sugar content and promotes the formation of aroma compounds and acidity.

Sulphur (S) is essential for protein synthesis and for the formation of aromatic compounds in the fruit. S containing substances can either enhance the plant's tolerance to diseases or act as repellents to pests.

The significance of micronutrients in fruit quality has not been evaluated in detail. However, most of the physiological processes depend on the action of iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and boron (B), which are involved in numerous enzymatic reactions. Micronutrient deficiencies appear mainly on soils with a high pH, where their availability is very low. Deficient trees develop characteristic leaf symptoms.

Iron (Fe) is an abundant element in soils, mostly present in unavailable form (oxidized form Fe^{3+}). The element is closely linked to CO_2-assimilation in the leaf with 80% of total Fe in plants being localized in the chloroplasts. In addition to that, Fe is an activator of many biochemical processes such as regulation of oxidation/reduction pathways. The mobility of Fe in the tree is very low, as is also true of Zn, therefore young leaves and shoots show typical deficiency symptoms.

Manganese (Mn) is also involved in CO_2-assimilation and respiratory pathways. The element plays a crucial role in N-assimilation and Mg uptake. It activates enzymes and regulates membrane permeability. Manganese improves fruit size and also fruit yield attributes.

Zinc (Zn) is one of the most deficient micronutrients in many calcareous or alkaline soils. The element has been found to be essential for fruit set of trees. It has a strong influence on elongation growth.

Copper (Cu) is of crucial importance for growth related processes such as in meristematic tissues as well as in xylem development.

Boron (B) imparts beneficial effect on fruit set and yield which is in accord with physiological evidence of a high requirement of B during the reproductive phase of growth. B inhibits post- harvest disorders and increases both uptake and deficiency of Ca. Recent studies have pointed out the role of B in alleviating water deficiency stress in plants. B deficiency impairs Ca transport in trees and may lead to Ca deficiency in fruits. B is the microelement which is most strongly connected to fruit quality.

Assessment of nutrient status of orchard

Plant tissue test

Leaf tissues testing are very important for guiding fertilizer application in pomegranate orchard. The right time for leaf tissues testing is 3-4 months before imposition of stress in newly established non-bearing orchard and immediately after harvest of previous crop in bearing orchard. About 20-30 leaves should be drawn from 7-8th pair leaves in all sides of a plant selected randomly and total 500 leaves should be collected from 20-30 such randomly selected plants for 1 ha orchard area, so that it represents the orchard. The leaf samples so collected should be sent immediately for analysis to a recognized laboratory in order to know the nutrient status of pomegranate orchard.

Table 1.The optimum leaf nutrient norms for getting higher productivity is given below-

Nutrients	Optimum range
Nitrogen (%)	1.32-2.15
Phosphorus (%)	0.18-0.24
Potassium (%)	1.29-1.99
Calcium (%)	0.64-1.20
Magnesium (%)	0.23-0.45
Sulphur (%)	0.16-0.26
Iron (mg kg^{-1})	103.04-149.12
Manganese (mg kg^{-1})	39.60-72.85
Zinc (mg kg^{-1})	15.99-26.10
Copper (mg kg^{-1})	6.16-9.32
Boron (mg kg^{-1})	23.38-39.88

Fertilizer application in pomegranate is planned based on leaf tissues test reports. As general thumb rule, if the test value falls within the optimum range, recommended fertilizer dose (RFD) i.e. N: 625 g/plant, P_2O_5: 250 g/plant and K_2O: 500 g/plant are required to be applied for the crop season. If the test value is lower than the optimum range, N-P_2O_5-K_2O fertilizer quantities are required to be increased by 25% of RFD while, if the test value is higher than the optimum range, N-P_2O_5-K_2O fertilizer quantities are required to be reduced by 25% of RFD. For perennial crop like pomegranate, leaf tissues test report-based fertilizer application is more appropriate than soil test report.

Table 2. Recommended nutrient dose for pomegranate

Age of tree (Year)	FYM (kg / tree)	N (g / tree)	P_2O_5 (g / tree)	K_2O (g / tree)
1	10	250	125	125
2	20	250	125	125
3	30	500	125	500
4 and above	40	625	250	500

Application of organic manures

These are very important class of nutrient sources for most of the fruit crops and a key component of integrated nutrient management. Organic manures improve soil physical properties, tilth, water holding capacity and microbial population in addition to providing essential plant macro and micro-nutrients. Of course, these organic manures should be well decomposed. Nutrients in organic form in the manure are first converted to mineral forms in the soil before plant root can use them. Among organic manures, green manures, farmyard manures, poultry manures, vermin-compost, bonemeal, biogas slurry and de-oiled cake etc. are important for pomegranate production. Well decomposed poultry manures are good source of major and micronutrients and can be applied @ 10-15 kg per plant for good growth and fruiting. The nutrient content of various organic manures are given below.

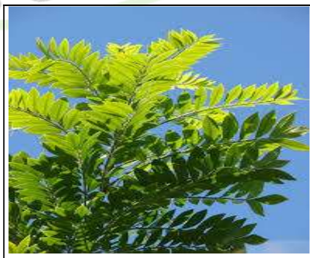
Table 3. Nutrient content of various organic manures

Organic manures	Nutrient content (%)		
	N	P_2O_5	K_2O
Farmyard manure	1.0	0.6	1.2
Vermi-compost	1.0	1.0	1.0
Phospho-compost	0.8	3.5	1.0
Poultry manure	2.2	2.0	4.2
Bone meal (steamed)	1.5	25	-
Biogas slurry	1.4	0.7	0.8
Neem cake	5.2	1.1	1.5
Groundnut cake	7.0	1.7	1.3
Castor cake	4.4	1.8	1.4
Green manures			
Sesbania aculeata	4.0	0.4	4.8
Crotalaria juncea	1.9	0.3	3.6
Green leaf manures			
Gliricidia sepium	2.8	0.3	4.6
Pongamia glabra	2.8	0.3	0.2

Green manures are plants (mostly N-fixing legumes) which are grown and then buried into the soil during rainy season to add organic matter (biomass) and nutrients present in them. Such manures can be either grown in the orchard between the plant rows [e.g. Dhaincha (*Sesbania aculeate),* Sunnhemp *(Crotalaria juncea)*] or green leaves from plants grown on the boundary of the orchard can be brought in and buried (e.g. Subabul). A good 60 days crop of Dhaincha can add 60-80 kg N plus other nutrients to the soil.

Sesbania aculeata

Crotalaria juncea



Gliricidia sepium

Pongamia glabra

Fig. 1. Photos showing promising green manure and green leaf manure crops

Application of bio-fertilizers

Bio-fertilizers are not traditional fertilizers in that they do not contain plant nutrient. Most bio-fertilizers are cultures of either bacteria or fungi which fix atmospheric N into ammoniacal form so that it can be used by plant or solubilize insoluble P and K or helps plant roots to gather more nutrients from bigger soil volume. While buying a bio-fertilizer, the growers should make sure the crop for which it is meant and the date of expiry printed on the packet.

Table 4. Important bio-fertilizers for pomegranate

Associative N_2 fixer-fix atmospheric N_2	*Azospirillum brasilense*
Phosphate solubilizer - Solubilize insoluble P and make them available to plant	*Bacillusmegaterium* *Pseudomonasstriata* *Aspergillusniger*
Potassium solubilizer- Solubilize insoluble K and make them available to plant	*Bacillus mucilaginosus* *Penicilliumpinophilum*
Fe solubilizer and growth promoter- Solubilize insoluble Fe in soil and also promote plant growth	*Pseudomonasfluorescens*
Arbuscular mycorrhizal fungi- Mobilize P and Zn in soil, protect plant root from the attack of soil borne pathogens and make plant tolerant to drought or moisture deficit	*Glomas* sp

Bio-fertilizers like associative N_2 fixer, *Azospirillum braselense*, phosphate solubilizer viz. *Bacillus megaterium*, *Pseudomonas striata*, *Aspergillus niger* etc., potassium solubilizer viz. *Bacillus mucilaginosus*, *Penicillium pinophylum*, Fe solubilizer and growth promoter viz. *Pseudomonas fluorescens* need to be applied two times during the crop season viz. one at after harvest of previous crop and another during release of stress period. Bio-fertilizers are required to be mixed with ground well decomposed FYM (1:25 ratio) and incubated for 21 days with 3 turnings at 7 days interval and maintaining moisture content at field capacity under shed. Apply the mixture of bio-fertilizer and FYM @ 2 kg per plant followed by mixing with the rhizospheric soil either 7-10 days prior to chemical fertilizer application or 7-10 days after chemical fertilizer application. Bio-fertilizer should not be mixed with any chemical fertilizers. Immediately after bio-fertilizer application light irrigation should be provided to the crop.

Fertilizer application

Nitrogen (N)

The entire tree root system is capable of nutrient absorption; however, the absorption rate is greatest in new root growth (root tips), which usually are white in color. The period of greatest nutrient uptake coincides with the period of maximum root growth. Depending on the year, this would be from about March to October. About 80% of the annual nitrogen use is from tree reserves, while only 20% is from the immediate nitrogen application. The later nitrogen is applied during the growing season, the less it is used in the year of application, the greater its contribution in the next year. Nitrogen used during bloom is drawn from the store, the tree has created from the previous year's application. In order to have good production, 45% of the recommended nitrogen dose (i.e. 280 g N/plant) should be applied during the post-harvest period to be stored and used early in the following season. The rest of the N is required to be applied in two splits, one during 0-60 days after full bloom (DAFB) and another during 115-180 DAFB in 1:3 ratio (i.e. 115 g N/plant during 0-60 DAFB and 345 g N/plant during 115-180 DAFB). Ammonium fertilizers are superior as compared to nitrate fertilizers in very slightly alkaline soils (pH 7.0-7.5) due to its side effect as soil acidifier through nitrification process. Following an application of ammoniacal-N or urea to the soil surface, the fertilizer should be moved into the soil profile through irrigation or mechanical incorporation in rainfall is not imminent. In order to minimize NH_3 losses from urea, additional practices like mixing urea with KCl, $CaCl_2$ or triple super phosphate and use of granular forms, urease inhibitors, sulfur and neem coated urea may be followed.

Phosphorus (P)

Phosphorus availability in calcareous soils is usually restricted owing to fixation in the soil. Maximum availability to plants of both native and applied P is in the pH range of 6.0 to 7.5. Consequently, P availability to plants is controlled by the application rate of soluble P fertilizers viz. triple super phosphate, mono or di-ammonium phosphate are the preferred source in calcareous soils. The main strategy of P fertilization is through the manipulation of its placement and timing, aiming to ensure sufficient quantities of soil solution Pat points of greatest root activity and at times of peak plant requirement. Application of P in bands instead of broadcasting and mixing with large soil volume and as large granules instead of a fine powder decreases the reversion to less soluble forms by reducing the contact between fertilizer and soil. In pomegranate grown on calcareous soil, 25% of recommended dose (i.e. 63 g P_2O_5/plant) of P should be applied during the post-harvest period and rest of the phosphorus should be applied in two splits in 1:2 ratio as like nitrogen (i.e. 63 g P_2O_5/plant during 0-60DAFB and 124 g P_2O_5/plant during 115-180 DAFB).In highly calcareous soil under drip irrigation, P may be applied in the form of single super phosphate as basal band fertilization combined with soluble P as KH_2PO_4 with the irrigation water.

Potassium (K) and Magnesium (Mg)

The status of available potassium and magnesium are usually found in an adequate supply in calcareous soils owing to native high levels of exchangeable K and Mg which are hardly leached in low rainfall regions. However, an imbalance between plant available Ca and K, Mg ions may lead to K and / or Mg deficiencies in plants. High Ca levels in soils generally suppress uptake of K and Mg by plants in part presumably through competition. Therefore, crops growing on soils high in Ca often require above recommended level of K and Mg fertilization for satisfactory nutrition. It is generally suggested to apply 40% of the recommended dose of K (i.e. 200 g K_2O/plant) during post-harvest period of previous crop and rest of the K to be applied in two split in 1: 2 ratio (i.e. 100 g K_2O/plant during 0-60 DAFB and another 200 g K_2O/plant during 115-180 DAFB) through soil incorporation as this nutrients will spread throughout the soil and be available for root uptake for several years. In alkaline soils readily soluble material like $MgSO_4$ are required. However, fertilizing with soluble Mg salts may not always be effective due to rapid formation of low soluble Mg salts such as magnesite ($MgCO_3$). In cases, where soil applied fertilizer is ineffective the only way to increase leaf K and Mg content may be through foliar application of water soluble fertilizers such as potassium nitrate (KNO_3) or magnesium nitrate [$Mg(NO_3)_2$]. A spray solution concentration of 25 g KNO_3 L^{-1} may be safely advocated to increase leaf K concentration, especially if application is made several times during the year. Higher concentrations should be avoided, since high salt levels may result in burning of leaf. The amount of N applied as foliar KNO_3 should be taken into account when determining annual N fertilization plans for pomegranate.

Calcium (Ca)

Pomegranate is Ca loving plant and most pomegranate growing areas are characterized by high free calcium carbonate content in the soil. In calcareous soil (having free $CaCO_3$ content > 5%) incorporation of well decamped organic manure in sufficient quantity (say 40-50 kg per plant) followed watering will serve the purpose of supplying Ca to the plant. Alternatively, farmers can apply in the localized rhizosphere elemental sulphur @ 20- 30 g per plant depending on the pH of the soil for mobilizing soil Ca into the plant. Gypsum (24 percent Ca) are used as source of Ca in alkaline soil after working out the gypsum requirement of the soil. Calcium should not be applied through foliar application as it is mainly translocated by the xylem. Sometimes boron deficiency may also lead to appearance of Ca deficiency in plant although soil is sufficient with bioavailable Ca.

Before onset of monsoon fertilizers and manures should be applied in trenches made around the canopy line (Fig.2a) but in other application fertilizers and manures should be put under the dripper (Fig. 2b) placed on canopy line.

(a) Trenches around canopy line (b) Under drippers placed on canopy line

Fig. 2: Method of applying fertilizers to the soil

Fertigation

The term "fertigation" means the application of fertilizers through irrigation water. In fruit production, fertigation usually refers to drip irrigation of trees including an injection system for liquid fertilizers. Modern fertigation systems enable the farmer to tailor nutrient supply to trees to their varying nutrient demand throughout the season. This is of great importance for N supply, but as well as that also for P, K, Ca and Mg which can easily be supplied via the irrigation system. Fertilizers used for drip irrigation systems must be highly soluble in water, since residues in the solution may block the pipes and emitters. Low nutrient doses given in several split applications (at 7 days interval) over the season, usually starting from fruit set until early fruit growth, have been proved to be more effective than a single application alone. The best fertilizer management practice involves soil application of solid fertilizers during the rest period followed by fertigation with water soluble fertilizers during the fruit growth and development period. The use of complete fertilizer solutions is the most convenient way of applying nutrients via the