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Soil and Nutritional Aspects in Pomegranate (*Punica granatum* L.)

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Abstract

Majority of the lands in arid and semi-arid tracks of India falls under land capability class v and above and thought of unsuitable for cultivation of normal crops. Introduction of hardy fruit crops like pomegranate (*Punica granatum* L.) brought revolutionary changes in cropping pattern and uplifted the economic condition of the farmers of the region. The paper reviewed the works pertaining to suitability of land for cultivation of pomegranate in the region. It is most hardy fruit crop suitable for shallow, rocky, degraded and even for polluted soils. Being highly tolerant to saline and alkali soil conditions, it performed better using hardy irrigation water. Besides, the paper deals with the nutrient management aspects such as soil and leaf nutrient standards, leaf sampling techniques, schedules of fertilizer application and integrated nutrient management practices including use of bio-agents. Finally the paper reveals strategy and prospects for further research in soil and nutrient management to enhance production and productivity of pomegranate in India.
Key words : Pomegranate, Arid, Semi-arid, Soil suitability, Plant nutrition and quality.

Among the minor fruits, pomegranate has attained the premier position in the recent years due to its wider adaptability in semi-arid and arid regions of India particularly in Maharashtra State. This is well known that selection of proper soils assumes a paramount importance in success or failure of the fruit crop. Similarly, effect of plant nutrition on quality fruit production has been recognized for quite some time. Earlier, not much attention was paid on quality parameters as more intense interest lies to produce higher yields. But in recent past, paradigm shift has been taken place from improved production to quality fruit production. It is especially true for pomegranate which is globally considered to be foreign exchange earning crop and assumes great significance in arid and semi-arid tracks of India. Its cultivation is spread in an area of 106.6 thousand ha in India, out of which 87% is concentrated in Solapur and Nasik districts of Maharashtra alone (1). Most of the pomegranate cultivation in this region is on very shallow (10—25 cm), light textured and rocky soils having low moisture and poor nutrient holding capacity (2). In view of these reasons, selection of suitable soils and balanced nutrient management schedules are prerequisites to harness higher fruit yields with required quality standards.

Performance Under Different Soil Types

Pomegranate, the most hardy fruit crop has potential to grow on variety of soils and can adapt in different climatic conditions. Looking into its potential, it is being promoted under watershed programs in arid and semi-arid regions of Maharashtra, Andhra Pradesh and Karnataka for quality production and export. Recently, cultivation of pomegranate under Employment Guarantee Scheme implemented on watershed basis greatly improved the standard of living and income of the villagers in Maharashtra. Its cultivation provided them more profit, enhanced their marketing ability and improved economic conditions (3). Based on large scale surveys in pomegranate growing regions of Solapur and Nasik district of Maharashtra it is confirmed that exportable quality fruits are produced from very shallow, gravelly and undulating lands (2). Similarly, in Uzbekistan, Saidaliev (4) reported best performance of pomegranate varieties even on gravelly soils of the Fergana Valley. Out of 46 varieties tested, Bala-Myursal, Kara-Bala-Myursal, Gyuleisha Azerbaidzhanskaya, Bashkalinskii, Al Shirin Nar, Kai-Achik-Anor,Shirin Nor and Kazake Anor performed well on these soils. Even performance of pomegranate was equally well on heavy black soils. Reddy et al. (5) informed that Jyothi, Ganesh and Raichur-I clones of pomegranate performed well under the Vertisols of Tungabhadra project area in Karnataka. It has also been reported that it can be grown successfully in oil polluted soils of Apsheron peninsula (Azerbaijan) by using different organic and inorganic (NPK, ash, manure) sources of nutrients and incorporation of clean soil. Interestingly, within 4 years the content of oil in the soil was significantly reduced as a result of redox reactions (6) and the soil became fit for sustainable production.

Performance and Management Under Saline-Alkali Conditions

At present majority of soils in arid and semi-arid conditions are available as waste lands with salinity and alkalinity problems, but has potential for pomegranate cultivation. Hardy irrigation water in these areas often exaggerates this problem. In the last 2—3 decades, several workers studied the performance of pomegranate under these conditions and the results were very encouraging. In Gujarat, it was found to be an ideal fruit crop for saline black soils having salinity up to 12 dS/m which otherwise lying barren or allowing some hardy species and coarse grasses to grow (7). However there are reports that it can be cultivated in the soils of salt content up to 0.4% indicating scope to utilized such lands. Presence of salts such as NaCl, $Na_2 SO_4$ and $CaCl_2$ caused adverse effect in descending order on various growth parameters and Ca uptake (8) pomegranate and maximum tolerance levels of ESP (exchangeable sodium percent) for maximum plant height, number of leaves and stem diameter was found as 5.84, 1.14 and 4.38%, respectively (9), while it was 28.8 ESP in loamy soil of Uttar Pradesh for cv Dholka above which drastic reduction in plant growth attributes occurred (10). However, the effect was more harmful during metabolically active growth phase. Water table also plays role in increase or decrease of EC in soil. Highly significant and negative correlations between growth parameters and electrical conductivity (EC) of sandy loam soil with shallow water table depths was reported by Shashi Jain et al. (11). For EC values of 0—15 and 0—120 cm layers, similar results were obtained and hence performance of pomegranate may easily be established from the EC of the 0—15 cm layer and suitability of soil can also be predicted.

Salt tolerance also found to vary with the cultivars. Mridula cultivar of pomegranate showed better performance in respect of number of branches, canopy coverage and earliness to flowering as compared to Yerchud 1, Ganesh and GS 135 in sodic soil of Trichy, Tamil Nadu. Leaf Zn, K and P contents were also highest in this cultivar (12). Increase in soil salinity and sodicity levels adversely affected the N, K, P and Ca contents in the leaves, while the chloride, Mg and Na contents were increased. However, plant height, number of leaves, stem diameter, plant spread, leaf area, plant mortality, leaf chlorophyll content were decreased (13, 10). Interestingly, nitrate reductase activity in leaves were significantly increased under salt stress conditions. Moreover, salt treatments damaged the permeability of the membrane system even though the damage appeared slowly (14).

In arid and semi-arid conditions, poor quality of irrigation water is of serious concern and played important role in increasing soil hazards and limits the performance of pomegranate, though, it is comparatively more tolerant to saline and alkali conditions as compared to other arid and semi-arid fruit crops. The Khog cultivar of pomegranate survived well with irrigation water having EC values of 6.5 mmhos while cv Jallore seedless could tolerate salinity only up to 4.5 mmhos (15). Recently, decrease in water transpired by plants with increasing salinity levels has also been reported by Germana et al. (16) in pomegranate. Under these situations, they suggested to use saline water in combination with fresh or good quality water for irrigation. An attempt was made to utilize sea water for irrigation purpose and it was observed that 20% sea water mixed with good quality water can be safely used without making any harm to the pomegranate crop. Naeini et al. (17) reported that with increasing NaCl concentration in irrigation water, the amount of Na, Cl and K of the tissues increased, but amount of Ca, Mg and N of the tissues decreased in 3 commercial cultivars, Alak Torsh, Malas Torsh and Malas Shirin of pomegranate. However, there were no cultivar differences in the rate of uptake of the tested minerals. Interestingly, soluble sugars decreased as NaCl concentrations increased in irrigation water.

Doring and Ludders (18) studied the effect of different salts (NaCl, Na_2SO_4, $CaCl_2$, $MgCl_2$ or $MgSO_4$) at different concentrations (40, 60 or 80 meq/liter) on rooted pomegranate cuttings (cv Mytelinis) and found no change in dry weight of shoots while leaf and root dry weights were reduced by all salt treatments. There was accumulation of cations in all plant parts. With all rates, Na was concentrated mainly in the root tissue whereas the higher application rates of Ca and Mg resulted in high leaf rather than root concentrations of these minerals. They, further observed lowest chlorophyll contents and rate of photosynthesis. At all salt concentrations, the amount of reducing sugars increased in the leaves but decreased in the roots, while with non-reducing sugars the opposite effect occurred, which was due to the salts affecting enzyme activities involved with carbohydrate metabolism. Interestingly, the translocation of sugars from the leaves to roots was unaffected by the treatments. A salt-induced inhibition of sucrose and starch catabolism in the roots reduced the supply of monosaccharides (19).

Under arid hot climatic conditions of India, saline alkali soils occur on large scale. Several pomegranate orchards already exist on these soils and need to be managed by adopting suitable methods. It was observed that seedlings were more tolerant than grafts and their tolerance increased with age because of root penetration into deeper and less hostile layers (20). He advocated various management practices as replacement of saline-sodic soil with normal soil in trenches and pits, provision of 20 cm thick layer of gravel at the bottom of trenches, frequent irrigation and mulching with alfalfa to maintain a negative salt balance. Secondary salinization in these treatments during subsequent years was prevented by adding small amounts of waste sulfuric acid and iron sulfate. Some reports are available that pomegranate cannot tolerate water stagnation.Under highly alkali soil (pH > 10) condition in Kurukshetra district of Haryana, Dagar et al. (21) suggested raised and sunken bed technique to overcome water stagnation problem. The crop was successfully grown on raised bunds while rice-wheat and berseem-kallar grass rotation were grown on sunken-beds constructed for the purpose. After two years of experimentation, there was significant reduction in soil pH due to its well-developed lateral root system. Further attempts were also made in management of saline alkali soils by Singh et al. (22) who tried sulphitation cane filter cake (SCFC) to minimize the ill effects of alkalinity (pH 10.0) in pomegranate and proved much superior in increasing growth and biomass of pomegranate than gypsum and pyrites. Increased concentration of P, K, Ca, Mg and S in the harvested biomass, decreased soil pH, large increase in soil EC, organic carbon, available P and K were recorded in SCFC treatments.

Nutritional Aspects

Balance nutrition is important, both for young, growing and grown up productive trees. However, a bearing tree requires balanced nutrient application for maintaining vegetative growth and sustaining fruit production. Apart from fruits, considerable amount of major and micro-nutrients are removed from soil following annual pruning of shoots. There is report that harvesting of 30 t fruits of pomegranates cv Ganesh resulted in the removal of 33.6 kg N, 6 kg P, 52.2 Kg k, 13.6 kg Ca, 1.98 kg Mg and 4.38 kg S while micronutrients removal was 55 g Fe, 28.5 g Mn, 78 g Zn and 38.8 g Cu (23). Hence, the application of manures and fertilizers in a required dose is of paramount importance for sustaining the regular productivity of fruit crops. Survey of pomegranate orchards in Bijapur district of northern Karnataka, revealed that optimum NPK concentrations in leaves were 0.91—1.66, 0.12—0.18 and 0.61—1.59%, respectively. Similarly, optimum (available) NPK concentrations in soils having pH 8.1—8.6 were 44—103, 10—20 and 73—115 mg/kg, respectively. Under optimum concentration of nutrients supply, yields of 15.5—18.8 t/ha were recorded in pomegranate (24). Therefore, interpretation of this type of data is prerequisite to develop nutrient standards for the region. Now a days Diagnosis and Recommendation Integrated System (DRIS) Compositional Nutrient Diagnosis (CND) indices are commonly used for recommendations of nutrients. Using these indices Raghupathi and Bhargava (25) found that yields of pomegranate were limited by more than 2 or 3 nutrients as it is mainly grown on marginal soils with low fertility. They observed highly significant positive correlation between DRIS and CND indices. Three principal components explained 59.5% of the variation in the high yielding population : (N+S+Zn+Fe–Mn–) ; (N+P+Ca+Zn–) ; and (K–S+). CND is recommended for diagnosis of nutrient disorders as it expands the DRIS concept from bi-dimensional to multidimensional space and recognizes high-order interactions among nutrients while requiring less computational effort.

Leaf Sampling and Seasonal Variation in Nutrients Content

Foliar or leaf analysis came into widespread use not only as an aid in confirming the visual symptomology but as an effective method of detecting the trend towards nutritional deficiencies or sufficiency. The leaf nutrient contents found to vary with season and growth of the plant. Leaf N and carbohydrate contents of Banati pomegranate leaves decreased gradually during both growing seasons (26). Concentrations of major nutrients as N, P and K decreased with increasing leaf age whereas Ca concentration increased ; Mg, S, Mn, Zn and Cu increased slightly with leaf age, and Fe increased initially and then decreased (27). Munde et al. (28) reported that N was high in medium aged leaves, K in young leaves, Ca increases with age while highest content of Fe was in old leaves. Other parameters such as percentage of total sugars showed inconsistent fluctuations during a period of 2 years. The starch content decreased from May to August and then increased to the end of the season in both years (26). The leaf nutrient content also varied with the cultivars. Data on leaf nutrient content of 15 different cultivar revealed that P and Mg levels did not show significant differences among the cultivars. The N content was similar in eight cultivars, but it was significantly higher than in the remaining seven cultivars. The highest K content was found in Banipur Selection (2.18%) and the lowest in Shirine Anar (1.51%). Interestingly, Ca was highest in Bedana Sedana (2.71%) and lowest in Nabha (1.96%) as reported by Yamdagni et al. (29). Results on similar line were also noted by Gimenez et al. (30) where amounts of N, P, K, Ca, Mn, Zn, B and Na in the leaves of 2 pomegranate cultivars Mollar (local) and an Israeli cultivar differed significantly. Correlation studies between these nutrients and yield of Mollar cultivar showed negative correlation with K, Ca and B contents, but positively correlated with Fe content. In the Israeli cultivar, yield was negatively correlated with P, K and Mn contents. Thus it was observed that the success of foliar analysis as diagnostic tool largely depends on sampling of representative index tissue and proper period of sampling. The most suitable age for leaf sampling is identified as the period during minimum fluctuation in concentration of nutrient occurs. This is the period where most favorable and reproducible response of fertilizer application can be obtained. The period of such stability in leaf nutrient composition is designated as leaf sampling period which varies with agro-climatic conditions, species, rootstock, soil type and other cultural practices including mineralogical composition of soil. Munde et al. (28) advocated seven-month-old leaves for diagnosing N, P, K, Ca and Mg ; four-month-old for Fe and Zn and 11-month-old for Mn in Ganesh cultivar of pomegranate, while for Bassein Seedless cultivar, the best time of sampling for the February crop was April and for the June crop it was August of the previous year. The eighth leaf pair from the growing tip was the best for sampling (27). Fertilizer recommendations have to be based on foliar analysis, the advantages of which can only be obtained when it is supported by leaf nutrient standards. Shende (31) suggested optimum leaf nutrient content as 2.56% N, 0.194% P, and 1.47% K for Ganesh cultivar. While for Muskat cultivar, satisfactory range of leaf nutrient contents was 1.57 to 2.42% N, 0.13 to 0.39% P, 1.25 to 2.24% K, 19 to 49 ppm B and 146 to 227 ppm Zn (32). Placement of fertilizers is equally important as its incorporation directly in the active root-zone resulted in higher fertilizer use efficiency. It is reported that in Ganesh cultivar grown on red soils, spatially maximum density of roots were closest to the trunk and soil surface (55.67—57.74% at 0—25 cm depth and radial distance). Air-layers confined 98% of roots up to 50 cm depth while seedlings extended root systems as deep as 100 cm (33).

Effect of Nutrition on Yield and Quality

Availability of all three major nutrients N, P and K are essential for satisfactory root growth (34), higher photosynthesis rates (35) and highest yield with best fruit quality (36). In absence of any of these major nutrient elements sharp drop takes place in the performance of pomegranate plants. In Arabi pomegranates, increasing NPK rates resulted in increased leaf N, P, K and Mg contents and decreased Mn and Zn, while Ca and Fe showed inconsistent trends (37). With regard to type of fertilizer, horticultural crops like pomegranate respond better to sulfate of potash as compared to muriate of potash (38). Application of potassium chloride and potassium sulfate, both at 0.5, 1.0, 1.5, and 2.0%, from bud to harvesting stage at 15-day intervals increased leaf K level and fruit quality (39). Results of a large numbers of experiments on manures and fertilizers conducted countrywide showed that neither the chemical fertilizers alone nor the organic sources exclusively have been able to achieve the production sustainability of a soil and crop. While integrated supply of organics, in-organics along with microbial inoculations were highly beneficial. Padmavathamma and Hulamani (40) reported significant increase in spread and yield of pomegranate cv Jyoti and RCR-1 with the combined application of FYM and inorganic fertilizers. Application of 10 kg FYM/plant alone or in combination with N : P : K, poultry manure 5 kg/plant and bone meal 1 kg with N : P : K were the effective treatments to boost up the all around growth of pomegranate plants (41). Several researchers from different parts of the India suggested various nutrient doses under varied climatic conditions for different cultivars as 40 kg FYM and 3.5 kg cake or 1.0 to 1.25 kg sulfate of ammonia (42) ; 50 kg FYM + 375 g N + 375 g P + 375 g K for Dholka cultivar under Gujrat conditions (43) ; 250 g N + 125 g P + 125 g K for 2 year old plant grown in Rahuri, Maharashtra (44) ; 120 kg N + 90 kg P + 60 kg K per ha for Kzyr anar (36) ; 240 kg N + 160 kg P + 60 kg K per ha for Jodhpur Red cultivar of Rajasthan (45) ; 50 g N + 200 g P + 100 g K for Yarchud areas of Karnataka (46) ; 500 kg N + 250 kg P + 125 kg K per ha for 3-year old Maskat cultivar grown in Rahuri, Maharashtra (47) ; 625 g N + 250 g P + 250 g K per plant for 5 to 7 years plant grown in Hisar areas of Haryana (48).

Application of inadequate or excessive quantity of fertilizers specially micronutrients affect the yield and quality of fruit crops. Earlier, Patil et al. (49) reported increase in the yield of pomegranate with foliar application of Macroliq (0.33%) two times. Foliar sprays of each of $ZnSO_4$ (0.25 to 0.30%), $FeSO_4$ (0.25 to 0.40%), $MnSO_4$ (0.30%) and 0.15% boric acid alone or in various combination significantly increased the fruit yield of pomegranate (50, 51). Individual spray of boric acid effectively decreased the fruit cracking problems in pomegranate. In arid regions of Rajasthan, pomegranate cv Jalore Seedless with the spraying of 0.2% boron caused least cracking which in turn produced the highest yield (52). Further spraying of 0.2, 0.4 or 0.6% $ZnSO_4$, H_3BO_3, NAA and 2, 4-D application resulted in lower mean percentage of mature, premature and total fruit cracking as compared to the control. Recently, Khatri et al. (53) reported that spraying with 2, 4-D (10 ppm) minimized percent premature cracking (5.2), mature cracking (3.0) and total fruit cracking (8.3).

The effect of nutrition on quality of the produce has been recognized for quite some time. An improvement in fruit quality consequent with production is highly imperative to pin point the nutrients which may possibly affect the development of quality fruits. It was reported that rising N rates increased fruit weight , juice, percent seed and rind percentages (54), pH and acidity of the juice, sugar percentage (55) but decreased TSS, TSS : Acid ratio and ascorbic acid content. P significantly increased rind percentage and juice acidity but lowered the TSS : Acid ratio. Increased TSS and pH with K application (45) while decreased TSS : Acid ratio was reported by Sen and Chauhan (54). Application of potassium chloride and potassium sulfate from bud to harvesting stage at 15-day intervals increased number of fruits per tree, reducing, non-reducing and total soluble sugars, and ascorbic acid content (39). Soil application of 12.5 g B and 45 g Zn/ tree per year enhanced sugar content in pomegranate fruits. Similarly, combined application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and boric acid increased juice content from 65.6 to 74.8% (32). Increase in TSS (17.35^0Brix) was also obtained by application of $ZnSO_4$ (0.4%) combined with 0.2% boric acid (51). Spraying of 0.3% $MnSO_4$ produced the fruit having average weight and volume (50).

Biofertilizers, which plays important role in pomegranate production, are the preparations containing microorganisms in sufficient numbers helping plant growth and nutrition. They are widely accepted as low cost supplements to chemical fertilizers and have no deleterious effects either on soil health or environment. Inoculation of cuttings with various microorganisms was helpful to increase rooting and survival percentage. Microorganism *Trichoderma harzianum* gave best results compared to *Azospirillum lipoferum, Azospirillum brasilense* and *Azotobacter sp.* (56). Soil inoculation with pure cell suspensions of *Azospirillum brasilense* strains S14, S51 or S54 or *Azotobacter chroococcum* increased plant height and dry weight in rooted cuttings of pomegranate cv Jalore seedless grown in pots. *A. brasilense* strain S54 had the greatest effect on plant dry weight. In both cases this was correlated with a marked increase in N uptake (57). They suggested that growth enhancement could be due to the production of growth regulators and N fixation, as the rhizosphere of inoculated plants carried higher populations of *A. brasilense* than that of the uninoculated controls. Rupnawar and Navale (58) revealed that mycorrhizal (*Glomus epigaeum* [*G. versiforme*], *Glomus mosseae* and *Gigaspora calospora* strains) treatments were superior to non-mycorrhizal treatments. Mixture of these three strains was superior to their individual application and recorded the highest values for root colonization and N and P uptake. It also recorded the maximum height, root length, number of leaves, dry weight of shoot and root mycorrhizal dependency percentage (59). Thus application of such beneficial microbial cultures will minimize the dependency on chemical fertilizers could be beneficial in pomegranate for sustainable production.

Perspective Considerations

The reviewed works as mentioned earlier call for more research with improved scientific understanding. Some key issues to be addressed are : 1. Emphasis should be laid on quantification of soil factors in relation to yield with the help of available information in thresholds of soil physical, chemical properties along with fertility and soil health. This will lead to delineation of suitable soil areas free from soil related constraints to establish soil constraints free future pomegranate industry in potential areas with prolonged orchard life. Soil map superimposed with agro-climatic zones, showing the potential areas for further expansion of pomegranate cultivation will be highly beneficial. 2. Development of computerized yield forecasting models capable of predicting the total fruit production using the data on latest leaf nutrient status of pomegranate orchards would aid in contentment and ultimate control of pomegranate decline through an integrated approach of soil, water, and nutrition management. 3. Efforts should be made to develop better nutrient diagnostic technique(s) capable of detecting early stages of deficiency. The role of chemical markers holds a good promise since the physiological role of nutrient elements are established at genetic level. Such an attempt would not only save the current season crop but simultaneously safeguard the nutritional security of the orchard. 4. Efficient micro-irrigation systems along with distribution of nutrient and water in rhizosphere in right quantum of irrigation based on requirement at critical growth stages has to be laid as top priority in irrigation water management research. This can later be exploited for automated fertigation research in relation to changes in soil health and orchard life on long term basis. 5. Considering the medicinal importance of pomegranate fruits and plant parts as a whole, more rational approach to organic cultivation and production including use of green manure crops, various organics to restore soil organic carbon status, synchronization of nutrient release pattern based on plant requirement, use and prolonged shelf life of biofertilizers and microbial cultures should be practically implemented.

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