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Nutrient Management in Subtropical Fruit Production: A Review

Rakesh Sharma[1], Anil Kumar[1], Swapana Sepehya[1], Renu Kapoor[2]

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ABSTRACT

Nutrient management in the subtropical fruit production is very important for obtaining high quality fruits. It involves using crop nutrients as efficiently as possible to improve productivity while protecting the environment. The key principle behind nutrient management is balancing soil nutrient inputs with crop requirements. A well-nourished fruit plant not only produces good yield but also improves quality and remains for longer period in healthy and productive condition. This plan will lay out how nutrients are managed according to land base characteristics, crops being grown, type of nutrient, proximity to water and application methods. Records of nutrient application rates, methods and timing help with future planning. Thus, proper nutrient management helps the plants to meet their nutrient requirement and to restore the fertility of the soil.

Key words: Fertilizers, Fertigation, Integrated nutrient management, Organic manures, Subtropical fruit production.

Fruits are a very important part of human diet. At present, India is the second largest producer of fruits in the world, after China. India has a large range of varieties of fruits in its basket and accounts for 13 per cent of world's total fruit production. The country is a home to wide variety of fruits due to its various agro-climatic conditions. India's diverse climate ensures availability of all varieties of fresh fruits and vegetables. As per National Horticulture Database Estimate published by National Horticulture Board, India produced 99.07 million metric tonnes of fruits from 6.66 million hectares of land during 2019-20. Of these, tropical and subtropical fruits contribute a major share and the important fruits are mango, banana, papaya, citrus, guava, pineapple, litchi, sapota and pomegranate. Amongst fruits, the country ranks first in production of bananas (25.7%), papayas (43.6%) and mangoes (40.4%).

In the 21st century, nutrient efficient plants will play a major role in increasing crop yields compared to the 20st century, mainly due to limited land and water resources available for crop production, higher cost of inorganic fertilizer inputs, declining trends in crop yields globally and increasing environmental concerns. Furthermore, at least 60% of the world's arable lands have mineral deficiencies or elemental toxicity problems and on such soils fertilizers and lime amendments are essential for achieving improved crop yields (Pathak and Nedwell, 2001).

The perennial nature of woody framework (nutrients locked therein), extended physiological stages of growth, differential root distribution pattern (root volume distribution), growth stages from the point of view of nutrient requirement and preferential requirement of some nutrients by specific fruit crop, collectively make fruit crops nutritionally more efficient than annual crops (Srivastava and Singh, 2008). Nutrient management is the science and art directed to link soil, crop, weather and hydrologic factors with cultural, irrigation and soil and water conservation practices to achieve the goals of optimizing nutrient use efficiency, yields, crop quality and economic returns, while reducing off-site transport of nutrients that may impact the environment. Nutrient management, particularly in horticultural crops, is the skillful task of matching a specific field, soil, climate and crop management conditions to rate, source, timing and place of nutrient application (Mikkelsen, 2011).

[1]Department of Soil Science and Water Management, College of Horticulture and Forestry, Dr. YS Parmar University of Horticulture and Forestry, Neri, Hamirpur- 177 001, Himachal Pradesh, India.
[1]Regional Horticultural Research and Training Station, Jachh, Nurpur-176 202, Himachal Pradesh, India.

Corresponding Author: Swapana Sepehya, Department of Soil Science and Water Management, College of Horticulture and Forestry, Dr. YS Parmar University of Horticulture and Forestry, Neri, Hamirpur- 177 001, Himachal Pradesh, India.
Email: swapanasep@gmail.com

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Description of subtropical zone of Himachal Pradesh

Himachal Pradesh is a land of mountains with altitudes ranging from 350 meters to 6,975 meters above the mean sea level. It is located between Latitude 30° 22′ 40″ to 33°12′ 20″ N and Longitude 75° 45′ 55″ to 79° 04′ 20″E. It extends over a geographical area of 55, 673 sq kms, which is 1.69 per cent of the India's area and 10.54 per cent of the Himalayan landmass. It has a deeply dissected topography, complex geological structure and a rich temperate flora in the sub-tropical latitudes. Physiographically, the state can be divided into five zones *viz.* (i) Wet Sub-temperate zone,

(ii) Humid Sub-temperate zone (iii) Dry temperate-alpine High lands (iv) Humid Sub-tropical zone and (v) Sub-Humid Sub-tropical zone.

The sub-tropical zone consists of foothills and valleys from 365 to 914 meters above mean sea level. Overall climate is hot and comparatively dry, whereas, the winters are less cold. Rainfall varies widely from low to high (60-100 cm/annum). It occupies about 35% of the geographical area and about 40% of the cultivated area of the State. The major crops grown in this zone are Wheat, Maize, Paddy, Gram, Sugarcane, Mustard, Potato, Vegetables *etc*. Fruits grown in sub-tropical region are citrus (Sweet orange, mandarin, grapefruit, lime, lemon), litchi, guava, phalsa, fig, pomegranate, avocado *etc*. Tropical fruits like mango and banana can also be grown in this zone, whereas, the low chilling varieties of peach, pear, plum and almond of temperate zones can also be grown in sub-mountainous tracts of the sub-tropical zone.

Citrus, litchi, guava and mango are the major fruit crops grown in subtropical zone of Himachal Pradesh. At present, in Himachal Pradesh area (Ha) under citrus, mango, litchi and guava is 24869, 42248, 6028 and 2344 ha, respectively with production of 29344, 43540, 5467 and 3012 thousand MT, respectively.

Importance of nutrient management in horticultural crops

Nutrient management involves using crop nutrients as efficiently as possible to improve productivity while protecting the environment. The key principle behind nutrient management is balancing soil nutrient inputs with crop requirements. When applied in proper quantities and at the right times, added nutrients help achieve optimum crop yields; applying too little will limit yield and applying too much does not make economic sense and can harm the environment. Nutrients that are not effectively utilized by crops can potentially leach into groundwater or enter nearby surface waters. Too much nitrogen or phosphorus for example can impair water quality.

A major focus of nutrient management planning is to prevent the over-application of nutrients to protect water quality and minimize impact on the environment while still providing optimum yield for economic benefit. It involves accounting for and recording all the nutrients you have, determining what nutrients you will need and planning how, how much, when and where to apply them to your crop land. This involves first determining what nutrients are in the soil (soil-testing) and what's available in a growing or harvested crop and then determining what has to be added to meet the needs of crops. This plan will lay out how nutrients are managed according to soil characteristics, crops being grown, type of nutrient, proximity to water and application methods. Records of nutrient application rates, methods and timing help with future planning.

Nutrient management practices involving use of organic, inorganic sources, integrated nutrient management and efficient method of fertilizer application through fertigation could prove very effective for achieving a cost effective and eco-friendly programme. This review paper attempts to summarize the progress made globally in research efforts conducted over the past years to different nutrient management practices.

Impact of fertilization

Improved crop nutrition aims at maintenance of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of various plant nutrients.

Xiuchong *et al.* (2001) observed that after following the recommended dose of 400 g N, 125 g P_2O_5, 320 g K_2O, 40 g Mg and 80 g S per plant per year, the profitable yields increased up to 15,200 kg mango ha^{-1}. Fruit weight, colour, fragrance and taste were also improved by balanced fertilization which included N, P, K, Mg and S achieved by applying urea, DAP (diammonium phosphate), MOP (muriate of potash) and SPM (potassium-magnesium sulfate). Jitendra and Maurya (2004) studied the effect of micronutrients on bearing mango and found that to improve yield and quality of mango fruits, application of micronutrients *viz.,* $ZnSO_4$ (0.4 per cent), $FeSO_4$ (0.4 per cent), $MnSO_4$ (0.2 per cent), H_3BO_4 (0.2 per cent) separately and in different combinations was effective. Four kg NPK/tree gave the maximum plant height and plant spread in guava (Khattak *et al.* 2005). While studying the effect of foliar application of some micronutrients and growth regulators on fruit drop, yield, fruit quality and leaf mineral content of Mesk mango, Ebeed *et al.* (2007) reported that the most effective method to increase the number of mango fruits per tree was by foliar application of the mineral nutrients. They also found that, in order to improve the weight and volume of the fruits, spraying with some micronutrients and growth substances (Fe, Zn, Mn, Fe+Mn, Fe+Zn, Mn+Zn, Fe+Zn+Mn, PP333 [paclobutrazol] at 300 ppm and NAA at 40 ppm) was effective. Omar and Belal (2007) found that the type and rate of fertilizer source affects mango fruit yield and that organic matter needs long time to decompose and therefore yield remained close to that obtained with inorganic fertilizers. Significant increases in plant height (0.32 m), plant spread (0.33 m) and trunk girth (1.10 cm) were observed with the application of NPK (900:600:900 g/tree) to guava (Baksh *et al.* 2008).

Kumar *et al.* (2009) evaluated the effects of nitrogen, phosphorus and potassium on the vegetative growth of guava cv. Allahabad Safeda and they reported that application of K increased the fruit yield and quality but K at 100 kg K_2O ha^{-1} was more effective in boosting the fruit weight and size, as well as peel thickness than other K rates in selected orchards. Juice volume and percentage significantly increased when K was applied at 75 kg K_2O ha^{-1}. They further revealed that all rates of K improved the fruit yield and quality and reduced fruit dropping, however, 75 kg K_2O ha^{-1} rate was more effective as juice volume and

percentage, total soluble solid (TSS)/acid ratio and nutrient uptake showed significant improvements. Ramniwas *et al.* (2012) reported a significantly improved plant height, stem diameter and canopy spread with the application of NPK (600:300:600 g/tree). Maximum fruit weight (162.43 g) was observed with the application of NPK (60:30:30 g/tree) as compared to control (150.25 g) in guava. For mango Sunderja, Gautam *et al.* (2012) found the lowest vegetative growth in the treatment with a full dose of NPK alone, but treatment with 500:250:250 g NPK per tree, 50 kg FYM and 10 kg vermicompost improved growth characteristics, including plant height, canopy height, tree volume *etc.*

While studying the effects of doses and splits of fertilizer application on harvesting time, yield and quality of Mango, Sarker and Rahim (2012) showed that an application of 150% of fertilizer in three splits gave highest yield (19.55 kg per plant) and also increased fruit quality. Nasreen *et al.* (2014) reported that variations in nutrient application led to variations in mango fruit quality measured as fruit weight, stone weight, TSS content, peel weight, fruit size and yield. The highest mango yield and gross margin were obtained under the treatment $N_{960}P_{200}K_{300}S_{110}$ g per tree which was statistically identical in yield with treatment $N_{760}P_{160}K_{250}S_{90}$ g per tree. It was concluded that application of treatment $N_{960}P_{200}K_{300}S_{110}$ plus 20 kg cow dung per tree was the most economically viable. While evaluating the effect of different potassium fertilizer forms on yield, fruit quality and leaf mineral content of Zebda Mango trees, Taha *et al.* (2014) found that soil application of various forms of potassium showed positive effect on yield, fruit physical and chemical properties. Yang *et al.* (2015) studied the annual dynamic changes in elemental contents of litchi leaves and the effects of potassium and nitrogen ratios (K_2O/N ratios: 0.6, 0.8, 1.0, 1.2 and 1.4) on the yield and planting benefits of litchi. Under the same N application conditions, the yield and planting benefits of litchi initially increased and then subsequently decreased with increasing K_2O/N ratio but had the highest yield and plant benefit occurred at the ratio of K_2O to N ranged from 1.0 to 1.2.

Kaur and Kaur (2017) reported that guava trees fertilized with recommended dose of NPK yielded fruits with improved fruit length (9.2 cm), breadth (8.72 cm), weight (222.43 g) and high organoleptic rating, excellent fruit colour and minimum fruit firmness (2.93 kg/cm^2). Fruits obtained from guava trees treated with recommended dose of inorganic fertilizers had the highest TSS (12.19%), reducing sugars (5.43%), total sugars (7.97%), nonreducing sugars (2.54%), ascorbic acid content (203.91 mg/100 g of Pulp) and minimum titratable acidity (0.54%). Hence, the inorganic fertilizers were most efficient in boosting the quality and yield of Sardar guava fruits. Gupta *et al.* (2018) reported that application of NPK significantly influenced the canopy volume, trunk girth, spread, canopy height, panicle length, yield of litchi and number of fruits per tree.

Impact of organic manuring

Micronutrients and secondary nutrients deficiencies might have been the yield limiting factors following continuous cropping and supplying of mineral fertilizers alone. However, this can be overcome by application of organic manures such as FYM, vermicompost, poultry manure, biogas slurry, bio-compost, press mud, oil cakes *etc.* The influence of manures is of long-term nature since it restores the sustainability of the soil-plant system.

Iyer (2004) found that during the transition period from conventional to organic farming there was a decline in the yield and higher risks of pest and disease attack. However, this was compensated by the higher price (15-25%) offered for organic mangoes in the major world markets. Use of green manure, augmenting biomass, preparing good enriched compost and adopting bio-control measures to manage pests and diseases help in maintaining good soil health with adequate production of crops that are safe and healthy. Kaur *et al.* (2007) showed that FYM @ 100 kg/litchi tree significantly increased tree spread, stem girth, panicle length and fruit yield (55.17 kg/tree) and reduced cracking of fruits. The differences were non-significant in case of tree height, duration of flowering, sex ratio and fruit cracking of litchi. Naik and Babu (2007) concluded that the application of vermicompost maximized the number of shoots per plant, number of leaves per shoot and yield of guava. Application of animal manures produced more fruits per shoot. Per cent fruit drop was nil with sheep, goat and leaf litter application, but was higher with vermi- compost and poultry manures. Heaviest fruits were borne under sheep and goat manures.

Goswami *et al.* (2012) observed that tree growth with application of NPK (225:195:150 g) + 50 kg FYM enriched with 250 g Azospirillum/tree/year was most effective for increasing tree height, plant spread and trunk diameter in guava. In Pantnagar, Uttarakhand, India Lal *et al.* (2012) found that the highest fruit weight (20.75 g) and fruit volume (19.62 ml) of litchi were obtained with the application of vermicompost (75%). Rani *et al.* (2013) reported that maximum fruit set, fruit retention, fruit yield and minimum fruit drop of litchi was observed with application of 150 kg FYM per tree while fruit cracking was minimum under vermin-compost @75 kg/tree. Kumar and Kumar (2014) observed the highest TSS, titrable acidity and ascorbic acid content of mango fruits with application of 75 kg vermicompost per tree and concluded that the application of different organic manures to mango trees was useful for improving the yield and quality characteristics of fruits.

A study by Makode (2015) on the effect of vermicompost on the growth of Indian orange showed that the application of 10 kg vermicompost per plant in the month of June (during basin preparation) significantly increased the fruit number, fruit weight and fruit yield of orange. Saha *et al.* (2015) determined the effects of farmyard manure on soil organic carbon stock, the pattern of fertility build-up and plant growth in 'Mallika' mango and found that the SOC contents increased significantly in the FYM-treated plots. The rate of

increase in SOC density was highest with FYM at 10 kg/plant and lowest in the untreated control. Regular addition of FYM had a positive effect on the build-up of soil fertility. However, the greatest increases in soil N, P, K contents were in the 7.5 kg/plant FYM treatment. Farmyard manure significantly influenced the growth parameters of mango trees over the three seasons. There was a positive linear relationship between increasing rates of application of FYM and trunk cross-sectional area.

While studying the effect of organic manures on growth, yield, quality and shelf life of "Dashehari" mango, Kumar *et al.* (2015) concluded that the application of different organic manures was useful for improving the growth, yield and quality characteristics of fruits. Ennab (2016) found significant differences amongst various growth attributes, fruit yield, fruit quality, leaf mineral content and soil nutrients availability following farmyard manure and biofertilizer applications. Treatment with 50% NPK + 55 kg farmyard manure + biofertilizers gave the best growth, yield, fruit quality and nutritional status of Eureka lemon trees. Sau *et al.* (2017) studied the influence of bio-fertilizer and liquid organic manures on growth, fruit quality and leaf mineral content of mango was studied by and found that different treatments of bio fertilizer along with panchagavya significantly increased the canopy spread, fruit weight, yield and bio-chemical qualities compared with chemical fertilizers and control plants. Kumar *et al.* (2018) suggested that the combined application of 75 kg each of vermicompost and poultry manure was most effective for enhancing quality characteristics of mango fruits. Malsawmkimi and Hazarika (2018) observed that integrated application of FYM + CPP + BD 500 + BD 501 (T6) resulted in maximum plant height, plant girth, canopy spread and canopy volume as well as superior fruit quality of Khasi mandarin. A study by Rosangpuii *et al.* (2019) showed that the application of vermicompost (5 kg/tree) + mustard oil cake (1 kg/tree) before flowering gave the best yield and quality.

Impact of integrated nutrient management

Integration of INM components is useful in many ways. The fertilizer equivalent of different INM components varied in different agro ecological regions based on crop response. However, it differs a lot since crop response varies with varying nutrient content of manures, management practices and agro-ecological regions. Thus, its application in huge quantity is not regular due to its unavailability and non-remunerative nature that calls for an appropriate integration of several organic components like biofertilizers, FYM, vermicompost *etc.* along with mineral fertilizers for getting the best results. According to Hazarika and Ansari (2007) biofertilizers are live formulation of beneficial micro-organism which are able to fix 20-200 kg N/ha/year, solubilize P in the range of 30-50 kg/ha/year, mobilizes P, Zn, Fe, Mo to varying extent by their biological activity and help to build up the lost microflora and in turn improve the soil health.

Dutta *et al.* (2010) reported that different combinations involving the use of organic nutrition to reduce the inorganic fertilizers had significant effect on yield, fruit quality and leaf mineral content of litchi. The treatment consisting of 50 kg/tree FYM + 150 g *Azotobacter* + 100 g VAM + 500 g N: 250 g P_2O_5: 500 g K_2O/tree/year through fertilizer showed maximum yield (98.72 kg/plant) and also have a significant improvement in terms of TSS, total sugars, ascorbic acid, TSS: acid ratio, fruit weight and fruit size. Rathore *et al.* (2013) reported maximum fruit set, fruit retention percentage and yield of litchi cv. Rose Scented was recorded with the treatment 500:250:250 g NPK/tree+50 kg FYM/tree enriched with VAM. Fruit quality in terms of TSS, acidity and total sugars were found significantly maximum with 500:250:250 g NPK/tree+50 kg FYM/tree+10 kg/tree vermicompost. Hasan *et al.* (2013) found that vermicompost application in combination with 850 g N+425 g P_2O_5 + 1000 g K_2O + 250 g *Azospirillum* + 250 g phosphate-solubilizing bacteria +100 g zinc sulfate + 100 g borax/tree/year appreciably increased fruit weight (273.20 g), fruit length (9.53 cm) pulp weight (180.20), pulp content (65.96%) of mango.

From an experiment Kumar (2014) reported that the treatments having biofertilizers (*Azospirillum, Azotobactor, Aspergillus, Trichoderma* and *Pseudomonas*) with chemical fertilizers and organic manures clearly indicated the possibility of reducing the dose of chemical fertilizers to the tune of 50%, with quality fruit production of litchi in an economically-viable mode. The combined use of biofertilizers, chemical fertilizers and organic manures showed the overall improvement in physico-chemical characteristics of the soil. Singh *et al.* (2016) studied the effects of organic manures (FYM, Vermicompost), inorganic fertilizers (NPK), bio fertilizers (Azotobacter and PSB) on nutrient uptake in mango cv. Amrapali under high density orcharding and found that the fruit yield tree^{-1} was significantly influenced by the application of different sources of nutrient, bio fertilizers and different dose of NPK in mango and maximum fruit yield tree^{-1} was recorded in treatment applied with 75% RDF+20 kg Vermicompost + 250 g Azotobacter + 250 g PSB plant^{-1}. From a field experiment of acid lime Nurbhanej *et al.* (2016) reported significantly highest values of yield attributing characters like fruit volume, fruit weight, fruit diameter and fruit yield per tree as well as quality attributing characters like total soluble solids and ascorbic acid content with the application of 75% RDF + Vermicompost 9 kg/tree + AAU PGPR Consortium 3.5 ml/tree.

While evaluating the effect of organic and inorganic fertilizers on nutrient dynamics and mango orchard productivity Kumar et al. (2017) observed a wide range of yield variation across the seasons and treatments. Addition of FYM improved sustainability index (0.58) while green manuring further improved it (0.66) as compared to control (0.43). A field experiment was carried out by Singh *et al.* (2017) to evaluate the response of organic manures (FYM, Vermicompost), inorganic fertilizers (NPK), biofertilizers (Azotobacter and PSB) on flowering, fruit yield and quality of mango cv. Amrapali under high density orcharding and showed that the maximum plant height (396.67 and 416.92 cm), plant spread (311.67 and 337.67 cm), number of

panicles per plant (98.00 and 240.00), was recorded with the application of 75% RDF + 40 kg Vermicompost + 250 g Azotobacter + 250 g PSB /plant.

Bhandari *et al.* (2018) studied the effect of organic and inorganic nutrient sources on growth, yield and quality of Acid lime (*Citrus aurantifolia* Swingle) and found that the application of 50% RDF + 7 kg vermicompost + 15 kg FYM + 150 g VAM + 25 g Azotobactor had been found the most appropriate for physical and yield characteristics of the acid lime fruit. Gogoi *et al.* (2018) revealed that application of 75% RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum,* (100 g/plant*)* + *Trichoderma harzianum* (100 g/ plant) were found effective in improving the yield, soil nutrient status and quality of Khasi mandarin with B:C ratio (4.75). The fruit obtained under this treatment was found significantly superior in quality as evident from highest juice content. Jamwal *et al.* (2018) conducted trial on three years old guava plants under Meadow orcharding cv. Allahabad safeda. The results revealed that the application of Azatobacter + (100% Nitrogen through urea) T11, significantly influence the physical parameters of guava, maximum increase in tree height (21.99%), canopy spread N-S direction (23.57%) and E-W (23.50%) were obtained with treatment T11. Whereas maximum number of fruits/ tree (21), Maximum average fruit weight (190.10 gm), Maximum fruit length (7.10 cm), Maximum fruit diameter (7.15 cm), Maximum fruit volume (192.13), Maximum fruit yield/tree (3.99Kg),Fruit yield/ha (199.58 q) has been obtained with treatment T14 (Azotobacter + 75% Nitrogen through urea + 25% Vermicompost). Prabhu *et al.* (2018) studied the effect of integrated nutrient management on acid lime [*Citrus aurantifolia*. Swingle (L.)] and concluded that application of 100 per cent recommended dose of fertilizers (600:200:300 g NPK plant^{-1} year^{-1}) + *Azospirillum* (100 g plant^{-1}) + phosphobacteria (100 g plant^{-1}) + Arbuscular Mycorrizhal Fungi (500 g plant^{-1}) + *Trichoderma harzianum* (100 g plant^{-1}) has showed a superior performance regarding yield, yield attributing components and quality attributes of acidlime. An investigation was carried out by Raghavan *et al.* (2018) to study integrated nutrient management in Litchi (Litchi chinensis Sonn.) cv. Muzaffarpur for yield and fruit quality. Results revealed that the imposition of different treatments had a significant effect on yield and fruit quality of litchi. Maximum number of fruits per tree (1281), fruit yield (30.01 kg/tree), total sugar (26.14%), reducing sugar (14.51%) was observed in 500 g N+250 g P+250 g K+100 kg FYM+150 g Azotobacter+100 g PSM+100 g VAM (T9). The control 1000 g N+500 g P+500 g K recorded maximum fruit cracking.

The soil application of 75% RDF + FYM 40 Kg /tree (T3) recorded maximum growth parameters (plant height, trunk girth, tree canopy spread, number of leaves per shoot, number of branches per shoot, length of selected shoot and diameter), reproductive parameters (number of flowers and fruits per plant and fruit set per cent)and yield of guava (Singh *et al.* 2018). The application of integrated nutrient management had significant effect on yield and quality of guava fruits in both rainy and winter season. The treatment T5, 75% RDF +10 kg FYM + Micronutrients (Zn+B+Mn - 0.5, 0.2, 0.1%), recorded maximum number of flowers, higher fruit diameter, maximum fruit length, more number of fruits, fruit volume, average fruit weight, fruits yield per plant and highest yield (Gupta *et al.,* 2019). An experiment was carried out by Kumari *et al.* (2020) to study the feasibility of integrated nutrient management for improving soil properties, nutrient availability, fruit yield and carbon stock in a mango (*Mangifera indica* L.) orchard under a subtropical condition. They revealed that the organic mulching with straw and conjoint application of farmyard manure and vermicompost improved nutrient availability, microbial activeness (29-44%) and carbon stock (~40%) in soil at 0-60 cm soil depth which ultimately improves fruit yield (26-34%).

Impact of fertigation

Fertigation has the greatest potential for the efficient use of water and fertilizers. Fertigation allows nutrient placement directly into the plant root zone during critical periods in the required dose and also minimizes the losses of nutrients through leaching. By introducing drip fertigation, it is possible to increase the yield potential of fruit crops. Fertigation gives advantages such as higher use efficiency of water and fertilizer, minimum loss of N due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost (Solaimalai *et al.,* 2005). According to Sathya *et al.* (2008), frequent application of nutrients through drip system improves the uptake of nutrients through two main mechanisms: i) continuous replenishment of nutrients in the depletion zone at the vicinity of root interface; and ii) enhanced transport of dissolved nutrients by mass flow, due to the higher averaged water content in the medium.

Shirgure *et al.* (1999) studied the effect of nitrogen fertigation on vegetative growth and leaf nutrient content of acid lime (*Citrus aurantifolia*, Swingle) in Central India. They observed that the percentage increase in plant height, plant girth and canopy volume was maximum with 100 per cent N fertigation (31.0%, 52.3% and 48.26%) followed by with 80 per cent N fertigation (30.0%, 49.2% and 46.9%), respectively. While studying the effect on mango fruit yield and quality improvement through fertigation along with mulch, Panwar *et al.* (2007) found that the application of I_1F_1 treatment *i.e.* drip irrigation at 'V' level with mulch + full dose of fertilizer through fertigation resulted in maximum fruit yield. They also found that there was increase in nutrient status of leaves when fertigation was done with or without the use of mulch with regard to nitrogen, phosphorous and potassium. A study was carried out by Singh *et al.* (2008) to study the response of micro irrigation (bubbler + over canopy micro sprinkler) and fertigation on water requirement, fruit yield and fruit cracking of 'Rose Scented' litchi. Bubbler irrigation at 100% estimated water requirement and 125% of fertilizer recommended for conventional system recorded maximum fruit retention (13.88 / panicle), fruit weight (25.6 g) and fruit yield (191 kg/plant) along with yield increase of 70% over conventional irrigation and fertilizer application. Singh

et al. (2009) assessed the response of fertigation and plastic mulch on growth characteristics of young 'Dashehari' mango and found that there was significant increase in the growth characters like average scion height, scion girth, canopy diameter, canopy volume, shoot length and leaf area with drip irrigation as compared to conventional method but there was no increase in average rootstock girth. Yaseen and Ahmad (2010) revealed that NPK fertilizers application on drip line in combination with foliar spray was helpful to improve production of quality citrus (kinnow) fruits up to 63%. Yadav *et al.* (2011) reported that fertigation significantly improved yield and quality characters of litchi. Maximum fruit retention, yield and minimum fruit drop was recorded in treatment ID_2F_2 (Drip discharge at 0.75 V + 125% recommended doses of fertilizers). Fruit cracking was reduced by different levels of fertigation and minimum fruit cracking (5.08%) was recorded under treatment ID_1F_3 (1.0 V drip discharge + 137.50% recommended doses of fertilizers).

Ramniwas *et al.* (2012) evaluated the effect of irrigation and fertigation scheduling on growth and yield of guava (*Psidium guajava* L.). The investigation indicated that 75% irrigation of irrigation water/cumulative pan evaporation resulted in maximum plant spread east west-north south (1.91 to 1.79 m), fruit yield/plant (5.87 kg) with benefit: cost ratio of 2.62. Use of 60, 30 and 30 g NPK/plant/year produced maximum leaf area (63.39 cm^2), fruit weight (162.43 g) and fruit yield/plant (6.01 kg). Sharma *et al.* (2013) revealed that maximum fruit yield and water productivity was demonstrated under drip irrigation at 100% with 120% of recommended dose of N. Alternatively, surface irrigation scheduled at IW/ CPE 1.0 could also be used advantageously if the initial investment for laying the drip irrigation system is likely to be an impediment to the resource poor farmers for guava cultivation. Karuna *et al.* (2017) carried out study on the effect of fertigation on physico-chemical attributes and nutrient status in *Citrus reticulata* Blanco cv. Kinnow. The results showed significant difference in respect to weight (184.33 g), length (63.51 mm), width (75.70 mm), juice per cent (49.23%), total soluble solids (10.21° Brix), ascorbic acid (50.29 mg/100 g), total sugar (7.62%) and yield (32.07 t/ ha.) with higher dose of fertigation *i.e.* 100% and 120% RDF. Rao *et al.* (2017) indicated that the maximum plant height, periphery of rootstock, yield per plant (kg/plant) and yield (t/ha) of guava were higher under D1F1 (100% irrigation with 100% fertigation) followed by D2F1 (80% irrigation with 100% fertigation) and minimum under D3F2 (60% irrigation with 75% fertigation). Interaction effect was non-significant at 0.05 % level due to plant height (3.90 m) and periphery of rootstock (26.26 cm) but significantly influenced by yield per plant (27.65 kg/plant) and yield (7.65 t/ha). From an experiment Sudharshan *et al.* (2017) showed that optimum dose of fertigation (85%) is necessary for higher yields, improving fruit quality with saving of fertilizers in Nagpur Mandarin crop. To study the effect of fertigation on vegetative growth, yield and quality of mango cv. Pant sinduri, Devi (2018) concluded that treatment consisting of application of 100 per cent recommended dose of fertilizer *via* fertigation registered maximum fruit set percentage (16.59 per cent), fruit retention percentage (2.87 per cent) and yield (67.76 kg/tree). Moreover, other physical and chemical parameters of fruits were also registered maximum under this treatment.

CONCLUSION

From the foregoing review it can be concluded that judicial use of inorganic inputs with organic and also integrated nutrient management is beneficial to achieve the goals of optimizing nutrient use efficiency, yields, crop quality and economic returns. Further, yield returns may also be increased by using efficient method of fertilizer application through fertigation. The above nutrient management studies would find their worth only when backed up with sound methodologies of nutrient constraints diagnosis. Thus, proper nutrient management plan is a tool that farmers can use to increase the efficiency of all the nutrient sources to match nutrient application and availability to crop needs and ultimately increasing yield returns.

Conflict of interest

I on behalf of all the authors of the manuscript certify that there is no actual or potential conflict of interest in relation to this article.

REFERENCES

Antonio, N.P., Martinez, A.R., Roman, A.E.B., Contreras, D.J., Perez, A.L.D. (2014). Response to organic fertilization in mango cultivars: Manila, Tommy Atkins and Ataulfo. Journal of Soil Science and Plant Nutrition. 14: 688-700.

Baksh, H., Yadav, R., Dwivedi, R. (2008). Effect of INM on growth, yield, yield attributing characters and quality of guava (*Psidium guajava* L.) Cv. Sardar. Progressive Agriculture. 8(2): 141-144.

Bhandari, J., Kanpure, R.N., Singh, O.P., Kachouli, B. Patidar, D.K. (2018). Effect of organic and inorganic nutrient sources on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle). International Journal of Chemical Studies. 6(1): 1635-1639.

Devi, P. (2018). Effect of fertigation on vegetative growth, yield and quality of mango cv. Pant sinduri. M.Sc. Thesis. Department of Horticulture, G.B Pant University of Agriculture and Technology. Pantnagar.

Dutta, P., Kundu, S., Biswas, S. (2010). Integrated nutrient management in litchi cv Bombai in new alluvial zone of West Bengal. Indian Journal of Horticulture. 67(2): 181-184.

Ebeed, S., El-Gazzar, A., Bedier, R. (2007). Effect of foliar application of some micronutrients and growth regulators on fruit drop, yield, fruit quality and leaf mineral content of Mesk mango cv. trees. Annals of Agricultural Science Moshtohor. 39(2): 1279-1296.

Ennab, H.A. (2016). Effect of organic manures, biofertilizers and NPK on vegetative growth, yield, fruit quality and soil fertility of Eureka lemon trees [*Citrus limon* (L.) Burm]. Journal of Soil Sciences and Agricultural Engineering. 7(10): 767-774.

Gautam, U.S., Singh, R., Tiwari, N., Gurjar, P.S., Kumar, A. (2012). Effect of integrated nutrient management in mango cv. Sunderja. Indian Journal of Horticulture. 69(2): 151-155.

Gogoi, A, Barbora, A.C., Kakoti, R.K., Bhattacharya, D., Dutta, S., Medhi, B., Saikia, J. (2018). Effect of integrated nutrient management on growth, yield, quality and nutrient content of Khasi Mandarin (*Citrus reticulata*) in acidic soil of Assam, India. International Journal of Current Microbiology and Applied Sciences. 7(9): 1675-1680.

Goswami, A.K., Lal, S., Misra, K.K. (2012). Integrated nutrient management improves growth and leaf nutrient status of guava cv. Pant Prabhat. Indian Journal of Horticulture. 69(2): 168-172.

Gupta, K., Singh, P., Pandey, S.D., Pandey, A.K. (2018). Effects of graded levels of NPK on growth, flowering and yield attributing characters of shahi litchi (*Litchi chinensis* Sonn.). International Journal of Chemical Studies. 6(3): 250-254.

Gupta, P., Singh, D., Prasad, V.M., Kumar, V. (2019). Integrated nutrient management on yield and quality of guava (*Psidium guajava* L.) cv. Allahabad Safeda under high density planting. The Pharma Innovation Journal. 8(1): 320-323.

Hasan, M.A., Manna, M., Dutta, P., Bhattacharaya, K., Mandal, S., Banerjee, H., Ray, S.K., Jha, S. (2013). Integrated nutrient management in improving fruit quality of mango 'Himsagar'. Acta Horticulturae. 992: 167-172.

Hazarika, B.N. and Ansari, S. (2007). Biofertilizers in fruit crops– A Review. Agricultural Reviews. 28: 69-74.

Iyer, C.P.A. (2004). Growing mango under organic system. Acta Horticulturae. 645: 71-84.

Jamwal, S., Mishra, S., Singh, S. (2018). Effect of integrated nutrient management on physical characteristics of guava under meadow orcharding cv. Allahabad Safeda. Journal of Pharmacognosy and Phytochemistry. 7(1): 2076-2079.

Jitendra, S. and Maurya, A.N. (2004). Effect of micronutrients on bearing of mango (*Mangifera indica*) cv. Mallika. Progressive Agriculture. 4(1): 47-50.

Karuna, K., Mankar, A., Nirgude, V., Patel, V.B., Sinha, R. (2017). Effects of NPK fertigation on physico-chemical attributes and leaf nutrient status of *Citrus reticulata* Blanco cv. Kinnow. Chemical Science Review and Letters. 6(23): 1583-1586.

Kaur, H. and Kaur, G. (2017). Effect of inorganic and organic fertilizers on fruit quality and yield attributes in guava cv. Sardar. International Journal of Advance Research. 5(12): 1346-1351.

Kaur, B., Lal, R.L., Misra, K.K. (2007). Effect of organic manure on growth and yield of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. Progressive Horticulture, 39(1): 28-31.

Khattak, M.R., Abdul, L., Ahmad, B., Muhammad, W. (2005). Effect of different levels of nitrogen, phosphorus and potassium on growth and yield of guava. Sarhad Journal of Agriculture. 21(2): 185-187.

Kumar, D., Pandey, V., Anjaneyulu, K., Nath, V. (2009). Optimization of major nutrient for guava yield and quality under east coastal condition. Indian Journal of Horticulture. 66(1): 18-21.

Kumar, M. and Kumar, R. (2014). Response of organic manures on post-harvest quality of mango (*Mangifera indica* L.) cv. Dashehari. Agricultural Science Digest. 34: 310-312. doi: 10.5958/0976-0547.2014.01028.3.

Kumar, M., Rajkumar, Singh, R., Kumar, L. (2018). Effect of organic manures on physical and chemical characteristics of mango cv. Dashehari at ambient storage conditions. International Journal of Current Microbiology and Applied Sciences. 7: 31-39.

Kumar, M., Singh, C.P., Dhami, V. (2015). Response of organic manures on growth, yield, quality and shelf life of "Dashehari" mango (*Mangifera indica* L.). Acta Horticulturae. 1066: 117-22.

Kumar, R. (2014). Effect of INM on litchi (*Litchi chinensis*) for enhancing quality fruit production. Current Horticulture. 2(2): 58-62.

Kumar, K., Singh, A.T., Kumar, V. (2017). Green manuring and nutrient management impacting soil properties and sustainability of mango orchard. Journal of Soil and Water Conservation. 16(1): 72-78.

Kumari, R., Kundu, M., Das, A., Rakshit, R., Sahay, S., Sengupta, S., Ahmad, M.F. (2020). Long-term integrated nutrient management improves carbon stock and fruit yield in a subtropical mango (*Mangifera indica* L.) orchard. Journal of Soil Science and Plant Nutrition. 20: 725-737.

Lal, R.L., Mishra, D.S., Rathore, N., Chand, S. (2012). Effect of organic manures on fruit yield and quality of litchi cv. Rose Scented. Pantnagar Journal of Research. 10(2): 256-258.

Makode, P.M. (2015). Effect of vermicompost on the growth of Indian orange, *Citrus reticulatus* with reference to its quality and quantity. Bioscience Biotechnology Research Communications. 8(2): 217-220.

Malsawmkimi and Hazarika, T.K. (2018). Influence of organic manures and bio-dynamic preparations on growth, yield and quality of Khasi Mandarin (*Citrus reticulata* Blanco) in Mizoram, North-East India. Indian Journal of Agricultural Research. 52(5): 576-580.

Mikkelsen, R.L. (2011). The "4R" nutrient stewardship framework for horticulture. Horticultural Technology. 21: 658-662.

Naik, M.H. and Babu, R.S.H. (2007). Feasibility of organic farming in guava (*Psidium guajava* L). Acta Horticulturae. 735: 365-372.

Nasreen, S., Kamal, A.M., Siddiky, M.A., Rannu, R.P., Islam, M.S. (2014). Effect of nitrogen, phosphorus, potassium and sulphur on the yield of mango. Bangladesh Journal of Agricultural Research. 39(4): 631-640.

Nurbhanej, K.H., Patel, M. J., Barot, H.R., Thakkar, R.M., Gadhavi, A.V. (2016). Effect of integrated nutrient management (INM) on growth, yield and quality of acid lime (*Citrus aurantifolia* swingle) cv. Kagzi. International Journal of Agriculture Sciences. 8(51): 2360-2363.

Omar, A.E.K. and Belal, E.B.A. (2007). Effect of organic, inorganic and bio-fertilizer application on fruit yield and quality of mango trees [*Mangifera indica* (L.) cv. Sukari] in Balteem, Kafr El- Sheikh, Egypt. Journal of Agriculture Research. 33: 857-72.

Panwar, R., Singh, S.K., Singh, C.P., Singh, P.K. (2007). Mango fruit yield and quality improvement through fertigation along with mulch. Indian Journal of Agricultural Sciences. 77(10): 48-52.

Pathak, H. and Nedwell, D.B. (2001). Strategies to reduce nitrous oxide emissions from soil with fertilizer selection and nitrification inhibitor. Water, Air Soil Pollution. 129: 217-228.

Prabhu, M.S., Parthiban, A., Kumar, R.B., Rani, U., Vijayasamundeeswari, A. (2018). Effect of integrated nutrient management on acidlime [*Citrus aurantifolia*. Swingle (L.)]. Indian Journal of Agricultural Research. 52(3): 290-294. doi: 10.18805/IJARe.A-4978.

Raghavan, M, Hazarika, B.N., Das, S., Md., Ramjan., Longing, B.L. (2018). Integrated nutrient management in litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur for yield and fruit quality at foothills of Arunachal Pradesh. International Journal of Chemical Studies. 6(3): 2809-2812.

Ramniwas, Kaushik, R.A., Sarolia, D.K., Pareek, S., Singh, V. (2012). Effect of irrigation and fertigation scheduling on growth and yield of guava (*Psidium guajava* L.) under meadow orcharding. African Journal of Agricultural Research. 7(47): 6350-6356.

Rani, A., Lal, R.L., Uniyal, S., Chand, S. (2013). Response of organic manures on growth, nutrient status and yield of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. Progressive Horticulture. 45(1): 126-131.

Rao, K.R., Gangwar, S., Bajpai, A., Chourasiya, L., Soni, K. (2017). Influence of growth, yield and quality of guava (*Psidium guajava* L.) by drip irrigation and fertigation. Journal of Applied and Natural Science. 9(1): 642-645.

Rathore, N., Mishra, N.K., Lal, R.L., Mishra, D.S. (2013). Effect of integrated nutrient management on yield and quality of litchi cv. Rose Scented. Pantnagar Journal of Research. 11(3): 369-372.

Rosangpuii, P., Singh, B., Lalnunpuia, J., Lalthamawii, (2019). Effect of organic manures on growth, yield and quality of Assam lemon [*Citrus limon* (L.) Burm.]. International Journal of Current Microbiology and Applied Sciences. 8(9): 1009-1019.

Saha, R., Nath, V., Kumar, D. (2015). Effects of farmyard manure on soil organic carbon stock, the pattern of fertility build-up and plant growth in 'Mallika' mango (*Mangifera indica L.*). The Journal of Horticultural Science and Biotechnology. 85: 539-543.

Sarker, B.C. and Rahim, M.A. (2012). Effects of doses and splits of fertilizer application on harvesting time, yield and quality of Mango cv. Amrapali. Bangladesh Journal of Agricultural Research. 37(2): 279-293.

Sathya, S., James Pitachi, G., Indirani, R., Kannathasan, M. (2008). Effect of fertigation on availability of nutrient (N, P and K) in soil - A review. Agricultural Reviews. 29(3): 214-219.

Sau, S., Mandal, P., Sarkar, T., Das, K., Datta, P. (2017). Influence of bio-fertilizer and liquid organic manures on growth, fruit quality and leaf mineral content of mango cv. Himsagar. Journal of Crop and Weed. 13: 132-136.

Sharma, S., Kumar, S., Patra, G., Roy, B., Bera, S. (2013). Influence of drip irrigation and nitrogen fertigation on yield and water productivity of guava. The bioscan. 8(3): 783-786.

Shirgure, P.S., Lallan, R., Marathe, R.A., Yadav, R.P. (1999). Effect of nitrogen fertigation on growth and leaf nutrient content of acid lime (*Citrus aurantifolia,* Swingle) in Central India. Indian Journal of Soil Conservation. 27(1): 45-49.

Singh, J.P, Chaudhary, M., Tomar, S., Shukla, I.N. (2018). Assess the effect of integrated nutrient management on growth and yield parameters of Guava cv. L-49. International Journal of Chemical Studies. 6(3): 676-680.

Singh, P. K., Lal, R.L., Singh, N., Singh, J.P. (2008). Effect of micro irrigation and fertigation on yield and fruit cracking of litchi (*Litchi chinensis*) in tarai condition of Uttarakhand. Indian Journal of Agricultural Sciences. 78(12): 1075-1077.

Singh, S.K., Singh, C.P., Panwar, R. (2009). Response of fertigation and plastic mulch on growth characteristics of young 'Dashehari' mango. Indian Journal of Horticulture. 66(3): 390-392.

Singh, Y., Prakash, S., Prakash, O., Kumar, D. (2017). Effect of integrated nutrient management on fruit yield and quality of Amrapali Mango (*Mangifera indica* L.) under high density planting. International Journal of Pure and Applied Bioscience. 5(3): 67-73.

Singh, Y., Prakash, S., Singh, S., Kumar, D., Prakash, O. (2016). Effect of integrated nutrient management on nutrient uptake in Amrapali mango (*Mangifera indica* L.) under high density planting. Journal of Soils and Crops. 26(2): 193-198.

Solaimalai, A., Baskar, M., Sadasakthf, A., Subburamu, K. (2005). Fertigation in high value crops- A review. Agricultural Reviews. 26: 1-13.

Srivastava, A.K. and Singh, S. (2008). Citrus nutrition research in India: Problems and prospects. Indian Journal of Agricultural Science. 78: 3-16.

Sudharshan, G., Pimpale, A., Kharche, V. (2017). Effect of fertigation on growth, yield and quality of Nagpur Mandarin. Bulletin of Environment, Pharmacology and Life Sciences. 6(1): 172-176.

Taha, R.A., Hassan, H.S.A., Shaaban, E.A. (2014). Effect of different potassium fertilizer forms on yield, fruit quality and leaf mineral content of Zebda mango trees. Middle-East Journal of Scientific Research. 21(3): 518-524.

Xiuchong, Z., Guojian, L., Shaoying, A., Lixian, Y. (2001). Balanced fertilization on mango in southern China. Better Crops International. 15(2): 16-20.

Yadav, P., Lal, R.L., Pandey, C. (2011). Effect of different levels of fertigation on yield, quality and leaf nutrient status of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. Progressive Horticulture. 43(2): 276-280.

Yang, B.M., Yao, L.X., Li, G.L., He, Z.H., Zhou, C.M. (2015). Dynamic changes of nutrition in litchi foliar and effects of potassium-nitrogen fertilization ratio. Journal of Soil Science and Plant Nutrition. 15(1): 98-110.

Yaseen, M. and Ahmad, M. (2010). Nutrition management in citrus: Effect of multinutrients foliar feeding on the yield of kinnow at different locations. Pakistan Journal of Botany. 42(3): 1863-1870.