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Integrated nutrient management for subtropical fruit production: A review

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Abstract
Nutrient management in the fruit production is very important for obtaining high quality fruit. Excess supply of the inorganic nutrient sources, i.e., fertilizers not only harm the fruit quality and its efficiency, but also depletes the nutrient reserves in the soil. However, INM is a system which helps in the maintenance of soil health. Integrated nutrient management (INM) is the combined application of all the nutrient sources, namely organic and inorganic in the crop production. Thus, INM helps the plants to meet their nutrient requirement and to restore the fertility of the soil.

Keywords: Integrated nutrient management, subtropical fruit production, soil health

Introduction
Fruits are very important part of human diet. At present, India is the second largest producer of fruits in the world after China. The country ranks first in the production of banana (25.7%), papaya (43.6%) and mango (40.4%) (Gnanavel *et al.* 2019) [1]. India has a large variety of fruits in its basket and accounts for 13 per cent of world's total fruit production (Bhairwa *et al.* 2012) [2]. The country is a home to a wide variety of fruits due to its varying agro-climatic conditions. India's diverse climate ensures availability of all types of fresh fruits & vegetables all year round. As per the National Horticulture Database published by National Horticulture Board, during 2015-16, 90.2 million metric tonnes of fruits were produced India in an area of 6.3 million hectares. Out of these, tropical and subtropical fruits such as mango, banana, papaya, citrus, guava, pineapple, litchi, sapota and pomegranate contribute a major share.
Even though the total production of fruits in the country is high, still there exists a wide gap between the demand and supply of fruits. The present fruit production in India meets only the 46% of the total demand (Dolker *et al.* 2017) [3]. Thus, there is a great need to increase the production and productivity of fruit crops. The continuous and excessive use of inorganic fertilizers as source of nutrients in imbalanced proportion to increase the fruit production has created serious problems, causing economic inefficiency, damage to the environment and in certain situations, even harm the plants and also the human beings who consume them. On the other hand, a large amount of nutrients have to be supplied to the plants to meet their requirement for increasing the production. Without proper nutrient management, continuous production of crops declines nutrient reserves in the soil. Another great concern is the sustainability of soil productivity, as the land is intensively exhausted to achieve higher yields. Over the time, cumulative nutrient depletion decreases the soil fertility and production and eventually leads to soil degradation. High cost of inorganic fertilizers is another reason to reconsider their excessive use. Poor purchasing capacity and negative effect of chemical fertilizers on soil health has led to intensified attempts for the use of bio-fertilizers and organic matter beside inorganic fertilizers. These all factors have sparked the interest of farmers in adopting the Integrated Nutrient Management for production of fruit crops.

What is INM?
Integrated Nutrient Management (INM) is a system that helps to restore and sustain crop productivity (Meena *et al.* 2013) [4], and also assists in checking the emerging micro-nutrient deficiencies. Furthermore, it brings economy and efficiency in the use of fertilizers.

Integrated plant nutrient management can also be referred for the maintenance of soil fertility and plant nutrient supply to optimum level for sustaining the crop productivity through optimization of the benefits from all plant nutrients sources in an integrated manner. Adoption of INM practices by use of bio fertilizer, FYM, vermicompost, organic mulch etc. is a utilitarian approach to enrich the soil, increasing its organic matter content that will reduce soil degradation and improve the soil physical, chemical and biological properties (Kheyrodin and Antoun 2011) [5].

Components of INM in sub-tropical fruit production

1. **Mineral Fertilizers:** These are the inorganic chemicals which supply one or more plant nutrient. These are of 3 types:
   - **Straight fertilizers:** Those which supply only one primary nutrient namely nitrogen, phosphorous or potassium. E.g. - muriate of potash, single super phosphate, etc.
   - **Complex fertilizers:** Those which two or three primary nutrients of which two primary nutrients are in chemical combination. E.g. – ammonium phosphate, diammonium phosphate, etc.
   - **Mixed fertilizers:** These are physical mixture of straight fertilizers. They contain two or three primary nutrients in definite proportions. E.g. – 19:19:19, 12:32:16, etc.
2. **Organic manures:** These are the products resulting from biological decomposition of organic matter. They can be obtained from plant or animal waste products. They are of two types:
   - **Bulky organic manures:** They contain a small percentage of nutrients and need to be applied in large quantities. E.g. – FYM, compost, poultry manure, sheep manure, green manures, etc.
   - **Concentrated organic manures:** They have relatively higher nutrient content than bulky organic manures. E.g. – Oil cake, blood meal, etc.
3. **Crop residue:** It is the material left after harvesting of crop and by-products of agriculture-based industries. E.g. – stalks, leaves, stems, bagasse, etc. These can be used for preparing compost.
4. **Crop rotation:** It is an important practice in sustaining nutrient supply. Different crops are grown in succession on a piece of land to avoid exhausting the soil. E.g. – Banana may be rotated with paddy, sugarcane, pulses, vegetables, etc.
5. **Bio-fertilizers:** These are preparations containing living or latent cells of efficient strains of microorganisms that increase the uptake of nutrients by crop plants by their interactions in the rhizosphere. E.g. – nitrogen fixing bio-fertilizers like *Rhizobium*, *Azotobacte*r, *Azolla*, etc. and phosphate solubilizing bio-fertilizers like *Bacillus*, *Aspergillus*, *Pseudomonas*, etc.

Importance of INM in Sub-tropical Fruit Production

Balanced Soil Nutrition

Many research findings have shown that crop productivity cannot be improved by organic sources or inorganic sources alone (Biramo 2018) [6]. Balanced supply of the organic and inorganic nutrient sources to the soil is very important for the higher production and better quality of fruits. Long-term experiments have demonstrated that organic manures in addition to fertilizers can sustain high crop yields over a long period of time as compared to fertilizers alone (Prasad 2008) [7]. Various components of INM not only provide the nutrients to the soil but also increased availability of the native nutrients of the soil. INM ensures the balanced supply of the organic and inorganic nutrient sources to sustain the crop productivity. Imbalanced fertilizer application can create several problems in the fruit production like, high nitrogen availability leads to excessive vegetative growth which leads to delay in maturity. The exchange of nutrients in or out from the soil is called nutrient cycle (Smaling, 1993) [8]. It includes 'inputs' which refers to the addition of plant nutrients to the soil and 'outputs' which refers to their export from the soil in the form of agricultural products (Dolker *et al.,* 2017) [9]. From their study, Srivastava *et al.* (2019) [10] reported that available N, P, K and DTPA extractable micro-nutrients were high under INM-based treatments.

Improve productivity and quality

The results from the findings of Kumar and Ray (2018) [11] showed that the application of FYM @ 12.0 t ha^{-1} + poultry manure @ 600 kg ha^{-1} + Neem cake @ 460 kg ha^{-1} + vermicompost @ 1120 kg ha^{-1} and addition of fallen leaves at 0.5 t leaf litter ha^{-1} can result in higher litchi production than use of chemical fertilizers only. Dwivedi (2013) [12] reported that integrated use of NPK along with FYM, vermicompost and mulching gave higher yield by 8-12 percent as compared to control in guava. A study conducted by Bakshi *et al.,* 2017 [13] revealed that there was substantial improvement in leaf and fruit nutrient status of Kinnow mandarin through integrated nutrient management system comprising inorganic fertilizers, vermicompost and *Azotobacter*.

Mditshwa *et al.* (2017) [14] stated that physiochemical and nutritional quality such as vitamins, phenolics and antioxidants are higher in organically produced fruits. Kumar *et al.* (2017) [15] conducted an experiment and concluded that green manuring and FYM application in low fertility mango orchard soils had positive impact on soil quality and sustainable fruit production. Kour *et al.* (2019) [16] reported the beneficial effect of application of 25 per cent N through FYM and 75 per cent N per tree through urea along with Azotobacter @ 200 g per tree for increasing leaf and fruit nutrient status of Aonla. Integrated application of NPK fertilizers with FYM, Azotobacter and VAM resulted in increased total fruit yield, reducing, non-reducing and total sugar content and reduced titratable acidity in litchi over application of NPK fertilizers alone (Raghavan *et al.* 2018) [17].

Sustaining Soil Health

INM plays a vital role in sustaining the fertility of the soil. The combined application of the nutrient sources sustains the physical, chemical and biological functioning of the soil and further helps in enhancing the fruit quality and its productivity. FYM application not only adds different nutrients in to the soil but also helps in enhancing the water holding capacity of the soil (Biramo, 2018) [6]. The addition of NPK fertilizers along with organic manure, lime and biofertilizers also influences the soil physical properties i.e., increased soil organic carbon, water stable aggregates, moisture-retention capacity and infiltration rate of the soil while reducing bulk density (Saha *et al.* 2010) [18]. The combined use of bio-fertilizers and nitrogenous fertilizers improve the soil health and augments the fertilizer use efficiency (Vishwakarma *et al.,* 2017) [19]. INM-based treatments readily affect the soil microbial population *viz*., bacterial count, *Bacillus* count, fungal count, actinomycetes

count etc. (Srivastava *et al*., 2019) [10]. Microbial count is directly proportional to the soil health. In recent years, organic manures having high soil organic matter content, like urban wastes, are also being used for supplying plant nutrients (Srivastava and Ngullie, 2009) [20].

Ternisien and Ganry (1990) [21] studied the benefits of crop rotation in banana cultivation and reported that rotation of banana with crops such as sorghum, *Brachiaria decumbens*, *Crotolaria juncea*, *Desmodium distortum*, *Mucuna pruriens* and pineapple resulted in increased soil fertility and increased crop yield. Hazarika and Ansari (2007) [22] found that bio-fertilizers on their application to seed, root or soil, mobilize the nutrients and help in building up the lost microflora and ultimately improve the soil health. Kumari *et al.* (2019) [23] have stated that soils of mango orchards with low organic matter content and poor fertility can be effectively rejuvenated by using organic manures under sub-tropical conditions. The application of 50 per cent RDF through Vermicompost + 50 per cent DF through NPK fertilizers + PSB + *Azotobacter* significantly improved the physico-chemical attributes of soil under Ber (Bohane and Tiwari, 2014) [24].

Minimizing Nutrient losses

Sustainable use of the nutrient sources helps in minimizing the nutrient losses from the soil. The mobile nutrient elements like N can be lost from the soil through leaching, volatilization etc, which in turn decreases the nutrient use efficiency of the fruit crops. The combined use of organic manures and chemical fertilizers helps in minimizing the nutrient losses from the soil and increasing the fruit production, thus higher nutrient use efficiency can be realized. Lekasi *et al*. (1999) [25] reported recycling of nutrients to the extent of 69 kg N and 147 kg K per ha with the addition of crop residues such as banana leaves, pseudo stem, maize stover and bean trash in a banana-based cropping system.

Improving farmers economic condition

Orchards are the main source of income to the farmers of hilly regions. Fertilizers are quite costly input and purchasing capacity of the farmers is quite low. INM helps them to obtain more profit by using the on-farm nutrient sources by recycling the wastes and using them as manures. According to Jat *et al.* (2015) [26], green manures and grain legumes can meet up more than 50 per cent of the N requirement of the crops when integrated into cropping systems and hence reduce the expenses spent on fertilizers. Integration of FYM (12.0 t ha^{-1}) and inorganic fertilizers (urea 130 kg + SSP 69 kg + MOP 25 kg ha^{-1}) can produce comparable income from the orchard and thus can be more effective than the inorganic production solely (Kumar and Ray 2018) [11]. Abd El-Gleel Mosa *et al.* (2014) [27] stated that use of bio-fertilizers is economically efficient and sustainable alternative to recommended dose of nutrients fertilization in fruit production. Srivastava *et al.* (2019) [10] also reported that combined application of recommended dose of fertilizers, VAM, PSB, *Azospirillum* and *Trichoderma herzianum* gave higher net returns (Rs. 3.97 lakhs) and benefit cost ratio (5.29) over 100 per cent recommended dose of fertilizers in Nagpur mandarin.

Reduced Multi nutrient-deficiencies

Most of the chemical fertilizers supply only macro nutrients, not secondary and micro nutrients. The continuous and over use of straight chemical fertilizers like urea, SSP, MOP etc. can lead to multiple nutrient deficiencies in the fruit crops. On the other hand, organic manures, bio-fertilizers, crop residues, animal excreta are cheap and locally available but cannot meet the nutrient demand for fruit production completely due to their poor nutrient content. Alone use of either chemical fertilizer or organic plant nutrients cannot fulfil the nutrient requirement of the fruit trees. INM helps in reducing the multiple nutrient deficiencies of the plants by supplying not only primary nutrients but secondary, micro as well as beneficial nutrients.

Constraints of INM for Sub Tropical Fruit Production

Integrated nutrient management is an important aspect for increasing the production of sub tropical fruit crops in India *viz a viz* an effective method to improve soil physical, chemical and biological properties as well as reduces the adverse effect of excess use of inorganic fertilizers on the environment. However, there are certain factors which constricts adoption of INM by sub tropical fruit producers. These factors are discussed below:

- Organic matter contains high amount of insoluble compounds like cellulose, hemi-cellulose, lignin etc., which delay the process of degradation of organic matter and thereby pose problems in supplying the nutrients to the plants at required time.
- Availability of FYM is also an important factor that constrains the use of INM in sub tropical fruit production due to the fact that domestication of animals has reduced considerably, therefore FYM is not as easily available to farmers as it was used to once.
- Most of the farmers are not aware of the new research and technologies taking place in the field. So, their lack of awareness restricts the use of INM.
- Farmers do not have complete knowledge of the practice and moreover the interaction of farmers with researchers and extension workers is also weak. Therefore, it becomes more difficult for the famers to use INM.
- Most of the farmers prefer chemical farming and they are unwilling to the adoption of improved methods.
- Farmers often have inadequate knowledge on the use of fertilizers in balanced proportion which is an important aspect of INM.
- The production of fruits takes more time as compared to most of the other agricultural crops which does not go well with the insufficient funds that the farmers have.
- Mismatching of INM practices developed at the research stations with the farmers' resources and their practices. The research should be carried keeping in mind the needs of the farmers.
- Most farmers lack proper knowledge on the preparation of FYM and compost. They mostly use them as fuel.
- Biofertilizers are used in limited places due to low shelf life, availability, careful handling, storage etc. A strain found ideal at one location may not be the same at other location. Location-specific strains need to be developed.
- Farmers do not wish to spend 6-8 weeks for growing a green manure crop with no cash benefit. Moreover, as the result of green manuring is not immediately visible so farmers prefer to avoid it.
- Different crops have different nutrient requirements and the fertilizer recommendation in INM is not based on soil testing. Without proper soil testing it is difficult to apply the recommended the rate of fertilizers to the crop.
- Farmers prefer to use crop residues for fodder or fuel purposes instead of using them as manures.

- Crop rotation which is often ignored by the farmers plays an important role in sustaining nutrient supply. For example, Legumes used in crop rotation restores soil fertility. Farmers select crops according to their own needs.
- Handling bulky organic manures that contains small amounts of plant nutrients and preparation of composts is a very cumbersome process so farmers tend to use inorganic fertilizers.
- Unavailability of soil testing facilities also restricts the use of INM as you need to have the knowledge about the fertility status of your soil.
- Even with soil testing facilities there are very few farmers who get their soil tested due to lack of interaction between the farmers and the extension services.
- The subsidy on inorganic fertilizer like Urea by the State or Central government also restricts the farmer from using INM method.

Conclusion

A comprehensive concerted effort in utilization of locally available components of INM involving rational and appropriate use of fertilizers and organics will go a long way in providing a sustainable crop nutrition management in subtropical fruits. Moreover, more and more nutrient elements *viz*, Mg, S, Zn & B are likely to be critical nutrient element of fruits in future due to inadequate use of organic manures and application of chemical fertilizers devoid of secondary/trace elements. In addition, fertilizer management should be based on cropping systems rather than sole crop for higher nutrient use efficiency and economics. Thus, integrated nutrient management strategy utilizes a judicious combination of biofertilizers, inorganic fertilizers and organic manures to bring about improvement in soil fertility and helps in protecting the environment and producing higher crop yields than when applied singly.

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