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A Review

Balanced fertilization for increasing and sustaining fruit quality and productivity-A Review

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Abstract : Balance nutrient management is an approach to soil health management that combines organic and mineral methods of soil fertilization with physical and biological measures for soil and water conservation. The indiscriminate use of chemical pesticides along with improper nutrient management is deleterious to the plant and soil health, environment and human being who consume them. It also causes soil health deterioration and disturbs the soil microorganisms. Due to these practices, the plants also become susceptible to several biotic and abiotic stresses. The quality attributes of different fruits are badly affected due to indiscriminate application of inorganic agro-chemicals which results in quality deterioration with less consumer preference and low returns to the growers. Thus, adequate mineral nutrition is a pre-harvest factor affecting fruit quality. Therefore, it is a holistic approach based on usage of all possible sources of plant nutrients in an integrated manner is considered as alternative source to maintain soil fertility and plant nutrient supply for sustaining the desired crop productivity. Due to huge distinction in the nutrient use efficiency of perennial fruit crops, their nutrient management- based production system is characteristically intricate to understand. Integrated plant nutrient management aims to optimize the condition of the soil, with regard to its physical, chemical, biological and hydrological properties, for the purpose of enhancing farm productivity, whilst minimizing land degradation. There are studies that integrated nutrient management provide tangible benefits in terms of higher yields, but simultaneously and almost imperceptibly conserve the soil resource itself along with produce quality. The replenishment of soil nutrients lost by leaching and/or removed in harvested products through an integrated plant nutrition management approach that optimizes the benefits from all possible on- and off-farm sources of plant nutrients. The review on balanced fertilization on a variety of fruit crops revealed similar combinations. These observations provided a countrywide database that INM module which consists of nutrient sources having three-tier nutrient release pattern, has far reaching consequences on soil and plant health translating into real guard production sustainability, nearer to climate resilient fruit crops.

Key Words : Nutrient use efficiency, INM, Productivity, Mycorhizza, Fertilization, Soil fertility

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Introduction

Soil ecosystems are the foundation of human life support systems. The G20 Agriculture Ministers declaration in their meeting in 2018 in Buenos Aires,

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Argentina, specifically referred to 'Healthy Soils to Support Agriculture in Sustainable Human Development', reiterating the commitment of the German Presidency of 2017. The similar concerns found place in the subsequent Presidency of Japan in 2019 and current one of Saudi Arabia. Realizing the significant role that soils play in food and environmental security and in abating climate change, the United Nations declared 2015 as the Year of Soils. Similar to this the International Union of Soil Science (IUSS) has declared 2015-2024 as International Decade of Soils. The soil erosion, loss of soil organic matter and nutrient depletion are among the leading contributors which impair soil health, reduce fruit crop yields and quality. A due importance to nutrients is essential as they affect the productivity, quality and profitability. After achieving food security, it is being increasingly felt that India needed to achieve nutritional security for betterment of its population. "For every nutritional problem there is a horticultural solution". Hidden in this is the understanding of the dynamics of nutrients in horticulture. Studies indicate that one-third of the world's soils are degraded due to several reasons which include depletion of organic carbon and nutrient imbalance. Deterioration of soil nutrients also affect the quality and safety of agricultural produce and thereby comes the role of soils in achieving Sustainable Development Goal 2 — zero hunger. The rate of nutrient application is the result of tree requirement and soil availability. The former is estimated by the amount of nutrient found in the different tree organs during orchard lifetime. Soil fertility is measured, during the growing season, by soil analysis, and it is recommended particularly for nutrients that are easily leached out with the excess of water. Our soils are very low in organic matter content and thus have poor soil fertility. In view of poor soil fertility and shrinking land and water resources, the single option for India is through increase in fruit crop productivity. Not only the inherent soil fertility is poor and the nutrient input is low but also there is growing evidence of increasing deficiency of P and K, aggravated by the disproportionate/imbalance application of higher doses of N in relation to P and K (Tewatia *et al.*, 2017). The limiting nutrients do not allow the full expression of other nutrients, lower the fertilizer response and crop productivity. This imbalance in nutrient use has resulted in wide gap between crop removal and fertilizer application. Thus, Indian agriculture is operating as a net negative balance of plant nutrients resulting in chemical degradation and poor soil health. Due to low use of organic manures, organic carbon is an index of poor soil health and application of organic manures helps in maintaining high organic carbon content of the soil. Our soils have very low organic matter content. Therefore, without regular application of organic manures and recycling of crop residues, we cannot hope to maintain good soil health to sustain productivity and ensure high responses to NPK fertilizers. The green manuring practice is almost forgotten. Soil organic carbon (SOC) is the key constituent which dictates soil physical condition, chemical properties including nutrient status and biological health of a soil. Biological degradation of soil health occurs due to soil erosion by water resulting in loss of fauna and flora, loss of organic carbon, extremes of acidity and alkalinity, addition of toxic substances, excessive use of chemicals, intensive tillage, extremes of climate etc. Soil organisms, both animals (fauna/micro-fauna) and plants (flora/micro-flora), are important for maintaining the overall soil quality, fertility and stability of soil. The biological state of soil health furnishes early indication of soil degradation to help take timely additional prudent sustainable soil-nutrient management practices (Fig. 2).

Fruit crops are cultivated in India over 6664 thousand hectares with a total production of 99069 thousand metric tonnes and productivity of 15.36 t/ha (Anonymous, 2019). Though production of fruits has increased manifold over the last decade (Fig.1) but there exists a gap between the demand and supply of fruits. The present fruit production in India meets only the 46% of the total demand. Thus, there is strong need to increase the production and productivity through crop diversification and use of best horticultural techniques among which balanced fertilizer application is the one. India still lags behind many countries in terms of productivity. This might be because of improper orchard management particularly nutrient management. The continuous use of chemicals

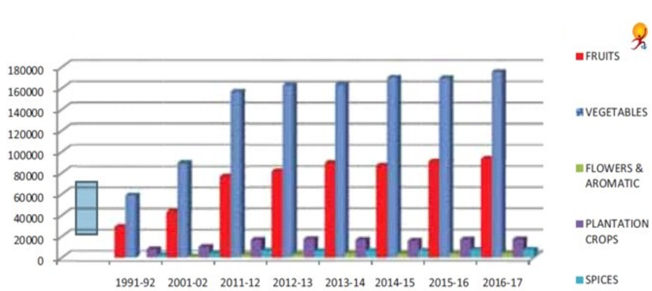
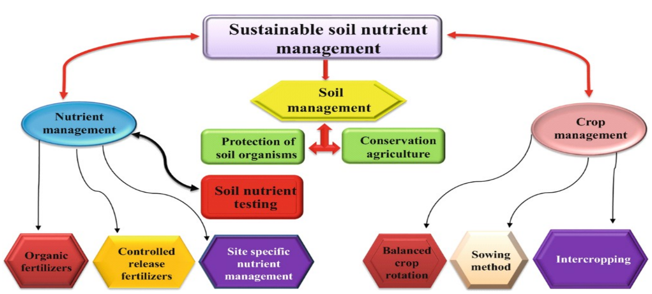


Fig. 1 : Production of various horticulture crops over the years

fertilizers particularly NP&K has impaired the soil fertility and decreased the factor productivity.

The increasing cost of fertilizers with poor purchasing capacity and their negative effect on soil health has led to intensified attempts to the use of bio-fertilizers and organic matter along with site specific and foliar application of inorganic fertilizers. Balance application of fertilization is a system that helps to restore and sustain crop productivity, and also assists in checking the emerging micro-nutrient deficiencies (Fig.3a). Integrated plant nutrient management can also be referred to as maintenance of soil fertility and plant nutrient supply to optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. It envisages the use of chemical fertilizers in conjunction with organic manures, biofertilizers, mycorrhiza, green manures, crop residues, and legumes in a cropping system and locally available resources with objectives of sustaining high yield and ensuring environmental safety. The horticultural production incorporates the idea that natural resources should be used to generate increased output and incomes, especially for low-income groups without depleting the natural resource base and by integrating the use of all natural and man-made sources of plant nutrients, so that crop productivity increases in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations (Peter.Gruhn, 2000).



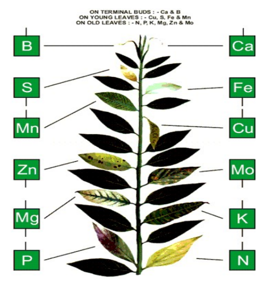
Goal of nutrient management:

The main goal is to reduce indiscriminate use of inorganic fertilizer along with restoring the organic matter which improve physical, chemical and biological properties of soil and also to increase nutrient use efficiency. Secondly the nutrient management maintain the quality in terms of proper fruit growth and nutritive composition of the fruits and also to maintain the nutrient balance between the supplied nutrient and nutrient removed by fruit plant and to improve soil health and fruit productivity on sustainable basis. The need involves growing of superior nutrient-efficient fruit plants which will receive balanced supply of macro-, secondary- and micro-nutrients through integrated nutrient management involving organic, mineral and biofertilizers applied in the most appropriate manner.

Steps of nutrients management:

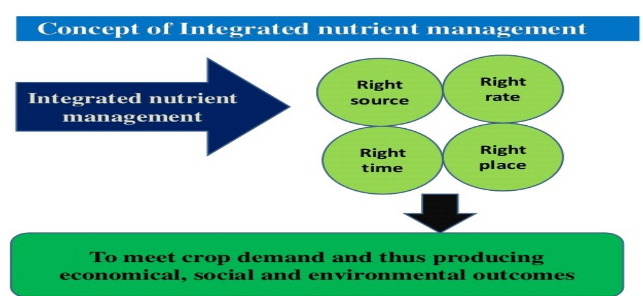
There are some steps of better nutrient management (Fig.4) in fruit crops for sustainable production:

– Know When to Fertilize
– Decide Whether Need to Fertilize
– Measure the Previous Year's Growth
– Check the Chart to Evaluate Growth (Fig.3)



Peaches and nectarines–non-bearing young trees should grow 18"-24", mature bearing trees should grow 12"-18". Likewise, apples and pears–non-bearing young trees should grow 18"-30", mature bearing pears and non-spur type apples should grow 12"-18".

– Choose the Right Fertilizer.
– Calculate how Much Fertilizer to Use
– Applying the Fertilizer



Productivity enhancement with nutrients management:

The increase in productivity of horticultural produce removes large amounts of essential nutrients from the soil. Without proper management, continuous production of crops reduces nutrient reserves in the soil. Another issue of great concern is the sustainability of soil productivity, as land began to be intensively exhausted to produce higher yields. Overtime, cumulative depletion decreases production, yield and soil fertility and lead to soil degradation. On the other hand, excess supply or continuous use of inorganic fertilizers as source of nutrient in imbalanced proportion is also a problem, causing economic inefficiency, damage to the environment and in certain situations, harm the plants themselves and also to human being who consume them. The new approach to farming often referred to as sustainable agriculture, seeks to introduce agricultural practices that are eco-friendly and maintain the long-term ecological balance of soil ecosystem. The use of organic manures *viz*. farmyard manure, vermicompost forest litter and biofertilizers *viz.* Azotobacter, Phosphate solublizing bacteria reduce the cost of cultivation and supplement the secondary and micronutrients to crops. The judicial use of organic inputs with inorganic is considered as the alternative source to meet the nutrient requirement of the crops. Bio-fertilizers combined with organic manure influences the plant growth by enhancing root biomass; total root surface facilitates higher absorption of nutrients and increase in yield by reducing consumption of natural sources of energy. Ashrafi et al., 2019 in a study of strawberry on direct application of rice straw compost in soil and foliar application enhances yield and quality of strawberry. Application of 80% rice straw compost along with 20% soil resulted in highest yield and sweetness of fruit. Rashid (2018) made a study on growth, yield and quality of strawberry cultivars *viz.,* Festival and AOG, by using different organic manures (cowdung, mustard oilcake and poultry manure) in single and in combined treatments and observed that combined application of cowdung + mustard oilcake + poultry manure is the best treatment in terms of yield. An experiment was conducted to investigate the effective use of plant growth promoting rhizobacteria on growth, yield and fruit quality of strawberry cv. Chandler at Nauni, Solan, HP, India during 2012-2013. It was observed that the root+ foliar application of plant growth promoting rhizobacteria gave the best results with respect to growth, yield and fruit quality as compared to other application methods. A field trail was conducted at Regional Research Station, Gayespur, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India during two successive seasons of 2014-2015 to investigate the influence of different fertilization sources (chemical, organic and biofertilizer) on growth, yield, fruit quality of mango trees cv. Himsagar, as well as to asses leaf mineral nutrient status of respective tree and soil health condition of the orchard. Results revealed that different treatments of bio fertilizer along with Panchagavya significantly increased the canopy spread, fruit weight, yield and bio-chemial qualities while minimum results recorded from trees treated with chemical fertilizers and control plant. Singh *et al*. (2017) studied the effect of integrated nutrient management on mango cv. Amrapali under high density planting at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut and reported that maximum plant height, spread and number of panicles/ plant were recorded in the plants treated with 75% RDF + 40 kg vermicompost + 250 g Azotobacter + 250 g PSB/ plant. Suhasini et al. (2018) studied the effect of integrated nutrient management on growth parameters of banana cv. Rajapuri and observed the maximum plant height and pseudostem girth at shooting with application of RDF 100% + 20 kg FYM + PSB (20 g) + Azospirilum (20 g) per plant.

Nurbhanej *et al.* (2016) studied the effect of integrated nutrient management on yield and quality of acid lime at Anand Agricultural University, Anand and reported that the acid lime trees treated with 75% RDF + 9 kg vermicompost + AAU PGPR Consortium (3.5 ml/tree) gave maximum fruit yield, fruit volume, fruit diameter, fruit weight, TSS, ascorbic. Prabhu et al. (2018) revealed that the application of 100 per cent recommended dose of fertilizers + Azospirillum (100 g per plant) + phosphobacteria (100 g per plant) + Arbuscular Mycorrizhal Fungi (500 g per plant) + Trichoderma harzianum (100 g per plant) has showed a superior performance with respect to yield, yield attributing components and quality attributes of acid lime. Dwivedi and Agnihotri (2018) revealed that application of 50 per cent RDF + 25 kg FYM + 5 kg vermicompost per tree gave maximum plant height and canopy height, spread E-W, plant girth and tree volume as well as significantly increased yield attributes *viz.*, number of fruits per tree, fruit weight and yield per tree in guava. Tiwari et al. (2018) observed maximum plant height, circumference of root stock and scion, plant spread, leaf length, leaf width, tree volume and fruit yield in the trees treated with 100% NPK + Zn (0.5%), B (0.2%), Mn (1%) as foliar spray twice + organic mulch (10 cm thick) in guava. Greeshma *et al.* (2017) carried out an experiment on pomegranate crop at Kaladagi village of Bagalkot district, Karnataka and recorded the highest number of hermaphrodite flowers, number of fruit and marketable fruit yield with application of 50% NPK (200: 100: 200 gram per plant) + 20 kg oil cakes + bioinoculants treatment whereas, fruit weight and size was noticed maximum in 75% NPK (300: 150: 200 gram per plant) + 10 kg oil cakes + bioinoculants treatment. Tandel et al. (2017) indicated that the application of 25% RDN through biocompost + 25% RDN through castor cake + 50% RDN through inorganic fertilizer gave higher values of yield characters *viz.,* number of fruit, average weight of fruit, yield per plant, yield per hectare, fruit diameter and fruit volume with minimum fruit cavity index and initiation of flowering. Similarly, fruit firmness, shelf life, total soluble solid, total sugar, reducing sugar and vitamin C was also found good in same treatment along with minimum physiological loss in weight and titrable acidity in papaya fruit. An investigation was conducted during the year 2018-19 at Research Farm of Centre of Excellence on Protected Cultivation and Precision Farming under net house, College of Agriculture (IGKV) Raipur (C.G.). Result revealed that treatment (75% RDF + 10 kg Vermi-compost + 100 g Azotobacter +100 g PSB/Plant) showed maximum number of fruits, fruit length, fruit weight, and yield per plant in papaya. Vishwakarma et al. (2017) showed that maximum fruit length, fruit width, fruit weight, pulp weight, TSS and ascorbic acid were recorded in bael fruit with application of 50 kg FYM + 100% NPK + 200 g each (Azotobacter + PSB). Rani et al. (2013) conducted an experiment on litchi cv. Rose Scented for two years at Horticulture Research Centre, Patharchatta, Pantnagar and obtained maximum tree height, tree spread, tree volume, panicle length, fruit set, fruit retention and higher yield through application of FYM at 150 kg per tree. Mandal et al. (2013) concluded that the application of 100: 25:150 g NPK/plant + 10 kg FYM + 50 g PSB /plant is beneficial for increasing vegetative growth as well as improving yield and yield attributing characters of aonla cv. NA-7 under red and lateritic region of West Bengal. Basith *et al*. (2018) concluded that pruning of phalsa bushes around 20th December has resulted in more number of fruit clusters and yield under the Southern Telengana Agro-climatic conditions. Integrated application of 50% RDF along with organic manure and biofertilizers is best option to obtain higher yields and superior fruit quality in phalsa.

Quality improvement with nutrients management:

There are many components of fruit quality such as size, colour, firmness, soluble solids and acidity. In addition there are many factors which may influence fruit quality, some of which are outside of control such as weather, site suitability and varietal genetic potential. But now days we can improve the fruit quality through modern management practices such as site specific nutrient management, drip irrigation etc. Calcium is important in apple fruit quality by delaying cell wall breakdown, maintains firmness, retarding ethylene production and alleviates internal break down. Boron is important in pollen germination and pollen tube growth resulting in successful fruit setting. Anthocyanins are water-soluble vascular plant pigments that are mainly synthesized in epidermal layers and the flesh of fruits such as apples, cherries, grapes, and other berries. Because of their attractive red to purple coloration and their health-promoting potential, anthocyanins are significant determinants for the quality and market value of fruits and fruit-derived products. In crops, anthocyanin accumulation in leaves can be caused by nutrient deficiency which is usually ascribed to insufficient nitrogen or phosphorous fertilization. However, it is a little-known fact that the plant's nutrient status also impacts anthocyanin synthesis in fruits. The quality attributes of different fruits are badly affected due to indiscriminate application of inorganic agro-chemicals which results in quality deterioration with less consumer preference and low returns to the growers. Patel *et al.* (2017) recorded maximum total soluble solids, acidity, ascorbic acid, reducing sugar, non-reducing sugar, total sugars, shelf life of fruits, fruit firmness and physiological loss in weight 4th day after harvest when trees were treated with 75% NPK + vermicompost 15 kg + AAU Bio NPK 10 ml/tree in sapota. Bohane and Tiwari (2014) conducted an experiment at College of Horticulture, Mandsaur on five years old trees of ber cv. Gola and revealed that the application of 50 per cent recommended dose of NPK as vermicompost + 50 per cent RDF NPK + 50 g Azotobacter + 50 g PSB significantly increased the fruit length and diameter, fruit volume, pulp weight, stone weight, TSS, ascorbic acid, reducing sugar, non-reducing sugar, total sugars, TSS/acid ratio and chlorophyll content in leaves spad value over other treatments. Kumar (2010) conducted a study on substrate dynamics under integrated plant nutrient management in litchi cv. Shahi. The treatments comprised the application of biofertilizers (*Azospirillum, Azotobacter, Aspergillus*, *Trichoderma* and *Pseudomonas*) conjointly with chemical fertilizers and organic manures. It was observed that the treatment having *Azotobacter* (250 g tree-1) with half of the recommended dose of chemical fertilizer and 50 kg of FYM proved to be the most dynamic substrate to record maximum percentage of quality fruits under superior grade. Dadashpour and Mohammad (2012) conducted an experiment on the influence of different organic combinations on yield and quality of strawberry cv. Kurdistan. The experiment comprised of five organic nutrient treatment combinations including the recommended dose of N, P and K through chemical fertilizer as control. Combined application of manure + *Azotobacter* +woodash + phosphorus solubilizing bacteria + oil cake improved significantly fruit diameter, length, volume, weight, total sugars, total soluble solids, acidity, TSS: acidity ratio and yield.

Sangeeta *et al.* (2017) reported maximum TSS, reducing sugar, non-reducing sugar and total sugar by application of FYM @ 10 kg per tree + *Neem* cake @ 1.25 kg per tree + vermicompost @ 5 kg per tree + wood ash @ 3.75 kg per tree in banana crop. Shukla et al. (2014) stated that application of 10 kg vermicompost + *Azotobacter* + phosphate solubilizing microrganism + Trichoderma harzianum + organic mulching recorded the highest fruit weight, fruit diameter, TSS, titratable acidity, total sugars and ascorbic acid content in guava fruit. An investigation was conducted in the University Fruit orchard, Department of Horticulture, College of Agriculture, Gwalior (M.P.) on Guava cv. G-27 was conducted during the year 2013-14 and 2014-15, foliar spray of zinc, boron and magnesium was done. Zinc sulphate @ 0.75%, Boric acid @ 0.3%, Magnesium sulphate @ 0.60% had significantly improved the various yield attributing parameters of guava. Kumrawat et al (2018) reported in guava that the application of 100% NPK + 5 kg vermicompost + 150 gm *Azatobactor* recorded maximum TSS, TSS/acid ratio, ascorbic acid, pectin, total sugars, reducing sugars and non-reducing sugars with minimum acidity, whereas, the maximum number of fruits per tree, fruit weight and yield per tree were recorded with the application of 100% NPK + 5 kg vermicompost + 150 g VAM. Kirankumar *et al.* (2018) conducted an experiment on pomegranate at the farmer's field of Somerhalli village, Hiriyurtaluk of Chitradurga district, Karnataka and revealed that application of 100% recommended dose of fertilizers (RDF) along with vermicompost + poultry manure + Azospirillum + PSB + KSB has recorded the maximum aril weight, aril per cent and lowest seed: aril ratio, whereas, maximum TSS, TSS/acid ratio, reducing sugars, non-reducing sugars, total sugars and lowest titratable acidity was also recorded in 100% recommended dose of fertilizers (RDF) along with vermicompost + poultry manure + *Azospirillum* + PSB + KSB.

In a study carried out at Sher-e-Kashmir University of Agricultural Science and Technology-Jammu correlation coefficient values (Table 1) indicated that fruit yield was significantly correlated with all the macronutrients in leaf. Highest significant positive correlation was observed with N (r = 0.925) followed by Mg (r = 0.759), Ca (r = 0.677) and P (r = 0.558).

Future research:

Despite many cutting-edge technologies addressing a variety of core issues of nutrient management, many more issues are yet to be attempted with respect to INM-based citrus production vis-à-vis rhizosphere dynamics. Nutrient dynamics is another virgin area where limited attempts have been made using citrus as test crop. Amongst different nutrients, Zn has attracted worldwide investigation from various angles (Srivastava and Singh 2009). Additionally, the conditions under which citrus trees are most likely to respond to corrective Zn-treatments are still not fully understood. The role of Zn

Table 1 : Correlation of leaf nutrient content with yield and quality of kinnow mandarin

Leaf nutrient	Coefficient of correlation (r) values				
	Yield	Quality parameter			
		Juice content	TSS	Total sugars	Ascorbic acid content
N	0.925**	0.966**	0.679**	0.605*	0.365
P	0.558*	0.559*	0.927**	0.946**	0.727**
K	0.268	0.342	0.793**	0.860**	0.778**
Ca	0.677**	0.837**	0.893**	0.848**	0.740**
Mg	0.759**	0.852**	0.900**	0.855**	0.722**

* and ** Significant at 5% and 1% level, respectively

in flowering, fruit set, fruit quality (external and internal) and juice shelf life; models defining the critical periods of Zn-supply to assure sustained response and its uptake for helping the management decision under different citrus-based cropping systems; and devising means for improved Zn-uptake efficiency need to be attempted to unravel many of the complexities involved with Zn-nutrition under INM-based production management. Impacts due to environmental changes and anthropogenic activity are the potential threats to the conservation of soil quality, while expanding citriculture to marginal soils having a wide range of limitations. With the availability of more technical know-how on efficient use of bulky organic manures, prolonged shelf life of microbial bio-fertilizers, and better understanding on citrus - mycorrhiza symbiosis with regard to nutrient acquisition and regulating the water relations, a more effective integrated citrus production system could be evolved in future.

The molecular approach to breeding of mineral deficiency resistance and mineral efficiency would facilitate to produce nutritionally efficient biotypes in order to maximise the quality production on sustained basis. Fertilizer applications are currently managed to protect environmentally sensitive areas by using controlled release fertilizers (use of organic manures, a befitting option), frequent low concentration fertigation, multiple applications, and variable rate application technology in order to improve fertilizer use efficiency. However, using newly emerging techniques of nutrient management and site-specific management on the principles of INM could be worked out accommodating soil's nature and properties. Simultaneously, concerted efforts would be required to develop INM-based yield monitors and soil quality indicators in order to develop a comprehensive system, whereby the concept of soil security could be effectively brought into a reality with an emphasis on development of minimum data set to define Soil Health Card for different commercial citrus cultivars grown in India.

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