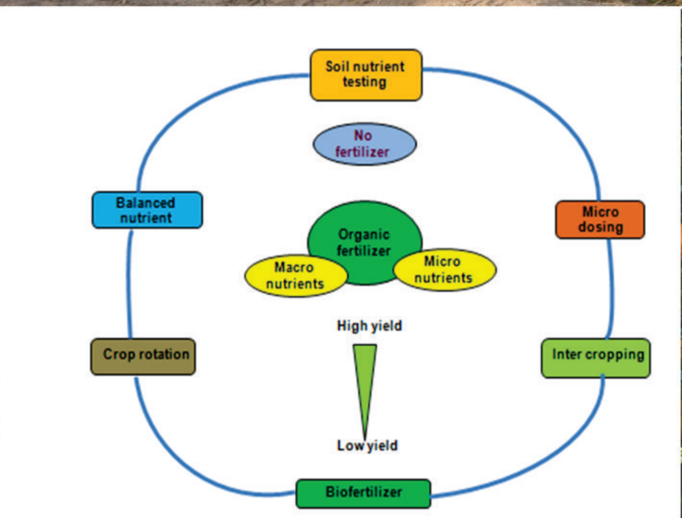
Technical Bulletin No. 77

INTEGRATED NUTRIENT MANAGEMENT FOR HORTICULTURAL CROPS IN ARID REGION



ICAR-CENTRAL INSTITUTE FOR ARID HORTICULTURE
Bikaner–334 006, Rajasthan, India

Technical Bulletin No. 77

INTEGRATED NUTRIENT MANAGEMENT FOR HORTICULTURAL CROPS IN ARID REGION

B.D. Sharma, Anita Meena
M.K. Jatav and Roop Chand Balai

ICAR-Central Institute for Arid Horticulture, Bikaner
Bikaner–334006, Rajasthan, India

Correct citation
Sharma, B.D., Meena Anita, Jatav, M.K. and Balai, Roop Chand (2018):
Integrated nutrient management for horticultural crops in arid region.
CIAH/ Tech./ Pub. No. 77, pp 42. ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan, India

Year:
2018

Published by:
Prof. (Dr.) P. L. Saroj
Director
ICAR-Central Institute for Arid Horticulture
Beechwal, Bikaner-334 006, Rajasthan, India

Technical Assistance:
Shri B.R. Khatri

Laser typeset & Printed at:
M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi-110 028
Mobile: 9811622258

PREFACE

Low rainfall regions (rainfall below 500 mm year) mainly in the north western part of the country cover about 45 million hectares area in Rajasthan, Gujarat, Haryana and small parts in Tamil Nadu and Telangana. About 82% of this area is rainfed. In this region climate is harsh with high temperature during major part of the year and rainfall is not only low but highly unpredictable in both distribution and amount Low rainfall and its erratic distribution are the major causes of uncertainty of agricultural production. This condition is further getting aggravated due to climate change. Under such conditions use of synthetic inputs *i.e.* fertilizers, pesticides *etc.* is risk prone and uneconomic. Fertilizer is an essential component of modern agriculture. Though there has been substantial increase in production and consumption of fertilizers over the years, nutrient response ratio is not so encouraging mainly due to imbalanced fertilization and lack of use of micro and secondary nutrients. Integrated nutrient management which utilizes local resources in an optimum way maintaining the sustainability of the system and health of the environment is a good choice for these areas. Farmers are practicing with integrated nutrient management since ages by design or default according to soil and climatic conditions. In this bulletin, an overview of integrated nutrient management and possibilities in arid and low rainfall regions, and results of inter-disciplinary studies on soil properties, crop production and plant protection. We wish to express our sincere thanks and gratitude to Director ICAR-CIAH, Dr. P.L Saroj for his guidance and for providing facilities and support for research work

Authors

Date: 27.09.2018

Place: Bikaner

CONTENTS

S. No.	Item	Page
1.	Introduction	1
2.	Integrated nutrient management	2
3.	Objectives of INM	2
4.	Need of INM	2
5.	Soil health management	3
6.	Nutrient status of Indian soils	3
7.	Movement of ionic forms of nutrients	5
8.	Nutrient management of arid and semi-arid fruit crops	5
9.	Integrated approach of nutrient application	9
10.	Soil management	9
11.	Leaf analysis	11
12.	Method of leaf sampling	11
13.	Common guidelines for leaf and petiole sampling	11
14.	Interpretation of leaf analysis data	13
15.	Diagnosis and recommendation integrated system (DRIS)	13
16.	DRIS norms	14
17.	DRIS index interpretation	15
18.	Optimum leaf nutrient status of the important fruits	15
19.	Manure and fertilizer recommendations for some tropical and subtropical fruits	16
20.	Time and method of nutrient application	17
21.	Active Root Zone of fruit crops for nutrient application	19
22.	Foliar root zone application of nutrients	20

S. No.	Item	Page
23.	Application of biofertilizers in horticultural crops	20
24.	Management of the farm waste for INM	20
25.	Nutrient imbalance status in Indian Soils	20
26.	Recommendations based on soil fertility rating	23
27.	Critical limit based on recommendations	24
28.	Tissue testing for nutrient recommendation in horticultural crops	24
29.	Nutrients losses in arid region	26
30.	Influence of INM practices on biological, physico-chemical properties of soil and horticultural crops	26
31.	Management practices and recommendation for safe and economic use of fertilizers.	33
32.	Summary	36
33.	Future thrust	37
34.	Conclusion	38
35.	References	39

Tables

S. No.		Page
Table 1.	Nutrient defeciencies status in different zone (state wise)(ppm)	4
Table 2.	List of essential macro and micro plant nutrient	6
Table 3.	Nutrient harvested by fruit crops	6
Table 4.	Manure and fertilizer recommendations for aonla fruit crop	7
Table 5.	Pit filling mixtures in sodic soils for aonla plantation	7
Table 6.	Response of pit size and filling mixture on the establishment of pomegranate	8
Table 7.	Soil categorized for the fertility parameters	10

S. No.		Page
Table 8.	Nutrient balance sheet in dry land agriculture	10
Table 9.	Leaf sampling technique and nutrient norms for fruit crops	12
Table 10.	Leaf nutrient guides for the mango cv. Dashehari	13
Table 11.	Optimum leaf nutrient status of some important fruit crops	16
Table 12.	Manure and fertilizer recommendations for some tropical and subtropical fruits	17
Table 13.	Active root zone of some important fruit plants and the place of fertilizer application	19
Table 14.	Soil nutrient balance sheet in India	21
Table 15.	Nutrient removal by different horticulture crops	22
Table 16.	Plant tissue sampling guidelines for horticultural crops	24
Table 17.	Effect of different INM treatments on physico-chemical properties of the soil	27
Table 18.	Effect of different INM treatments on soil moisture of the soil.	27
Table 19.	Effect of N and *Rhizobium* inoculation on seed yield of cluster bean crop	30
Table 20.	Effect of N levels and *Rhizobium* on N use efficiency and percent yield response	31
Table 21.	Effect of organic and inorganic source of nutrient on yield performance of *kachri*	31
Table 22.	Effect of different INM treatments on yield and fruit quality parameters of kinnow orchard	32
Table 23.	Effect of different INM treatments on morphological parameter of kinnow orchard	33
Table 24.	Generalized symptoms of nutrient deficiency and excess in crops.	34

Introduction

The Indian hot arid zone occupies an area of 0.32 million km to forming a continuous stretch in the north western states of Rajasthan, Gujarat, Punjab, Haryana and scattered land masses in the states of Maharashtra, Karnataka and Andhra Pradesh, 70 per cent of it falls in western Rajasthan. Low and erratic rainfall, extreme temperatures, long sunshine duration (6.6-10 hours), low relative humidity (30-80%), high wind velocity (9-13 km/h) and high evapo transpiration (1600-1800 mm) and characteristic features of the region. Moreover the soils are poor in nutrients and scarcity of water and recurring droughts are perennial constraints. Despite hostile conditions, the western arid Rajasthan supports a large human and livestock population and a variety of flora and fauna. However, the ever increasing human and livestock population and development activities exert enormous pressure on the natural resource in the region. These areas experience an annual rainfall between 100 and 500 mm with a coefficient of variation varying from 40 to 70 %. The region is characterized by low and erratic rainfall with extremes of temperature (1–48 °c), high wind velocity and sandy soils. In dry and arid region, wind erosion affects 13.5% in India (Sehgal, *et al.*, 1994, Kar, *et al.*,1959). Wind erosion is very active in the Indian *Thar* Desert and poses severe multifaceted problems (Dey, *et al.,* 2016). Loss of nutrient-rich particles from agricultural fields has been occurring due to suspension of fine particles in air and deposition of eroded soil. Among terrain properties, soil aggregate distribution, surface roughness, soil moisture and vegetation cover are important factors influencing wind erosion. Indiscriminate grazing in the region also further destroys vegetation and exposes the land surface, thus making it more vulnerable to wind erosion.

High summer temperature (often reaching 50ºc) and very low winter temperature (sometimes below 0ºc), with large diurnal and spatial variability, as well as high wind speed between March and July with speed gusts of >50 km/h during dust storms, are the other major climatic characteristics. The mean annual potential evapo transpiration exceeds precipitation by a wide margin (1400-2000 mm). Broadly, the soils in large parts of the western sandy plains and in the dune-covered areas are deep, excessively drained, calcareous or non-calcareous sandy.

High population pressure has forced us to plough 46% of our country area for food production. The present productivity is 12.36 tones/ha of fruits needs to be raised to 40.0 tones/ha by using N: P_2O_5: K_2O with other inputs, since recommended ratio being 0.75:0.50:1.00. To achieve this target, the present day requirement of 0.67 million tones N, 0.46 million tones P_2O_5 and 0.91 million tones K_2O has been raised to 1.07, 0.58 and 1.14 million tones, respectively in order to supply the recommended ratio of fertilizers to an area of 3.65 million ha growing fruits (Yadav, 2009). Similarly in vegetables, the present production level of 13.41 tones/ha to be raised to 40 tones/ha requiring 1.25 million tones of N, P_2O_5 and K_2O combined at the ratio of 1.33: 0.88 and 1.00.

The soils of India and especially of arid and semi-arid regions are impoverished and hungry to plant nutrients. The soils are very poor in fertility and single grained structure and needs proper nutrient management for optimum production of the horticultural crops. Considering economy, energy and environment, it is imperative that nutrients are to be used effectively by adopting the appropriate doses of nutrients to be applied, their placement and correct timings to ensure higher yields and to sustain the available nutrients in soil at the optimum level.

Since cost of the inputs like fertilizers and manures are very high, thus, efficient nutrient management not only help in increasing the present fruit and vegetable production level but also sustained the fruit production and protect the environment from different types of hazards occurring due to misuse of costly fertilizers. Therefore, sustainable nutrient management is the passport to enter into the 21st century. In view of these situations, the application of nutrients from the combinations of inorganic, organic and biological sources not only fulfills the nutrient requirement of the crop but also improves the soil health. Hence integrated nutrient management practices will help to increase the productivity of the crop and also enrich the biota of soil. So first one should know the integrated nutrient management, objectives of INM and their need in the agricultural system so that practice can be implemented in the field effectively.

Integrated nutrient management

The maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner (Roy, R.N., 1995)

Integrated nutrient management, developed on the principles of eco-friendly and efficient balanced fertilization and based on optimization of nutrient supplies from all the available sources, inorganic and organic, for pre-defined yield targets of the crop through an efficient combination of soil, water, organic matter etc. INM is a system that helps to restore and sustain crop productivity and also assist in checking the emerging micro-nutrient deficiencies.

Objectives of INM

The objectives of integrated plant nutrient management are:

- To increase the availability of nutrients from all sources in the soil during growing season
- To reduce the inorganic fertilizer requirement
- To match the demand of nutrients by the crop and supply of the nutrients from all sources
- To optimize the functioning of the soil biosphere with respect to specified function
- To minimize the losses of nutrients to the environment through volatilization, denitrification, surface runoff and leaching beyond the rooting zone.

Need of INM

- Decline in productivity of the crop due to decrease in effective nutrient supply
- Poor utilization of the nutrients by the crop
- Accelerated appearances of P, S and Zn deficiencies associated with more N fertilizer use
- On acute P-deficient soils, N application alone depresses

- Decline in SOM associated with continuous application of nitrogen fertilizer
- Accentuation of soil acidity by continuous application of acid forming fertilizers.
- Changing land use pattern from the forest ecosystem to agro ecosystem is responsible for depletion in SOM, impoverishment of soil fertility

In India, effective nutrient management has played a major role in accomplishing the enormous increase in food production. However, it is not possible to supply all the nutrient requirements of crops through inorganic fertilizers. So by taking into consideration the above facts, integrated nutrient management (INM) has been developed. INM has multifaceted potential for the improvement of plant performance and resource efficiency while also enabling the protection of the environment and resource quality. Integrated nutrient management (INM) involves the use of manures, chemical fertilizers and biological agent achieve sustainable crop production and improved soil health. INM is the best approach for better utilization of available resources and to produce crops with less expenditure. In soils of India, Nitrogen, Phosphorus and sulfur deficiencies are principal yield-limiting factors in crop production. INM, which entails the maintenance of soil fertility to an optimum level for crop productivity to obtain the maximum benefit from all possible sources of plant nutrients organics as well as inorganic in an integrated manner (Aulakh, *et al.* 2005 & 2010) is essential to address the twin concerns of nutrient excess and nutrient depletion. INM is also beneficial for marginal farmers who cannot afford to supply all crop nutrients through costly chemical fertilizations (Meena, *et al*., 2013, Singh, *et al.,* 2014).

For making the INM practice effectively fruitful, status of soil health should also be known; therefore soil health can be defined as given below:

Soil health management

- Soil health capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health.
- In the context of agriculture, it may refer to its ability to sustain productivity.
- A healthy soil would ensure proper retention and release of water and nutrients, promote and sustain root growth, maintain soil biotic habitat, respond to management and resist degradation.

Nutrient status of Indian soils

- Indian soils poor in N and P with 89 and 80 percent soil samples in low to medium category; relatively better in K with 50 percent samples only low to medium.
- S, Zn, B, Mo, Fe, Mn and Cu are deficient to the tune of 41, 49, 33, 22, 12, 5 and 3% respectively.

Table 1. Nutrient defeciencies status in different state (ppm)

States	N	P	K	S	Zn	Fe	Cu	Mn	B
Andrapradesh	100	100	58	28.9	22.3	16.8	1.0	1.7	2.8
Assam	100	100	82	16.7	25.6	00	3.8	00	11.9
Bihar	94	97	96	42.8	37.9	9.9	1.9	7.4	36.3
Chhattisgarh	100	100	59	-	20.1	6.8	3.2	14.1	-
Gujarat	89	100	37	42.0	23.1	23.9	0.4	6.3	17.9
Haryana	100	100	39	35.8	15.3	21.6	5.2	6.1	3.3
HimachalPresh	24	88	100	00	11.1	0.8	2.1	3.5	32
Jharkhand	100	98	79	-	20.3	0.0	.5	0.0	56.0
Karnataka	81	96	22	-	13.5	3.5	2.7	-	-
Kerala	94	76	82	-	1.2	1.3	11.4	-	24.7
Madhya Pradesh	90	87	46	27.7	66.9	10.2	.6	1.8	1.7
Maharashtra	100	100	21	26.5	54.0	21.5	.2	3.8	54.7
Orissa	100	100	69	31.1	22.7	1.8	.3	1.1	52.5
Punjab	100	47	11	53.3	16.6	6.2	3.6	15.2	17.5
Rajasthan	100	100	24	-	85.5	35.5	63.7	-	-
Tamil nadu	98	62	32	14.3	65.5	10.6	13	7.9	19.9
Telengana	-	-	-	31.8	26.9	17.0	1.4	3.8	16.1
Uttarpradesh	100	100	61	32.5	33.1	7.6	6.3	6.5	16.2
Uttrakhand	80	100	67	11.2	9.9	1.4	1.4	4.7	7.0
West bangal	100	90	19	37.4	11.9	0.0	1.2	.9	46.9
AllIndia	95	95	48	24.7	43.3	14.4	6.1	7.9	20.6

Source: Katyal et al.,(2016)

Rainfed ecosystem and its soil resources

Soil depth (cm)	Clay (%)	pH	Organic Carbon (%)	EC (dSm^{-1})	$CaCO_3$ (%)	CEC cmole (p+) kg^{-1}
Hot hyper -arid eco-subregion						
0-30	5.7	8.0	0.10	<0.2	6.0	2.3
30-60	6.2	8.2	0.10	<0.2	6.6	2.2

Kachchh Peninsular, hot hyper arid Eco-subregion						
0-30	41.6	8.7	0.10	1.7	1.3	28.6
30-60	50.3	8.5	0.10	3.1	3.0	29.3
Hot Typic -arid eco-subregion						
0-30	6.0	8.2	0.30	0.2	0.1	14.6
30-60	9.0	8.2	0.34	2.1	0.7	14.0
Deccan plateau hot arid eco-region						
0-30	11.0	6.5	0.30	<0.2	0.1	-
30-60	32.0	6.6	0.34	<0.2	0.7	-

Source: Yadav, J.S.P. and Singh, G.G (Eds.) 2000: Natural Resource Management for Agriculture Production in India.

Movement of ionic forms of nutrients:

For making effective INM schedule the knowledge of movement of ionic forms of nutrients in soil and plant system should be known for their availability and uptake pattern.

In soil system:

- Mobile: The nutrients are highly soluble and are not adsorbed on clay complex NO_3^-, SO_4^{-2}, BO_3^{-2}, Cl^-, Mn^{2+}
- Less mobile: They are soluble, but they are adsorbed on clay complex so their mobility is reduced NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Cu^{2+}
- Immobile : These nutrient ions are highly reactive and get fixed in soil $H_2PO_4^-$, HPO_4^{2-}, Zn^{2+}

In plant system:

- Highly mobile: N, P and K
- Moderately mobile: Zn
- Less mobile: S, Fe, Mn, Cl, Mo and Cl
- Immobile: Calcium and Boron

Components of nutrients

- Labile soil nutrient pool
- Inorganic or mineral fertilizers
- Organic manures /composts / vermicompost
- Biofertilizers

Nutrient management of arid and semi-arid fruit crops

Plant nutrient refers to those compounds, which are required by the plant as a source of body building material and for the energy, without which, it will not be able to complete its life cycle. The fruit tree nutrition is concerned with the provision of plant with nutrients as well as nutrient uptake and their distribution in their plant system. Integrated nutrient management refers to maintain the soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner. Therefore, it is holistic approach, where we first know what exactly required by the plant for optimum level of production, in what different forms these nutrients should be applied in soil and at what different timings with the best possible method, and how best these forms should be integrated to obtain the highest productive efficiency on the economically acceptable limits in an environmental friendly manner.

Sixteen elements are essential for the satisfactory development of any plant. On the basis of requirement by the plant, the nutrients have been classified into two groups: macronutrient and micronutrient (Table 2). Generally carbon, hydrogen, oxygen, nitrogen, phosphorus and potassium are absorbed in large quantities and therefore, referred to the macronutrients nutrients. The nutrients are required in small quantities are zinc, boron, iron, manganese, molybdenum, copper and chlorine and fall in the micronutrients category.

Table 2. List of essential macro and micro plant nutrient

Macronutrients		Micronutrients	
Carbon	Potassium	Zinc	Boron
Hydrogen	Calcium	Iron	Molybdenum
Oxygen	Magnesium	Copper	Chlorine
Nitrogen	Sulphur	Manganese	
Phosphorus			

At harvest of one tone fruits of some species absorbs different quantities of the nutrients are presented in table 2 . (Iyengar, 1993).

Table 3. Nutrient harvested by fruit crops

Fruit	Nutrient absorbed in kg/tone of the fruits		
	N	P	K
Aonla	4.3	1.7	7.3
Citrus	1.1	0.6	6.3
Date palm	4.2	2.0	9.0
Pomegranate	1.6	0.5	5.0
Ber	1.4	0.4	4.8

The data presented in the table 3 revealed that the fruit plants need higher amount of nitrogen and potassium and a small quantity of phosphorus. The nutrient requirement of fruit and vegetable crops may varies from species to species, therefore, precise estimate of the nutrient requirement in fruit trees, it is necessary to determine not only the quantities removed annually by the fruits and new shoots but also those accumulating over the years in other plant parts and the proportion of the of the currently fertilizer nutrients moving into different parts.

The requirement of nutrients depends upon soil fertility and age of the plant. The studies carried out at AICRP centre Faizabad revealed that in aonla orchard, 100g nitrogen, 50 g phosphorus and 50 g potash along with 10 kg FYM has been recommended for one year oldplant. This dose should be increased every year in the same proportion upto the age of 10 yeares and thereafted the doses should be stabilized. Hence according to this recommendation the manuring and fertilization should be done as per detailed here:

Table 4. Manure and fertilizer recommendations for aonla fruit crop

Age of plant	FYM (kg)	Nitrogen (g)	Phosphorus (g)	Potash (K)
1	10	100	50	50
3	30	300	150	150
5	50	500	250	250
10 and onwards	100	1000	500	500

Studies carried out at Faizabad revealed that in sodic soils breaking of hard pan is essential before filling the pits. Pit should be dug in May and June and rainwater should be allowed to collect in the pit and collected water should be thrown outside. After 2-3 washing the pit must be filled as give below for successful cultivation of aonla in sodic soils.

Table 5. Pit filling mixtures in sodic soils for aonla plantation

Pit size (m^3)	Soil pH	FYM (kg)	Sand (kg)	Soil amendments (kg)		
				Gypsum	Pyrite	Usar tor masala
1.0	8.0	40-60	10-15	-	-	-
1.0	8.5	40-60	10-15	5	4	3
1.0	9.0	40-60	15-20	10	8	6
1.0	9.5	40-60	15-20	15	12	9

Considering the organic matter is poor in soil, one third of nutrients should be given through FYM and rest through inorganic sources. Site preparation is an integrated practice aimed at achieving higher percent of survival and rapid initial growth of tree plants. A study was carried out at ICAR-CIAH, Bikaner for micro site development for faster establishment of pomegranate plants. In this study different pit size and various filling mixtures were tried and results revealed that in 60 cm^3 pit size filled with pond silt, sand and FYM gave the maximum survival and rapid plant growth of pomegranate var. Jalore Seedless as depicted in the following table.

Table 6. Response of pit size and filling mixture on the establishment of pomegranate

Treatment	Survival (%)	Plant height (cm)	Plant spread N-S x E-W (cm)	RWC of leaf
No pit	59.5	60.50	62 x 65	82.50
45 cm^3 pit size				
TS +M	71.1	88.20	95 x 99	89.50
TS+M+PS	72.0	90.10	100 x 96	87.60
TS+M+PS+F	72.5	95.60	98 x 102	86.50
60 cm^3 pit size				
TS +M	81.5	112.50	108 x 115	88.50
TS+M+PS	82.0	112.10	110 x 111	89.50
TS+M+PS+F	88.0	115.00	115 x 116	90.50

TS= Top soil, M= Manure, PS= Pond silt F= Fertilizers

To ensure high economic productivity to sustain the available soil nutrients status at the desired level, correct dose of fertilizers and manures must be applied by use of suitable diagnostic tools designated to avoid nutrients shortage and excesses. Several diagnostic methods have been developed to arrive at need based manuring schedule.

Nutrient management is extremely important for fruit and vegetable crops where many time quality of the produce assumes greater consideration than productivity per se. Application of too much nitrogen (N), in general, results in oversized, poorly coloured fruit with poor keeping quality. Too little N also cause problems poor fruit set, small fruit, pale foliage and stunted growth. Excessive or deficient of other nutrients also can result in serious problem in fruits. Many fruit crops are heavy removers of nutrients and high yield can only be sustained through the application of optimal doses of nutrients in balanced proportion. Diagnosing nutrient deficiency symptoms in fruit and vegetable crops can help in proper nutrient management. Use of soil and or tissue analysis may help to confirm whether symptoms are nutritional or due to some other factors.

The productivity of fruits is comparable to China and other leading fruit producing countries of the world but India still lags behind USA and Indonesia in terms of productivity. This might be because of improper orchard management particularly nutrient management. The continuous use of chemical fertilizers particularly N, P and K has impaired the soil fertility and decreased the factor productivity. The increasing cost of fertilizers and poor purchasing capacity and their negative effect on soil health has led to intensified attempts to the use of biofertilizers and organic matter with inorganic fertilizers. The Indian soils are mostly poor in nitrogen and phosphorus and 50% soils are low in potassium.

The main objective behind INM system is to manage and sustain the agricultural productivity and improve the farmers profitability through the judicious and efficient use of chemical fertilizer, organic farming , green manure and compost including vermicompost , crop residues and biofertilizers. However, this does not mean adding everything everywhere, rather, a well considered practical and efficient blend of diverse nutrient source is required which can produce desired yield and maintain soil health on long term basis. INM system helps to restore and sustain crop productivity, and also assists in checking the emerging micronutrient deficiencies. Further, it brings economy and efficiency in use of fertilizer.

Major components of integrated nutrient management are (i) integration of soil fertility restoring crops like green manures, legumes, etc.; (ii) recycling of crop residues; (iii) use of organic manures like FYM, compost, vermicompost, biogas, slurry, poultry manure, Biological composts, Press mud cakes, Phospho-compost (iv) utilization of biological agent; (v) efficient genotypes; (vi) balanced use of fertilizer nutrients as per the requirement and target yields. Strong and convincing evidence indicates that INM practice could be an innovative and environment friendly practice for sustainable horticulture in arid region. In general following are the common sources of nutrients and type of material which can provided nutrients are given here:

Inorganic sources	Straight & Mixed fertilizers
Organic sources	Manure, Compost, Green manure
Biofertilizers	Nitrogen fixer, PSB, VAM
Crop management	Legumes, crop rotation, etc.

Integrated approach of nutrient application

- Soil management
- Soil moisture management
- Fertilizer management
- Crop management

Before adopting the integrated nutrient management approach in horticultural crops, farmer should analyze their field soil and evaluate the soil conditions on the basis of the criteria given in the table 3.

Soil Management

Assessment of soil nutrient status is based on the assumption that root extract nutrients from the soil in a manner comparable to chemical soil extractants and that there is a direct relationship between levels of extractants and nutrients in soil and their uptake by plants. Chopra and Kanwar (1986) stated that the soil chosen for plantation of any fruit and vegetable crops, initially, should be brought to an optimum fertility level after its chemical analysis. The fertility parameters are presented in table 4 for the soil categorization.

Table 7. Soil categorized for the fertility parameters

Soil Parameters	Category		
	Low (<)	Medium	High (>)
Soil pH (1.2.5)		6 to 7	
Organic carbon (%)	0.50	0.50 to 0.75	0.75
Available N (kg /ha)	280	280 to 560	560
Available P_2O_5 (kg /ha)	25	28 to 56	56
Available K_2O (kg /ha	140	140 to 280	280
Sulphur (ppm)	10	10 to 20	20
Zinc (ppm)	0.5	0.5 to 1.0	1.0
Iron (ppm)	5	5 to 10	10
Copper (ppm)	0.2	0.2 to 0.4	0.4
Manganese (ppm)	5	5 to 10	10
Molybdenum (ppm)	0.05	0.05 to 1.0	1.0
Boron (ppm)	0.1	0.1 to 0.5	0.5

Chopra and Kanwar (1986)

An assessment of nutrient additions, removals, and balances in the agricultural production system generates useful, practical information on whether the nutrient status of a soil (or area) is being maintained, built up or depleted. Estimates of nutrient input and output allow the calculation of nutrient balance sheets both for individual fields and for geographical regions. This is primarily because nutrient removals by crops far exceed the nutrient additions through manures and fertilizers. For the past 50 years the gap between removals and additions has been estimated at 8 to 10 Mt $N+P_2O_5+K_2O$ per year (Tandon, 2004). For example, nutrient losses through soil erosion are alarmingly large, but are rarely taken into account. Nutrient loss through soil erosion is second only to nutrient removal as a result of crop production. An annual loss of 8 Mt plant nutrients has been mentioned through 5.3 billion t of soil lost by water erosion (Prasad and Biswas, 2000). Estimates of removals through leaching and gaseous losses are not available in Cropping based system (Tondon, 2004).

Table 8. Nutrient balance sheet in dry land agriculture

	$N+P_2O_5+K_2O$ (Mt)
Estimated additions(fertilizers)	1.0 mt
Estimated removals (crops)	7.4mt
Balance	-6.4mt

(Tandon 2004)

Leaf analysis

Leaf is the center of physiological activity in plants where translocated minerals are known to involved in such vital reactions such as photophosphorylation, synthesis of chlorophyll, amino acids, nucleic acid, proteins *etc*. and consequently any deficiency of a nutrient would drastically effect the related activity. Leaf analysis methodology consists of leaf sampling technique, sample preparation, analysis and making diagnosis and nutrient recommendations using leaf nutrient guide. A large number of fruit plants, environmental and procedural factor vitiate leaf nutrient concentration, however, a careful worked out sampling technique for index tissue will make a sound foundation of leaf analysis programme. Modern methods of interpretation of leaf analysis data such as DRIS and Boundary Line Concept can be adopted to diagnose the growth/ yield limiting nutrients and to recommend the optimum use of nutrients. The merits of leaf analysis are: (1) understand the internal function of the nutrient in the plant, (2) confirm toxicity/ deficiency (3) identify mineral imbalance (4) ascertain whether applied nutrients have entered in the plant system and (5) identify hidden hunger

Method of leaf sampling

There are various steps in carrying out tissue analysis (a) Leaf sampling (b) Sample handling and processing (c) Leaf analysis methodology (d) Leaf nutrient norms (e) Diagnosis of nutrient disorders (f) Interpretation of data and nutrient recommendation.

Leaf sampling: The general principle in leaf sampling is to collect recently youngest mature leaf or petiole considering the following factors.

a) Factors associated with crops

(i) Plant part (ii) Leaf part (iii) Leaf age (vi) Leaf portion (v) Flush (vi) Type of shoot (vii) Leaf size (viii) Leaf health (ix) Alternate bearing (x) Cultivars/Root stock (xi) Crop load (xii) Plant size (xiii) Sample size

b) Environmental factors

(i)Temperature (ii) Leaf exposure (iii) Season (vi) Geographical direction (v) Moisture (vi) Sampling height (vii) Spray of chemicals (viii) Dent (ix) Soil fertility variations

Sampling handling

(a) Time taking during transit (b) Working technique (c) Temperature of even (d) Processing equipment (e) Analytical technique .

Common guidelines for leaf and petiole sampling

1. Select a vegetative terminal unless otherwise specified
2. Sample at chest height (>2 m)
3. Collect composite sample from north, south, east and west
4. Select leaves which are fully exposed to light

5. Collect sample prior to irrigation and fertilizer application
6. Collect 50 for small size leaves, 30 leaves in medium sized and 20 leaves having large leaves
7. Avoid sampling from soiled, diseased/insect
8. Avoid sample contamination
9. Index tissue sampling technique in fruit crops for yield and quality

The leaf sampling technique has been standardized for most of the arid zone fruits using the leaf sampling norms and the details are given in table 7

Table 9. Leaf sampling technique and nutrient norms for fruit crops

Crop	Plant part, age, stage and position	Sample size	Optimum leaf nutrient (%)		
			N	P	K
Mango	Collect 4-5 month-old leaf from current season's growth from middle part of the shoot	30	0.84-1.53	64-147	0.52-1.10
Mandarin	Basal 6 month-old leaf from current growth in march	50	3.00-3.50	150-250	0.90-1.10
Acid lime	Basal leaf at 5- month-age from current Season's growth	50	1.96-2.30	120-290	1.60-1.90
Sweet Orange	Basal leaf 6- month-age from current season's growth emerged in march to September	50	2.00-2.20	100-110	0.40-1.20
Lemon	Basal 6- month-old leaf from current Season's growth	50	2.20-2.70	150-300	1.00-2.00
Guava	Third pair of leaf from apex in August/ December	30	1.60-2.40	150-300	1.30-1.70
Pomegranate	Eight leaf pair from tip in 15 April flush for February crop and from August flush for June crop	50	1.20-1.40	100-200	1.00-1.40
Ber	Fifth leaf from tip of secondary and tertiary shoot in June	50	1.50-2.20	140-450	1.60-2.00
Phalsa	Fourth leaf from growing tip one month after pruning	30	1.50-1.60	150-200	1.60-2.00
Custard apple	Fifth leaf from growing point in May/June	50	1.40-1.80	70-100	0.80-1.20
Fig	Basal leaf from mid-summer growth	40	2.00-2.50	90-100	0.70-0.90

(Source: Bhargava,B.S., 1999. Leaf analysis for diagnosing nutrients need in fruit crops)

Interpretation of leaf analysis data

Critical nutrient concept

This technique has been used by *Subramanian, et al.,* (1974), Samra and Thakur (1978), Chaddha *et al.* (1980) and Bhargava (1992) to divide orchards expected to give a relatively large response to a particular nutrient from those expected to give little or no response, assuming that other nutrients are present in adequate amounts. A dividing line between two categories (high and low) might be determined approximately by a graphical technique in which vertical and horizontal lines are superimposed on a scatter diagrams so as to maximize the number of points in the positive quadrants. The horizontal lines are 90% probability line and the vertical line is so drawn that maximum points of the scatter diagram are on two positive quadrants. The vertical line, which is determined by eye judgment, is known the critical level.

Yield groups and nutrient content

Samra, *et al*., (1978) adopted grouping of yield level in mango e.g. less than 150, 150-300 and more than 300 fruits/tree to work out leaf nutrien standards (Table 6). There were variations between the critical limits reported for young trees in sand culture and those actually observed in fully-grown trees in orchards.

Table 10 . Leaf nutrient guides for the mango cv. Dashehari

Nutrient	Critical limits
Nitrogen (%)	1.23
Phosphorus (%)	0.06
Potassium (%)	0.54
Calcium (%)	1.71
Magnesium (%)	0.91
Sulphur (%)	0.12
Iron (ppm)	171
Manganese (ppm)	66
Zinc (ppm)	25
Copper (ppm)	12

Diagnosis and Recommendation Integrated System (DRIS)

The DRIS was developed by Beaufils (1957, 1971 and 1973) as an objective means of coping with the difficulties inherent in diagnostic procedures. It has long been recognized that the nutrient concentrations change markedly as plant age. In general the foliar concentrations of N, P, K and S tend to decrease during aging. In contrast Ca and Mg concentrations tend to increase.

The dynamic nature of plant tissue nutrient concentration, which has been illustrated by the examples cited, imposes severe limitations on the use of foliar analysis of diagnostic purposes (Bates, 1971& Bouma, 1983). Critical nutrient value or sufficiency range system generally depend on diagnostic norms derived from plant tissue of a specific age and categorize plant health based solely on nutrient concentration. Thus, the age of growth of the sampled plant is a prime concern. If the concentrations of the nutrients are decreasing during aging, then the ratios N/P, N/K and P/K or their reciprocals should remain fairly constant. Similarly, because Ca and Mg concentrations usually decrease during aging, a quotient formed from these nutrients (Ca/Mg or Mg/Ca) should also produce a content value. Furthermore, products of two nutrients, one of whose content decreases with time should also be fairly constant nevertheless, these forms of expression are often less affected by aging processes and so present an opportunity to expand the usefulness and accuracy of foliar diagnoses.

$$N\%/P\% = (100N/DM)/(100P/DM) = (100N/DM) * (DM/100P)$$

Where DM is dry matter.

Even though a ratio such as N/P can be easily calculated from N% and P%, commonly reported values, interpretation may be more difficult (Sumner, 1978). For example, if the optimum leaf N/P ratio is 10.04 and an individual sample has a value of 14.00, it is impossible to determine whether N is to high, P is too low or N is too low and P is too low. Taking a holistic approach and considering a single ratio for a single nutrient (N/P, N/K, etc.) is even more confusing than considering a single ratio and is probably one reason that dry matter ratio have been preferred than nutrient ratios.

DRIS Norms

In contract to the classical field experiment approach to leaf analysis the DRIS employ survey technique where a large number of randomly distributed sites throughout the area are selected. At each site samples of leaf and soil are taken for analysis and the details of applied manures and fertilizers are recorded. Experiment conducted at one place employing various levels of 1, 2 and 3 plant nutrients can also be used to develop DRIS taking the following steps:

1. Define the parameters to ber improved and the factors likely to affect them.
2. Collect the reliable data available from fields and experimental plots.
3. Study the relationship between yield and environmental and external factors such as soil composition, weather conditions, *etc.* so that the most favourable condition can be determined in a particular case.
4. Study the relationship between yield and internal parameters such as petioles compositions using following steps
    a. Each internal plant parameter is expressed in as many forms as possible i.e. N/DM, DM/N, N/P, P/N, N*P, *etc.*

b. The whole population is divided into a number of sub-groups based on yield into two groups of high and low yield.

c. The means of such population are calculated for various forms of expression.

d. If necessary, class interval limits between average and outstanding yields are readjusted to so that means of below average and average yielding population remains comparable.

e. Chi-square test is used to know that sub population confirm to a normal distribution.

f. The variance rations between yields of sub-populations for all norms of expressions are calculated together with the coefficient of variation.

g. The forms of expressions, for which significant variance ratio are obtained and the mean values for the population are the essentially the same are selected and related to one another in expression with common nutrient.

DRIS index Interpretation

The nutrient indices should some to zero. The more negative an index, the more lacking is the nutrient it represent relative to other nutrients used in the diagnosis. Alternatively, a large positive nutrient index indicates that the corresponding nutrient is present in relatively excess quantity. For example indices for N, P and K are as follows:

N index= [f (N/P) + f (N/K)]/2 = 45.96 + 40.27)/2 = 43

P index = [-f (N/P) – f (K/P)/2 = (-45.96 + 5.61)/2 = -20

K index = [-f(N/K) + f(K/P)/2 = (-40.27 - 5.61)/2 = -23

The N index is (+43)> > P index (-20) > K index (-23).

This is interpreted to mean that in terms of relative importance to yield, K is more required than P, which is more required than N. In plant sample with optimal nutrient balance, all nutrient indices would equal zero. However, it is important to recognize that an individual nutrient is not necessarily present in optimum concentration if its index equal zero.

Optimum leaf nutrient status of the important fruits

Leaf is the principle site of plant metabolism and changes in the nutrient supply are reflected in composition of leaf. The concentrations of the nutrient in leaf at a specific growth stage are related to the performance of the crop. The leaf nutrient levels required for optimum production in some important fruit crops have been presented in table 7. Efforts in the nutritional management programme should be directed towards the maintenance of these levels in tree leaves before flowering.

Table 11. Optimum leaf nutrient status of some important fruit crops

Fruit	Nutrients											
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	References
Mango	1.23	0.06	0.54	1.71	0.91	0.12	-	171.0	66.0	25.0	12.0	Samra *et al.* (1978)
Citrus	2.50	0.14	0.90	4.20	0.43	0.25	-	90.0	112.5	62.5	10.5	Reuther *et al.* (1967)
Guava	1.70	0.50	1.30	2.10	0.46	-	10.0	-	-	77.5	75.0	Singh (1981)
Grape	1.75	0.56	1.66	0.94	-	0.20	-	-	125.0	92.0	-	Bhargava and Chadha (1993)
Litchi	1.47	1.03	-	-	-	-	-	-	-	-	-	Ghosh *et al.* (1986)
Sapota	1.66	0.08	0.80	0.83	0.48	0.07	-	100.0	39.3	15.7	6.7	Annapurna *et al.* (1988)
Pomeg ranate	2.50	0.19	1.47	-	-	-	96.0	199.0	196.0	55.0	-	Shende (1977) and Bambal (1991)
Ber	2.50	0.25	1.82	1.21	0.45	-	-	-	-	-	-	Khanduja and Garg (1984)

Manure and fertilizer recommendations for some tropical and subtropical fruits

To optimize the soil fertility level and to keep the plant nutrient status above the critical levels, a number of recommendations for the fruit crop are available region wise. Based on the averages of these recommendations and results available under the All India Coordinated Research project on fruit crops, the recommendations are being made for different fruit crops are presented in Table 10. Besides these recommendations application of Zinc and iron has become common. Spray of boron has helped in aonla and mango. Therefore, regular application of micronutrients is necessary to get an optimum production per unit area.

Table 12. Manure and fertilizer recommendations for some tropical and subtropical fruits

Fruit	FYM (Kg/plant)	Nutrient recommendation (g/plant /annum)		
		N	P_2O_5	K_2O
Mango	75	775	500	700
Citrus (Acid lime)	50	900	250	500
Guava	60	360	180	180
Pomegranate	30	600-700	200-250	200-250
Ber	50	500	200	300
Sapota	50	1,000	500	500
Aonla	50	1,500	750	1,000
Date palm	30	1,000	500	500

To meet the requirement of nutrients recommendation for different fruit crops, it could either be inorganic source or organic source, but each one has its limitations. General consensus is that, it is desirable to meet fifty per cent of nitrogen through organic sources and fifty per cent through fertilizers for good performance; otherwise continuous use of inorganic fertilizers is detrimental to the soil health. Addition of the organic matter would not only provide the needed nutrient including micro-nutrient at a slow pace for continuous growth, but it would also improve the physical condition of soil. Furthermore, it would also improve the aeration of soil, providing a good scope for the better root growth and increased production. Fortunately, in fruit crops from the very beginning, application of organic manures has been practice and all our recommendations have organic component. It should be pursued. The evidence that the organic manures and biofertilizers reduce the need of chemicals supplying specific micronutrient and to minimize the risk of inducing deficiencies of many other micro-nutrients also commands itself a sound practice for a sustainable horticulture based on the low external chemical input.

Time and method of nutrient application

To improve the efficiency of applied nutrients, they should be made available at an appropriate time, like new vegetable growth phase, fruit growth phase and they should be placed near the active roots. These timings and the zones of activity vary from fruit to fruit and are influenced by cultural practices in different regions and some other factors. Some of the standards developed for different fruit crops as reviewed by Chundawat (1997) are presented below.

Mango

In two doses, i.e. soon after the harvest, full does of FYM, phosphorus and potash and 50 per cent of nitrogen and rest of the 50 per cent nitrogen at pea stage of the fruit development should be applied.

(b) Unirrigated

On the onset of monsoon, full does of FYM, phosphorus and potash and 50 per cent nitrogen should be given and 50 per cent of nitrogen should be applied after the end of the monsoon.

Citrus

In arid conditions citrus crop can be grown successfully with assured irrigated conditions. In such situations, organic manure should be applied in the month of January and inorganic fertilizers in two or three equal split doses, i.e. first does 15 days before the expected flowering, second does after fruit set and third does soon after the rainy season is over (September-October).

Guava

In guava, the time of nutrient application is governed by the choice of crop to be taken and generally winter season crop, which is based on June-July flowering gives a good remuneration. Therefore, total quantity of the organic manure, phosphorus and potash and half does of the nitrogen should be applied with onset of monsoon (June-July). The balance nitrogen should be applied in October-November.

Grape

North India

Total quantity of the organic manure, phosphatic fertilizer and half does of the nitrogen and potash should be applied immediately after winter pruning and half of nitrogen and potash should be applied after berry set.

(b) Tropical condition

Thirty per cent of the nitrogen and 50 per cent of the phosphorus in April; 30 per cent nitrogen and 40 per cent potash in May; 20 per cent nitrogen and 50 per cent phosphorus in October; 20 per cent nitrogen and 30 per cent potash in November and rest 30 per cent potash in December should be applied.

Pomegranate

Choice of crop determines the timings of nutrient application. In arid conditions, generally *mrig bahar* crop is being taken. Full does of the organic manure, phosphorus and potassium and half does of the nitrogen should be applied in circular trenches at 20-30cm deep and 1m away from main shoots in the month of June just after first irrigation of *bahar* treatment and second half dose of the nitrogen should be applied after three weeks.

Ber

The total quantity of the organic manure, phosphorus and potassium and half does of the nitrogen should be applied after pruning in June- July coinciding with monsoon in circular trenches at 15-20cm deep and 1-1.5m away from the main trunk and half does of the nitrogen should be applied in post monsoon period, i.e. September-October.

Sapota

a. **Rainfed:** Under rainfed condition, the fertilizers should be applied once in a year, i.e. before monsoon.

b. **Irrigated**: The total quantity of the organic manure and half does of the chemical fertilizer should be applied in beginning of the monsoon and second half does in the month of October.

Aonla

The total quantity of the organic manure, phosphatic, nitrogen and potash should be applied in equal two splits doses to mature bearing tree once after fruit set and again during fruit growth and development. The plants need to be irrigated after fertilizer application. All fertilizer and FYM should be placed in trenches under full canopy covered are.

Active Root Zone of fruit crops for nutrient application

For the efficient utilization of applied nutrient, it is essential to know the active root zone, so that the nutrients may be placed around this zone, to be made available to the plant. The active root zones as well as place of the application of fertilizers as summarized by Chundawat (1997) have been presented in table 11.

Table 13. Active root zone of some important fruit plants and the place of fertilizer application

Fruit	Area of the active root zone	Place of the application
Mango	82 to 88.5 % of the active roots are located within a radius of 300 cm with the highest activity at 120 cm from the trunk.	One meter away from the main trunk under the drip and mix thoroughly.
Citrus	Within a redial distance of 120 cm at the depth of 15 to 30 cm.	30 to 45 cm away from the trunk under the drip followed by light working.
Guava	At 30 cm distance from the trunk at depth of 30-60 cm.	Within the drip at a depth of 15-20 cm.
Litchi	Shallow and on the surface.	Soil surface with light working.
Pineapple	Highly restricted.	9 to 10 cm away in 10-15 cm deep Strip around the plants.
Ber	50 to 75 cm deep under the drip.	Under the drip and mix Upto the depth of 30 cm depth.
Sapota	Under the canopy within a depth of 0 to 30 cm.	Under the canopy and mix in the soil Upto 15 cm depth.
Date palm	Upto a radius of 1.7 m from the bole.	Around the tree upto a radius of 2.0 m.

Foliar application of nutrients

Foliar application is based on the principle that the nutrients are quickly absorbed by leaves and transported to different parts of the plant to fulfill the functional requirement of nutrition. Foliar application of the nutrients is obviously an ideal way of evading the problems of nutrient availability. This method is highly helpful for the correction of trace element deficiencies to restore disrupted nutrient supply and to overcome stress factors limiting their availability. This method has been commercialized in a number of fruits, like citrus, pineapple, guava etc.

Application of biofertilizers in horticultural crops

Increased fertilizer cost and the awareness of environmental pollution due to fertilizer runoff necessitated the use of biofetilizers for the development of more efficient fertility management programme. However, very little work has been done on the use of biofertilizers in fruits.

In case of pomegranate, nitrogen use efficiency has been increased through the use of 250 g *Azotobactor* culture with hundred-gram nitrogen per plant. Similarly, VAM (Vescular Arbuscular Mycorrhiza) fungi are of the great significance for fruits. It forms a symbiotic association with the roots of plants and helps them in transfer of the nutrients from the soil to the root system. In India, studies on the VAM fungi have so far remained confined to some inoculation trails in some fruits, like citrus, banana, lichi, mango and papaya indicating an increased efficiency of the water and nutrient uptake by host plant. However, more studies are required to adjudge the role of biofertilizer in production of the fruits.

Management of the farm waste for INM

Biomass is available in the form of leaf fall or plant residue and it may become an integral part of the soil fertility management. The organic farmers, who combine earthworm culture in plant basin with the degradation of such biomass and have come out with some excellent results in sapota, mango, completely eliminating inorganic fertilizer application, are intelligently managing this. A study carried out at Central Institute for Arid Horticulture, Bikaner using the different types of manure either as a sole source or in combinations with inorganic fertilizers in pomegranate crop and results depicted in Table 5 revealed that application of vermicompost alongwith inorganic fertilizers in 50: 50 ratio gave the best results in plant growth, fruit yield and fruit quality. Thus integration of inorganic and organic sources of nutrients may be proved better in sandy soils of arid region for supplying required nutrients to the crop as well as improve the physical properties of the soil.

Nutrient imbalance status in Indian soils

Nutritional stress in plants results from nutrient imbalances in the soil. Balanced plant nutrient supply ensures high yields and quality food. It refers to application of different nutrient elements in the proportion required for optimum growth of plants. Balanced nutrition eliminates all deficiencies.

When nutrition becomes imbalanced, the plant becomes stressed and does not develop normally and result is low yield and poor quality produce. Fertilizers are meant to correct nutrient deficiencies and improve soil fertility so that higher productivity is sustained. Due to intensive cultivation and imbalance of nutrients, the deficiency of secondary and micronutrients have developed in addition to N, P and K **(**Muralidharudu, *et al.,* 2011**).** Soil analysis data has shown the soils of 93%, 91% and 51% were low in available N, P, and K, respectively. Incidences of micronutrient deficiencies are also increasing. Among the secondary and micronutrients, 41% of soils have been found deficient in S, 44% in Zn, 15% in Fe, 8% in Cu, 6% in Mn, 33% in B and 13% in Mo (Shukla, *et al.,* 2012). The consumption ratios are more towards N in vegetables than in the fruits. Out of total NPK usage, the share of N was 50% in vegetables and 44% in fruits. In contrast to the overall fertilizer consumption, where in the share of N, P and K is 64%, 26% and 10% respectively, the general nutrient uptake and removal pattern in horticultural crops shows that the highest uptake is that of potash, much above that of N. Although, potash consumption by horticultural crops, itself and in relation to N, is higher than in food grains, it is still well below the quantities removed by the fruits and vegetables (Srivastava, *et al.,*2008).

Low level of nutrient input is one of the reasons for relatively low yields, much below the realizable potential. There are number of reasons why better nutrient management in horticultural crops deservers serious attention:

- Obtain higher yield and higher returns,
- Increase the returns from establishment expenses of orchard,
- Help to improve the nutritional standards of the people by providing adequate supply of fruits and vegetables at affordable prices,
- Provide greater and better quality raw material for fruit and vegetable processing industries To help in earning foreign exchange through the export of high quality produce in fresh or processed form.

Table 14. Soil nutrient balance sheet in India

	Gross balance sheet ,000t			Net Balance sheet ,000t		
Nutrient	**Addition**	**Removal**	**Balance**	**Addition**	**Removal**	**Balance**
N	10923	9613	1310	5461	7690	-2229
P_2O_5	4188	3702	486	1466	2961	-1496
K_2O	1454	11657	-10202	1018	6994	-5976
NPK total	16565	24971	-8406	7945	17645	-9701

Table 15. Nutrient removal by different horticulture crops

Crop	Yield (t/ha)	Nutrient removal (kg/ha)		
Fruits		N	P_20_5	K_2O
Mango	15	100	25	110
Banana	57	322	73	1180
Citrus	20	22	12	57
Apple	29	18	2	40
Pineapple	84	150	45	530
Papaya	80	225.5	60	180
Grape	20	169	40	180
Vegetables				
Potatao	28	202	50	225
Brinjal	60	175	40	300
Tomato	37	104	22	141
Cauliflower	50	250	100	350
Cabbage	37	112	28	112
Beans	35	130	40	160
Green Peas	25	55	20	40
Lettuce	30	107	30	234
Spinach	25	120	45	200
Celery	20	140	55	220
Onion	30	73	36	68

Source: Ganeshamurthy, et al., 2011

Fertilizer is one of the costliest inputs in agriculture and the use of right amount of fertilizer is fundamental for farm profitability and environmental protection. Dumping of fertilizers by the farmers in the fields without information on soil fertility status and nutrient requirement by crop causes adverse effects on soil and crop regarding both nutrient toxicity and deficiency either by overuse or inadequate use (Ray, *et al.*, 2000). Managing the location specific variability in nutrient supply is a key strategy to overcome the current mismatch of fertilizer rates and crop nutrient demand in environments (Dobermann and Cassman, 2002). To enhance farm profitability under different soil-climate conditions, it is necessary to have information on optimum doses for crops. Traditionally, to determine the optimum nutrient doses of most appropriate method is to apply fertilizer on the basis of soil test and crop response studies. Improved crop management needs to be envisaged with adequate emphasis on balanced plant nutrition for stability in production, appropriate soil nutrient resilience. Most often, prior estimation of the actual nutrient requirement of a particular crop, native soil fertility status, has been ignored. Soil test based fertilizer use is must for sustainable agriculture (Rao and Srivastava, 2000) .Thus, need based estimation of N, P, and K requirements may call for soil test crop response (STCR) based nutrient management, which can be represented in a linear relationship, correlating their requirement with a specified target yield depending on their native soil status. The fertilizer application by the farmers in the field without knowledge of soil fertility status and nutrient requirement of different crops usually leads to adverse effect on soil as well as crops by way of nutrient deficiency or toxicity due to over use or inadequate use of fertilizers.

In this regard, targeted yield approach has been found to be beneficial which recommends balanced fertilization considering available nutrient status in the soil and the crop needs. Targeted yield approach was first developed by Ramamoorthy, *et al.*(1967) established theoretical basis and experimental technique to suit it to Indian conditions. This target yield equation (TYE) is considered as a soil-and fertilizer-based precision farming strategy to meet nutrient demands for a specified yield (Balasubramanian, *et al.,* 1999). Location specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers and levels of targeted yield for similar soil classes and environment

Soil testing procedures have been developed to relate extractable nutrient levels to crop growth and yield. Nitrogen, phosphorus, potassium and micro -nutrients are most likely to be limiting crop growth. The nitrogen status in the soil is quite dynamic, and predicting its availability over time is difficult. The availability of phosphorus and potassium in the soil is fairly stable over time unless major additions are made. Additions of these two elements and micronutrient over time in manures and commercial fertilizers have caused significant increases in the available levels in the soil. Balance nutrition of crop should ensure that the nutrients in available forms are in adequate quantities and right proportions as per the requirement of the crops. Therefore, the addition of fertilizers and manures should be such that in combination with indigenous nutrient supply, they provide the nutrients in appropriate quantities and ratios matching the plant requirement for desired yield goals. Different approaches of fertilizer recommendations in vogue are briefly discussed here.

Recommendations based on soil fertility rating

Most of the recommendations prescribed by the soil testing laboratories in India are based on soil fertility ratings, the medium soil fertility being equated with general recommended dose. In low and very low or high and very high categories the fertilizer doses are raised or lowered by 25 to 50 percent of the general recommended dose as per situation. Since, nutrient recommendations with this approach are irrespective of yield goal and variation in soil type. These may perform well for moderate yield levels under optimal soil conditions. For high yield expectations as under commercial farming, however the approaches taking in to account yield target are more suitable.

Critical limit based on recommendations

The critical level concept was developed by Cate and Nelson, (1965). Critical limits is the level of soil available nutrient above which sufficiency level sets-in, and that nutrient remains no longer a primary limiting factor from crop production. This concept considers that soil test values should be inversely proportional to the yield gains from applied nutrients. Thus, probability of getting economic response to fertilizer application in the soil below the critical limit is quite high, whereas in soils below the critical limit is quite high, whereas in soils having the nutrient above the critical limit, such a probability is quite low. The critical level varies depending on the soil types. This concept is useful for categorizing the soil in to responsive and non-responsive groups, but the quantification of fertilizer dose for individual situations is not possible. It is more suitable for micronutrient recommendations for responsive category soils.

Tissue testing for nutrient recommendation in horticultural crops

Soil tests, although useful in predicting fertilizer and soil amendment needs, are not the final measure of what nutrients a plant will absorb. Because temperature, moisture regimes, soil acidity and other soil conditions may modify the uptake of different nutrients by plants, it is sometimes necessary to determine nutrient content in the plants to evaluate the actual soil nutrient availability status. Total plant analysis and green tissue analysis are the most important diagnostic techniques for determining deficient, sufficient or excessive amounts of essential elements in plant tissue. Tissue tests are of immense help to farmers in overcoming many problems and are the better approaches for nutrient management of horticultural crops. The success of this approach depends mainly on selecting the right tissue and deciding on the right stage of sampling. The sampling guide and the optimum nutrient levels developed for different horticultural crops are given (Table 16).

Table 16. Plant tissue sampling guidelines for horticultural crops

Crop	Plant part	Growth stage/ Time
Fruit Crops		
Custard Apple	5th leaf from	Apex 2 months after new growth
Fig	Fully expanded leaves, mid-shoot current growth	July-August
Citrus	3 to 5 month-old leaf from new flush. 1st leaf of the shoot	June
Guava	3rd pair of recently matured leaves	Bloom stage (August or December)
Pomegranate	8th leaf from apex Bud differentiation.	In April for February and August for June
Sapota	10th leaf from apex	September
Phalsa	4th leaf from apex	One month after pruning

Ber	6th leaf from apex from secondary or tertiary shoot.	Two months after pruning
Vegetable Crops		
Cluster bean	1st fully developed leaf	
Cucumber	5th leaf from tip	Flower bud start to small fruit
Brinjal	Leaf blades with midribs minus petioles from most recent fully developed leaf	
Garlic	Most recent fully matured leaf	Pre-bulb
Peas	Most recent fully developed leaflet	First bloom
Tomato	Leaves adjacent to inflorescence	Mid bloom

Integrated nutrient management is the combined application of chemical fertilizers along with organic resource materials like, organic manures, green manures, biofertilizer and other organic decomposable materials for crop production. Integrated nutrient management is a practice where all source of nutrient namely organic, inorganic (chemical fertilizer), biofertilizer can be combined and applied to soils so that crop growth is enhanced and can get good yield with quality product.

Integrated nutrient management (INM) has to be considered an integral part of any sustainable agricultural system.

Soil fertility in systems under arid and semi-arid conditions referred to as dry areas or dry lands, is constrained by environmental extremes of hot and cold temperatures, as well as by low water availability. With some exceptions, these soils have inherently low fertility, low availability of nitrogen and phosphorus, low water-holding capacity, high pH, low soil organic matter shallowness, stoniness, and other specific problems (Matar, *et al*., 1992). These areas are given the vulnerability of these lands to degradation and the arid ecology of Rajasthan suffers from inherent soil or land degradation, caused by overgrazing, lack of adoption of modern farming technologies, limitation of the farmers in ability to replenish nutrients lost in the continuous cultivation, annual bush burring, soil and wind erosion among others. Hence, these lands are of great global significance even if their agricultural production potential is relatively low. There is considerable information on the use of fertilizers and legumes to enhance soil fertility in dry areas, including timing and amount of fertilizers, application methods, crop responses, and effects of crop rotations and also on dryland fallowing and water use, however, despite evidence that some nutrient inputs are required to sustain higher agricultural production on these lands. It is recommended that the application of INM is needed, not only to replenish soil nutrients but also to improve the physical, chemical and biological properties of soil and increase the agriculture production with farmer income.

Nutrients losses in arid region

Sandy soil which is remarkably available in the arid region is made up of coarse large soil particles which are mainly composed of the mineral quartz. Sand soil particles are loosely packed and they create large pore spaces which encourage the easy circulation of air in the soil, hence the soil type is said to be well aerated. It is gritty to touch and glassy in appearance due to the presence of the mineral quarts in the soil. The soil type due to the inherent large pore spaces allows easy movement of water though the soil and as a result, it is said to be porous. This soil is liable to excessive leaching of plant nutrients due to the action of percolating water being the force of gravity; otherwise called gravitational water. (Ugboh and Ulebor, 2011). Thus the leached plant nutrients may no longer be available for the plants to absorb. It has low capillarity force due to the large pore space. It is as a result of this that the soil is incapable of allowing soil water to rise up to the subsoil level, where it could be available for crop plants to absorb during the dry season. Thus, this accounts for the wilting of leaves of shallow rooted crops in the semi-arid regions. Sandy soil is said to have good physical properties which are constraints to the soil fertility (Ugboh and Ulebor, 2011). Continuous cropping of arid soil has resulted in a rapid decline in soil organic matter in the surface soil during the first few years following land clearing (Brams, 1971 and Juo, *et al.,* 1995). Continuous cropping cause significant decline in soil pH, exchangeable Ca and Mg levels. This is more pronounced when acidifying fertilizers are used. Research findings accounted for the decline of crop yields under continuous cropping as having been attributed to factors such as acidification, soil compaction and loss of soil organic matter (Juo, *et al.,* 1995).

Influence of INM practices on biological, phyco-chemical properties of soil and horticultural crops

The soil physico-chemical properties of the soil under different INM treatments were measured periodically.(Table 17) reported the changes in the different properties over the year and revealed that pH of the soil did not change much when only chemical fertilizers were applied but on the application of FYM, pH of the soil lower down. On the application of biofertilizers pH of the soil did not change much. Data regarding the organic carbon status revealed that application of FYM increased the level of OC while inorganic fertilizers and biofertilizers have not changed the OC status of the soil. Available P and K_2O also have been affected by the application of INM treatments and recommended dose of N, P and K increased the availability of P and K_2O in the soil and their maximum status were recorded on the application of application of inorganic fertilizers along with FYM. Likewise Availability of zinc and iron content in the soil has also been increased over the application of FYM (Anonymous, 2016).

In general, soil mulched with organic mulches showed beneficial effect in suppressing the fluctuation of soil temperature at 20 cm depth throughout the experiment at Godhara and revealed the significant differences with the organic mulches tried, soil temperature lowered significantly with paddy straw followed by grasses. and soil moisture content was recorded maximum with paddy straw mulch at both the depths of soil (0-15 cm and 15-30 cm). Amongst the organic mulches evaluated, soil moisture ranged 19.80-14.80, 20.60-16.70% in paddy straw and it was recorded 14.80-12.10, 16.40-13.50 % in control at both the depths from soil surface after mulching. (Anonymous, 2016).

Table 17. Effect of different INM treatments on physico-chemical properties of the soil

Treatment	pH	Organic carbon (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available Zn (ppm)	Available Fe (ppm)
Control	8.10	0.12	08.50	175.00	0.50	3.50
RDF	8.20	0.15	14.50	210.00	0.50	3.50
RDF + FYM	7.50	0.25	14.50	215.00	0.60	4.25
RDF +Azotobactor	8.00	0.15	14.00	200.00	0.60	3.80
RDF + PSB	8.00	0.15	16.00	200.00	0.60	3.80
RDF + VAM	8.00	0.15	16.50	200.00	0.60	3.80
RDF+FYM + AZB	7.60	0.28	14.50	210.00	0.65	4.80
RDF + FYM + PSB	7.60	0.28	17.50	210.00	0.65	4.80
RDF + FYM + VAM	7.60	0.28	18.50	220.00	0.65	4.80
RDF +FYM + PSB + AZB	7.60	0.28	18.50	220.00	0.65	5.00
RDF + FYM + PSB + AZB + VAM	7.50	0.28	18.50	220.00	0.65	5.00
Initial level	8.20	0.08	08.00	180.50	0.50	3.50

The soil moisture status of the soil under different INM treatment was monitored and revealed that application of FYM alone or in combination with inorganic and bio fertilizers increased the soil moisture status at both the strata. Monitoring of soil status at two depths revealed the more moisture has been accumulated at lower depths (Table 18). Application of bio fertilizers alone did not improve the soil moisture status of the soil. (Anonymous, 2016).

Table 18. Effect of different INM treatments on soil moisture of the soil

Treatment	Soil moisture (%) after 24 hrs of irrigation	
	0-30cm	30-60cm
Control	2.80	3.50
RDF	3.50	3.50
RDF + FYM	5.50	6.00
RDF +Azotobactor	3.40	3.50
RDF + PSB	3.50	3.50
RDF + VAM	3.80	4.50

RDF+FYM + AZB	5.50	6.50
RDF + FYM + PSB	500	6.00
RDF + FYM + VAM	6.00	6.00
RDF +FYM + PSB + AZB	6.50	6.50
RDF + FYM + PSB + AZB + VAM	6.00	6.00

Organic carbon of the soil improved by the application of organic manure with recommended dose of fertilizer, this combination significantly influenced crop growth, development and productivity (Jat, *et al.,* 2013). Most of the research results clearly demonstrated that INM enhances the yield potential of crops over and above achievable yield with recommended fertilizers (Table 17) and results in better synchrony of crop N needs due to (a) slower mineralization of organics (b) reduced N losses via denitrification and nitrate leaching; (c) enhanced nutrient use efficiency and recovery by crops, and (d) improvements in soil health and productivity and sustain high crop yields in various cropping systems ensuring long term sustainability of the system (Sharma, *et al.,* 2013). Judicious application of mineral fertilizers and organic manure along with biofertilizers and micronutrients gave highest available NPK in soil as compared to other treatment combination. (Meena, *et al.,* 2013, Aulakh, *et al*., 2 010). Incorporation of FYM, Green Manure and BGA, through an inorganic source in the treatment increased organic carbon, mineralisable N and reduced the bulk density of soil . (Kumar, *et al.,* 2012 and Rahman, *et al.* 2014). Pintu, *et al.,* (2010) studied the adoption of integrated nutrient management practices helped to build up soil nutrient status with respect to N, P, K, Fe, Mn, Cu and Zn contents. However, the highest organic carbon content (0.88%) was observed in the treatment where 4tonnes /ha organic manure was applied along with recommended levels of NPK and zinc at 0.5 kg/ha.

Bio-fertilizer has been identified as an alternative to chemical fertilizer to increase soil fertility and crop production in sustainable farming. The use of bio-fertilizers effectively enrich the soil and cost less than chemical fertilizers, which harm the environment and deplete non-renewable energy sources. Bio-fertilizers have definite advantage over chemical fertilizers. Chemical fertilizers supply over nitrogen where as bio-fertilizers provide in addition to nitrogen certain growth promoting substances like hormones, vitamins, amino acids, etc, crops have to be provided with chemical fertilizers repeatedly to replenish the loss of nitrogen utilized for crop growth. On the other hand bio-fertilizers supply the nitrogen continuously throughout the entire period of crop growth in the field under favorable conditions. Bio-fertilizers improve the soil structure. Bio-fertilizers, however, have no toxic effects. Bio-fertilizers are commonly called as microbial inoculants which are capable of mobilizing important nutritional elements in the soil from non-usable to usable form by the crop plants through their biological processes.

Biofertilizer is a substance which contains living microorganism which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant**.** Very often microorganisms are not as efficient in natural surroundings as one would expect them to be and therefore artificially multiplied cultures of efficient selected microorganisms play a vital role in accelerating the microbial processes in soil. Use of biofertilizers is one of the important components of INM, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture. Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers.

The seed inoculation with *Rhizobium* on cluster bean grain yield was increased under graded doses of nitrogen application *viz*., 15, 30, 45 and 60 kg N/ha and the application of 60 kg N/ha along with *Rhizobium* inoculation maximized cluster bean seed yield (13.28 q/ha) which was 152.47% higher and significantly better than the yield obtained at same level of N application without *Rhizobium* inoculation. However, it was statistically at par with 60 kg N application and 45 kg N/ha + *Rhizobium* (12.26 q/ha). Higher value yield, nitrogen use efficiency and apparent nutrient recovery were optimized under seed inoculation with *Rhizobium* as compared to non inoculated seeds. The results depicts the beneficial effects of *Rhizobium* inoculation on cluster bean grain yield resulting in saving of 13.37 to 21.73 kg/ha nitrogen and an enhanced seed yield ranging from 2.34 to 8.05 q/ha along with nitrogen application compared to control. (Jatav, *et al.,* 2016).

Rathore, (2007) study the effect of chemical and biofertilizer on growth, yield and nutrient uptake of rainfed clusterbean *(Cyamopsis tetragonoloba* L.) and achieved significant improvement in growth, yield and nutrient uptake was recorded with sole and integrated application of nutrients through chemical fertilizers and biofertilizers. Association between *Rhizobium* and phosphate solublising bacteria was synergistic and inoculation of both fertilizers significantly improved the seed yield. Inoculation of *Rhizobiunr,* phosphate solublising bacteria and *Rhizobium* + phosphate solublising bacteria recorded 21.0, 14.0 and 24.6 % higher seed yield than the control respectively. Integration of biofertilizer with chemical fertilizer @ 50 % recommended dose of fertilizer brought significant improvement in yield and nutrient uptake over the respective sole application of chemical and biofertilizer and was comparable with application of 100 % recommended dose of fertilizer. The maximum plant height (2.70 m), plant spread East- West (2.30 m), north-south (2.60 m) and scion girth (27.00 cm) was recorded in T_6- FYM + std. dose of NPK + *Azotobactor* + PSB closely followed by Castor cake + standard dose of NPK+ *Azotobactor* + PSB. (Anonymous, 2016)

The integrated nutrient management influenced the fruit set and fruit yield. The quality parameters of fruits were markedly improved by integrated application of inorganic fertilizers and organic manures. The maximum fruit weight (152.81 g), fruit length (6.33cm), fruit breadth (6.15 cm), fruit volume (250.67 cm^3), total soluble solids (10.58 ˚B), total sugars (6.70 %), reducing sugars (3.17%), non-reducing sugars (3.54 %) were recorded with the application of [60% nitrogen of recommended dose of fertilizer + 40% organic manure (FYM)]. This might be due to good nutrient status, improved plant conditions, efficient functioning of leaf area and increased photosynthetic activity. These results are in conformity with the results obtained by Singh and Banik (2011) in sweet orange. It was further observed that significant increase in TSS was recorded by the application of FYM and NPK. This was because adequate dose of NPK stimulated the functioning of number of enzymes in the physiological process which might have increased the total soluble solid content. Fruit set and fruit yield are highly correlated with dry matter content and balanced level of hormones. Superior fruit quality might be due to the fact that, farm yard manure combined with fertilizers enhanced the nutrient availability by enhancing the capability of plants to better solute uptake from rhizosphere. Sanwal*, et al.,* (2007) concluded the significantly higher rhizome yield was recorded with the application of FYM@ 18 t/ha which was statistically at par with 10 t/ha poultry manure and application of various organic sources resulted in 16–103 per cent higher rhizome yield over control and also improved the quality parameters and improved the soil fertility and productivity. With the straw mulch practices the maximum fruit yield per plant (40.20kg) was recorded in paddy straw mulch followed by grasses (36.10 kg/plant), black polythene mulch (32.10kg). Minimum fruit yield (24.00 kg/ plant) was recorded under control. Maximum fruit weight (236.10) and TSS (13.30°Brix) was also recorded in paddy straw mulch, followed by grasses and black polythene mulch in sweet orange fruit crop. With the inter cropping practices the maximum yield per plot was recorded with sweet orange + bottle gourd combination followed by sweet orange + pumpkin among the different combinations. (Anonymous, 2016). Kumar, *et al.,* (2014) revealed that the increase in number of fruiting nodes is due to higher level of N and K in the soil increased synthesis of amino acids and better carbohydrate transformation which in turn resulted in to better growth and better length of shoot which has ultimately produced more fruiting nodes shoot^{-1}. The effect of seed inoculation with *Rhizobium* on cluster bean with nitrogen application compared to control grain yield under graded doses of nitrogen application *viz*., 15, 30, 45 and 60 kg N/ha and revealed that inoculation significantly increased the cluster bean seed grain yield at all levels of nitrogen application including control. Application of 60 kg N/ha along with *Rhizobium* inoculation maximized cluster bean seed yield (13.28 q/ha) which was 152.47% higher and significantly better than the yield obtained at same level of N application without *Rhizobium* inoculation (Jatav, *et al.*, 2016).

Table 19. Effect of N and *Rhizobium* inoculation on seed yield of cluster bean crop

Nitrogen level(kg/ha)	Yield (q/ha)	
	Without Rhizobium	With Rhizobium
5	5	7.57
15	8.58	9.89
30	9.87	11.42
45	10.06	12.26
60	12.23	13.28
Mean	9.20	10.88
CD at 5%	0.85	

Application of 15, 30, 45 and 60 kg N/ha, the percent increase in yield by the seed inoculation with *Rhizobium* was 24.90, 29.44, 41.77 and 19.96% respectively and maximum increase in yield was at 15kg N/ha application with *Rhizobium* (Table 20).

Table 20. Effect of N levels and *Rhizobium* on N use efficiency and percent yield response

Nitrogen level (kg/ha)	NUE (kg seed/kg N)		Yield response (%	
	Without Rhizobium	With Rhizobium	Without Rhizobium	With Rhizobium
15	22.13	30.87	63.12	88.02
30	15.37	20.53	87.64	117.08
45	10.67	15.56	91.31	133.08
60	11.62	13.37	132.51	152.47
Mean	14.95	20.08	93.65	122.66

Jatav, *et al.,(*2016) studied the application of organic and inorganic sources of nutrients significantly increased yield of *kachri* as compared to control (Table 21). Integration of organic and inorganic sources at equal proportion (application of 50% NPK from inorganic fertilizers and 15 tonnes/ha FYM) gave the highest *kachri* yield (113.08 q/ha) which was significantly higher than all other treatments. The increase in total yield was 26.77% higher over recommended NPK through fertilizers. Application of 100% NPK through FYM a so increased yield significantly by 32.71% compared to control. Whereas, this treatment gave only 5.12% more fruit yield as compared to recommended dose of fertilizers. Other treatments, where 25, 75 or 100% of NPK were applied through organic sources were better than control, but were inferior to 50% replacement and *at par* among treatments. In dry matter yield (q/ha), dry matter (%), average weight of fruit (kg) and fruit yield was same trend as observed in yield.

Table 21 . Effect of organic and inorganic source of nutrient on yield performance of *kachri*

Treatment	Yield	Average weight of fruit (g)	Dry matter (%)	Dry matter yield (q/ha)
Control	68.71	26.13	8.16	5.60
100% (I)	87.89	34.06	8.69	7.64
75% (I)+7.5 t/ha FYM	104.00	36.25	8.79	9.15
50% (I)+ 15 t/ha	113.08	38.78	9.81	11.09
25% (I)+ 22.5 t/ha	93.27	37.00	9.98	9.31
30 t/ha FYM t/ha	91.19	34.78	8.99	8.19
SEm+	4.86	1.98	0.4 0.	46
CD (P=0.05	14.88	6.03	1.29	1.44

Different INM practices were with different growth parameter were studied in Kinnow and bael crops and significant result were observed with application of different treatment with RDF. The fruit weight, fruit yield, TSS, acidity and juice recovery were measured in different INM treatment. It was revealed that maximum fruit weight (235 g) was recorded in RDF of N, P, K + FYM + PSB + Azotobactor + VAM which was significantly at par with RDF of N, P, K +FYM + Azotobactor treatment. The TSS was measured in mature fruits from all treatment and recorded in the range of 12.50 to 15.00 ° Brix and data revealed that addition of FYM, inorganic fertilizers increased the TSS content. The acidity content was maximum in control and inorganically fertilized treatments while FYM reduced the juice acidity. The juice recovery was ranged from 40 to 55 percent and maximum juice (55 %) was recorded in those treatments where FYM was the component of the treatment. (Table 20).The Morphological parameter were also observed with the INM practices. The data presented in table 10 revealed that significantly maximum plant height (4.50 m) was recorded in RDF of N, P, K + FYM + PSB + Azotobactor + VAM treatment and minimum was in control (2.80 m). The pattern in plant height revealed that addition of RDF along with FYM and consortium of biofertilizers has the highest increment in plant growth. Likewise plant spread in both the directions was also more in the same INM treatment. The data on stem diameter was also significantly differed among INM treatments and maximum stem diameter was recorded in RDF + FYM + PSB + AZB + VAM and RDF +FYM + PSB + AZB treatments. (Table 22).

Table 22. Effect of different INM treatments on yield and fruit quality parameters of kinnow orchard

Treatment	Fruit weight (g)	Fruit yield (t/ha)	TSS (° Brix)	Acidity (%)	Juice (%)
Control	125	10.00	12.50	0.85	40.00
RDF	165	12.00	12.00	0.70	50.00
RDF + FYM	225	16.50	12.50	0.60	55.00
RDF +Azotobactor	175	12.00	12.50	0.60	50.00
RDF + PSB	165	12.00	12.50	0.70	55.00
RDF + VAM	165	12.00	12.50	0.70	50.00
RDF+FYM + AZB	190	19.00	15.00	0.70	55.00
RDF + FYM + PSB	200	19.50	15.00	0.70	55.00
RDF + FYM + VAM	200	18.50	15.00	0.70	55.00
RDF +FYM + PSB + AZB	225	20.25	15.00	0.65	55.00
RDF + FYM + PSB + AZB + VAM	235	22.50	15.00	0.65	55.00
SE±	15.25	1.95	0.65	0.26	1.20
CD 5%	42.90	5.25	1.80	NS	3.55

Table 23 . Effect of different INM treatments on morphological parameter of kinnow orchard

Treatment	Tree height (m)	Tree Spread		Stem diameter (cm)
		N-S (m)	E-W (m)	
Control	2.80	2.65	2.65	80
RDF	3.00	2.70	2.65	80
RDF + FYM	3.65	3.00	3.00	80
RDF +Azotobactor	3.00	2.70	3.00	80
RDF + PSB	3.00	2.90	2.95	80
RDF + VAM	3.00	2.90	2.80	80
RDF+FYM + AZB	4.00	3.00	2.95	80
RDF + FYM + PSB	4.00	3.00	3.00	80
RDF + FYM + VAM	4.00	3.00	3.00	85
RDF +FYM + PSB + AZB	3.90	3.25	3.00	85
RDF + FYM + PSB + AZB + VAM	4.50	3.45	3.00	85
SE±	0.22	0.15	0.18	6.20
CD 5%	0.54	0.42	0.40	16.00

Management practices and recommendation for safe and economic use of fertilizers

Of all the essential nutrients, nitrogen is the one most often limiting for crop growth and nitrogenous fertilizers supply N which is very essential for plant growth and development. Many soils contain large amounts of nitrogen, but most of the nitrogen is tied up in the organic fraction and only slowly released. For most non legume crops, some nitrogen fertilizer is required for adequate yields. Nitrogen is available to the plant in two forms ammonium (NH4 +) and nitrate (NO). In most soils, ammonium is quickly converted to the nitrate form, a process called nitrification. This nitrate form is not tightly held on soil particles and is soluble in water. Consequently, nitrogen management is important both from a production and environmental standpoint. On sandy soils, nitrogen applied early in the season can be easily leached out of the root zone with heavy rainfall or excess irrigation. Nitrogen deficiency may result, as well as an increased potential for nitrate contamination of the groundwater. On irrigated sandy soils, nitrogen should be split applied a small portion at planting and the remainder during the growing season after the crop has become established. The need for split applications on fine-textured or organic soils is not as critical as on irrigated sandy soils. For some crops, response to nitrogen will depend on the cultivar. In many cases too much nitrogen applied will result in excessive vegetative growth at the expense of fruit growth. Certain cultivars of tomato, potato, and many of the vine crops are susceptible to producing excessive vegetative growth with too much applied nitrogen.

Table 24. Generalized symptoms of nutrient deficiency and excess in crops.

Element/ status	Visual symptoms	
	Deficiency	**Excess**
Nitrogen (N)	Light green leaf and plant colour with the older leaves turning yellow, leaves that will eventually turn brown and die. Plant growth is slow, plants will be stunted, and will mature early.	Plants will be dark green in colour and new growth will be succulent; susceptible, if subjected to disease and insect infestation; and subjected to drought stress, plants will easily lodge. Blossom abortion and lack of fruit set will occur.
Phosphorus (P)	Plant growth will be slow and stunted, and the older leaves will have a purple coloration, particularly on the underside	Phosphorus excess will not have a direct effect on the plant, but may show visual deficiencies of Zn, Fe and Mn. High P may also interfere with the normal Ca nutrition, with typical Ca deficiency symptoms occurring.
Potassium (K)	On the older leaves, the edges will look burned, a symptom known as scorch. Plants will easily lodge and be sensitive to disease infestation. Fruit and seed production will be impaired and of poor quality.	Plants will exhibit typical Mg, and possibly Ca deficiency symptoms due to a cation imbalance.
Calcium (Ca)	The growing tips of roots and leaves will turn brown and die. The edges of the leaves will look ragged as the edges of emerging leaves stick together. Fruit quality will be affected with the occurrence of blossom-end rot on fruits.	Plants may exhibit typical Mg deficiency symptoms, and when in high excess, K deficiency may also occur
Magnesium (Mg)	Older leaves will be yellow in colour with interveinal chlorosis (yellowing between the veins) symptoms. Plant growth will be slow and some plants may be easily infested by disease.	Results in a cation imbalance showing signs of either a Ca or K deficiency.
Sulfur (S)	A general overall light green colour of the entire plant with the older leaves being light green to yellow in colour as the deficiency intensifies.	A premature senescence of leaves may occur.
Boron (B)	Abnormal development of the growing points (meristematic tissue) with the apical growing points eventually becoming stunted and dying. Flowers and fruits will abort. For some grain and fruit crops, yield and quality is significantly reduced	Excess Leaf tips and margins will turn brown and die

Chlorine (Cl)	Younger leaves will be chlorotic and plants will easily wilt. For wheat, a plant disease will infest the plant when Cl is deficient.	Premature yellowing of the lower leaves with burning of the leaf margins and tips. Leaf abscission will occur and plants will easily
Copper (Cu)	Plant growth will be slow and plants stunted with distortion of the young leaves and death of the growing point.	Fe deficiency may be induced with very slow growth. Roots may be stunted.
Iron (Fe)	Interveinal chlorosis will occur on the emerging and young leaves with eventual bleaching of the new growth. When severe, the entire plant may be light green in colour.	Bronzing and tiny brown spots on the leaves.
Manganese (Mn)	Interveinal chlorosis of young leaves while the leaves and plants remain generally green in colour. When severe, the plants will be stunted	Excess Older leaves will show brown spots surrounded by a chlorotic zone
Molybdenum (Mo)	Symptoms will frequently appear similar to N deficiency. Older and middle leaves become chlorotic first, and in some instances, leaf margins are rolled and growth and flower formation are restricted.	Not of common occurrence.
Zinc (Zn)	Upper leaves will show interveinal chlorosis with an eventual whiting of the affected leaves. Leaves may be small and distorted with a rosette form.	Excess Fe deficiency will develop.

Nutrient management involves proper placement and timing of fertilizer considering the nature of fertilizer/nutrient and crop requirement as well as the rooting characteristics of plant. Nitrogen is a mobile nutrient both in soil and within in plant. Due to high mobility in soil no special effort is required to placement although banding of nitrogenous fertilizers does improve their use by the crops. The emphasis is more on how to manipulate N applied among various vegetables in a cropping sequence should be identified. During the crop duration of each vegetable the number of split applications and time of each application should be manipulated to achieve maximum utilization and minimum loss of the applied fertilizer. The N fertilizer should be applied in splits and each application should be properly timed. It is advisable to reduce the proportion of nitrogen applied in basal and also to delay its application by about 10 days after planting to improve its use by the crop and avoid leaching and volatilization: Slow release and neem extract coated use can also be used for better FUE. Phosphorus is relatively immobile nutrient in soil and data tend to fix into less soluble forms. These P fertilizers to be banded to minimize fixation in other word banding at proper depth markedly enhance the utilization of phosphate fertilizers. In general banding at 5 cm below seed/ plant results in maximum utilization of applied. Potassic fertilizers intermediate in mobility in soil are usually applied along with basal does at sowing/planting. However, split application may be adapted in long duration crop like chili, capsicum for better utilization. By adopting appropriate placement method and time of application of fertilizers to fruit and vegetable crop, the efficiency of absorption and utilization of fertilizer nutrients can be enchanted.

Inorganic sources of nutrients are the major input accounting one-third of the cost of cultivation. The increasing cost of fertilizers and negative impact on ground water pollution through leaching from the soils are discouraging the use of fertilizers. However, the encouraging results obtained by conjunctive use of the fertilizers, organic manure, green manure, biofertilizers and fertigation are providing leads to future strategies for the rational use of fertilizers and manure for enhancing the productivity without detrimental effect to the environment. Correct recommendation for each crop under a given set of the agroclimatic conditions needs to be worked out through critical experimantation and a strategy for the balanced integrated nutrient management for different horti-ecological system is needed. Meanwhile we should continue to adopt the following pratices of INM.

- Before planting an orchard, soil should be brought to an optimum level by green manuring or FYM application, creation of drainage, pit making and filling mixtures and required quanity of nutrients and soil amendments
- Timing of nutrient application should be need and system based
- Placement of nutrients should be in the absorption zone.
- Use of biofertilizers like Azotobactor, Azospirillum and VAM should be standardized for various horticultural crops.

Summary

1. For an exhaustive and resource intensive crop integrated nutrient management is inevitable. Soil inherent fertility, organic sources like *in situ* green manuring, FYM and vermicompost along with inorganic fertilizers must be integrated depending upon available resources, cultivar and cropping system to get optimum yield and return while maintaining soil health and minimum environmental damage.
2. Nitrogen is a first limiting nutrient in all type of soils and has great influence on crop growth, yield and its quality
3. In general, application of N in three split dose produces higher yields and results in higher N recovery than applying entire dose at planting. Normally, basal application of urea at higher rate should be avoided, however, at earthing up being cost effective urea may be preferred.
4. Phosphorus and potassium are the second and third limiting nutrients, respectively, in crop production and a healthy crop removes about 25-30 kg P_2O_5 and 170-230 kg K_2O/ha with the fertilizer use efficiency for P 10-15 and K 50-60 per cent thus the residual effect of P and K applied to crop effects the fertilizer needs of succeeding crops.
5. The most common P fertilizer used in crop cultivation is a single super phosphate, whereas, among K fertilizers the potassium chloride (MOP) constitutes 97% of potassium fertilizers

consumption. Potassium sulphate (SOP) has not found much use due to its high cost. Furrow placement of P and K has been more economical than broadcasting or band placement.

6. Extent of deficiency of different micro nutrients is increasing in growing areas, the most important being Zn and these must be applied on soil test basis Factors influencing the magnitude of response to the applied micronutrients are crops/ cultivars, soil types and their nutrient status, soil environment, climate, cultural practices and nutrient interactions.

Future Thrust

Studies on following aspects need to be done/strengthened.

1. Nutrient indexing in horticultural crops

- Development of nutrient management schedules through diagnostic tools on regional scale in major horticultural growing pockets.
- Delineate nutrient deficiency in horticultural growing areas and forecasting of nutrient imbalances and deficiencies.

2. Characterization and parameterization of nutrient use efficient cultivars.

- Identification and quantification of nutrient efficiency traits including use of radiotracer technique.
- Identification of nutrient stress tolerant cultivars.

3. Develop integrated nutrient management techniques for horticultural crops.

- Standardization of integrated nutrient management in horticultural crops including biofertilizers, organics and micronutrients on yield and quality.
- Evaluate phosphate solubilizing bacteria on P use efficiency including radiotracer techniques.
- Studies on mineralization of macro and micro nutrients from organic manures and rock phosphate through radiotracer techniques.

4. Development of farmer friendly Site specific nutrient management (SSNM) tool in horticultural crops production.

- Adaptation and modification of SSNM methodology to horticultural crops.
- To develop SSNM options for cultivar specific nutrient recommendation.

5. Improving organic horticultural crops production.

- In order to harvest a good crop of organic horticultural crops, selection of suitable varieties is one of the most important pre-requisites. The use of varieties that are better adapted to local biotic conditions (e.g. biological control of pests and diseases, climatic stress) shall be promoted.
- Similarly additional genes conferring resistance to horticultural crops crop against disease and insect-pests need to be introduced.
- Improved nutrient use efficiency is required for better utilization of nutrients that will in turn, result in production of higher biomass, partitioned efficiency to improve the harvest index/ economic yield. horticultural crops varieties with a long period of nutrients uptake can make better use of slow, but prolonged release of available nutrients.

- The possibilities to supply nutrients particularly nitrogen and suppression of diseases through periodic spray of vermiwash should be investigated. Similarly studies on use of biopesticides to minimize reported fifty percent yield loss in organic horticultural crops production due to insects and pests should be given due attention. Biological controls may have been weakened or destroyed by chemicals and efforts should be made to build up them.

Conclusions

India has a wide variety of climate and soil on which a large range of horticultural crops such as fruits, nuts, vegetables, root tubers, palms, spices, cashew, cocoa, ornamental crops, medicinal and aromatic plants are grown. The policymakers have realized that the horticultural crops need promotion for achieving sustainability of small holdings, crop diversification, increasing employment, providing an enormous export potential, improving environment, and more than anything for achieving nutritional security. A due importance to nutrients is essential as these affect the productivity, quality and profitability of horticultural crops. To obtain desired yields in horticultural crops sufficient amounts of readily available essential plant nutrients need to be supplied to the plant. Soil nutrients, like all agricultural inputs, need to be managed properly to meet the fertility requirements of horticultural crops. Appropriate nutrient management practices for horticultural crops vary widely due to cropping, topographical, environmental, and economic conditions. With the variety of factors complicating the fertility management in horticultural crops, it is nearly impossible to recommend single set of best management practices uniformly to all the horticultural farms. Nutrient management practices for maintaining or improving farm profitability must be tailored to the unique conditions of individual farms. A number of options for improved nutrient management are available for the horticultural crops and are discussed in this bulletin.

References

1. Annapurna, K., Bojappa, K.M. and Bhargava B.S., (1988). Leaf sampling guide for sapota (*Manilkara achras* M. Fosberg) cv. Cricket Ball. *Crop Res*., 1: 69-75.
2. Anonymous, (2016). Annual Report, ICAR-Central Institute for arid horticulture, Bikaner, 334006
3. Aulakh, M.S., Khurana, M.P.S. and Singh, D.(2010). Water pollution related to agricultural, industrial and urban activities, and its effects on food chain: case studies from punjab. *j. new seeds,*112-137.
4. Aulakh, M.S. and Adhya, T.K (2005). Impact of agricultural activities on emission of greenhouse gases - indian perspective. in 'international conference on soil, water and environmental quality - issues and strategies" 319-335
5. Balasubramanian, V. (1999). Farmer adoption of improved nitrogen management technologies in rice farming: technical constraints and opportunities for improvement. *Nut. Cycling in Agro–Ecosystem*. 53:93-101.
6. Bambal, S.B., Wavhal, K.N. and Nasalkar, S.D. (1991) . Effect of foliar application of micronutrients on fruit quality and yield of pomegranate *(Punica granatum* L. cv. Ganesh). *Maharashtra Journal of Horticulture*. 5, 2, 32-36.
7. Bates, T. F.(1971). Factors affecting nutrient concentrations in plants and their evaluation. A Review, *Soil Sci*. 112: 116-130.
8. Beaufils, E. R. (1971). Physiological diagnosis- A guide for improving maize production based on principles developed for rubber trees. *Fertil. Soc. S. Afr. J*. 1: 1-28.
9. Beaufils, E. R. (1973). Diagnosis and recommendation integrated system (DRIS). *Soil Sci. Bull. No. 1*, University of Natal, S. Africa.
10. Beaufils, E.R.(1957). Research for rational exploitation of hevea using a physiological diagnosis based on the mineral analysis of various parts of the plants. *Fertilite*. 3: 27-38.
11. Bhargava, B.S. and Reddy, B.M.C. (1992). Selection of index tissue in banana for nutritional diagnosis. *Indian J. Hort,*. 49(2): 120-126.
12. Bhargava, B.S. and Chadha, K.L. (1999). Leaf nutrient guide for fruit crops. *Advances in Hort*., Vol. 2. pp.973-1029.
13. Bouma, D. (1983) Diagnosis of mineral deficiencies using plant tests. In: A. Lauchli and Bieleski, R. L. (eds) Encyclopedia of plant physiology. Vol. 15A. *Inorganic plant nutrition*. Springer- Verlag, Berlin, pp. 120-148.
14. Brams., E.A.(1971). Continuous cultivation of West African soils: Organic matter diminution and effects of applied lime and phosphorus. *Plant and Soil* 35:401-414.
15. Cate, R.B. and Nelson, L.A.(1965). Tech. Bull. North Carolina Agric. Exp. Stn., Int. Soil Test Service
16. Chadha, K. L., Samra, J.S. and Thakur. R.S. (1980). Appraisal of recommended manurial schedule in mango. *Punjab Hort. J.* 20: 13-23.
17. Chopra, S.L. and Kanwar, J.S. (1986). *Analytical Agricultural Chemistry*. pp.250-252. Kalyani Publishers, Ludhiana.

18. Chundawat, B.S. (1997). *Nutritional Management in Fruit Crops*. Agrotech Publishing Academy, Udiapur.

19. Dey, B.N.(2016). Reclamation of Sand Dunes and Other Shifting Sand Dunes. Available online: http://www

20. Dobermann, A. and Cassman, K.G.(2002). Plant nutrient management for enhanced productivity in intensive grain production systems of the united states and Aasia. *Plant and Soil.* 247(1):153–175.

21. Ganeshamurthy, A. N. Satisha, G. C. and Patil, Prakash (2011). Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes", Karnataka Journal of Agricultural Sciences, 24.1 .

22. Ghose, B., Bose, T.K. and Mitra, S.K. (1986). Chemical induction of flowering and control of fruit drop in litchi (*Litchi chinesis* Sonn.) *Proc.*, 22nd *Int. Hort. Cong.*, California. Abst., 1189.

23. Iyenger, B. R. V. (1993). Fertilizer management. In: *Advances in Horticulture* Vol. 2 pp. 1055-1072. Chaddha, K. L. and Pareek, O. P. (eds). Malhotra Publishing House, New Delhi.

24. Jat, G, Majumdar, S.P., Jat N.K., Majundar, SP. (2013). Potassium and zinc fertilization of wheat (Triticum aestvum) in Western arid zone of India. *Indian J Agron*, 58(1):67-71.

25. Jatav, M.K, Sharma, B.D., Samadia, D.K. and Meena, S.R. (2016). Yield of kachri (cucumis callosus) as influenced by organic and inorganic sources of nutrients in arid zone *Indian journal of agricultural sciences* 86 (7): 961–3.

26. Juo, ASR, Franziuebbers K, Dabiri A, Ikhile B (1995). Changes in soil properties during long-term fallow and continuous cultivation after forest clearing in Nigeria. Agric. Ecosyst. Environment 56: 9-18

27. Kar, A., Moharana, P.C., Raina, P., Kumar, M., Soni, M.L., Santra, P., Ajai, Arya, A.S., Dhinwa, P.S. Kaul, R.N. (1959). Shelterbelt to stop creep of the desert. Indian For., 85, 191–195.

28. Katyal, J.C., Chaudhari, S.K., Dwivedi, B.S., Biswas, D.R., Rattan, R.K. and Majumdar, K. (2016). Soil Health: Concept, Status and Monitoring. *Bulletin of the Indian Society of Soil Science* 30, 1-98.

29. Khanduja, S.D. and Garg, V.K. (1984). Micronutrient elements composition of leaves from jujube trees in North India. *Indian Journal of Horticulture* 41: 22-29.

30. Kumar, M. Dwivedi R, Anand A.K. and Kumar. A (2014). Effect of nutrient on vegetative growth, fruit maturity and yield attributes of phalsa (grewia subinaequalis d.c.), g.j.b.b., vol.3 (3), 264-268.

31. Kumar, M., Baishaya, K., Ghosh D.C. Gupta, V.K. Dubey, S.K, Das, A and Patel, D.P. (2012) : Productivity and soil health of potato (*solanum tuberosum*.) field as influenced by organic manures, inorganic fertilizers and biofertilizers under high altitudes of eastern himalayas. *j. agric. sci.,* 4 (5): 223-234.

32. Matar, A., Torrent, J., and Ryan, J.,(1992:) Soil and fertilizer phosphorus and crop responses in the dryland Mediterranean zone, *Adv. Soil Sci.*,18, 81– 146 .

33. Meena, R.S. Ramawatar, Kamalesh Meena V.S. and Ram, Kalu.(2013). Effect of organic and inorganic source of nutrients on yield, nutrient uptake and nutrient status of soil after harvest of greengram. A*n asian j soil sci*.. 8, 80-83.

34. Muralidharudu, Y., Reddy, K.S.,Mandal, B.N., Subba Rao, A., Singh,K.N. and Sonekar, S., (2011). GIS based soil fertility maps of different states of India. IISS, Bhopal

35. Pintu, Sur Mandal,M. and Das, D. K. (2010). Effect of integrated nutrient management on soil fertility and organic carbon in cabbage (Brassica oleracea var. capitata) growing soil ,*Indian Journal of Agricultural Sciences* 80 (8): 38–00, August 2010.

36. Prasad, R.N. and Biswas, P.P. (2000). In Singh, G.B. and Sharma, B.R. (eds). 50 years of natural resource management research, ICAR. New Delhi, pp 644.

37. Roy, R.N. (1995). FAO, Rome

38. Rahman, M.H., Islam, M.R. Jahiruddin, M., Rafii, M.Y., Hanafi, M.M., Malek, M.A.(2014). Integrated nutrient management in maize-legume-rice cropping pattern and its impact on soil fertility. *j. food agric. environ*., 11: 648-652

39. Ramamoorthy, B, Narasimham, R.L., Dinesh, R.S.(1967). Fertilizer application for specific yield target of sonara-64 wheat. Indian Farming. 17:43–45.

40. Rao, S. and Srivastava, S. (2000). Soil test based fertilizer use a must for sustainable agriculture. *Fertilizer News*.45:25–38.

41. Rathore, V.S., Singh, J.P., Soni, M.L., Yadava, N.D. and Beniwal, R.K. (2007). Productivity, quality and resource utilization by clustercan (Cyamopsis tetragonoloba) as influenced by nutrient management. *Indian Journal of Agronomy*, 52 (3): 243-246.

42. Ray, P.K., Jana, A.K., Maitra, D.N., Saha, M.N., Chaudhaury, J., Saha, S. and Saha. R. (2000): Fertilizer prescriptions on soil test basis for jute, rice and wheat in typic ustochrept. *Journal of Indian Society of Soil Science*. 48: 79–84.

43. Reuther, W., Webber, H. J., and Batchelor, L. D. (1967). The Citrus Industry, Vol. 1. Div. Agric. Sci., Univ. of California, Berkeley.

44. Samra, J.S., Thakur, R.S. and Chada, K.L. (1978). Evaluation of existing critical limits of leaf nutrient standards in mango. Scientia Hort. 8: 349-355.

45. Sanwal, S. K., Laxminarayana, R. K., Yadav, N., Rai, N., Yadav, D. S and Bhuyan, M. (2007). Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. Indian J. Hort., 64(4): 105-111.

46. Sehgal, J. and Abrol, I.P. (1994). Soil Degradation in India: Status and Impact; Oxford and IBH: New Delhi, India,1994; p. 80.

47. Sharma, R.(2013). Effect of long term integrated nutrient management system on soil and crop productivity in Rice -Wheat crop sequence. Indian ETD Repository @ inflibnet, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Department of Agronomy Forages and Grassland Management**.**

48. Shende, D G. (1977). Effect of N, P and K on growth, yield and quality of pomegranate. M.Sc. (Agri.) Thesis, MPKV, Rahuri.

49. Shukla, A.K., Behera, S.K., Subba Rao, A. and Singh, A.K., (2012). State-wise micro and secondary nutrients recommendations for different crops and cropping systems. *Research Bulletin No*. 1/2012, IISS, Bhopal

50. Singh, N.P. (1981). Studies on guava nutriation with special referance to leaf analysis. *National Symp.Trop.Subtrop. Fruit Crop.* Bangalore, pp. 75

51. Singh, S.R. and Banik, B.C. (2011). Response of integrated nutrient Management on flowering, fruit setting, yield and Fruit quality in sweet orange (Citrus sinensis). Asian Journal of Horticulture 6(1): 151- 154.

52. Singh, S.K., Shahi, S.K. Singh, D.K. and Meena, V.S.(2014): Soil properties and productivity of rice (oryza sativa) as influenced by urea, fym and biofertilizers. *ann. of boil*, 30 (2) : 335-339.

53. Srivastava, A.K. and Shyam Singh (2008). DRIS norms and their field validation in Nagpur mandarin (Citrus reticulata Blanco). *Journal of Plant Nutrition* 31, 91-107.

54. Subramanian, T.R., Chadha, K.L, Melanta, K.R. and Srinivasa Murthy, H.K.(1974). Studies on nutrition of pineapple. III. Effect of varying levels of NPK on leaf nutrient status in variety 'Kew' in high fertility soil. *Indian J. Hort*. 31: 219-23.

55. Sumner, M. E. (1978). Diagnosing the sulphur requirements of corn and wheat using foliar analysis. *Soil Science Society of American Journal* 45, 87-90.

56. Tandon, H.L.S. (2004). Fertilizers in Indian Agriculture – from 20th to 21st century. FDCO, New Delhi, India. pp. 240.

57. Ugboh, O. and Ulebor, J.U. (2011).Application of integrated soil fertility approach in the improvement of soil fertility in semi arid ecology *, Journal of agriculture and social research* (jasr) vol. 11, no. 2, 81.

58. Yadav, R.L. and Meena, M.C.(2009). Available micronutrients status and relationship with soil properties of Degana soil series of Rajasthan. *Journal of the Indian Society of Soil Science* 57(1) 90-92.

59. Yadav, J.S.P. and Singh, G.G. (2000). Natural resource management for agricultural productivity in India, Indian society of Soil Science, New Delhi, India.

NOTE

NOTE

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch