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Micronutrients importance in hi-tech horticulture

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Abstract
India is a major producer of horticultural crops growing close to 100 crops. It is the second largest producer of fruits and vegetables after China and is an integral part of food and nutritional security. It is an essential component of economic security of the stakeholder. Demand for increasing production, will require a thorough knowledge of the soil factors that regulate the supply and availability of micronutrients in soils. Hi-tech horticulture is a technology which is modern, less environment-dependent and capital intensive but with a capacity to improve productivity and farmers' income. The stagnation in crop productivity has been found due to deficiency of some micro and secondary nutrients. Hence, micronutrients (Zn, Fe, Mn, Cu, B, Mo and Ni) have assumed increasing importance in crop production under modern agriculture. The need for application of micro-nutrients is thus, increasingly felt. At present about 47.0, 11.5, 4.8 and 4.0 per cent of soils are found to be deficient in zinc, iron, copper and manganese, respectively. It is estimated that about 324, 130, 11, 11 and 3.0 thousand tones of zinc, iron, manganese, copper and boron will be required by 2025 AD. In the new era of changing climate, hi-tech horticulture has become necessity so as to sustain productivity and economic stability of the Indian farmers. Hi-tech horticulture is useful not only for production of fruits, vegetables and flowers but also for conservation, plant protection, post-harvest management including value-addition. Hi-tech horticulture relies heavily on judicious application of irrigation and nutrients to horticultural crops. Adoption of drip irrigation has resulted in high yields and better quality in fruits (mango, coconut, arecanut, cashew, banana, grape, papaya, pomegranate and mandarin), vegetables (okra, chilli, tomato, brinjal, coriander, cucumber and watermelon) and cut-flowers (rose, carnation and gerbera). Due to advancement in biotechnology, planting practices and novel fertilizer application techniques, it is necessary to revisit the recommended doses and schedules. The concepts of site specific, orchard-specific, tree specific and phenophase-specific application of nutrients are taking roots in scientific discourse. The present article reviews various aspects of hi-tech horticulture in relation to micronutrients hinting future prospects.

Keywords: micronutrients, hi-tech, horticulture, fruits, vegetables, flowers, fertilizers, etc.

Introduction

The word 'micronutrients' represents some essential nutrients that are required in very small quantities for the growth of plants and microorganisms. Micronutrients, also called as 'trace elements', are: iron, manganese, zinc, copper, boron, molybdenum, nickel, cobalt and chlorine. Amongst these eight micronutrients, the content of iron in soil as well as in plant is the highest and sometimes higher than even P and S content. Of the nine micronutrients, iron, manganese, zinc, copper, cobalt and nickel behave like cations and boron, molybdenum and chlorine behave like anions in soils. Thus, the chemistry of micronutrient cations is different from that of micronutrients anions. There is no further scope for horizontal expansion of area under plough, as the per capita land is decreasing every year due to unabated increase in human population. Hence, the further requirement of food has to be met through vertical expansion or more intensification of agriculture. About 40Mt fertilizer nutrients will have to be used to produce 380-400 Mt of food grains to feed an estimated population of 1.5 billion by 2050 AD. The importance of micronutrients has been realized during the past three decades when widespread micronutrient deficiencies were observed in most of the soils in our country, where intensive agriculture is practiced. The micronutrient deficiency in soils has been attributed to the following changes in India agriculture: (i) Continuous removal of micronutrients from soil by the recently introduced fertilizer responsive improved varieties of crops, particularly cereals which produce high biomass on fertilizer application. It reduces the concentration of micronutrients in soil solution below that required for normal growth. (ii) Use of macronutrient free high analysis fertilizers in modern agriculture. (iii) Improved instrumentation techniques and increased knowledge of mineral nutrition of plants help in the diagnosis of micronutrient deficiencies in soils and plants which escaped our attention earlier. Demand for increasing crop production will require a thorough knowledge of the soil factors that regulate the supply and availability of micronutrients in soils.

Patil (2004) [18] reported soils of south zone of Konkan belong to lateritic (Typic Ustropepts), acid sulphate (Entic Chromusterts) coastal saline (Vertic Halaquepts) whereas, those from north Konkan are medium black (Vertic Ustropepts), heavy clay (Vertic Ustropepts) coastal saline (Vertic Halaquepts) and Red brown (Lithic Ustorthents) types. The physico-chemical properties indicated that soils from south zone are slightly acidic, free from salts and lime, sandy clay loam to clay in texture. The high intensity of rainfall of the zone caused heavy leaching of bases. The CEC is observed to be lower than that of north Konkan soils. The soils of north Konkan are neutral to alkaline in reaction, clay in texture, calcareous in some places, with higher CEC than the soils of south Konkan. Soils from both zones indicated high organic carbon content. Available P and K content were comparatively less in south Konkan than in north Konkan. Pockets of K deficiency are also observed in the region. Coastal saline soils in both the zones owe their salinity to the ingress of sea water. They indicated exceptionally higher K content than in other soils of the region (Patil, 2001) [21]. Deficiency of micronutrient showed in soils of Maharashtra widespread zinc throughout state followed by boron and iron. However, in India, micronutrients deficiency occurs as 47%, 13%, 5%, 4% and 35% under Zn, Fe, Cu, Mn and Boron respectively.

Agriculture and allied sectors contributed 18% of the India's gross domestic product (GDP) in the year 2014-15. A large proportion of this contribution comes from the horticulture sub-sector. Fruits and vegetables constitute the second largest category among agricultural crops in terms of gross value of output (GVO) with 25% contribution in 2014-15 (Table 1). It is second only to the cereals but has recorded a steady increase over 2011-12. On the contrary, cereals have recorded a decline in GVO. Thus, horticulture under which fruits and vegetables are counted has been consistently emerging as a mainstay of Indian economy and rightly the budget outlay for horticulture increased to 4.6% in the XII Five Year Plan to support this encouraging sector (Bhattacharyya *et al.* 2017) [6].

Micronutrints in soils of Konkan

Available micronutrients in soils

The status of DTPA extractable micronutrients namely Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) also hot water soluble boron in different soil types of Konkan.

Available Iron

The mean content of available iron in lateritic, medium black and coastal saline soils was observed to be 21.57, 21.25 and 12.56 mg kg^{-1}, respectively which indicate its adequate status in general. However, its deficiency is noticed in few pockets particularly in strongly alkaline (pH 8.4 to 9.0), calcareous ($CaCO_3$ > 8 per cent), medium black soils (Yadav, 1988) [23] and in coastal saline soils of north Konkan due to high salinity (Andhalkar, 1984; Anonymous, 1988) [1, 2]. Recent Studies by (Patil, 2012) [19] indicated its content varied from 8.0 to 111.95 mg kg^{-1} indifferent soil types of Konkan.

Available manganese

The available manganese content in different soil types was observed to be adequate (Pereira *et al*. 1986) [17]. It was higher in lateritic soil (mean 86.29 mg kg^{-1}) than in medium black (mean 78.78 mg kg^{-1}) and coastal saline (mean 33.89 mg kg^{-1}) soils. Further, Patil (2001) [21] revealed that DTPA extractable Mn was observed to be least in acid sulphate (Entic Chromusterts) ranging from 0.29-2.74 (mean 1.36) mg kg^{-1}.

Available Copper

The content of available copper in medium black soils was the highest (mean 6.30 mg kg^{-1}) followed by coastal saline soils (mean 5.63 mg kg^{-1}) and lateritic soil (mean 3.87 mg kg^{-1}) revealing that its status is well above the critical limit of 0.2 ppm DTPA extractable copper. Patil *et al.* (2016) [20] reported deficiency of available copper in bench terraced lateritic soils.

Available zinc

The mean content of zinc was the highest in coastal saline soils (2.74 mg kg^{-1}) followed by medium black soils (2.05 mg kg^{-1}) & lowest in lateritic soils (1.61 mg kg^{-1}). About 65 per cent of medium black soils of sapota garden from Dahanu (Yadav, 1988) [23] and 50.87 per cent lateritic soils of Agricultural Research Station, Phondaghat (Dabke, 1987) [8] were marginally adequate to deficient in zinc status.

Available boron

Boron content in lateritic and coastal saline soils varied from 0.03 to 0.29 mg kg^{-1} and from 0.03 to 2.06 mg kg^{-1}, respectively with corresponding mean values of 0.154 and 1.24 mg kg^{-1}. The bench terraced lateritic soils are reported to be deficient in available boron (Patil *et al.* 2016) [20].

Micronutrient status of mango orchards in the South Zone of Konkan

A survey on status and distribution of micronutrients in lateritic soils under mango orchards in South Konkan (Mahajan, 2001) [15] indicated that the soils are sufficient in available iron, copper, molybdenum, high in manganese but mostly deficient in Zinc (87%) and boron (90.4%). Data further indicated that though the total micronutrient reserve in soil is very high, their available form constitutes a small fraction of their total quantity. Each micronutrient tended to decrease down the profile, probably because in the surface layers there is incorporation of organic residues increasing their quantity in the surface layers. The study also revealed variations in the micronutrient content due to the effect of slope, age and elevation of the orchards.

Available micronutrients in soil samples from mango orchards of Ratnagiri and Sindhudurg district (Lateritic soil).

Available Micronutrient	Surface samples (mg kg^{-1})	Critical limit (mg kg^{-1})	Level of the available micronutrient
1. Iron	10.31-44.75	4.5	Sufficient
2. Manganese	7.90-50.35	1 or 3	High
3. Copper	1.14-5.09	0.2	Sufficient
4. Zinc	0.22 -1.769	0.8	13% Soils sufficient 87% deficient
5. Boron	0.076-0.0695	0.5	9.6% well supplied 90.4% Deficient
6. Molybdenum	0.083-0.178	0.05	Adequate

* g kg^{-1} (Mahajan, 2001) [15]

Maharashtra scenario: Available micronutrients in soils:

More or less similar trends in deficiencies of micronutrients in Maharashtra soils as that of Indian soils were noticed by Malewar (2005) [16]. Zinc, iron, boron and manganese showed their deficiencies to the extent of 38.2, 24.7, 31.7 and 5.0% in soil samples, respectively. Ustorthents (Entisols) were more prone to deficiencies of micronutrients in general followed by intensively cultivated matured Usterts (Vertisols) of Maharashtra. Kharche *et al.* (2003) [13] further added on the basis of 20 dominating soil series of western Maharashtra that

Entisols are more prone to the deficiency of Zn and Fe followed by Inceptisols and Vertisols. However, Alfisol did not record deficiency of Zn and Fe but B was largely deficient. Boron deficiency was to the extent of 68% in Entisols followed by Vertisols (62%) and Inceptisols (47.0%). Patil *et al*. (2004) [18] and Kharche *et al* (2003) [13] further reported 40%, 12.0%, 34.7 and 31.7% soils deficient in zinc and iron in Vidarbha and western Maharashtra region, respectively. Increasing decline trend in available B (11.0%) and Mo (8.0) was noticed in Vidarbha. Maharashtra state soil testing laboratories analyzed 17540 soils for micronutrients and summary report indicated 41 and 11% soils as zinc and iron deficient, respectively (Anonymous 2003) [3]. Thus, widespread deficiency of zinc is the most serious constraint to sustainable productivity of major soil groups of the state. Variations in the content of DTPA zinc and per cent deficiency in soils were observed.

The DTPA zinc ranges from 0.02 to 16.50 mg kg^{-1} in varied soil groups in western Maharashtra while in varied from 0.13 to 3.66 mg kg^{-1}, 0.18 to 4.25 mg kg^{-1} and 0.02 to 6.84 mg kg^{-1} in soils of Konkan, Vidarbha and Marathwada regions, respectively. Highest per cent deficient samples in zinc were recorded in Vidarbha followed by Marathwada and western Maharashtra. Next deficient micronutrient noted was iron and highest per cent deficiency of Fe in soils (29.0%) was in western Maharashtra, followed by Marathwada (26.0%) soils. Though, soil samples analyzed for boron and copper were not sizeable, the trends of B and Cu deficiency were found very critical to the soils of various regions. Sixty-one and 42% analyzed soils were deficient in B and Cu from Konkan region. This trend in deficiency of B and Cu may be attributed to laterization process on the parent material. DTPA-Mn, available Mo and exchangeable Co are now expressing their deficiencies or relatively their lower supply to the crops. Thus, zinc and iron levels in soils of Maharashtra declined to the status of insufficiency which leads to threat to sustainability in varied soil groups.

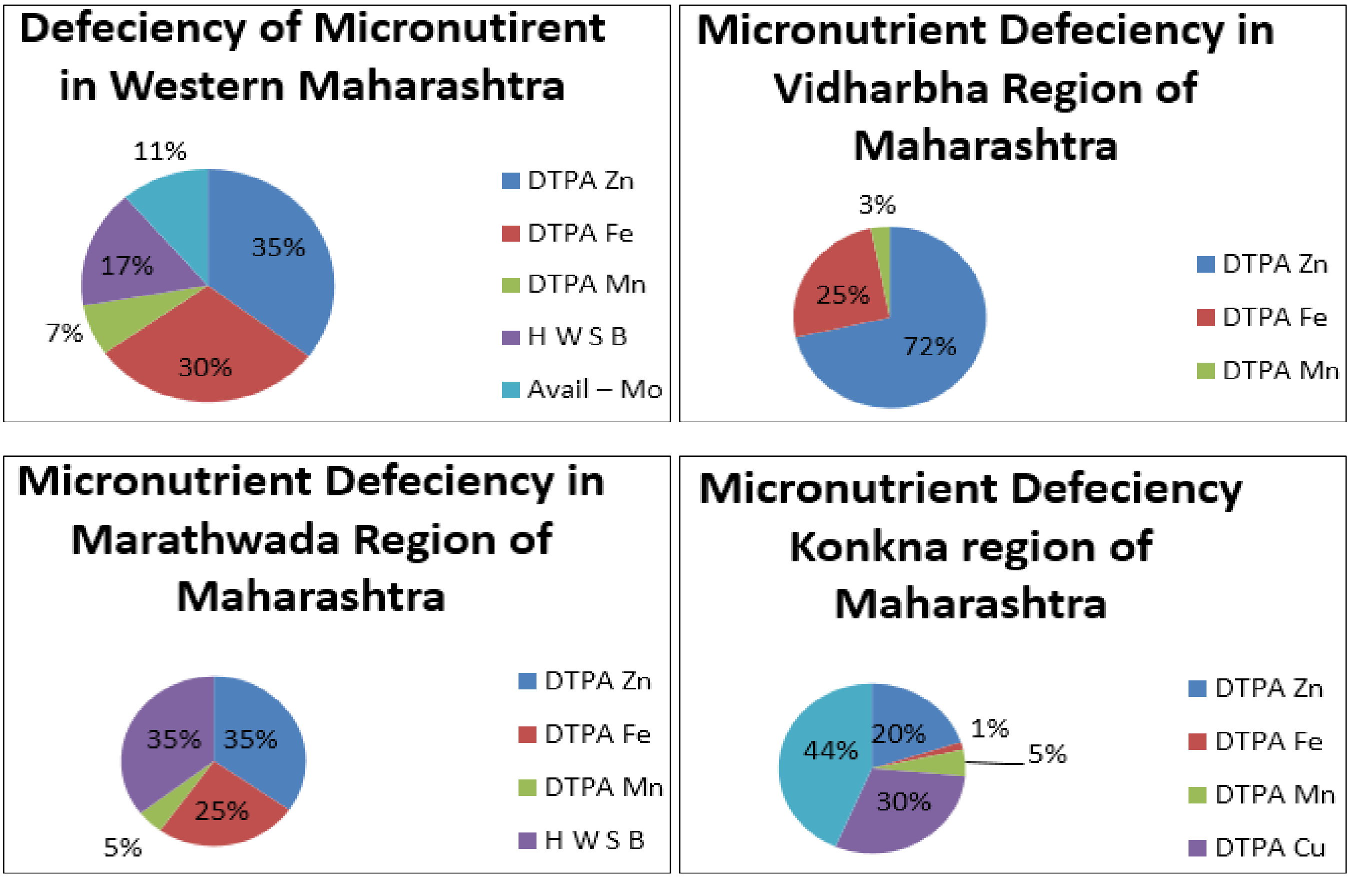
Growth trends of area and production of horticultural crops, 1991- 1992 to 2015-2016 (values in per cent)

Crops	2010-11 over 2009-10		2011-12 over 2010-11		2012-13 over 2011-12		2013-14 over 2012-13		2014-15 over 2013-14		2015-16over 2014-15	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Fruits	-1.4	4.4	5.0	2.1	4.1	6.4	3.4	9.5	-11.9	-0.2	-0.9	1.5
Vegetables	6.4	9.6	5.8	6.7	2.4	3.7	2.1	0.4	1.5	3.3	5.5	0.4
Flowers	4.4	1.0	33.0	60.2	-8.3	4.7	9.5	1.5	24.4	0.4	10.5	-0.8
Aromatics	0.2	5.6	-0.8	-6.4	10.1	62.2	-11.4	-2.5	1.2	3.4	10.5	-0.8
Plantation crops	1.3	0.7	8.2	36.2	1.8	3.8	0.9	-4.0	-3.7	5.1	3.8	-2.8
Spices	19.3	33.2	9.3	11.2	-4.2	-3.5	2.8	2.9	0.0	0.0	8.9	15.4
Total Horticultural crops	4.5	7.8	6.5	7.0	1.9	4.5	2.1	3.2	-3.2	2.2	7.9	2.1

Micronutrient status of different soils of Konkan.

Soil sampling zone/location	DTPA extractable (available) micronutrients (mg kg^{-1})				Boron (mg kg^{-1})
	Fe	Mn	Cu	Zn	
Lateritic soils					
South Konkan (14)*	18.0-36.0 (28.43)	26-144 (104)	2.0-7.92 (6.99)	1.0-3.70 (2.01)	-
Bench terraces Wakawali (125)	10.2-16.4 (11.83)	4.8-200.0 (40.74)	0.1-1.2 (0.33)	-	0.03-0.29 (0.154)
A.R.S. Phondaghat (114)*	9.0-30.00 (24.17)	4.90-260.0 (105.9)	-	0.16-1.40 (0.76)	-
A.R.S. Vengurla (27)*	15.66-58.37 (27.25)	4.00-128.0 (88.4)	1.32-6.13 (2.53)	0.46-3.62 (1.41)	-
From South Konkan	11.1-28.9 (16.16)	34-164.1 (92.38)	6.6-12.5 (9.48)	1.1-4.3 (2.24)	-
Mean	21.57	86.29	3.87	1.61	0.154
Medium black soils					
North Konkan (14)*	16.0-35.8 (28.75)	30.0-156.0 (89)	4.60-12.40 (7.34)	1.40-30 (2.19)	-
Sapota garden, Dahanu (110)*	2.2-26.8 (7.48)	1.8-74.0 (13.25)	1.0-6.6 (2.98)	0.2-4.8 (1.16)	-
A.R.S. Karjat (117)*	7.5-30.0 (14.62)	13.50-74.50 (40.70)	0.90-8.0 (3.22)	2.0-4.0 (2.12)	-
Agril. School, Roha (38)*	22.1-52.0 (36.52)	64.2-282.5 (187.61)	3.2-9.6 (6.81)	1.2-2.8 (1.91)	-
North Konkan (5)*	4.8-26.1 (18.88)	36.6-75.1 (63.34)	7.5-10.9 (11.14)	1.1-5.1 (2.86)	-
Mean	21.25	78.78	6.30	2.05	
Coastal Saline Soils					
From North Konkan (76)*	1.9-41.92 (9.77)	0.48-111.8 (35.73)	0.08-17.4 (6.80)	0.46-6.58 (1.73)	0.034-2.06 (1.39)
From South Konkan (35)*	2.94-53.2 (28.71)	0.32-108.0 (36.94)	1.02-24.66 (8.60)	0.44-5.72 (1.75)	0.008-2.02 (0.98)
ARS, Panvel (87)*	1.0-21.8 (7.75)	10.0-92.0 (34.8)	1-12 (3.59)	2.0-14.4 (4.19)	-
KLRS, Pargaon Panvel (56)*	1.40-32.0 (3.99)	3.0-121.0 (28.11)	3-6 (3.51)	3.0-4.0 (3.26)	-
Mean	12.56	33.89	5.63	2.74	1.19

Note: Figure in parentheses indicates average. (Patil, 2016) [20]
* No. of samples Source: Malewar (2005) [16]



Source: Malewar (2005)

Fig 1: Micronutrients defeciencies in soils of different regions of Maharashtra

Status of micronutrient deficiencies in Maharashtra soils

The overall picture of different soils of Maharashtra showed widespread zinc deficiency (36.71%) throughout the state followed by boron 31.76% and iron (24.54%). According to recent scenario on micronutrient status of soils. Vidharbha region showed 48.97 per cent deficient soils in zinc followed by western Maharashtra (35.17%), Konkan (28.08) and Marathwada (21.5%). Relatively calcareous soils of Marathwada, Vidharabha and Western Maharashtra registered 35.1, 17.30 and 26.88% available iron deficiency. Surprisingly, Konkan soils were found to be deficient in Boron (61.00%) and Copper (42%).

Micronutrient Management in Soil Plant System

The examples of beneficial and antagonistic relationships between nutrients do caution about the difficulty in proper soil management for the maintenance of adequate levels of micronutrients in soil. Since production is to be increased per unit area of land, favourable balances are to be maintained between different nutrients so as to overcome the nutritional constraints in limiting the crop production. The micronutrients need of a crop is specific and the micronutrients are interrelated in their functional relationship. It is very difficult to generalize the soils management practices for maintaining adequate levels of micronutrients in soil. Since there is not much difference in the toxic and deficiency levels of a micronutrient, location specific expertise hence the management is essential.

A knowledge about factors affecting the availability of micronutrients in soils provide a general guidance to the management practices to be followed for keeping them in available forms. Due consideration is to be given to soil texture, pH, soil water regimes and $CaCO_3$ content before any management step is decided. The next consideration to be given is the intensity of cropping and the fertilizer consumption pattern. If consumption of NPK fertilizer is very high in an intensive cropping system, micronutrient deficiency is expected and micronutrient fertilizers should be recommended if the soil tests show micronutrient deficiency. The incipient micronutrient deficiency in soil can be overcome by selecting crop varieties which can be efficiently absorb micronutrients from soil solid phases also. The simplest management of micronutrient deficiency in soils is to add micronutrient fertilizers along with NPK in alternate years if soil test shows deficiency. Soil application of micronutrients fertilizers is more effective in field crops than spray application. In fruit trees, however, both are considered as effective methods of application. In spray application, micronutrients may be mixed with plant protection chemicals and micronutrients to reduce the cost of application.

Most of the micronutrients occur in acid soils in very high amounts which may become toxic to sensitive crops. It is very difficult to remove the micronutrients from the soils system once these have entered there. But their solubility or availability can be changed by adding appropriate soil amendments. If lime is added to the acid soil, the micronutrient availability is decreased considerably. Similarly, in calcareous, alkaline and sodic soils deficiencies of Fe, Zn, Cu and Mn are frequently observed. Use of gypsum, pressmud or sulphur as soil amendments is beneficial in bringing down the high pH and increasing the availability of micronutrients in soils. Application of green manure is also beneficial in reclaiming such soils if rice is grown under submerged soil conditions. It has been observed that maintaining soil pH around 6.0 is beneficial for the maintenance of adequate level of micronutrients in soils. The micronutrient availability is regulated by soil moisture regime. Since a good drainage condition of soil maintains aerobic environment, micronutrients occur in their oxidized states. Under submerged soil conditions, the reduced forms of Fe and Mn dominate the soil solution however Zn and Cu may become deficient to crop if the native content of these two micronutrients is low.

The most modern concept of micronutrient management in soil is to grow such varieties of crop which have the ability to extract the required micronutrients from insoluble sources. Such crop varieties are to be developed by genetic engineering by combining nutrient utilization efficient varieties with those having high yield attributes by genetic manipulation and genetic engineering. A few such crop varieties are available now for cultivation in Australia and the USA without micronutrient fertilizer application. The response of cereals, pulses and oilseeds to micronutrient fertilizer application in India.

Micronutrient removal

Species	Micronutrients (g/ha/yr)				
	Fe	Mn	Cu	Zn	B
Banana	15	270	180	30	35
Mango	15	10	16	14	

Source: Ghosh (2000) [10].

Micronutrients and Mango

Mango fruit yield per tree (50.24 kg) having significant higher flowering fruit set fruit retention percentage and higher C:B ratio (1:3.15) was recorded with treatment 0.5 percent (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$, Borax, CuSO4 each) + 0.01% (Sodium molybdate) first spray at bud break stage second at full boom inflorence stage and third at egg size fruit. The higher TSS and low spongy tissue was observed in same treatment (Patil, 2010) [22].

Micronutrient composition of healthy pulp, healthy pulp from spongy fruit and spongy tissue in ripe Alphonso fruit

Sample	Content of micronutrients (ppm)			
	Fe	Cu	Mn	Zn
Healthy pulp	35.50	1.80	6.00	8.00
Healthy pulp from Spongy fruit	60.10	2.60	11.00	ND
Spongy tissue	17.00	1.30	6.90	36.90

Chavan and Gupta (1987) [7]

The data presented in Table 9 indicated that the spongy tissue had lower concentration of iron and copper and much higher concentration of zinc as compared to healthy pulp. It has accumulated 4.5 times more zinc as compared to healthy pulp, when the iron concentration approached a level of 60.10 ppm, the zinc was 17 ppm the concentration of zinc reached to a significant level of 36.9 ppm in spongy tissue.

Effect of foliar application of B and Zn on micronutrient composition, Fe: Zn ratio and incidence of spongy tissue in ripe Alphonso fruits.

Treatment	Content of micro elements				Fe: Zn	percent Incidence
	Cu	Fe	Mn	Zn		
Control: S	1.8	10.5	2.1	13.5	0.77	15
:H	2.4	22.3	6.0	4.4	5.0	(60)
Boron	3.0	40.2	5.5	7.4	5.4	Nil (30)
Zinc	2.2	42.9	2.5	10.3	4.1	Nil (30)

Chavan and Gupta (1987) [7]

S: Spongy tissue
H: Healthy pulp from healthy Fruit
Note: Figure in parenthesis indicate the no. of fruits.

It is seen that none of the treated fruit had spongy tissue while the control fruits showed 15 per cent spongy tissue. The foliar application of both the Boron and Zinc has increased the levels of Fe and Zn in the fruits as compared to control.

It was however interesting to note that the ratio of Fe to Zn due to foliar spray was not change appreciably and it was maintained between 4.1 to 5.4as compared to 5.0 in control. The ratio of iron to Zinc in control fruit was decreased appreciably from 5.0 in healthy fruits to only 0.77 in spongy tissue of spongy fruit. These results are very much in con formation with our previous findings and strongly suggest the insolvent of Fe: Zn interaction in the development of spongy tissue in Alphanso mango

Cashew

In case of Cashew three sprays of 0.25% (Urea, SOP, SSP each) + 0.25% ($ZnSO_4$ each) + 0.01 % (Sodium molybdate) first spray be given one month before flowering, second at flowering and third at nut setting time of cashew along with recommended dose of fertilizer in lateritic soil of Konkan to obtain maximum yield (1648 kg/ha) and to control yellow leaf spot (Anon. 2012) [4].

Gavit (2018) [9] conducted an experiment on effect of different levels of nitrogen, phosphorus and potassium along with soil and foliar application of zinc and boron on yield and quality of cashew nut (*Annacardium occidentale* L.) Variety Vengurla-4 in lateritic soil of Konkan at Rukhi Block of Irrigation Water Management, Central Experimental Station, Wakawali during May 2015 to April 2017, where the effect of different treatments on leaf nutrient status at various growth stages and on physico-chemical properties of soil at different growth stages of cashew nut (*i.e.* at new emergence shoot stage, flowering stage, nut setting stage and at harvest) were studied. The experiment was laid out in Randomized Block Design with four levels of NPK (1.0:0.25:0.25, 1.0:0.50:0.50, 1.5:0.75:0.75 and 2.0:1.0:1.0 kg NPK per tree) with or without soil application of boron through borax @ 50g + zinc through zinc sulphate @ 125g/tree or foliar application of boron through borax @ 0.25% + zinc through zinc sulphate @ 0.5% /tree, an absolute control (to judge the fate of native nutrients) comprising thirteen treatments replicated thrice. Two trees were selected for each treatment. Total seventy eight uniform cashew trees of variety *Vengurla*-4 were selected from the orchard at the slope of the hill.

It is revealed from the study that 22.36 to 57.97 per cent increase in the yield of cashew nut was recorded during 2015-16 and 12.80 to 44.09 per cent increase in the yield of cashew nut was recorded during 2016-2017 with application of different levels of nitrogen, phosphorus and potassium along with soil or foliar application of boron through borax and zinc through zinc sulphate. The highest yield of cashew nut per tree (11.80 kg $tree^{-1}$ during first year and 10.36 kg $tree^{-1}$ during second year) and number of nuts per kg were was recorded with the application of recommended dose of fertilizer + soil application of boron through borax @ 50 g + zinc through zinc sulphate @ 125g/tree (treatment T_6). Application of 1.5:0.75:0.75 kg /tree + boron through Borax @ 0.25% + zinc through zinc sulphate @ 0.5% /tree (T_{12}) exhibited significantly higher total N, P and K as well as protein and oil content of cashew kernel.

Effect of different levels of NPK along with soil and foliar application of Zn and B on yield of cashew nut.

Treatment	2015-2016			2016-2017		
	Nut yield kg/tree	No. of nut/kg	Average wt. of nut	Nut yield kg/tree	No. of nut/kg	Average wt. of nut
T_1	7.47	136	7.12	7.19	138	6.58
T_2	9.14	137	7.20	8.11	141	6.70
T_3	9.73	137	7.26	8.28	141	6.72
T_4	10.81	137	7.28	9.32	140	6.87
T_5	10.37	137	7.27	8.82	141	6.84
T_6	11.80	141	7.46	10.36	142	6.79
T_7	10.58	140	7.39	9.86	141	6.84
T_8	10.67	139	7.32	9.72	140	6.91
T_9	10.58	145	7.34	10.04	140	6.80
T_{10}	10.55	139	7.42	9.50	140	7.07
T_{11}	10.74	143	7.33	9.80	142	6.80
T_{12}	9.92	142	7.31	8.93	140	6.86
T_{13}	10.54	140	7.35	9.41	141	6.87
Mean	10.22	139	7.31	9.21	140	6.82
SE±	0.675	1.374	0.06	0.512	1.929	0.043
C.D. (P=0.05)	1.970	4.01	N.S.	1.494	N.S.	0.125

Application of 1.0:0.50:0.50 NPK kg/tree+ foliar application of boron through borax @ 0.25% +zinc through zinc sulphate @ 0.5%/ tree (T_{11}) recorded significantly higher total nitrogen and copper in cashew nut leaves, while Application of 2.0:1.0:1.0 NPK kg/ tree + boron through borax @ 0.25% + zinc through zinc sulphate @ 0.5%/tree (T_{13}) recorded significantly higher total micronutrient (*viz.* Mn, Zn and B) in cashew nut leaves and also micronutrient (*viz.* Fe. Mn, Zn and Cu) in cashew kernel.

By considering the higher yield of cashew nut, protein and oil content, NPK and micro-nutrient (*i.e.* Fe, Mn, Cu, Zn and B) content in leaf at different growth stages of cashew (*i.e.* at new emergence shoot stage, flowering stage, nut setting stage and at harvest) and availability of nutrients in the soil, application 1.0:0.50:0.50 kg NPK per tree along with spraying of foliar application of boron though borax @ 0.25% + zinc through zinc sulphate @ 0.5% was to be beneficial in lateritic soils of Konkan.

An experiment was conducted on Effect of Boron containing briquettes on yield of arecanut in Shrivardhan. It was observed that the T_6 treatment in which 150% RDF along with 4kg B ha^{-1} through KAB was applied recorded highest yield (11.56 kg per palm) which found to be at par with all treatments except T_1 and T_7 (Anonymous, 2017) [5].

Effect of Boron containing briquettes on yield kg per palm (Fresh wt.) of arecanut (Pooled Data)

Treatment Details	2013-14	2014-15	2015-16	Pooled
T_1: Recommended Dose of Fertilizers	7.50	9.38	8.35	8.41
T_2: RDF + 4 kg B ha^{-1} through soil application	8.88	9.28	10.23	9.46
T_3: RDN + 4 kg B ha^{-1} containing KAB	11.38	7.88	12.51	10.59
T_4: RDN + 2 kg B ha^{-1} containing KAB	8.44	9.63	10.21	9.43
T_5: 150 % RDF + 4 kg B ha^{-1} through soil application	11.88	10.23	9.57	10.56
T_6: 150 % RDN + 4 kg B ha^{-1} through KAB	11.50	13.00	10.20	11.56
T_7: 150 % RDN + 2 kg B ha^{-1} through KAB	10.13	8.73	8.65	9.17
SE ±	0.78	0.50	0.55	0.75
CD (P=0.05)	2.35	1.47	1.63	2.31

The application of the Boronated KAB as well as application of straight fertilizers showed the significant results to reducing the splitting of nuts as well as increasing the yield of arecanut. The above data showed that the application of 150% RDF along with 4 kg B ha^{-1} through KAB recorded highest B: C ratio with higher yield and lowest percentage of splitting of the nuts in the arecanut of Konkan region. The treatment T_6 recorded highest number of fruits per palm (357.42) which found to be significantly superior over rest of all the treatments.

Effect of Boron containing briquettes on number of fruits per palm (Pooled Data)

Treatment Details	2013-14	2014-15	2015-16	Pooled
T_1: Recommended Dose of Fertilizers	223.63	286.25	226.13	245.34
T_2: RDF + 4 kg B ha^{-1} through soil application	272.75	339.50	266.50	292.92
T_3: RDN + 4 kg B ha^{-1} containing KAB	296.38	249.75	287.50	277.88
T_4: RDN + 2 kg B ha^{-1} containing KAB	245.38	292.13	247.13	261.55
T_5: 150 % RDF + 4 kg B ha^{-1} through soil application	289.25	268.00	282.50	279.92
T_6: 150 % RDN + 4 kg B ha^{-1} through KAB	384.00	308.25	380.00	357.42
T_7: 150 % RDN + 2 kg B ha^{-1} through KAB	311.63	251.25	286.63	283.17
SE ±	17.89	17.55	14.30	19.20
CD (P=0.05)	53.16	52.14	42.50	60.70

Effect of micronutrient on yield and quality of Nagpur mandarin

Treatments	Yield		Weight per fruit (g)	Volume per fruit (cc)
	No. of fruits/tree	Weight of fruits/tree		
T_1- ZnSO4 (02.5%)	739	130.39	167.85	186.71
T_2 ZnSO4 (0.50%)	665	127.13	167.91	185.47
T_3 B (0.1 %)	797	134.15	149.89	165.80
T_4- B (0.2 %)	721	131.36	161.72	181.57
T_5- FeSO4 (0.5%)	731	124.19	154.65	174.38
T_6 –ZnSO4 @ 200 g/tree	1153	193.22	153.74	171.80
T_7- Control	784	129.15	148.0	8164.57
CD at 5%	50.92	11.73	3.82	5.92

Effect of Boron application to tomato in lateritic soils and its uptake.

Experiments conducted during 1987-1990 at Soil Conservation Research Station, Awashi (Tal Khed, Ratnagiri) indicated that the application of 100 kg N + 50 kg P_2O_5 + 50 kg K_2O + B @ 0.5 kg ha^{-1} through borax is the most remunerative treatment for tomato grown in *Rabi* season on lateritic soils of Konkan (C:B ratio 1.307) (Mahajan *et al.* 1992) [14].

Yield of tomato fruits (q ha^{-1}) as influenced by foliar and soil application of boron in lateritic soil of Konkan

Treatment Details	Pooled mean	C:B ratio
Basal dose (No boron)	123.90	0.988
Basal dose + soil application of B @ 0.5 kg/ha through BSP	154.69	1.231
Basal dose + soil application of B @ 0.5 kg/ha through borax	166.36	1.307
Basal dose + soil application of B @ 1.0 kg/ha through borax	150.46	1.164
Basal dose + soil application of B @ 1.5kg/ha through borax	161.45	1.231
Basal dose + two foliar sprays of 0.5 ppm B	157.79	1.257
S.E. ±	7.670	
C.D. @ 5%	23.126	

(Mahajan *et al.* 1992) [14]

Kadam *et al,* (2017) [12] conducted an experiment on Effect of Boron and Konkan Annapurna Briquettes on yield and nutrient uptake by Okra [*Abelmoschus esculentus* (L.)] was conducted at Central Experiment Station, Wakawali during *kharif* season 2015. The tar coated KAB found to be superior for slow release of nutrients to be promising source of NPK fertilizers as compared to the conventional fertilizers method for enhancing the green pod yield of *Varsha uphar* variety of okra in lateritic soils of Konkan. Amongst the application of different levels of NPK and boron, it was concluded that the application of 75% RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} which was applied in two splits i.e. 1/2 quantity of briquettes at 2-3 leaf emergence stage of okra plant and 1/2 quantity of briquettes at 30 days after sowing @ 2 briquettes per plant found to be superior for increasing okra pod yield.

Effect of Boron and Konkan Annapurna Briquettes on length and number of okra fruit per plant

Treatments	Average weight of fruit per plant (gm)						Fruit yield (q ha^{-1})					
	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean
B_0	309.46	343.39	405.86	339.41	361.39	351.90	114.61	127.18	150.32	125.71	133.85	130.33
B_1	314.45	346.90	390.47	346.35	385.70	356.78	116.46	128.48	144.62	128.28	142.85	132.14
B_2	328.51	378.18	462.88	413.69	433.37	403.33	121.67	140.07	171.44	153.22	160.51	149.38
Mean	317.47	356.15	419.74	366.48	393.49		117.58	131.91	155.46	135.73	145.74	
	F		B		F x B		F		B		F x B	
S.E. ±	13		5.94		13.28		2.84		2.20		4.92	
C.D (P=0.05)	22.20		17.20		38.46		8.22		6.37		14.24	

Jadhav *et al,* (2017) [11] studied on effect of micronutrients on yield, Nutrient Uptake and Quality of Coriander (*Coriandrum sativum* L.) in Lateritic Soils of Konkan Region". Coriander, variety Konkan Kasturi was taken as a test crop during the *Rabi* season of the year 2016-2017 with a spacing of 30 x 10cm and the gross plot size was 3.0m x 3.0m. The field experiment was laid out in randomized block design. The experiment included ten treatments comprising of soil application and foliar spray of $ZnSO_4$ and $CuSO_4$ in varying concentrations along with 100 per cent RDF in three replications. The highest yield of 11.18 t ha^{-1} of coriander was obtained with the application of 0.5 per cent $ZnSO_4$ through foliar spray along with 100 per cent RDF (T_5) with highest chlorophyll content of 2.54 mg g^{-1} and ascorbic acid content of 524.79 mg 100 g^{-1} of coriander. However, the yield of coriander (10.56 t ha^{-1}) with the soil application of $ZnSO_4$ @ 20 kg ha^{-1} along with 100 per cent RDF (T_6) which is at par with the treatment T_5 had significantly superior β-carotene content of 2502.12 µg 100 g^{-1} in coriander. Thus, the application of $ZnSO_4$ @ 0.5 per cent foliar spray along with 100 per cent RDF or the soil application of $ZnSO_4$ @ 20 kg ha^{-1} along with 100 per cent RDF to coriander crop significantly increase the yield.

Effect of zinc and copper on the yield of coriander

Treatments	Yield (kg plot^{-1})	Yield (t ha^{-1})
T_1-Absolute control	4.79	5.32
T_2-100 % RDF (60:60:30 N: P_2O_5: K_2O kg ha^{-1})	8.71	9.68
T_3-100 % RDF + $ZnSO_4$ @ 0.25 % Foliar spray	9.15	10.17
T_4-100 % RDF + $ZnSO_4$ @ 15 kg ha^{-1} through soil	9.04	10.04
T_5-100 % RDF + $ZnSO_4$ @ 0.5 % Foliar spray	10.06	11.18
T_6-100 % RDF + $ZnSO_4$ @ 20 kg ha^{-1} through soil	9.50	10.56
T_7-100 % RDF + $CuSO_4$ @ 0.25 % Foliar spray	8.92	9.91
T_8-100 % RDF + $CuSO_4$ @ 15 kg ha^{-1} through soil	8.82	9.80
T_9-100 % RDF + $CuSO_4$ @ 0.5 % Foliar spray	9.13	10.14
T_{10}-100 % RDF + $CuSO_4$ @ 20 kg ha^{-1} through soil	8.99	9.98
Mean	8.71	9.68
SE (m) ±	0.23	0.25
CD at 5 %	0.68	0.75

(Jadhav *et al.* 2017) [11]

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