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# Micronutrients for Horticultural Crops in Soils of Konkan Region, Maharashtra

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## Abstract

It is established that micronutrients are important for agricultural crops. However, the way these nutrients are widely-used and made popular for field crops, similar situation does not hold good for horticultural crops. This is in spite of many research publications showing usefulness of micronutrients for fruits, flowers, vegetables and spices including plantation crops. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (DBSKKV) in Maharashtra is an Agricultural University engaged in research on horticulture and other agricultural fields for the last 45 years or so with a mandate specific to Konkan region. Available micronutrient status of the soils of Konkan region has been extensively assessed. Many research findings reported increased yield, better fruit size, and better quality products of fruits, vegetables, flowers and spices if practices recommended by DBSKKV along with required quantity of micronutrients are applied. The present article takes a tour on such research endeavours of DBSKKV for the benefit of researchers, planners and other experts in the line departments in other parts of the country. The present information forms a state-of-art information on micronutrients for horticultural crops. It has also a larger connotation on the role of fertilizer industry to make micronutrients available at the door steps of the farmers at the appropriate time. Once put into practice, this will bring happiness to the farmers and shall enthuse them towards doubling their income.

**Key words :** Micronutrients, horticulture, DBSKKV, fertilizer industries, doubling farmers' income

## Introduction

Seventeen nutrients namely carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), zinc (Zn), copper (Cu), manganese (Mn), iron (Fe), chlorine (Cl), boron (B) and molybdenum (Mo) and nickel (Ni) have been recognized so far as essential for plant growth. Carbon, H and O supplied from air and water constitute approximately 95% of the plant dry matter. Depending on the plants' requirements as witnessed in terms of plant composition, N, P, K, Ca, Mg and S have been classified as major nutrients and Fe, Mn, Zn, Cu, Ni, B, Mo and Cl designated as micronutrients. Micronutrients together constitute only 0.05% of the total dry matter, but needless to say that absence of one Mo atom makes one million of N atoms redundant as without Mo, N can't organize itself to produce plant.

In practical agriculture emphasis is on Fe, Mn, Zn, Cu, B and Mo. Globally soils either suffer from deficiencies of Zn or B (Sillanppa, 1982). Simultaneous occurrence of their deficiencies together is rare (Rattan et al., 2008). Horticultural crops suffer widely due to zinc (Zn) deficiency followed by boron (B), manganese (Mn), copper (Cu), iron (Fe) (mostly induced) and molybdenum (Mo) deficiencies (Ganeshamurthy et al., 2018). While Zn deficiencies affect cereals more severely, B deficiency disorders are more prevalent in fruit, vegetable and other horticultural crops. Importance of micronutrients in horticultural crops is highlighted from the fact that their nutritional disorders have been given specific names like apple scab (Zn deficiency), whiptail of cauliflower (Mo deficiency), hollow stem of cauliflower (B deficiency) etc. Implication of Fe deficiency in accentuation of citrus canker is another example. Chlorine (Cl), copper (Cu), iron (Fe) and manganese (Mn) are involved in various processes related to photosynthesis and Zn, Cu, Fe, and Mn are associated with various enzyme systems; Mo is specific for nitrate reductase (NR) activity, enzyme critical for nitrogen assimilation and metabolism. Boron may not be involved either in photosynthesis or enzyme function, but carbohydrate chemistry and reproductive system of the plant is influenced by its deficiency (Jeyakumar and Balamohan, 2018).

In general, deficiency of micronutrients causes fall in crop productivity and farm income, because healthy yield-enhancing elements like number of flowers, grain filling, number, shape, size and weight of fruits, integrity of fruits/vegetables get adversely affected. Optimum B supply is not only closely related to productivity, but is crucial for sustaining quality of produce also. On this account, small and marginal farmers who primarily earn their livelihood from cultivation of fruits and vegetables are likely to be hit hardest by expanding incidences of micronutrient deficiencies. Role of iron and zinc in human nutrition has been clearly established during last sixty years or so. World Health Organization has ranked Fe and Zn deficiencies as 5th and 6th among top ten leading causes of illness and diseases in the low income countries (WHO, 2006). Alarmed at the gravity of situation, CGIAR institutes have launched Harvestplus programme on biofortification of major crops with Zn and Fe. Some zinc-fortified rice varieties have already been released for cultivation (Rattan, 2017).

Micronutrient deficiencies in

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Indian soils are on rise due to agricultural intensification exacerbated by application of micronutrient-free NPK fertilizers with virtual exclusion of organic inputs. External application of micronutrients is critical because this will not only replenish them in soil nutrition but will also help in getting better quality fruits, flowers, vegetables and spices including the plantation crops. Judicious application of micronutrients in horticultural crops holds an additional advantage as more food intake through these horticultural products makes human diet healthy and balanced (Bhattacharyya et al., 2017). Needless to say micronutrients via horticultural crops are critical in making India nutritionally secure. This article critically analyzes the role and effects of micronutrients in fruits, flowers, vegetables and spices.

## Micronutrients and Horticultural Crops

Micronutrients are required in smaller amounts than the other essential nutrients. Generally, soils contain sufficient levels of micronutrients to meet crop demands; however, in some areas micronutrient shortages occur and may limit yields. Some crops have a higher demand for certain micronutrients than others and should be considered in determining whether a micronutrient fertilizer should be applied or not **(Table 1)**.

### *Role of Micronutrients in Fruit Crops*

As compared to major nutrients like NPK, the role and requirements of micronutrients in horticultural crops received less attention. It is generally believed that micronutrients are present in adequate quantities in Indian soils for optimum production. However, it is now recognized that with the adoption of improved agronomic practices for increasing production, use of high yielding varieties, adoption of intensive farming and cropping systems, the demand for micronutrients has been on rise. This is more so due to the advent of hi-tech horticulture for producing more from the same area. **Table 2** details the importance of various micronutrients for a wide range of fruits. **Figure 1** shows some examples of micronutrient deficiencies in fruit crops.

### *Role of Micronutrients in Production of Flowers*

Floriculture is the art and knowledge of growing flowers to perfection. It is a fast emerging and highly competitive industry. To reach out to the competitive export and domestic markets, quality plays an important role in growing business of flowers. To control the plant growth in flower crops combinations of major and micronutrients are important. Information on micronutrients' role in flowers is presented in **Table 3. Figure 2** shows the effects of these nutrients on flowers.

### *Role of Micronutrients in Vegetables*

Micronutrients are indispensable for growth and development of crops in general, and vegetables in particular. The nutritional value of crops is becoming a major issue. Therefore, the application of

**Table 1. Relative response of fruit and vegetable crops to micronutrients under soil conditions favourable to a deficiency (Lucas and Knezek, 1973)**

| Crop | Response to micronutrients | | | | | |
|---|---|---|---|---|---|---|
| | Zn | Fe | Mn | Mo | Cu | B |
| **Fruits** | | | | | | |
| Apples (*Pyrus malus*) | H* | – | H | L* | M | H |
| Grapes (*Vitis vinifora*) | M* | H | H | L | L | M |
| Raspberries (*Rubus idaeobatus*) | – | H | H | L | – | M |
| Strawberries (*Fragaria ananassa*) | – | H | H | – | M | M |
| **Vegetables** | | | | | | |
| Asparagus (*Asparagus officinalis*) | L | M | L | L | L | L |
| Beans snap (*Phaseolus vulgaris*) | H | H | H | L | L | L |
| Broccoli (*Brassica oleracea var. italica*) | – | H | M | M | M | H |
| Cabbage (*Brassica oleracea var. capitata*) | L | M | M | M | M | M |
| Carrots (*Daucas carota*) | L | – | M | L | H | M |
| Cauliflower (*Brassica oleracea var. botrytis*) | – | H | M | H | M | H |
| Cucumber (*Cucumis sativus*) | – | – | H | – | M | L |
| Onions (*Allium cepa*) | H | – | H | H | H | L |
| Peas (*Pisum sativum*) | L | – | H | M | L | L |
| Potatoes (*Solanum tuberosum*) | M | – | H | L | L | L |
| Radishes (*Raphanus sativus*) | M | – | H | M | M | M |
| Spinach (*Spinacia oleracea*) | H | H | H | H | H | M |
| Tomatoes (*Lycopersicon esculentum*) | M | H | M | M | M | M |

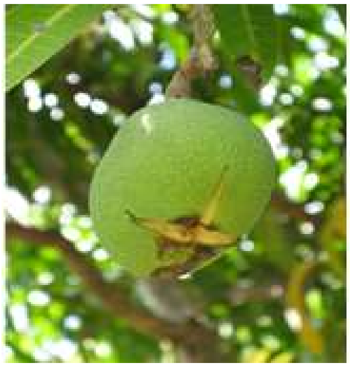
* H = High; M : Medium; L: Low

Table 2. Role of micronutrients in selected tropical fruits ((Yadav and Solanki, 2015)

| Fruits | Micro-nutrients | Functions | Reference |
|---|---|---|---|
| Banana (*Musa paradisicum*) | Zn,Cu | Root growth | Srivastava (1964a,b) |
| | B, Zn, Cu, Mn | Plant height, girth, leaf area and number of functional leaves | Das and Mohan (1993) |
| | Zn, Cu, B | Plant growth at flowering in terms of height, girth of pseudo-stem and number of leaves per plant | Ghanta and Mitra (1993) |
| Mango (*Mangifera indica*) | Zn | Length of terminal shoot, number of leaves and leaf area per shoot | Singh and Rajput (1976) |
| | Zn, Fe, B | Vegetative growth in terms of plant height, trunk girth and spread of young plants | Singh and Rajput (1976) |
| Guava (*Psidium guava*) | Zn | Increases leaves and number of flowers. | Sharma and Bhattacharyya (1994) |
| | Cu | Increases terminal shoot length, number of leaves and leaf area. | Singh and Singh (2002) |
| Grape (*Vitis vinifora*) | | Improves fruit set and reduces panicle drying. | Kumar et al. (1988) |
| Papaya (*Carica papaya*) | Fe | Plant height and girth | Veena and Lavania (1998) |
| Litchi (*Litchi chinensis*) | Zn, Cu, B | Plant growth and vigour | Babu and Singh (2002) |
| Citrus fruits (*Citrus spp.*) | Zn | Increases the leaf area. | Bhambota et al. (1962) |
| | Cu, Zn, B | Increases the number of fruits per plant, total fruit weight per plant, fruit diameter and yield of Mandarin orange. | Haque et al. (2000) |
| Pineapple (*Ananaus sativus*) | Zn | Improves fresh, dry weight and edible portion of fruits | Srivastava (1969) |

**Mango tree loaded with fruits**

**Fummosis-Cu deficiency**



**Cracking of fruits - Boron deficiency**

**Jackfruit loaded tree - Early harvest before rains**

**Cracking of nuts - Boron deficiency**

**Nuts loaded of arecanuts due to reduction in fruit drop**

**Figure 1. Deficiency of micronutrients in fruit crops**

**Table 3. Role of micronutrients in selected flowers**

| Fruits | Micro-nutrients | Functions | Reference |
|---|---|---|---|
| Gladiolus (*Gladiolus oppositiflorus*) | Fe, B, Zn | Increases plant height, leaf chlorophyll content, flower stalk length, flower fresh weight, spike length, florets per spike, florets' fresh weight and diameter, flower vase-life, flower diameter as well as fresh weight of corms | Fahad et al. (2014) |
| Rose (*Rosa spp.*) | Fe, Zn | Plant height, number of leaves and leaf area | Patel et al. (2016) |
| Tuberose (*Polianthes tuberosa*) | Zn | Increases length of spike, diameter of spike, length of rachis, length of floret, diameter of floret, and vase life. | Tayade et al. (2018) |

**Table 4. Role of micronutrients in selected vegetables**

| Fruits | Micronutrients | Functions | References |
|---|---|---|---|
| Tomato (*Lycopersicon esculentum Mill.*) | B | Increases no. of leaves and height. | Verma et al. (1973) |
| | Zn, B, Fe | Increases plant height. | Hussain et al. (1989) |
| Chilli (*Capsicum annuum L.*) | B | Increases fruit yield. | Dongre et al. (2000) |
| Cabbage (*Brassica oleracea* L.) | Fe, Mn, Zn, Cu, B | Increases plant growth and yield. | Chaudhari et al. (2017) |
| Broccoli (*Brassica oleracea*) | B, Mo, Mn, Zn | Increases vitamin C and total soluble solids (TSS). | Pankaj et al. (2018) |

micronutrients to sustain soil health and crop productivity besides maintaining the quality of vegetables is of profound importance. However, foliar application of micronutrients shows better efficacy than soil application as the uptake and assimilation of micronutrients by latter method takes more time. **Table 4** and **Figure 3** summarize role of these nutrients in selected vegetables.

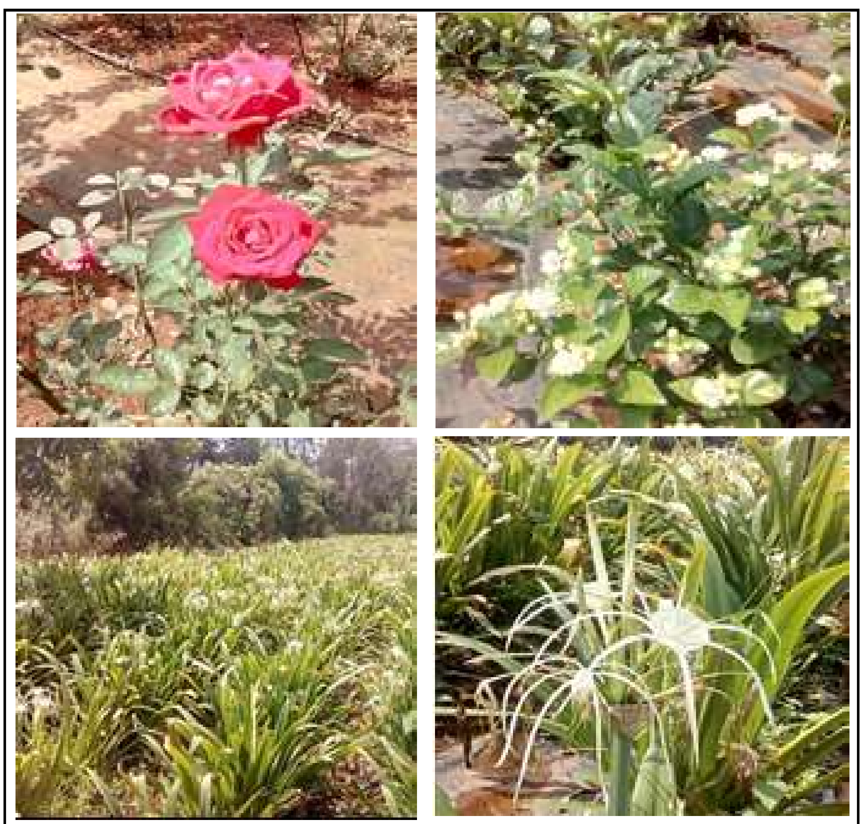


**Figure 2. Effects of micronutrients on flowers**

### *Role of Micronutrients in Spices*

Spices are exclusively of vegetable origin and occupy important position in the diet of human race. These are seed, fruit, bark or root of a plant which possess high fragrance and pungent aroma, being valued for their taste or smell, and when added to foods make them more palatable and stimulate digestion. Cardamom, the "Queen of Spices" is native to evergreen Western Ghats of India and is one of the most valuable spices in the world. Indian cardamom is known for its luxuriant green colour with good aroma quality, which was internationally accepted. The cardamom oil is found to be anti-microbial in nature and hence used in mouth fresheners and confectioneries. Currently it is being grown in Kerala, Karnataka, Tamil Nadu and parts of Sikkim in India (Subbiah et al., 2008). Seeds of spices are important horticultural commodities. Micronutrients affect various characters of spices. For

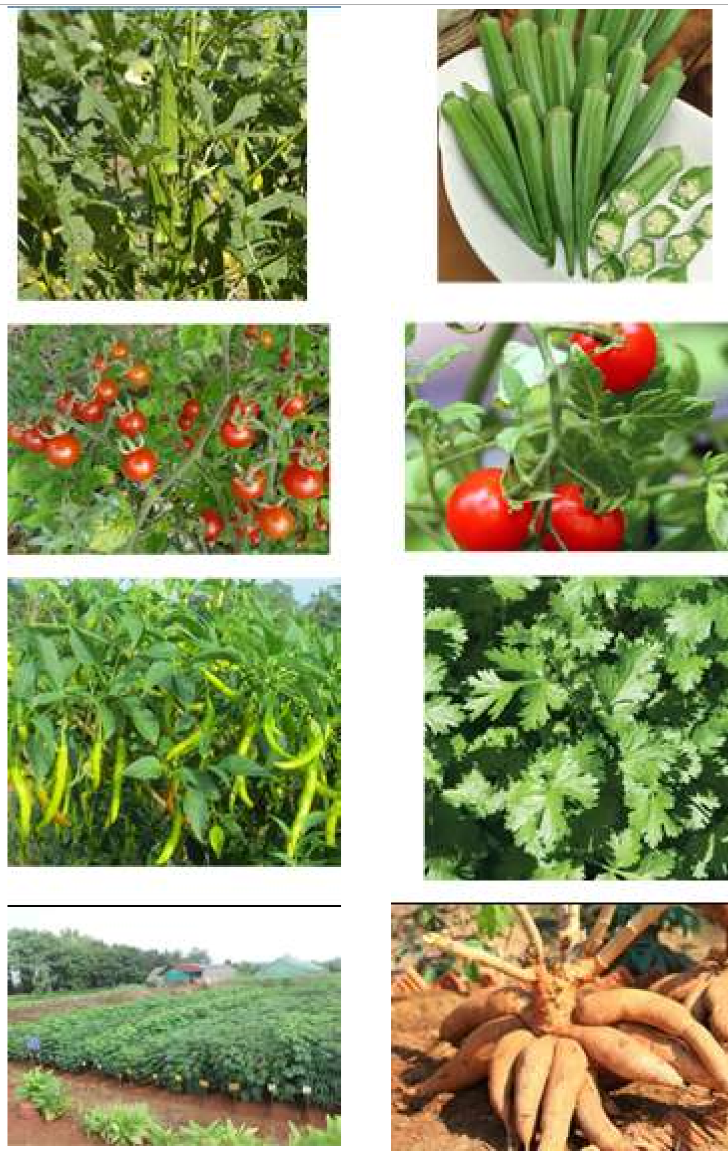


**Figure 3. Effects of micronutrients in vegetables**

example, in coriander (*Coriandrum sativum*, L.) application of Fe, Zn, Mn, and Cu influences number of branches, umbels per seed, and seed yield. Coriander needs external applications of Fe, Zn, Mn, and Cu when grown on calcareous soils (Sinta et al., 2015). Garlic (*Allium sativum* L.) is an important bulb crop next to onion. The cloves of garlic bulb are used in flavouring of various dishes. The significance of this spice is increasing owing to its wide range of medicinal properties. Role of micronutrients in spices is given in **Table 5**. India ranks second in the world in respect of area and production (Chanchan et al., 2013) **(Figure 4)**.

### Available Micronutrient Status of the Soils of Konkan Region

DTPA soil test of Lindsay and Norvell (1978) has been used to assess the available Fe, Mn, Cu and Zn content of the soils of Konkan region whereas hot water is used to assess the B availability (Berger and Truog, 1939). Data for different soil types of the region are presented in **Tables 6** and **7**. Available micronutrient status in the ferruginous red soils of Konkan has also been summarized by Malewar (2005) and the same is presented in **Table 8.**

#### *Available Iron*

The mean content of available iron in ferruginous red (22 mg $kg^{-1}$),

**Table 5. Role of micronutrients in spices**

| Crops | Nutrients | Role | References |
|---|---|---|---|
| Fenugreek (H. *Methi*) (*Trigonella foenum-graecum*) | Cu | Early germination | Anonymous (2013) |
| Saffron (*Crocus sativa*) | K, Zn, Fe | Influences leaf length, leaf area index (LAI), stigma dry weight, crocin, picrocrocin and safranal. | Akbarian et al. (2012) |
| Cardamom (*Elettaria cardamomum*) | Zn | Growth and yield | Anonymous (2018 a,b) |
| Garlic (*Allium sativum*) | Zn | Increases the number of cloves per bulb and weight of cloves. | Chanchan et al. (2013) |
| Ginger (*Zingiber officinale*) | Zn, B | Increases yield. | Halder et al. (2007) |
| Black pepper *(Piper nigrum)* | Zn | Reduces spike shedding, increases yield. | Hamza and Sadanandan (2005) |
| Coriander *(Coriandrum sativum)* | Fe, Zn, Mn, Cu | No. of branches, umbels, seed yield | Sinta et al. (2015) |

**Figure 4. Effects of micronutrients on spices**

medium black (21 mg $kg^{-1}$) and coastal saline soils (13 mg $kg^{-1}$) shows its adequacy to plants grown thereon as the critical level of Fe deficiency is between 2.5-4.5 mg $kg^{-1}$. However, its deficiency is noticed in few pockets particularly in strongly alkaline (pH 8.4 to 9.0), calcareous ($CaCO_3$ >8%), medium black (Yadav 1988) and coastal saline soils of north Konkan (Andhalkar, 1984; Anonymous, (1988). Recent studies by Patil (2012) indicated that the DTPA-Fe content varied from 8 to 112 mg $kg^{-1}$ in different soil types of Konkan region (**Table 7**).

### *Available Manganese*

The available manganese content in different soil types was adequate (Pereira et. al., 1986). It was higher in ferruginous red soils (86 mg $kg^{-1}$) than in medium black (79 mg $kg^{-1}$) and coastal saline (34 mg $kg^{-1}$) soils. Later, DTPA extractable Mn was reported low (0.3-2.7 mg $kg^{-1}$) in acid sulphate soils (Entic Chromusterts) (**Table 6**) (Patil 2001).

### *Available Copper*

Available copper (**Table 6**) in

**Table 6. Micronutrient status of different soils of Konkan (Patil, 2016)**

| Soil sampling zone/location | *DTPA extractable (available) micronutrients (mg $kg^{-1}$) | | | | Hot water soluble B (mg $kg^{-1}$) |
|---|---|---|---|---|---|
| | Fe | Mn | Cu | Zn | |
| **Ferruginous red 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 (0.15) |
| 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) | 34.0-164.1 (92.38) | 6.6-12.5 (9.48) | 1.1-4.3 (2.24) | - |
| Mean | 21.57 | 86.29 | 3.87 | 1.61 | 0.15 |
| **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** | | | | | |
| 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) |
| 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: Figures in parentheses indicates average.* * No. of samples in brackets

| Table 7. Available micronutrient status of rice soils of Konkan region (Patil, 2012)) | | | | |
|---|---|---|---|---|
| Soil type | DTPA extractable content (mg $kg^{-1}$) of | | | |
| | Fe | Mn | Cu | Zn |
| **A) Very high rainfall lateritic soils (South zone)** | | | | |
| ***Ferruginous red soils (Typic Haplustepts)*** | | | | |
| Range | 14.98-111.95 | 06.06-68.60 | 1.49-9.32 | 0.29-2.28 |
| Mean | 46.54 | 42.47 | 3.32 | 1.03 |
| ***Acid sulphate soils (Entic Chromusterts)*** | | | | |
| Range | 26.68-108.90 | 0.29-2.74 | 1.40-2.63 | 0.46-0.85 |
| Mean | 71.76 | 1.38 | 2.01 | 0.59 |
| ***Coastal saline soils (Vertic Halaquepts)*** | | | | |
| Range | 29.07-53.44 | 37.62-58.24 | 6.17-6.59 | 2.90-3.25 |
| Mean | 44.47 | 51.30 | 6.35 | 2.76 |
| **B) Very high rainfall non-lateritic soils (North zone)** | | | | |
| ***Medium black soils (Vertic Haplustepts)*** | | | | |
| Range | 8.0-89.63 | 7.09-72.35 | 1.60-9.55 | 0.42-1.90 |
| Mean | 37.29 | 32.01 | 5.15 | 1.01 |
| ***Heavy clay soils Vertic Haplustepts)*** | | | | |
| Range | 12.11-42.42 | 49.42-71.84 | 3.0-5.08 | 0.62-1.71 |
| Mean | 31.67 | 63.14 | 3.92 | 1.08 |
| ***Coastal saline soils (Vertic Halaquepts)*** | | | | |
| Range | 34.04-91.42 | 41.42-68.04 | 6.42-8.47 | 1.73-2.62 |
| Mean | 48.70 | 55.17 | 7.19 | 2.24 |
| ***Red brown (Lithic Ustorthents)*** | | | | |
| Range | 20.32-60.15 | 38.73-54.70 | 1.23-5.93 | 0.64-1.81 |
| Mean | 49.30 | 47.17 | 3.48 | 1.17 |

**Table 8. Micronutrient status in ferruginous red soils of Konkan, Maharashtra (Malewar, 2005)**

| Micronutrients | No. of samples | Range (mg $kg^{-1}$) | No of samples deficient | per cent deficiency |
|---|---|---|---|---|
| DTPA-Zn | 245 | 0.13-3.66 | 68 | 28.0 |
| DTPA-Fe | 445 | 1.90-124.70 | 30 | 2.0 |
| DTPA-Mn | 445 | 0.32-200.0 | 09 | 7.0 |
| DTPA-Cu | 571 | 0.10-24.60 | 238 | 42.0 |
| Hot water soluble B | 503 | 0.008-2.06 | 302 | 61.0 |
| Available Mo | 176 | 0.05-0.45 | - | - |
| Exchangeable Co | 30 | 0.06-0.46 | 07 | 23.0 |

**Table 9. Growth trends of area and production of horticultural crops, 2010- 2011 to 2015-2016 (values in per cent) (Bhattacharyya et al., 2017)**

| 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—16 over 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 |

Table 10. Few recommendations of micronutrients for the selected horticultural crops in Konkan, Maharashtra

| Sr. No. | Name of crop | Doses of nutrients | Comments | Reference |
|---|---|---|---|---|
| 1 | Mango | ✓ 3 multi-nutrient sprays<br>✓ 0.5% (urea, SOP, SSP each),<br>✓ 0.25% ($ZnSO_4$, borax, $CuSO_4$ each)<br>✓ 0.01% sodium molybdate | • 1st spray at bud break<br>• 2nd spray on full bloom inflorescence<br>• 3rd spray at egg stage on Alphonso mango in ferruginous red soils of Konkan. | Anonymous (2011) |
| | | • 2 sprays<br>• chelated calcium 0.02% ·<br>200 ppm NAA (Naphthalene<br>• acetic acid) or<br>0.15% chelated zinc | • first at egg stage and<br>• second at 10 days after first spray<br>• Reduces spongy tissue | Anonymous (2016 a,b) |
| 2 | Cashew | • 2 sprays of 0.01% $CuSO_4$<br>• 0.05% lime ($CaCO_3$) | • Each spray at flowering and fruit set | Anonymous (2018 a,b) |
| | | • 3 sprays of<br>• 0.25% (Urea, SOP, SSP each)<br>• 0.25% ($ZnSO_4$)<br>• 0.01 (Sodium molybdate) | • First spray one month before flowering<br>• Second spray at flowering, and<br>• Third at nut setting<br>Increases yield and controls yellow leaf spot | Anonymous (2012) |
| 3 | Coconut | • Ormichem (Micronutrient complex) at 1.5 kg/palm/year | To be applied in<br>• June,<br>• September, and<br>• January | • Shinde et al. (2016).<br>• Nagvekar et al. (1998) |
| 4 | Areca nut | • 150% RDN (225 kg N) ·<br>• 4 kg B $ha^{-1}$<br>Increases yield | Through Konkan Annapurna Briquette (KAB) | Anonymous (2017) |
| | | 600 g of micronutrients<br>• B 1 %,<br>• Zn 5%,<br>• Fe 2% and<br>• Cu 5% | To apply in August –September | Anonymous (2016 a,b) |
| 5. | Tomato | • 100 kg N<br>• 50 kg $P_2O_5$<br>• 50 kg $K_2O$<br>• B @ 0.5 kg $ha^{-1}$ through borax | • Remunerative treatment for *rabi* tomato on ferruginous red soils of Konkan<br>• C:B ratio 1.307 | Mahajan et al, (1992) |
| 6. | Okra | • 75% RDN through tar coated KAB<br>• Fortified with boron (B) @ 4 kg $ha^{-1}$ | Two splits<br>• Half quantity of briquettes at 2-3 leaf emergence stage of okra plant and<br>• Half quantity of briquettes at 30 days after sowing @ 2 briquettes per plant | Kadam et al. (2017) |
| 7. | Cassava | • 20 kg $MgSO_4$,<br>• 12.5 kg $ZnSO_4$,<br>• 10 kg borax through soil and foliar spray of $FeSO_4$ @ 0.5% nutrient<br>· Along with recommended dose of fertilizer (FYM @ 10 t + 100:50:100 kg NPK $ha^{-1}$) | • Higher tuber yield and<br>• More economic returns from cassava in Konkan region | Anonymous (2018 a,b) |
| 8. | Coriander | • $ZnSO_4$ @ 0.5% foliar spray<br>• Along with 100% RDF or<br>• The soil application of $ZnSO_4$ @ 20 kg $ha^{-1}$ along with 100 per cent RDF | Significantly increases the yield. | Jadhav et al. (2017) |

**Table 11. Recommendations of micronutrients for various horticultural crops**

| Crop | Recommendation | Frequency |
|---|---|---|
| | **Fruit crops** | |
| Mango *(Mangifera indica)* | 0.5% urea, SOP (K), SSP (P), 0.25% Na molybdate (Mo) | 3 sprays<br>1. Vegetative growth<br>2. Flowering stage<br>3. After fruit set |
| Cashew nut *(Anacardium occidentale)* | 0.25% urea, SOP (K), SSP (P), 0.25% $ZnSO_4$ (Zn), borax (B), $CuSO_4$ (Cu), 0.1% Na molybdate (Mo) | 3 sprays<br>1. One month before flowering<br>2. Flowering stage<br>3. Fruit set |
| Gauva *(Psidium guava)* | 0.5% each of Zn, Mn and Mg + 0.25% each of Cu and Fe | 2 sprays |
| Sapota *(Manilkara zapota)* | 0.1% boric acid | 4 sprays<br>From June, at an interval of 1 month |
| Grape *(Vitis vinifera)* | 0.2% $FeSO_4$ + 0.5-1% $ZnSO_4$ + 0.2% boric acid | 2 spraysFirst before bloom and second after fruit set |
| | **Plantation crops** | |
| Areca nut *(Areca catechu)* | Soil: 4 kg B $ha^{-1}$, 300 kg N $ha^{-1}$ (N and B through Konkan Annapurna Briquettes) along with recommended dose (200 kg P+ 200 kg K $ha^{-1}$) | 2 split doses at<br>• August-September<br>• December-January |
| Banana *(Musa paradisicum)* | 0.3% $ZnSO_4$ + 0.5% urea | 2 sprays one each at 45 and 60 days after planting |
| | **Vegetable crops** | |
| Tomato *(Lycopersicon esculentum* Mill.*)* | Boron @ 0.5 kg $ha^{-1}$ along with RDF | Basal dose |
| Brinjal *(Solanum melongena)* | 0.5% $FeSO_4$ + 0.1% urea | 2-3 sprays at an interval of 20 days each |
| | **Flowering crops** | |
| Jasmin *(Jasminum* spp.*)* | 225 g each of borax, $ZnSO_4$, $MnSO_4$, $FeSO_4$ and $CuSO_4$ + 10 g ammonium molybdate + 10 liters of water | Poured in the basin of 1.5 m radius |

**Sources** : Shetiwadi Kokanachi (2018), DEE, DBSKKV, Dapoli, Maharashtra (dbskkv.org); Jeyakumar and Balamohan (2018); Jyolsna and Mathew (2008)

medium black soils was the highest (6.3 mg $kg^{-1}$) followed by coastal saline (mean 5.6 mg $kg^{-1}$) and ferruginous red soils (mean 3.9 mg $kg^{-1}$ ) which is well above the critical limit of 0.2 mg $kg^{-1}$ DTPA-Cu. However, deficiency of available copper in bench-terraced ferruginous red soils is also reported at certain places (Patil et al., 2016).

### *Available zinc*

The mean content of zinc was more in coastal saline soils (2.7 mg $kg^{-1}$) than medium black soils (2.0 mg $kg^{-1}$) and in ferruginous red soils (1.6 mg $kg^{-1}$) **(Table 6)**. About 65% of medium black soils of sapota garden from Dahanu in North Konkan (Yadav, 1988) and 50.9% soils at Agricultural Research Station, Phondaghat in South Konkan (Dabke, 1987) were marginally adequate to deficient in zinc status.

### *Available Boron*

Boron content in ferruginous red and coastal saline soils ranged from 0.03 to 0.29 and 0.03 to 2.06 mg $kg^{-1}$, respectively. The bench-terraced ferruginous red soils are, however, reported to be deficient in available boron (Patil et al., 2016) **(Table 6)**.

## Micronutrient Recommendations in Horticultural Crops

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 came from the horticulture sub-sector. Fruits and vegetables constituted the second largest category among agricultural crops in terms of gross value of output (GVO) with 25% contribution in 2014-15 (**Table 9**). 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).

The soils in Konkan need micronutrients not only to boost yield of the horticultural produce but also can maintain the soil quality and health in this fragile coastal ecosystem of Konkan. Over years DBSKKV, Dapoli has recommended several viable technologies to increase economic yield, and fruit quality. A few are summarized in **Table 10**. It may be mentioned that all these recommendations are to be followed along with the recommended doses of fertilizers (RDF). Konkan, Maharashtra is an excellent place for growing various horticultural crops. General recommendations of nutrients for a few other horticultural crops are given in **Table 11** from different sources.

## Conclusions

Demand for micronutrients has shown steady rise with the adoption of improved agronomic practices for increasing production. The shortage of organic manure for large scale application and higher use of micronutrient-free NPK fertilizers make it essential to apply micronutrients for increasing quantity and quality of horticultural produce and also ensure efficient use of major nutrients and sustenance of soil health. This demands application of micronutrients as discussed in this article. It also necessitates planning on the part of fertilizer industry to meet the rapidly-increasing demand for these nutrients

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