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Soil Micronutrients-Unsaid

Baseerat Binti Nabi and Rehana Rasool

Abstract
Micronutrients are essential plant mineral nutrients taken up and utilised by fruit crops in very small quantities. They constitute in total less than 1% of dry weight of most plants. Micronutrients increase the quality and yield of fruit trees. Besides they play multiple roles in fruit development for example formation of growth hormones, chlorophyll formation, oxidation-reduction reactions, colour development, etc. Plant growth and development may be retarded if any of these elements is lacking within soil or is not adequately balanced with other nutrients. Factors such as soil pH, organic matter, temperature, soil type and moisture are important determining factors for the availability of micronutrients (Fageria *et al*, 2001). In recent years however deficiencies of micronutrients have been diagnosed more frequently by farmers due to greater amount of intensive cropping, high demand of modern crop cultivars, losses through leaching and so on (Scherer, 2001). Micronutrient deficiency is usually corrected by addition of micronutrient containing compounds such as, sodium tetraborate (14-20% B), boric acid (17%B), ferrous ammonium sulphate (14% Fe), zinc sulphate (23-36% Zn), copper sulphate (13-35% Cu), potassium chloride (47% Cl), manganese sulphate (23-25% Mn), ammonium molybdate (54% Mo), nickel chloride (25% Ni) (Lohry, 2007). Without adequate micronutrients, crops can't reach their full potential in terms of both yield as well as quality. Highest yield of pistachio was produced in two levels of Zn and maximum vegetative growth took place in Zn and Fe treatment, whereas highest of splitting rate was detected in combination of Cu and Fe and lowest one in control, but effect of Zn, Cu and Fe on blankness was not significant (Soliemanzadeh *et al*., 2013). Since micronutrients are involved in various enzymatic activities, their deficiency causes malfunctioning of plant activities. Response to micronutrients varies from crop to crop and depending upon the soil type and its status. In addition to yield it improves quality of fruit (Bahmanyar and Mashaee, 2010).

Keywords: Micronutrients, chlorophyll formation, oxidation-reduction reactions, colour development, etc.

Introduction
One hundred and nine elements have been identified and included in the periodic table so far. Most of these exist in the periodic table so far. Most of these exist in earth's mantle, earth's crust and soil, though the magnitude of their occurrence varies. To a certain extent plant composition reflects the chemical composition of the soil. A nutrient element is one that is required to complete the life cycle of the organism and its relative deficiency produces specific deficiency symptoms. The adverse effects are relieved by the supply of that specific element only. Elements essential for the plants may not be essential for the other organisms and vice versa. Depending upon availability, the nutrient content in a plant could be deficient, sufficient or toxic. Nutrient content is considered deficient when it severely limits growth and produces characteristic deficiency symptoms. Nutrient contents associated with only growth reductions and not accompanied by appearance of deficiency symptoms are termed insufficient. Range of nutrient content in plants associated with optimum crop yields is called sufficient. When the concentration of a nutrient element rises too high to cause significant growth reductions, it is termed toxic. (Rattan and Goswami, 2012) [28].

Essential elements
Elements needed by the plant without which it will not be able to survive are called as essential nutrients. For an element to be regarded as an essential nutrient, it must satisfy the following criteria, as propounded by Arnon and Stout (1939):
1. A deficiency of an essential nutrient element makes it impossible for the plant to complete the vegetative or reproductive stage of its life-cycle.
2. The deficiency is specific to the element and can be prevented or corrected only by supplying that element.

3. The element is involved directly in the nutrition of the plant, quite apart from its possible effects in correcting some microbiological or chemical conditions of the soil or other culture medium.

The seventeen nutrients recognised essential for the plant growth are: carbon(C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl), nickel (Ni). Nickel is the last addition to the list of essential elements, done in 1987.
Depending upon the quantity required by the plants nutrients are classified into macronutrients and micronutrients.

Macronutrients
Macronutrients or major nutrients are so called because these are required in large quantities, more than that of iron. These include C, H, O, N, P, K, Ca, Mg, and S. Carbon, hydrogen and oxygen constitute 90 to 95 % of the plant drymatter weight and are supplied through carbon dioxide (CO_2) and water. Remaining six major nutrients, viz. N, P, K, Ca, Mg and S are further subdivided into primary and secondary nutrients. Primary nutrients: Nitrogen, phosphorus and potassium are termed as primary nutrients because of their larger requirement by the plants and correction of their wide spread deficiencies is often necessary through application of commercial fertilizers of which these are the major constituents.

Secondary nutrients
Calcium, magnesium and sulphur are termed as secondary nutrients because of their moderate requirements by plants, localised deficiencies and their inadvertent alleviation by incidental accretions. For example, the phosphatic fertilizers, single superphosphate (SSP) contains Ca and S. Likewise ammonium sulphate, a nitrogenous fertilizer also supplements S.

Micronutrients
Micronutrients are elements which are essential for plant growth, but are required in much smaller amounts than those of the primary nutrients; nitrogen, phosphorus and potassium. The micronutrients are boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), and chloride (Cl). While chloride is micronutrient, deficiencies rarely occur in nature, so discussions on supplying micronutrient fertilizers are confined to the other six micronutrients. Deficiencies of micronutrients have been increasing in some crops. Some reasons are higher crop yields which increase plant nutrient demands, use of high analyses NPK fertilizers containing lower quantities of micronutrient contaminants, and decreased use of farmyard manure on many agricultural soils. Micronutrient deficiencies have been verified in many soils through increased use of soil testing and plant analysis.

Micronutrient Nutrition
A brief discussion of micronutrient functions and nutrient deficiency symptoms in plants and soil conditions affecting micronutrient availability serves to help understand their importance in crop production and to recognize symptoms of possible deficiencies:

Boron
A primary function of boron is related to cell wall formation, so boron-deficient plants may be stunted. Sugar transport in plants, flower retention and pollen formation and germination also are affected by boron. Seed and grain production are reduced with low boron supply. Boron-deficiency symptoms first appear at the growing points. This results in a stunted appearance (rosetting), barren ears due to poor pollination, hollow stems and fruit (hollow heart) and brittle, discoloured leaves and loss of fruiting bodies. Boron deficiencies are mainly found in acid, sandy soils in regions of high rainfall, and those with low soil organic matter. Borate ions are mobile in soil and can be leached from the root zone. Boron deficiencies are more pronounced during drought periods when root activity is restricted.

Copper
Copper is necessary for carbohydrate and nitrogen metabolism, so inadequate copper results in stunting of plants. Copper also is required for lignin synthesis which is needed for cell wall strength and prevention of wilting. Deficiency symptoms of copper are dieback of stems and twigs, yellowing of leaves, stunted growth and pale green leaves that wither easily. Copper deficiencies are mainly reported on organic soils (peats and mucks), and on sandy soils which are low in organic matter. Copper uptake decreases as soil pH increases. Increased phosphorus and iron availability in soils decreases copper uptake by plants.

Iron
Iron is involved in the production of chlorophyll, and iron chlorosis is easily recognized on iron sensitive crops growing on calcareous soils. Iron also is a component of many enzymes associated with energy transfer, nitrogen reduction and fixation, and lignin formation. Iron is associated with sulphur in plants to form compounds that catalyze other reactions. Iron deficiencies are mainly manifested by yellow leaves due to low levels of chlorophyll. Leaf yellowing first appears on the younger upper leaves in interveinal tissues. Severe iron deficiencies cause leaves to turn completely yellow or almost white, and then brown as leaves die. Iron deficiencies are found mainly on calcareous (high pH) soils, although some acid, sandy soils low in organic matter also may be iron-deficient. Cool, wet weather enhances iron deficiencies, especially on soils with marginal levels of available iron. Poorly aerated or compacted soils also reduce iron uptake by plants. Uptake of iron decreases with increased soil pH, and is adversely affected by high levels of available phosphorus, manganese and zinc in soils.

Manganese
Manganese is necessary in photosynthesis, nitrogen metabolism and to form other compounds required for plant metabolism. Interveinal chlorosis is a characteristic manganese-deficiency symptom. In very severe manganese deficiencies, brown necrotic spots appear on leaves, resulting in premature leaf drop. Delayed maturity is another deficiency symptom in some species. Whitish-gray spots on leaves of some cereal crops and shortened internodes in cotton are other manganese-deficiency symptoms. Manganese deficiencies mainly occur on organic soils, high-pH soils, sandy soils low in organic matter, and on over-limed soils. Soil manganese may be less available in dry, well-aerated soils, but can become more available under wet soil conditions when manganese is reduced to the plant-available form. Conversely, manganese toxicity can result in some acidic, high-manganese soils. Uptake of manganese decreases with increased soil pH and is adversely affected by high levels of available iron in soils.

Molybdenum

Molybdenum is involved in enzyme systems relating to nitrogen fixation by bacteria growing symbiotically with legumes. Nitrogen metabolism, protein synthesis and sulphur metabolism are also affected by molybdenum. Molybdenum has a significant effect on pollen formation, so fruit and grain formation are affected in molybdenum-deficient plants. Because molybdenum requirements are so low, most plant species do not exhibit molybdenum-deficiency symptoms. These deficiency symptoms in legumes are mainly exhibited as nitrogen-deficiency symptoms because of the primary role of molybdenum in nitrogen fixation. Unlike the other micronutrients, molybdenum-deficiency symptoms are not confined mainly to the youngest leaves because molybdenum is mobile in plants. The characteristic molybdenum-deficiency symptom in some vegetable crops is irregular leaf blade formation known as whiptail, but interveinal mottling and marginal chlorosis of older leaves also have been observed. Molybdenum deficiencies are found mainly on acid, sandy soils in humid regions. Molybdenum uptake by plants increases with increased soil pH, which is opposite that of the other micronutrients. Molybdenum deficiencies in legumes may be corrected by liming acid soils rather than by molybdenum applications. However, seed treatment with molybdenum sources may be more economical than liming in some areas.

Zinc

Zinc is an essential component of various enzyme systems for energy production, protein synthesis, and growth regulation. Zinc-deficient plants also exhibit delayed maturity. Zinc is not mobile in plants so zinc deficiency symptoms occur mainly in new growth. Poor mobility in plants suggests the need for a constant supply of available zinc for optimum growth. The most visible zinc-deficiency symptoms are short internodes (rosetting) and a decrease in leaf size. Chlorotic bands along the midribs of corn, mottled leaves of dry bean and chlorosis of rice are characteristic zinc-deficiency symptoms. Loss of lower bolls of cotton and narrow, yellow leaves in the new growth of citrus also have been diagnosed as zinc deficiencies. Delayed maturity also is a symptom of zinc-deficient plants. Zinc deficiencies are mainly found on sandy soils low in organic matter and on organic soils. Zinc deficiencies occur more often during cold, wet spring weather and are related to reduced root growth and activity as well as lower microbial activity decreases zinc release from soil organic matter. Zinc uptake by plants decreases with increased soil pH. Uptake of zinc also is adversely affected by high levels of available phosphorus and iron in soils.

Chloride

Because chloride is a mobile anion in plants, most of its functions relate to salt effects (stomatal opening) and electrical charge balance in physiological functions in plants. Chloride also indirectly affects plant growth by stomatal regulation of water loss. Wilting and restricted, highly branched root systems are the main chloride-deficiency symptoms, which are found mainly in cereal crops. Most soils contain sufficient levels of chloride for adequate plant nutrition. However, reported chloride deficiencies have been reported on sandy soils in high rainfall areas or those derived from low-chloride parent materials.

Nickel

As nickel is taken by plats in nickel ion forms it is associated with nitrogen metabolism by way of influencing urease activity. In systems where urea is used as the sole N fertilizer for foliar spray and Ni-supply is poor, lower urease activity causes urea toxicity to foliage and leads to severe necrosis of the root tips. In free living *Rhizobia*, adequate Ni-supply ensures optimum hydrogenase activity. It facilitates transport of nutrients to the seeds or grains. There is reduction in dry matter, decrease in amino acid content and accumulation of nitrates due to nickel deficiency.

Concentration of micronutrients in plants (dry weight basis)

Table 1

Element	Symbol	Form	Range of concentration	Adequate concentration
Boron	B	H_3BO_3	0.2-800ppm	20ppm
Chlorine	Cl	Cl^-	10-80,000ppm	100ppm
Copper	Cu	Cu^+,Cu^{2+}	2-50ppm	6ppm
Molybdenum	Mo	MoO_4^{2-}	0.10-10ppm	0.1ppm
Manganese	Mn	Mn^{2+}	10-600ppm	50ppm
Iron	Fe	Fe^{3+},Fe^{2+}	20-600ppm	100ppm
Zinc	Zn	Zn^{2+}	10-250ppm	20ppm

Source: TNAU Agri Portal

Micronutrient sources commonly used for correcting deficiencies in plants

Table 2

Micronutrient	Common fertilizer sources
B	Sodium tetraborate (14%-20%B), Solubor (20%B), Liquid boron (10%B), Boric acid (17%B)
Fe	Ferrous ammonium sulfate (14%Fe), Ferrous ammonium phosphate (29%Fe)
Zn	Zinc sulfate(23-36%Zn), Zinc ammonia complex(10%Zn), Zinc oxide (50-80%Zn) Zinc chelate (9-14%Zn)
Cu	Copper sulfate(13-35%Cu), Copper oxide(75-89%Cu)
Cl	Potassium chloride (47%Cl), Sodium chloride (60%Cl), Ammonium chloride (66%Cl), Calcium chloride (64%Cl), Magnesium chloride (74%Cl)
Mn	Manganese sulfate (23-25%Mn), Manganese oxide (41-68%Mn)
Mo	Ammonium molybdate (54%Mo), Sodium molybdate (39%Mo), Molybdenum trioxide (66%Mo), Molybdic acid (53%Mo)
Ni	Nickel chloride (25%Ni), Nickel nitrate(20%Ni), Nickel oxide(79%Ni)

Lohry, 2007 [22]

Methods of correcting micronutrient deficiencies

Element	Corrective measures	
	Soil application	Foliar application
B	0.5-2kg borax ha^{-1}	0.15% B
Cl	20-50 kg KCl ha^{-1}	Unknown
Cu	5-10 kg $CuSO_4$ ha^{-1}	0.1-0.5% $CuSO_4.5H20$
Fe	30-100 kg $Feso_4$ ha^{-1}	2% $FeSO_4.7H_2O$.
Mn	5-50 kg $MnSO_4$ ha^{-1}	0.4-0.6% $MnSO_4$
Mo	0.01-1 kg Ammonium Molybdate ha^{-1}	0.07-0.1% Na
Zn	0.5-35 kg $ZnSO_4$	0.1-0.5% $ZnSO_4.7H_2O$

Importance of micronutrients

1. Increase quality and yield: Most micronutrients act as co-factors in various enzymes taking part in various metabolisms of plants like protein metabolism, carbohydrate metabolism, photosynthesis etc. therefore there will be increase in protein content, total soluble salts (TSS) and other quality parameters, which result in improving the quality. Micronutrients such as iron which is essential for chlorophyll formation and as a result photosynthesis will increase and thus there will be increase in yield as well.
2. In legumes it influences nitrogen fixation: N-fixation takes place using enzyme nitrogenase. This enzyme consists of two proteins- Fe & Mo protein. Reaction occurs while N_2 is found in nitrogenase complex. Fe protein first is reduced by electrons donated by ferrodoxin. Then this reduced Fe protein binds ATP and reduces Mo-Fe protein, which donates electrons to N_2 producing HN=NH. Further HN=NH is reduced to H_2N=H_2N and this is in turn reduced to $2NH_3$.
3. Effect of micronutrient concentrations in planting seed on the vigour of the next season's crop.
4. Major economic impact of micronutrients in a farming operation is through the increased efficiency of macronutrient fertilizer use.

Determining the need for micronutrients

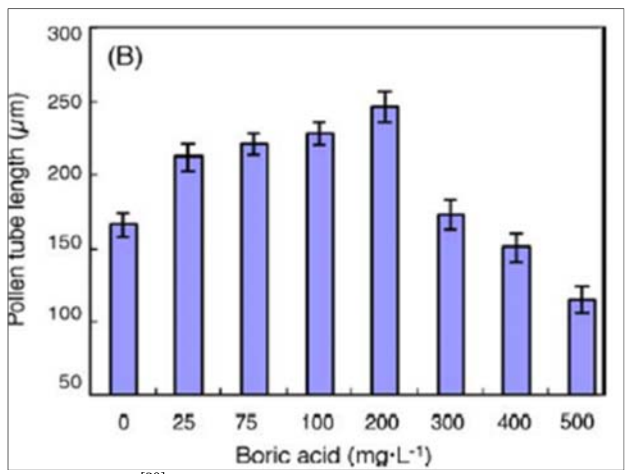
1. Ensure that poor crop growth is not due to macronutrient deficiency or some environmental problems like drought, salinity, disease or insect problems.
2. Look for the micronutrient deficiency in the field.
3. Take soil & plant tissue samples from both affected & unaffected areas and send them for testing.
4. Go for the specific micronutrient application to the crop as per the analysis of the testing.

Causes of micronutrient deficiencies

1. Intensive cropping: Crops are grown intensively on a piece of land which results in depletion of micronutrients.
2. High demand of modern crop cultivars: Since there is need to develop new crop cultivars which have high yield potential and high quality parameters to meet the market demand. These modern crop cultivars are exhaustive in nature that is they deplete soil of micronutrients.
3. Loss of top soil by erosion: Due to heavy precipitation, heavy wind which is rich in micronutrient and thus deficiency occurs.
4. Losses of micronutrients through leaching: Excessive rainfall results in leaching of micronutrients to deeper layers of soil. Thus there is deficiency of micronutrient in rhizosphere.
5. Use of marginal lands for crop production: since these lands have less fertility for crop production so micronutrients availability is less.

Factors affecting the availability of micronutrients

1. Soil pH: Most micronutrients are available under acidic conditions except Mo and B. At low pH micronutrient cations have high solubility as a result it becomes available whereas at high pH these micronutrient forms hydroxy ions which finally are changed to insoluble hydroxides and oxides of elements as a result it becomes unavailable. Mo and B get fixed by silicate clays and oxides of Fe and Al as a result become unavailable.
2. Organic matter: It contains organic compounds, these organic compounds react with micronutrients and form chelates which have high solubility and thus availability increases.
3. Temperature: Availability of most micronutrients tends to decrease at low temperature because root activity and microbial activity gets reduced and low rates of diffusion and dissolution of micronutrients increases temperature.
4. Moisture: Low moisture content decreases the micronutrient availability. When moisture content decreases colloidal particles may become immobilised as a result micronutrient adsorption on surface takes place and decreases their availability.



Lee *et al.* 2009 [20]

Fig 1: Effect of boron on pollen tube length in pear.

Results

Boron has been demonstrated to perform a crucial function in the synthesis and/or structure of plant cell walls, via its binding with rhamnogalacturonan II chains, resulting in the formation of the B-polysaccharide complex (Kaneko *et al*., 1997; Kobayashi *et al*., 1996) [16, 18]. Boron-complexing capability promotes the migration of B and polysaccharides across biological membranes (Matoh, 1997) [24] to pollen tube wall synthesis sites. Pollen tube precursors are known to be rich in polypeptides, most notably glycoprotein and arabino furanosyl residue-rich polysaccharides (Li and Liskens, 1983) [21]. Many of these compounds have been determined to form strong complexes with boron (Loomis and Durst, 1992) [23]. Therefore, the inhibitory effects on pollen tube growth associated with high boron contents may be attributable to excessive cross-linking of pollen cell walls (Hu and Brown, 1994). This would imply that moderate levels of boron might stimulate pollen germination and subsequent pollen tube growth in pear pollen.

Table 2: Effect of zinc, copper and iron on yield, nut weight, splitting rate, blank nut rate and vegetative growth of Pistachio.

Treatments	Yield(dryweight,cluster^{-1})	Nut weight(100 nut g^{-1})	Splitting rate (%)	Blankness (%)	Vegetative growth (cm)
Control	8.09	90.57bc	83.03c	11.53a	11.55ab
$Zn_0Cu_0Fe_1$	10.51bc	89.69c	85.89bc	21.27a	10.45ab
$Zn_0Cu_1Fe_0$	8.55dc	91.11bc	91.86ab	10.82a	12.12ab
$Zn_0Cu_1Fe_1$	10.79ab	94.13ab	**95.52a**	20.88a	11.97ab
$Zn_1Cu_0Fe_0$	**12.77a**	94.55ab	89.25abc	15.28a	10.70ab
$Zn_1Cu_0Fe_1$	8.032d	**95.86a**	82.22c	14.90a	11.42ab
$Zn_1Cu_1Fe_0$	9.12bcd	92.86abc	86.88bc	18.54a	10.57ab
$Zn_1Cu_1Fe_1$	8.37cd	85.53d	87.21bc	16.27a	10.12ab
$Zn_2Cu_0Fe_0$	10.86ab	90.82bc	88.68bc	20.58a	9.82b
$Zn_2Cu_0Fe_1$	7.12d	84.10de	81.50c	20.94a	**13.25a**
$Zn_2Cu_1Fe_0$	7.27d	93.26abc	85.19bc	17.08a	10.85ab
$Zn_2Cu_1Fe_1$	8.37cd	80.92e	89.75abc	14.14a	12.55ab

Soliemanzadeh *et al*. 2013 [33]

Zn_0=0 mgl^{-1}, Zn_1=1000 mgl^{-1}, Zn_2=2000 mgl^{-1}; Cu_0=0 mgl^{-1}, Cu_1=200 mgl^{-1}; Fe_0=0 mgl^{-1}; Fe_1=300 mgl^{-1}

Results

Perhaps these increases in yield were due to significant increase in leaf Zn and Fe concentrations, which in turn induce more flowering an minimize fruit let drop in pistachio trees. Zn-deficient shoots are markedly smaller in size and much redder than normal. This results indicating foliar spray of Zn were effective in increasing the nut weight of pistachio trees. Probably zinc does not play an important role in shell splitting of pistachio. This may result from the limited mobility of applied Zn, which has been attributed, at least in part, to the high binding capacity of leaf tissue for Zn (Zhang and Brown 1999) [37]. Blanking can occur during two different phases of pistachio nut development, nut setting and nut filling. It can be affected by crop load and production practices (Ferguson *et al*. 2005) [11]. The higher vegetative growth for $Zn_2Cu_0Fe_1$ treatment could be explained by the competition for assimilates between vegetative and fruit growth.

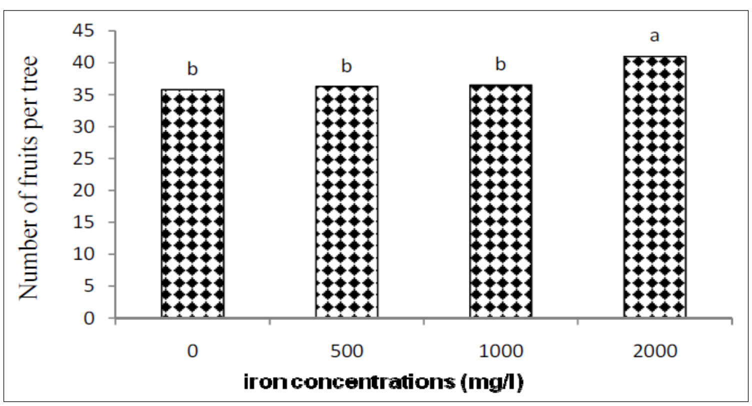
Table 3: Effect of different micronutrients on fruit parameters of peach.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (ml)	Fruit firmness (lb inch $^{-2}$)
T1(0.1%H3BO3)	5.38	4.61	41.68	10.97
T2(0.5%ZnSO4.7H2O)	5.18	4.62	42.50	10.94
T3 (0.5%FeSO4.7H2O)	5.30	4.62	41.74	10.96
T4(0.1%H3BO3+0.5%ZnSO4.7H2O)	5.48	4.69	43.17	11.71
T5(0.1%H3BO3+0.5%FeSO4.7H2O)	5.57	4.68	43.83	11.99
T6(0.5%ZnSO4.7H2O+0.5%FeSO4.7H2O)	5.25	4.68	42.53	11.29
T7(0.1%H3BO3+0.5%ZnSO4.7H2O+0.5%FeSO4.7H2O	5.59	5.08	44.57	12.37
T8(control)	5.12	4.33	39.76	10.35
CD at 5%	0.09	0.02	0.20	0.52

Yadav *et al*. 2013 [36]

Results

The increase in size of fruit as a result of foliar application of micronutrients might be because it improved the internal physiology of developing fruit in terms of better supply of water, nutrients, and other compounds vital for their proper growth and development (Dutta and Banik, 2007) [9]. The increase in fruit weight and volume might be due to increase in cell size and intercellular space (Basker and Davis, 1951) [3]. Zinc has been identified as component of almost 60 enzymes and it has a role in synthesis of growth promoter hormone (auxin). Which is directly associated with improvement of Fresh weight of fruits (Shivanandam *et al.*, 2007) [32]. A favorable effect of foliar application of boron might be due to its role in cell division, cell elongation, sugar metabolism and accumulation of carbohydrates (Sourour, 2000) [34].

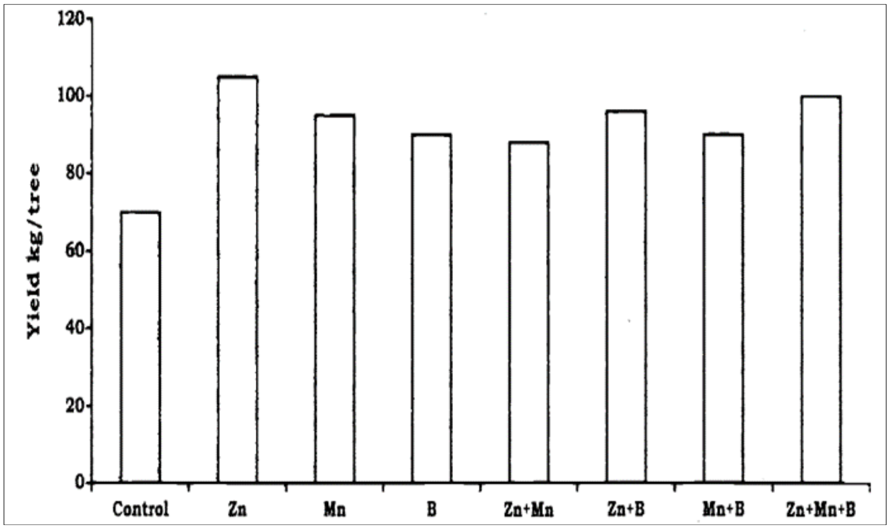


Davarpanah *et al.* 2013

Fig 2: Effect of different concentrations of iron chelated foliar feeding on the number of fruit per tree in Pomegranate.

Results

Irons have a positive effect on the synthesis and activity of chlorophylls and thereby increase the Photosynthesis. The ability of having more Photosynthesis and food cause to increase generative power and whereby the tree can hold more fruits. Foliar injecting of Iron sulfate in apple treesnincreased the amount of fruit in following year (Barney *et al*., 1984).



Parveen *et al.* 2000

Table 3: Effect of zinc, manganese and boron on the yield of orange.

Results

The main effect Zn shows 13% increase in yield as compared to yield obtained from trees where Zn was not included in foliar spray. This significant increase in yield was due to the significant increase in leaf Zn concentration which in turn induced more flowering and minimize fruitlet drop in sweet oranges. It was reported that fruitlet drop was decreased as leaf Zn and Mn content increased (Garcia *et al*, 1984) [13]. Foliar application of Mn to trees significantly increased the yield as compared to trees not sprayed with Mn. The optimum yield was obtained from trees sprayed with Mn alone followed by trees sprayed with Mn+B and these were significantly higher than the control treatment. The increase in yield was due to more fruit setting and less fruit drop in sweet orange. Foliar application of B to trees increased yield significantly as compared to trees not sprayed with B. These results confirm the findings of Chiu and Chang (1986) who reorted 3-15% increase in yield due to B sprays. The cumulative effect of Zn and B was found in reducing heavy fruit drop and increased fruit set (Sato, 1962) [29]. It was concluded that foliar spray of Zn, Mn and B corrected the deficiency symptoms and increased the yield.

Table 6: Effect of micronutrient sprays on morphological and reproductive parameters of Aonla.

Treatment	Plant height (m)	Fruit drop (%)	Fruit retention (%)
T0 (control)	0.69	79.19	20.80
T1 (0.2% Borax)	0.77	74.70	25.30
T2 (0.4% Borax)	0.79	64.19	35.81
T3 (0.4% Zinc Sulphate)	0.75	78.80	21.20
T4 (0.8% Zinc Sulphate)	0.78	69.40	30.60
T5 (0.6% Calcium Nitrate+ 0.4% Borax)	0.93	50.95	49.04
T6 (0.6% Calcium Nitrate + 0.8% Zinc Sulphate)	0.84	60.30	39.70
T7 (0.3% Calcium Nitrate + 0.2% Borax +0.4% Zinc Sulphate)	0.94	40.29	59.71
T8 (0.6% Calcium Nitrate + 0.4% Borax + 0.8% Zinc Sulphate)	0.95	32.60	67.40
CD (5%)	0.07	2.82	2.63

Meena *et al*. 2014

Results

The increase in vegetative growth of plants might be due to stimulative effect of zinc because it is an essential element for chlorophyll formation which is directly related to photosynthetic activity of the plant (Khan *et al.,* 2009). Maximum fruit retention and minimum fruit drop might be due to calcium and boron being main constituent of cell wall (middle lamella) of plant cell in the form of calcium pectate which play an important role in strengthening of pedicel attached to proximal end of fruit resulted less fruit drop. Similarly reduction in fruit drop by spray of borax can be due to the indirect action of boron in auxin synthesis that delayed the formation of abscission layer during early stages of fruit development (Guardiola and Garcia, 2000) [14]. According to Krishnamoorthy (1992) fruit drop is an abscission phenomenon controlled by the inter play of hormones. Zinc application at higher level increased the foliar zinc content which ultimately encourages the endogenous production of auxin thereby reducing fruit drop. Zinc is required for the synthesis of tryptophan a precursor of auxin thus helps in reducing fruit drop.

Table 7: Effect of micronutrients on fruit set and quality of litchi.

Treatment	Fruit weight (g)	Fruit size (cm) Length	Fruit size (cm) Diameter	L:D ratio	T.S.S. (%)	Titratable acidity (%)	TSS : acid ratio
Boron 100 ppm	15.96	3.44	2.94	1.17	17.88	0.44	40.78
Boron 200 ppm	17.26	3.48	3.01	1.16	19.00	0.41	47.07
Zinc 100 ppm	18.17	3.60	3.06	1.18	18.75	0.42	45.29
Zinc 200 ppm	16.55	3.32	2.96	1.12	18.25	0.39	46.83
Control	15.47	3.29	2.93	1.10	17.75	0.43	41.05
$CD_{(0.05)}$	0.95	0.13	0.07	-	0.89	NS	-

Sharma *et al*. 2005

Results

Higher fruit set by zinc application might be due to its effect on processes of fertilization and hormonal metabolism. Zinc is known to be essential for auxin synthesis (IAA) as it is an activator of enzyme tryptophan synthetase. Boron in higher-plants, has a crucial role in flowering, pollen germination and fruiting (Gauch and Dugger, 1954) [12], it also increases the pollen producing capacity of the anthers and pollen viability, thus finally leads to higher fruit set. The possible reason for increase in fruit weight by the micro-nutrients and PBRs might be due to faster loading and mobilization of simple sugars into fruits and involvement in cell division and cell expansion (Brahamchari *et al*, 1997). Increase in TSS content with these PBRs and micro-nutrients may be attributed to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to developing fruits (Brahmachari and Rani, 2001) [5].

Conclusion

Micronutrients are required in very small quantities by the plant for their function. Since they are involved in various enzymatic activities, their deficiencies causes malfunctioning of the plant activities. To manage these micronutrient deficiencies spraying of suitable chemicals at recommended levels by foliar application will alleviate the deficiency. Increases in crop yields from application of micronutrients have been reported in many parts of the world. Factors such as pH, redox potential, biological activity, SOM, cation - exchange capacity, and clay contents are important in determining the availability of micronutrients in soils, Further, roots –induced changes in the rhizosphere affect the availability of micronutrients to plants. Major root induced changes in the rhizosphere are pH, reducing capacity, redox potentials, and root exudates that mobilize sparingly soluble mineral nutrients. Root exudates may make elements like Fe more available, but they may also produce water - soluble metal chelating agents which reduce metal activity with roots. Micronutrient application rates range from 0.2-100kg/ha, depending on the micronutrient, crop requirement and method of application. Higher rates are required for broadcast than for banded applications on soil or as foliar sprays. The development micronutrient-efficient and/or tolerant-resistant genotypes appear promising for improving future crop production.

References

1. Arnon DI, Stout PR. An essentiality of certain elements in minute quantity for plants with special reference to copper. Plant Physiology, 2000; 14:371-375.
2. Bahmayar MA, Mashaee SS. Influences of micronutrients on yield and yield components in pistachio African Journal of Biotechnology. 2010; 9(18):2648-2653.
3. Baker GA, Davis ID. Growth of the cheek diameter of peaches. Proc. Amer. Soc. Hort. Sci. 1951; 57:104-110.
4. Barney D, Walser RH, Nelson SD, Williams CF, Jolley VD. Control of iron chlorosis in apple trees with injections of ferrous sulphate and ferric citrate and with soil-applied Iron-Sulphate. Journal of Plant Nutrition. 1984; 7:313-317.
5. Brahmachari VS, Rani R. Effect of growth substances on productivity, cracking, ripening and quality of fruits of litchi. Orissa J Hort., 2001; 29:44-45.
6. Brahmachari VS, Yadava GS, Kumar N. Effect of foliar feeding of calcium, zinc and boron on yield and quality attributes of litchi (Litchi chinensis. Sonn.). Orissa Journal of Horticulture, 1997; 25:49-53.
7. Chiu TS, Chang SS. Diagnosis and correction of boron deficiency in citrus orchard of Taiwan. Soils and fertilizers of Taiwan, 1986, 33-44.
8. Davarpanah S, Akbari M, Askari MA, Babalar M, Naddaf ME. Effect of iron foliar application (Fe-EDDHA) on quantitative and qualitative characteristics of pomegranate CV. Malas-e-Saveh. World of Sciences Journal, 2013, 4.
9. Dutta P, Banik AK. Effect of foliar feeding of nutrients and plant growth regulators on physico-chemical quality of sardar guava grown in red and lateritic tract of West Bengal. Acta Hortic, 2007, 735.
10. Fageria NK, Brazil NB. Micronutrients in crop production. Advances in agronomy. Academic Press, 2001, 39-50.
11. Ferguson L, Polito V, Kallsen C. The pistachio tree; botany and physiology and factor that affect yield. In: L. Ferguson (ed), Pistachio production manual. 4thedition.Division of Agriculture and Natural Resources. University of California: Oakland, 2005, 31-39.
12. Gauch HG, Dugger WW Jr. The physiological action of boron in higher plants. A review and interpretation. Univ. Maryland Agric. Expt. Sta. Tech. Bull. A, 1954, 80.
13. Garcia A Haydar, NE, Ferrer C. Influence of Zn and Mn on the physiological behaviour and yields of Velancia oranges. Center Agricola, 1982. Institute Superior Agricola Ciego de Avila, Cuba. 1984; 10(2):57-58.
14. Guardiola JL, Garcia Luis. Increasing fruit size in citrus. Thinning and stimulation of fruit growth. Plant Growth Regulation, 2000; 31:121-32.
15. Hu H, Brown PH. Localization of boron in cell walls of squash and tobacco and its association with pectin:

evidence for a structural roles of boron in the cell wall. Plant Physiology. 1994; 105:681-689.
16. Kaneko ST, Ishii T, Matsunaga T. A boron rhamnogalacturonan II complex from bamboo shoot cell walls. Phytochemistry, 1997; 44:243-248.
17. Khan S, Singh HK, Vishwanath Pratap B. Impact of foliar application of micronutrients and thiourea on growth, fruit yield and quality of aonla (Emblica officinalis G.) cv. NA-6. Annals of Horticulture. 2009; 2(1):83-85.
18. Kobayashi M, Matoh T, Azuma J. Two chains of rhamnogalacturonan II are cross- l inked by borate-diol ester bonds in higher plant cell walls. Plant Physiology, 1996; 110:1017-1020.
19. Krishnamoorthy HN. Physiology of plant growth and development. Atma Ram & Sons, Keshmere Gate, New Delhi, 1992, 253-283.
20. Lee HS, Kim SW, Han HT. Effects of post-harvest foliar boron and calcium applications on subsequent season's pollen germination and pollen tube growth of pear (Pyrus pyrifolia). Scientia horticulturae, 2009; 122:77-82.
21. Li Y, Liskens HF. Wall bound proteins of pollen tubes after self and cross pollination. Theor. Appl. Genet, 1983; 67:11-16.
22. Lohry R. Micronutrients: Functions, sources and application method. Indiana CCA conference proceedings, 2007.
23. Loomis WD, Durst RW. Boron and cell walls. Curr. Top. Plant Biochemistry and Physiology, 1992; 10:149-178.
24. Matoh T. Boron in plant cell walls. Plant Soil, 1997; 193:59-70.
25. Meena D, Tiwari R, Singh OP. Effect of nutrient spray on growth, fruit yield and quality of Aonla. Annals of Plant and Soil Research. 2014; 16(3):242-245.
26. Mortvedt J. Effecient fertilizer use manual-Micronutrients, 2000.
27. Parveen S, Rehman HU. Effect of foliar application of zinc, manganese, and boron in combination with urea on the yield of sweet orange. Pakistan Journal of Agriculture Research, 2000; 16:2.
28. Rattan RK, Goswami NN. Fundamentals of soil science. Indian society of soil science, 2012, 349.
29. Sato K. Boron deficiency in citrus. Bulletin of Horticultural Research State, Hiratsuka, Ser. A. 1962; 1:37-64.
30. Scherer HW. Micronutrients in crop production-invited paper. European Journal Agronomy, 2001; 14:81-111.
31. Sharma P, Singh AK, Sharma RM. Effect of plant bio-regulators (PBRs) and micro-nutrients on fruit set and quality of litchi cv. Dehradun. Indian Journal of Horticulture. 2005; 62(1):24-26.
32. Shivanandam VN, Pradeep SL, Rajanna KM, Shivappa. Effect of zinc sulphate on growth and yield of mango varieties and hybrids. Journal Soil Crop. 2007; 17:225-229.
33. Soliemanzadeh A, Mozafari V, Pour AT, Akhgar A. Effect of Cu, Zn and Fe foliar application on fruit set and some quality and quantity characteristics of pistachio trees. South Western Journal of Horticulture, Biology and Environment. 2013; 4(1):19-34.
34. Sourour MM. Effect of foliar application of some micronutrient forms on growth, yield, fruit quality and leaf mineral composition of Valencia orange trees grown in North Sinai. Alexandria Journal of Agricultural Research. 2000; 45(1):269-285.
35. TNAUagritech portal. Agritech.tnau.ac.in/agriculture/agri_min_nutri_essentialelements.html.
36. Yadav V, Singh PN, Yadav P. Effect of foliar fertilization of boron, zinc and iron on fruit growth and yield of low-chill peach cv. Sharbati. 2013; 3:8.
37. Zhang Q, Brown P. The mechanism of foliar zinc adsorption in pistachio and walnut. Journal of American Society of Horticultur Science, 1999; 124:312-317.