academicJournals

Vol. 10(5), pp. 416-422, 29 January, 2015
DOI: 10.5897/AJAR2014.9287
Article Number: AD42BFA49892
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

Use of micronutrients in tropical and sub-tropical fruit crops: A review

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Received 29 October, 2014; Accepted 9 January, 2015

Soil is the reservoir of macro and micro nutrients with the inception of commercial farming the emphasis is given to production without taking care of soil health and eventually soil health deteriorates and production falls. One of the very important components of soil health remained neglected and now reached to the threatening level. Management of balanced nutrients has become of vital importance. Without minimizing the importance of macronutrients in quadrupling the fruit production in the world during the last 50 years, it can be stated that micronutrients are going to play a major productive and qualitative role in bringing stability and sustainability in the production system during the next few decades, particularly in respect of tropical and sub-tropical fruit crops.

Key words: Micronutrient, tropical, sub-tropical.

INTRODUCTION

India is one of the horticultural rich countries of the world, produces large varieties of fruits, and banana is one of them. Since the last 50 years a considerable research work has been done in the country on various aspects such as varieties, irrigation, weed management, spacing, post harvest etc. for increase in yield and quality of banana. It would therefore be worthwhile to improve the growth, yield and quality of banana with basal feedings on nutrients. Moreover, elements like nitrogen, phosphorus and potash play a vital role in promoting the plant vigour and production and the micronutrients like Fe, Zn, Mn, Cu and B are not only essential but they are equally important like other macro nutrients, in spite of their requirement in micro quantities. Micronutrients are key elements in plants growth and development. These elements play very important role in various enzymatic activities and synthesis. Their acute deficiencies some time poses the problem of incurable nature (Kumar, 2002). These micronutrients also help in the uptake of major nutrients and play an active role in the plant metabolism process starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity hormone synthesis, nitrogen fixation and reduction (Das, 2003).

Soil is the reservoir of macro and micro nutrients with the inception of commercial farming, the emphasis is given to production without taking care of soil health and eventually soil health deteriorates and production falls. One of the very important components, that is, micronutrients of soil health remained neglected and now reached to the threatening level. Management of balanced nutrients has become of vital importance.

Without minimizing the importance of macronutrients in quadrupling the fruit production in the country during the last 50 years, it can be stated that micronutrients are going to play a major productive and qualitative role in

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bringing stability and sustainability in the production system during the next few decades, particularly in respect of tropical fruits. The micronutrients are available in non-chelated (sulphate) and chelated form. The chelates are the complex compound in which certain cations are complexed or bound to an organic molecule in complex form. The cations are protected from reactions with inorganic soil constituents that would make them unavailable for uptake by plants. Chelates also provide a continuous supply of nutrient without any danger of toxicity (Tisdale et al., 1985). The role of major nutrients in fruit crops have been intensively investigated on experimental farms as well as on the farmers' field, but less attention has been paid in the past to the requirements of micronutrients for tropical fruits. It is generally believed that micronutrients are present in adequate quantities in Indian soils for optimum production. It is however, 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 demands for micronutrients will also increase. The shortage of organic manure for large scale application and higher use of NPK fertilizers, micronutrients are essential for efficient use and balance soil status of major nutrients, hence application of micronutrients is obvious. An attempt is being made here to present a brief Account of some previous studies related to the present investigation in banana and other fruit crops.

EFFECT OF MICRONUTRIENTS ON GROWTH PARAMETERS

Banana

Micronutrients such as Zn and Cu had been reported to be essential for the growth and development of banana plants (Srivastava, 1964a and b). He further stated when Zn at 2-4 ppm was applied to the roots or as a foliar spray, all the applications of Zn greatly improved both top and roots growth of the plants compared to control plants. Various levels of Cu, Zn, Mo, B and Mn when applied as the substrate and as foliar sprays, Zn and Cu proved essential for growth and development, favorable responses were also obtained to B and Mo and there was a slight response to Mn (Srivastava, 1964). Das and Mohan (1993) reported that application of micronutrients with combination of B + Zn + Cu + Mn, induced marked improvement in plant height, girth, leaf area and number of functional leaves. Ghanta and Mitra (1993) found that the combined application of Zn (0.3%), Cu (0.1%) and B (0.2%) showed the best response in plant growth at flowering in terms of height, girth of pseudostem and number of leaves per plant and maximum days required for flowering from planting. The number of suckers produced per plant at flowering reduced considerably over control. The combined application of 25 kg Farm Yard Manure (FYM) + 0.5 kg Neem cake per plant and 25 kg $ZnSO_4$ per hectare had improved the plant height, plant girth and total functional leaves after 60 days of application (Subramanian and Pillai, 1997). Yadav et al. (2010) recorded maximum plant growth and minimum crop duration with recommended dose of fertilizers (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant.

Mango

Singh and Rajput (1976) reported that the various levels of $ZnSO_4$, increased the length of terminal shoot, number of leaves and leaf area per shoot of mango tree. An experiment on the foliar applications of Zn (0.1, 0.2 and 0.4%), Fe (0.1, 0.2 and 0.4%) and B (0.1, 0.2 and 0.4%) indicated that both Zinc and Boron promoted vegetative growth in terms of plant height, trunk girth and spread of young plants.

Guava

Sharma and Bhattacharyya (1994) obtained the highest number of leaves and total number of flowers when plants treated with non-chelated and chelated Zinc at the concentrations of 0.4%. Copper at 0.4% significantly increased terminal shoot length, number of leaves and leaf area (Singh and Singh, 2002).

Papaya

The monthly spray of $FeSO_4$, $ZnSO_4$ and borax @ 0.1% with or without combination were effective in increasing the plant height and girth compared to control. The $FeSO_4$ sprays were most effective in the plant height and girth (Veena and Lavania, 1998).

Grape

Aggarwal et al. (1975) noted that micronutrient applications increased the shoot growth over control with or without combinations of Zn, Cu and Fe. The 0.2% concentration of $ZnSO_4$ was found to be more effective out of different concentration tried for improving berry (fruit) set and reducing panicle drying over control (Kumar et al., 1988). Singaram and Prabu (2001) reported that the foliar application of $ZnSO_4$, 0.5% + borax 0.2% increased the shoot length, number of internodes per shoot and number of leaves per shoot compared to other combination of Zn and Boron.

Litchi

Foliar application of Zinc (0.6%), Copper (0.3%) and

Boron (0.3%) was found to accelerate the growth and vigour of the plant (Babu and Singh, 2002).

Citrus fruits

The spray with Zinc or Zinc + Iron increased the leaf area of citrus fruit (Bhambota et al., 1962). Supriya and Bhattacharyya (1993) reported that the highest number of leaves per terminal shoot and highest leaf area of Assam lemon (*Citrus limon*) with 0.4% Zinc treatment. Ram and Bose (2000) observed that the application of Mg and micronutrients (Cu, Zn, Fe and B) had significant effect on plant height, stem girth and spread of canopy. The combinations of Mg + Cu + Zn showed the maximum increase in height, stem girth and canopy of the Mandarin orange (*C. reticulata*). Haque et al. (2000) reported that the foliar spray of $ZnSO_4$ (0.5%) and phosphoric acid (0.1%) either alone or in combination with other nutrients (Mg and Cu) on Mandarin showed effective in increasing the plant height and plant spread. However, the significant maximum increase in plant height and spread was found with combined application of Mg, Cu and Zn.

Pineapple

An experiment was conducted on the effect of five concentration of Zinc (that is, 0, 1, 2, 3 and 4 ppm) as foliar spray on pineapple. Significant improvement in leaf area and plant height were noted with 2 ppm Zinc (Shrivastava, 1969). Shrivastava (1970) concluded that the application of Boron increased the growth characters such as, height of plant, total leaf area per plant, fresh and dry weight of plant and shortening the total period of cropping.

EFFECT OF MICRONUTRIENT ON YIELD AND YIELD PARAMETERS

Banana

The combined application of Zn (0.3%), Cu (0.1%) and B (0.2%) resulted in maximum number of hands per bunch, number of fingers per bunch, bunch weight and yield per hectare (Ghanta and Mitra, 1993). The study conducted by Subramanina and Pillai (1997) revealed that the maximum number of hands per bunch, number of fingers per hand, bunch length and bunch yield per hectare recorded when 25 kg $ZnSO_4$/ha + FYM @ 25 kg/plant + neem cake @ 0.5 kg/plant were applied. Suresh and Savithri (2001) observed that the soil application of N, P, K and foliar spray of nutrients (1% DAP + 1% MOP + 0.5% $ZnSO_4$+ $CuSO_4$ + 0.2% Borex) in addition to liming caused substantial increase in the yield of bunch per hectare.

Mango

Singh and Rajput (1976) found that in different levels significantly increased the fruit yield as compared to control. The size of the fruit (length and diameter) and fresh weight were increased greatly when boric acid and Zinc sulphate were sprayed at the rate of 0.8% concentration (Rath et al., 1980). Banik et al. (1997a) reported that the plants treated with Zinc at the highest level (0.4%) in combination with Iron and Boron at the lowest level (0.1%) produced maximum number of fruits and yield per plants as against the control. Banik and Sen (1997) observed that the application of Zinc, Iron and Boron was found to increase the number of fruit, individual fruit weight and fruit yield. Spraying of Zinc, Magnese and iron each at 0.1 and 0.2% improved the fruit weight, size, number of fruits per plant and yield per plant in mango irrespective of the stages of application and the effect of Zn was more marked in improving fruit yield when applied at higher concentration twice (at flowering + pea stage) as compared to Mn and Fe (Dutta and Dhua, 2002).

Guava

Zinc chelated at 0.4% increased percent fruit set per plant, total number of fruits per plant and reduced flowering-harvesting interval (Sharma and Bhattacharyya, 1994). Pandey et al. (1998) reported that the fruits of bigger size were obtained with the application of urea + $ZnSO_4$ + etherel + NAA. However, the spraying of borax also proved equally effective. Foliar spray of Zn @ 4 g/plant/year and Mn at same rate/plant/year significantly increased the fruit yield (Lal et al., 2000). Singh and Singh (2002) concluded that foliar application of Copper at 0.4% significantly increased number of flower buds, fruit set, fruit retention and yield per tree.

Papaya

Veena and Lavania (1998) reported that foliar sprays of $FeSo_4$, $ZnSo_4$ and Borex singly or $ZnSo_4$ in combination with $FeSO_4$ or borax gave remarkable increase in the fruit diameter and yield over the control. It was noted that the foliar sprays of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting improved the total number of fruits per tree, fruit characters, fruit and latex yield (Kavitha et al., 2000a).

Grape

Daulta et al. (1983) reported that all the concentrations of $ZnSO_4$ (0.2, 0.4 and 0.6%) and two concentrations of $FeSO_4$ (0.1 and 0.2%) significantly improved berry size and berry weigh ove$_r$ the control. An experiment conducted

by Kumar et al. (1988) noted that the application of $ZnSO_4$ was found to be more effective for increasing weight, length and breadth of bunch and berry over the control. The spray of Boron (0.4% and $ZnSO_4$ (0.2%) proved to be better in increasing the size and weight of bunches (Kumar and Pathak, 1992). Prabu and Singaram (2001) found that the applications of $ZnSO_4$ and borax single or in combination at different levels, increased the yield than the control. The treatment $ZnSO_4$ 0.5% + borax 0.2% foliar spray produced the maximum yield.

Litchi

Awasthi et al. (1975) reported that the foliar sprays of $ZnSO_4$ @ 0.5, 1.0 and 1.5% on litchi considerably increased the fruit yield and reduced fruit drop. Misra and Khan (1981) found maximum length and diameter of fruit in $ZnSO_4$ at 0.4% spray whereas the weight of fruit was obtained highest in $ZnSO_4$ at 0.2% and 0.4% during the study. Foliar applications of Zn, Cu, B and K in different concentrations increased the length and diameter of fruit, weight of fruit and reduced fruit drop (Sarkar et al., 1984). Dutta et al. (2000) reported that the foliar application of B as boric acid improved fruit set and fruit weight over control. The fruit size and weight of fruit were increased greatly with borax applied at 0.4% and $ZnSO_4$ at 1.0% through foliar spray (Rani and Brahmachari, 2001).

Citrus fruits

Bhambota et al. (1962) noted that the application of Zinc (0.6%) + Iron (0.4%), significantly increased the number of fruits, mean weight of fruit, diameter and volume of each fruits of citrus plant. The foliar applications of $ZnSO_4$ (0.5, 0.75 and 1.0%) and $FeSO_4$ (0.5, 0.75 and 1.0%) in Kinnow mandarin, improved the fruit yield. Among their respective concentrations 1.0% $ZnSO_4$ and 0.5% $FeSO_4$ were most effective (Dixit et al., 1977). The foliar application of Zinc had considerably increased the number of fruit per plant and yield and reduced fruit fall and flowering harvesting interval of Assam Lemons (Supriya and Bhattaacharyya, 1993). Durgadevi et al. (1997) reported that the highest fruit yield of Sathgudi orange was recorded in trees treated with soil application @ 50 g/plant combined with foliar spray of 0.5% each of $ZnSO_4$, $FeSO_4$ and $MnSO_4$. Spraying of micronutrients (Cu, Zn and B) alone and their combinations significantly increased the number of fruits per plant, total fruit weight per plant, fruit diameter and yield of Mandarin orange (Haque et al., 2000).

Pineapple

Shirvastava (1969) reported that the fresh and dry weight of fruits and percent edible portion were improved with 2 ppm Zinc spray but higher doses were unfavorable.

Other minor fruit crops

Foliar applications of $ZnSO_4$ at 0.4%, $FeSO_4$ at 0.4% boric acid at 0.2% in ber gave best results on fruit weight and yield (Kamble et al., 1994). Afria et al. (1999) reported that the foliar spray of $ZnSO_4$ + $FeSO_4$ + Borex in pomegranate produced the maximum number of fruits per plant, average fruit weight and yield per plant compared to other combinations of treatments.

EFFECT OF MICRONUTRIENTS ON QUALITY PARAMETERS

Banana

Pulp: peel ratio and fruit quality in terms of Total Soluble Salts, total sugars, reducing sugars, sugar acid and ascorbic acid content were highest with foliar application of 0.3% Zn + 0.1% Cu + 0.2% B at 3 and 5 months after planting (Ghanta and Mitra, 1993). Suresh and Savithri (2001) found that the soil application of N, P and K and foliar spray on nutrients (1% DAP + 1% MDP + 0.05% $ZnSO_4$ + 0.2% $CuSO_4$, 0.2% Borex) in addition to liming had increased the TSS, sugar acid ratio and decreased the titrable acidity. Yadav et al. (2011) recorded maximum TSS and other quality parameters with RDF (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant.

Mango

The Zinc application (0.8%) significantly increased the reducing and non-reducing sugars, ascorbic acid and TSS (Singh and Rajput, 1976). Rath et al. (1980) reported that the total sugars, ascorbic acid content, acidity and TSS of the fruit pulp were increased greatly by the higher (0.8%) concentrations of boric acid and Zinc sulphate. The quality of mango fruit was improved by the application of 0.6 and 0.8% $ZnSO_4$ and 500 ppm CCC (Daulta et al., 1981; Banik et al., 1997a). An experiment was conducted by Banik et al. (1997b) to assess the quality of mango fruit under the influence of three levels of Zinc, Iron and Boron. The size of the fruit and fresh weight increased greatly when Zinc sulphate and borax were sprayed. Fruit quality as evident by TSS and sugar content was enhanced markedly by the application of Zn and B in young mango plants. Application of Zn, Fe and Mn at 0.1 and 0.2% showed a considerable improvement in TSS, sugars and ascorbic acid contents in fruit at harvest as well as on ripening as compared to control (Dutta and Dhua, 2002).

Guava

Foliar spray of Zn, B, and Mo at the rate of 0.2% $ZnSO_4$, 0.4% boric acid and 0.05% ammonium molybdate, singly and in various combinations revealed that Zinc gave maximum TSS, reducing and non reducing sugars. Maximum ascorbic acid was noted with the treatment of Boron (Singh and Chonkar, 1983). Pandey et al. (1998) reported higher TSS, sugars and ascorbic acid content in fruits than control when plants treated with Borex and $ZnSO_4$. The size of fruits and fruit quality as evident by TSS and sugars content were enhanced markedly by the application of Boron and Zinc (Singh and Brahmachari, 1999).

Papaya

Veena and Lavania (1989) observed that TSS, sugars, acidity and sugar: acid ratio increased remarkably, when $FeSO_4$, $ZnSO_4$ and borax applied at monthly interval as foliar spray singly or in combinations over control. The foliar spray of Zn, 0.5% + B 0.1 at 4^{th}, 8^{th}, 12^{th} and 16^{th} months after planting increased total sugars, reducing sugars, non-reducing sugars, ascorbic acid and sugar acid ratio, in association with bio-chemical traits (Kavitha et al., 2000b).

Grape

The foliar spray of $ZnSO_4$ (0.2, 0.4 and 0.6%) $FeSO_4$ (0.1, 0.2 and 0.6 %) and Boron (0.50 and 0.75%) improved TSS, however, the acidity of berries was not affected by different chemicals except $FeSO_4$ (0.2 and 0.4%) which significantly increased the acid content of the grape berries (Daulta et al., 1983). Kumar et al. (1988) reported that among the different concentrations of $ZnSO_4$ (0.2, 0.3 and 0.4%), concentration of 0.2% gave the maximum juice, TSS and acidity percent. All concentrations of $ZnSO_4$ were found better than control. The maximum TSS, total sugars as well as reducing and non-reducing sugars were found with the spray of 0.2% $ZnSO_4$ followed by its higher concentration 0.4% (Kumar and Pathak, 1992). Prabu and Singaram (2001) reported that the application of $ZnSO_4$ at 0.5% + borax at 0.2% through foliage increased the TSS, reducing sugars, many reducing sugars, total sugars and sugar acid ratio and reduced acidity.

Litchi

Foliar sprays of $ZnSO_4$ at 0.5, 1.0 and 1.5% concentrations on litchi considerably increased the pulp weight and TSS and decreased total acidity (Awasthi et al., 1975). Sarkar et al. (1984) studied that the foliar application of Zn, Cu, B and K in different concentrations increased the pulp weight, total sugars and TSS over control. The foliar application of $ZnSO_4$ at 1.0% and potassium chloride at 2.0% found to be the most effective treatments for improving i TSS, sugar: acid ratio and ascorbic acid of the fruit. The total sugar and sugar: acid ratio were recorded higher with $ZnSO_4$ at 0.1% spray (Kumar et al., 1995). Dutta et al. (2000) found that the foliar application of B as boric acid improved TSS, total sugars, non-reducing sugars, TSS: acid ratio and ascorbic acid, while the acid content of fruits decreased with higher doses of Boron. The spray of various concentrations of $ZnSO_4$ and borax increased the pulp weight, pulp: peel ratio, TSS and sugar: acid ratio and significantly decreased the acidity (Rani and Brahmachari, 2001).

Citrus fruits

Studies conducted by Dixit et al. (1977) revealed that the sprays of $ZnSO_4$ and $FeSO_4$ on Kinnow mandarin, improved the juice content, TSS, total and reducing sugar, sugar acid ratio and ascorbic acid content. Foliar application of micronutrients were made for fruit quality improvement in orange. Borax at 0.6% and Zn and Cu as combined treatments increased the fruit TSS, sugar contents, sugar acid ratio and ascorbic acid content (Rai et al., 1988). Haque et al. (2000) found the maximum total sugar content, reducing sugar content, non-reducing sugar content and ascorbic acid content in fruit juice with spraying of $ZnSO_4$ 0.5% in Mandarin orange.

Pineapple and Ber

Shrivastava (1969) found that the reducing sugars, total sugars and sugar: acid ratio were improved with 2 ppm Zinc but non-reducing sugars and acidity were more with 4 ppm Zinc concentration. Shrivastava (1970) reported that the application of Boron at 1.0 ppm concentration increased the reducing, non-reducing and total sugars TSS and sugar: acid ratio, over control. Yadav et al. (2008) recorded maximum ber fruit quality parameters when trees feed with 40 g FeEDTA /plant.

EFFECT OF MICRONUTRIENTS ON NUTRIENTS CONTENT IN LEAF

Banana

Spraying with different micronutrients (Zn 0.3%, Cu 0.1%, B 0.2% and Mn 0.05%) with or without combinations significantly increased the leaf nitrogen, phosphorus and potassium content before flowering compared with control. Single application of Boron showed the highest amount of N (3.11%), P (0.175%) and K (3.13%) in leaf

(Ghanta and Mitra, 1993). Yadav et al. (2010) recorded Zn content in leaf with RDF (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant. While maximum Fe content in leaf noted from RDF + 25 g $FeSO_4$ + 2 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax and RDF + 25 g Fe EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant, respectively (Yadav et al. 2009).

Mango

Dutta and Dhua (2002) reported that the leaf nutrient status of mango increased with application of Zn (0.1 and 0.2%), Mn (0.1 and 0.2%) and Fe (0.1 and 0.2%). Application of Zn improved the leaf N and Zn content while Fe improved P and Fe and Mn improved the Mn and K contents.

Guava

Lal et al. (2000) found that the basal application of N, Zn and (2 and 4 g/plant) and Mn (2 and 4 g/plant), significantly increased the Zn and Mn content individually in guava leaves.

Grape

Aggarwal et al. (1975) observed that different combination of $ZnSO_4$ (0.54), $CuSO_4$ (0.25) and $FeSO_4$ (0.25%) increased the Zn, Cu and Fe contents in leaf tissues over the control.

Litchi

Foliar sprays of Zinc sulphate of 0.5, 1.0 and 1.5% concentrations on litchi considerably increased the Zinc content of the leaves (Awasthi et al., 1975).

Citrus fruits

Durgadevi et al. (1997) reported that the application of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ as foliar spray or soil application or combination of both, significantly increased the N, P, K, Ca and Mg contents in the Sathgudi orange leaves. Ram and Bose (2000) found that the foliar spray of $MnSO_4$. (2%), $CuSO_4$ (0.4%), $ZnSO_4$ (0.5%), boric acid (0.1%) and $FeSO_4$ (0.25%) either singly or in various combinations significantly increased the N, P and K content of the Mandarin orange leaf.

Pomegranate

Afria et al. (1999) reported that the foliar application of $FeSO_4$ (0.4%), $ZnSO_4$ (0.25%) and borax (0.2%) increased the Fe, Zn and B content in leaves individually or in combination.

CONCLUSIONS

It is 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 demands for micronutrients will also increase. The shortage of organic manure for large scale application and higher use of NPK fertilizers, micronutrients are essential for efficient use and balance soil status of major nutrients, hence application of micronutrients is obvious.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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