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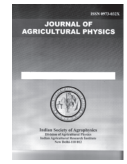

Research Article

Status and Distribution of Micronutrients in Mango Orchards under Subtropical Region of Uttar Pradesh

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ABSTRACT

Orchard soils need special attention on micronutrient management as fruit crops require micronutrient for nutrition, physiological need and quality control. Distribution and variability of micronutrients in the soil and leaf tissue of mango orchards of Moradabad, Rampur, Bareilly, Shahjahanpur, Hardoi, Lakhimpur kheri and Sitapur districts of Uttar Pradesh, India were studied. Majority of orchard soils had organic carbon content less than 0.5% while 25.4% soils could maintain C to the optimum level. Deficiency of Mn, Cu and Zn was observed in 92.0, 45.6 and 23.2% of soil samples, respectively. DTPA extractable Fe was in sufficient quantity in most of the orchards as evident by soil and foliar analysis data. Seventy five per cent mango orchards of Shahajahanpur and adjoining areas showed Zn deficiency while all orchards of Bareily, Shahjahanpur and Hardoi districts showed Cu deficiency in soil. Foliar nutrient analyses indicated widespread K deficiency while N and P were sufficient. Leaf tissue analysis also confirmed widespread Cu and Zn deficiency in all the mango orchards. Thus, deficiency of micronutrients (Cu and Zn) seems to be one of the major constraints in mango fruit production in Uttar Pradesh. This should be addressed on priority basis in nutrient management schedule of mango orchards to sustain the productivity and ensuring quality of mango fruits in this region.

Key words: Mango orchard, micronutrient, Uttar Pradesh

Introduction

Mango (*Mangifera indica* L.) is one of the most important fruit crops in India and its cultivation in different agro-ecological regions have significance in terms of economic dependency and livelihood security of farming community (Ravishankar, 2010). However, its average national productivity is very low compared to the world. The subtropical region of Uttar Pradesh contributes 23.5% of mango production of the country (NHB data base 2014). In this region, mango is grown predominantly as monoculture or as a component of integrated farming system. Reduction in fruit size, fruit drop, fruit cracking etc. are noticed as the emerging problems associated with low productivity of the mango orchards. One of the major reasons of such a low productivity could be deficiency for micronutrients (Kumar *et al*., 2012).

Synchronization of the nutrient supply with plant demand is essential for sustainability of orchards (Adak *et al*., 2012; Bhrighvanshi *et al*., 2013). However, efforts to sustain productivity in fruit production systems in the subtropical regions of India were less successful owing to low soil organic C content and inherent low fertility status. Optimal management of tree nutrition is order of the day to reap the nutrient rich harvest (Satpathy

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and Banik, 2002; Ravishankar *et al*., 2010; Bhrighvanshi et al., 2012b). Benefits of any such integrated nutrient management modules depend on the soils' capacity and ability to supply nutrients to demand driven cycles and sustain biogeochemical processes for future stock (Adak *et al*., 2014). Conventional farming systems do not promote micronutrient application as farming community is lack in knowledge and technological knowhow. Fruit crops need micronutrients to meet physiological demand, and micronutrient application needs immediate attention to restrict nutrient imbalances and unfavourable interactions from underscoring the productivity and quality issues of mango.

Of course, nutrient status in soil varies greatly with space and time by management (uneven fertilizer application, natural deposition or occurrences) and environmental conditions (temperature and precipitation), their availability depends on the interactions with other soil nutrients (Bhriguvanshi *et al*., 2014). Generally, the availability of micronutrients in orchard soils is a function of soil management systems across land use and therefore, an urgent view is needed for systematic information on micronutrient status of existing orchards so that effective and efficient orchard management practices could be adopted in a holistic manner. Kumar *et al*. (2011) reported deficiency of certain micronutrients from some of the mango orchards, indicated a positive role for intervention for optimum micronutrient management strategy to correct the deficiency limits for nutrition. In the above backdrop, the present study is aimed at studying the micronutrient status of mango orchards of Uttar Pradesh, India and identifying the limiting micronutrients in mango.

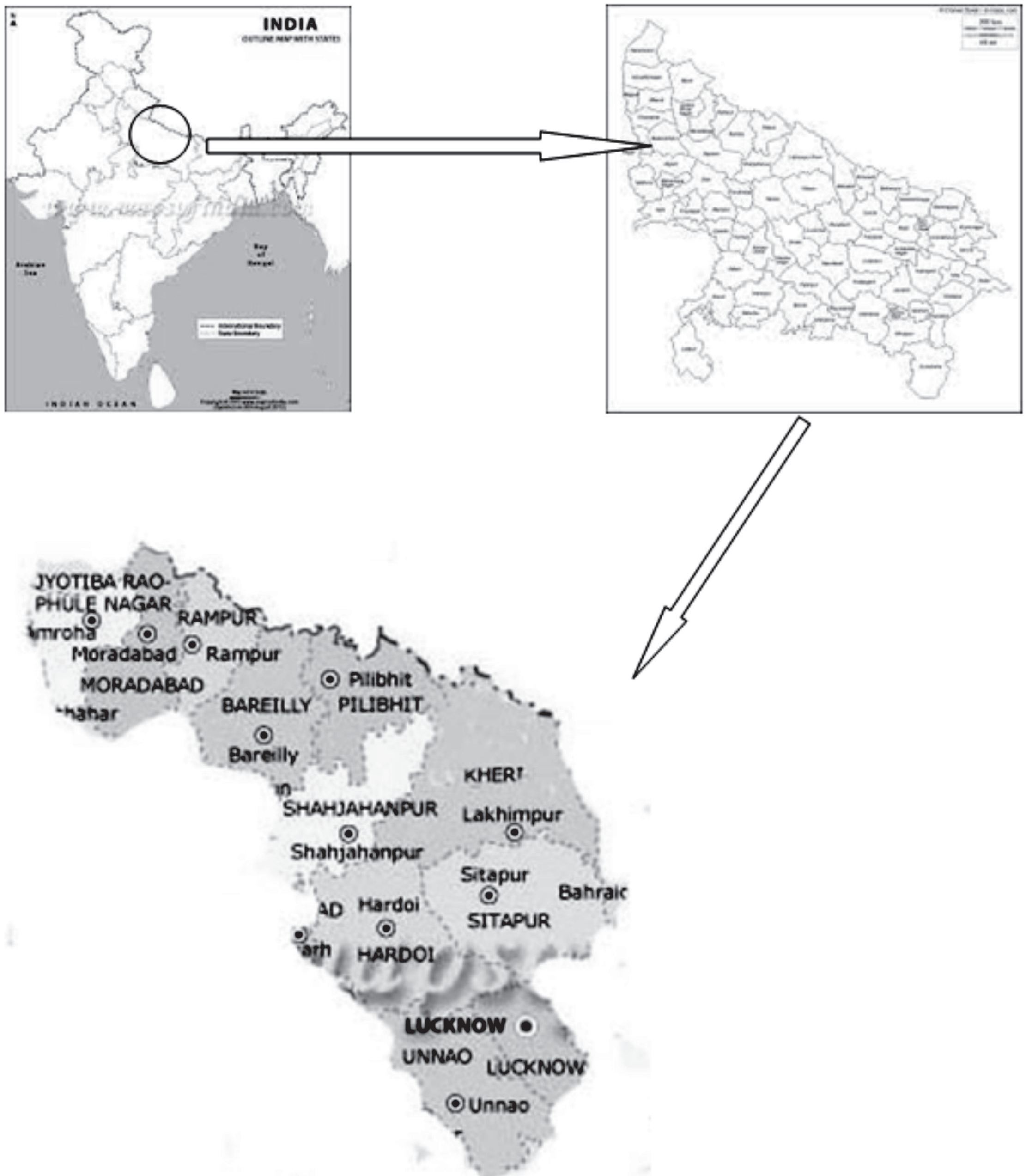
Materials and Methods

Site description

Present study was carried out in some mango orchards of subtropical region of Uttar Pradesh India (Fig. 1). The area is characterized by its semi-arid nature, with a dry hot summer and cold winters. May and June are the hottest months while January is the coldest. The mean annual rainfall is 1000 mm, of which 80% is received during the southwest monsoon from July to September; the rest is received through the 'Western Disturbances' from December to February. The soil of the region belongs to Indo-Gangetic alluvium with sandy loam texture and is well drained.

Sample collection and analysis

A sum of two hundred and fifty one soil samples were collected from mango orchards of Moradabad, Rampur, Bareilly, Shahjahanpur, Hardoi, Lakhimpur kheri and Sitapur districts of Uttar Pradesh, India during 2006-08. Soil samples from 0-25 and 25-50 cm layers were processed (<2 mm) and air dried. Determination of pH and electrical conductivity (EC) were estimated in 1: 2.5 soil water (w/v) suspension following half an hour equilibrium (Jackson, 1973). Soil organic carbon (SOC) content was estimated using wet digestion method (Walkley and Black, 1934). Available Zn, Cu, Mn and Fe (DTPA extractable) in the soil were measured by atomic absorption spectrophotometer ('Chemito' AA203D) as per the procedure of Lindsay and Norvell (1978). Composite leaf samples (5-7 month old) were collected from the orchards, decontaminated by washing first with tap water and then in 0.2% detergent solution and in N/10 HCl solution, followed by washing in single and double distilled water (Bhargava and Raghupathi, 2005). Excess water on the surface of the leaves was removed by pressing between the folds of blotting paper and the leaves were dried in an oven at 48^0C for 72 hours. After complete drying, the samples were ground and analyzed for different nutrients by digesting 1 g tissue in di-acid mixture (9:4 ratio of nitric acid and perchloric acid) by using standard analytical methods. Nitrogen was estimated by micro-Kjeldahl method and P by vanado-molybdate colorimetric method. Potassium, Ca, Mg and the micronutrients Fe, Mn, Cu, Zn and B were analyzed using Inductively Coupled Plasma Emission (ICPE) spectrophotometer (IRIS Intrepid II XSP).



Districts of Uttar Pradesh, India	Latitude	Longitude
Moradabad	28°51’N	78°49’E
Rampur	28°48’N	79°05’E
Bareilly	28°22’N	79°27’E
Shahjanpur	27°54’N	79°57’E
Hardoi	27°23’N	80°10’E
Lakhimpur Kheri	27°57’N	80°49’E
Sitapur	27°50’N	80°92’E

Fig. 1. Site description of present study
Source: www.mapsofIndia.com

Table 1. Status of soil pH, OC, available micronutrients in mango orchard soils of different districts in Uttar Pradesh, India

Soil parameters	Range	Mean	Standard deviations	Standard error of mean	CV %
pH	4.36-8.57	7.0	0.75	0.002	11
EC (dS m^{-1})	0.03-0.59	0.12	0.08	0.0001	72
Soil organic carbon (%)	0.05-1.99	0.54	0.25	0.0001	46
Available Zn (mg/kg)	0.12-13.06	1.51	1.77	0.012	117
Available Cu (mg/kg)	0.01-6.24	1.39	1.14	0.005	82
Available Mn (mg/kg)	0.12-22.78	3.35	3.23	0.042	96
Available Fe (mg/kg)	1.72-99.68	15.08	13.90	0.77	92

Statistical analysis

The pooled data were analyzed and statistical significance was drawn at 5% level of significance in software SPSS version 12.0. Frequency distributions of micronutrients were graphically depicted in the form of histograms using SPSS 12.0 version and correlation matrix were developed using SPSS software package. Other data analyses were done using MS Excel software.

Results and Discussion

General soil properties

Data on pH, EC and organic carbon are presented in Table 1. Soils had pH ranging from 4.4 to 8.6 with mean value of 7.0. The lowest pH was recorded in an orchard of village Mura, district Moradabad which may be attributed to the presence of very high SOC (1.99%). However, all the soils were non-saline (EC <0.2 dS m^{-1}). Mean SOC was 0.54%. The frequency distribution indicated that majority of the soils had pH 6.5 to 8.0 indicating the optimum range for available soil nutrients (Fig. 2). Low SOC content were found in majority of orchard soils and only 25.4% soils maintained optimum or high level of SOC considering the critical limit of 0.58 % for mango (Biswas *et al*., 1987). Thus, low SOC in subtropical orchard soils are of great concern for economic viability of fruit productivity and sustainability. Low SOC in these soils may be due to rapid organic matter decomposition and microbial activity under high temperature of subtropical region restricting carbon build up in soils (Kumar *et al*., 2011). Moreover, under conventional system of orchard management, farmers are not adopting any organic sources for nutritional and health management. Wide ranges of the values of the estimated soil properties were recorded, which indicated heterogeneity of the orchard soils associated with different orchard ground floor management options adopted by farmers of different districts.

Distribution of micronutrients

Descriptive statistics of DTPA-extractable Zn, Cu, Mn and Fe in soils is presented in Table 1. The content of Zn in soils varied widely from 0.12 to 13.06 mg kg^{-1} (mean 1.51 mg kg^{-1}). The Zn distribution showed wide variability among the mango orchards. Major distribution was around <2 mg kg^{-1} (Fig. 3). Katyal (1985) reported wide spread DTPA-extractable Zn deficiency *viz*., 67% soils in Hariaharpur series, 82% in Debatoli, 7% in Rajpora and 14% in Neeleswaram series were below the critical level of Zn deficiency (~0.6 mg kg^{-1}). Functional relationship between soil pH and Zn availability confirmed that majority of the DTPA-Zn was in the range of pH 6.5 to 8.0. Wu and Aasen (1994) also reported that under low pH conditions (pH < 6.5), Zn availability is governed by the soil Zn quantity and is relatively independent of soil pH. Practically, there could be a lower pH limit below which the solubility of soil Zn is so high that major fraction of soil Zn becomes available to plants, and thus, a further decrease in pH will no longer have a significant influence on soil Zn availability. Moreover, a negative correlation

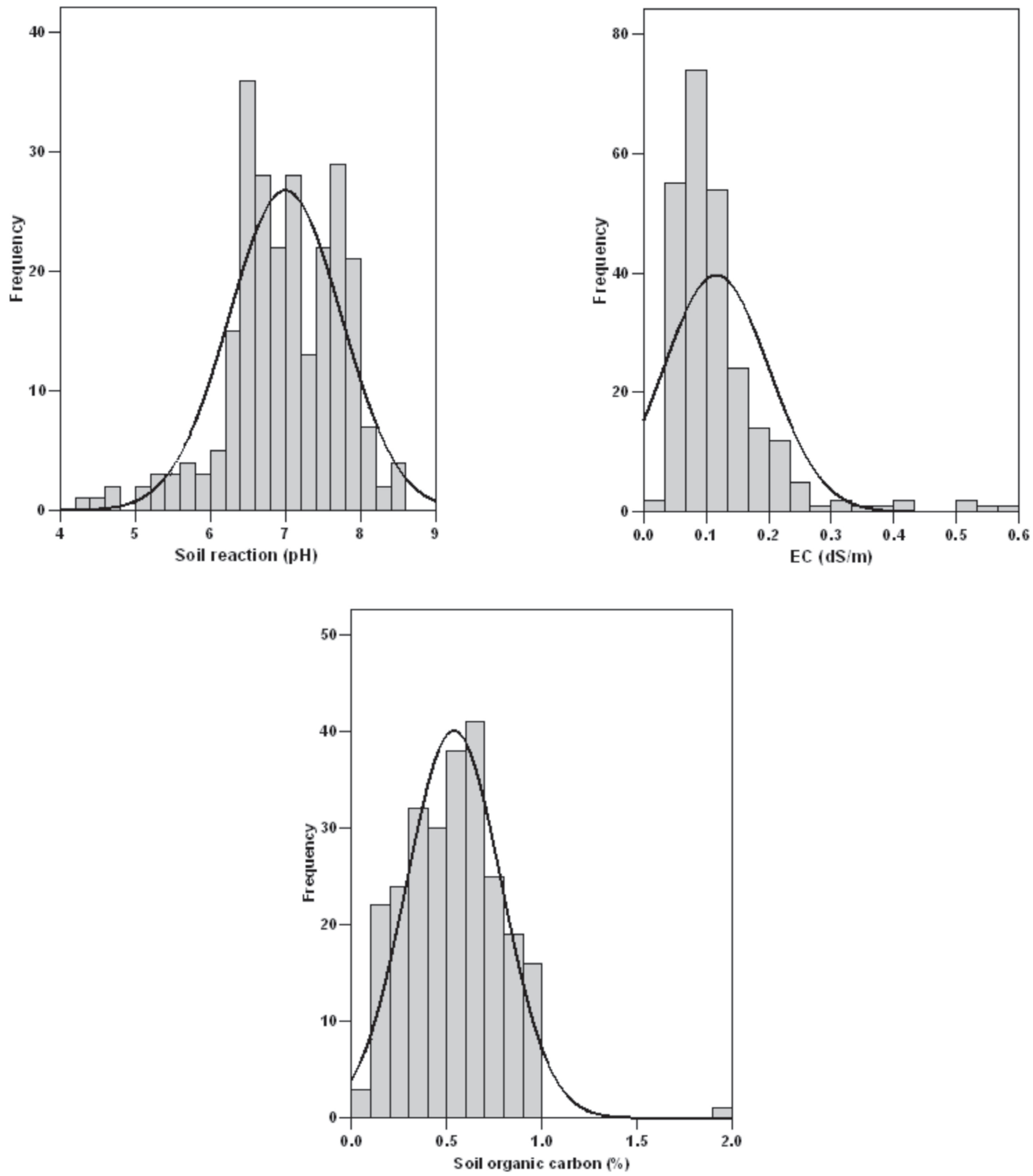


Fig. 2. Frequency distribution of soil pH, EC and organic C content in mango orchard soils of Uttar Pradesh

between soil pH and DTPA-Zn was observed in these mango orchard soils (Table 3). This may be due to negatively charged zincate ions (ZnO_2^{2-}) in the alkaline pH range (> pH 7.50), which resulted in reduced availability of Zn (Kanwar, 1976). A change in pH may also alter the stability of soluble and insoluble organic complexes of Zn (Somasundaram *et al*., 2011). However in acid soils, pH less than 6.5 favours Zn availability (Behera *et al*., 2011). The availability was also closely associated with the SOC content at lower EC. This is in agreement with findings of Katyal and Sharma (1991) who reported that changes in soil hydrothermal regimes and dynamic properties like pH, organic matter, size fractions (clay) had a strong influence on the micronutrient distribution.

Average content of available Cu was 1.39 mg kg^{-1} (0.01-6.24 mg kg^{-1}). It was inferred from the frequency distribution that majority of soil samples had higher distribution in the range of <1 mg kg^{-1}. Availability of DTPA-extractable Cu was more in effective rhizosphere zone compared to subsoil depth. Lower Cu concentrations in these

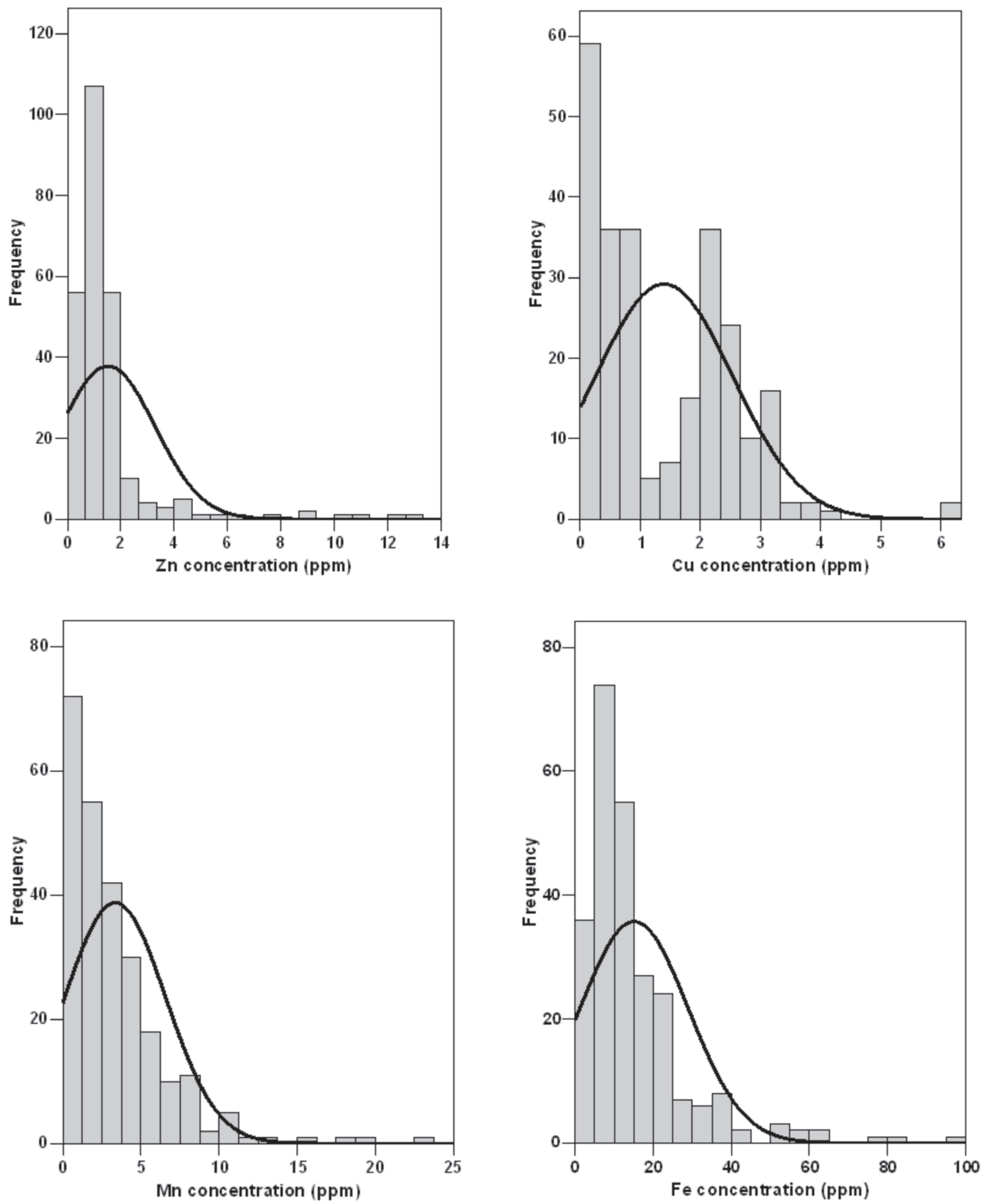


Fig. 3. Frequency distribution of DTPA-extractable Zn, Cu, Mn and Fe in mango orchard soils of Uttar Pradesh

orchards may be due to the fact that Cu is mainly bound to organic materials, oxides, and clay minerals (residual). Actually, different fractions of Cu like acid-soluble, oxide-, and organic matter-bound fractions are potentially bioavailable under changing biogeochemical environment (decomposition of organic matter, redox potential, pH, etc.) unlike water-soluble and exchangeable Cu which are readily bioavailable (Shuman, 1991; Alva *et al*., 2000).

Wide variability (~96%) of the available Mn content was found, indicating differences in orchard ground floor management system adopted by mango growers particularly in terms

Table 2. Spatial distribution of range and deficiency of micronutrients in mango orchard soils of Uttar Pradesh, India

District	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})
Moradabad	0.44-13.60 (5.9%)	0.38-6.24 (2.94%)	0.86-22.78 (67.6%)	6.54-99.68 (0.0%)
Rampur	0.16-3.96 (32.7%)	0.08-1.72 (50.0%)	0.24-2.44 (100.0%)	1.72-31.2 (5.24%)
Bareilly	0.28-2.08 (36.6%)	0.01-0.38 (100.0%)	0.12-2.38 (100.0%)	1.92-24.40 (3.3 %)
Shahjahanpur	0.12-1.30 (75.0%)	0.10-0.36 (100.0%)	0.72-2.96 (100.0%)	3.18-22.76 (0.0%)
Hardoi	0.36-1.16 (50.0%)	0.16-0.30 (100.0%)	0.62-1.34 (100.0%)	2.60-4.26 (0.0%)
Lakhimpurkheri	0.26-2.98 (16.6%)	0.32-0.86 (3.0%)	0.26-3.62 (100.0%)	2.60-29.8 (0.0%)
Sitapur	0.88-11.1 (0.0%)	0.40-1.40 (0.0%)	1.10-4.92 (91.6%)	7.04-12.90 (0.0%)

* Values in parentheses shows percentage of nutrient deficient samples

of micronutrient management. A range of 0.12 to 22.78 mg kg^{-1} of available Mn content with mean values of 3.35 mg kg^{-1} was recorded in these orchards. Orchard soils were sufficient in available Fe; ranged between 1.72-99.68 mg kg^{-1} with an average of 15.08 mg kg^{-1}. However, some orchards in Rampur (5.24% and Bareilly (3.3%) were found to be deficient in Fe content. Actually, Fe availability is not a problem in the soil series developed under the Indo-Gangetic belts of Uttar Pradesh. Available Cu, Mn and Fe were positively correlated with SOC (Fig. 6), while Cu and Mn showed positive correlation with EC (Fig. 5). All the micronutrients except Cu showed negative correlation with soil pH (Fig. 4). This suggested that availability of these micronutrients depends on the land use system and nutrient management modules adopted by the growers. Jiang *et al*. (2009) inferred that the profile distribution of soil micronutrients was mainly controlled by biological cycling, anthropogenic disturbance and leaching and strongly affected by land use patterns. Considering 0.58, 0.4 and 4.0 mg kg^{-1} as critical limits for Zn, Cu and Mn respectively, 23.2, 45.6 and 92% mango orchard soils were deficient in available Zn, Cu and Mn (Fig. 7).

Deficiency of micronutrients in different districts

Spatial distribution indicated that 75% orchards of Shahjahanpur districts are deficient in Zn followed by 50 and 36.6% orchards of Hardoi and Bareilly districts respectively (Table 2). Hundred per cent orchards of Bareilly, Shahjahanpur and Hardoi were deficient in both Cu and Mn while the soils of the orchards of Rampur and Lakhimpur kheri districts were deficient in Mn. Available Fe was in optimum range in most of the orchards of all the districts. However, only few orchards of Rampur and Bareilly showed Fe deficiency. Factors like coarse texture of soils, low organic matter content and microbial activity under subtropical environment may be responsible for this.

Correlation of micronutrients: The statistical significance and Pearson's correlation coefficient amongst the soil factors presented in Table 3 indicated significant interaction among the soil micronutrients. The SOC is positively correlated with Cu, Mn and Fe content. Positive and significant correlation was observed among the micronutrients. There was significant positive correlation between soil and leaf Zn ($r = 0.342^{**}$),

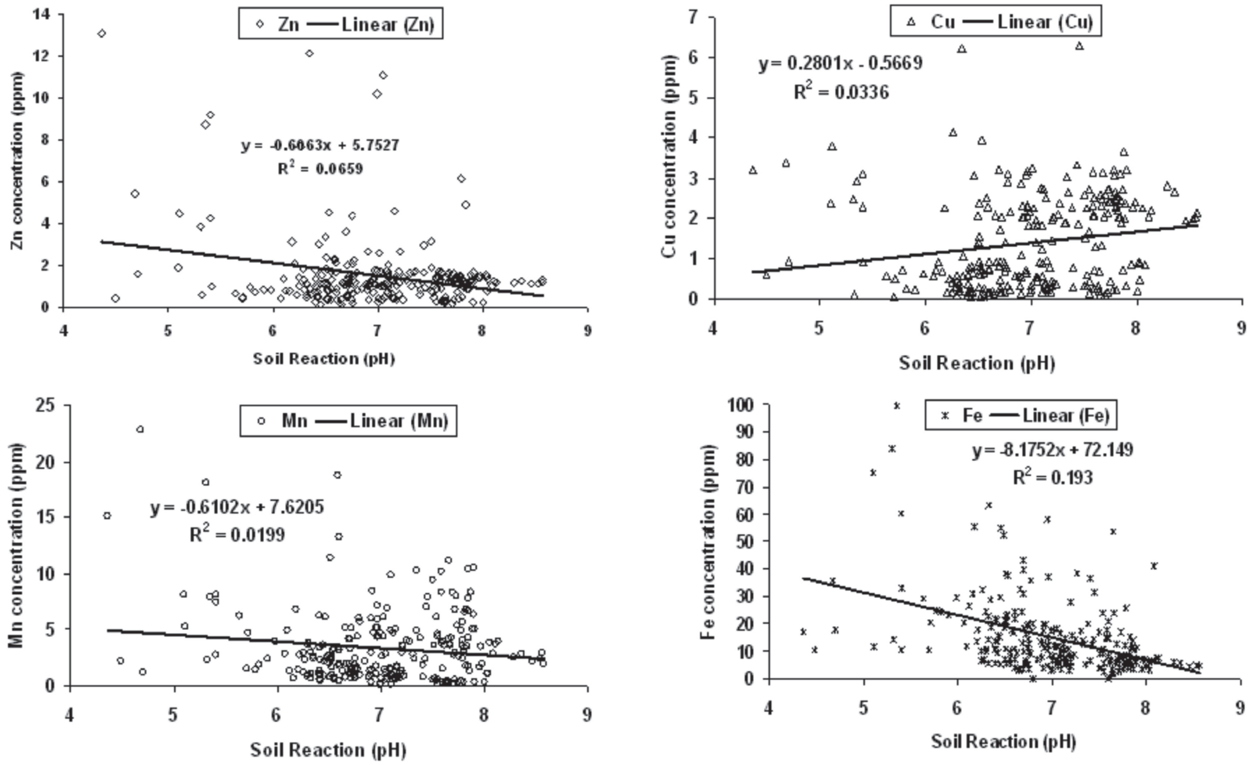


Fig. 4. Relationship of soil pH with available micronutrients

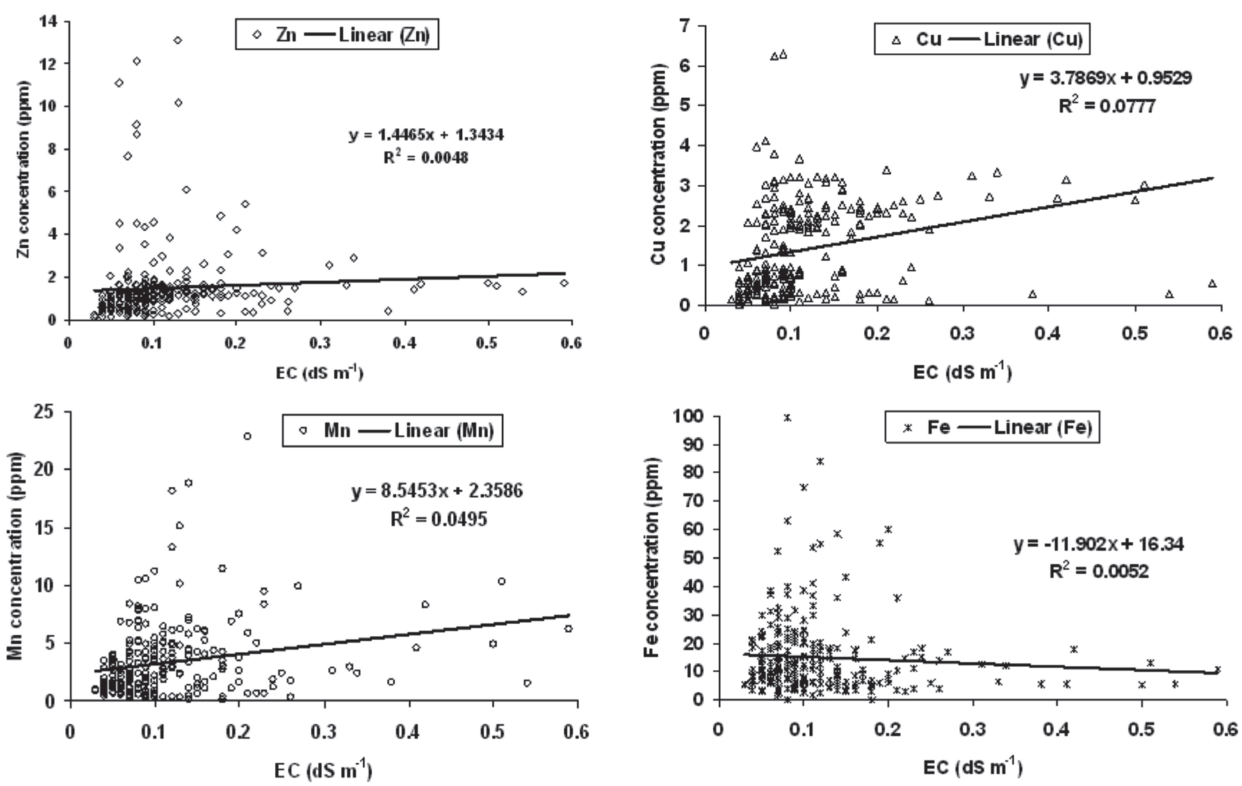


Fig. 5. Relationship of soil EC with available micronutrients

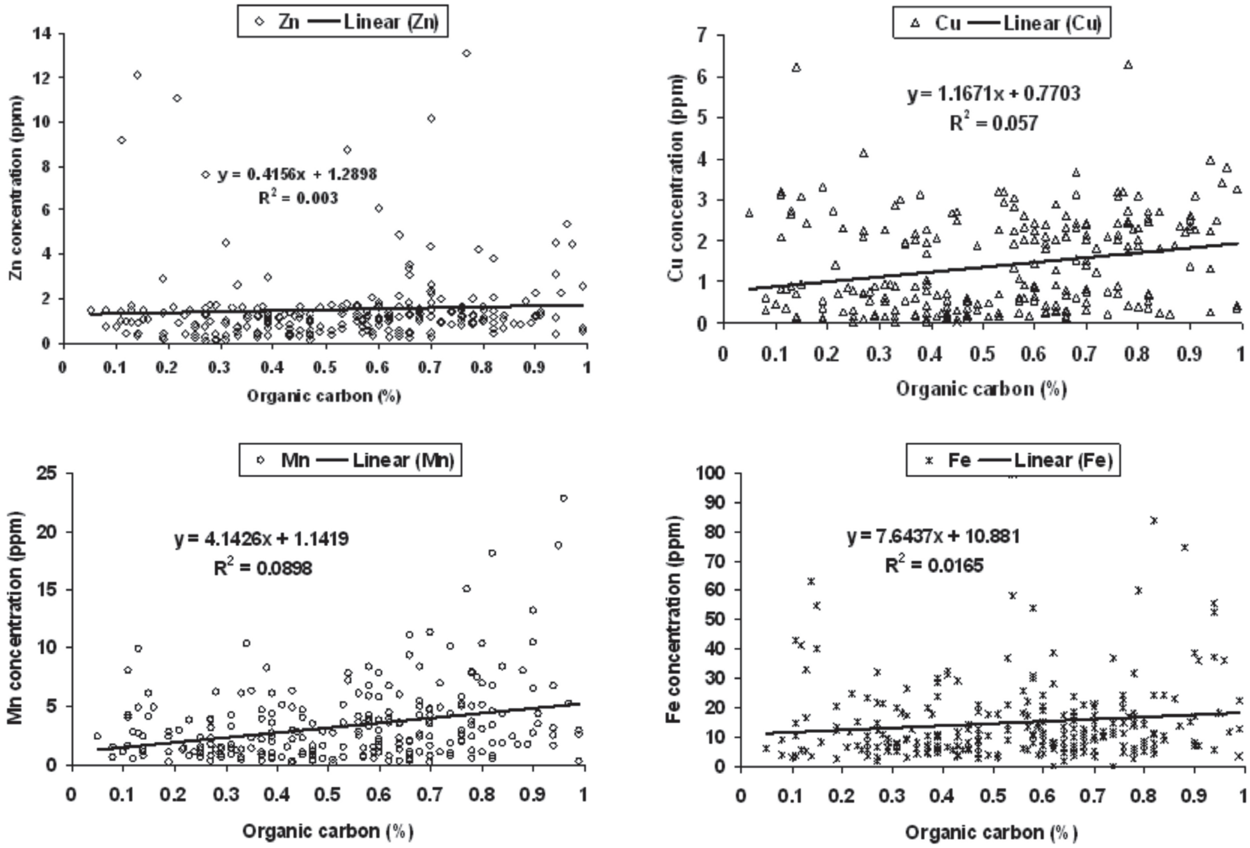


Fig. 6. Relationship of soil organic C with available micronutrients

Table 3. Correlation matrix among the soil properties of mango orchard soils

Parameters	pH	EC	Organic carbon	Zn	Cu	Mn	Fe
pH	1	0.176(**)	0.007	-0.257(**)	0.183(**)	-0.141(*)	-0.440(**)
EC		1	-0.013	0.069	0.279(**)	0.223(**)	-0.071
Organic carbon			1	0.055	0.239(**)	0.300(**)	0.135(*)
Zn				1	0.470(**)	0.355(**)	0.330(**)
Cu					1	0.616(**)	0.364(**)
Mn						1	0.388(**)
Fe							1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

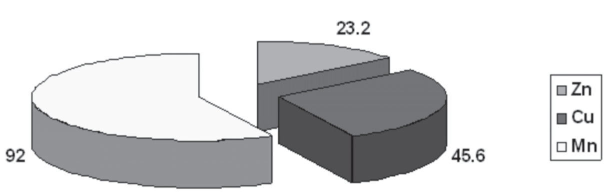


Fig. 7. Micronutrient deficiency in some mango orchard soils of Uttar Pradesh

Cu (r = 0.463**) and Fe (r = 0.655**) contents. However, Mn content of leaf and soil did not show any relationship. Availability of micronutrients in soil is a function of soils physical, chemical and biological properties, also interactions among the nutrients determines the rate and kinetics of their distribution in soil. Bhriguvanshi *et al*. (2012a) inferred that distribution of micronutrients in mango orchard soils is a function of soil moisture and organic carbon content. The degree of variability of such nutrient dynamics appeared to be 41-82% under different fertigation regimes. In fact, micronutrient cycling is quite different among various terrestrial ecosystems and land use changes may strongly affect their distributions in agro-forestry ecosystems (Eneji *et al*., 2003, Venkatesh *et al*., 2003, Parihar *et al*., 2013). Singh *et al*. (2006) indicated that the land use systems in hilly regions, wherein orchards existed, suffers from wide spread micronutrient deficiencies. Based on 80 surface and subsurface soil samples representing eight different land use systems, Somasundaram *et al*. (2009) reported that the micronutrient contents were low in agricultural fields and ravine lands as compared to the other land uses. Deficiency of micronutrients in soils, especially Fe, Zn, and Cu, are the major disorders in citrus orchards of semi-arid region of Rajasthan, India (Somasundaram *et al*., 2011). Shukla *et al* (2012) concluded wide spread micronutrient deficiency from a study of mango orchards in the adjoining areas of Lucknow, Uttar Pradesh, where 48, 14 and 8% orchard soils were deficient in available Zn, Cu and Mn while complete B deficiency (100%) was recorded in soil and also in leaf samples. Chattopadhhyay *et al*., (2012) reported that average availability of Mn showed a decreasing trend in soil samples of 2010 as compared to 1982 but average status of available Fe did not change over the time period. Even, under rubber cultivation in southern agro ecological region, wide variation (extreme deficiency to sufficiency) in available Zn was recorded (Joseph and Sudhakumari, 2013).

Leaf nutrient dynamics

Leaf tissue analysis indicates nutrient status of the tree at any given period of time and henceforth its importance in deciding the nutrition of fruit crop is considered as an essential component in decision making. Foliar nutrient analyses of mango orchards of different districts indicated that trees were well nurtured with respect to N and P whereas widespread K deficiency was revealed (Table 4). The K deficiency ranged from 33.3% in Muradabad to 100% in leaf tissue samples of Lakhipur Kheri mango orchards. This has emerged as an indicator for optimum K management in these orchards as K is indeed needed for quality fruit production. In respect of micronutrients, absolute Zn and Cu deficiency was observed in Bareilly, Shahjahanpur, Hardoi, Lakhimpur kheri and

Table 4. Spatial distribution of range and deficiency of foliar nutrients in mango orchards of different districts in Uttar Pradesh, India

District	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Moradabad	1.40-2.17 (0.0%)	0.144-0.215 (0.0%)	0.34-0.92 (33.3%)	1.80-4.28 -	0.35-0.78 -
Rampur	1.54-2.10 (0.0%)	0.129-0.183 (0.0%)	0.24-0.82 (57.9%)	1.53-3.52 -	0.25-0.85 -
Bareilly	1.68-2.10 (0.0%)	0.119-0.183 (0.0%)	0.24-0.82 (57.9%)	1.53-3.52 -	0.25-0.85 -
Shahjahanpur	1.68-1.96 (0.0%)	0.153-0.167 (0.0%)	0.20-0.52 (66.7%)	1.93-2.17 -	0.42-0.66 -
Hardoi	0.96-1.96 (0.0%)	0.154-0.189 (0.0%)	0.46-0.52 (50.0%)	2.48-2.55 -	0.35-0.38 -
Lakhimpurkhiri	1.05-2.24 (16.6%)	0.036-0.173 (0.0%)	0.22-0.51 (100.0%)	1.80-2.70 -	0.40-0.53 -
Sitapur	1.75-2.10 (0.0%)	0.134-0.167 (0.0%)	0.34-0.80 (82.3%)	1.17-3.01 -	0.40-0.53 -

* Values in parentheses shows percentage of nutrient deficient samples

Table 5. Spatial distribution of range and deficiency of foliar micronutrients in mango orchards of different districts in Uttar Pradesh

District	Zn (mg kg $^{-1}$)	Cu (mg kg $^{-1}$)	Mn (mg kg $^{-1}$)	Fe (mg kg $^{-1}$)
Moradabad	10-270 (33.3%)	0.8-18.0 (72.2%)	48-689 (0.0%)	526-3378 (0.0%)
Rampur	0.2-51.0 (63.2%)	Trace -7.0 (94.7%)	28-283 (0.0%)	217-1367 (0.0%)
Bareilly	Trace-12.0 (100%)	Trace (100%)	42-396 (0.0%)	257-662 (0.0%)
Shahjahanpur	0.8-9.0 (100%)	Trace (100%)	74-100 (0.0%)	230-414 (0.0%)
Hardoi	7.0-10.0 (100%)	Trace (100%)	63-75 (0.0%)	318-390 (0.0%)
Lakhimpurkhiri	2.2-7.0 (100%)	Trace (100%)	29-145 (0.0%)	233-427 (0.0%)
Sitapur	2.0-8.0 (100%)	Trace (100%)	48-123 (0.0%)	260-427 (0.0%)

* Values in parentheses shows percentage of nutrient deficient samples

Sitapur districts (Table 5). The status of Fe, Zn and Cu in leaf was exactly in the line with those in soil. In spite of wide spread deficiency of Mn in the orchard soils the leaf samples showed a reverse trend which indicated that mango is a good absorber of Mn. Micronutrient analysis of leaf indicated that 40% of leaf samples were deficient in Zn and 100% was deficient in B (Kumar *et al*., 2012). Srivastava and Singh (2005) concluded that micronutrient management of fruit trees are essentially required in order to sustain optimum productivity level as well maintaining good soil health. Kumar *et al.* (2012) also recorded sufficiency of N and P contents of leaf in the mango orchards of adjoining areas in Lucknow, Uttar Pradesh while K deficiency was reported in few orchards only. Mean values of Ca and Mg were 3.2 and 1.9%, respectively and no deficiency of these elements was observed. Thus the study indicated an immediate production technological intervention for sustaining the orchard health. Judicious nutrient management strategy based on both soil and leaf tissue analysis should be followed to optimize the productivity level in such orchards.

Conclusions

The present study revealed wide spread deficiency of Zn, Cu and Mn in soils of mango orchards of Uttar Pradesh, India, however, foliar analysis confirmed the deficiency of only Zn and Cu. Although Mn deficiency was observed in soil in most of the orchards, the leaf samples did not show any deficiency. Mango roots may be efficient miner of Mn. Low SOC was recorded in these orchards and thereby optimum C management in subtropical orchard soils is of immediate concern. Deficiency of K might contribute to lower yields of the orchards and inferior quality of fruits. This emphasizes the immediate and urgent need for adoption of judicious nutrient management system in these orchards for sustaining optimum productivity level and fruit quality of mango in the state.

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