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Impact of Micronutrients and Sea Weed Sap on Nutrient Availability and Leaf Nutrient Concentrations of Mango (*Mangifera indica* L.) CV. Dashehari in Mollisols of Uttarakhand

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Authors' contributions

This work was carried out in collaboration among all authors. Author RP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AKS and KPR managed the analyses of the study. Authors CK and JL managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was undertaken to study the effect of micronutrients and sea weed sap on nutrient availability and leaf nutrient concentrations of mango cv. Dashehari in the year 2014-2015. The experiment was conducted in a randomized block design with three replications and ten treatments

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consisting of various concentrations and combinations of micronutrients, sea weed sap along with recommended dose of fertilizers in sub-tropical region of GBPUA&T, Pantnagar, Uttarakhand, India. The highest available soil nitrogen, phosphorus, potassium (195.51, 74.30 & 218.79 kg ha^{-1}), B, Zn, Fe, Cu and Mn (1.41, 0.85, 16.78, 3.21 and 25.50 ppm) after harvest were observed with the application of RDF + IIHR Mango Special @ 5 g/l (2 sprays at two months before flowering and marble stage). RDF + IIHR Mango Special also increased the nitrogen, phosphorus, potassium (1.88, 0.99, 0.83 %); B, Zn, Fe, Cu and Mn (18.17, 69.29, 199.49, 48.89 and 84.40 ppm) in leaves of mango cv. Dashehari. Foliar application of sea weed sap @ 10% (2 sprays at panicle emergence and marble stage) + RDF + $ZnSO_4$ @ 200 g + $CuSO_4$ @ 100 g + Boric acid @ 100 g (soil application) per plant in basin after harvest, also resulted in enhanced status of nutrients in plants and soil over various treatments followed to RDF + IIHR Mango Special @ 5 g/l foliar application.

Keywords: Mango; micronutrients; sea weed sap; soil properties; leaf nutrient status.

1. INTRODUCTION

Mango is called as “King of fruits” because of its rich source of nutrient, luscious, aromatic flavour, good amount of dietary fibre, carbohydrates and a delicious taste in which sweetness and acidity delightfully blended. It occupies a prominent place among the fruits of world as well as of India. In India, mango has a great cultural, socio-economic and religious significance. Mango has been naturalized and adapted throughout the tropics and sub-tropics in the world. As many as 111 countries of the world have been growing mango but India continues to be the largest mango producing country in the world. In India, it is grown over an area of 2.26 million hectares with annual production of 21.82 million tonnes having productivity of 8.7 metric tons per hectare [1]. The area under mango is increasing steadily. However, imbalanced use of nutrients, indiscriminate use of chemical fertilizers, neglecting organic manures and bio-fertilizers deteriorating the soil health *vis-a-vis* tree yield and fruit quality. Micronutrients are key elements in plant growth and development and play a very important role in various enzymatic activities and synthesis. Their acute deficiency sometimes poses the problem of incurable nature. Various micronutrients also help in the uptake of major nutrients and play an active role in the plant metabolism process. Foliar spray of micronutrients is the common practice to overcome the micronutrients deficiencies in order to improve the fruit quality. Nutrients are generally quickly available to the plants by the foliar application than the soil application [2]. Amendment of seaweed liquid fertilizer (SLF) improves the soil health by enhancing the micronutrient status and microbial activity [3]. They enhanced the soil health by improving moisture-holding capacity and by promoting the growth of beneficial soil microbes, besides eliciting a growth-promoting effect on plants, yield and quality of produce [4]. Seaweeds also affect the physical, chemical and biological properties of soil which in turn influence plant growth [5]. It also improves the root system by influencing endogenous auxins as well as other compounds in the extract. Sea weed extracts improve nutrient uptake by roots resulting in improved water and nutrient efficiency, thereby causing enhanced plant growth and vigour [6]. A field experiment was, therefore carried out to evaluate the role of application of micronutrients in soil or on foliage and/or sea weed sap along with RDF on nutrient availability status in soil and nutrient concentrations in leaf tissues.

2. MATERIALS AND METHODS

A field experiment was conducted at Horticulture Research Centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (29.5°N latitude, 79.3°E longitude and at an altitude of 243.84 meters above the mean sea level) Uttarakhand, India. The soil of the experimental plot has been classified as series II Patharchatta silty clay loam under the Order Mollisol [7]. Soil is dark coloured, imperfectly drained with organic matter content in medium range. The soil has high cation exchange and water holding capacity and also contains about 90 per cent saturation. Twenty-year old bearing mango trees of cv. Dashehari, planted at spacing of 10 m x 10 m, under uniform management practices were selected. The experiment was laid out in a randomized block design with ten treatments replicated thrice with a unit of one plant per treatment per replication. The treatments were applied to individual tree as per the treatment details (Table 1).

Table 1. Treatment details of micronutrient and sea weed sap application on mango cv. Dashehari [8]

Treatment symbol	Treatment details
T_1	Control (RDF)
T_2	RDF + $ZnSO_4$ @ 200 g + Boric acid @ 100 g (soil application) in basin after harvest
T_3	RDF + $ZnSO_4$ @ 200 g + $CuSO_4$ @ 100 g + Boric acid @ 100 g (soil application) in basin after harvest
T_4	RDF + foliar spray of $ZnSO_4$ @ 0.4% + Boric acid @ 0.2% (2 sprays at just before flowering and marble stage)
T_5	RDF + foliar spray of $ZnSO_4$ @ 0.4% + $CuSO_4$ @ 0.2% + Boric Acid @ 0.2% (2 sprays at just before flowering and marble stage)
T_6	RDF + $ZnSO_4$ @ 100 g + $CuSO_4$ @ 50 g + Boric acid @ 50 g (soil application) in basin after harvest + foliar spray of $ZnSO_4$ @ 0.2% + Boric acid @ 0.1% (2 sprays at just before flowering and marble stage)
T_7	RDF + $ZnSO_4$ @ 100 g + $CuSO_4$ @ 50 g + Boric acid @ 50 g (soil application) in basin after harvest + foliar spray of $ZnSO_4$ @ 0.2% + $CuSO_4$ @ 0.1% + Boric acid @ 0.1% (2 sprays at just before flowering and marble stage)
T_8	RDF + IIHR Mango Special* @ 5 g/l (2 sprays at two months before flowering and marble stage)
T_9	RDF + 10% Sea weed sap** (2 sprays at panicle emergence and marble stage)
T_{10}	RDF + 10% Sea weed sap** (2 sprays at panicle emergence and marble stage) + $ZnSO_4$ @ 200 g + $CuSO_4$ @ 100 g + Boric acid @ 100 g (soil application) in basin after harvest

*Note: RDF: Recommended dose of fertilizers (1000 g N: 750 g P_2O_5: 1000 g K_2O), **Sea weed sap: Kappaphycus spp., *IIHR Mango Special composition (Zn-0.2%, Fe-0.2%, Cu-1%, Mn-1%, B-0.75% and Mg-1%)*

After harvest of the crop, samples were collected at 0-30 cm soil depth from the tree basin in all the treatments. Samples were air dried at room temperature and passed through a 2 mm sieve and homogenized. Soil pH and electrical conductivity (EC) was determined in soil: water (1:2.5) suspension [9]. Soil organic carbon (SOC) content was estimated by the standard potassium dichromate oxidation method [10]. Mineralizable nitrogen was determined by distillation with alkaline 0.32% potassium permanganate method [11].

Available phosphorus was estimated colorimetrically by blue colour method after extraction with sodium bicarbonate solution [12] while available potassium was extracted with neutral 1N NH_4OAc [13] and measured by Spectrophotometer. Available Zn, Cu, Mn and Fe contents (DTPA extractable) in the soil were estimated by atomic absorption spectrophotometer as per the procedure of [14] and available boron in soil was determined by hot water soluble boron determination method.

The representative leaves were collected after the harvest of fruits from all the treatments. Leaf samples were successively washed with tap water, 0.1 M HCl and distilled water and dried at 70°C. After proper drying, samples were ground in Wiley mill and passed through the 20 mesh sieve. Nitrogen content in leaf tissues was estimated by Kjeldahl method [9]. The samples were digested in nitric acid and perchloric acid (4:1) and phosphorus was estimated using molybovanadate yellow colour method using the transmittance at 420 nm while potassium concentrations were measured with flame photometer [15]. From the digested plant material micronutrients were estimated by atomic absorption spectrophotometer. The data were analysed according to the procedure of analysis for Randomized Block Design and significance of difference between pair of means was tested by the least significant difference (LSD) test at 5% level of probability [16].

3. RESULTS AND DISCUSSION

3.1 Soil pH, Organic Carbon and Electrical Conductivity

The data presented in Fig. 1 showed that soil pH, organic carbon and electrical conductivity in soil measured at harvest of fruits were influenced significantly with the application of recommended dose of fertilizers, micronutrients, sea weed sap and their combinations. The data showed significant variation with the treatments. The highest pH (7.74), electrical conductivity (0.45 dS m^{-1}) and soil organic carbon (SOC) content (0.97%) were observed with the application of RDF + $ZnSO_4$ @ 100 g + $CuSO_4$ @ 50 g + Boric acid @ 50 g (soil application) in basin after harvest + foliar spray of $ZnSO_4$ @ 0.2% + $CuSO_4$ @ 0.1% + Boric acid @ 0.1% (2 sprays at just before flowering and marble stage) [T_7]; RDF + IIHR Mango Special @ 5 g/l (2 sprays at two months before flowering and marble stage) [T_8] and RDF + 10% sea weed sap (2 sprays at panicle emergence and marble stage) + $ZnSO_4$ @ 200 g + $CuSO_4$ @ 100 g + Boric acid @ 100 g (soil application) in basin after harvest [T_{10}], respectively. Similar findings were also reported in aonla [17]. The differences in pH and electrical conductivity might be due to leaching of bases from the surface and its accumulation in sub-surface. The enhanced organic carbon content in soil could be attributed to decomposition of additional dead tissues added to soil because of higher biomass production due to balanced nutrition.

3.2 Available N, P and K in Soil

Positive effect of different nutrient sources on availability of N, P and K was inferred from this study (Table 2). The higher available nitrogen (195.51 kg ha^{-1}), available phosphorus (74.30 kg ha^{-1}) and available potassium (218.79 kg ha^{-1}) were found in soil due to RDF + IIHR Mango Special @ 5 g/l (2 sprays at two months before flowering and marble stage) as compared to control. An application of RDF + 10% Sea weed sap (2 sprays at panicle emergence and marble stage) and RDF + 10% Sea weed sap* (2 sprays at panicle emergence and marble stage) + $ZnSO_4$ @ 200 g + $CuSO_4$ @ 100 g + Boric acid @ 100 g (soil application) in basin after harvest (T_9 and T_{10}, respectively) also resulted in enhanced available nutrient status which was at par with that of T_8. It was suggested that the available soil nitrogen was influenced by inorganic fertilizer, micronutrients and sea weed sap. The experiment also revealed that the use of different nutrient sources not only supplemented the soil nitrogen but also upgraded the overall available nitrogen level of the soil for sustainable use. These findings are in agreement in peach [18] and in mango [19]. Similar findings for availability of phosphorus and potassium were also reported in pineapple [20] and in aonla [21]. It was concluded that organic or inorganic fertilizers alone not showed any significant or appreciable improvement in the available nutrient status of soil over initial status. However, it was profoundly influenced by an integrated application of inorganic fertilizer, micronutrients, sea weed sap and their suitable combinations improved the available nutrient status profoundly compared to the initial status.

3.3 Available B, Zn, Fe, Cu and Mn in Soil

The micronutrient availability in the soil treated with micronutrients and sea weed sap showed significant difference among treatments (Table 3). Considering the effects of organic (FYM) and inorganic (N, P, K) sources of nutrition including micronutrients (boron, zinc, copper) and sea weed liquid fertilizer, it was revealed that the highest content of B, Fe, Cu, Mn and Zn (1.41, 0.85, 16.78, 3.21 and 25.50 ppm) were recorded in soil due to RDF + IIHR Mango Special @ 5 g/l (2 sprays at two months before flowering and marble stage) and the lowest in the treatment (control) wherein micronutrient (boron, zinc, copper) and sea liquid fertilizers were not included. Micronutrient contents were significantly enhanced over initial level primarily may be due to the application of different organic and inorganic nutrient sources. As well as, an application of seaweed extract might have resulted in improving micronutrient status in soil as it constitutes the appreciable amounts of various micronutrients along with vitamins and many growth hormones [22]. Sea weed extract have been reported to enhance soil fertility by improving the moisture holding capacity and growth of soil micro-biota [3]. Therefore, it is evident that the inorganic sources of nutrition along with micronutrients and sea weed liquid fertilizers played significant role in nutrient acquisition and availability in the soil.

3.4 Macronutrient Status in Leaf Tissues

Various nutrient application treatments did not influence the leaf N status significantly, however it improved over control highest being 1.88% in T_8. Significantly higher P and K content were registered in T_6-T_{10} and T_8, respectively. The highest leaf phosphorus and potassium content *i.e.,* 0.99% and 0.83% were recorded in treatment T_8 [RDF + IIHR Mango Special @ 5 g/l (2 sprays at two months before flowering and marble stage)] and lowest in T_1 [Control (RDF)] (Table 2). The phosphorus and potassium content in leaves were significantly increased

Table 2. Macronutrient status in leaf tissues of mango cv. Dashehari, their availability in soil and their relationship as influenced due to an application of micronutrients and sea weed sap

Treatments	Nitrogen		Phosphorus		Potassium	
#	Soil (kg ha^{-1})	Leaf (ppm)	Soil (kg ha^{-1})	Leaf (ppm)	Soil (kg ha^{-1})	Leaf (ppm)
T_1	151.56	1.62	62.38	0.61	171.27	0.56
T_2	171.99	1.71	59.00	0.82	187.84	0.61
T_3	167.95	1.76	55.43	0.83	192.48	0.60
T_4	169.62	1.77	67.67	0.85	200.62	0.62
T_5	176.68	1.77	68.85	0.86	207.77	0.64
T_6	174.98	1.74	66.87	0.95	202.08	0.73
T_7	189.19	1.70	68.49	0.95	206.83	0.74
T_8	195.51	1.89	74.30	1.00	218.79	0.83
T_9	189.98	1.85	70.71	0.99	209.74	0.79
T_{10}	191.73	1.85	71.81	0.95	206.61	0.78
CD (5%)	8.70	NS	3.06	0.30	8.27	0.25
Correlation values (r)	0.793*		0.640*		0.832*	

 # See the treatment details from Table 1

Table 3. Micronutrient status in leaf tissues of mango cv. Dashehari, their availability in soil and their relationship as influenced due to an application of micronutrients and sea weed sap

Treatments #	Boron (ppm)		Zinc (ppm)		Iron (ppm)		Copper (ppm)		Manganese (ppm)	
	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf
T_1	0.43	8.30	0.54	52.79	10.28	168.29	1.89	33.00	17.20	64.09
T_2	0.70	13.95	0.58	55.23	12.43	174.70	2.29	39.40	18.84	69.79
T_3	0.59	12.73	0.64	58.49	13.29	173.29	2.33	37.90	19.96	71.60
T_4	0.82	14.55	0.73	59.69	13.57	186.20	2.80	42.40	20.93	71.96
T_5	0.99	16.83	0.76	63.59	14.36	189.76	2.85	44.75	21.60	75.89
T_6	0.91	15.62	0.78	60.69	13.69	176.10	2.76	42.92	21.54	72.14
T_7	0.92	15.69	0.77	62.80	14.07	182.76	2.93	40.90	22.15	73.39
T_8	1.41	18.17	0.85	69.29	16.78	199.49	3.21	48.89	25.50	84.40
T_9	1.31	17.13	0.75	66.06	15.53	198.09	2.98	46.50	22.38	76.74
T_{10}	1.37	17.36	0.79	64.43	16.72	194.19	2.95	44.89	23.80	79.34
CD (5%)	0.31	0.73	0.33	2.01	0.56	10.15	0.12	1.37	0.79	2.86
Correlation values (r)	0.903*		0.923*		0.906*		0.940*		0.966*	

 # See the treatment details from Table 1

with urea, DAP and murate of potash (MOP). As the urea, DAP and MOP applied in the soil act as a source of phosphorus and potassium, respectively which could be easily absorbed by the plants and translocated to the leaves. Similarly in T_9 and T_{10}, an application of sea weed sap provided the various nutrients along with plant growth substances. The obtained results of leaf mineral contents are in agreement with the findings of Ahmad et al. (2003) who mentioned that an application of micronutrients improved the nutritional status with respect to N, P and K content in leaves. These results are also in conformity with the observations made in mango [23] and in kinnow [24].

3.5 Micronutrient Status in Leaf Tissues

The data in Table 3 indicate the effect of micronutrients and liquid sea fertilizer on boron, zinc, iron, copper and manganese in leaves of mango cv. Dashehari. The boron (18.17), zinc (69.29 ppm), iron (199.49 ppm), copper (48.89 ppm) and manganese (84.40 ppm) content was found to be highest with an application of RDF + IIHR Mango Special @ 5 g/l (2 sprays at two months before flowering and marble stage) (T_8) and the lowest contents were in the control (T_1). An enhanced concentration in leaf tissues was attributed to the foliar nutrition of IIHR Special which consists of boron, zinc, iron, copper and manganese (0.75, 0.2, 0.2, 1.00 and 1.00 per cent, respectively). It was also suggested that an application of N as basal dressing led to increase N and Fe content in the leaves. The increase in the copper content in leaves may be attributed to the soil properties, availability of added and bound nutrients making them available to the plants. Similar findings have also been reported in mango [25,23].

3.6 Correlation Studies between Nutrients in Soil and Leaf

3.6.1 Correlation studies between soil and leaf macronutrients

The relationship of available soil nutrients with total leaf nutrients in Dashehari mango at harvest is depicted in Table 2. The concentration of nitrogen in leaf was significantly correlated (r = 0.793*) with the available nitrogen status in soil. In a study on Alphonso, Totapuri and Banganpalli varieties of mango, the available nitrogen content of soil and total nitrogen content of leaf had positive correlation between each other after harvest of fruits (Anonymous, 2012). The available phosphorus and potassium content in soil also found correlated positively (r = 0.640*, 0.832*, respectively) with P and K concentrations in leaf tissues, respectively. Similar positive and significant relationship was also reported in case of Dashehari variety of mango [26,27,28].

3.6.2 Correlation studies between soil and leaf micronutrients

Boron, zinc, iron, copper and manganese content of soil and leaf were positively and significantly correlated with each (r = 0.903*, 0.923*, 0.906*, 0.940* and 0.966*, respectively). Positive and significant correlations between soil and leaf nutrients suggested that the increase in nutrient content of soil resulted in an increase in leaf content. This indicates that there is positive effect of applied fertilizers through soil in increasing the nutrient status of leaf. Hence, it is important to maintain better fertility of soil at various growth stages of Dashehari mango for maintaining nutrient content of leaves and improving the yield. These findings are in conformity with the results obtained in mango [26].

3.7 Correlation Studies of Nutrients with Yield

3.7.1 Correlation of macronutrients with yield

An available nitrogen content and available phosphorus content in soil did not exhibit any positive correlation with yield (Table 4). However, a positive and significant correlation (r = 0.751**) was obtained at 0.01 level of significance between the available potassium in soil and yield. The total nitrogen content in leaf tissues also affect the fruit yield as evident from the positive and significant correlation with yield (r = 0.688*). However, no positive correlation was observed between total phosphorous, total potassium content in leaf and fruit yield. Similar correlations were in mango [29, 30]. They also found that nitrogen content in leaf at flowering and pre-flowering stages had a positive correlation with yield while phosphorous content in leaf and soil did not show any correlation with yield. They further stated that leaf nutrient status had greater effects on fruit growth and yield than soil nutrient status. In another study, also found that fruit yield of mango trees from peninsular India showed positive correlation with nitrogen content in leaf before and during flowering [31]. They also observed that phosphorous content in leaf had a positive correlation with yield after harvest while, potassium content of leaf had a positive correlation with yield before flowering.

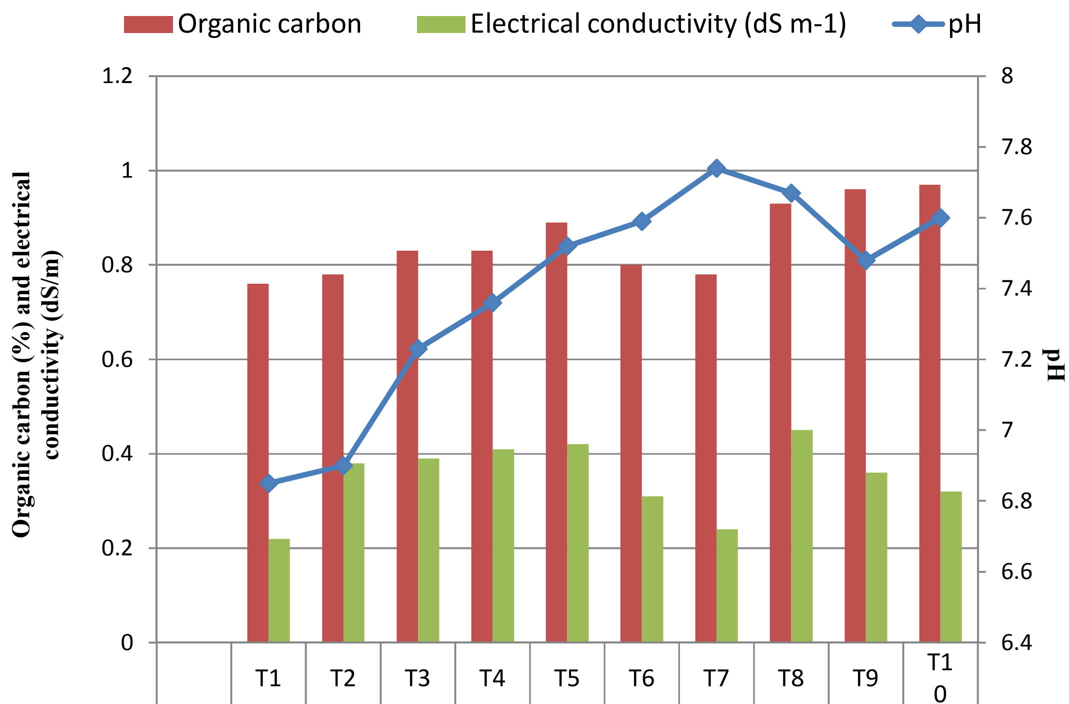
3.7.2 Correlation of micronutrients with yield

The available zinc, iron, copper and manganese content in soil exhibited a positive and significant correlation with yield (r = 0.614*, 0.693*, 0.685* and 0.636*, respectively. The concentration of boron, zinc, iron, copper and manganese in leaf tissues shared significant influence on fruit yield as indicated by r = 0.777**, 0.676*, 0.685*, 0.736** and 0.733*, respectively. B, Fe, Zn, Cu and Mn content of soil and leaf in mango were

Table 4. Relationship between macronutrients and yield

Nutrient	Correlation with yield	
	Soil	Leaf
Nitrogen	0.592	0.688*
Phosphorus	0.408	0.584
Potassium	0.751**	0.342

** Significant at 5 per cent level, ** Significant at 1 per cent level*



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Organic carbon	0.76	0.78	0.83	0.83	0.89	0.8	0.78	0.93	0.96	0.97
Electrical conductivity (dS m-1)	0.22	0.38	0.39	0.41	0.42	0.31	0.24	0.45	0.36	0.32
pH	6.85	6.9	7.23	7.36	7.52	7.59	7.74	7.67	7.48	7.6

Fig. 1. Effect of micronutrients and sea weed sap application on pH, organic carbon and electrical conductivity of soil

Table 5. Relationship between micronutrients and yield

Nutrient	Correlation with yield	
	Soil	Leaf
Boron	0.584	0.777**
Zinc	0.614*	0.676*
Iron	0.693*	0.685*
Copper	0.685*	0.736**
Manganese	0.636*	0.733*

** Significant at 5 per cent level, ** Significant at 1 per cent level*

positively and significantly correlated with each other [32]. Positive and significant correlations of soil and leaf nutrient status with yield showed that the increase in the nutrient status of soil and leaf was related with increase in the yield. In present studies too the B, Zn, Fe, Cu and Mn status in soil was strongly and significantly correlated with the status of these micronutrient element in leaf tissues. This indicates the relevance of nutrient content in soil and leaf or the effect of applied nutrients through soil and leaf in increasing the yield. Further, it was also noticed that the leaf nutrient content had better correlation with yield than soil nutrient status. The present investigation further affirmed that the appropriate nutrient management in case of mango is crucial for higher yields.

4. CONCLUSION

Now days, horticulture crops are considered as one of the essential part of daily meal of a human being. These crops give its best in productivity, net return, foreign exchange and their contribution towards GDP is also much higher than the field crops. In mango production, certain heights have already attained, so, our concern should be much more towards the quality and nutrient values. The micronutrients are required in traces, which is partly met from the soil or through chemical fertilizers or through other sources microelement deficiencies causes a great disturbance in the growth and physiology. The present investigation revealed that the soil and foliar nutrient concentrations were significantly influenced by the application of organic and inorganic fertilizer (macro and micronutrients), which, are necessary amendments for the stable and sustainable production of mango. Moreover, further in depth research in the field of sea liquid fertilizers is required as they are having a profound effect in the improvement of the nutritional status of mango cv. Dashehari.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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