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Research article

Estimating soil nutrient index *vis-a-vis* mango orchard productivity of Lucknow region, Uttar Pradesh, India

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Abstract: Soil nutrient index was developed in mango orchard soils for which a sum of 88 soil samples were recently collected from the root zone depth (0–30 cm) of 22 fixed mango orchards of Lucknow region of Uttar Pradesh, India. Analysis of data indicated orchards had wider contents in nutrients in soil and foliar parts. Developed soil nutrient index concluded that mango orchard soils were categorized as low SOC, N and K, whereas P designated in medium rating. In case of available micronutrients, Zn, Fe and Mn falls under medium rating while Cu in low rating. Productivity analysis showed 4.92 to 8.68 t ha^{-1} with majority of the orchards had production from 6 to ≤8.0 t ha^{-1}. Such lower productivity is linked to low to medium soil nutrients. The study showed for ensuring better productivity, proper nutrition management systems should be adopted by the growers.

Keywords: Soil nutrient index - Orchard productivity - Mango - Lucknow region.

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INTRODUCTION

Nutrient indexing in fruit orchards are order of the day for estimating the conditions of the orchards in terms of available nutrients. These nutrients are in turn contributes to the not only fruit productivity but also indicate the status of the orchards soil health for the consecutive fruiting season (Laishram & Ghosh 2018, Adak *et al.* 2018a). Changes in nutrient content over the year of fruit-bearing had an impact on the soils are emphasizes the need for balanced nutrient doses so that productivity can be maintained to the desired level. Mango orchards based on their productivity many times decided in to low medium and high category showing the indirect or direct effect of nutrients on their productivity level (Bie *et al.* 2004). Thus, the estimation of soil nutrient index is essentially required to draw a relationship between the soil properties and its productivity level.

Evaluating the soil fertility status as a function of several soil properties in fruit agroecosystem and other agroecological regions is of immense important from viewpoint of yield gap analysis (Wang *et al.* 2015, Kavitha & Sujatha 2015). The soil fertility status of major mango belts in India needs to be studied for assessing the potential productive capacity of the soil and to develop soil nutrient index. Ofcourse the Indian soils are deficient in many major and minor nutrients and trends of soil fertility indicated the shifts from deficiency of one to other nutrients based on locations (Pathak 2010). Thus, the role of assessment of soil fertility status is urgent and keeping in view of lack in information, the present study was conducted to develop soil nutrient index in 22 mango orchards of Lucknow region of Uttar Pradesh, India.

MATERIALS AND METHODS

The study was laid out in 22 fixed orchards of mango cv. Dashehari aged between 25–35 yrs in Lucknow region, Uttar Pradesh, India. A sum of 88 soil samples from the 0–30 cm depths was collected from the tree basins in mango orchards of Allupur, Kanar, Malihabad, Kakori, CISH block, Methenagar, Ulrapur, NaibastiDhaneva, Mehmoodnagar, Nabipanah, Hafizkhera orchards. Two fixed orchards were identified in each village. From each tree basin, 4 soil samples were collected from the east-west and north-south sides within the canopy area to represent single composite soil sample, likewise from the each orchard, 4 composite soil samples were collected randomly during September to October. The leaf samples were also collected from these

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orchards, washed and processed as per the standard leaf tissue preparation. All the soil and leaf tissues were digested as per the protocols for determining the respective nutrient contents. Atomic Absorption Spectrometer (chemicto 203D model) was used for this purpose and spectrophotometer for soil available P. The rating chart was developed following the percentage of soil samples falls in different low, medium and high category of soil fertility status. Soil fertility ratings were developed following Amara *et al.* (2017).

RESULTS AND DISCUSSION

The nutrient contents in soil and leaf tissues in mango cv Dashehari is presented in table 1 and 2. The analytical data showed soil organic carbon (SOC) content varied between 0.38 to 0.54% across 22 fixed mango orchards. Soil available N, P and K was recorded between 65.8 to 131.95, 26.05 to 40.05 and 88.55 to 201.95 mg kg^{-1} respectively. A critical analysis of soil samples indicated the majority of mango orchard soils had lower SOC as compared to the critical limit of 0.50%. The mango orchard situated at Ulrapur fixed plot II had the highest SOC content of 0.57% while Kanar Fixed plot I had the lowest value of 0.38% followed by Nabipanah fixed plot II (0.39%). Mango orchard of Ulrapur fixed plot I had highest available N of 131.95 mg kg^{-1} as compared to lowest (65.80 mg kg^{-1}) in Hafizhera fixed plot II. Similarly, highest (40.05 mg kg^{-1}) and lowest (23.95 mg kg^{-1}) available P content in soil was found in Nabipanah fixed plot I and Meethenagar fixed plot I respectively. In the case of soil available K, wider content was observed, may be due differential nutrient management and cultural practices adopted by farmers. Highest of 201.95 mg kg^{-1} being in Malihabad fixed plot II followed by 186.38 mg kg^{-1}in Nabipanah fixed plot I. The lowest (88.55 mg kg^{-1}) availability was observed in Meethenagar fixed plot II. In case of micronutrient availability, except one mango orchard, all others had sufficient Zn availability. Ranges of 0.44 to 1.13 mg kg^{-1} Zn content across 22 mango orchards were found. A range of 0.57 to 4.19, 5.0 to 12.96 and 2.61 to 8.26 mg kg^{-1} Cu, Mn and Fe content respectively across these mango orchards were revealed. The highest Cu content was recorded in CISH block II plot followed by lowest in Hafizkhera fixed II plot. Similarly, mango orchard soil of Hafizkhera fixed I plot recorded the highest content of Mn and Fe. The lowest content of Mn however observed in Nabipanah fixed II plot and in case of Fe, it was Hafizkhera fixed II plot.

Analysis of foliar nutrient concentrations indicated wider variations in K and micronutrients contents except P (Table 2). A range of 0.09 to 0.13 and 0.61 to 0.90 mg kg^{-1} of P and K was recorded. In terms of Zn, Cu, Mn and Fe, 20.75 to 31.75, 9.5 to 34.0, 71.25 to 143.25 and 120.75 to 216.50 mg kg^{-1} were observed across 22

Table 1. Soil nutrient contents of 22 mango orchards at Lucknow, Uttar Pradesh, India.

Fixed plots	SOC (%)	P (mg kg^{-1})	K (mgkg^{-1})	N (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})	AY (t ha^{-1})
Al I	0.43±0.03	31.85±7.64	123.30±14.76	118.65±7.78	0.81±0.12	1.33±0.46	8.61±4.46	4.42±1.12	7.68
Al II	0.47±0.05	28.03±3.79	105.30±16.79	130.20±16.29	0.65±0.04	1.05±0.13	5.92±0.87	2.77±0.28	6.01
Kn I	0.38±0.04	28.90±6.44	140.63±18.52	104.30±14.30	0.85±0.19	1.37±0.23	6.80±1.19	3.26±0.90	6.92
Kn II	0.50±0.09	34.10±3.23	121.79±25.65	116.90±6.10	0.86±0.18	1.49±0.28	8.33±3.54	3.70±0.62	8.36
Ml I	0.54±0.11	32.65±6.82	144.56±19.70	119.00±9.77	0.73±0.20	1.51±0.70	6.51±0.90	3.96±0.25	7.01
Ml II	0.54±0.08	37.83±2.19	201.95±13.64	122.15±14.61	0.94±0.39	1.88±1.32	5.51±0.26	5.84±1.41	8.12
Kk I	0.46±0.07	33.00±3.05	146.33±37.40	112.00±6.57	0.92±0.39	1.17±0.62	9.67±4.31	7.30±2.51	6.57
Kk II	0.50±0.11	33.00±6.77	160.93±60.80	113.40±4.12	1.13±0.30	1.45±0.63	10.03±5.28	3.52±0.18	7.98
Cb II	0.42±0.02	26.48±6.60	138.13±6.15	127.30±11.40	1.08±0.20	4.19±0.63	10.25±1.71	5.16±2.33	7.92
Cb III	0.50±0.08	27.75±7.28	161.64±36.83	114.10±19.08	0.93±0.34	2.15±1.12	8.00±2.47	4.28±2.47	6.68
Mt I	0.43±0.11	23.95±9.40	120.24±22.92	100.80±23.87	1.05±0.40	1.91±1.46	6.81±1.91	3.12±0.78	8.10
Mt II	0.44±0.07	33.45±3.89	88.55±4.74	92.40±12.36	0.85±0.51	0.86±0.45	7.03±1.12	2.77±0.55	5.72
Ul I	0.46±0.11	28.35±1.59	101.21±13.16	131.95±27.06	0.71±0.18	0.86±0.18	7.28±1.82	4.73±1.90	7.98
Ul II	0.57±0.05	26.05±6.58	151.65±51.21	114.10±4.35	0.72±0.17	0.72±0.10	6.86±0.80	4.89±2.17	7.86
ND I	0.43±0.11	32.95±3.61	98.69±20.75	103.95±10.18	0.75±0.11	0.95±0.02	7.76±1.92	2.97±0.73	8.12
ND II	0.45±0.08	33.80±4.95	136.21±37.63	97.65±3.68	1.12±0.63	1.42±0.46	7.38±3.21	3.42±0.43	7.80
Mh I	0.45±0.05	38.80±1.85	150.01±32.27	112.00±11.32	0.72±0.12	1.06±0.29	7.76±4.41	4.86±0.57	7.92
Mh II	0.48±0.04	37.68±2.79	151.10±25.56	100.45±28.45	0.78±0.27	1.16±0.39	5.52±0.96	4.03±1.05	7.12
Nb I	0.54±0.05	40.05±2.79	186.38±41.78	115.15±8.03	1.08±0.65	1.41±0.46	7.58±4.36	3.45±0.35	6.24
Nb II	0.39±0.04	28.50±7.47	139.45±10.70	114.10±16.66	0.86±0.26	1.43±0.26	5.00±0.47	3.75±0.72	6.60
Hf I	0.43±0.08	27.08±7.11	170.06±24.75	124.95±15.90	1.02±0.14	1.46±0.14	12.96±2.45	8.26±2.77	8.68
Hf II	0.40±0.05	30.00±7.78	105.70±36.61	65.80±13.28	0.44±0.08	0.57±0.17	6.69±0.39	2.61±0.36	4.92

Note: Al I- Allupur I, Al II- Allupur II, Kn I- Kanar I, Kn II- Kanar II, Ml I- Malihabad I, Ml II- Malihabad II, Kk I- Kakori I, Kk II- Kakori II, Cb II- CISH block II, Cb III- CISH block III, Mt I- Meethenagar I, Mt II- Meethenagar II, Ul I- Ulrapur I, Ul II- Ulrapur II, ND I- NaibastiDhaneva I, ND II- NaibastiDhaneva II, Mh I- Mehmoodnagar I, Mh II- Mehmoodnagar II, Nb I- Nabipanah I, Nb II- Nabipanah II, Hf I- Hafizkhera I, Hf II- Hafizkhera II; AY- Average Yield.

mango orchards. Mango orchard of Meethenagar fixed plot I and Allupur fixed plot I had highest and lowest K content respectively. In terms of micronutrients, Kanar fixed plot I and Hafizkhera fixed plot I had maximum and minimum content of Zn respectively while Cu content was recorded in Nabipanah fixed plot I and CISH block II respectively. Mango orchards of CISH block III and Nabipanah fixed plot II had maximum and minimum foliar Mn content respectively. In contrast to Mn content, highest and lowest of Fe content was recorded in Kakori fixed plot II and Allupur fixed plot II respectively.

Table 2. Foliar nutrient concentrations in 22 mango orchards at Lucknow, Uttar Pradesh, India.

Fixed plots	P (mg kg^{-1})	K (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})
Al I	0.10±0.01	0.61±0.04	22.00±3.56	10.25±4.03	93.00±4.32	179.25±71.65
Al II	0.13±0.01	0.76±0.16	20.75±2.99	17.50±7.05	107.75±21.64	120.75±17.71
Kn I	0.11±0.01	0.75±0.10	31.75±7.97	21.75±0.96	91.75±2.87	125.00±2.94
Kn II	0.10±0.01	0.76±0.11	28.25±8.62	20.25±12.37	91.25±12.89	159.00±29.86
Ml I	0.11±0.02	0.82±0.20	24.25±6.65	12.25±3.30	91.75±27.45	171.75±33.96
Ml II	0.09±0.001	0.80±0.14	24.75±0.96	10.00±2.16	76.50±7.55	170.50±24.62
Kk I	0.11±0.02	0.76±0.08	29.50±4.93	12.50±1.73	75.25±10.01	174.75±34.17
Kk II	0.10±0.01	0.82±0.11	26.50±3.11	10.50±4.51	92.50±27.45	216.50±60.83
Cb II	0.10±0.02	0.75±0.23	25.50±5.69	34.00±11.17	127.00±14.72	176.25±40.98
Cb III	0.12±0.03	0.63±0.06	23.00±3.16	15.50±3.51	143.25±31.08	166.25±35.31
Mt I	0.11±0.02	0.90±0.13	24.50±8.50	19.00±5.35	110.00±24.60	194.75±76.08
Mt II	0.11±0.02	0.75±0.11	29.25±6.99	14.50±5.80	89.00±18.24	154.00±22.20
Ul I	0.09±0.01	0.72±0.12	29.00±7.16	13.75±4.65	114.75±15.78	182.25±32.97
Ul II	0.09±0.01	0.80±0.09	28.25±3.30	12.25±1.50	83.75±15.28	202.00±16.12
ND I	0.09±0.001	0.74±0.05	27.75±6.99	16.25±3.10	96.25±9.46	175.25±37.38
ND II	0.10±0.02	0.73±0.14	27.75±4.11	14.75±3.86	77.25±9.84	174.50±32.96
Mh I	0.09±0.01	0.83±0.014	29.00±4.08	12.00±2.83	79.00±9.63	182.75±19.03
Mh II	0.11±0.02	0.76±0.07	26.25±4.79	17.50±6.19	88.50±18.98	156.75±40.51
Nb I	0.10±0.01	0.72±0.03	27.75±2.06	9.50±1.29	80.00±8.76	200.50±4.80
Nb II	0.11±0.02	0.75±0.10	26.75±4.79	15.75±4.03	71.25±12.09	194.75±19.29
Hf I	0.12±0.01	0.81±0.11	20.75±2.99	15.00±6.68	90.50±15.18	130.00±21.02
Hf II	0.10±0.01	0.74±0.12	23.25±6.65	21.75±8.54	90.50±21.89	156.75±53.19

Note: Al I- Allupur I, Al II- Allupur II, Kn I- Kanar I, Kn II- Kanar II, Ml I- Malihabad I, Ml II- Malihabad II, Kk I- Kakori I, Kk II- Kakori II, Cb II- CISH block II, Cb III- CISH block III, Mt I- Meethenagar I, Mt II- Meethenagar II, Ul I- Ulrapur I, Ul II- Ulrapur II, ND I- NaibastiDhaneva I, ND II- NaibastiDhaneva II, Mh I- Mehmoodnagar I, Mh II- Mehmoodnagar II, Nb I- Nabipanah I, Nb II- Nabipanah II, Hf I- Hafizkhera I, Hf II- Hafizkhera II.

It was inferred from the nutrient data that differential nutrient content was recorded across 22 mango orchards. Some of the orchards had higher content while others had to some extent lower content. Lower content was mostly recorded as resultant of un-managed practices. Analysis of nutrient content in productive orchards are crucial for further planning, keeping the sustainability option intact, advanced protocols needed to be followed. Foliar content was also variable yet orchards are having sufficient micronutrient content in foliar parts. These suggest that focus on soil parts needs more attention. Raj & Rao (2006) identified the yield-limiting nutrients in mango and suggested for balanced tree nutrition for obtaining the best yields. Durán *et al.* (2005) revealed that for enhancing the fruit growth, yield in mango, soil nutrient status is a key factor. Evaluating nutrient status in mango is also crucial not only for production purpose but also for breeding purposes (Adak *et al.* 2018b). For the betterment of sustaining Mango cv Dashehari yield, soil and foliar management is crucial under semi-arid regions (Adak *et al.* 2019). The nutrient management should be location-specific as different soils had different nutrient content (Gautam *et al.* 2012). Ganeshamurthy *et al.* (2016) suggested for management options based on delineated areas and deficiencies in the soil and foliar parts in mango growing regions across the country. Thus, the needs for soil fertility status in productive fruit orchards are key components to successful mango production and business.

The soil nutrient index was developed for these 22 mango orchards falls under different fertility rankings. The percentage of different nutrients across 88 soil samples in Low, medium and high categories was tabulated in table 3. It indicated the wide variations across orchards towards the nutrient content in three different categories. The fertility ratings showed orchard soils fall under low ratings in terms of soil organic carbon (SOC%), soil available N and K whereas available P belongs to the medium rating (Table 4). Micronutrients *viz*., Zn, Fe and Mn were in medium ratings while Cu falls under the low category. The soil nutrient index was correlated with the productivity level in these mango orchards. A range of 4.92 to 8.68 t ha^{-1} was recorded. Majority of the orchards had production from 6 to ≤8.0 t ha^{-1}. Such lower productivity is linked to the low to

medium soil nutrients. Thus results of the study inferred that soil nutrient management should be given a due focus for improving yield in mango orchards.

Table 3. Categorization of soil samples across 22 fixed mango orchards in Lucknow, Uttar Pradesh, India.

	Percentage of samples falling within the range		
	Low	**Medium**	**High**
N	<280	280-560	>560
	100	0	0
P	<22	22-54	>54
	10.2	89.8	0
K	<123	123-293	>296
	35.2	64.8	0
SOC	0.5	0.51-0.75	>0.76
	35.2	64.8	0.0
Zn	0-0.5	0.5-1.0	>1.01
	4.5	75.0	20.5
Cu	<4.5	4.5-5.5	>5.5
	98.9	1.1	0.0
Mn	4	>4	
	0	100	0
Fe	<2.0	>2.01	
	0	100	0

Table 4. Soil nutrient index for major soil properties across 22 mango orchards of Lucknow, Uttar Pradesh, India.

	Soil nutrient index	**Fertility rating**
SOC	1.65	Low
Zn	2.16	medium
Cu	1.01	Low
Mn	2.00	medium
Fe	2.00	medium
P	1.90	Medium
K	1.65	Low
N	1.00	Low

Mango yield in 22 fixed orchards of Lucknow, Uttar Pradesh, India region recorded lower as compared to the national and international average. Dong *et al.* (2018) reported yield of 15.4 to 18.3 t ha^{-1} in different provinces in China under soil management system. Lower yield could by several reasons involving lack of practicing in production technologies. Farmers need to apply paclobutrazol for improving the flowering, fruit setting for better growth, yield and quality purposes (Kurian & Iyer 1993, Burondkar *et al.* 2013). Soil nutrient index showed lower and medium ratings for which growers should focus on the nutrient management. Lower N, K suggests use of slow-release fertilizer like neem coated urea. It not only increases the nutrient use efficiency but also lower down volatilization losses. Mango growers of the region should also apply K in both soils and after fruit set for improving the soil available K as well as fruit quality. For enhancing the organic carbon content, several organic sources of nutrition which are locally available and economically viable like vermicompost, on-firm compost, biofertilizers etc. should be applied post-harvest periods from Set to October. Many times, due to lack of labour, farmers avoid applying organic manuring, but this is important for nutrient recycling purpose. Therefore, their application is must for sustaining the fruit orchard (Ganeshamurthy *et al.* 2018). Medium ratings of micronutrients like Zn, Fe and Mn also suggest for balanced micronutrient application both in soil and leaf tissues to provide better nutrition to tree and fruit. Well nutritive orchards produce more fruits. Critical tree management practices like irrigation must be followed to improve mango orchard sustainability (Adak *et al.* 2018c). For better yield sustainability crop protection measures also needed for which real-time based agro-advisory is to be followed (Adak *et al.* 2018d). The soil nutrient index and yield in mango orchards are thus referred for precision management of mango orchards of the region.

CONCLUSIONS

The novelty of the current research to develop soil nutrient index based on fertility ratings was achieved. Soil nutrient contents both in soil and leaf tissues across 22 fixed mango orchards were evaluated under semi-arid conditions of Lucknow, Uttar Pradesh. Wider contents of nutrient were noted. The results showed fertility

ratings of these orchards based on nutrient contents. Soil available N, K, soil organic carbon, Cu was recorded in low category whereas P, Zn, Fe and Mn fall under medium ratings. Lower productivity levels are the reason for such low to medium ratings in soil nutrients. Adoption of precision farming technologies is advocated.

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