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Original Research Paper

Interlinking soil, water and plant health status of mango orchards of Ramanagara and Srinivaspura regions for higher productivity

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ABSTRACT

Interrelationship among soil, water and plant health and its influence on crop productivity of mango was investigated Soil, water and plant samples from mango orchards of Ramanagara and Srinivaspura areas of Karnataka, India were collected and analyzed. Soil quality (SQI), water quality (WQI) and plant health (PHI) indices were calculated adopting scoring procedure and interrelated. Few soils were deficient in organic C, available N, K, S, and Fe. Irrigation water of few samples had slightly higher bicarbonate, Cl^- and sodium hazards. Most of the leaf samples had very less N and K contents. Soil quality and plant health status of study area were moderately poor to good and irrigation water quality was medium to very good. There was significant positive correlation existed between SQI and PHI, SQI and yield and PHI and yield. However, WQI did not show any significant relationship with SQI, PHI and yield. These results confirmed that soil health influences plant health and crop productivity. Therefore, maintenance of soil health through good cultivation practices is important to enhance plant health and mango productivity.

Keywords: Mango, nutrient composition, plant health, soil quality, water quality

INTRODUCTION

Mango is one of the major fruit crops grown in India. The current area, production and productivity of mango in India is 2.32 million ha, 20.3 million tonnes and 8.83 tonnes/ha, respectively (Narayan et al., 2023). It is generally grown in almost all the states across India mainly in Uttar Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, etc. In Karnataka, area, production and productivity is 0.17 million ha, 1.65 million tonnes and 9.65 tonnes/ha, respectively (Narayan et al., 2023). In Karnataka, Ramanagara and Kolar districts are the major mango growing belts. Total mango growing area in these regions is more than 75000 ha (Manjunath et al., 2019). The production and productivity of mango in these regions is also comparatively higher than the other regions.

Soil health plays a major role in improving crop productivity. Different soil properties like physical, chemical and biological parameters govern the soil health. The nutrient elements present in the soil are taken up by the plants. The crop yield and quality is associated with fertility status of the soil (Rajendiran et al., 2020a). For maintaining soil health proper sustainable management practices like adequate supply of organic manures, irrigation with good quality water, balanced nutrient supply, green manuring and other conservation management practices need to be followed (Rajendiran et al., 2020b). Further, healthy soil produce healthy crop. It is considered that there is a link among soil-plant-animal-human health. Therefore, it is essential to maintain the overall health of a production system for sustaining crop productivity and quality. However, the relationship among soil, plant, water health and their influence on crop productivity is not clearly understood in perennial crop like mango. To understand the reason behind the higher productivity of the crop in Ramanagara and Srinivaspura regions of Karnataka, India, a survey work was carried out in these regions and soil, water and plant samples were collected from some selected mango orchards and analyzed. The integrated health status of these mango orchards and their influence on crop productivity are presented.

MATERIALS AND METHODS

General information of study area

Ramanagara and Srinivaspura are well known places for mango production in Karnataka, India. Mangoes are cultivated on 46,679 hectares with production of 4,03,884 tonnes in Kolar is the highest in the State.

This is followed by Ramanagara, where the cultivation area is 26,889 hectares with a production of 2,45,686 tonnes of mangoes in 2024 (The Hindu Report, 2024). Ramanagara district is located approximately 50 km southwest of Bengaluru. It has an average elevation of 747 m above mean sea level and is famous for the huge rocky outcroppings. It comes under Agro ecological sub region (ICAR), Karnataka Plateau, Hot Moist semi arid eco sub region (8.2), Agro-climatic region (Planning Commission) - Southern Plateau and Hills region (X) with average annual rainfall of 823 mm in 63 rainy days. Similarly, Srinivaspura is a taluk of Kolar district which comes under same Agro Ecological Sub Region and Agro-climatic region with annual rainfall of about 643 mm. Parent materials are laterites developed from granite and soil group is Kandic Paleustalfs. The soils belong to Alfisols and are base rich, mineral soils of sub-humid and humid regions light coloured surface, with clay enriched subsoil (argillic horizon), rich in exchangeable cations because of high base saturation and favourable texture. These soils are fertile and productive (NBSS & LUP, 1998). The major soil groups are deep and moderately deep red clay soils in Ramanagara district and red loamy and sandy loam soils in Srinivaspura. Major agricultural crops grown in theregion are ragi, red gram, groundnut, paddy, pulses, etc. and in case of horticultural crops mango, banana, tomato, potato, tamarind, cashew, coconut etc.

Survey and sample collection

Survey of study area was conducted during October and November of 2019 in the selected mango orchards of Ramanagara and Srinivaspura (Table 1) regions of Karnataka. The major mango cultivar grown in Ramanagara is Alphonso and Totapuri in Srinivaspura. Soil, water and leaf samples were collected from the mango orchards of these regions for studying the overall health status. Total number of soil and plant samples collected was 16 leaves and soil and 5 water samples from Ramanagara and 15 leaves, soil and water samples from Srinivaspura. The representative surface soil samples (0-15 cm depth) were collected manually. Leaf samples (recently matured 6th leaf from the top of non-bearing branches) were collected from all the four sides of tree canopy (Ragupathi et al., 2004). The age of trees was more than 10 years old. The water samples were collected from the motor pumps after running for 15 minutes and stored in polythene bottles. As such there is not much variation in fertilizer practices among planters of these regions. They apply inadequate organic matter to the plants (10-15 kg/plant) and application of mineral nutrients is rare. Few farmers apply DAP or NPK complex (0.5-1 kg/plant) during fruit setting and fruit development stage.

Sample analysis

The soil and water samples were analyzed following the standard procedure in the laboratory. Soil pH,

Table 1 : Location and other details of sampled area in Ramanagara and Srinivaspura

Ramanagara					Srinivaspura				
Village	Variety	Tree age (y)	Sampling points		Village	Variety	Tree age (y)	Sampling points	
			Latitude	Longitude				Latitude	Longitude
Kurubarahalli	Alphonso	30	12°44’49"	77°14’34"	Arikere	Totapuri,	20	13°18’06"	78°15’6"
	Alphonso	30	12°44’45"	77°14’25"		Alphonso	20	13°17’52"	78°15’17"
	Alphonso	30	12°44’35"	77°14’21"		Banganappalli	15	13°17’60"	78°15’27"
	Alphonso	20	12°44’21"	77°14’47"		Totapuri	15	13°18’04"	78°15’25"
Bilagumba	Alphonso	20	12°43’37"	77°16’31"		Alphonso	18	13°18’05"	78°15’29"
	Alphonso	20	12°45’20"	77°16’03"		Mallika	12	13°17’60"	78°15’31"
	Alphonso	20	12°45’31"	77°16’02"	Lakshmi	Alphonso	12	13°14’55"	78°16’44"
	Alphonso	20	12°45’39"	77°15’56"	sagara	Banganappalli	12	13°14’21"	78°16’18"
	Alphonso	45	12°45’39"	77°15’48"		Totapuri	13	13°14’14"	78°17’50"
	Sindhura	45	12°45’40"	77°15’47"		Totapuri	15	13°14’16"	78°17’52"
	Alphonso	25	12°45’40"	77°15’39"		Totapuri	15	13°14’18"	78°17’53"
	Neelam	25	12°45’40"	77°15’39"		Totapuri	18	13°14’19"	78°17’55"
Arehalli	Alphonso	25	12°46’2"	77°15’41"		Totapuri	21	13°14’19"	78°17’3"
	Alphonso	25	12°45’36"	77°15’30"		Totapuri	16	13°13’56"	78°16’51"
Bilagumba	Alphonso	20	12°45’13"	77°15’22"		Totapuri	15	13°13’56"	78°16’51"
	Alphonso	20	12°45’15"	77°15’23"					

electrical conductivity, organic carbon, available nutrients (macro and micro) and microbial properties were analyzed. The leaf samples were analyzed for the major, secondary and micro nutrients. In water samples, pH, EC, carbonates and bicarbonates, chloride, sulfate, nitrate, calcium, sodium and magnesium contents were analyzed. Further sodium adsorption ration (SAR) was also calculated following the equation given below:

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}} \quad \text{.....Eq. (1).}$$

Where, SAR is sodium adsorption ration ($me^{1/2}\ L^{-1/2}$), Na is concentration of sodium (me L^{-1}), Ca is concentration of calcium (me L^{-1}), and Mg is concentration of magnesium (me L^{-1}).

Table 2 : Soil, water and plant health indicators and their weights and classes

Soil quality indicators	**Weights**	**Class I**	**Class II**	**Class III**	**Class IV**
Total Bacteria (10^8 CFUg^{-1})	0.05	>30	10-30	10-1	<1
Azotobacter (10^6 CFUg^{-1})	0.05	>300	100-300	100-10	<10
PSB (10^5 CFUg^{-1})	0.05	>10	5-10	5-1	<1
Actinobacteria (10^5 CFUg^{-1})	0.05	>10	5-10	5-1	<1
Fungi (10^4 CFUg^{-1})	0.05	>5	5-3	3-1	<1
Organic carbon (%)	0.10	>1	1-0.75	0.75-0.5	<0.5
Soil pH	0.10	6.5- 7.5	6.5- 6/7.5-8	6- 5.5/8-8.5	<5.5 />8.5
Soil EC(dSm^{-1})	0.05	<1.0	1.0-2.0	2.0-4.0	>4.0
Avail. N (mg kg^{-1})	0.05	>280	210-280	140-210	<140
Avail. P (mg kg^{-1})	0.05	>12.5	7.5-12.5	5-7.5	<5
Avail. K (mg kg^{-1})	0.05	>140	100-140	60-100	<60
Avail. Ca (mg kg^{-1})	0.05	>1000	750-1000	500-750	<500
Avail. Mg (mg kg^{-1})	0.05	>500	500-400	300-400	<300
Avail. S (mg kg^{-1})	0.05	>25	25-15	15-10	<10
Avail. Zn (mg kg^{-1})	0.05	>2.0	2.0-1.0	1.0-0.5	<0.5
Avail. Fe (mg kg^{-1})	0.05	>10.0	10-5.5	5.5-2.5	<2.5
Avail. Mn (mg kg^{-1})	0.05	>10.0	10.0-4.0	4.0-2.0	<2.0
Avail. Cu (mg kg^{-1})	0.05	>2.0	2.0-0.5	0.5-0.2	<0.2
Score	*1.0*	*1*	*0.75*	*0.5*	*0.25*
Plant health indicators	**Weights**	**Class I**	**Class II**	**Class III**	**Class IV**
N content (%)	0.1	>1.0	0.8-1.00	0.5-0.8	<0.5
P content (%)	0.1	>0.12	0.1-0.12	0.08-0.1	<0.08
K content (%)	0.1	>1.5	1-1.5	0.5-1.0	<0.50
Ca content (%)	0.1	>5.0	4.0-5.0	3.0	<3
Mg content (%)	0.1	>0.7	0.7-0.6	0.6-0.5	<0.5
S content (%)	0.1	>0.1	0.08-0.1	0.05-0.08	<0.05
Fe content (mg kg^{-1})	0.1	>150	125-150	100-125	<100
Zn content (mg kg^{-1})	0.1	>30	25-30	20-25	<20
Cu content (mg kg^{-1})	0.1	>10.0	8.0-10.0	5.0-8.0	<8.0
Mn content (mg kg^{-1})	0.1	>150	125-150	100-125	<100
Score	*1.0*	*1*	*0.75*	*0.5*	*0.25*
Water quality indicators	**Weights**	**Class I**	**Class II**	**Class III**	**Class IV**
pH	0.1	6.5- 7.5	6.5- 6/7.5-8	6- 5.5/8-8.5	<5.5 />8.5
EC (dSm^{-1})	0.1	<0.5	0.5-1.0	1.0-2.0	>2.0
CO_3 (meL^{-1})	0.1	<.0.05	0.05-0.10	0.10-0.20	>0.02
HCO_3 (meL^{-1})	0.1	<2.0	2.0-5.0	5.0-10.0	>10.0
Cl (meL^{-1})	0.1	<3.0	3.0-6.0	6.0-10.0	>10.0
Na (meL^{-1})	0.1	<10	10-30	30-50	>50
Ca (meL^{-1})	0.1	<5	5-15	15-25	>25
Mg (meL^{-1})	0.1	<3	3-5	5-10	>10
SO_4 (meL^{-1})	0.1	<0.5	0.5-1.0	1-2	>2.0
NO_3 (meL^{-1})	0.1	<0.10	0.1-0.3	0.3-0.5	>0.5
Score	*1.0*	*1*	*0.75*	*0.5*	*0.25*

Calculation of soil, plant and water quality index

Each assessed soil, water and plant parameter of study area was given weights and scores accordingly (Table 2) based on the available expertise and the quality or health indices were calculated. The quality or health index was calculated by adopting the following equation given by Wang & Gong (1998):

$$\text{Quality or Health Index} = \sum(W_i * I_i) \quad \text{.....Eq. (2).}$$

Where, W_i indicates the weight of the indicator, and I_i indicates the marks/score of the indicators classes. As per the minimum dataset followed in the study, the maximum and minimum values of quality or health indexcould be 1.0 and 0.25, respectively. The classes of indices were categorized into very good (0.9-1.0), good (0.8-0.9), medium (0.7-0.8), moderately poor (0.6-0.7) and poor (less than 0.6) according to index value range.

Statistical analysis

Descriptive statistics such as range, mean, standard deviation (SD) and coefficient of variations (CV) of different soil, plant and water parameters were calculated. Further correlation and linear relationship between different health and quality indices as well as with mango yield were established.

RESULTS AND DISCUSSION

Soil health parameters

Most of the soils of study area had slightly acidic to neutral soil reactions. The pH of soil ranged from 5.74 to 7.64 in Ramanagara and 6.20 to 7.29 in Srinivaspura (Table 3). The salt concentration was also under normal range (<1 dS m^{-1}). Organic C content ranged from 0.33%-2.08% in Ramanagara and 0.13%-1.85% in Srinivaspura soils. Most of the soils had higher range (>0.75%) and three samples in Ramanagara and five samples in Srinivaspura had low range (<0.5%) of soil organic C status which reflects the status of soil available N and other nutrients. The soil available N ranged from 53.5-465 ppm in Ramanagara and 21.3-299 ppm in Srinivaspura. Largely the soils in the region had medium available N fertility status. Similarly, all the soils had sufficient available P, Ca and Mg. The available K in soil was found to be low in few locations in both the regions. Soil available S in Ramanagara and Srinivaspura varied from 4.9-47.20 ppm and 11.9-23.8 ppm, respectively (Table 3). About five soil samples had low S content in Ramanagara. In case of micronutrients (Zn, Mn, Cu and Fe), except Fe others were in the sufficient range. Overall the soil fertility status of the region was high with respect to all the nutrients. Few

Table 3 : Soil properties of mango orchards of Ramanagara and Srinivaspura region

Soil properties	Ramanagara (N=16)				Srinivaspura (N=15)			
	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
pH	5.7-7.64	6.83	0.39	5.71	6.20-7.29	*6.83*	0.34	*4.96*
EC (dS m^{-1})	0.04-0.23	0.14	0.06	46.2	0.04-0.20	*0.10*	0.06	*57.2*
OC (%)	0.33-2.87	1.25	0.69	55.3	0.13-1.85	*0.78*	0.53	*68.8*
N (ppm)	53.4-465	202	112	55.4	21.3-299	*126*	86.4	*68.8*
P (ppm)	5.00-17.2	9.27	3.46	37.3	3.73-46.7	*14.5*	10.7	*74.1*
K (ppm)	30.0-867	172	195	114	2.50-135	*58.8*	43.9	*75.0*
Ca (ppm)	1495-5634	3408	1110	32.6	451-2938	*1641*	713	*43.4*
Mg (ppm)	548-1035	819	143	17.4	237-739	*522*	168	*32.1*
Cu (ppm)	0.60-5.48	2.53	1.60	63.3	0.48-11.4	*3.81*	3.19	*84.0*
Zn (ppm)	1.40-28.1	5.46	7.03	129	0.83-17.8	*5.06*	4.85	*95.9*
Fe (ppm)	2.00-24.0	10.3	6.85	66.2	0.63-37.6	*12.7*	11.1	*87.6*
Mn (ppm)	8.43-46.1	25.0	11.73	46.9	56.3-253	*132*	57.1	*43.3*
S (ppm)	4.90-47.2	14.8	10.9	73.5	11.9-23.8	*16.4*	3.58	*21.9*
Total bacteria (10^8 CFU g^{-1})	1.00-600	74.4	187	251	1.00-900	*70.0*	230	*329*
Azotobacter (10^6 CFU g^{-1})	5.00-500	102	145	142	1.00-150	*27.5*	44.6	*162*
PSB (10^5 CFU g^{-1})	1.00-16.0	5.81	4.58	78.8	0-98.0	*19.3*	26.5	*137*
Actinobacteria (10^5 CFU g^{-1})	1.00-32.0	10.3	9.21	89.8	1.00-85.0	*33.3*	23.8	*71.6*
Fungi (10^4 CFU g^{-1})	1.00-7.00	3.88	1.75	45.1	0-47.0	*7.27*	12.2	*168*

PSB: phosphate solubilizing bacteria; CFU: colony forming unit

deficient soil samples needs to be taken care by supplying additional fertilizer nutrients.

The soils of study area are rich in microbial load and diversity with population ranging from 10^5 to 10^8 CFU g^{-1} of soil within different species of bacteria. Among the two regions, based on the mean values, microbial populations were found to be higher in Ramanagara than in Srinivaspura. In Ramanagara, the total bacteria population ranged from $1x10^8$ CFU g^{-1} of soil to $600x10^8$ CFU g^{-1} of soil with mean value of $74.43x10^8$ CFU g^{-1} of soil. In case of *Azotobacter*, P solubilizer and *Actinobacteria* population varied from 5 to $500x10^6$ CFU g^{-1} of soil, 1 to $16x10^5$ CFU g^{-1} of soil and 1 to 32 $x10^5$ CFU g^{-1} of soil, respectively. The fungal population ranged from 1 to 7 $x10^4$ CFU g^{-1} of soil (Table 3). In case of Srinivaspura, the total bacteria population ranged from $1x10^8$ CFU g^{-1} of soil to $900x10^8$ CFU g^{-1} of soil with mean value of $70.0x10^8$ CFU g^{-1} of soil. In case of *Azotobacter*, P solubilizer and actinobacteria population varied from 1 to 150 $x10^6$ CFU g^{-1} of soil, 1 to $98x10^5$ CFU g^{-1} of soil and 1 to $85x10^5$ CFU g^{-1} of soil, respectively. The fungal population was ranging from 1 to $47x10^4$ CFU $g^{-1}$of soil (Table 3). The data showed the large variation in the population among the mango orchards. This might be due to variation in management practices adopted or followed by the farmers in the region.

Overall SQI of Ramanagara and Srinivaspura ranged from 0.71-0.89 and 0.61-0.85, respectively. Further, SQI data indicates that most of the soils of Ramanagara had good soil quality and in Srinivaspura the majority of soils are medium category in soil quality (Table 6). There is further scope to improve soil quality through increasing soil organic matter and correcting nutrient deficiency by adopting appropriate management practices. The soil quality parameters selected for assessment were simple and easily quantifiable parameters. Majority of them particularly soil organic carbon, microbial activity, and available nutrients were regularly used and recommended as important soil quality indicators by the previous workers (Buennemann et al., 2018; Mahajan et al., 2020; Rajendiran et al., 2020a).

Water quality parameters

Water samples in Ramanagara region had almost neutral pH with normal salt concentration. Bicarbonate content of the water samples were little higher than the safer limit. Sodium adsorption ratio (SAR) showed potential sodium hazards. Nitrate and sulphate concentrations were below the normal range. In some cases Cl^- concentration was on higher side (Table 4).Irrigation water quality results of mango orchards of Srinivaspura region revealed that pH of the water was in acceptable normal range (7.01-7.87). The salt concentration in terms of EC (0.03-2.84 dS m^{-1}) found to be little higher in some samples, was not safe for frequent irrigation for longer period. Chloride content of few samples was high (beyond 10 me L^{-1}) that might have caused chlorine toxicity during summer. The SAR was also found to be slightly higher in many water samples (Table 4). However, the overall

Table 4 : Water quality parameters of mango orchards of Ramanagara (N=16) and Srinivaspura (N=15)

Water properties	Ramanagara (N=16)				Srinivaspura (N=15)			
	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
pH	6.67-7.66	7.21	0.40	5.55	7.01-7.85	7.42	0.25	3.40
EC (dS m^{-1})	0.84-1.56	1.06	0.29	27.2	0.03-2.84	1.13	0.70	62.1
CO_3 (me L^{-1})	ND	0	0	0	ND	0	0	0
HCO_3 (me L^{-1})	3.50-8.70	6.14	2.39	38.9	1.00-5.50	3.02	1.26	41.6
Cl (me L^{-1})	2.80-9.00	5.68	2.52	44.4	2.00-14.6	9.13	6.29	68.8
Na (me L^{-1})	4.75-11.3	8.06	2.72	33.8	0.65-15.4	8.81	5.50	62.5
Ca (me L^{-1})	1.20-5.72	3.39	1.99	58.8	1.02-10.2	4.18	2.17	51.9
Mg (me L^{-1})	3.56-5.01	4.21	0.54	12.9	1.60-3.39	2.89	0.55	19.2
SO_4 (me L^{-1})	0.62-1.18	0.88	0.22	25.4	0.10-1.54	0.88	0.49	55.4
NO_3 (me L^{-1})	0-0.140	0.05	0.05	100	0.01-0.35	0.08	0.11	146
SAR (me $L^{-1})^{1/2}$	2.36-6.26	4.28	1.58	37.0	0.57-7.31	4.50	2.51	55.7

water quality of study area was medium to very good quality category with WQI ranged from 0.73-0.90 in Ramanagara and 0.73- 0.95 in Srinivaspura (Table 6). Majority of the water samples had very good quality, however periodical monitoring is necessary for their effective utilization.

Plant health parameters

The nutrient content of mango leaf samples collected from different mango orchards of Ramanagara is depicted in Table 5. The N content ranged from 0.14%-1.43%, P from 0.08-0.13%, K content from 0.10-0.80%. Most of the leaf samples had very less N and K contents. In case of Ca ranged from 2.64-6.28% and Mg 0.34-0.96%, and were in sufficient level. The S content varied from 0.03-0.25%, few samples found to be very low. The micronutrients Fe, Mn, Zn and Cu were in the range of 79.20-182.1 ppm, 42.8-429 ppm, 17.10-34.0 ppm and 6.7-14.0 ppm, respectively, mostly they were in sufficient range. Leaf nutrient concentration of mango orchards of Srinivaspura ranged from 0.17-1.57% for N, 0.09-0.18% for P, 0.1-5.0% for K, 4.04-6.37% for Ca, 0.44-0.93% for Mg, 0.09-0.23% for S, 14.5-303 ppm for Fe, 28.7- 339 ppm for Mn, 16.3-23.2 ppm for Zn and 5.80-10.6 ppm for Cu (Table 5). This showed that N, P and K range in the plant is relatively low in many samples. In case of secondary nutrients mostly were in sufficient range. In case of micronutrients, some of the samples had deficient level of Zn, Fe and Mn. The PHI ranged from 0.65-0.96 in Ramanagara and 0.44-0.86 in Srinivaspura (Table 6). Majority of plant samples had medium and good health status in Ramanagara and good health status in Srinivaspura. Few plant samples had poor and moderately poor health status in Srinivaspura.

Linking soil, water and plant health and crop productivity

Mango yield of Ramanagara ranged from 8.5-14.5 t ha^{-1} and in Srinivaspura it varied from 5.0-30 t ha^{-1} (Table 7). There was large variation in productivity among Srinivaspura orchards, but the variation among Ramanagara orchards was very narrow. The variation in mango yield might be due to age of tree, cultivar, climate, soil type, management practices, etc. Correlation co-efficient and linear regression relationship reflected that soil quality was positively correlated with plant health and crop productivity. However, water quality was not significantly correlated with soil quality; plant health and crop yield (Table 7). As such there was not much difference in water quality status and was also not much hazardous in irrigation water samples of the study area. Further less difference in water quality parameters might not have shown any changes in growth of aged tree crops. Besides, the active roots generally distributed below 30 cm and irrigation water would be filtered and buffered by the soil column. Moreover perennial crop like mango largely depends on rain water and underground water for its growth and development. The variation in soil quality among samples of study area might be due to difference in climate, topography, management practices, etc. Further plants grown in good quality soil had higher crop productivity and

Table 5 : Leaf nutrient contents of mango orchards of Ramanagara and Srinivaspura region

Mango leaf	Ramanagara (N=16)				Srinivaspura (N=15)			
nutrient content	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
N (%)	0.28-1.43	0.86	0.45	52.2	0.17-1.60	0.65	0.48	73.5
P (%)	0.08-0.13	0.11	0.02	15.6	0.09-0.18	0.10	0.02	22.3
K (%)	0.10-0.80	0.23	0.24	103	0.10-5.00	0.51	1.25	246
Ca (%)	2.64-6.28	4.31	1.20	27.9	3.26-6.37	4.68	0.70	15.0
Mg (%)	0.34-0.96	0.63	0.19	29.5	0.44-0.93	0.75	0.13	16.9
S (%)	0.03-0.25	0.10	0.06	56.8	0.09-0.23	0.13	0.05	36.2
Cu (ppm)	5.00-11.4	8.44	2.35	27.9	5.80-10.6	8.11	1.40	17.2
Zn (ppm)	17.1-34.0	23.5	4.27	18.2	16.4-23.2	19.8	2.56	13.0
Fe (ppm)	79.2-182	118	29.8	25.2	88.0-186	147	52.6	35.8
Mn (ppm)	42.8-429	184	111	60.3	28.7-295	131	95.6	73.1

Table 6 : Soil and water quality, plant health status and yield of mango orchards of Ramanagara and Srinivaspura region

Ramanagara								Srinivaspura							
Sample No	SQI	Remarks	WQI	Remarks	PHI	Remarks	Yield (t ha^{-1})	Sample No	SQI	Remarks	WQI	Remarks	PHI	Remarks	Yield (t ha^{-1})
1	0.89	Good	0.80	Good	0.96	Very good	14.5	1	0.85	Good	0.73	Medium	0.84	Good	12.5
2	0.81	Good			0.86	Good	11	2	0.79	Medium	0.90	Very good	0.80	Good	12
3	0.81	Good	0.83	Good	0.84	Good	13	3	0.76	Medium	0.93	Very good	0.78	Medium	15
4	0.73	Medium			0.76	Medium	12	4	0.75	Medium	0.95	Very good	0.80	Good	14
5	0.71	Medium	0.90	Very Good	0.71	Medium	11	5	0.75	Medium	0.98	Very good	0.44	Poor	5
6	0.80	Good			0.68	Mod. Poor	10	6	0.71	Medium	0.90	Very good	0.46	Poor	5
7	0.81	Good			0.79	Medium	14	7	0.84	Good	0.73	Medium	0.68	Mod. Poor	8
8	0.80	Good			0.79	Medium	11.5	8	0.71	Medium	0.73	Medium	0.66	Mod. Poor	8
9	0.64	Mod. Poor			0.70	Medium	8.5	9	0.70	Medium	0.88	Good	0.71	Medium	10
10	0.63	Mod. Poor			0.69	Mod. Poor	9	10	0.61	Mod. Poor	0.83	Good	0.46	Poor	5
11	0.81	Good	0.73	Medium	0.88	Good	12	11	0.84	Good	0.88	Good	0.84	Good	12
12	0.83	Good			0.65	Mod. Poor	10	12	0.70	Medium	0.78	Medium	0.86	Good	30
13	0.81	Good	0.78	Medium	0.73	Medium	10	13	0.80	Good	0.88	Good	0.86	Good	15
14	0.84	Good			0.84	Good	14	14	0.80	Good	0.78	Medium	0.76	Medium	18
15	0.74	Medium			0.84	Good	13	15	0.80	Good	0.75	Medium	0.80	Good	12
16	0.71	Medium			0.86	Good	12								

good health status. These findings were in concurrence with the earlier reports that indicated healthy soil produces healthy crops (Weil and Brady, 2017; Havlin et al., 2013; Rajendiran et al., 2020a). This study also confirmed that there was positive correlation exists between soil quality and plant health. Further healthy plants produced more yield than that of unhealthy plants. Therefore maintenance of soil quality is very important to enhance plant health and productivity.

CONCLUSION

Table 7 : Relationship between SQI, WQI, PHI and mango yield

Ramanagara				Srinivaspura			
Correlation matrix							
	SQI	PHI	Yield		SQI	PHI	Yield
WQI	-0.61	-0.45	-0.06	WQI	-0.19	-0.24	-0.19
SQI	-	0.47*	0.60*	SQI	-	0.56*	0.13
PHI	-	-	0.78*	PHI	-	-	0.73*
Linear regression relationship							
	SQI	PHI	Yield		SQI	PHI	Yield
WQI	y = -0.589x + 1.282 R^2 = 0.375	y = -0.723x + 1.405 R^2 = 0.198	y = -1.641x + 13.42 R^2 = 0.003	WQI	y = -0.145x + 0.883 R^2 = 0.037	y = -0.416x + 1.065 R^2 = 0.058	y = -13.78x + 23.65 R^2 = 0.035
SQI	-	y = 0.560x + 0.351 R^2 = 0.217*	y = 14.73x + 0.205 R^2 = 0.355*	SQI	-	y = 1.281x - 0.258 R^2 = 0.314*	y = 12.57x + 2.530 R^2 = 0.016
PHI	-	-	y = 15.93x - 0.917 R^2 = 0.601*	PHI	-	-	y = 31.11x - 10.20 R^2 = 0.531*

No. of soil and plant samples = 16 each; No. of water samples = 5 in Ramanagara;
No. of soil, plant and water samples = 15 in Srinivasapura each

*Significant at 5%

The results of soil, water and plant parameters of different mango orchards of Ramanagara and Srinivaspura region indicated that soil quality influences the plant health and productivity. Further, there was large variation observed in soil quality and plant health status of the study area. Moreover the healthy soils produced the healthy crops and higher yield. In contrast there was not much variation in water quality status of study area and there was no significant relationship existed between water quality with soil quality, plant health and mango yield. Sustainable management of soils, that are low in soil organic carbon, N, K, S and micro nutrients (Fe and Zn) could improve overall soil quality and plant health status as well crop productivity of the region. Supply of adequate organic manures/compost and potash fertilization is essential to improve the soil quality of these regions. Periodical monitoring and assessment need to be carried out over a longer period to understand the long term changes and for systematic recommendations.

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