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Mrunali R Manekar
PG Scholar, Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Dr. Maya M Raut
Associate Professor, Soil Science Section, College of Agriculture, Gadchiroli, Maharashtra, India

Dr. PD Raut
Assistant Professor, Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Dr. RN Katkar
Associate Dean (LAE), Dr. PDKV, Akola Dr. Shalini Badge, Associate Professor, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Dr. Shalini Badge
Associate professor, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Pooja P Kad
PG Scholar, Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Pragati D Marape
PG Scholar, Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Shweta B Bhagat
PG Scholar Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Divya V Rane
PG Scholar, Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Corresponding Author:
Mrunali R Manekar
PG Scholar, Soil Science Section, College of Agriculture, Nagpur, Maharashtra, India

Comparative assessment of soil properties in healthy and declining Nagpur Mandarin (*Citrus reticulata* Blanco) Orchards of Morshi Tehsil, Amravati District

Mrunali R Manekar, Maya M Raut, PD Raut, RN Katkar, Shalini Badge, Pooja P Kad, Pragati D Marape, Shweta B Bhagat and Divya V Rane

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Abstract
The present investigation in relation to "Comparative study of soil characteristics of healthy and declining Nagpur mandarin orchards in Morshi tehsil, Amravati district, was undertaken during 2024-25. Ten healthy and ten declining orchards were selected on the basis of their visual observations from seven locations of Morshi tehsil were selected to evaluate the soil characteristics of Nagpur mandarin orchards. Fourty soil samples were taken from 0-20 and 20-40 cm depth randomly selected over the field of Nagpur mandarin.

The results indicated that, the hydraulic conductivity ranges between 0.68 to 0.90 cm hr^{-1} in healthy orchards and 0.57 to 0.81 cm hr^{-1} in declining orchards. The bulk density and mean weight diameter in healthy orchards ranged 1.30 to 1.41 g cm^{-3}**,** 0.85 to 0.99 mm in declining orchards it varied from 1.34 to 1.44 g cm^{-3},0.74 to 0.95 mm respectively soil reaction was slightly to moderately alkaline, with pH value varied from 7.41 to 8.02 in healthy orchards and in declining condition it is in the range of 7.55 to 8.03, EC ranges between healthy and declining orchards were 0.24 to 0.30 and 0.25 to 0.39 dS m^{-1} resp. indicating the non-saline nature of these soils, organic carbon content in healthy and declining orchards soil are varied as 4.21 to 6.02 g kg^{-1} and 4.11 to 5.12 g kg^{-1} resp., free calcium carbonate in healthy and declining orchards varied from 4.37 to 6.21% and 6.21 to 9.99% resp. As all soils contained more than 5% CaCO3 they were categorized as calcareous soils. Organic carbon showed decreasing trend with soil depth and soils contained low in organic carbon. The available nitrogen was found to be low both healthy and declinings, phosphorus was medium in healthy orchards and low to medium in declining condition, potassium was high to very high and sulphur was low to moderate. The DTPA extractable micronutrients in soil varied from marginal to moderately high for zinc, iron, copper and manganese respectively.

Keywords: Morshi tehsil, Amravati, Nagpur mandarin, manganese respectively, moderately alkaline

Introduction
Citrus is among the most important fruit crops globally, particularly in tropical and subtropical regions. In India, citrus ranks third in fruit production after banana and mango, with a cultivated area of 0.89 million hectares and a production of approximately 0.923 million tonnes. Among various citrus species, sweet orange constitutes 34%, mandarin 26%, lime 34%, and the remaining 5% includes citron, lemon, tangerine, and grapefruit (NHB, 2020). Nagpur mandarin (*Citrus reticulata* Blanco), locally known as orange, is a prominent citrus cultivar native to India and Southeast China. It is widely cultivated in central and western India, particularly in Maharashtra. The crop occupies around 310.42 thousand hectares nationally, contributing to 12.4% of the total area under fruit cultivation, with an annual production of 100.9 lakh tonnes and an average productivity of 9.7 t ha^{-1} (NHB, 2020). In Maharashtra alone, Nagpur mandarin is grown on 1.48 lakh hectares (bearing area 86,200 ha), producing about 8.75 lakh tonnes of fruit. However, its productivity (10–14 t ha^{-1}) remains suboptimal compared to other citrus cultivars. In recent years, a considerable decline in Nagpur mandarin orchards has been reported in key production areas, especially in Morshi tehsil of Amravati district. This decline is associated with poor soil health, nutrient imbalances, and improper orchard management.

Soil characteristics and leaf nutrient status are critical indicators of orchard productivity and sustainability. However, limited studies have addressed their comparative evaluation in healthy versus declining orchards. Therefore, the present investigation was undertaken to assess and compare the soil properties of healthy and declining Nagpur mandarin orchards in Morshi tehsil. The study aims to identify nutrient limitations and soil constraints contributing to orchard decline and to provide a scientific basis for improving citrus orchard management in the region.

2. Materials and Methods

Under present investigation seven villages in Morshi tehsil of Amravati District were surveyed, ten healthy and ten declining condition orchards were selected on the basis of visual observations. Out of total orchards, depth wise samples were collected from each healthy and declining Nagpur mandarin orchards. Soil samples were analyzed for hydraulic conductivity, bulk density, mean weight diameter by the standard methods respectively [1, 2].

The chemical properties like soil pH, electrical conductivity, free calcium carbonate and organic carbon were determined by appropriate methods of analysis [3]. Available nitrogen, phosphorus, potassium and sulphur were determined by alkaline potassium permanganate method [4], Olsen's method and flame photometer method [5], Turbidimetric method by using spectrophotometer [6] respectively.

3. Results and Discussion

Data on physio-chemical properties of healthy and declining Nagpur mandarin orchards soils are presented in Table 1 and 2.

3.1 pH and Electrical Conductivity

The pH values in soils of healthy orchards ranged from 7.41 to 8.10, while those in declining orchards varied between 7.81 to 8.25. A slight increase in pH with increasing soil depth was observed across all sites, consistent with earlier findings [7]. Notably, higher pH levels were recorded in declining orchards, which can be attributed to greater concentrations of free lime-a trend also reported by previous researchers [8]. Despite this variation, the pH across the studied locations remained within the optimal range of 6.0 to 8.0 for citrus cultivation [9].

Electrical conductivity (EC), which indicates the presence of soluble salts in the soil, ranged from 0.25 to 0.29 dS m^{-1} in healthy orchard soil and in declining orchard soil it varied from 0.26 to 0.39 dS m^{-1}. Although a tendency for EC to increase with depth was noted. Since all EC values were below 1 dS m^{-1}, the soils are considered free from harmful levels of soluble salts, as per the threshold described [10]. Thus, EC levels in the studied soils fall within the safe range for citrus production

3.2 Organic carbon and calcium carbonate

In the surface soils of healthy orchards, organic carbon content ranged from 5.54 to 8.02 g kg^{-1}, whereas in declining orchards it varied from 4.11 to 5.12 g kg^{-1}. This indicates that soils supporting healthy orchards had higher organic carbon levels compared to those under declining conditions. In healthy orchard soils, surface layers generally exhibited medium to high organic carbon content, while subsoil layers showed a noticeable decline. A consistent decrease in soil organic carbon with increasing depth was observed across both healthy and declining orchard soils, aligning with findings reported by earlier studies [11].

Free lime content in surface soils of healthy and declining orchards ranged from 5.37% to 7.92% and 6.82% to 10.05%, respectively. All sampled soils contained more than 5% free lime, classifying them as calcareous. All sites exhibited a steady increase in free lime content with soil depth. Overall, soils in declining orchards had higher free lime content compared to those in healthy orchards, a trend also reported in previous research [12].

3.3 Available nitrogen, phosphorus potassium and sulphur

The available nitrogen content in soils of healthy and declined Nagpur mandarin gardens ranged from 253.2 to 300.9 kg ha^{-1} and 141 to 177.8 kg ha^{-1}, respectively. Based on standard classification, all soils were categorized as medium, low to very low in available nitrogen. However, higher nitrogen levels were observed in soils of healthy gardens compared to those of declining ones. Similar findings have been reported previously [8]. Additionally, available nitrogen consistently decreased with increasing soil depth across both orchard types, which aligns well with earlier studies.

In the case of available phosphorus, surface soils of healthy and declined gardens recorded values ranging between 30.80 to 38.20 kg ha^{-1} and 13.18 to 14.84 kg ha^{-1}, respectively. According to standard ratings, soils from healthy gardens were classified as low to medium in phosphorus content, while those from declined gardens were rated as low. The comparatively higher phosphorus levels in healthy garden soils could be attributed to regular incorporation of organic manures, which enhance phosphorus availability. Similar observations have been previously documented [8]. A consistent decline in phosphorus content with increasing soil depth was noted (refer to Table 1).

Available potassium levels in the surface soils of healthy and declined gardens ranged from 343.2 to 491.2 kg ha^{-1} and 120.69 to 191.65 kg ha^{-1}, respectively. As per the standard classification, all garden soils were rated as high to very high in available potassium content. Comparable results for black soils have also been reported earlier [8]. However, the data did not reveal a uniform pattern of potassium variation with soil depth.

The results indicated that available sulphur in the surface soils ranged from 11.00 to 14.67 mg kg^{-1} in healthy orchards soil. No consistent trend was observed in the distribution of available sulphur with increasing soil depth, as the values did not show a uniform increase or decrease throughout the soil profile and in declining condition it is in the range of 8.24 to 9.64 mg kg^{-1}**.** Based on standard classification, these values place the soils in the marginal in healthy orchards and low in declining orchards category for available sulphur.

3.4 Available micronutrients

Data on micronutrient status of healthy and declining Nagpur mandarin orchards soils are presented in Table 3.

The analysis of surface soil layers revealed that healthy orange orchards exhibited higher concentrations of available iron compared to declining ones, with values ranging from 7.10 to 7.98 mg kg^{-1}in healthy soils and 3.14 to 4.51 mg kg^{-1} in declining orchards. Available manganese content ranged

from 13.06 to 17.36 mg kg^{-1} in healthy orchards, whereas it varied between 8.11 to 10.34 mg kg^{-1} in declining orchards. The manganese levels were consistently higher in healthy soils, supporting the findings of previous researchers. Available zinc levels in surface soils ranged between 0.54 to 0.70 mg kg^{-1} in healthy orchards and 0.39 to 0.61 mg kg^{-1}in declining orchards. Overall, the declining orchards showed lower available zinc content, a trend consistent with earlier reports [11]. Given that critical limit for zinc is 1.0 ppm, all declining orchard soils demonstrated a deficiency in available zinc. The analysis of surface soil layers revealed that healthy orange orchards exhibited higher concentrations of DTPA-extractable copper compared to declining ones, with values ranging from 2.63 to 3.16 mg kg^{-1} in healthy soils and 2.12 to 2.80 mg kg^{-1} in declining orchards. These findings align with those previously reported by [11]. Notably, the copper content in both healthy and declining orchards exceeded the critical level of 0.2 ppm, as established by [5], consisting with earlier studies [9].

Table 1: Soil physico-chemical properties of healthy Nagpur mandarin orchard

Sr. No	Depth (cm)	HC (cm hr^{-1})	Bulk density (g cm^{-3})	MWD (mm)	pH	EC (dS m^{-1})	Organic Carbon (g kg^{-1})	$CaCO_3$ (%)	Available macronutrients (kg ha^{-1}), N, P_2O_5, K_2O			Available Sulphur (mg kg^{-1})
Location 1 (Yerla)												
1	0-20	0.71	1.33	0.99	7.41	0.27	6.00	4.37	260.6	24.30	393.0	11.00
	20-40	0.68	1.34	0.97	7.72	0.26	4.70	5.31	220.1	19.00	294.6	10.30
Location 2 (Yerla)												
2	0-20	0.78	1.30	0.96	7.42	0.28	6.01	4.39	264.1	25.01	412.3	11.30
	20-40	0.70	1.35	0.95	7.82	0.26	5.81	5.30	224.5	15.20	399.3	11.11
Location 3 (Pala)												
3	0-20	0.75	1.36	0.88	7.74	0.27	5.81	5.76	233.2	21.40	343.2	11.21
	20-40	0.69	1.38	0.87	8.02	0.25	4.65	6.01	220.7	15.50	284.8	10.12
Location 4 (Pala)												
4	0-20	0.84	1.37	0.98	7.81	0.28	5.54	5.72	244.1	20.80	392.0	11.41
	20-40	0.78	1.39	0.97	7.90	0.27	4.31	6.00	224.5	14.90	274.7	10.90
Location 5 (Raipur)												
5	0-20	0.77	1.36	0.90	7.45	0.26	5.62	4.82	248.3	27.40	460.0	11.34
	20-40	0.71	1.39	0.89	7.72	0.24	4.21	6.21	215.7	20.60	390.2	11.27
Location 6 (Raipur)												
6	0-20	0.90	1.34	0.94	7.49	0.27	5.01	4.62	255.1	23.60	491.2	11.32
	20-40	0.83	1.36	0.91	8.01	0.25	4.30	5.71	226.6	22.80	458.3	10.98
Location 7 (Durgwada)												
7	0-20	0.86	1.35	0.97	7.85	0.28	6.01	4.87	266.0	24.40	392.0	12.97
	20-40	0.72	1.41	0.95	7.95	0.26	4.90	6.16	249.1	19.50	298.2	11.99
Location 8 (Durgwada)												
8	0-20	0.82	1.39	0.92	7.80	0.29	5.05	5.91	251.6	25.03	395.2	12.34
	20-40	0.70	1.40	0.88	8.02	0.28	4.56	6.01	247.2	18.20	294.9	11.01
Location 9 (Khanapur)												
9	0-20	0.76	1.32	0.89	7.61	0.29	5.65	4.92	278.1	28.20	445.3	14.51
	20-40	0.69	1.41	0.86	7.73	0.24	4.45	5.09	259.2	19.02	421.8	13.34
Location 10 (Khanapur)												
10	0-20	0.80	1.38	0.87	7.75	0.30	5.48	4.52	261.6	24.82	424.0	14.67
	20-40	0.71	1.39	0.85	7.81	0.28	4.88	5.01	259.3	20.90	405.2	13.57
Mean		0.76	1.37	0.92	7.75	0.27	5.15	5.34	245.5	21.53	383.5	11.83

Table 2: Soil physico-chemical properties of declining Nagpur mandarin orchard

Sr. No	Depth (cm)	HC (cm hr^{-1})	Bulk density (g cm^{-3})	MWD (mm)	pH	EC (dS m^{-1})	Organic Carbon (g kg^{-1})	$CaCO_3$ (%)	Available Nutrients (kg ha^{-1}), N, P_2O_5, K_2O			Available Sulphur (mg kg^{-1})
Location 1 (Udkhed)												
1	0-20	0.63	1.43	0.89	7.91	0.37	5.11	6.82	206.8	22.2	320.0	10.5
	20-40	0.57	1.44	0.86	8.01	0.36	4.94	7.73	186.6	17.0	212.8	9.42
Location 2 (Udkhed)												
2	0-20	0.66	1.40	0.87	7.87	0.38	5.12	6.85	208.8	19.8	368.2	10.4
	20-40	0.62	1.41	0.86	8.00	0.36	4.96	7.75	180.6	16.1	380.8	9.34
Location 3 (Yerla)												
3	0-20	0.64	1.42	0.95	7.84	0.36	4.92	6.21	177.8	20.2	354.0	9.70
	20-40	0.60	1.44	0.92	8.03	0.35	4.82	7.32	152.4	19.1	313.7	9.67
Location 4 (Yerla)												
4	0-20	0.72	1.38	0.87	7.91	0.37	4.93	7.16	198.5	23.6	420.1	10.8
	20-40	0.66	1.40	0.85	8.00	0.35	4.84	8.28	182.6	20.5	314.8	8.90
Location 5 (Pala)												
5	0-20	0.66	1.39	0.81	7.55	0.30	4.11	7.15	169.5	23.2	313.3	11.50
	20-40	0.62	1.40	0.78	7.82	0.25	3.91	9.12	161.6	19.6	299.3	10.61
Location 6 (Pala)												
6	0-20	0.81	1.34	0.82	7.59	0.29	4.12	7.18	205.1	22.1	291.6	11.40

	20-40	0.71	1.36	0.79	8.02	0.26	3.97	9.14	196.0	18.1	270.3	8.19
Location 7 (Pardi)												
7	0-20	0.75	1.38	0.84	7.71	0.38	4.51	8.31	210.4	20.8	269.3	10.1
	20-40	0.61	1.40	0.81	7.83	0.36	4.41	9.12	199.6	18.1	245.6	9.95
Location 8 (Pardi)												
8	0-20	0.71	1.39	0.82	7.86	0.36	4.42	8.41	209.1	19.5	264.1	11.0
	20-40	0.63	1.40	0.78	7.96	0.34	4.31	9.14	198.1	17.5	245.2	10.0
Location 9 (Raipur)												
9	0-20	0.65	1.43	0.79	7.71	0.39	4.22	7.05	196.3	19.2	263.2	10.41
	20-40	0.60	1.44	0.74	7.83	0.38	4.14	8.03	185.5	16.9	242.3	9.98
Location 10 (Raipur)												
10	0-20	0.72	1.39	0.77	7.76	0.39	4.24	9.41	201.1	20.7	372.2	10.08
	20-40	0.64	1.42	0.73	7.91	0.36	4.15	9.99	197.1	18.9	299.6	9.05
Mean		0.66	1.40	0.83	7.89	0.35	4.51	8.01	191.2	19.66	303.0	10.0

Table 3: Micronutrients status of healthy and declining Nagpur mandarin orchard soils

Location	Depth (cm)	Fe	Mn	Zn	Cu
		mg kg^{-1}			
Healthy Nagpur mandarin orchards					
1) Yerla	0-20	7.58	12.33	0.61	2.64
	20-40	6.53	10.34	0.44	2.22
2) Yerla	0-20	7.63	12.12	0.65	3.16
	20-40	6.51	11.72	0.43	2.28
3) Pala	0-20	7.54	13.12	0.64	3.15
	20-40	6.51	11.01	0.43	2.28
4) Pala	0-20	7.71	11.06	0.61	2.91
	20-40	6.86	9.86	0.54	2.66
5) Raipur	0-20	7.10	15.06	0.54	2.65
	20-40	6.64	10.28	0.53	2.01
6) Raipur	0-20	7.21	12.01	0.58	2.63
	20-40	6.67	10.04	0.55	2.12
7) Durgwada	0-20	7.98	11.14	0.66	2.67
	20-40	6.62	11.21	0.42	2.51
8) Durgwada	0-20	7.79	11.21	0.70	2.64
	20-40	6.86	10.01	0.56	2.57
9) Khanapur	0-20	7.23	17.09	0.64	2.75
	20-40	6.67	15.02	0.51	2.59
10)Khanapur	0-20	7.15	13.04	0.65	2.76
	20-40	6.78	12.01	0.52	2.51
Mean		7.08	11.98	0.56	2.59
Declining Nagpur mandarin orchards					
1) Udkhed	0-20	5.58	10.07	0.46	2.12
	20-40	4.53	8.98	0.37	1.69
2) Udkhed	0-20	6.63	9.36	0.40	2.28
	20-40	5.54	8.05	0.32	1.50
3) Yerla	0-20	5.54	11.01	0.53	2.80
	20-40	4.99	10.03	0.43	2.11
4) Yerla	0-20	6.10	10.06	0.52	2.72
	20-40	5.54	9.06	0.35	2.11
5) Pala	0-20	6.21	12.07	0.43	2.21
	20-40	5.67	9.09	0.40	2.04
6) Pala	0-20	6.98	10.56	0.47	2.41
	20-40	5.62	10.01	0.37	2.04
7) Pardi	0-20	6.23	11.04	0.52	2.45
	20-40	5.67	10.92	0.43	2.39
8) Pardi	0-20	6.15	10.98	0.49	2.43
	20-40	5.78	10.04	0.44	2.35
9) Raipur	0-20	6.11	11.09	0.61	2.17
	20-40	5.78	10.78	0.50	1.94
10) Raipur	0-20	5.96	10.78	0.60	2.19
	20-40	4.78	10.01	0.50	1.97
Mean		5.57	10.20	0.46	2.20

4. Conclusion

On the basis of result generated during the present investigation following conclusion can be drawn.

The comparative assessment of soil properties in healthy and declining Nagpur mandarin orchards of Morshi tehsil, Amravati district, clearly revealed significant differences between the two orchard conditions. Healthy orchards exhibited better soil physical properties such as lower bulk density, higher hydraulic conductivity, and greater mean weight diameter, indicating improved soil structure, porosity, and water movement. In contrast, declining orchards showed compacted soils with poor aggregate stability and reduced water permeability.

Chemical analysis showed that healthy orchard soils had higher organic carbon, calacareous nature of soil, adequate levels of available nitrogen, phosphorus, potassium, and sulphur. Micronutrient availability (Fe, Mn, Zn, Cu) was also found to be more favorable in healthy soils as compare to declining one.

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