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Assessment of soil fertility status in vegetable-growing areas of Patehara Block, Mirzapur District, Eastern Uttar Pradesh

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Abstract

Assessment of soil fertility status is essential for formulating site-specific nutrient management recommendations and sustaining crop productivity. The present study was undertaken to evaluate the physicochemical properties and available macro- and micronutrient status of vegetable-growing soils of Patehara block, Mirzapur district, Uttar Pradesh. A total of 60 surface soil samples (0–15 cm) were collected from vegetable-growing fields of different villages of Patehara block and analysed using standard analytical procedures. The soils ranged from slightly acidic to moderately alkaline (pH 5.6–8.1) with electrical conductivity varying from 0.22 to 0.95 dS m⁻¹. Organic carbon content ranged from 0.25 to 0.72%, of which 71.7% of the samples were low in organic carbon. Available nitrogen, phosphorus and potassium varied from 125.52–363.78, 10.52–21.21 and 96.62–302.21 kg ha⁻¹, with mean values of 227.65, 17.32 and 198.95 kg ha⁻¹, respectively. Based on nutrient index values, available nitrogen was rated low, whereas available phosphorus and potassium were in the medium fertility category. DTPA-extractable Fe, Cu, Zn and Mn ranged from 11.15–79.21, 0.12–4.05, 0.11–5.99 and 0.09–85.99 mg kg⁻¹, with mean values of 49.16, 1.48, 1.13 and 32.53 mg kg⁻¹, respectively. Iron, copper and manganese were generally sufficient, whereas zinc deficiency was observed in 23.3% of the samples. Correlation analysis revealed significant positive relationships among organic carbon, electrical conductivity, while available nitrogen showed positive association with organic carbon. The study indicates that improvement of soil organic matter, balanced nitrogen fertilization and site-specific zinc application are required to sustain soil fertility and vegetable productivity in the Patehara block.

Keywords: Soil fertility, site-specific nutrient management, macro & micronutrients, correlation

Introduction

Soil fertility is governed by the availability and balanced supply of essential macro- and micronutrients, which directly influence crop growth, productivity and soil health. Continuous intensive cultivation, imbalanced fertilizer use and inadequate recycling of organic residues have resulted in depletion of soil organic carbon and emergence of multiple nutrient deficiencies in many agricultural soils of India (Ladha *et al.* 2003; Pathak 2010, Sharma *et al.* 2021) [7, 13, 17]. Therefore, assessment of soil fertility is essential for understanding nutrient constraints and developing soil test-based nutrient management strategies for sustainable crop production (Behera *et al.* 2023) [1].

Vegetable crops are highly nutrient exhaustive because of their intensive cultivation and higher nutrient demand. Continuous cultivation of vegetables with indiscriminate use of high-analysis fertilizers and limited application of organic manures often leads to nutrient imbalance, decline in soil fertility and reduced fertilizer use efficiency (Srinivasarao *et al.* 2010; Doneriya *et al.* 2013, Gurjar *et al.* 2017) [22, 4, 5].

Previous studies have indicated considerable spatial variation in soil fertility across Mirzapur district. Singh *et al.* (2015) [20] reported widespread deficiencies of sulphur and boron in the soils of eastern Uttar Pradesh, including Mirzapur district. Soil fertility assessment in Majhwa block showed medium fertility status for available nitrogen, phosphorus and potassium, with low

sulphur availability (Singh *et al.* 2017) ^[21]. Similarly, Pandey *et al.* (2020) ^[11] reported low available nitrogen, sulphur and boron and medium phosphorus and potassium status in the alluvial soils of Chunar area of Mirzapur district. These studies clearly indicate that nutrient availability varies across locations depending upon soil characteristics, cropping systems and nutrient management practices.

Patehara block is an important vegetable-growing area of Mirzapur district where crops such as potato, brinjal, cauliflower, garlic, lady finger and bottle gourd are cultivated intensively. Continuous vegetable cultivation with frequent use of chemical fertilizers and inadequate application of organic and secondary nutrient sources may lead to nutrient imbalance and deterioration of soil fertility. Although soil fertility studies have been conducted in different parts of Mirzapur district, the fertility status of vegetable-growing soils of Patehara block has not been evaluated. Therefore, the present investigation was undertaken to assess the physicochemical properties and available macro- and micronutrient status of these soils to facilitate soil test-based fertilizer recommendations and appropriate nutrient management for sustainable vegetable production.

Materials and Methods

Study area

The study was conducted in Patehara block of Mirzapur district, Uttar Pradesh, located at 25°15' N latitude and 82°58' E longitude. The block falls under Agro-climatic Zone IV of Uttar Pradesh and experiences a semi-arid to sub-humid climate with an average annual rainfall of about 1043 mm, most of which is received during the southwest monsoon. The soils are developed from Gangetic alluvium and are extensively cultivated under irrigated vegetable-based cropping systems. Potato, brinjal, cauliflower, garlic, lady finger, bottle gourd and other seasonal vegetables are the major crops grown in the study area.

Collection and processing of soil samples

Surface soil samples (0–15 cm) were collected from vegetable-growing fields of the major vegetable-producing villages of Patehara block, namely Adhiya, Haraura, Fuliya, Atari, Kotwa Pandey, Gohiya Kalan, Kalwari Mafi and Kotwa Ghasiram. Composite soil samples were collected following the standard zig-zag sampling procedure using a khurpi. The samples were air-dried under shade, gently crushed with a wooden pestle, passed through a 2-mm sieve and stored in labelled polyethylene bags for laboratory analysis.

Soil analysis

The collected soil samples were analysed for physicochemical properties and available macro- and micronutrients following standard analytical procedures. Soil pH and electrical conductivity (EC) were determined in a 1:2 soil-water suspension (Jackson 1973) ^[6]. Organic carbon was estimated by the Walkley and Black (1934) ^[24] wet oxidation method. Available nitrogen was determined by the alkaline KMnO₄ method (Subbiah and Asija 1956) ^[23], available phosphorus by Olsen's sodium bicarbonate extraction method (Olsen *et al.*

1954) ^[9], and available potassium by neutral ammonium acetate extraction followed by flame photometry (Hanway and Heidal 1952), whereas DTPA-extractable Fe, Cu, Zn and Mn were determined using the method of Lindsay and Norvell (1978) ^[8]. Bulk density and particle density were determined by the pycnometer method (Black *et al.* 1965) ^[2].

Nutrient index

The nutrient index (NI) was calculated according to Parker *et al.* (1951) ^[12] using the expression:

$$NI = (L \times 1 + M \times 2 + H \times 3) / \text{Total number of samples}$$

where L, M and H denote the number of soil samples falling under low, medium and high fertility categories, respectively. Based on the nutrient index values, soils were classified as low (<1.67), medium (1.67–2.33) and high (>2.33) fertility status.

Statistical analysis

Descriptive statistics were computed for all soil properties. Pearson's correlation coefficients were worked out to determine the relationships among physicochemical properties and available nutrient contents of the soils.

Results and Discussion

Physico-chemical properties

The physicochemical properties of the vegetable-growing soils of Patehara block are presented in Table 1. Bulk density and particle density varied from 1.16 to 1.39 Mg m⁻³ and 2.21 to 2.69 Mg m⁻³, with mean values of 1.30 and 2.57 Mg m⁻³, respectively. Water holding capacity ranged from 22.02 to 34.09%, while soil porosity varied between 39.81 and 58.10%. The physical properties indicate that the soils possess favourable conditions for root growth and moisture retention under vegetable cultivation.

The soil reaction varied from slightly acidic to moderately alkaline, with pH ranging from 5.6 to 8.1 (mean 7.32). Such variation is expected in alluvial soils owing to differences in parent material, cropping history and management practices. Similar variability in soil reaction has also been reported for the alluvial soils of Mirzapur district (Pandey *et al.* 2020) ^[11].

Electrical conductivity ranged between 0.22 and 0.95 dS m⁻¹, with an average value of 0.57 dS m⁻¹. The EC values were well below the critical limit of 4.0 dS m⁻¹, indicating that salinity is not a constraint in the vegetable-growing soils of the study area.

Organic carbon content ranged from 0.25 to 0.72%, with a mean value of 0.44% (Table 1). Based on the fertility ratings, 71.7% of the soil samples were low and 28.3% were medium in organic carbon content (Table 3). The nutrient index value of 1.28 indicated low organic carbon status. Similar organic carbon levels have been reported for the alluvial soils of Mirzapur district (Singh *et al.* 2017; Pandey *et al.* 2020) ^[21, 11]. The low organic carbon status may be attributed to continuous intensive cultivation, rapid decomposition of organic matter under the prevailing climatic conditions and inadequate addition of organic manures.

Table 1: Physicochemical properties of soils of vegetable-growing villages of Patehara block, Mirzapur

Village	No. of Samples	BD (Mg m ⁻³)	PD (Mg m ⁻³)	WHC (%)	Porosity (%)	pH	EC (dS m ⁻¹)	OC (%)
Adhiya	12	1.31	2.58	47.5	49.4	6.2-8.1 (7.11)	0.22-0.95 (0.55)	0.28-0.47 (0.38)
Haraura	8	1.30	2.57	46.1	50.2	5.6-7.9 (7.40)	0.45-0.95 (0.63)	0.25-0.72 (0.46)
Fuliyari	5	1.28	2.57	45.2	48.5	6.2-7.8 (7.38)	0.38-0.82 (0.58)	0.45-0.63 (0.53)
Atari	5	1.31	2.55	48.0	51.5	7.3-7.9 (7.66)	0.35-0.65 (0.49)	0.33-0.61 (0.49)
Kotwa Pandey	5	1.29	2.55	46.7	52.9	7.2-7.7 (7.38)	0.36-0.82 (0.55)	0.29-0.49 (0.42)
Gohiya Kalan	6	1.28	2.57	47.9	50.9	5.9-7.9 (7.30)	0.22-0.84 (0.50)	0.32-0.59 (0.47)
Kalwari Mafi	7	1.32	2.60	44.5	51.5	7.1-7.9 (7.47)	0.22-0.72 (0.48)	0.29-0.65 (0.44)
Kotwa Ghasiram	12	1.30	2.57	48.7	53.7	6.0-8.1 (7.22)	0.39-0.84 (0.54)	0.35-0.72 (0.46)
Range		1.16-1.39	2.21-2.69	22.02-34.09*	39.81-58.10*	5.6-8.1	0.22-0.95	0.25-0.72
Mean	60	1.30	2.57	28.19*	49.08	7.32	0.57	0.44
SD		0.04	0.13	3.70*	5.22*	0.56	0.19	0.11
CV (%)		2.89*	5.22*	13.14	10.64	7.62	35.18	24.69

Available macronutrients

The range and mean values of available macronutrients in the soils of Patehara block are presented in Table 2. Available nitrogen content varied from 125.52 to 363.78 kg ha⁻¹, with an average of 227.65 kg ha⁻¹. The highest mean available N was recorded in Gohiya Kalan (303.1 kg ha⁻¹), whereas the lowest was observed in Kalwari Mafi (176.9 kg ha⁻¹). Based on the fertility ratings, 83.3% of the soil samples were low and 16.7% were medium in available nitrogen, resulting in a nutrient index value of 1.17 (Table 3). The low nitrogen status may be attributed to low organic carbon content and continuous removal of nitrogen under intensive vegetable cultivation. Similar observations were reported by Singh *et al.* (2017) [21] for soils of Mirzapur district.

Available phosphorus ranged from 10.52 to 21.21 kg ha⁻¹, with a mean value of 17.32 kg ha⁻¹. Among the villages, Gohiya Kalan recorded the highest mean available P (18.29 kg ha⁻¹), while Kotwa Pandey had the lowest (14.88 kg ha⁻¹). All the soil samples were classified under the medium fertility category, with a nutrient index value of 2.00 (Table 3). The medium phosphorus status of the soils may be due to regular application of phosphatic fertilizers in vegetable-based cropping systems.

Available potassium content varied between 96.62 and 302.21 kg ha⁻¹ and averaged 198.95 kg ha⁻¹. The highest mean available K was recorded in Haraura (237.0 kg ha⁻¹), whereas the lowest was observed in Atari (163.1 kg ha⁻¹). Overall, 81.7% of the soil samples were medium and 18.3% were low in available potassium, with a nutrient index value of 1.82, indicating medium fertility status (Table 3). The medium availability of potassium could be attributed to the presence of K-bearing minerals in the alluvial parent material, which contribute to the replenishment of exchangeable potassium.

DTPA-extractable micronutrients

The range and mean values of DTPA-extractable micronutrients in the soils of Patehara block are presented in Table 4. The DTPA-extractable Fe content ranged from 11.15 to 79.21 mg kg⁻¹ with a mean value of 49.16 mg kg⁻¹. Among the villages, the highest mean Fe content was recorded in Fuliyari (62.42 mg kg⁻¹), whereas the lowest was observed in Kalwari Mafi (28.18 mg kg⁻¹). The available Cu content varied from 0.12 to 4.05 mg kg⁻¹ with an overall mean of 1.48 mg kg⁻¹, the lowest mean being recorded in Haraura (0.90 mg kg⁻¹) and the highest in Kotwa Ghasiram (2.34 mg kg⁻¹). Similarly, available Mn ranged from 0.09 to 85.99 mg kg⁻¹ with a mean value of 32.53 mg kg⁻¹, varying from 25.51 mg kg⁻¹ in Adhiya to 45.87 mg kg⁻¹ in Kalwari Mafi.

Based on the critical limits of Lindsay and Norvell (1978) [8], all the soil samples contained sufficient Fe, while Cu deficiency was observed only in a few samples. Likewise, Mn was adequate in most of the soils. In contrast, available Zn showed comparatively greater variation, ranging from 0.11 to 5.99 mg kg⁻¹ with a mean value of 1.13 mg kg⁻¹. The lowest mean Zn content was observed in Haraura (0.53 mg kg⁻¹), whereas Adhiya recorded the highest (1.48 mg kg⁻¹). About 23.3% of the soil samples were deficient in Zn, while the remaining samples contained adequate levels.

The adequate availability of Fe, Cu and Mn may be attributed to the alluvial parent material and the presence of Fe- and Mn-bearing minerals in the soils. The occurrence of Zn deficiency, however, could be associated with continuous removal of Zn by intensive vegetable cultivation and inadequate replenishment through organic and inorganic sources. Similar trends in the availability of cationic micronutrients have been reported for the alluvial soils of Mirzapur by Singh *et al.* (2015) [20], Singh *et al.* (2017) [21], Kashiwar *et al.* (2018) and Pandey *et al.* (2020) [11].

Table 2: Available macronutrients (N, P and K) in soils of vegetable-growing villages of Patehara block, Mirzapur

Village	No. of Samples	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
		Range (Mean)	Range (Mean)	Range (Mean)
Adhiya	12	194.51-250.97 (224.1)	14.67-19.46 (17.59)	182.56-250.51 (225.9)
Haraura	8	125.52-250.82 (183.8)	15.45-18.54 (17.35)	140.06-296.92 (237.0)
Fuliyari	5	161.21-241.51 (218.9)	16.89-19.02 (18.04)	112.02-302.21 (214.2)
Atari	5	245.23-322.78 (277.3)	14.72-21.21 (17.85)	96.62-242.51 (163.1)
Kotwa Pandey	5	137.98-340.96 (289.1)	10.52-19.18 (14.88)	101.21-219.02 (179.8)
Gohiya Kalan	6	200.21-363.78 (303.1)	15.51-19.29 (18.29)	111.61-232.24 (169.1)
Kalwari Mafi	7	125.52-250.09 (176.9)	13.59-19.89 (16.46)	105.21-261.55 (176.4)
Kotwa Ghasiram	12	140.21-250.09 (209.7)	14.21-19.58 (17.59)	120.02-232.51 (191.3)
Overall Range	60	125.52-363.78	10.52-21.21	96.62-302.21
Mean		227.65	17.32	198.95
SD		58.63	2.04	51.90
CV (%)		25.75	11.82	26.08

Table 3: Fertility classification and nutrient index for organic carbon and available macronutrients in soils of Patehara block

Nutrient	Category	Limit	No. of samples	% samples	Nutrient Index	Status
Organic Carbon	Low	<0.5%	43	71.7	1.28	Low
	Medium	0.5-0.75%	17	28.3		
	High	>0.75%	0	0.0		
Available N	Low	<280 kg ha ⁻¹	50	83.3	1.17	Low
	Medium	280-560	10	16.7		
	High	>560	0	0.0		
Available P	Low	<10 kg ha ⁻¹	0	0.0	2.00	Medium
	Medium	10-25	60	100.0		
	High	>25	0	0.0		
Available K	Low	<135 kg ha ⁻¹	11	18.3	1.82	Medium
	Medium	135-335	49	81.7		
	High	>335	0	0.0		

Table 4: DTPA-extractable micronutrients in soils of vegetable-growing villages of Patehara block, Mirzapur

Village	No. of Samples	Available Fe (mg kg ⁻¹)	Available Cu (mg kg ⁻¹)	Available Zn (mg kg ⁻¹)	Available Mn (mg kg ⁻¹)
Adhiya	12	39.05-77.90 (59.74)	0.18-2.92 (1.34)	0.11-5.99 (1.48)	12.95-38.31 (25.51)
Haraura	8	23.06-79.02 (44.79)	0.12-2.01 (0.90)	0.32-0.92 (0.53)	24.02-46.28 (36.10)
Fuliyari	5	51.02-76.50 (62.42)	0.31-3.22 (1.95)	0.63-1.62 (1.32)	12.21-34.15 (25.57)
Atari	5	21.54-65.15 (39.75)	0.32-1.30 (0.89)	1.21-1.62 (1.46)	27.19-41.25 (36.62)
Kotwa Pandey	5	35.21-79.21 (53.67)	0.56-2.02 (1.05)	0.58-1.51 (1.13)	10.15-39.16 (25.74)
Gohiya Kalan	6	14.09-65.25 (35.97)	1.05-2.67 (1.80)	0.25-0.93 (0.60)	0.09-85.24 (29.17)
Kalwari Mafi	7	11.15-48.02 (28.18)	0.22-2.32 (1.13)	0.23-1.51 (1.24)	0.35-67.21 (45.87)
Kotwa Ghasiram	12	31.47-76.32 (57.06)	1.06-4.05 (2.34)	0.58-1.64 (1.22)	0.19-85.99 (35.11)
Overall Range	60	11.15-79.21	0.12-4.05	0.11-5.99	0.09-85.99
Mean		49.16	1.48	1.13	32.53
SD		17.85	0.97	0.78	21.63
CV (%)		36.31	65.30	69.46	66.51
Critical Limit*		>4.5	>0.2	>0.6	>2.0

*Critical limits as per Lindsay and Norvell (1978) [8]

Correlation among soil properties**Correlation among soil properties and available nutrients**

The simple correlation coefficients among different soil properties and available nutrients are presented in Table 5. Soil pH showed significant positive correlations with bulk density ($r = 0.510^{**}$), particle density ($r = 0.602^{**}$), porosity ($r = 0.584^{**}$), water holding capacity ($r = 0.563^{**}$), available nitrogen ($r = 0.346^{**}$), available phosphorus ($r = 0.545^{**}$) and available potassium ($r = 0.253^{*}$). Electrical conductivity exhibited an almost perfect positive correlation with organic carbon ($r = 0.998^{**}$) and was also highly and positively correlated with bulk density, particle density, Cu and Zn. Organic carbon followed a similar trend and showed highly significant positive correlations with Cu ($r = 0.992^{**}$) and Zn ($r = 0.993^{**}$).

Among the macronutrients, available nitrogen showed significant positive relationships with phosphorus ($r = 0.347^{**}$), potassium ($r = 0.350^{**}$), and Fe ($r = 0.337^{**}$). Available phosphorus was positively correlated with potassium ($r = 0.332^{**}$) and Fe ($r = 0.342^{**}$), whereas potassium exhibited a significant positive association with Fe ($r = 0.405^{**}$). Iron showed significant positive correlations with available N, P and K, while Mn exhibited only weak relationships with most of the soil properties.

The close relationship between EC and organic carbon may reflect the contribution of soluble ions released during decomposition of organic matter. Similar relationships among soil properties and nutrient availability have also been reported in alluvial soils of eastern Uttar Pradesh (Singh *et al.* 2017; Pandey *et al.* 2020) [21, 11].

Table 5: Correlation coefficient among soil parameters in vegetable-growing soils of Patehara block (n = 60)

	pH	EC	OC	BD	PD	Por	WHC	N	P	K	Fe	Cu	Zn	Mn
pH	1													
EC	0.07	1												
OC	0.07	.998**	1											
BD	.510**	.775**	.776**	1										
PD	.602**	.710**	.708**	.884**	1									
Por	.584**	-.607**	-.610**	-0.11	0.11	1								
WHC	.563**	-.346**	-.340**	0.08	0.17	.672**	1							
N	.346**	-.347**	-.348**	-0.03	-0.02	.470**	.403**	1						
P	.545**	-0.19	-0.19	.263*	.316**	.633**	.586**	.347**	1					
K	.253*	-.335**	-.335**	0.00	-0.00	.447**	.396**	.350**	.332**	1				
Fe	0.22	-0.06	-0.07	0.17	0.16	.287*	0.01	.337**	.342**	.405**	1			
Cu	0.07	.992**	.992**	.773**	.710**	-.594**	-.327**	-.332**	-0.18	-.327**	-0.05	1		
Zn	0.07	.992**	.993**	.772**	.712**	-.595**	-.319**	-.333**	-0.19	-.312*	-0.04	.987**	1	
Mn	0.07	0.19	0.19	.273*	.262*	0.02	0.06	-0.05	0.16	0.09	0.04	0.21	0.22	1

** Correlation significant at 0.01 level; * Correlation significant at 0.05 level

Conclusion

The vegetable-growing soils of Patehara block were generally neutral to slightly alkaline in reaction, non-saline, and low to medium in organic carbon. Available nitrogen, exchangeable calcium and magnesium were predominantly low, whereas available phosphorus and potassium were mostly in the medium fertility category. Among the micronutrients, Fe, Cu and Mn were present in adequate amounts, while Zn deficiency was observed in a considerable proportion of the soils. Significant correlations between soil properties and nutrient availability indicated the influence of soil characteristics on nutrient dynamics.

Overall, the study highlights the need for balanced and soil test-based nutrient management in the vegetable-growing soils of Patehara block. Integrated use of organic manures with balanced fertilization, along with zinc application in deficient soils, would help improve soil fertility, sustain vegetable productivity and support appropriate nutrient and crop management practices in the region.

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