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Assessment of Soil Fertility Status of Panipat District of Haryana

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Abstract
A soil survey was conducted in the Panipat district to assess the soil fertility status of the district. The interpretation of data generated by lab analysis of soil samples revealed that the soils of all blocks were majorly alkaline in reaction but few sample were slightly acidic (6.0-9.4). The electrical conductivity of the Bapoli, Samalkha, Panipat, Madlauda, and Israna blocks ranged from 0.09-0.66, 0.21-1.5,0.21-0.51,0.19-1.93 and 0.12-1.95 dSm-1. The respective mean values of EC were 0.38, 0.49, 0.35, 0.61, and 0.69 dSm-1. The soil texture ranged from sandy loam to clayey loam. The organic carbon content of the Panipat district ranged from 0.29-1.08% with a mean value of 0.58%. Approximately 74.6% of the soils were in the medium category, followed by 14.2 and 11.2 percent in the low and high categories, respectively. The nitrogen, phosphorous, potassium, and sulfur content in the soils of the Bapoli block ranged from 91-244, 4.8-71.2, 77-373 and 9-184.4 kg ha-1, with mean values of 175, 21.8, 158, and 65.6 kg ha-1, respectively. The nitrogen, phosphorous, potassium, and sulfur content in the soils of Smalkha block ranged from 113-230, 7.2-57, 67-391 and 26.9-261 kg ha-1 with mean values of 162, 24.6, 189, and 124.6 kg ha-1, respectively. The nitrogen, phosphorous, potassium, and sulfur content in the soils of Panipat block ranged from 99-216, 4.4-57.6, 80-373 and 31-215 kg ha-1 with mean values of 153, 26.2, 221, and 106 kg ha-1, respectively. The nitrogen, phosphorous, potassium, and sulfur content in the soils of Madlauda block ranged from 114-235,3.6-64.6,125-747 and 57.8-252.8 kg ha-1 with a mean value of 174, 29.9,277 and 137.5 kg ha-1, respectively. The nitrogen, phosphorous, potassium, and sulfur content in the soils of Israna block ranged from 125-236, 4.7-41.8, 126-586 and 23-530 kg ha-1 with a mean value of 110, 21.3, 255, and 161 kg ha-1, respectively. These findings provide a comprehensive baseline for targeted soil management and fertility enhancement strategies tailored to the specific conditions of each block within the district.

Keywords: Available nitrogen, available phosphorus, available potassium, available sulphur, Organic carbon

Introduction
The Panipat district is situated in the northern region of Haryana state in northwestern India, encompassing an area of 1,268 square kilometers. It is located approximately 90 kilometers north of Delhi. The district is bordered by Karnal district to the north, Sonipat district to the south, Jind district to the west, and the state of Uttar Pradesh to the east. Panipat district is part of the Indo-Gangetic plain, renowned for its fertile alluvial soil. The topography of the district is predominantly flat, with occasional undulations. The Western Yamuna Canal and its branches serve as the primary sources of irrigation in the district. The climate of Panipat district features hot summers, cold winters, and a brief monsoon. In summer (May-June), temperatures range from 35 to 45 °C, while in winter (December-January), they drop to 4 to 5 °C. The monsoon (July-September) offers relief with occasional heavy rain. Panipat is mainly agricultural, with farming as the primary occupation. Its fertile soil and irrigation make it ideal for crops like wheat, rice, sugarcane, cotton, and vegetables. Modern agricultural practices, including fertilizers and pesticides, sustain soil fertility and boost yields. Organic manures like farmyard manure and compost are also used, especially by small farmers. However, excessive chemical fertilizers and poor soil conservation have caused degradation in some areas. Soil fertility, a key factor in productivity, involves chemical and biological soil qualities (Singh and Singh, 2015) [16]. It denotes the soil's

capacity to supply nutrients for crop growth when conditions are favorable. Understanding soil fertility is crucial for recommending appropriate crop nutrients (Bationo et al., 2018) [1]. Soil fertility assessment and mapping are vital for sustainable agriculture and land management. It involves collecting data on soil properties to determine fertility and crop suitability. Soil mapping creates a detailed map of soil types, their properties, and distribution within a region. Fertility assessment involves analyzing soil samples for physical and chemical properties like pH, nutrients, texture, and organic matter. This data creates a fertility map showing soil types and nutrient levels. Fertility mapping informs land-use decisions and crop management, identifying areas with varying nutrients to adjust fertilizers and select suitable crops. It also reveals soil health issues like erosion and nutrient depletion, aiding conservation strategies like cover cropping and rotation. As land is finite, sustaining food production for a growing population will be challenging. Soil fertility is dynamic, involving nutrient cycling and ensuring water and aeration for plant growth. In dry regions, fertility is limited by water scarcity and low organic matter. Soil fertility is crucial for agriculture sustainability (Hag et al., 2021) [7]. Fertility maps provide essential spatial planning data. Creating these maps requires modeling soil properties (Hounkpatin et al., 2022) [8]. Thus, assessing fertility status yields valuable management information. This study evaluates fertility status, characterizes, classifies, and prepares a fertility map of Panipat district.

Materials and Methods

General description of study area

The research was carried out on five blocks of the Panipat district of Haryana state. Bapoli, Israna, Madlauda, Panipat, and Samalkha. The Panipat district is located between 29.2315°N and 29.5667°N latitude and 76.7220°E and 77.2996°E longitude (Fig. 1). The climate of Panipat district is semi-arid, with hot summers and cool winters. It follows a typical North Indian pattern, with extreme temperatures and limited rainfall. Summers start in April and last until June, reaching 45°C. The monsoon season from July to September brings most of the annual 534.7 mm rainfall. Winters begin in December and last until February, with temperatures dropping to 2°C and frequent dense fog.

These conditions impact cropping patterns in the district. Predominant crops include wheat, rice, sugarcane, and mustard, suitable for semi-arid climates. Wheat is mainly grown in winter, rice during the monsoon, sugarcane year-round, and mustard primarily in winter.

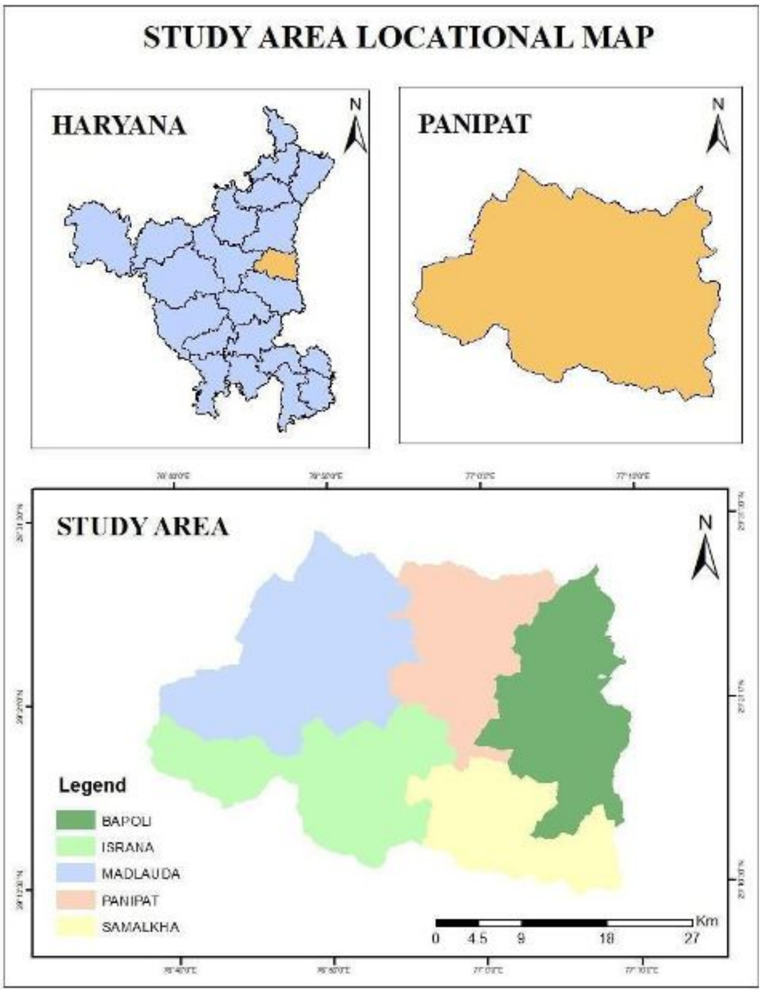


Fig 1: Study area map of Panipat district

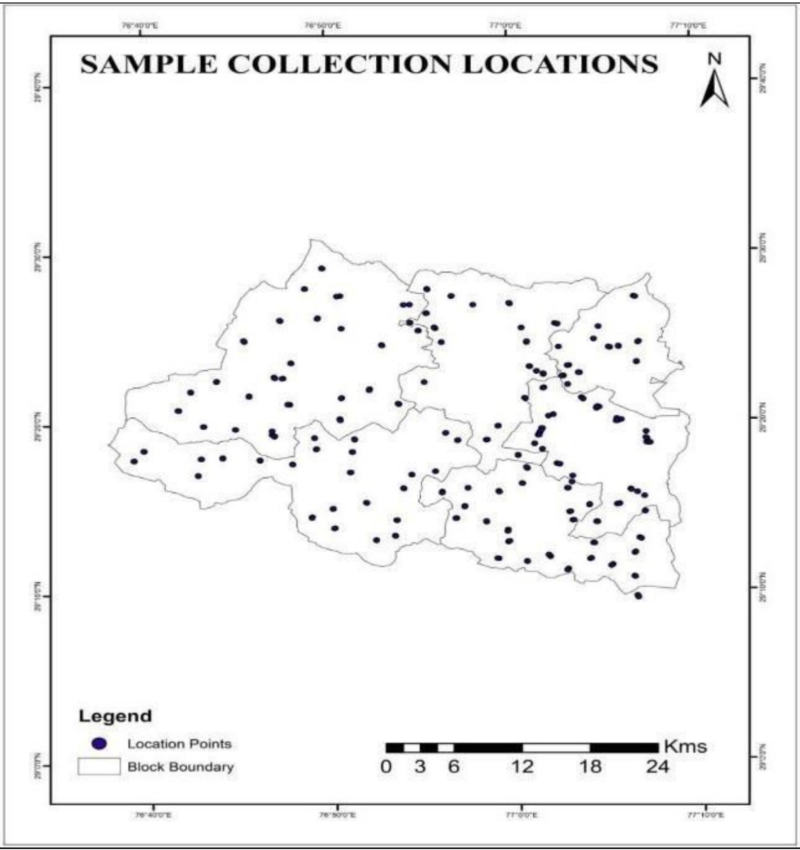


Fig 2: Soil sample location of Panipat district

Collection & preparation of soil samples

For this study, 250 soil samples (0-15 cm depth) were randomly collected from farmers' fields in five blocks of Panipat district. Soil samples were obtained using a post-hole auger. The longitude and latitude of all sampling locations were recorded using portable GPS. The locations of all sampling sites from which samples were collected are presented in fig. 2. All samples were brought to the Regional Soil Testing Laboratory, KVK, Karnal, and spread out on plastic sheets separately for air drying. After air drying, soil samples & were crushed with wooden & mortar and pestle and sieved through a 2 mm sieve. The soil samples were processed and stored in cloth or plastic bags in the laboratory with necessary labelling for further analysis.

Analysis of Soil Samples

The physicochemical parameters of the soil were investigated, including soil texture, soil pH, electrical conductivity, soil organic carbon, and available major nutrients (N, P, K, and S).

Soil texture, pH, EC & Organic carbon

Soil texture was analyzed using the feel method. Soil pH was determined by preparing a 1:2 soil: water suspension and stirring intermittently for half an hour. The pH reading was taken using a glass electrode of a digital pH meter after calibrating it with three buffer solutions of pH 4.0, 7.0, and 10.0 (Jackson, 1973) [9]. Subsequently, the suspensions were allowed to settle until a clear supernatant liquid phase was obtained. The EC was determined by dipping the electrode of the EC meter in the clear supernatant liquid (Jackson, 1973). The results were reported in dSm-1 at 25 °C.

Soil OC was determined using the wet digestion method (Walkley and Black 1934) [23]. One gram of soil sample was placed in a 500 ml conical flask and oxidized by adding 10 ml of potassium dichromate and 20 ml of sulfuric acid. The contents were swirled and kept for 30 min to complete the reaction. Thereafter, the suspension was diluted by adding 200 ml distilled water along with 0.5 g of sodium fluoride (NaF) and 1 ml of diphenylamine indicator, which gives a violet color. Thereafter, soil OC was measured by titration of excess potassium dichromate against 0.5 N ferrous ammonium sulfate.

Available Soil Nitrogen

Available soil N was determined using the alkaline potassium permanganate method (Subbiah and Asija,1956) [22]. Two grams of soil was placed in a 1 l flask, and 10 ml each of 0.32% $KMnO_4$ and 2.5% NaOH were added. The flask was heated and attached to the distillation assembly, and distilled ammonia was collected in 0.1N H_2SO_4. Finally, available soil N was determined by titration of excess sulfuric acid against 0.1N NaOH using a methyl red indicator.

Available Soil Phosphorus

Olsen's method was used to determine the available P (Olsen *et al.,* 1954) [13]. Available P in the soil was extracted using 0.5 M sodium bicarbonate ($NaHCO_3$) at pH 8.5 in the presence of Darco-G 60, shaken for approximately 30 min, and then filtered. The phosphorus in the extract was treated with ammonium molybdate solution, forming phosphomolybdate. This compound was then reduced with stannous chloride ($SnCl_2$), creating a blue complex. Finally, the available was determined by measuring the intensity of the blue color with a spectrophotometer at a wavelength of 660 nm.

Available Potassium (K)

Available K was determined by Jackson (1973) [9] approach. Five grams of soil was placed in a 250 ml conical flask, and

25 ml of 1N neutral ammonium acetate was added to it, followed by shaking for 5 min and then filtered using filter paper. Finally, the available K was measured in the extract using a flame photometer.

Available Sulphur (S)

The available sulfur in the soil was determined using the method described by Chensin and Yien (1950) [4]. Five grams of soil was shaken for 30 min in a calcium chloride solution on a mechanical shaker to extract the available sulfur in the soil. Thereafter, turbidity was produced by adding barium chloride. A blue filter was used to detect the turbidity caused by the precipitation of SO4 2- using a spectrophotometer at a wavelength of 420 nm.

Statistical Analysis

Statistical analysis, that is, Pearson Correlation between soil parameters and nutrient contents, was performed using the OPSTAT-CCSHAU, Hisar (Haryana) program (Sheoran *et al.* 1998) [15].

Results and Discussion

Surface soil samples (0-15 cm depth) were randomly collected from farmers' fields in various blocks using a Global Positioning System (GPS) to study the fertility status of the district. The results of this study entitled "Assessment of soil fertility status of Panipat district" are summarized under different headings.

Soil pH and Electrical Conductivity (EC)

The data on soil pH are presented in Table 1. The data revealed that the soil pH of blocks Bapoli, Samalkha, Panipat, Madlauda, and Israna ranged from 6.0-8.8, 7.2-8.4, 7.6-9.4, 6.7-8.6 and 6.3-9.2 with mean values of 7.9, 7.8, 8.2, 7.8, and 8.0, respectively. The status of soil pH in Panipat district is respresented through map in figure 3(a). The results show that the district's soils are neutral to alkaline. Gyawali et al. (2016) [6] and Gora (2013) [5] also found similar outcomes in their research on the soils of Haryana. The interaction of applied fertilizer material with soil colloids, which resulted in the retention of basic cations on the soil's exchangeable complex, may have caused the pH shift from neutral to alkaline. Another reason could be the presence of basic parent material, which may be the cause of alkaline soil.

The electrical conductivity of the Bapoli, Samalkha, Panipat, Madlauda, and Israna blocks ranged from 0.09-0.66, 0.21-1.5, 0.21-0.51, 0.19-1.93 and 0.12-1.95 dSm-1. The respective mean values of EC were 0.38, 0.49, 0.35, 0.61, and 0.69 dSm-1 (Table 1). The highest mean pH was observed in the Panipat block (8.2), whereas the lowest was observed in the Samalkha block (7.8). The highest individual pH was also recorded in the Panipat (9.4) block, whereas the minimum was recorded in the Bapoli (6.0) block. Similarly, the highest electrical conductivity (EC) mean was observed in the Israna block (0.69 dSm-1), whereas the minimum EC mean was observed in the Paniapt block (0.35 dSm-1). The highest and lowest EC values were recorded in Israna (1.95 dSm-1) and Bapoli (0.09 dSm-1) blocks, respectively. The status of soil EC in the Panipat district is represented by the map in figure 3 (b). None of the blocks were saline. Similar findings to the current observations were recorded in Bhimber in Azad Jammu and Kashmir by Nazif *et al.* (2006) [11].

Table 1: Soil pH and EC status of different blocks of Panipat district

Block	**Soil pH**	**EC (dSm-1)**	**Soil texture**		
Range	Mean	Range	Mean		
Bapoli	6.0-8.8	7.9	0.09-0.66	0.38	Sandy-Clay loam
Samalkha	7.2-8.4	7.8	0.21-1.5	0.49	Sandy loam-Clay loam
Panipat	7.6-9.4	8.2	0.21-0.51	0.35	Sandy loam-Clay loam
Madlauda	6.7-8.6	7.8	0.19-1.93	0.61	Sandy loam-Clay loam
Israna	6.3-9.2	8.0	0.12-1.95	0.69	Loamy sand-Clay loam

Soil texture

The data presented in Table 1 indicated that the soils of Bapoli, Smalkha, Panipat, Madlauda and Israna block varied from sandy - Clay loam, sandy loam - Clay loam, sandy loam - Clay loam, sandy loam - Clay loam and loamy sand - clay loam, respectively.

Soil Organic Carbon

The data presented in table 2 clearly reveales that the organic carbon content of Bapoli, Samalkha, Panipat, Madlauda and Israna blocks ranged from 0.29-1.08, 0.33-0.96, 0.27-0.74, 0.37-0.93 and 0.38-0.90% with a mean value ranged from 0.60, 0.56, 0.52, 0.61 and 0.60 % respectively. The highest mean value of organic carbon was observed in the Matlauda block (0.61%), whereas the minimum organic carbon was observed in the Panipat block (0.52 %). In individual samples, the maximum value of organic carbon was recorded in the Bapoli block (1.08%), whereas the minimum value was observed in the Panipat block (0.27%). The status of soil OC in the Panipat district is represented by the map in figure 3(b). For ease of understanding, the percent distribution of OC in the low, medium, and high classes was calculated. The data in Table 3 clearly show that in the Bapoli block, 13, 69%, and 18% of the samples fell in the low, medium, and high categories, respectively. The respective values of OC in the other blocks (*viz.* Samalkha, Panipat, Madlauda, and Israna) were 16, 77, 7; 27, 73, 0; 9, 71, 20; and 6, 83, 11, respectively.

The organic carbon status in all blocks ranged from 0.27-1.08. It was found that the majority of soils for organic carbon content were in the medium range. Among the various blocks, Bapoli (69%), Samalkha (77%), Panipat (73%), Madlauda (71%), and Israna (83%) fell in the medium range. Overall, the OC status of 74.6 % of soils was in the medium category, whereas only 14.2 % of soils were categorized under the low category. The fast rate of organic matter breakdown under the hyperthermic temperature regime, resulting in exceptionally high oxidizing conditions, is likely the cause of the low to medium levels of organic carbon in these places (Kameriya, 1995) [10]. In their previous investigations on the soils of Haryana, Singh *et al.* (1997) [17] and Gora (2013) [5] also observed similar outcomes. The continuous rice-wheat system may have provided more residues to the soil, which may have caused the medium organic carbon status. Studies showing that the rice-wheat farming system enhances the soil's organic carbon status (Zhang and He, 2004; Benbi and Brar, 2009; Benbi *et al.*, 2012) [2, 3, 24] provide evidence for this claim.

Available soil nitrogen and available soil phosphorus

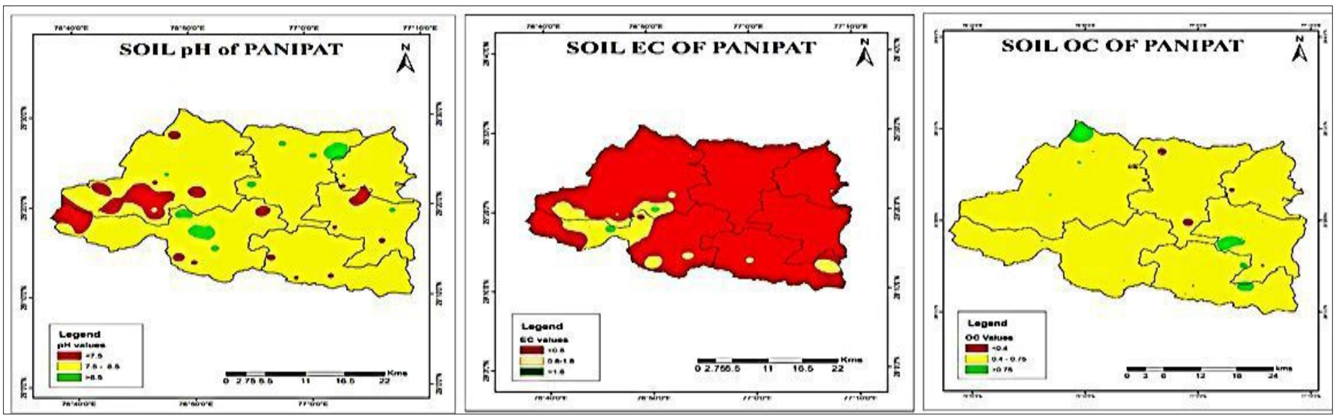
The data presented in Table 2 revealed that the available nitrogen content in soils of the Bapoli, Smalkha, Panipat, Madlauda, and Israna blocks ranged from 91-244, 113-230, 99-216, 114-235 and 125-236 kg ha-1 with mean values of 175.6, 162.6, 153.9, 174.3, and 170.4 kg ha-1, respectively. The phosphorous content in soils of the Bapoli, Smalkha, Panipat, Madlauda, and Israna blocks varied from 4.8-71.2, 7.2-57, 4.4-57.2, 3.6-64.6 and 4.7-41.8 with mean values of 21.8, 24.6, 26.2, 29.9, and 21.3 kg ha-1, respectively. The mean available N was the lowest in Panipat and the highest in Bapoli. The highest available nitrogen mean (175 kg ha-1) and available phosphorus (29.9 kg ha-1) were recorded in the Bapoli and Madlauda blocks, respectively, whereas the minimum available nitrogen (153 kg ha-1) and available phosphorus (21.3 kg ha-1) were recorded in the Panipat and Israna blocks. The maximum values of available nitrogen (244 kg ha-1) and available phosphorus (64.6 kg ha-1) in individual samples were recorded in the Bapoli and Madlauda blocks, respectively. The status of soil available nitrogen in the Panipat district is represented by the map in figure 3(c) and 3 (d), respectively. Further, according to the threshold values of <250 (low), 250-500 (medium), and >500 kg ha-1 (high) for soil available nitrogen status, it was deficient in all the blocks. The low N might be due to nitrogen losses via volatilization, runoff, microbial fixation, and denitrification. Likewise, based on threshold value of <10, 10-20 and >20 kg ha-1 ha for available phosphorus 8, 47 and 45 % samples in Bapoli block; 2, 41 and 57 % samples in Smalkha block; 10, 23 and 67 % samples In Panipat block, 11, 25, and 64 % of samples in Madlauda and 19, 25, and 56 % of samples in Israna block fell in the low, medium, and high ranges, respectively. The majority of soils were under high status (56 %) of available phosphorus. The changes in the status of available phosphorus in these soils were due to the continuous application of phosphatic fertilizers. Similar results were observed by Singh *et al.* (2011) [19].

Table 2: Soil organic carbon, available nitrogen, phosphorus, potassium and sulphur status of different blocks of Panipat district

Block	Soil Organic Carbon (%)	Available Nitrogen (kg ha-1)	Available Phosphorus (kg ha-1)	Available Potassium (kg ha-1)	Available Sulphur (kg ha-1)					
Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Bapoli	0.29-1.08	0.60	91-244	175	4.8-71.2	21.8	77-373	156	9-184.4	65.6
Smalkha	0.33-0.96	0.56	113-230	162	7.2-57	24.6	67-391	189	26.9-261	124.6
Panipat	0.27-0.74	0.52	99-216	153	4.4-57.2	26.2	80-373	221	31-215	106
Madlauda	0.37-0.93	0.61	114-235	174	3.6-64.6	29.9	125-747	277	57.8-252.8	137.5
Israna	0.38-0.90	0.60	125-236	170	4.7-41.8	21.3	126-586	255	23-530	161

Table 3: Percent distribution of Soil organic carbon, available nitrogen, phosphorus, potassium and sulphur status of different blocks of Panipat district

Block	Soil Organic Carbon (%)	Available Nitrogen (kg ha-1)	Available Phosphorus (kg ha-1)	Available Potassium (kg ha-1)	Available Sulphur (kg ha-1)										
Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	
Bapoli	13	69	18	100	0	0	8	47	45	18	72	10	8	17	75
Smalkha	16	77	7	100	0	0	2	41	57	5	77	18	0	7	93
Panipat	27	73	0	100	0	0	10	23	67	3	67	30	0	7	93
Madlauda	9	71	20	100	0	0	11	25	64	0	48	52	0	0	100
Israna	6	83	11	100	0	0	19	25	56	0	65	35	0	8	92



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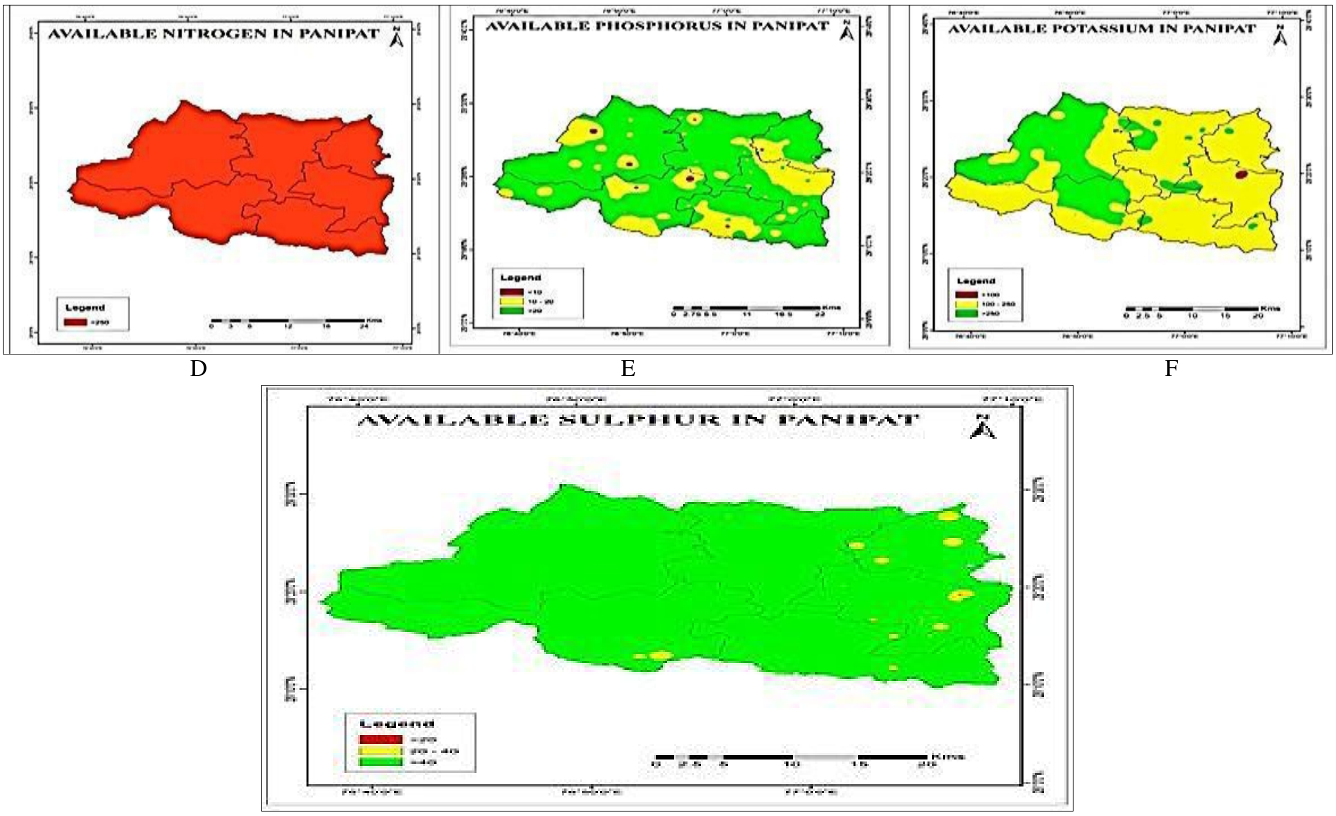

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Fig 3 (a-g): Map of Soil pH (a), EC (b), Organic carbon (c), Available Nitrogen (d), Available Phosphorus (e), Available Potassium (f) and Available Sulphur (g) of district Panipat

Available Potassium and Sulphur

The data presented in Table 2 revealed that the available K in all blocks ranged between 67 and 747 kg ha-1. The mean value of available K was lowest in Bapoli block (156), and the highest in Madlauda (277) block. In the remaining blocks, the available K followed the order Smalkha (189), Panipat (221), and Israna (255 kg ha-1). The status of soil available potassium in the Panipat district is represented by the map in figure 3(f). Based on threshold values of potassium it was observed that 18, 72 and 10 % samples of Bapoli block, 5, 77 and 18% samples of Smalkha block, 3, 67 and 30 % samples of Panipat block, 0, 48, and 52 % samples of Madlauda block, 0, 65, and 35 % samples of Israna block were in low, medium, and high range, respectively (Table 3).

The available potassium was mostly under medium to high status in the soils of district Panipat. Approximately 66 % of soils in the Panipat district were observed to be in the medium status for available potassium, whereas 28 % of soils were found to be in the high status, followed by 6 % in the low status of available potassium. The medium to high amount of available potassium in soil could be most probably due to its potassium-rich parent material, such as feldspar and illite (Sharma et al., 2012) [14]. Singh and Poonia (1982) [18] also reported that the available potassium in soil was low due to continuous uptake of potassium by field crops as the farmers' field has been intensively cultivated for a long period of time without potassium fertilization. Similar results were observed by Singh *et al.* (2011) [19].

Similarly, the available sulfur value of individual sample was minimum in Bapoli Block (9.0) and maximum in Israna Block (530 kg ha-1) (Table 2). The minimum and maximum levels of available S were found in the Bapoli (65.6) and Israna blocks (161 kg ha-1), respectively. The Magnitude of Available S expressed as number of samples in a range followed the order Israna>Madlauda>Smalkha>Panipat>Bapoli, respectively. The status of soil available sulphur in the Panipat district is represented by the map in figure 3 (g). Based on threshold value of sulphur, 8, 17, and 75% samples of Bapoli block, 0, 7, and 93% samples of Smalkha block, 0, 7, and 93 % samples of Panipat block, 0, 0, and 100% samples of Madlauda block, and 0, 8, and 92% samples of Israna block were in low, medium, and high ranges of sulphur, respectively. (Table 3).

Nearly 89 % of soils of Panipat district were high in available sulfur status, followed by medium (9 %) and low (2 %), while in each block, the magnitude of samples under high available sulfur was 75, 93, 93,100 and 92 % in Bapoli, Smalkha, Panipat, Madlauda, and Israna blocks, respectively. The higher status of available sulphur in these areas was due to S-rich parent material and the application of zinc sulfate as a common practice for correcting Zn deficiency in rice-wheat cropping systems.

Correlation between soil properties and nutrient content

The Relationship between soil properties and available nutrient status is presented in Table 4. The correlation matrix clearly revealed a positive and significant correlation between soil organic carbon and available nitrogen (r = 0.928), available phosphorus (r = 0.328), and available potassium (r = 0336**). Figure 4 shows the relationship between OC and N, with an R2 value of 0.8621. A significant positive correlation (r=0.081) was found between organic carbon and available potassium. This might be due to the creation of a favorable soil environment with the presence of high organic matter. A positive but nonsignificant correlation (r=0.042) was observed between organic carbon and available sulfur content. This relationship existed because most of the sulfur is associated with organic matter. The results obtained are in line with those observed by Nor (1981) [12] and Singh and Mishra (2012) [20].

Table 4: Correlation between soil properties and nutrient content in soils of Panipat District

	pH	EC	SOC	N	P	K	S
pH	1						
EC	0.025	1					
SOC	-0.04	0.067	1				
N	-0.029	0.05	0.928***	1			
P	0.007	0.156*	0.328**	0.341**	1		
K	0.159	0.169**	0.336**	0.318**	0.274**	1	
S	-0.135	0.258**	0.042	0.042	0.065	0.139*	1

Significant at the 0.05 level (2-tailed) and *. Significant at the 0.01 level (2-tailed), *SOC: Soil Organic Carbon, N: Nitrogen, P: Phosphorus, K: Potassium, S: Sulphur

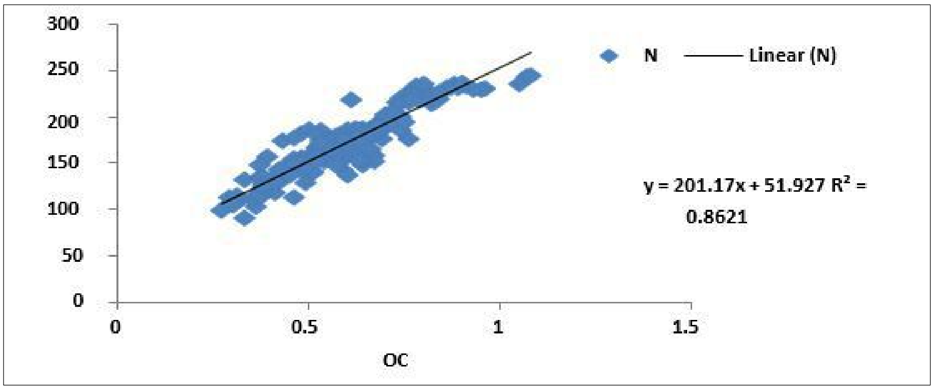

Fig 4: Relationship between OC and available N in Pant district

Conclusion

The soils of Panipat district are predominantly alkaline and non-saline, with textures ranging from sandy loam to clayey loam. Organic carbon content is generally low to medium, with a mean value of 0.58%, and approximately 74.6% of samples falling in the medium category. Available nitrogen status is low across all blocks, likely due to losses from volatilization, runoff, microbial fixation, and denitrification. In contrast, available phosphorus and sulfur levels are high, while available potassium ranges from medium to high, with the highest values observed in Madlauda and Israna blocks. The positive and significant correlations between soil organic carbon and available nitrogen, phosphorus, and potassium indicate the importance of organic matter in nutrient availability. These findings provide a comprehensive baseline for targeted soil fertility management and enhancement strategies tailored to the specific conditions of each block within Panipat district.

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