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# Fertility status in geo-referenced soils of Deoghar District, Jharkhand

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**Abstract**
To establish the fertility status in soils, a delineation programme was conducted in Deoghar district of Jharkhand (Subzone IVth of VIIth ACZ), India. Total 352 geo-referenced surface (0.0-15.0 cm) soil samples were collected randomly from ten blocks of the district (Lat. 24019' to 24053', Log. 86050' to 87003' and Alt. 176 to 295 msl). Based on the analysis of collected soils, pH were strongly acidic to moderately alkaline in reaction (pH 4.80-8.10) with low electrical conductivity (0.01 to 0.77 dS $m^{-1}$) and organic carbon content varied from very low (0.17 g $kg^{-1}$) to high (15.30 g $kg^{-1}$) status with their mean values of 5.96 (pH), 0.13 dS $m^{-1}$ (EC) and 4.46 g $kg^{-1}$ (OC), respectively. The Nitrogen, phosphorus, potash and sulphur content were varied from 116.62 to 510.00, 0.56 to 365.68, 26.88 to 909.44 kg $ha^{-1}$ and 0.66 to 62.83 mg $kg^{-1}$ with their mean values of 255.41, 35.15, 134.49 kg $ha^{-1}$ and 13.44 mg $kg^{-1}$, respectively. While micronutrients *i.e.*, Fe, Zn, Mn, Cu and B content were varied from 4.27 to 743.66, 0.04 to 12.62, 4.65 to 28.04, 0.00 to 6.24 and 0.01 to 6.35 mg $kg^{-1}$ with their mean values of 72.54, 1.35, 24.06, 2.35 and 0.88 mg $kg^{-1}$, respectively. Out of the nine analyzed essential nutrients, only Fe, Mn and Cu content were well sufficient while others nutrients *i.e.*, N, P, K, S, Zn and B were observed emerging deficiency (45-67%) in this district. While deficiency of nitrogen has reached at alarming stage and 67% soils suffering from N deficiency in the district. On the other hand, heavy metals *i.e.*, Pb, Ni, Co and Cd content range between 0.22-25.10, ND, 0.00-3.54 and 0.00-3.43 mg $kg^{-1}$ with their mean values of 5.03, ND, 1.42 and 1.64 mg $kg^{-1}$ respectively. As per considering the safe limit of Pb (20 mg $kg^{-1}$), Ni (10 mg $kg^{-1}$), Co (20 mg $kg^{-1}$) and Cd (5 mg $kg^{-1}$) in soil all the heavy metals have available below the safe limit and no risk for cultivation land and sustainable crop productions. Hence, deficiencies of N, P, K, Zn, B and S are most common in Deoghar district soils. Therefore, for successful and profitable crop production maintaining soil and plant health immediate need to give more attention to supply N, P, K, Zn, B and S fertilizers at village level and create awareness to use these fertilizers in judicious and scientific way among the farmers. In organic matter concern farmers of the Deoghar district should be encouraged to apply organic matters along with the balance use of fertilizers for optimum yield potential.

**Keywords:** Geo-referenced, soil fertility status, primary-secondary-micro nutrients, pollutant elements, soil health

## Introduction
In any agricultural operations, soil is the utmost importance as it is the cradle for all crops and plants. Now-a-days, it is facing serious problems due to human pressure and utilization incompatible with its capacity. Hence, it is important to keep healthy and productive soil to continue our soil to function optimally to increase agriculture production with appropriate soil amendment and crop management practices. The peoples of rural areas in Deoghar district, more than 75% income come from agricultural sectors; therefore soil fertility status is a very important matter for profitable crop productions. While fertility status depend on the availability of essential nutrients in the soils. But at present continuously removals of nutrient by crops, with little or no replacement with increase the nutrient status in plants and ultimately lower the productivity. To consider these aspects a detail study of macro and micro and polluted elements were under taken in a Deoghar district, Jharkhand which is a representative location of subzone IVth of VIIth ACZ, India (Figure 1). Deoghar district is lies in the western portion of Santhal parganas. It is bounded by Bhagalpur district in north, Dumka in south and east and Giridih in west. Deoghar district is spread out in an area of 2473.38 Sq.km in the NE part of Jharkhand state.

There are ten blocks (Palajori, Sonaray Thari, Sharwa, Madhupur, Devipur, Mohanpur, Sarath, Karon, Margo Munda and Deoghar) in the district.

Nearly 44 percent of the total area of the district is utilized for cultivation, out of which only 10.55 percent is irrigated. Economy and livelihood of the farmers mainly depends upon rain-fed agriculture and trading of forestry products. The average annual rainfall varies from 1200 mm to 1250 mm and district experiences a prolonged dry period during January to May which keeps the soil dry for more than 90 days. Agriculture is characterized by paddy based primary cropping system (Rice-fallow) was found in the district, while as per irrigation facility availability and market linkage facility in different blocks wheat, oilseed, pulses and vegetables, etc. also in cultivation practice as secondary crop in limited areas of the district.

Fertility status of the district mainly affected by severe soil erosion in undulating topography, use of low organic matter, follow the HYV/ Hybrid rice cultivars, imbalance use of nutrients, indiscriminate use of irrigation water, natural sink of effluents and dump of waste materials particularly in industries and mining areas of the district. Hence, monitoring of soil fertility status as per land situation in the district is mandatory and therefore, GPS based delineation programme to assessing the status of available essential macro and micro nutrients, and side by side pollutant elements in soils of Deoghar district was planned.

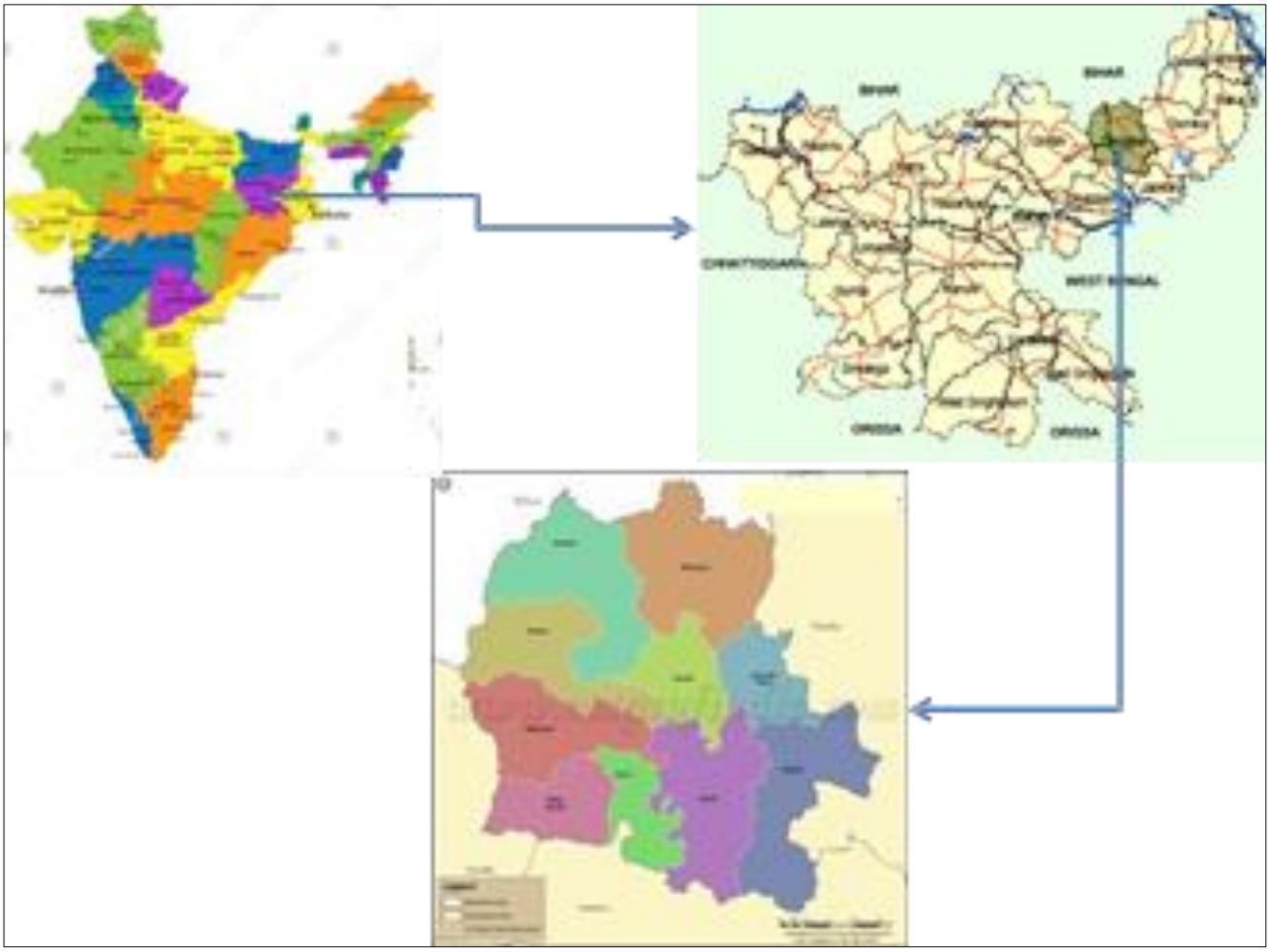

**Fig 1:** Location map of Deoghar district

## Materials and Methods

The Global Positioning System (GPS) based 352 surface (0.0-15.0 cm) soils were collected from ten blocks (Palajori, Sonaray Thari, Sharwa, Madhupur, Devipur, Mohanpur, Sarath, Karon, Margo Munda and Deoghar) of Deoghar district (Latitude N24019' to N 24º53' and longitude E86º50' to E 87º03' with the variation of altitude from 176 to 295 m) during December 2022 to February 2023 under the delineation programme of "All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (ICAR)", Ranchi Centre. Collected soil samples were air dried, ground in wooden pestle and mortar and passed through 0.5 and 2.0 mm sieve, stored in properly labeled cloth's bags for analysis. Processed soil samples were analyzed for pH, electrical conductivity (EC) by employing the method (1:2.5: soil: water) as outline by Jackson (1973) [6], organic carbon (potassium dichromate and sulfuric acid method) by Walkley and Black (1934) [34]. The available phosphorous and potassium were analyzed by employing the method of available nitrogen was analyzed using the method as outline. The DTPA extractable Zn, Cu, Fe, Mn, Pb, Ni, Co and Cd was extracted with di-ethelene tri-amine penta-acetic acid (DTPA) solution (Lindsay and Norvell, 1978) [12]. Hot water solution boron of soils was estimated as per method outlined using Azomethine-H through UV-spectrophotometer at 420 nm. Sulphur was analyzed by employing the method (0.15% CaCl2 as the extractant) of Williams and Steinbergs (1954). Descriptive statistical and simple correlation coefficients

were analyzed with the help of statistical software (Microsoft XL 2007).

## Results and Discussion

**Soil reaction (pH):** The soil reaction of Deoghar district varied from strongly acidic (4.80 pH) to moderately alkaline (8.10 pH) in reaction with the mean value of 5.69 pH (Table 1). Out of the ten blocks, higher mean value of pH was recorded from Margo Munda block followed by Deoghar, Sharwa and Palajori blocks. While, overall status of soil pH in this district was found about 85, 13 and 2 percent cultivated area covered by acidic, neutral and saline soil reaction, respectively (Figure 2). Whereas the highest strongly acidic soil was found in Devipur block (42.9%) followed by Deoghar block (37.2%). The strongly acidic soil of the district may be attributed to excessive leaching of basic cations due to heavy rainfall on undulating topographic cultivated lands.

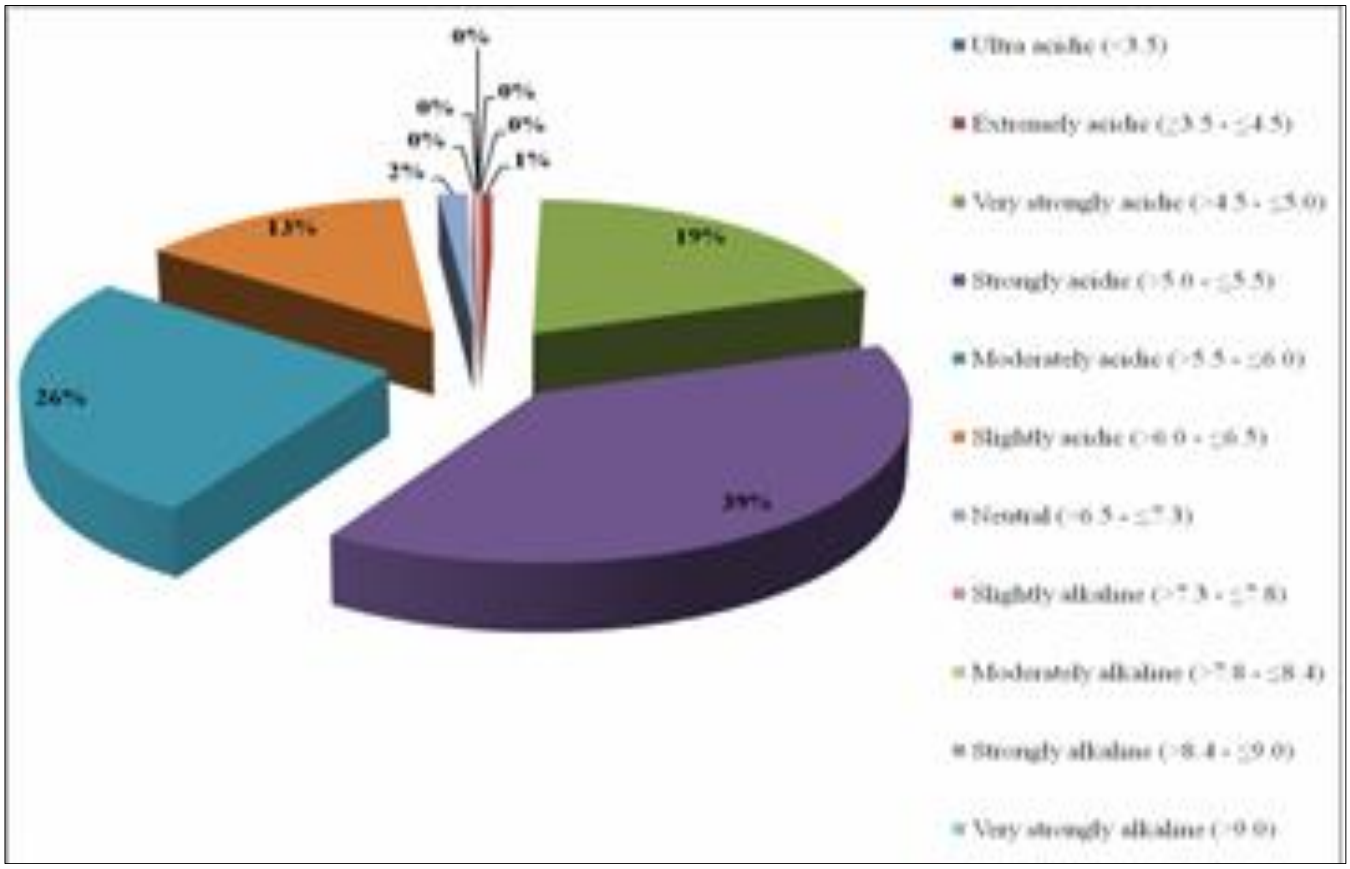


**Fig 2:** Soil pH status in Deoghar district

**Electrical conductivity (EC)**

Electrical conductivity (EC) of the soils was found in the range of 0.01 to 0.77 dS $m^{-1}$ with the mean value of 0.13 dS $m^{-1}$ (Table 1). As per categorized of EC *i.e.*, Low (<1.5 dS $m^{-1}$), medium (1.5-3.0 dS $m^{-1}$) and high (>3.0 dS $m^{-1}$), all the soils were covered by low category, because high conductivities are associated with clay-rich soils and low conductivities are associated with sandy and gravelly soils that can be attributed to the shape and fabric of these soils. Clay particles tend to be pancake-shaped and lie flat against each other, giving them a high degree of surface-to-surface contact and thus allowing electricity to pass easier from grain to grain. Sand grains tend to be more spherical and thus they have a lower degree of grain-to-grain contact (Ouhadi and Goodarzi, 2007) [17].

**Table 1:** Block wise variation of pH, Electrical conductivity (EC) and Organic carbon (OC) in soils

| Block | No. of Soil | pH | | EC (dS $m^{-1}$) | | OC (g $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 5.20-6.90 | 6.00±0.42 | 0.06-0.41 | 0.16±0.09 | 1.87-15.13 | 6.27±3.23 |
| Sonaray Thari | 35 | 5.20-6.89 | 5.85±0.41 | 0.04-0.77 | 0.16±0.16 | 1.36-13.60 | 4.96±3.05 |
| Sharwa | 35 | 5.26-6.85 | 6.05±0.42 | 0.06-0.38 | 0.13±0.08 | 1.19-13.26 | 4.24±3.06 |
| Madhupur | 39 | 5.22-7.07 | 5.99±0.55 | 0.05-0.51 | 0.16±0.11 | 1.19-9.35 | 3.84±2.02 |
| Devipur | 35 | 5.06-6.61 | 5.70±0.36 | 0.02-0.17 | 0.08±0.04 | 1.53-15.30 | 3.88±2.95 |
| Mohanpur | 35 | 5.11-6.92 | 5.98±0.42 | 0.02-0.30 | 0.10±0.06 | 0.17-8.67 | 3.45±2.11 |
| Sarath | 36 | 5.17-6.59 | 5.88±0.42 | 0.01-0.20 | 0.11±0.05 | 1.19-13.77 | 3.91±2.65 |
| Karon | 35 | 5.37-7.45 | 5.96±0.56 | 0.03-0.43 | 0.14±0.11 | 1.53-12.75 | 3.98±2.37 |
| Margo Munda | 34 | 5.40-8.10 | 6.18±0.57 | 0.04-0.56 | 0.16±0.12 | 1.53-8.33 | 3.68±1.86 |
| Deoghar | 35 | 4.80-7.60 | 6.06±0.79 | 0.03-0.48 | 0.11±0.10 | 1.53-15.13 | 6.58±3.32 |
| Overall | 352 | 4.80-8.10 | 5.96±0.52 | 0.01-0.77 | 0.13±0.10 | 0.17-15.30 | 4.46±2.86 |

**Organic carbon (OC)**

The organic carbon content in soils varied from very low (0.17 g $kg^{-1}$) to high (15.30 g $kg^{-1}$) with a mean value of 4.46 g $kg^{-1}$ (Table 1). Out of the ten blocks, the highest soil OC content was observed in Deoghar block followed by Palajori block which may be due to high amount of leaf fall from forest vegetation and higher rainfall with prevailing warm and hot climate causing faster decomposition of organic matter. Whereas, the highest low category soil was found in Mohanpur followed by Margomunda, Devipur and Karon blocks (Table 3) might be due to intensive cultivation in this block year after year and little addition of organic residues as well as hot climate causing oxidation of organic matter. The overall soil OC status in this district was found about 68, 19 and 14 percent under low, medium and high categories, respectively (Figure 3).

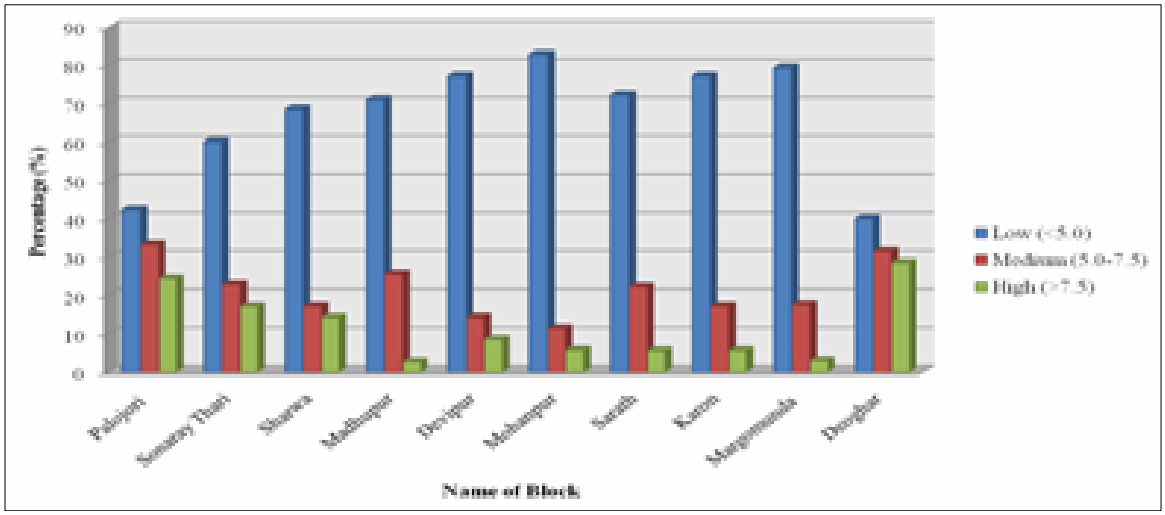


**Fig 3:** Organic carbon status in Soils in Deoghar district

**Available Nitrogen (N)**

Table 2 indicated that the available nitrogen content in soils of Deoghar district varied from 116.62 to 510.00 with a mean value of 255.41 kg $ha^{-1}$. Among the ten blocks, higher mean value of N was recorded from Deoghar followed by Palajori block. Out of 352 soil samples, 67% fell into the low category, while 33% fell into the medium category (Figure 4). The low concentration in the soils might be due to N leaching and surface runoff in the undulating topography. While, block wise low status of N availability was observed highest in Mohanpur followed by Madhupur, Devipur, Margo Munda and Sarath block, respectively (Table 3).

**Table 2:** Block wise variation of available Nitrogen and Phosphorus in soils

| Block | No. of Soil | N (kg $ha^{-1}$) | | P (kg $ha^{-1}$) | |
|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 144.50-422.00 | 288.95±78.85 | 1.40-246.96 | 43.72±67.68 |
| Sonaray Thari | 35 | 145.60-496.58 | 268.30±83.52 | 0.56-254.24 | 36.30±64.21 |
| Sharwa | 35 | 116.62-474.60 | 255.36±95.71 | $0.56^{-1}$18.16 | 15.96±21.56 |
| Madhupur | 39 | 127.91-389.70 | 221.96±68.67 | 2.52-365.68 | 48.90±78.67 |
| Devipur | 35 | 150.48-480.60 | 234.71±86.17 | 0.56-217.28 | 25.96±45.58 |
| Mohanpur | 35 | 146.90-380.60 | 220.96±63.03 | $0.56^{-1}$77.24 | 23.91±39.10 |
| Sarath | 36 | 146.90-390.50 | 246.83±72.73 | 0.56-222.32 | 30.71±44.73 |
| Karon | 35 | 146.72-430.60 | 250.47±77.60 | $1.40^{-1}$75.84 | 21.62±42.80 |
| Margo Munda | 34 | 142.00-400.30 | 243.02±73.95 | 1.40-302.12 | 71.09±84.44 |
| Deoghar | 35 | 154.24-510.00 | 329.14±96.65 | 0.56-268.52 | 33.41±57.69 |
| Overall | 352 | 116.62-510.00 | 255.41±85.14 | 0.56-365.68 | 35.15±59.01 |

**Table 3:** Block wise percent (%) status of available Nitrogen and Phosphorus in soils

| Block | No of Soil | OC (g $kg^{-1}$) | | | N (kg $ha^{-1}$) | | | P (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Low <5.0 | Medium 5.0-7.5 | High >7.0 | Low <280 | Medium 280-560 | High >560 | Low <10 | Medium 10-25 | High >25 |
| Palajori | 33 | 42.4 | 33.3 | 24.3 | 48.5 | 51.5 | 0.00 | 45.5 | 15.2 | 39.3 |
| Sonaray Thari | 35 | 60.1 | 22.8 | 17.1 | 65.8 | 34.2 | 0.00 | 51.5 | 25.7 | 22.8 |
| Sharwa | 35 | 68.6 | 17.2 | 14.2 | 68.6 | 31.4 | 0.00 | 48.6 | 40.0 | 11.4 |
| Madhupur | 39 | 71.1 | 25.6 | 2.7 | 79.4 | 20.6 | 0.00 | 35.8 | 35.8 | 28.4 |
| Devipur | 35 | 77.2 | 14.3 | 8.5 | 74.4 | 25.6 | 0.00 | 42.9 | 40.0 | 17.1 |
| Mohanpur | 35 | 82.9 | 11.4 | 5.7 | 82.9 | 17.1 | 0.00 | 57.2 | 20.0 | 22.8 |
| Sarath | 36 | 72.3 | 22.2 | 5.5 | 72.3 | 27.7 | 0.00 | 41.7 | 30.6 | 27.7 |
| Karon | 35 | 77.2 | 17.2 | 5.6 | 68.6 | 31.4 | 0.00 | 68.6 | 17.2 | 14.2 |
| Margo Munda | 34 | 79.4 | 17.6 | 3.0 | 73.5 | 26.5 | 0.00 | 32.3 | 20.7 | 47.0 |
| Deoghar | 35 | 40.0 | 31.5 | 28.5 | 31.5 | 68.5 | 0.00 | 34.3 | 45.7 | 20.0 |
| Overall | 352 | 67.12 | 21.31 | 11.51 | 66.55 | 33.45 | 0.00 | 45.84 | 29.09 | 25.07 |

**Available phosphorus (P)**

The results showed that the available phosphorus content in soils of Deoghar district varied from 0.56 to 365 with a mean value of 35.15 kg ha$^{-1}$ (Table 2). Out of the ten blocks, higher and lower mean value of P was recorded in soils of Margo Munda and Sharwa block, respectively. While 46, 29 and 25 percent soil samples were recorded as Low, medium and high category status in this district. Whereas the highest of low category (<10.0 kg ha$^{-1}$) soils was found in Karon block followed by Mohanpur and Sonaray Thari blocks (Table 3) (Figure 4). The low phosphorus concentrations in the soils of different blocks of this district might be due to fixation of released P by oxides of iron and aluminum. The fixed P can be made plant available form by applying native phosphate solubilizing fungi.

**Table 4:** Block wise variation of available Potassium and Sulphur in soils

| Block | No. of Soil | K (kg ha$^{-1}$) | | S (mg kg$^{-1}$) | |
|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 59.36-909.44 | 237.40±185.72 | 2.75-35.44 | 13.91±8.29 |
| Sonaray Thari | 35 | 43.68-758.24 | 129.95±124.68 | 1.14-46.85 | 9.62±8.68 |
| Sharwa | 35 | 50.40-267.68 | 103.17±42.41 | 1.91-62.83 | 13.04±12.62 |
| Madhupur | 39 | 54.88-349.44 | 134.06±79.73 | 2.43-43.99 | 14.30±10.64 |
| Devipur | 35 | 31.36-224.00 | 95.14±47.75 | 0.66-41.95 | 11.63±7.49 |
| Mohanpur | 35 | 58.24-641.76 | 133.02±98.09 | 3.53-37.19 | 17.45±7.89 |
| Sarath | 36 | 35.84-271.04 | 101.05±65.31 | 2.20-33.43 | 12.73±7.33 |
| Karon | 35 | 26.88-381.92 | 106.43±80.64 | 1.31-45.08 | 13.40±11.82 |
| Margo Munda | 34 | 28.00-629.44 | 152.44±128.85 | 1.05-62.41 | 15.22±17.27 |
| Deoghar | 35 | 72.44-492.17 | 159.60±75.17 | 2.70-33.86 | 13.05±9.77 |
| Overall | 352 | 26.88-909.44 | 134.49±106.61 | 0.66-62.83 | 13.44±10.62 |

**Table 5:** Block wise percent (%) of available Potassium and Sulphur in soils of Deoghar district.

| Block | No of Soil | K (kg ha$^{-1}$) | | | S (mg kg$^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | Low <120 | Medium 120-280 | High >280 | Low <10 | Medium 10-20 | High >20 |
| Palajori | 33 | 27.3 | 51.5 | 21.2 | 39.4 | 42.4 | 18.2 |
| Sonaray Thari | 35 | 65.8 | 31.5 | 2.7 | 65.8 | 28.6 | 5.6 |
| Sharwa | 35 | 71.5 | 28.5 | 0.00 | 51.5 | 42.9 | 5.6 |
| Madhupur | 39 | 56.3 | 33.3 | 10.4 | 38.4 | 38.4 | 23.2 |
| Devipur | 35 | 77.2 | 22.8 | 0.00 | 48.6 | 45.8 | 5.6 |
| Mohanpur | 35 | 51.5 | 45.8 | 2.7 | 11.4 | 65.8 | 22.8 |
| Sarath | 36 | 69.5 | 30.5 | 0.00 | 38.9 | 44.5 | 16.6 |
| Karon | 35 | 71.5 | 23.0 | 5.5 | 54.3 | 25.7 | 20.0 |
| Margo Munda | 34 | 52.9 | 35.3 | 11.8 | 56.0 | 26.5 | 17.5 |
| Deoghar | 35 | 25.7 | 71.5 | 2.8 | 57.2 | 28.6 | 14.2 |
| Overall | 352 | 56.92 | 37.37 | 5.71 | 46.15 | 38.92 | 14.93 |

**Available potassium (K)**

The available potassium content in soils of Deoghar district ranged from 26.88 to 909.44 with a mean value of 134.46 kg ha$^{-1}$ (Table 4). While block wise the higher and lower mean value of K was bserved in soils of Palajori and Devipur blocks, respectively. Among the 352 analyzed soil samples, about 56, 36 and 08 percent under low (<120 kg ha$^{-1}$), medium (120-280 kg ha$^{-1}$) and high (>280 kg ha$^{-1}$) categories were recorded, respectively (Table 5). Whereas the lower category status of soils was observed highest in Devipur block followed by Sharwa, Karon, Sarath and Sonaray Thari blocks, respectively (Table 5) (Figure 4). The poor concentration of potassium in the soils of different blocks in this district might be due to the absent of K-bearing clay minerals such illite, biotite, and orthoclase in red and lateritic soils. Whatsoever may be attributed to excessive leaching and surface runoff of K-bearing clay minerals due to heavy rainfall in the undulating topographic cultivated Lands.

**Available sulphur (S)**

A wide variation (0.66-62.83 mg kg$^{-1}$) was observed in case of sulphur availability in soils with the mean value of 13.44 mg kg$^{-1}$ (Table 4). Out of the ten blocks, lower mean S content was found in Sonaray Thari block and higher mean S content was observed in Mohanpur block. On the basis of categorized status, about 46, 39 and 15 percent soil samples were recorded under the status as low, medium and high categorize, respectively in this district. Whereas the highest of low category status soils was observed in Sonaray Thari block followed by Deoghar, Margo Munda, Karon and Sharwa blocks, respectively (Table 5) (Figure 4). Moreover, earlier Agarwal *et al*. (2013) [1] was observed that S availability in soils of Jharkhand range from 0.30 to 80.3 mg kg$^{-1}$ and 37.7% soil suffering from S deficiency.

**Available iron (Fe):** The Table 6 indicated that available iron content in soils varied from 4.27 to 743.66 with a mean value of 72.54 mg kg$^{-1}$ (Table 3). Among all the ten blocks, lower and higher mean Fe content was observed in Sarath (38.00 mg kg$^{-1}$) and Deoghar (93.56 mg kg$^{-1}$) block's soils. While higher Fe availability in soils of deoghar block may probably be due to presence of mangniferrous concentrations in the soil (Rashmi Baruah *et al*., 2014) [2]. This was corroborated with the finding of Kumar *et al.* (2018) [9, 11]. Considering 4.5 mg kg$^{-1}$ as critical limit for Fe in soils, 99.44 percent soil samples were well sufficient in Fe availability in the all blocks of Deoghar district. Sakal *et al.* (1996) [20] also reported that the higher content of available Fe in the soils of plateau region of Jharkhand.

**Table 6:** Block wise variation of available Iron and Zinc (mg $kg^{-1}$) in soils.

| Block | No. of Soil | Fe | | Zn | |
|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 35.76-[1]04.68 | 85.82±23.19 | 0.21-7.43 | 1.32±1.28 |
| Sonaray Thari | 35 | 36.66-[1]04.66 | 83.03±23.23 | 0.24-5.47 | 0.85±0.93 |
| Sharwa | 35 | 27.10-[1]04.68 | 89.49±19.79 | 0.04-2.28 | 0.69±0.54 |
| Madhupur | 39 | 33.32-[1]04.68 | 91.32±21.25 | 0.16-3.53 | 0.85±0.66 |
| Devipur | 35 | 18.42-[1]04.68 | 83.73±29.61 | 0.14-3.44 | 0.97±0.73 |
| Mohanpur | 35 | 10.72-[1]04.56 | 58.72±31.56 | 0.13-5.70 | 1.25±1.38 |
| Sarath | 36 | 4.27-82.46 | 38.00±16.12 | 0.10-4.54 | 1.52±1.24 |
| Karon | 35 | 12.79-[1]83.32 | 44.52±40.59 | 0.04-[1]2.62 | 2.63±3.12 |
| Margo Munda | 34 | 16.17-[1]98.32 | 56.38±36.74 | 0.04-6.08 | 1.30±1.28 |
| Deoghar | 35 | 12.04-743.66 | 93.56±158.84 | 0.22-7.62 | 2.13±1.82 |
| Overall | 352 | 4.27-743.66 | 72.54±59.35 | 0.04-[1]2.62 | 1.35±1.57 |

**Available zinc (Zn)**

Available Zn content in different blocks varied widely and it ranged from 0.04 to 12.62 mg $kg^{-1}$ with an average of 1.35 mg $kg^{-1}$ (Table 6). The highest and lowest mean Zn content were recorded in soils of Karon (2.63 mg $kg^{-1}$) and Sharwa (0.69 mg $kg^{-1}$) blocks, respectively. Considering 0.6 mg $kg^{-1}$ as critical limit for Zn in soils, the highest Zn deficiency soils was observed in Sharwa block followed by Sonaray Thari block (Figure 4). The overall, about 35% soil samples was observed Zn deficiency in this district (Figure 7). The deficiency may be due to continuous use of HYV/ Hybrid rice cultivars, imbalance use of nutrients and year after year no use of Zn containing fertilizers especially in low land soils. Our results also agree with the earlier reported by Tiu *et al*. (2018) [25] they were observed that about 47 percent soil samples were found deficient in Sahibganj district of Jharkhand.

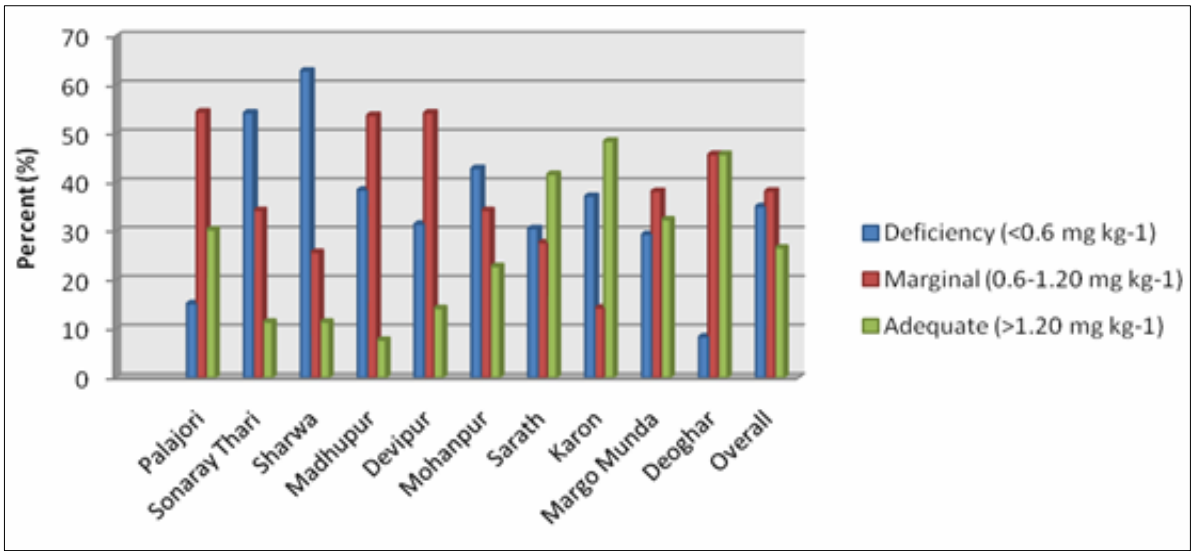


**Fig 4:** Block wise percent (%) Zinc status in soils of Deoghar district

**Available Manganese (Mn)**

Table 7 indicated that the available Mn content in soils ranged from 4.65 to 28.04 mg $kg^{-1}$ with an overall mean of 24.06 mg $kg^{-1}$ (Table 8). Considering the critical limit 2.0 mg $kg^{-1}$ for Mn, all the blocks contents sufficient amount of available Mn in soils of this district (Figure 4). While, earlier Mishra *et al*. (2016) [14] and Bhuyan *et al*. (2014) [3] also reported almost similar trend of Mn availability in acidic soil of Jharkhand, Odisha and Assam, respectively.

**Table 7:** Block wise variation of available Manganese, copper and boron (mg $kg^{-1}$) in soils.

| Block | No of Soil | Mn | | Cu | | B | |
|---|---|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 20.51-25.79 | 25.23±0.97 | 0.00-4.16 | 2.27±1.40 | 0.11-3.62 | 1.20±0.80 |
| Sonaray Thari | 35 | 21.26-25.85 | 25.43±0.78 | 0.00-4.58 | 2.03±1.32 | 0.49-3.73 | 1.18±0.83 |
| Sharwa | 35 | 22.35-25.82 | 24.88±0.84 | 0.00-4.40 | 2.50±1.18 | 0.09-6.35 | 1.38±1.60 |
| Madhupur | 39 | 11.58-25.79 | 24.20±2.93 | 0.00-4.50 | 2.30±1.01 | 0.01-5.67 | 1.47±1.32 |
| Devipur | 35 | 12.48-25.46 | 22.95±2.75 | 0.00-4.92 | 1.85±1.50 | 0.05-[1].23 | 0.50±0.27 |
| Mohanpur | 35 | 19.52-27.89 | 25.11±1.61 | 0.00-4.34 | 2.02±1.62 | 0.50-[1].15 | 0.60±0.17 |
| Sarath | 36 | 10.85-27.56 | 24.42±3.73 | 0.00-3.80 | 2.07±1.22 | 0.44-[1].49 | 0.83±0.26 |
| Karon | 35 | 5.60-28.04 | 23.39±4.08 | 0.00-5.30 | 2.85±1.41 | 0.05-0.61 | 0.26±0.15 |
| Margo Munda | 34 | 4.65-26.87 | 21.60±5.58 | 0.68-6.24 | 2.39±1.55 | 0.17-[1].74 | 0.78±0.44 |
| Deoghar | 35 | 17.94-27.36 | 23.34±1.98 | 0.00-5.22 | 3.24±1.26 | 0.09-[1].89 | 0.56±0.34 |
| Overall | 352 | 4.65-28.04 | 24.06±3.12 | 0.00-6.24 | 2.35±1.40 | 0.01-6.35 | 0.88±0.87 |

**Available Copper (Cu)**

The available Cu content in different blocks varied widely and it ranged from 0.00 to 6.24 mg $kg^{-1}$ with an average value of 2.35 mg $kg^{-1}$ (Table 7). Such variations of availability of Cu status in acid soils of Jharkhand plateau have also been reported earlier by Kumar *et al*. (2001) [10]. The highest and lowest mean Cu content were observed in soils of Deoghar (3.24 mg $kg^{-1}$) and Devipur (1.85 mg $kg^{-1}$) blocks, respectively. Considering the critical limit 0.2 mg $kg^{-1}$ for Cu, about 85% soil samples were well sufficient in available Cu while only 15% soils of this district deficiency of Cu has been started under red and lateritic soil condition due to low organic matter and low pH will precipitate Cu in soil system (Figure 5 & 7). While block wise the highest percent of deficient soils were found in Mohanpur block followed by Devipur block. Our results also agree with the earlier reported by Kumar *et al*. (2018) [9, 11] they were observed that about 10 percent soil samples were found deficient in Khunti district of Jharkhand.

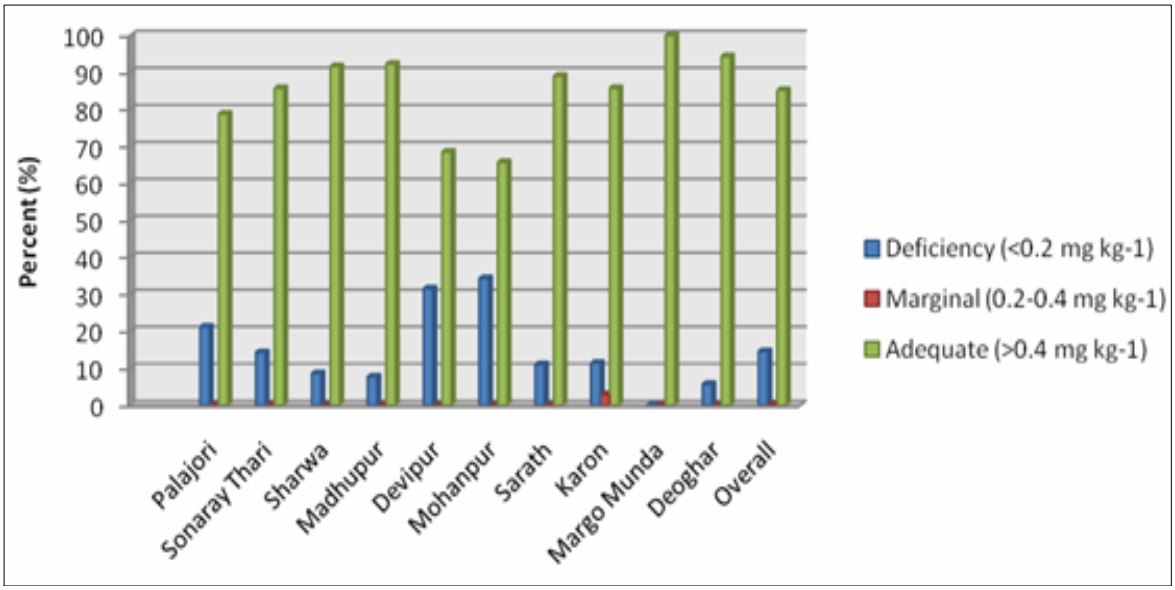


**Fig 5:** Block wise percent (%) Copper status in soils of Deoghar district

**Available Boron (B)**

The available boron content in soils of Deoghar district varied from very low (0.01 mg $kg^{-1}$) to high (6.35 mg $kg^{-1}$) with a mean value of 0.88 g $kg^{-1}$ (Table 7). The similar finding was also reported by Kumar *et al*. (2018) [9, 11] in the soils of Khunti district of Jharkhand. While block wise the higher and lower mean B contents were observed in Madhupur (1.47 mg $kg^{-1}$) and Karon (0.26 mg $kg^{-1}$) blocks, respectively. Considering the critical limit 0.5 mg $kg^{-1}$ for B in soils, overall boron deficiency of this district was recorded about 59%, whereas the highest B deficiency was observed in Mohanpur block followed by Devipur block (Figure 6 & 7). While, earlier Agarwal *et al*. (2013) [1] also reported that the available B content varied from 0.01 to 4.2 mg $kg^{-1}$ and about 63.3% areas were deficient of B in soils of Jharkhand. However, strongly acid soils also tend to be low in available B because of B sorption to iron and aluminum oxide surfaces of soil minerals and more leaching due to course texture soil and high precipitation.

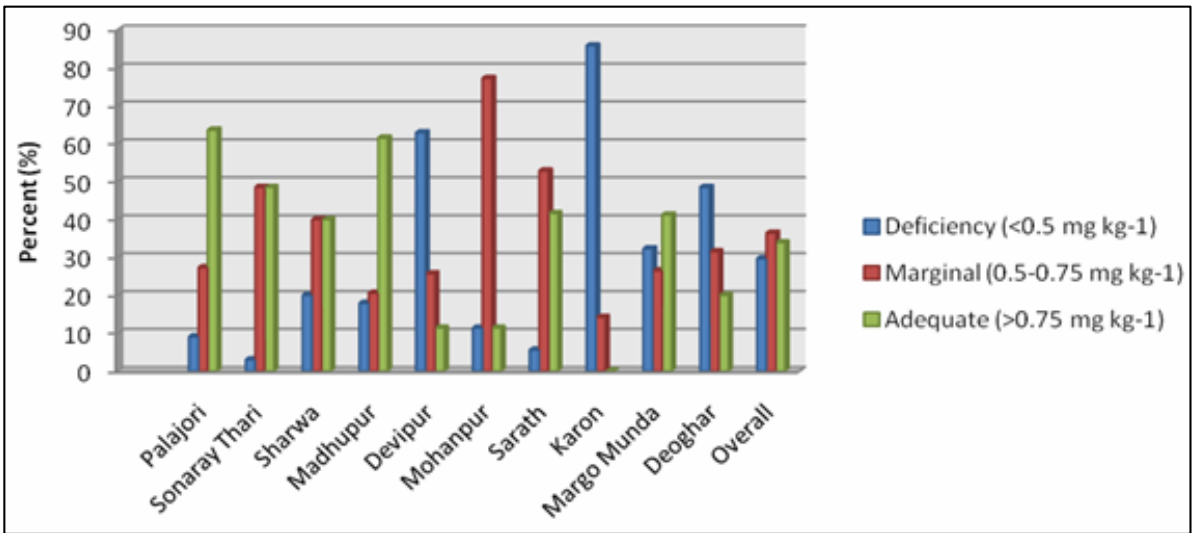


**Fig 6:** Block wise percent (%) Boron status in soils of Deoghar district

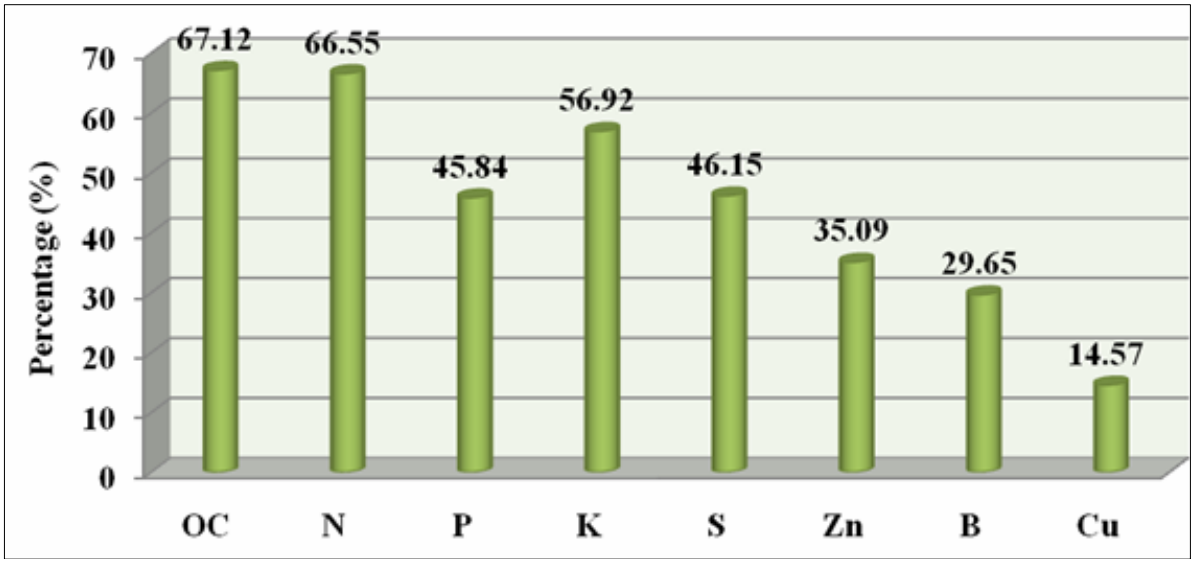


**Fig 7:** Deficiency status of nutrients in soils of Deoghar district

**Heavy metals (Pb, Ni, Co and Cd)**

DTPA extractable Pb, Ni, Co and Cd in soils varied from 0.22 to 25.10, not detected, 0.00 to 3.54 and 0.00 to 3.43 mg $kg^{-1}$ with their mean values of 5.03, ND, 1.42 and 0.45 mg $kg^{-1}$, respectively (Table 8 & 9). Out of the ten blocks, higher mean value of Pb, Co and Cd were recorded in Deoghar, Deoghar and Devipur blocks, respectively (Table 10). On the other hand, Ni content in soils of different blocks was observed not detected. Considering the safe limit 20.00, 10.00, 20.00 and 5.00 mg $kg^{-1}$ for Pb, Ni, Co and Cd, all the soil samples of this district were observed below the safe limit except only 2.9% soils of Deoghar block was recorded as above the safe limit of Pb. This finding was corroborated with the earlier reported by Kumar *et al*. (2018) [9, 11] and Tiu *et al*. (2018) [25].

**Table 8:** Block wise variation of Heavy metals concentration (mg $kg^{-1}$) in soils

| Block | No. of Soil | Pb | | Ni | |
|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 1.02-1.90 | 1.46±0.62 | ND | --- |
| Sonaray Thari | 35 | 1.48-5.10 | 3.40±1.09 | ND | -- |
| Sharwa | 35 | 2.28-5.70 | 4.49±0.95 | ND | -- |
| Madhupur | 39 | 0.52-5.70 | 4.62±1.47 | ND | --- |
| Devipur | 35 | 2.28-5.70 | 5.17±0.82 | ND | -- |
| Mohanpur | 35 | 2.98-5.70 | 5.34±0.65 | ND | -- |
| Sarath | 36 | 5.24-5.68 | 5.57±0.12 | ND | -- |
| Karon | 35 | 3.98-5.70 | 5.49±0.38 | ND | -- |
| Margo Munda | 34 | 4.52-5.70 | 5.51±0.31 | ND | -- |
| Deoghar | 35 | 0.22-25.10 | 6.03±6.26 | ND | --- |
| Overall | 352 | 0.22-25.10 | 5.03±2.04 | ND | --- |

**Table 9:** Block wise variation of Heavy metals concentration (mg $kg^{-1}$) in soils.

| Block | No of Soil | Co | | Cd | |
|---|---|---|---|---|---|
| | | Range | Mean±Std. | Range | Mean±Std. |
| Palajori | 33 | 0.00-2.32 | 1.29±0.60 | 0.26-1.99 | 1.27±0.50 |
| Sonaray Thari | 35 | 0.70-2.02 | 1.20±0.36 | 2.01-2.77 | 2.46±0.24 |
| Sharwa | 35 | 0.60-1.02 | 0.81±0.30 | 2.80-3.16 | 3.00±0.11 |
| Madhupur | 39 | 0.00-0.00 | ND | 3.16-3.41 | 3.32±0.05 |
| Devipur | 35 | 0.70-2.62 | 1.23±0.60 | 3.29-3.43 | 3.34±0.03 |
| Mohanpur | 35 | 0.60-2.22 | 1.01±0.49 | 0.11-3.43 | 2.27±1.54 |
| Sarath | 36 | 0.00-1.82 | 1.18±0.42 | 0.00-0.23 | 0.12±0.07 |
| Karon | 35 | 0.60-3.54 | 1.36±0.55 | 0.00-0.25 | 0.06±0.05 |
| Margo Munda | 34 | 0.80-2.12 | 1.48±0.34 | 0.00-0.30 | 0.09±0.07 |
| Deoghar | 35 | 1.52-2.52 | 1.96±0.27 | 0.00-0.94 | 0.22±0.19 |
| Overall | 352 | 0.00-3.54 | 1.42±0.53 | 0.00-3.43 | 1.64±1.45 |

**Correlation coefficient between different soil physiochemical properties**

Correlation of different physiochemical properties was depicted in Table 10. Soil pH is an important soil property, which affects the availability of several plant nutrients. Our results also showed that the soil pH significantly positive correlation with available P (r =234*), K (r =0.241*), S (r =0.271*) and Zn (r =0.314) which is in conformity with the finding of Bhuyan *et al*., 2014 [3], Nazif *et al*., 2006 [18], Sharma *et al*., 2003 [21], Dhane and Shukla 1995 [5]. The soil

organic matter plays a vital role in supplying plant nutrients. While our results also observed that a positive significant correlation of organic carbon with available N (r = 0.904*), K (r = 0.166*), Zn (r = 0.116*) and Cu (r = 0.121*), which is in conformity with the finding Bhuyan *et al*. 2014 [3]. A positively significant correlation was observed between available P with K (r= 0.306*) and Zn (r= 0.155*); N with K (r= 0.146*), Zn (r= 0.126*) and Cu (r= 0.128*); K with Zn (r= 0.218*) and Fe with Cu (r=0.215*), respectively. There were also showed that a significantly positive correlation of available S with Fe (r = 0.109*), Zn (r = 0.202*) and Cu (r = 0.269*). While significantly a negative correlation also showed that available P with Fe (r= -0.119*) and Cu (r= -0.297*); and available Zn with B (r=-0.114*). These views were corroborated with the observation of Kumar *et al*. (2018) [9, 11]. Moreover, the increase in soil OC and EC with increase in soil pH was observed, which is also supported by finding of several workers (Dhane and Shukla 1995) [5].

**Table 10:** Correlation coefficient between different soil physiochemical properties

| | EC | OC | N | P | K | S | Fe | Zn | Mn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 0.355* | 0.119* | 0.100 | 0.234* | 0.241* | 0.271* | 0.078 | 0.314* | 0.063 | -0.020 | -0.093 |
| EC | | 0.111* | 0.141* | 0.141* | 0.173* | 0.397* | -0.004 | 0.208* | 0.131* | 0.067 | -0.043 |
| OC | | | 0.904* | 0.003 | 0.166* | 0.083 | 0.004 | 0.116* | 0.066 | 0.121* | -0.035 |
| N | | | | -0.007 | 0.140* | 0.070 | -0.004 | 0.126* | 0.057 | 0.128* | -0.050 |
| P | | | | | 0.306* | -0.065 | -0.119* | 0.155* | -0.063 | -0.297* | 0.004 |
| K | | | | | | 0.057 | -0.007 | 0.218* | 0.099 | -0.097 | 0.026 |
| S | | | | | | | 0.109* | 0.202* | 0.100 | 0.269* | -0.035 |
| Fe | | | | | | | | 0.013 | 0.015 | 0.215* | 0.091 |
| Zn | | | | | | | | | -0.004 | 0.037 | -0.114* |
| Mn | | | | | | | | | | 0.052 | 0.045 |
| Cu | | | | | | | | | | | 0.072 |

* Correlation significant at the 0.05% level

## Conclusions

Soils of Deoghar district are highly deficient in available N, P, K, Zn, B and S that may cause decline the fertility status of soils as well as productivity of crops in future. Here soil pH and organic carbon were the main factors, which contributing the variability and availability of N, P, K, Zn, B and S in soils of this district. Therefore, for profitable crop yield and sustain the soil-plant health for poor resource farmers of Deoghar district need more attention to make availability of N, P, K, Zn, B and S containing fertilizer at village level and to create awareness to use these fertilizers in judicious and scientific way among the farmers. In organic matter concern farmers of the Deoghar district should be encouraged to apply organic matters along with the balance use of fertilizers for optimum yield potential.

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