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# Study on Soil Fertility Status of Kalapipal Tehsil of Shajapur District, Madhya Pradesh

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**ABSTRACT: The study was carried out during 2020–21 on the soil fertility status of Kalapipal tehsil in Shajapur district, Madhya Pradesh. The decline in soil fertility is causing growing concerns over the sustainability of Indian agriculture. The study included soil physical properties, soil chemical properties, and correlations among various soil properties for detailed data on soil fertility. The physical properties of the soil included the sand, silt, and clay content of the soils of Kalapipal tehsil. The sand content ranged from 13.7 to 28.7% among the 101 collected samples, with an average of 22.1%. The silt content of the soils of Kalapipal tehsil ranged from 24.4 to 34.6% among the 101 collected samples. The clay content of the studied soils ranged from 41.4% to 47.5%, with a mean value of 48.9%. The water-soluble cations, *viz.*, $Ca^{++}$, $Mg^{++}$, $Na^{+}$, and K+, content of the soils of Kalapipal tehsil ranged from 3.23 to 15.47 me $L^{-1}$, 2.32 to 9.18 me $L^{-1}$, 0.79 to 2.30 me $L^{-1}$ and 0.21 to 1.87 me $L^{-1}$, respectively. The mean water-soluble $Ca^{++}$, $Mg^{++}$, Na+, and K+ contents of the studied soils were 9.78 me $L^{-1}$, 4.68 me $L^{-1}$, 1.31 me $L^{-1}$ and 0.54 me $L^{-1}$, respectively. Similarly, the water-soluble anions, viz., $CO_3^{2-}$, $HCO_3^{-}$, $Cl^{-}$, and $SO_4^{2-}$ content of the soils of Kalapipal tehsil ranged from 0.40 to 3.33 me $L^{-1}$, 4.75 to 12.40 me L-1, 1.66 to 9.89 me $L^{-1}$ and 0.21 to 10.03 me $L^{-1}$, respectively, among the studied samples. The mean water soluble $CO_3^{2-}$, $HCO^{3-}$, $Cl^{-}$ and $SO_4^{2-}$ content of studied soils was found 1.39 me $L^{-1}$, 8.36 me $L^{-1}$, 4.56 me $L^{-1}$ and 1.92 me $L^{-1}$, respectively. Further, the exchangeable cations *viz.*, $Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$ content of soils of Kalapipal tehsil ranged 13.70 to 32.26 me $L^{-1}$, 4.98 to 19.67 me $L^{-1}$, 2.44-7.07 me $L^{-1}$ and 0.16-0.44 me $L^{-1}$, respectively. The mean exchangeable $Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$ content of soils of Kalapipal tehsil was found 21.12 me $L^{-1}$, 9.95 me $L^{-1}$, 4.04 me $L^{-1}$ and 0.26 me $L^{-1}$, respectively. The CEC of soils of Kalapipal tehsil ranged from 30.07 to 51.47 cmol $kg^{-1}$ with an average value of 35.37 cmol $kg^{-1}$ pH of soils of Kalapipal tehsil ranged from 7.22 to 8.26, with an average value of 7.70 indicating the neutral to slightly acidic nature of the studied soils. Similarly, the EC of soils of Kalapipal tehsil ranged from 0.14 to 1.94 dS $m^{-1}$ among the 101 collected samples. The mean EC of soils of Kalapipal tehsil was found to be 0.67 dS $m^{-1}$. The results revealed the non-saline nature of the studied soils. The SOC content of soils of Kalapipal tehsil ranged from 0.32% to 0.92% among the 101 collected samples. The mean SOC content of soils of Kalapipal tehsil was found to be 0.52% indicating medium SOC content in studied soils. The available N, P and K content of the soils of Kalapipal tehsil ranged from 96.6 to 392.3 kg $ha^{-1}$, 5.5 to 34.2 kg $ha^{-1}$ and 218.1-593.8 kg $ha^{-1}$, respectively among the studied samples. Further, the mean available N, P and K content of soils of Kalapipal tehsil was found 195.1 kg $ha^{-1}$, 14.7 kg $ha^{-1}$ and 393.3 kg $ha^{-1}$, respectively.**

**Keywords:** Electrical conductivity, exchangeable cation, soil physical properties, soil fertility, water soluble cation.

## INTRODUCTION

Soil is a most valuable natural resource which is vital to life of all living and non-living things on the planet (Kopittke *et al.,* 2019). Directly or indirectly, all living beings use soil for their shelter, food and other requirements. Soil is the primary medium for plant growth as it provides physical supports by anchorage

and supply necessary plant nutrients (Devkota *et al*., 2019). So, soil health in respect of soil fertility is an important parameter to promote the healthy and vigorous growth of the plants. The physical, chemical and biological properties of soil determine status of soil health. Any deterioration in soil properties within agricultural zone limits the healthy growth of plants and crops as a whole suffer. Soil fertility is an important criterion to judge the soil health also. Intensive cultivation without effective soil management depletes plant available soil nutrients from soil. In both rain-fed and irrigated systems, nutrient replenishment through fertilizers and manures remains far below the crop removal, thus causing mining of native reserves over the years.

Soil characterization, particularly soil fertility assessment of an area or a region is an important aspect in view of sustainable agricultural production (Singh *et al*., 2017). As soil nutrients, both macro as well as micro nutrients, governs the fertility of soil and controls the crop productivity (Bharti *et al*., 2017).

Now a day, soil fertility plays a key role in increasing crop production. It comprises not only in supply of nutrients but also their efficient management. The fertility status of soil indicates their nutrient supplying capability. The most important constituents in soil is organic matter, an appreciable amount of organic matter in soil tremendously increase soil fertility. Decay of organic matter release nitrogen, phosphorus and mineral nutrients in a form available to plant. Availability of N, P, K, secondary and micronutrients induce better germination of seeds and hence subsequent better growth and stronger root development. Agriculture activities change the soil chemical, physical and biological properties. The core constraints in relation to land use include, depletion of organic matter due to wide spread use of biomass as fuel, depletion of macro and micro nutrients, removal of top soil by erosion, change of physical properties and increased soil salinity. So, maintenance of organic matter status in soil is a prime importance reflects to soil fertility improvement. Continuous cropping for enhanced yield removes substantial amounts of nutrients from soil. Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (Medhe *et al.*, 2012).

## MATERIAL AND METHODS

The investigation entitled "Study on Soil Fertility Status of Kalapipal Tehsil of Shajapur District, Madhya Pradesh" carried out at Department of Soil Science and Agricultural Chemistry, College of Agriculture, Indore during 2020-2021. This chapter deals with material used and methods employed for site selection, collection of soil samples, processing and their analysis. The Kalapipal tehsil of Shajapur district is situated about 160 km away from Indore and situated at 23° 20' N 76° 85' E. Kalapipal is one of the important tehsil of Shajapur district. The Kalapipal tehsil contributes significantly with respect to the agriculture production. The soybean-wheat is the predominant cropping system of the tehsil. The normal annual rainfall of Shajapur district is 1020.2 mm. Three distinct seasons are observed: summer, monsoon and winter. Summers start in mid-March and can be extremely hot from April through June. The normal maximum temperature recorded during the month of May is 39.9° C and minimum during the month of January 9.6° C. The normal annual means maximum and minimum temperature of Shajapur district is 31.3° C and 35.5° C respectively. Total 101 surface (0-15 cm) soil samples from all grids (15 grids) of Kalapipal tehsil of Shajapur district were collected during Feb-March. Each sampling location was recorded using hand held GPS. The basic details of the sample like, name of the farmer, village, location, crops grown etc. were recorded. The details are presented in Table 1. The collected samples were brought to the Department of Soil Science, College of Agriculture, Indore. The samples were processed further for analysis of various physico-chemical properties. The analysis of physical and chemical properties of soil was carried out in the laboratory of Department of Soil Science and Agriculture Chemistry, College of Agriculture, Indore following standard methods. The particle size analysis (i.e., sand, silt and clay percent) of soil was determined by Bouyoucous hydrometer method (Bouyoucos, 1962). Soil pH was determined by using pH meter with glass electrode 1:2 soil: water suspension using pH meter with glass electrode (Piper, 1950). The supernatant solution of the soil suspension 1:2 formerly used for pH determination was used for the determination of electrical conductivity with electrical conductivity meter (Piper, 1950). The organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). Available Nitrogen was determined by alkaline permanganate method (Subbiah and Asija 1956). Twenty gram of soil samples were taken in one liter flask and to it added 100 ml of 0.32% $KMnO_4$ and 2.5% NaOH each. The flask was immediately connected to distillation assembly and heated. The distilled ammonia was collected in 0.1N $H_2SO_4$ using methyl red indicator. The excess of sulphur acid was titrated against 0.1N NaOH. Results have been expressed in N kg/ha. Available phosphorus was determined by using Olsen's extraction (0.5 N sodium bicarbonate solution of pH 8.5, Olsen *et al*. 1954). For determination of available potassium,1 gram of soil was shaken with 100 ml of neutral normal ammonium acetate solution as an extraction in 200 ml conical flask for 30 minutes and then filtered through Whatman number 1 filter paper. The amount of potassium present in extract was determined by flame photometer as described by Black (1965). The results were calculated as K kg/ha. The water soluble cation ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$) and anion ($CO_3^{2-}$, $HCO_3^{-}$, $Cl^{-}$ and $SO_4^{2-}$ ) were determined using EDTA Titration method (Richards, 1954) and Volumetric titration method (Richards, 1954), respectively. The exchangeable cations viz., $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ were determined by following standard method described by

Richards (1954). The CEC of soil was analyzed by leaching it with 1N neutral $NH_4OAc$ solution as described by Jackson (1973). Statistical analysis in respect of mean, min, max, standard deviation and correlation was computed by standard methods outlined by Panse & Sukhatme (1985).

## RESULTS AND DISCUSSION

*A. Particle size distribution in soil samples of Kalapipal tehsil*

The particle size distribution of soil samples of Kalapipal tehsil is presented in Table 1. The data revealed that the sand content of soils of Kalapipal tehsil ranged 13.7-28.7% among the 101 collected samples. The mean sand content of soils of Kalapipal tehsil was found 22.1%. The silt content of soils of Kalapipal tehsil ranged 24.4-34.6% among the 101 collected samples. The mean silt content of soils of Kalapipal tehsil was found 29.0%. The clay content of soils of Kalapipal tehsil ranged 41.4-57.5% among the 101 collected samples. The mean clay content of soils of Kalapipal tehsil was found 48.9%. The mean sand, silt and clay content of soils of Kalapipal tehsil was found 22.1%, 29.0% and 48.9%, respectively.

*B. Distribution of soil pH of Kalapipal tehsil*

The distribution of pH of soils of Kalapipal tehsil is presented in Table 2. The pH of soils of Kalapipal tehsil ranged 7.22-8.26 among the 101 collected samples. The mean pH of soils of Kalapipal tehsil was found 7.70%. The pH of the soil of Kalapipal tehsil belongs to neutral to slightly alkaline nature. Around 28.7% samples showed neutral pH whereas 71.3% samples showed slightly alkaline pH.

*C. Distribution of EC of soils of Kalapipal tehsil*

The EC of soils of Kalapipal tehsil is presented in Table 3. The EC of soils of Kalapipal tehsil ranged 0.14-1.94 dS $m^{-1}$ among the 101 collected samples. The mean EC of soils of Kalapipal tehsil was found 0.67 dS $m^{-1}$. The distribution of soil EC revealed that 13.9%, 11.9% and 74.3% samples belongs to the EC classes 0.1-0.2 dS $m^{-1}$, 0.2-0.3 dS $m^{-1}$ and >0.3 dS $m^{-1}$, respectively. The majority of soil samples showed soil EC more than 0.3 dS $m^{-1}$.

**Table 1: Particle size distribution of soil samples.**

| Parameter | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|
| **Range** | 13.7-28.7 | 24.4-34.6 | 41.4-57.5 |
| **Mean** | 22.1 | 29.0 | 48.9 |
| **SD (±)** | 3.5 | 2.1 | 3.6 |
| **CV (%)** | 15.7 | 7.2 | 7.3 |

**Table 2: Distribution of soil pH.**

| Soil pH class | No. of Samples | % Samples |
|---|---|---|
| **Strongly acid (<5.0)** | Nil | Nil |
| **Moderately acid (5.0-6.0)** | Nil | Nil |
| **Slightly acid (6.1-6.5)** | Nil | Nil |
| **Neutral (6.6-7.5)** | 29 | 28.7 |
| **Slightly alkaline (7.6-8.5)** | 72 | 71.3 |
| **General Statistics** | | |
| **Range** | | 7.22 - 8.26 |
| **Mean** | | 7.70 |
| **Standard deviation** | | 0.23 |
| **Coefficient of variation % (CV %)** | | 3.03 |

**Table 3: Distribution of soil EC.**

| EC ($dSm^{-1}$) | No. of Samples | % Samples |
|---|---|---|
| <0.1 | Nil | Nil |
| 0.1-0.2 | 14 | 13.9 |
| 0.2-0.3 | 12 | 11.9 |
| >0.3 | 75 | 74.3 |
| **General Statistics** | | |
| **Range** | | 0.14-1.94 |
| **Mean** | | 0.67 |
| **Standard deviation** | | 0.43 |
| **Coefficient of variation % (CV %)** | | 64.9 |

*D. Distribution of soil organic carbon of soils of Kalapipal tehsil*

The SOC content of soils of Kalapipal tehsil is presented in Table 4. The SOC content of soils of Kalapipal tehsil ranged 0.32-0.92% among the 101 collected samples. The mean SOC content of soils of Kalapipal tehsil was found 0.52%. The soils of Kalapipal tehsil belongs to low to medium SOC category. The low (0.25-0.50%) and medium category (0.50-0.75%) SOC accounted 38.6% and 59.4% samples, respectively. Only 02 No. of samples were found with high SOC content.

*E. Distribution of soil available N of soils of Kalapipal tehsil*

The available N content of soils of Kalapipal tehsil is presented in Table 5. The available N content of soils of Kalapipal tehsil ranged 97-392 kg $ha^{-1}$ among the 101 collected samples. The mean available N content of soils of Kalapipal tehsil was found 195 kg $ha^{-1}$. The soils of Kalapipal tehsil showed low to medium soil available N status. About 84.2% samples belong to low (<250 kg $ha^{-1}$) whereas 15.8% samples belong to medium (250-400 kg $ha^{-1}$). No sample with high available N content was found in the Kalapipal tehsil.

*F. Distribution of soil available P of soils of Kalapipal tehsil*

The available P content of soils of Kalapipal tehsil is presented in Table 6. The available P content of soils of Kalapipal tehsil ranged 5.5-34.2 kg $ha^{-1}$ among the 101 collected samples. The mean available P content of soils of Kalapipal tehsil was found 14.7 kg $ha^{-1}$. Most of the samples belongs to medium (10-20 kg $ha^{-1}$) soil available P status. The low (<10 kg $ha^{-1}$) and high (>20 kg $ha^{-1}$) status of soil available P showed in 17.8% and 14.9% samples of Kalapipal tehsil, respectively.

**Table 4: Distribution of soil organic carbon.**

| Organic carbon (%) | No. of Samples | % Samples |
|---|---|---|
| **Very Low (<0.25)** | Nil | Nil |
| **Low (0.25-0.50)** | 39 | 38.6 |
| **Medium (0.50-0.75)** | 60 | 59.4 |
| **High (>0.75)** | 2 | 2.0 |
| **Very high (>1.0)** | Nil | Nil |
| **General Statistics** | | |
| **Range** | | 0.32-0.92 % |
| **Mean** | | 0.52% |
| **Standard deviation** | | 0.11 |
| **Coefficient of variation % (CV %)** | | 21.9 |

**Table 5: Distribution of soil available N.**

| Available-N (kg $ha^{-1}$) | No. of Samples | % Samples |
|---|---|---|
| **Low (<250)** | 85 | 84.2 |
| **Medium (250-400)** | 16 | 15.8 |
| **High (>400)** | Nil | Nil |
| **General Statistics** | | |
| **Range** | | 97-392 |
| **Mean** | | 195 |
| **Standard deviation** | | 62 |
| **Coefficient of variation % (CV %)** | | 32.03 |

**Table 6: Distribution of soil available P.**

| Available-P (kg $ha^{-1}$) | No. of Samples | % Samples |
|---|---|---|
| **Low (<10.0)** | 18 | 17.8 |
| **Medium (10 - 20)** | 68 | 67.3 |
| **High (>20)** | 15 | 14.9 |
| **General Statistics** | | |
| **Range** | | 5.5-34.2 |
| **Mean** | | 14.7 |
| **Standard deviation** | | 5.3 |
| **Coefficient of variation % (CV %)** | | 36.1 |

*G. Distribution of soil available K of soils of Kalapipal tehsil*

The available K content of soils of Kalapipal tehsil is presented in Table 7. The available K content of soils of Kalapipal tehsil ranged 274-594 kg $ha^{-1}$ among the 101 collected samples. The mean available K content of soils of Kalapipal tehsil was found 398 kg $ha^{-1}$. All the samples belong to medium (250-400 kg $ha^{-1}$) to high (>400 kg $ha^{-1}$) soil available K status. These categories accounted 48.5% and 51.5% soil samples of Kalapipal tehsil, respectively.

*H. Correlations among various soil parameters*

The correlation among various soil parameters viz., pH, EC, organic carbon, and available macronutrients (N, P and K) is presented in Table 8. The data revealed that the soil parameters have significant and positive correlation. The soil electrical conductivity showed significant and positive correlation with soil available P (r=0.636). The soil organic carbon content of soil showed significant and positive correlation with soil available N (r=0.516). The soil available N showed a significant and positive correlation with soil available P (r= 0.223). Similarly, the soil available N showed positive and significant correlation with soil available K (r= 0.258). The soil available K also showed a significant and positive correlation with soil available P (r=0.283) (Table 8).

**Table 7: Distribution of soil available K.**

| Available-K (kg ha$^{-1}$) | No. of Samples | % Samples |
|---|---|---|
| **Low (<250)** | Nil | Nil |
| **Medium (250-400)** | 49 | 48.5 |
| **High (>400)** | 52 | 51.5 |
| **General Statistics** | | |
| **Range** | | 274-594 |
| **Mean** | | 398 |
| **Standard deviation** | | 69 |
| **Coefficient of variation % (CV %)** | | 17.4 |

**Table 8: Correlations among various soil parameters.**

| Parameter | pH | EC | SOC | N | P | K |
|---|---|---|---|---|---|---|
| **Ph** | 1.000 | | | | | |
| **EC** | 0.138 | 1.000 | | | | |
| **SOC** | -0.005 | 0.061 | 1.000 | | | |
| **N** | 0.097 | 0.014 | 0.516** | 1.000 | | |
| **P** | 0.076 | 0.636** | 0.007 | 0.223* | 1.000 | |
| **K** | 0.013 | 0.069 | 0.064 | 0.258** | 0.283** | 1.000 |

*Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level. P value for 0.05 and 0.01 are 0.195 and 0.254, respectively.

*I. Analysis of soil saturation extract*

**Table 9: General statistics of saturation extract (pHs, ECs, water soluble cations and anions) of soil samples.**

| Parameter | Minimum | Maximum | Mean | SD± | CV (%) |
|---|---|---|---|---|---|
| **pHs** | 7.38 | 8.43 | 7.87 | 0.24 | 3.03 |
| **ECs (dS m$^{-1}$)** | 0.94 | 1.99 | 1.62 | 0.26 | 16.12 |
| **$Ca^{++}$ (me L$^{-1}$)** | 3.23 | 15.47 | 9.78 | 2.69 | 27.53 |
| **$Mg^{++}$ (me L$^{-1}$)** | 2.32 | 9.18 | 4.64 | 1.26 | 27.22 |
| **$Na^{+}$ (me L$^{-1}$)** | 0.79 | 2.30 | 1.31 | 0.29 | 21.86 |
| **$K^{+}$ (me L$^{-1}$)** | 0.21 | 1.87 | 0.54 | 0.35 | 65.27 |
| **$CO_3^{--}$ (me L$^{-1}$)** | 0.40 | 3.33 | 1.39 | 0.54 | 38.96 |
| **$HCO_3^{-}$ (me L$^{-1}$)** | 4.75 | 12.40 | 8.36 | 1.35 | 16.15 |
| **$Cl^{-}$ (me L$^{-1}$)** | 1.66 | 9.89 | 4.56 | 2.11 | 46.23 |
| **$SO_4^{--}$ (me L$^{-1}$)** | 0.21 | 10.03 | 1.92 | 2.37 | 123.13 |

**(i) pHs.** The pH of soil saturation extract (pHs) is presented in Table 9.The pHs of the soil saturation extract of the samples collected form Kalapipal tehsil ranged 7.38-8.43 with a mean value of 7.87.

**(ii) ECe.** The EC of soil saturation extract (ECe) is presented in Table 9. The ECs of the soil saturation extract of the samples collected form Kalapipal tehsil ranged 0.94-1.99 dS m$^{-1}$ with a mean value of 1.62 dS m$^{-1}$.

**(iii)Water soluble cations ($Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$)**

**Water soluble calcium ($Ca^{++}$).** The water soluble $Ca^{++}$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $Ca^{++}$ content of soils of Kalapipal tehsil ranged 3.23-15.47 me L$^{-1}$ among the 101 collected samples. The mean water soluble $Ca^{++}$ content of soils of Kalapipal tehsil was found 9.78 me L$^{-1}$.

**Water soluble magnesium ($Mg^{++}$).** The water soluble $Mg^{++}$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $Mg^{++}$ content of soils of Kalapipal tehsil ranged 2.32-9.18 me L$^{-1}$ among the 101 collected samples. The mean water soluble $Mg^{++}$ content of soils of Kalapipal tehsil was found 4.64 me L$^{-1}$.

**Water soluble sodium ($Na^{+}$).** The water soluble $Na^{+}$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $Na^{+}$ content of soils of Kalapipal tehsil ranged 0.79-2.30 me L$^{-1}$ among the 101 collected samples. The mean water soluble $Na^{+}$ content of soils of Kalapipal tehsil was found 1.31 me L$^{-1}$.

**Water soluble potassium ($K^{+}$).** The water soluble $K^{+}$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $K^{+}$ content of soils of Kalapipal tehsil ranged 0.21-1.87 me L$^{-1}$ among the 101 collected samples. The mean water soluble $K^{+}$ content of soils of Kalapipal tehsil was found 0.54 me L$^{-1}$.

**(iv) Water soluble anions ($CO_3^{--}$, $HCO_3^{-}$, $Cl^{-}$ and $SO_4^{--}$)**

**Water soluble carbonates ($CO_3^{--}$).** The water soluble $CO_3^{--}$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $CO_3^{--}$ content of soils of Kalapipal tehsil ranged 0.40-3.33 me L$^{-1}$ among the 101 collected samples. The mean water soluble $CO_3^{--}$ content of soils of Kalapipal tehsil was found 1.39 me L$^{-1}$.

**Water soluble bi-carbonates ($HCO_3^-$).** The water soluble $HCO_3^-$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $HCO_3^-$ content of soils of Kalapipal tehsil ranged 4.75-12.40 me $L^{-1}$ among the 101 collected samples. The mean water soluble $HCO_3^-$ content of soils of Kalapipal tehsil was found 8.36 me $L^{-1}$.

**Water soluble chlorides ($Cl^-$).** The water soluble $Cl^-$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $Cl^-$ content of soils of Kalapipal tehsil ranged 1.66-9.89 me $L^{-1}$ among the 101 collected samples. The mean water soluble $Cl^-$ content of soils of Kalapipal tehsil was found 4.56 me $L^{-1}$.

**Water soluble sulphates ($SO_4^{--}$).** The water soluble $SO_4^{--}$ content of soils of Kalapipal tehsil is presented in Table 9. The water soluble $SO_4^{--}$ content of soils of Kalapipal tehsil ranged 0.21-10.03 me $L^{-1}$ among the 101 collected samples. The mean water soluble $SO_4^{--}$ content of soils of Kalapipal tehsil was found 1.92 me $L^{-1}$.

**(v) Correlation between various parameters of soil saturation extract.** The correlation between various parameters of soil saturation extract viz., pHe, ECe, water soluble cations ($Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$) and water soluble anions ($CO_3^{--}$, $HCO_3^-$, $Cl^-$ and $SO_4^{--}$) is presented in Table 10.

**Table 10: Correlation among saturation extract (pH, ECe, water soluble cations and anions).**

| Parameter | pHs | ECe | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ | $CO_3^{--}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{--}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **pHs** | 1.000 | | | | | | | | | |
| **ECe** | -0.003 | 1.000 | | | | | | | | |
| **$Ca^{++}$** | -0.146 | 0.214* | 1.000 | | | | | | | |
| **$Mg^{++}$** | 0.019 | 0.252* | 0.246* | 1.000 | | | | | | |
| **$Na^+$** | 0.013 | 0.351* | 0.469** | 0.312* | 1.000 | | | | | |
| **$K^+$** | 0.000 | 0.453** | 0.132 | 0.010 | 0.157 | 1.000 | | | | |
| **$CO_3^{--}$** | -0.093 | 0.221* | 0.286* | 0.160 | 0.256* | 0.008 | 1.000 | | | |
| **$HCO_3^-$** | -0.066 | 0.528** | 0.130 | 0.121 | 0.007 | -0.240* | 0.055 | 1.000 | | |
| **$Cl^-$** | 0.039 | 0.533** | 0.085 | 0.021 | 0.424** | 0.272** | 0.144 | 0.109 | 1.000 | |
| **$SO_4^{--}$** | -0.024 | 0.663** | 0.006 | 0.011 | 0.515** | 0.986** | 0.015 | 0.243* | 0.304** | 1.000 |

*Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level. P value for 0.05 and 0.01 are 0.195 and 0.294, respectively

The ECe of soil saturation extract showed significant positive correlation with water soluble $Ca^{++}$ (r=0.214), water soluble $Mg^{++}$ (r=0.252), water soluble $Na^+$ (r=0.351), water soluble $K^+$ (r=0.453), water soluble $CO_3^{--}$ (r=0.221), water soluble $HCO_3^-$ (r=0.528), water soluble $Cl^-$ (r=0.533) and water soluble $SO_4^{--}$ (r=0.663). The water soluble $Ca^{++}$showed significant positive correlation with water soluble $Mg^{++}$ (r=0.246), water soluble $Na^+$ (r=0.469) and water soluble $CO_3^{--}$ (r=0.286). The water soluble $Mg^{++}$showed significant positive correlation with water soluble $Na^+$ (r=0.312). The water soluble $Na^+$ showed significant positive correlation with water soluble $CO_3^{--}$ (r=0.256), water soluble $Cl^-$ (r=0.424) and water soluble $SO_4^{--}$ (r=0.515). The water soluble $K^+$ showed significant positive correlation with water soluble $Cl^-$ (r=0.272) and water soluble $SO_4^{--}$ (r=0.986) whereas it showed significant negative correlation with water soluble $HCO_3^-$ (r= -0.240). The water soluble $SO_4^{--}$ showed significant positive correlation with water soluble $HCO_3^-$ (r=0.243) and water soluble $Cl^-$ (r=0.304).

*J. Exchangeable cations and cation exchange capacity of soil*

**(i) Exchangeable cations ($Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$)**

**Table 11: General Statistics of Exchangeable Cations and CEC of Soil Samples.**

| Parameter | Min | Max | Mean | Std Dev | CV |
|---|---|---|---|---|---|
| **Ex-$Ca^{++}$ (me $L^{-1}$)** | 13.70 | 32.26 | 21.12 | 3.56 | 16.84 |
| **Ex-$Mg^{++}$ (me $L^{-1}$)** | 4.98 | 19.67 | 9.95 | 2.71 | 27.22 |
| **Ex-$Na^+$ (me $L^{-1}$)** | 2.44 | 7.07 | 4.04 | 0.88 | 21.86 |
| **Ex-$K^+$ (me $L^{-1}$)** | 0.16 | 0.44 | 0.26 | 0.05 | 19.40 |
| **CEC (cmol $kg^{-1}$)** | 30.07 | 51.47 | 35.37 | 4.45 | 12.57 |

**Exchangeable calcium ($Ca^{++}$).** The exchangeable $Ca^{++}$ content of soils of Kalapipal tehsil is presented in Table 11. The exchangeable $Ca^{++}$ content of soils of Kalapipal tehsil ranged 13.70-32.26 me $L^{-1}$ among the 101 collected samples. The mean exchangeable $Ca^{++}$ content of soils of Kalapipal tehsil was found 21.12 me $L^{-1}$.

**Exchangeable magnesium ($Mg^{++}$).** The exchangeable $Mg^{++}$ content of soils of Kalapipal tehsil is presented in Table 11. The exchangeable $Mg^{++}$ content of soils of Kalapipal tehsil ranged 4.98-19.67 me $L^{-1}$ among the 101 collected samples. The mean exchangeable $Mg^{++}$ content of soils of Kalapipal tehsil was found 9.95 me $L^{-1}$.

**Exchangeable sodium ($Na^+$).** The exchangeable $Na^+$ content of soils of Kalapipal tehsil is presented in Table 11. The exchangeable $Na^+$ content of soils of Kalapipal tehsil ranged 2.44-7.07 me $L^{-1}$ among the 101 collected

samples. The mean exchangeable $Na^+$ content of soils of Kalapipal tehsil was found 4.04 me $L^{-1}$.

**Exchangeable potassium ($K^+$).** The exchangeable $K^+$ content of soils of Kalapipal tehsil is presented in Table 11. The exchangeable $K^+$ content of soils of Kalapipal tehsil ranged 0.16-0.44 me $L^{-1}$ among the 101 collected samples. The mean exchangeable $K^+$ content of soils of Kalapipal tehsil was found 0.26 me $L^{-1}$.

**(ii) Cation exchange capacity (CEC).** The CEC of soils of Kalapipal tehsil is presented in Table 11. The CEC of soils of Kalapipal tehsil ranged 30.07-51.47 cmol $kg^{-1}$ among the 101 collected samples. The mean CEC of soils of Kalapipal tehsil was found 35.37 cmol $kg^{-1}$.

**(iii) Correlation between exchangeable cations and CEC.** The correlation between various size soil particles (sand. Silt and clay), soil exchangeable cations viz., $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$ and soil cation exchange capacity is presented in Table 12.

**Table 12: Correlations among soil particles, exchangeable cations and cation exchange capacity.**

| Parameter | Sand | Silt | Clay | Ex-$Ca^{++}$ | Ex-$Mg^{++}$ | Ex-$Na^+$ | Ex-$K^+$ | CEC |
|---|---|---|---|---|---|---|---|---|
| **Sand** | 1.000 | | | | | | | |
| **Silt** | -0.601** | 1.000 | | | | | | |
| **Clay** | -0.848** | 0.086 | 1.000 | | | | | |
| **Ex-$Ca^{++}$** | 0.013 | 0.073 | 0.348** | 1.000 | | | | |
| **Ex-$Mg^{++}$** | -0.032 | 0.095 | 0.223* | 0.531** | 1.000 | | | |
| **Ex-$Na^+$** | -0.046 | 0.104 | 0.413** | -0.264* | 0.022 | 1.000 | | |
| **Ex-$K^+$** | 0.045 | -0.036 | 0.633** | 0.258* | -0.125 | -0.007 | 1.000 | |
| **CEC** | -0.023 | -0.110 | 0.845** | 0.888** | 0.836** | 0.832** | 0.520* | 1.000 |

The data revealed that the soil sand content showed significant negative correlation with soil silt (r= -0.601) and clay (r= -0.848) content. The soil clay content showed significant positive correlation with exchangeable $Ca^{++}$ (r=0.348), exchangeable $Mg^{++}$ (r=0.223), exchangeable $Na^+$ (r=0.413), exchangeable $K^+$ (r=0.633) and CEC (r=0.845). The soil exchangeable $Ca^{++}$ showed significant positive correlation with exchangeable $Mg^{++}$ (r=0.531), exchangeable $K^+$ (r=0.258) and CEC (r=0.888) whereas it showed significant but negative correlation with exchangeable $Na^+$ (r= -0.264). The soil cation exchange capacity showed significant positive correlation with exchangeable $Mg^{++}$ (r=0.836), exchangeable $Na^+$ (r=0.832) and exchangeable $K^+$ (r=0.520).

## DISCUSSION

The results obtained under the study entitled **"**Study on Soil Fertility Status of Kalapipal Tehsil of Shajapur District, Madhya Pradesh" carried out during 2020-21 have been discussed in this chapter under following subheads:

*A. Soil Physical properties*

In investigation, the sand content of soils of Kalapipal tehsil ranged 13.7-28.7% among the 101 collected samples with an average of 22.1%. The silt content of soils of Kalapipal tehsil ranged 24.4-34.6% among the 101 collected samples. The mean silt content of soils of Kalapipal tehsil was found 29.0%. The clay content of studied soils ranged 41.4-57.5% with a mean value of 48.9%. The determination of soil particle size distribution is a basic measure of soil texture and many researchers successfully attempted. Niranjana *et al.* (2009) studied 20 pedons in Chikmagalur district of Karnataka and found that the texture of the soils varied from sandy clay loam to clay loam. Sharma *et al.* (2013) studied the soils of rice land use system of Nagaland and observed that the sand, silt and clay content of the soils ranged from 17.8 to 56.0, 22.0 to 57.0 and 14.5 to 36 %.

*B. Soil chemical properties*

The results of the study showed that the water soluble cations *viz.,* $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$ content of soils of Kalapipal tehsil ranged 3.23-15.47 me $L^{-1}$, 2.32-9.18 me $L^{-1}$, 0.79-2.30 me $L^{-1}$ and 0.21.1.87 me $L^{-1}$, respectively. The mean water soluble $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$ content of studied soils were found 9.78 me $L^{-1}$, 4.68 me $L^{-1}$, 1.31 me $L^{-1}$ and 0.54 me $L^{-1}$, respectively. Similarly, the water soluble anions viz., $CO_3^{--}$, $HCO_3^-$, $Cl^-$ and $SO_4^{--}$ content of soils of Kalapipal tehsil ranged 0.40-3.33 me $L^{-1}$, 4.75-12.40 me $L^{-1}$, 1.66-9.89 me $L^{-1}$ and 0.21-10.03 me $L^{-1}$, respectively among the studied samples. The mean water soluble $CO_3^{--}$, $HCO_3^-$, $Cl^-$ and $SO_4^{--}$ content of studied soils was found 1.39 me $L^{-1}$, 8.36 me $L^{-1}$, 4.56 me $L^{-1}$ and 1.92 me $L^{-1}$, respectively. Further, the exchangeable cations viz., $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$ content of soils of Kalapipal tehsil ranged 13.70-32.26 me $L^{-1}$, 4.98-19.67 me $L^{-1}$, 2.44-7.07 me $L^{-1}$ and 0.16-0.44 me $L^{-1}$, respectively. The mean exchangeable $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$ content of soils of Kalapipal tehsil was found 21.12 me $L^{-1}$, 9.95 me $L^{-1}$, 4.04 me $L^{-1}$ and 0.26 me $L^{-1}$, respectively. The CEC of soils of Kalapipal tehsil ranged 30.07-51.47 cmol $kg^{-1}$ with an average value of 35.37 cmol $kg^{-1}$. The water soluble cations/anions and exchangeable cations are the key elements which are responsible for cation exchange capacity. The soil fertility and weathering intensity of soil is greatly governed by the exchangeable cations. Manorama Thamptti and Jose (2000) observed that the subsurface layers showed an increase in CEC compared to surface layers for all pedons. However, present study was focused only on surface soil layer (0-15 cm).

In the study the pH of soils of Kalapipal tehsil ranged 7.22-8.26 with an average value of 7.70 indicating the neutral to slightly nature of the studied soils. Similarly, the EC of soils of Kalapipal tehsil ranged 0.14-1.94 dS

$m^{-1}$ among the 101 collected samples. The mean EC of soils of Kalapipal tehsil was found 0.67 dS $m^{-1}$. The results revealed non saline nature of the studied soils. Singh *et al*. (2009) reported normal to slightly alkaline pH (7.1 to 8.6) of the soils of district Ghazipur, Uttar Pradesh. Further they also reported that electrical conductivity varied between 0.10 and 0.38 dS $m^{-1}$. These results are in line with the findings of present investigation. Kumar *et al*. (2009) also reported wide variation in pH (4.60 to 7.70) in sandy loam soils of Santhal Paraganas Region of Jharkhand. Ram *et al*. (2010) found pH and EC value around 8.5 and > 4.0dsm$^{-1}$, respectively.

In investigation, the SOC content of soils of Kalapipal tehsil ranged 0.32-0.92% among the 101 collected samples. The mean SOC content of soils of Kalapipal tehsil was found 0.52% indicating medium SOC content in studied soils. Ram *et al*. (2010) recorded SOC content of soil varied from 0.08 to 0.23%.

The available N, P and K content of soils of Kalapipal tehsil ranged 96.6-392.3 kg $ha^{-1}$, 5.5-34.2 kg $ha^{-1}$ and 218.1-593.8 kg $ha^{-1}$, respectively among the studied samples. Further, the mean available N, P and K content of soils of Kalapipal tehsil was found 195.1 kg $ha^{-1}$, 14.7 kg $ha^{-1}$ and 393.3 kg $ha^{-1}$, respectively. Bali *et al*. (2010) studied the soils of Punjab and reported that the available phosphorus ranged from 1.12 to 238 kg $ha^{-1}$ with mean value of 42.77 kg $ha^{-1}$. Further they reported that the available K in between 33.6 to 1192 kg $ha^{-1}$. Seta *et al*. (2011) also found available K (1N $NH_4OAc$ extractable K) from 44.8 kg $ha^{-1}$ to 784 kg $ha^{-1}$. Singh and Mishra (2012) observed available potassium in the soils of Chiraigaon block of district Varanasi ranged between 134.6 and 310.4 kg $ha^{-1}$ with an average of 201.7 kg $ha^{-1}$.

*C. Correlation among various soil properties*

In correlation study, the data in present investigation revealed that the soil electrical conductivity showed significant and positive correlation with soil available P (r=0.636). The soil organic carbon content of soil showed significant and positive correlation with soil available N (r=0.516). The soil available N showed a significant and positive correlation with soil available P (r= 0.223). Similarly, the soil available N showed positive and significant correlation with soil available K (r= 0.258). The soil available K also showed a significant and positive correlation with soil available P (r=0.283). Similarly, The ECs of soil saturation extract showed significant positive correlation with water soluble $Ca^{++}$ (r=0.214), water soluble $Mg^{++}$ (r=0.252), water soluble $Na^{+}$ (r=0.351), water soluble $K^{+}$ (r=0.453), water soluble $CO_3^{--}$ (r=0.221), water soluble $HCO_3^{-}$ (r=0.528), water soluble $Cl^{-}$ (r=0.533) and water soluble $SO_4^{--}$ (r=0.663). The water soluble $Ca^{++}$ showed significant positive correlation with water soluble $Mg^{++}$ (r=0.246), water soluble $Na^{+}$ (r=0.469) and water soluble $CO_3^{--}$ (r=0.286). The water soluble $Mg^{++}$showed significant positive correlation with water soluble $Na^{+}$ (r=0.312). The water soluble $Na^{+}$ showed significant positive correlation with water soluble $CO_3^{--}$ (r=0.256), water soluble $Cl^{-}$ (r=0.424) and water soluble $SO_4^{--}$ (r=0.515). The water soluble $K^{+}$ showed significant positive correlation with water soluble $Cl^{-}$ (r=0.272) and water soluble $SO_4^{--}$ (r=0.986) whereas it showed significant negative correlation with water soluble $HCO_3^{-}$ (r= -0.240). The water soluble $SO_4^{--}$ showed significant positive correlation with water soluble $HCO_3^{-}$ (r=0.243) and water-soluble $Cl^{-}$ (r=0.304).

In the earlier studies with respect to the correlation between various soil properties, Sharma *et al*. (2008) found positive and non-significant relationship(r = 0.105) between available nitrogen content and pH in soils of Amritsar district (Punjab). Similarly, they obtained positive and non-significant correlation (r = 0.148) between available phosphorus and EC in soils. Wagmare *et al*. (2009) observed that the available N was positive and significant correlation with pH in soils of Ausha tahsil of Latur District.

## CONCLUSIONS

The soil of Kalapipal tehsil belongs to clayey texture (sand, silt and clay found 22.1%, 29.0% and 48.9%, respectively). The studied soil is neutral to slightly alkaline (pH-7.70) in reaction, non-saline (EC-0.67 dS $m^{-1}$) and medium in soil organic carbon content (0.52%). The soil available N (195.1 kg $ha^{-1}$) and P (14.7 kg $ha^{-1}$) content are medium whereas the K (393.3 kg $ha^{-1}$) content is high. The soil organic carbon content of soil showed significant and positive correlation with soil available N. The EC of soil saturation extract showed significant positive correlation with water soluble $Ca^{++}$, water soluble $Mg^{++}$, water soluble $Na^{+}$, water soluble $K^{+}$, water soluble $CO_3^{--}$, water soluble $HCO_3^{-}$ , water soluble $Cl^{-}$ and water soluble $SO_4^{--}$. The soil electrical conductivity showed significant and positive correlation with soil available P.

## FUTURE SCOPE

The study will be helpful in understanding the fertility status of the soil in the Kalapipal tehsil of Shajapur district, Madhya Pradesh, and will be helpful for future research work in that area. The soil biological properties and various carbon fractions in soils of Kalapipal tehsil may be studied. The fertilizer use pattern and soil nutrient availability of Kalapipal tehsil may be studied.

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**Conflict of Interest.** None.

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