International Journal of Chemical Studies 2019; 7(6): 810-814

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 810-814

Received: 15-09-2019
Accepted: 19-10-2019

**Sourav Choudhury**
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

**JM Patel**
Soil and Water Management Research Unit, Navsari Agricultural University, Navsari, Gujarat, India

**CS Gavit**
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

**BK Gadhavi**
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

**Mitul Saxena**
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

**Corresponding Author:**
**Sourav Choudhury**
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

# Vertical distribution of available nutrients in soils of paddy and sugarcane growing areas of Navsari district in Gujarat

**Sourav Choudhury, JM Patel, CS Gavit, BK Gadhavi and Mitul Saxena**

**Abstract**
The detailed soil survey was carried out in paddy and sugarcane growing areas of village Butlaw and Dabhalia in Navsari district during 2016-2017, using cadastral maps of the villages as base map and three pedons were studied. Soil samples were collected horizon wise and analyzed for physico-chemical properties and available nutrients status by adopting standard analytical procedures. Soils were having deep solum with the development of Ap-C2, Ap-B24ss and Ap-B23ss pedons. Soil pH was found as alkaline in the reaction without any salinity hazard. The OC content was more in surface horizons than in sub-surface horizons. CEC values show that these soils are having good nutrient supply capacity and water holding capacity. There was a presence of free $CaCO_3$ in all the pedons but the soils were non-calcareous. Available N was rated as low; available P was rated as low to high; available K was rated as low to medium; available S was rated as high; available Fe, Mn and Cu were found to be sufficient irrespective of horizons whereas available Zn was found sufficient in the upper horizons and deficient in the lower horizons. All the available nutrients were found to decrease with increasing depth.

**Keywords:** Macronutrients, micronutrients, pedon, physico-chemical

## Introduction
Soil is an important dynamic natural body that supports all sorts of living things on the earth. It is the most precious natural resource for plant growth and development. Soils, in general, are degrading day by day due to poor management and faulty land-use practices at a rate faster than their natural degeneration. It becomes crucial to protect them from further degradation as there is a concomitant decline in soil quality to produce healthy crops. Many crops are of long duration and heavy feeder of nutrients, they uptakes a considerable amount of plant nutrients from the soil. As a result, the ability of soil to supply plant nutrients is declining day by day which leads to a decline in productivity of crops. Further, intensive cropping and imbalanced use of essential plant nutrients have rendered the soils to be poor in nutrient content and deterioration in physical properties (Speir *et al*., 2004) [16] leads to restricted growth and development of the crop. The macro and micronutrients govern the fertility of the soils and control the yields of the crops. Study of physico-chemical properties and vertical distribution of available nutrients in soils to ascertain their present fertility conditions is important to maintain soil fertility and crop productivity. Such kind of study in paddy and sugarcane growing areas i.e. village Butlaw and Dabhalia of Navsari district, Gujarat has not been reported yet. Keeping all these in view, the present study has been conducted.

## Materials and Methods
### Study area
Gujarat is situated on the west coast of India and lies between $20^0$01' and $24^0$00' North latitude and $68^0$04' and $74^0$04' East longitude. Navsari district is located between $20^0$07' and $21^0$00' North latitude and $72^0$43' and $73^0$00' East longitude. The district is located in the south-eastern part of Gujarat in the coastal low land along Purna river. The study was carried out in paddy and sugarcane growing areas of village Butlaw and Dabhalia in Navsari district which was represented by three pedons viz., Butlaw-East (P1), Butlaw-West (P2), and Dabhalia (P3). Geologically this is a very young region. Accumulation of volcanic rocks principally formed by basaltic lava known as Deccan Traps is the single most important and extensive geological formation. The climate of the area is sub-humid with the mean annual rainfall of about 1623 mm. The mean monthly minimum temperature was ranging from 13.04 $^0$C during

January to 27.01 $^0$C during June with an average of 21.16 $^0$C. Similarly, the maximum temperature was varying between 29.30 $^0$C during August and 35.20 $^0$C in April with a mean value of 32.05 $^0$C. The area has Ustic soil moisture regime and Hyperthermic soil temperature regime. The district abounds in rice and sugarcane field crops with sapota mango horticultural crops.

**Soil sampling and analysis**

During the traverse based on geology, drainage pattern, surface features, slope characteristics and land use, landforms and physiographic divisions were identified. After delineating the landform on the satellite image, intensive traversing of each landform was undertaken to select the representative areas for transect study. Horizon-wise soil samples were collected from the pedons and analyzed for their physico-chemical properties and available nutrients status using standard procedures and pedons were classified according to Soil Taxonomy (Soil Survey Staff, 2014) [15].

The horizon-wise collected soil samples from the study area were dried and crushed with the help of the wooden club and passed through 2 mm sieve and stored at suitable room temperature in the laboratory of Soil and Water Management Research Unit of Navsari of Agricultural University. The stored samples were then analyzed for soil reaction ($pH_{1:2.5)}$), soil salinity ($EC_{e)}$), organic carbon (OC), cation exchange capacity (CEC), exchangeable sodium percentage (ESP), free lime ($CaCO_{3)}$), available macronutrients viz. Nitrogen (N), phosphorus ($P_2O_5$), potassium ($K_2O$) and sulphur (S) and available micronutrients viz. iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) using standard analytical methods. Soil reaction (pH) was determined by using 1:2.5 soils: water suspension with the calibrated pH meter by following the method given by Jackson (1973) [3]. The electrical conductivity of saturation extract (ECe) was determined by following the method given by Jackson (1973) [3]. Organic carbon was determined by following the modified Walkley and Black (1934) [18] method. The cation exchange capacity of the soil was evaluated by subtracting summation of water-soluble bases from the summation of neutral normal ammonium acetate extracted bases (Black *et al.* 1965) [1]. Exchangeable sodium percentage (ESP) was computed by dividing exchangeable $Na^+$ ions by CEC of soil and multiplying the same with 100. Free calcium carbonate was determined by neutralization with an acid (Piper, 1950) [16]. Available nitrogen was determined by the alkaline permanganate method as described by Subbiah and Asija (1956) [17]. Available phosphorous was determined using the spectrophotometer by following the method given by Olsen *et al.*, (1954) [5]. Available $K_2O$ was determined by Flame photometer with neutral normal ammonium acetate as an extractant following the method given by Jackson (1973) [3]. Available sulphur was determined by using 0.15% $CaCl_2$ solution following Willams and Steinbergs (1959) [20] method. Available micronutrient cations (Fe, Mn, Cu and Zn) were determined by following Lindsay and Norvell (1978) [4].

**Results and Discussion**

**Physico-chemical properties**

The variation in soil characteristics is mostly associated with variation in slope, vegetation cover, parent material etc. In this current study depth of all the three pedons was reported more than 110 cm which shows the pedons have deep solum. Slickensides were reported which formed mainly due to the differences between horizontal and vertical stress (Wilding and Tessier, 1988) [19]. The values of physico-chemical properties viz. $pH_{1:2.5}$, ECe, OC, ESP, CEC and $CaCO_3$ were determined and the data are reported here. Irrespective of the pedons and different horizons the $pH_{1:2.5}$ values were varied from 7.62 to 8.75 with a mean of 8.18. It shows that soils of the study area were alkaline in reaction. The ECe values were varied from 0.51 $dSm^{-1}$ to 2.29 $dSm^{-1}$ with a mean of 1.02 $dSm^{-1}$ which shows the soils do not have any salinity problem. Soil OC content was ranging from 0.15% to 1.83% with a mean value of 0.66% following a decreasing trend with an increase in the soil depth in all the pedons. High organic carbon content in soils might be due to the proper crop residue management and green manuring practices by the farmers of that particular area. The CEC values of the soils were ranging from 38.90 to 46.77 $cmol(p^+)kg^{-1}$ with a mean of 44.58 $cmol(p^+)kg^{-1}$ which shows these soils are having good nutrient supply capacity and water holding capacity. The mean CEC of individual pedon differed slightly from each other but the magnitude of CEC changes with depth following irregular pattern, which might be due to the presence of varying proportions of sand, silt, clay, and exchangeable $Na^+$, $Ca^{2+}$ and $Mg^{2+}$ ions (Patel, J.M., 2001). From the sodicity point of view, the ESP values were varied from 0.93 to 5.47% with a mean of 2.78% which shows that the soils do not have any sodicity hazard. There was a presence of $CaCO_3$ in all the pedons irrespective of depths and varied from 0.61% to 1.68% with a mean of 0.92% which shows the soils are non-calcareous in nature.

**Table 1:** Depth wise physico-chemical properties of the pedons

| Horizon | Depth (cm) | $pH_{(1:2.5)}$ | ECe(dS $m^{-1}$) | O.C. (%) | CEC (cmol ($p^+$) $kg^{-1}$) | ESP % | $CaCO_3$ (%) |
|---|---|---|---|---|---|---|---|
| **Pedon No. 1: Butlaw-East (Typic Haplustepts)** | | | | | | | |
| Ap | 0-25 | 7.98 | 0.79 | 1.08 | 44.65 | 1.75 | 0.61 |
| B21 | 25-50 | 8.13 | 0.82 | 0.54 | 45.93 | 1.79 | 0.73 |
| B22 | 50-70 | 8.21 | 0.61 | 0.36 | 44.90 | 1.85 | 0.88 |
| C1 | 70-90 | 7.85 | 0.51 | 0.24 | 40.87 | 1.86 | 0.65 |
| C2 | 90-110 | 7.91 | 0.51 | 0.15 | 38.90 | 1.95 | 0.97 |
| | SD± | 0.13 | 0.15 | 0.15 | 0.37 | 3.01 | 0.08 |
| | Min | 7.85 | 0.51 | 0.15 | 38.90 | 1.75 | 0.61 |
| | Max | 8.21 | 0.82 | 1.08 | 45.93 | 1.95 | 0.97 |
| | Mean | 8.01 | 0.65 | 0.48 | 43.05 | 1.84 | 0.77 |
| **Predon No. 2: Butlaw-West (Typic Haplusterts)** | | | | | | | |
| Ap | 0-25 | 7.62 | 0.65 | 1.41 | 44.18 | 0.93 | 0.68 |
| B21 | 25-50 | 7.95 | 0.72 | 0.71 | 46.02 | 1.41 | 0.76 |
| B22ss | 50-75 | 8.16 | 0.79 | 0.63 | 47.87 | 1.86 | 0.83 |
| B23ss | 75-105 | 8.46 | 0.85 | 0.54 | 44.28 | 3.18 | 0.93 |
| B24ss | 105-120 | 8.54 | 0.85 | 0.42 | 42.78 | 2.66 | 0.99 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | SD± | 0.38 | 0.09 | 0.39 | 1.96 | 0.91 | 0.13 |
| | Min | 7.62 | 0.65 | 0.42 | 42.78 | 0.93 | 0.68 |
| | Max | 8.54 | 0.85 | 1.41 | 47.87 | 3.18 | 0.99 |
| | Mean | 8.15 | 0.79 | 0.74 | 45.03 | 2.01 | 0.84 |
| **Pedon No. 3: Dabhalia (Typic Haplusterts)** | | | | | | | |
| Ap | 0-30 | 7.99 | 1.27 | 1.53 | 45.45 | 3.50 | 0.66 |
| B21ss | 30-60 | 8.30 | 1.33 | 0.51 | 46.55 | 4.21 | 0.97 |
| B22ss | 60-85 | 8.49 | 1.61 | 0.51 | 43.85 | 4.83 | 1.33 |
| B23ss | 85-110 | 8.75 | 2.29 | 0.18 | 46.77 | 5.47 | 1.68 |
| | SD± | 2.69 | 0.32 | 0.47 | 0.59 | 1.33 | 0.84 |
| | Min | 7.99 | 1.27 | 0.18 | 43.85 | 3.50 | 0.66 |
| | Max | 8.75 | 2.29 | 1.83 | 46.77 | 5.47 | 1.68 |
| | Mean | 8.38 | 1.63 | 0.76 | 45.66 | 4.50 | 1.16 |
| Overall | Min | 7.62 | 0.51 | 0.15 | 38.9 | 0.93 | 0.61 |
| | Max | 8.75 | 2.29 | 1.83 | 47.87 | 5.47 | 1.68 |
| | Mean | 8.18 | 1.02 | 0.66 | 44.58 | 2.78 | 0.92 |

## Distribution of nutrients

### Macronutrients

#### Nitrogen

The available N content in the different horizons of the pedons were found varied from 20 to 143 kg $ha^{-1}$ with a mean value of 60 kg $ha^{-1}$ (Table 2), which reflects the low available N status. Data shows that the available N content decreases with the increase in depth irrespective of horizons and pedons. Surface soils contain more available N than sub-surface soils and the reason might be due to the decreasing trend in organic carbon with depth similar results was also reported by Satish *et al*. (2018) [11].

#### Phosphorus

The available $P_2O_5$ in the pedons were found varied from 4 to 152 kg $ha^{-1}$ with a mean value of 32 kg $ha^{-1}$ (Table 2) and was rated as low to high. The higher available $P_2O_5$ was observed in the surface horizons and decreased with depth regularly. The higher levels of $P_2O_5$ found in the surface horizons which might be resulted due to continuous use of phosphatic fertilizers in soils (Singh and Mishra, 2012) [13] presence of high OC in the surface horizons. The low $P_2O_5$ content in the lower depths might be due to the fixation of released phosphorus by clay minerals and carbonates of calcium and magnesium.

#### Potassium

The available $K_2O$ content in the pedons was found varied from 134 to 259 kg $ha^{-1}$ with a mean value of 193 kg $ha^{-1}$ (Table 2) and was rated as low to medium. Available $K_2O$ level was found medium in surface horizons and decreased with the depth regularly. The highest available potassium was observed in the surface horizons and showed more or less a decreasing trend with depth (Sireesha and Naidu, 2013) [14]. Slow weathering of mica and fixation of released potassium might have resulted in low exchangeable potassium status (Ramprakash and Rao, 2002) [10] in the lower depths. The higher potassium could be attributed to more intense weathering, the release of liable K from organic residues, application of K fertilizers.

#### Sulphur

The available S in the pedons was found varied from 12 to 197 mg $kg^{-1}$ with a mean value of 55 mg $kg^{-1}$ (Table 2) and was rated as high. The clayey texture of the soils with low infiltration rate and irrigation with saline ground water might be the reasons of high S build up. Surface layers contained more available S than sub-surface layers which could be due to a higher amount of organic matter in surface layers than in deeper layers, varying in land use and parent materials (Farida, 1997) [2].

### Micronutrient

#### Iron

The available Fe in the pedons was found varied from 3.51 to 65.19 mg $kg^{-1}$ soil with a mean value of 15.15 mg $kg^{-1}$ soil (Table 2). According to the critical limit of 4.5 mg $kg^{-1}$ soil given by Lindsay and Norvell (1978) [4], the soils were rated as deficient to sufficient in available Fe content. The vertical distribution of available Fe in all the pedons shows a decreasing trend with depth. The surface horizons contain more Fe than sub-surface horizons might be due to the higher biological activity and accumulation of high organic carbon in the surface horizons. The organic carbon due to its affinity to influence the solubility and availability of iron by chelating effect might have protected the Fe from oxidation and precipitation, which consequently increased the availability of iron (Prasad and Sakal, 1991) [9].

#### Manganese

The available Mn in the pedons was found varied from 3.61 to 24.39 mg $kg^{-1}$ with a mean value of 9.43 mg $kg^{-1}$ (Table 2). According to the critical limit of 2.5 mg $kg^{-1}$ given by Lindsay and Norvell (1978) [4], the soils were rated as sufficient in available Mn content. Vertical distribution of available Mn exhibited in all the pedons a decreasing trend with depth was reported which might be due to higher biological activity and organic carbon in the surface horizons. The higher content of available Mn in surface soils might be attributed to the chelating of organic compounds released during the decomposition of organic matter.

#### Zinc

The available Zn in the pedons was found varied from 0.24 to 0.99 mg $kg^{-1}$ soil with a mean value of 0.49 mg $kg^{-1}$ soil (Table 2). Vertical distribution of Zn exhibited decreasing trend with depth in all the pedons. Considering 0.6 mg $kg^{-1}$ soil as critical level (Lindsay and Norvell, 1978) [4] for available Zn, these soils were rated as sufficient in surface horizons and deficient in sub-surface horizons in all the pedons. The relatively higher values of available Zn in the surface horizons might be attributed to variable intensity of pedogenic processes and high content of organic matter which resulted in chelating of Zn. The low available Zn in the sub-surface horizons was possibly due to high soil pH values which might have resulted in the formation of insoluble compounds of zinc or insoluble calcium zincate (Prasad *et al.*, 2009) [8].

## Copper

The available Cu in the pedons was found varied from varied from 0.84 to 7.36 mg kg$^{-1}$ soil with mean value of 3.05mg kg$^{-1}$ soil (Table 2). Vertical distribution of Cu exhibited decreasing trend with depth in all the pedons. Values found more than the critical limit of 0.2 mg kg$^{-1}$ soil as suggested by Lindsay and Norvell (1978) [4] shows the Cu sufficiency in all the pedons. Accumulation of Cu in surface horizons of all the pedons might be due to high OC content and the intensive weathering of parent material. Similar kind of relationship between Zn and OC was also reported by (Sharma *et al*., 2003) [12]. The variation observed in available nutrients within and among the pedons might be the result of variable intensity of different pedogenic processes taking place during soil development. Organic matter has been reported to play an important role in controlling the soil physico-chemical properties and availability of all the nutrients in soils. Decomposition of organic matter releases macro and micronutrients further it reduces pH of soil locally, which helps in increasing solubility of micronutrient cations in soil. The availability of micronutrient cations increases with increase in organic matter because organic matter acts as a chelating agent for complexation of these micronutrients which reduces their adsorption, oxidation and precipitation into unavailable forms.

**Table 2:** Depth wise nutrient status of the pedons

| Horizon | Depth (cm) | Available macronutrients (kg ha$^{-1}$) | | | (mg kg$^{-1}$) | Available micronutrients (mg kg$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ | S | Fe | Mn | Zn | Cu |
| **Pedon No. 1: Butlaw-East (Typic Haplustepts)** | | | | | | | | | |
| Ap | 0-25 | 118 | 76 | 259 | 23 | 31.20 | 9.68 | 0.55 | 5.96 |
| B21 | 25-50 | 51 | 13 | 231 | 15 | 7.28 | 4.64 | 0.47 | 3.12 |
| B22 | 50-70 | 41 | 10 | 196 | 19 | 9.01 | 3.61 | 0.41 | 2.31 |
| C1 | 70-90 | 31 | 8 | 149 | 19 | 5.61 | 5.55 | 0.31 | 0.93 |
| C2 | 90-110 | 20 | 7 | 134 | 16 | 7.63 | 4.26 | 0.41 | 0.84 |
| | SD± | 38.54 | 29.83 | 52.97 | 3.13 | 10.72 | 2.41 | 0.09 | 2.09 |
| | Min | 20 | 7 | 134 | 14 | 5.61 | 3.61 | 0.31 | 0.84 |
| | Max | 118 | 76 | 259 | 23. | 31.20 | 9.68 | 0.55 | 5.96 |
| | Mean | 52 | 23 | 194 | 18 | 12.15 | 5.55 | 0.43 | 2.63 |
| **Pedon No. 2: Butlaw-West (Typic Haplusterts)** | | | | | | | | | |
| Ap | P1/1 | P1/1 | P1/1 | P1/1 | P1/1 | P1/1 | P1/1 | P1/1 | P1/1 |
| B21 | 25-50 | 61 | 9 | 218 | 14 | 7.28 | 13.29 | 0.41 | 2.89 |
| B22ss | 50-75 | 61 | 10 | 204 | 13 | 6.02 | 12.52 | 0.44 | 3.36 |
| B23ss | 75-105 | 41 | 8 | 196 | 13 | 3.51 | 8.77 | 0.45 | 2.61 |
| B24ss | 105-120 | 41 | 6 | 191 | 12 | 4.77 | 8.90 | 0.43 | 1.38 |
| | SD± | 33.29 | 46.87 | 19.73 | 3.65 | 7.18 | 6.39 | 0.24 | 1.22 |
| | Min | 41 | 6 | 191 | 12 | 3.51 | 8.77 | 0.41 | 1.38 |
| | Max | 122 | 113 | 240 | 21 | 21.13 | 24.39 | 0.97 | 4.75 |
| | Mean | 65 | 29 | 210 | 15 | 8.54 | 13.57 | 0.54 | 2.99 |
| **Pedon No. 3: Dabhalia (Typic Haplusterts)** | | | | | | | | | |
| Ap | 0-30 | 143 | 152 | 218 | 197 | 65.19 | 14.19 | 0.99 | 7.36 |
| B21ss | 30-60 | 51 | 17 | 190 | 110 | 11.69 | 6.45 | 0.24 | 2.61 |
| B22ss | 60-85 | 41 | 13 | 157 | 123 | 16.1 | 8.72 | 0.52 | 3.54 |
| B23ss | 85-110 | 21 | 4 | 148 | 101 | 6.02 | 7.35 | 0.28 | 1.03 |
| | SD± | 54.12 | 70.54 | 32.07 | 43.77 | 27.27 | 3.47 | 0.34 | 2.69 |
| | Min | 21 | 4 | 148 | 101 | 6.02 | 6.45 | 0.24 | 1.03 |
| | Max | 143 | 152 | 218 | 197 | 65.19 | 14.19 | 0.99 | 7.36 |
| | Mean | 64 | 47 | 178 | 133 | 24.75 | 9.18 | 0.51 | 3.64 |
| Overall | Min | 20 | 4 | 134 | 12 | 3.51 | 3.61 | 0.24 | 0.84 |
| | Max | 143 | 152 | 259 | 197 | 65.19 | 24.39 | 0.99 | 7.36 |
| | Mean | 60 | 32 | 193 | 55 | 15.15 | 9.43 | 0.49 | 3.05 |

## Conclusion

The soils of the study area were alkaline in reaction and non-saline in terms of salinity. OC content was high in the upper horizons as compare to the lower horizons and decreased with depth regularly. Soils were having good CEC which ensures better nutrient supply and water holding capacity. Soils were low in available N, low to high in available P, low to medium in available K and high in available S. Available Fe, Mn and Cu were sufficient irrespective of pedons and horizons. However, the available Zn was sufficient in surface horizons and deficient in sub-surface horizons in all the pedons. Land-use planning should be done in the study area on the basis of physico-chemical properties and nutrient status in this soils. Supplementing the deficient nutrients through organics in combination with inorganic fertilizers will not only improves the soil health but also sustains production in these soils.

## References


1. Black CA, Evans DD, Ensminger LE, White JL, Clerk FE. Methods of soil analysis-Part 2: Chemical and Microbial Properties. American Society of Agronomy, Inc., Publisher, Madison, Wisconsin, USA, 1965.
2. Farida A. Evaluation of sulphur in some paddy growing soils of Kashmir. M. Sc. (Agri.) Thesis submitted to SKUAST Kashmir, Srinagar, 1997, 1-102.
3. Jackson ML. Soil Chemical Analysis. Oxford IBH Publishing House, Bombay, 1973, 38.
4. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of American Journal. 1978; 43:421-428.
5. Olsen SR, Cole CV, Watanable JS, Dean LA. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA circular No. 939, 1954.

6. Patel JM. Natural resources characterisation at sub watershed level (5b2d6a) through conventional and Morden techniques. M. Sc. (Agri.) Thesis submitted to N.A.U., Navsari, 2001, 1-160.
7. Piper CS. Soil and Plant Analysis, Academic Press, New York, 1950.
8. Prasad J, Ray SK, Gajbhiye KS, Singh SR. Soils of Selsura research farm in Wardha district, Maharashtra and their suitability for crops. Agropedology. 2009; 19:84-91.
9. Prasad SN, Sakal R. Availability of iron in calcareous soils in relation to soil properties. Journal of the Indian Society of Soil Science. 1991; 39:658-661.
10. Ramprakash T, Rao MS. Characterisation and classification of some soils in a part of Krishna district, Andhra Pradesh. The Andhra Agricultural Journal. 2002; 49:228-236.
11. Satish S, Naidu MVS, Ramana KV. Zzzvertical distribution of available nutrients in soils of Brahmanakotkur watershed of Kurnool district in Andhra Pradesh. International Journal of Chemical Studies. 2018; 6(5):2916-2925.
12. Sharma RP, Singh M, Sharma JP. Correlation studies on micronutrients *vis-a vis* soil properties in some soils of Nagpur district in semi-arid region of Rajasthan. Journal of the Indian Society of soil Science. 2003; 51:522-527.
13. Singh VN, Mishra BB. Pedogenetic characterization of old alluvial soils of Gendak command area of Bihar for evaluation of land suitability. Journal of the Indian society of soil science. 2012; 44(2):136-142.
14. Sireesha PVG, Naidu MVS. Studies on genesis, characterization and classification of soils in semi-arid Agro-ecological region: A case study in Banaganapalle mandal of Kurnool district, Andhra Pradesh. Journal of the Indian Society of Soil Science. 2013; 61(3):167-178.
15. Soil Survey Staff. Keys to Soil Taxonomy (Twelveth edition), USDA, Natural Resource Conservation Service, Washington, DC, 2014.
16. Spier TW, Horswell J, Mclaren RG, Fietje G, Van Schalk AP. Composted biosolids enhance fertility of sandy loam soil under dairy pasture. Biology and Fertility of Soils. 2004; 40:349-358.
17. Subbaiah BV, Asija CL. A rapid procedure for the estimation of available nitrogen in soils. Current Science. 1956; 25:32.
18. Walkley A, Black IA. An examination of the Kjeldahlmethod for determining soil organic matter. Soil Sci. 1934; 37:29-38.
19. Wilding LP, Tessier D. Vertisols: Their distribution, properties, classification and management. Texas A and M University publishing centre, college station, Texas, 1988, 55.
20. Williams CH, Steinbergs A. Methods and Analysis of Soils, Plants, Water and Fertilizers. FDCO, New Delhi. India. 1959; 58:133.