*Int.J.Curr.Microbiol.App.Sci* (2018) *7*(6): 2735-2748

*International Journal of Current Microbiology and Applied Sciences*
***ISSN: 2319-7706* Volume 7 Number 06 (2018)**
Journal homepage: http://www.ijcmas.com

**Original Research Article** https://doi.org/10.20546/ijcmas.2018.706.322

# Soil Physical, Physico-Chemical Properties of Mulugu Division Soils of Warangal District, India

**E. Narsaiah[1]*, T. Ramprakash[1], M. Chandinipatnaik[1], D. Vishnuvardhan Reddy[2] and G. Bhupal Raj[1]**

*[1]Department of Soil science and Agricultural Chemistry, [2]Department of Crop Physiology, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500030, India*

**Corresponding author*

**Keywords**

Soil physical, Physico-chemical, Nutrient status, Classification and Pedons

**Article Info**

***Accepted:***
20 May 2018
***Available Online:***
10 June 2018

**A B S T R A C T**

Six typical pedons from mulugu division of warangal district were studied for physical, physico-chemical and chemical properties of the area. The soils were moderately deep to very deep, very dark brown to strong brown in colour, gravelley sand to clay in texture and had varied structure including single grain, granular, sub-angular blocky and angular blocky. The clay content in soils varied from 1.4 to 67 per cent. The clay content increased with depth in all pedons. Silt fraction in the soils 6.7 to 32.6 per cent. The sand content in the soils under investigation varied from 8.2 to 80.6 per cent. Most of the pedons exhibited more or less an increasing trend in bulk density with depth. These soils were near slightly acidic to moderately strong alkaline in reaction, non-saline and very low to medium in organic carbon. The CEC varied from 3.9 to 59.4 c mol ($p^+$) $kg^{-1}$ soil and dominated by $Ca^{+2}$ followed by $Mg^{+2}$, $Na^+$ and $K^+$. The soils were very low to medium in available nitrogen, low to medium in available phosphorus and potassium. Available zinc was deficient to sufficient in all the horizon. The soils were defficient in available iron, copper and manganese. The soils were classified as Typic Haplustepts, Typic Haplustalfs, Typic Haplusterts, Lithic Haplustalfs, Typic Haplusterts and Vertic Haplustept.

## Introduction

In the recent past, productivity of agricultural soils worldwide in general is on the decline, which prompted the per capita availability of food grain to fall from 510 g per day in 1991 to 463 g per day in 2004. These declining trends across the world can be attributed to ever growing population, raising incomes of populous Asian nations and discovery of new uses such as bio-fuels, besides weather based abnormalities owing to climate change (Sidhu and Vatta, 2008). Under these circumstances, ensuring self sufficiency and food security are challenging tasks before the populous nations like India. Soil characterization determines the soil's individual inherent potentials and constraints for crop production besides giving detailed information about the different soil properties. Characterization and systematic classification of dominant soil groups is an essential tool and a pre-requisite for soil

fertility evaluation and efficient soil-fertilizer-water management practices and thus, crop management. The newly formed Telangana state has variable types of soils. Any progress and development in agriculture depends largely on soil resources. Maintaining soil in the state of high productivity on sustainable basis is an important for meeting basic needs of the people. Systematic study of soils is important for scientific utilization of these soils and land resources.

## Materials and Methods

The pedons from the study area in Mulugu division of warangal district, lies in Central Telangana Zone in Telangana state which lies between 17$^{o}$ 33' and 18$^{o}$ 14' North latitude and 79$^{o}$ 23' and 79$^{o}$ 59' East longitude. The study area is characterised by semi arid climatic condition, with the average rainfall of 803.2 mm (decennial average of 2004-13) of which 90.11 per cent is received during southwest monsoon, 4.80 per cent during northeast monsoon and 5.08 per cent during summer season. Mean monthly rainfall is highest in the month of July month (214.4 mm) followed by September (177.5 mm), August (164.1 mm) months.

Annual mean maximum and minimum temperatures of the district are 32.44 $^{o}$C and 23.31$^{o}$C respectively. The maximum and minimum mean monthly temperature ranges from 17.0$^{o}$C to 40.8$^{o}$C. The mean minimum temperature is recorded during December (17.0$^{o}$C) and maximum in May (40.8$^{o}$C). Mean annual air temperature of the district is 27.78 $^{o}$C. Therefore, the temperature regime of the study area was classified as isohyperthermic. Natural vegetation comprises of *Ficus* spp, Tamarind (*Tamarindus indica*), neem (*Ajadiracchta indica*), *Prosopis* and ber (*Zizyphus jujube*) are predominated trees in the study area.

## Results and Discussion

### Soil morphology

The soil morphological description of the study area will be presented in the table 2.The depth of different pedons of study area of mulugu division of Warangal district varied from 12 to 160 cm and found to have moderately shallow to very deep solum. The highest depth of pedon was observed in the horizon $BSS_3$ of pedon 2. While the lowest depth and pedon was found to be horizon of AP of pedon 4. Nasre *et al.,* (2013) noticed that soil depth is related to slope and degree of soil erosion. It was noticed that, soils developed on plateau top, escarpments, isolated hillocks and foot slopes were shallow and soils developed on undulating lands, alluvial plains and valleys were deep.

The colour of the soil pedons of the study area were varied from strong brown to gray colour. Whereas hue in the range of 2.5 YR 5 YR,7.5 YR and 10 YR, value of 3 to 6 and chroma in the range of 1 to 6 respectively. Occurrence of iron oxides at various hydrated forms might have resulted in dark brown colour to the soils (Ramprakash and Seshagiri Rao, 2002).

The texture of the pedons of study area was varied from gravelly sand to clay. Whereas in the pedons 1, 2 and 5 the texture was clay throughout depth of the profile. However, significant increase in the clay content with increasing depth of the profile was noticed in the pedons 11. In case of pedon 2, the clay content increased with depth up to three horizons and later on it decreased. In pedons 3 the texture was clay loam throughout the depth of the profile but the clay content increased with increasing depth of the profile. In case of pedons 4 and 6 the finer fractions of the increased significantly with the depth of the soil mainly due to eluviation and illuviation processes operated in the pedons.

This resulted in the formation of a distinct argillic horizon in the subsurface horizons. Sand content in the soil decreased with increasing depth in these pedons. These variations were caused by topographic position, difference in the nature of parent material, *in-situ* weathering and translocation of clay and age of soils. The variations in texture of soils were mainly associated with the differences in composition of parent material and topography (Nayak *et al.* 2002 and Sitanggang *et al.* 2006). The structure of the soil pedons size of aggregate was medium to coarse, grade was week to medium, the type of aggregate was sub-angular blocky to angular blocky structure. The blocky structures *i.e.,* sub-angular and angular blocky were attributed to the presence of higher quantities of clay fractions. Similar observations were reported by Meena *et al.* (2012) in Malwa plateau of Banswara district in Rajasthan.

The consistence of the soil pedons of mulugu division pedons 1 to 6 varied from slightly hard to hard, loose to very firm and nonsticky to non plastic and very sticks to very plastic under dry, moist and wet conditions respectively. Whereas in pedons 1, 2, 3 and 5 the consistency was very sticky to very plastic in most of the horizons indicating the predominance of higher content of high active clays. Presence of loose, friable and non-sticky and non-plastic or slightly sticky and slightly plastic consistency might be due to negligible or very small amount of expanding clay minerals. Satyavathi and Suryanarayana Reddy (2004) reported similar consistency in soils of Telangana at different soil moisture limits. Whereas in the pedon 4 and 6 were non sticky to non plastic and slightly sticky to slightly plastic in dry, moist and wet condition respectively. Sticky and plastic to very sticky and very plastic, firm to very firm and slightly hard to very hard consistence in wet, moist and dry conditions, respectively might be due to high clay content of the soils. Similar observations were also made by Leelavathi *et al.* (2009) in soils of Yerpedu mandal of Chittoor district in Andhra Pradesh.

## Soil physical properties

The detailed Physical properties of the study area of Mulugu division of Warangal district presented in table 3. The sand percentage of the pedons varied from 8.2 to 80.6 per cent The highest sand percentage was found in pedon 6 (80.6 per cent) horizon of (AP) where as the lowest sand percentage was observed in pedon 5 (15.2 per cent) horizon of (BW2). Higher sand content in these surface soils could be attributed loss of finer fractions of soils due to erosion, movement of clay to deeper horizons due illuviation and more active chemical weathering in the lower horizons due to better availability of moisture. Similar findings were also reported by Basavaraju *et al.* (2005).

The silt content varied from 6.7 to 32.6 per cent. The highest silt percentage was observed in pedon 2 of BSS3 and lowest percentage of silt was observed in the pedon 6. This might be due to variation in weathering of parent material or *in situ* formation. These results were in agreement with the findings of Satish Kumar and Naidu (2012a).

The clay content varied from 1.4 to 67.0 per cent**.** The highest the clay percent was recorded in the pedon 5 horizon of BSS3 (67.0 per cent) and lowest clay percentage was recorded in the pedon 4 of the AP horizon (1.4 percent). Increase in clay content with depth might be due to more intensive chemical weathering at deeper layer and eluviation of finer particles from surface horizon leaving behind coarse particles in surface layers. The enrichment of clay in Bw and Bss horizons of pedons 1, 2, 3 and 5 was primarily due to *in situ* weathering of parent material. Satish

Kumar and Naidu (2012a) in soils of Vadamalapeta mandal of Chittoor district. The increase in clay content in the Bt horizon in the pedons 4 and 6 is mainly due to illuviation of the clay form the upper horizons. Similar enrichment Bt horizons with the clay content was reported by Ramprakash and Rao (2002) in Krishna district of Andhra Pradesh. The bulk density of different pedons varied from 1.38 to 1.78 Mg $m^{-3}$. The higher bulk density values in some pedons may be due to high clay content resulting in greater compaction in swelling clay soils. Similar results were reported by Ashokkumar and Jagdish Prasad (2010) who reported higher bulk density values in the soils of Ahmadnagar district of Maharashtra. The particle density of different pedons varied from 2.55 to 2.65 Mg $m^{-3}$. Not much variation in the particle density was recorded among different pedons. No regular increasing or decreasing trend was recorded in particle density in any of the pedons studies in the Warangal district. The saturated hydraulic conductivity was ranged from 0.1 to 14.65 cm $hr^{-1}$. The highest hydraulic conductivity was recorded in the pedon 6 horizon of AP and lowest value of hydraulic conductivity. In all the pedons hydraulic conductivity decreased with increasing depth of the soil. Similar results were earlier reported by Ramprakash and Seshagiri Rao (2002) in Vertisols and Alfisols of Krishna district. Increasing compaction of soil with the depth resulting increasing bulk density, decreasing pore density might have resulted in reduction of the hydraulic conductivity with depth in all the studies pedons. Available water content in the study area ranged from 2.8 to 19.4 per cent. The highest AWC was observed in BSS3 horizon of pedon 5. While the lowest value of Available water content was observed in AP horizon of pedon 4. These differences in water holding capacity were due to variation in the depth, clay, silt and organic carbon content of the pedons. These results match with those of Thangasamy *et al.* (2005) in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh.

## Soil physico-chemical properties

The detailed Physico-chemical properties of the study area of Mulugu division of Warangal district presented in table 4. The soil reaction of the study area was ranged from 6.3 to 8.9 *i.e.,* slightly acidic to strongly alkaline in reaction. The highest value of pH was observed in pedon 2 of BSS2 horizon and while the lowest pH was found in pedon 4 horizon of Bt1 horizon. The near neutral to very strongly alkaline pH may be attributed to the reaction of applied fertilizer material with soil colloids, which resulted in the retention of basic cations on the exchange complex of the soil. Similar results were also reported by Sharma *et al.* (2011).

The electrical conductivity ranged from 0.14 to 1.15 $dSm^{-1}$. The highest value of 1.15 $dSm^{-1}$ was recorded in BSS2 horizon of pedon 5 and the lowest electrical conductivity was observed in horizon of Bt1 of pedon 6 indicating non-saline in nature. The results in the present study indicate the non-saline nature of soils. The lower electrical conductivity in soils was due to excess leaching of salts and due to free drainage conditions which favoured the removal of released bases by percolating and drainage water. Similar results were observed by Ramprasad *et al*. (2013).

The organic carbon content in study area was found to be very low to medium and ranged from 0.19 to 0.82 per cent. The highest Organic carbon content was recorded in AP horizon of pedon 5 and where as the lowest Organic carbon content was recorded in AP horizon of pedon 3. Organic carbon content in all the pedons showed a decreasing trend with depth. Almost all the pedons showed a decreasing trend in organic carbon with depth,

which may be due to the fact that the surface horizons showed more organic matter content than sub-surface horizons due to the addition of plant residues and farm yard manure to surface horizons which resulted in higher organic carbon content in surface horizons than in the lower horizons. This observation was in accordance with results of Basavaraju *et al*., (2005) in soils of Chandragiri mandal in Chittoor district of Andhra Pradesh.

The $CaCO_3$ content in soil under study area ranged from 1.2 to 12.1 per cent. The highest value of $CaCO_3$ content was observed in the BW3 horizon of pedon 3 and where as the lowest value of $CaCO_3$ content was found in the horizon of BW2 pedon1. Higher contents of $CaCO_3$ observed in the lower horizons of most of the pedons might be due to high clay content which led to impeded leaching, consequently accumulation of $CaCO_3$ in the lower horizons. Similar results were reported by Ramprakash and Seshagiri Rao (2002) in soils of Krishna district, Andhra Pradesh.

The CEC value of in the study area ranged from 3.9 to 59.4 C mol (p+) $Kg^{-1}$ of soil. The highest CEC was observed in the horizon of $BSS_3$ of pedon 5 and while the lowest CEC was found in the horizon of AP horizon of pedon 6. The higher CEC values observed throughout the soil depth in the pedons 5 was due to illuvial accumulation of clay and also because of dominance of smectite clay mineral. These findings were amply supported by the observations of Satish Kumar and Naidu (2012) and Leelavathi *et al.,* (2010). Relatively low CEC is the reflection of parent material and higher degree of weathering leading to depletion of bases. Further, it may be due to dominance of clay minerals with low CEC especially illite and kaolinite. Similar findings were observed by Patil and Jagdish Prasad (2004) and Gangopadhyay *et al.* (2001)

**Table.1** Landscape characteristics of pedons

| Pedon | Location | Elevation above mean sea level (m) | Physiography | Slope (%) | Drainage | Parent material |
|---|---|---|---|---|---|---|
| 1 | Venkatapur | $18^0$14‘16.59”N $79^0$59‘12.91”E | Valley | 0-1 very slightly eroded | Moderately well drained | Sand stone |
| 2 | Mulugu | $17^0$33‘34.60”N $79^0$46‘04.06”E | Very gently sloping pediplain | 1-2 | Poorly drained | Weathered basalt |
| 3 | Ghanpur | $17^0$51‘19.27”N $79^0$23‘06.19”E | Very gently broad valley | 0–3 Moderately eroded | Important drainage | Alluvium Calluvium of lime stone |
| 4 | Chityal | $17^0$32‘37.27”N $79^0$37‘02.25”E | Gently sloping | 1-3 Moderately eroded | Moderately well drained | Granite gneiss |
| 5 | Regonda | $18^0$14‘14.72”N $79^0$46‘04.06”E | Gently sloping | 0-05 Slightly eroded | Poorly drained | Weathered lime stone |
| 6 | Atmakur (Wgl) | $18^0$00‘57.12”N $79^0$36‘10.72”E | Slightly evoded pediplain | <1 Slightly eroded | Poorly drained | Weathered lime stone |

**Table.2** Soil morphological description of Mulugu division of Warangal district in Telangana State

| Horizon | Depth (cm) | Soil colour | Texture | Structure | | | Consistence | | | Efferve-scence | Boundary | | Concretions $CaCO_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Moist | | S | G | T | Dry | Moist | Wet | | D | T | Q | S |
| **Pedon 1** | | | | | | | | | | | | | | |
| **Ap** | 0-22 | 10.0YR 6/2 | sl | m | 2 | sbk | sh | fr | sopo | eo | c | s | - | - |
| **Bw1** | 22-55 | 7.5YR 5/8 | gscl | m | 2 | sbk | sh | fr | ssps | eo | c | s | - | - |
| **Bw2** | 55-87 | 7.5YR 5/8 | gscl | m | 2 | sbk | sh | fr | ssps | eo | c | s | f | f |
| **Cr** | 87+ | 7.5YR 5/8 | Weathered Parent Material | | | | | | | | | | | |
| **Pedon 2** | | | | | | | | | | | | | | |
| **Ap** | 0-26 | 10.0YR 3/2 | c | c | 2 | sbk | h | fi | ssps | e | c | s | f | f |
| **Bw** | 26-51 | 10.0YR 3/2 | c | m | 2 | sbk | h | fi | sssp | e | c | s | c | f |
| **Bss1** | 51-86 | 10.0YR 3/2 | c | m | 2 | sbk | sh | fi | sp | es | g | w | c | f |
| **Bss2** | 86-125 | 10.0YR 3/2 | gc | m | 2 | abk | sh | fi | sp | es | g | s | c | f |
| **Bss3** | 125-160 | 10.0YR 5/4 | gc | m | 2 | abk | sh | fi | sp | es | - | - | m | f |
| **Pedon 3** | | | | | | | | | | | | | | |
| **Ap** | 0-22 | 10.0YR 4/2 | cl | c | 2 | sbk | - | fr | sp | e | g | s | f | f |
| **Bw1** | 22-45 | 10.0YR 3/3 | cl | m | 2 | sbk | - | fi | sp | e | g | s | f | f |
| **Bw2** | 45-72 | 10.0YR 3/2 | cl | m | 2 | sbk | - | fi | sp | ev | g | s | c | f |
| **Bw3** | 72-118 | 10.0YR 3/3 | cl | m | 2 | sbk | - | fi | sp | ev | g | s | c | f |
| **Bw4** | 118-150 | 10.0YR 3/3 | cl | m | 2 | sbk | - | fi | sp | e | - | - | f | f |
| **Pedon 4** | | | | | | | | | | | | | | |
| **Ap** | 0-12 | 5.0YR 5/4 | gsl | m | 1 | sbk | - | fr | sopo | eo | c | s | - | - |
| **Bt1** | 12-28 | 2.5YR 3/2 | gsc | m | 1 | sbk | - | fr | sps | eo | g | S | - | - |
| **Bt2** | 28-42 | 2.5YR 3/4 | gc | m | 1 | sbk | - | fr | sp | eo | c | s | - | - |
| **Cr** | 42+ | Weathered Parent Material | | | | | | | | | | | | |
| **Pedon 5** | | | | | | | | | | | | | | |
| **Ap** | 0-25 | 10.0YR 4/1 | gc | m | 2 | sbk | h | fi | vsvp | es | c | s | m | f |
| **Bw1** | 25-57 | 10.0YR 3/2 | gc | m | 3 | sbk | vh | vfi | vsvp | es | c | s | m | f |
| **Bss1** | 57-96 | 10.0YR 4/1 | gc | c | 3 | abk | vh | vfi | vsvp | es | c | s | c | f |
| **Bss2** | 96-120 | 10.0YR 4/1 | gc | c | 3 | abk | exh | efi | vsvp | es | g | s | m | f |
| **Bss3** | 120-155 | 10.0YR 3/3 | gc | c | 3 | abk | eh | efi | vsvp | es | - | - | m | f |
| **Pedon 6** | | | | | | | | | | | | | | |
| **Ap** | 0-16 | 7.5YR 4/3 | gls | m | 1 | sbk | - | fr | sp | eo | c | s | - | - |
| **Bt1** | 16-32 | 2.5YR 5/4 | gscl | m | 2 | sbk | - | fr | sp | eo | c | S | - | - |
| **Bt2** | 32-58 | 2.5YR 3/6 | gscl | m | 2 | sbk | - | fr | sp | eo | c | s | - | - |
| **BC** | 58-102 | 2.5YR 5/6 | gscl | m | 2 | sbk | - | fr | sp | eo | c | s | - | - |
| **Cr** | 102-117 | Weathered Parent Material | | | | | | | | | | | | |

**Table.3** Soil physical properties of Mulugu division of Warangal district in Telangana State

| Pedon No. & Horizon | Depth (cm) | Sand (%) (0.2-0.05 mm) | Silt (%) (0.5 mm) | Clay (%) (< 0.002 mm) | Bulk density (Mg $m^{-3}$) | Particle density (Mg $m^{-3}$) | Hydraulic Conductivity (cm $hr^{-1}$) | Water retention | | Available Water Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 33 Kpa | 1500 Kpa | |
| **P1** | | | | | | | | | | |
| **Ap** | 0-22 | 70.5 | 11.5 | 18 | 1.41 | 2.65 | 8.8 | 10.6 | 6.1 | 4.5 |
| **Bw1** | 22-55 | 65 | 14.5 | 20.5 | 1.46 | 2.6 | 6.5 | 11.9 | 7.1 | 4.8 |
| **Bw2** | 55-87 | 62.8 | 14.6 | 22.6 | 1.46 | 2.65 | 6.4 | 15.9 | 8.6 | 7.3 |
| **Cr** | 87+ | Weathered Parent Material | | | | | | | | |
| **P2** | | | | | | | | | | |
| **Ap** | 0-26 | 35.5 | 7.5 | 56 | 1.65 | 2.65 | 1.4 | 31.8 | 20.8 | 11 |
| **Bw** | 26-51 | 29.5 | 15.5 | 55 | 1.68 | 2.61 | 1.1 | 30.6 | 19.4 | 11.2 |
| **Bss1** | 51-86 | 25.5 | 16.5 | 58 | 1.71 | 2.63 | 0.65 | 31.5 | 22.1 | 9.4 |
| **Bss2** | 86-125 | 23.7 | 26.8 | 49.5 | 1.77 | 2.62 | 0.38 | 28.6 | 19.4 | 9.2 |
| **Bss3** | 125-160 | 19.3 | 32.6 | 48.1 | 1.77 | 2.65 | 0.21 | 28.1 | 18.1 | 10 |
| **P3** | | | | | | | | | | |
| **Ap** | 0-22 | 42.3 | 23.5 | 34.2 | 1.41 | 2.65 | 4.21 | 22.1 | 13 | 9.1 |
| **Bw1** | 22-45 | 43.7 | 19.7 | 36.6 | 1.41 | 2.64 | 3.21 | 23.2 | 13.8 | 9.4 |
| **Bw2** | 45-72 | 41.9 | 20.7 | 37.4 | 1.52 | 2.59 | 2.84 | 23.2 | 14.1 | 9.1 |
| **Bw3** | 72-118 | 39.7 | 17.8 | 42.5 | 1.56 | 2.65 | 2.1 | 26.2 | 16.2 | 10 |
| **Bw4** | 118-150 | 41.2 | 15.7 | 43.1 | 1.62 | 2.6 | 1.9 | 27.8 | 17 | 10.8 |
| **P4** | | | | | | | | | | |
| **Ap** | 0-12 | 78.7 | 10.9 | 10.4 | 1.45 | 2.63 | 12.5 | 6.1 | 3.3 | 2.8 |
| **Bt1** | 12-28 | 55.5 | 12.7 | 31.8 | 1.48 | 2.62 | 7.45 | 14.3 | 9.6 | 4.7 |
| **Bt2** | 28-42 | 42.9 | 13.8 | 43.3 | 1.59 | 2.65 | 4.65 | 19.8 | 13 | 6.8 |
| **Cr** | 42+ | Weathered Parent Material | | | | | | | | |
| **P5** | | | | | | | | | | |
| **Ap** | 0-25 | 9.5 | 29.3 | 61.2 | 1.56 | 2.63 | 1.21 | 33.8 | 22.7 | 11.1 |
| **Bw1** | 25-57 | 8.9 | 26.9 | 64.2 | 1.61 | 2.57 | 1.02 | 38.9 | 23.5 | 15.4 |
| **Bss1** | 57-96 | 8.7 | 26.7 | 64.6 | 1.62 | 2.65 | 0.65 | 40.1 | 23.8 | 16.3 |
| **Bss2** | 96-120 | 8.5 | 25.9 | 65.6 | 1.62 | 2.55 | 0.31 | 43.2 | 24.3 | 18.9 |
| **Bss3** | 120-155 | 8.2 | 24.8 | 67 | 1.78 | 2.65 | 0.1 | 44.5 | 25.1 | 19.4 |
| **P6** | | | | | | | | | | |
| **Ap** | 0-16 | 80.6 | 8.3 | 11.1 | 1.39 | 2.65 | 14.65 | 6.5 | 3.3 | 3.2 |
| **Bt1** | 16-32 | 63.7 | 7.9 | 28.4 | 1.38 | 2.56 | 10.2 | 14.8 | 8.4 | 6.4 |
| **Bt2** | 32-58 | 54.8 | 6.7 | 38.5 | 1.48 | 2.63 | 8.8 | 19.6 | 11.4 | 8.2 |
| **BC** | 58-102 | 68.7 | 7.5 | 23.8 | 1.52 | 2.58 | 5.6 | 15.2 | 7.1 | 8.1 |
| **Cr** | 102-117 | Weathered Parent Material | | | | | | | | |

**Table.4** Soil physico- chemical properties of Mulugu division of Warangal district in Telangana State

| Pedon No. & Horizon | Depth (cm) | pH (1:2.5) | EC (dS $m^{-1}$) | Organic carbon g $kg^{-1}$ | $CaCO_3$ (%) | CEC [c mol (p+) $kg^{-1}$] | Exchangeable bases [c mol (p+)$kg^{-1}$] | | | | Base Saturation (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | |
| **Pedon 1** | | | | | | | | | | | |
| **Ap** | 0-22 | 7.3 | 0.18 | 0.59 | - | 13.2 | 8.9 | 3.9 | 0 | 0.3 | 99.24 |
| **Bw1** | 22-55 | 7.4 | 0.28 | 0.32 | - | 14.2 | 9.8 | 3.8 | 0.1 | 0.4 | 99.3 |
| **Bw2** | 55-87 | 7.7 | 0.35 | 0.26 | 1.2 | 15.4 | 10.8 | 3.9 | 0.1 | 0.4 | 98.7 |
| **Cr** | 87+ | Weathered Parent Material | | | | | | | | | |
| **Pedon 2** | | | | | | | | | | | |
| **Ap** | 0-26 | 7.9 | 0.23 | 0.6 | 2.8 | 36.5 | 24.2 | 11.7 | 0 | 0.6 | 100 |
| **Bw** | 26-51 | 8.1 | 0.25 | 0.51 | 3.7 | 34.2 | 22.6 | 11.2 | 0.1 | 0.3 | 100 |
| **Bss1** | 51-86 | 8.2 | 0.29 | 0.35 | 8.5 | 33.6 | 21.6 | 11.3 | 0.4 | 0.3 | 100 |
| **Bss2** | 86-125 | 8.9 | 0.42 | 0.26 | 8.8 | 31.9 | 20.2 | 11 | 0.5 | 0.2 | 100 |
| **Bss3** | 125-160 | 8.8 | 0.58 | 0.26 | 9.6 | 30.5 | 19.5 | 10.3 | 0.5 | 0.2 | 100 |
| **Pedon 3** | | | | | | | | | | | |
| **Ap** | 0-22 | 7.8 | 0.15 | 0.76 | 1.6 | 20.5 | 13.5 | 6.2 | 0.4 | 0.4 | 100 |
| **Bw1** | 22-45 | 7.9 | 0.35 | 0.44 | 1.8 | 21.6 | 14.2 | 6.7 | 0.4 | 0.3 | 100 |
| **Bw2** | 45-72 | 8.1 | 0.32 | 0.38 | 12 | 23.1 | 16.4 | 6.2 | 0.3 | 0.2 | 100 |
| **Bw3** | 72-118 | 8.3 | 0.29 | 0.26 | 12.1 | 24.8 | 17.8 | 6.3 | 0.5 | 0.2 | 100 |
| **Bw4** | 118-150 | 7.9 | 0.25 | 0.19 | 11 | 26.4 | 18.9 | 6.7 | 0.6 | 0.2 | 100 |
| **Pedon 4** | | | | | | | | | | | |
| **Ap** | 0-12 | 6.5 | 0.15 | 0.38 | - | 6.1 | 2.5 | 1.1 | 0 | 0.2 | 62.3 |
| **Bt1** | 12-28 | 6.3 | 0.16 | 0.52 | - | 16.2 | 7.8 | 3.1 | 0 | 0.1 | 67.9 |
| **Bt2** | 28-42 | 6.8 | 0.18 | 0.58 | - | 20.1 | 10.6 | 4.2 | 0.1 | 0.1 | 74.63 |
| **Cr** | 42+ | Weathered Parent Material | | | | | | | | | |
| **Pedon 5** | | | | | | | | | | | |
| **Ap** | 0-25 | 7.9 | 0.39 | 0.82 | 7.7 | 51.8 | 32.1 | 17.8 | 1.3 | 0.6 | 100 |
| **Bw1** | 25-57 | 8.2 | 0.47 | 0.54 | 7.5 | 53.2 | 28.8 | 21.5 | 2.4 | 0.5 | 100 |
| **Bss1** | 57-96 | 8.2 | 0.55 | 0.36 | 7 | 55.7 | 26.4 | 24.4 | 4.5 | 0.4 | 100 |
| **Bss2** | 96-120 | 8.3 | 1.15 | 0.25 | 7.4 | 56.9 | 24.8 | 22.8 | 8.9 | 0.4 | 100 |
| **Bss3** | 120-155 | 8.4 | 1.09 | 0.24 | 7.8 | 59.4 | 23.1 | 25.6 | 10.5 | 0.2 | 100 |
| **Pedon 6** | | | | | | | | | | | |
| **Ap** | 0-16 | 7.2 | 0.15 | 0.32 | - | 3.9 | 1.6 | 0.6 | 0 | 0.1 | 59.49 |
| **Bt1** | 16-32 | 6.6 | 0.14 | 0.58 | - | 11.6 | 5.6 | 1.9 | 0 | 0.1 | 65.6 |
| **Bt2** | 32-58 | 6.7 | 0.19 | 0.42 | - | 14 | 6.8 | 2.4 | 0.1 | 0.2 | 68 |
| **BC** | 58-102 | 6.9 | 0.16 | 0.28 | - | 12.8 | 8.4 | 3.1 | 0.2 | 0.3 | 93.75 |
| **Cr** | 102+ | Weathered Parent Material | | | | | | | | | |

**Table.6** Available major nutrients (kg $ha^{-1}$) and micronutrient status (mg $kg^{-1}$) of Mulugu division soils of Warangal district

| Pedon No. & Horizon | Depth (cm) | Available macronutrients | | | Available micronutrients | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Cu | Fe | Mn |
| | | kg $ha^{-1}$ | | | mg $kg^{-1}$ | | | |
| **Pedon 1** | | | | | | | | |
| **Ap** | 0-22 | 270 | 18.5 | 350 | 0.48 | 0.79 | 12.5 | 25.2 |
| **Bw1** | 22-55 | 189 | 11.5 | 285 | 0.39 | 0.68 | 9.6 | 16.5 |
| **Bw2** | 55-87 | 162 | 9.5 | 215 | 0.22 | 0.46 | 9.4 | 15.2 |
| **Cr** | 87+ | Weathered Parent Material | | | | | | |
| **Pedon 2** | | | | | | | | |
| **Ap** | 0-26 | 285 | 22.5 | 320 | 0.56 | 0.9 | 8.8 | 10.06 |
| **Bw** | 26-51 | 175 | 19.5 | 280 | 0.49 | 0.86 | 6.8 | 9.2 |
| **Bss1** | 51-86 | 164 | 17.5 | 250 | 0.38 | 0.82 | 4.2 | 8.4 |
| **Bss2** | 86-125 | 155 | 18.5 | 192 | 0.41 | 0.72 | 6.6 | 8.2 |
| **Bss3** | 125-160 | 145 | 17.5 | 165 | 0.32 | 0.63 | 5.5 | 7.9 |
| **Pedon 3** | | | | | | | | |
| **Ap** | 0-22 | 245 | 23.5 | 360 | 0.56 | 0.88 | 8.8 | 10.6 |
| **Bw1** | 22-45 | 178 | 16.5 | 325 | 0.49 | 0.68 | 6.8 | 9.2 |
| **Bw2** | 45-72 | 185 | 13.5 | 295 | 0.38 | 0.45 | 4.2 | 8.4 |
| **Bw3** | 72-118 | 262 | 10.5 | 264 | 0.41 | 0.66 | 6.6 | 8.2 |
| **Bw4** | 118-150 | 195 | 17.5 | 250 | 0.32 | 0.58 | 5.8 | 7.9 |
| **Pedon 4** | | | | | | | | |
| **Ap** | 0-12 | 296 | 19.5 | 345 | 0.44 | 0.72 | 3.2 | 9.5 |
| **Bt1** | 12-28 | 265 | 16.1 | 315 | 0.36 | 0.56 | 4.6 | 6.5 |
| **Bt2** | 28-42 | 185 | 14.1 | 295 | 0.35 | 0.42 | 6.2 | 9.2 |
| **Cr** | 42+ | Weathered Parent Material | | | | | | |
| **Pedon 5** | | | | | | | | |
| **Ap** | 0-25 | 274 | 15.5 | 356 | 0.41 | 0.48 | 7.6 | 15.2 |
| **Bw1** | 25-57 | 185 | 12.5 | 296 | 0.39 | 0.42 | 6.6 | 12.6 |
| **Bss1** | 57-96 | 165 | 10.5 | 185 | 0.24 | 0.22 | 5.2 | 10.3 |
| **Bss2** | 96-120 | 155 | 4.5 | 176 | 0.19 | 0.19 | 4.6 | 10.2 |
| **Bss3** | 120-155 | 140 | 5.5 | 156 | 0.19 | 0.18 | 5 | 11.2 |
| **Pedon 6** | | | | | | | | |
| **Ap** | 0-16 | 295 | 19.5 | 345 | 1.29 | 3.9 | 10.9 | 10.23 |
| **Bt1** | 16-32 | 255 | 9.5 | 285 | 1.1 | 2.15 | 10.21 | 10.23 |
| **Bt2** | 32-58 | 185 | 7.6 | 195 | 0.7 | 1.65 | 7.65 | 9.87 |
| **BC** | 58-102 | 165 | 6.5 | 175 | 0.34 | 1.55 | 6.65 | 6.91 |
| **Cr** | 102-117 | Weathered Parent Material | | | | | | |

**Table.5** Soil classification of the study area

| Pedon No. | Order | Sub-order | Great group | Sub-group | Family | Tentative soil series |
|---|---|---|---|---|---|---|
| 1 | Inceptisols | Ustepts | Haplustepts | Typic Haplustept | Loamy-skeletal, mixed, isohyperthermic Typic Haplustept | Venkatapur |
| 2 | Vertisol | Usterts | Haplusterts | Typic Haplusterts | Fine, smectitic, isohyperthermic, Typic Haplusterts | Mulugu |
| 3 | Inceptisols | Vertic | Haplustepts | Vertic Haplustept | Fine, smectitic, isohyperthermic Vertic Haplustept | Ghanpur |
| 4 | Alfisols | Ustalfs | Haplustalfs | Lithic Haplustalfs | Loamy-skeletal, mixed, isohyperthermic Lithic Haplustalfs | Chityal |
| 5 | Vertisols | Usterts | Haplusterts | Typic Haplusterts | Very fine, smectitic, isohyperthermic Typic Haplusterts | Regonda |
| 6 | Alfisols | Ustalfs | Haplustalfs | Typic Haplustalfs | Loamy-skeletel, mixed, isohyperthermic, Typic Haplustalfs | Malyal |

The exchangeable bases in all the pedons found to be in the order of $Ca^{2+}$ >$Mg^{2+}$ >$Na^{+}$ > $K^{+}$ on the exchangeable complex. The percent base saturation on the exchange complex of soil under investigated area varied from 59.49 to 100 per cent. Comparatively exchangeable bases in the present study were more or less in the order of Vertisols > Inceptisols > Alfisols. The basic cations content was low in Entisols which might be due to less clay and high silica content. Similar observations were earlier made by Sarkar *et al.* (2001) and Arun Kumar *et al.* (2002). Relatively higher exchangeable Ca was observed in surface horizons of some pedons which might be due to redistribution of $Ca^{2+}$ by the vegetation. These observations were in agreement with the findings of Patil and Jagdish Prasad (2004).

## Soil classification

The detailed classification of the study area of Mulugu division of Warangal district presented in table 5. Based on morphological, physical, physico-chemical, mineralogical and meteorological data, the soils in the study area of Mulugu division of Warangal district were classified as Alfisols, Inceptisols and Vertisols.

Following features in the sub-surface horizons within a depth of 69 to 160 cm in pedon 1 (with a thickness of >15 cm) were observed. Did not have anthropic, histic, melanic, mollic, plaggen and umbric epipedons. Absence of duripan, fragipan, argillic, calcic, gypsic, natric, oxic, petro-calcic, petro-gypsic, placic and spodic sub-surface horizons. The pedons did not exhibit intergradation with other taxa or an extragradation from the central concept. Hence, pedons 1 was logically classified as Loamy-skeletal, mixed, isohyperthermic Typic Haplustept Typic Haplustepts at sub-group level. Niranjana *et al.* (2011) classified banana growing soils in Pulivendla region of Andhra Pradesh as Typic Haplustepts at sub-group level.

The pedon 2 had shown the following characteristics, Cracks that are opened and closed periodically, Intersecting slicken-sides and / or wedge shaped aggregates and pressure faces, More than 30 per cent clay (weighted mean) in the fine earth fraction of all the horizons, Absence of lithic contact within 100 cm of the mineral soil surface, Absence of calcic, halic, salic and sodic horizons. Hence, pedons were classified as Fine, smectitic, isohyperthermic, Typic Haplusterts at sub-group level. Ramprakash and Seshagiri Rao (2002) and Ramprakash (2005), taxonomically classified some soils of Krishna district in Andhra Pradesh, Soils of Ramannagudem watershed in Nalgonda district.

Pedon 3 had shown cracks within 125 cm of the mineral soil surface that are 5 mm or more wide through a thickness of 30 cm or more for some time in normal years and slicken-sides or wedge shaped aggegates in a layer 15 cm or more thick that has its upper within 125 cm of the mineral soil surface were classified as Fine, smectitic, isohyperthermic, Vertic Haplustept. The presence of cambic sub-surface diagnostic horizon (Bw) in these pedon was recognized by the above features. Jagdish Prasad *et al.* (2001) reported that presence of cambic sub-surface horizon was the diagnostic criteria for Inceptisols.

Pedon 4 was showed the absence of characteristics of aqualfs, cryalfs, xeralfs and Udalfs, and, all the pedons had Ustic soil moisture regime and presence of lithic contact at < 50 cm depth (42 cm) was keyed as Loamy-skeletal, mixed, isohyperthermic Lithic Haplustalfs. Absence of lithic contact within 100 cm of the mineral soil surface and Absence of calcic, halic, salic and sodic horizons hence, these pedon 5 were qualified to be placed under Very Fine, smectitic, isohyperthermic, Typic Haplusterts. Ramprakash and Seshagiri Rao (2002) and Ramprakash (2005) taxonomically classified some soils of Krishna district in Andhra Pradesh,

Presence of argillic horizon, base saturation of more than 50 per cent in all the sub-surface layers due to the absence of Lithic contact, cracks with in 125 cm, lack of COLE value of more than 6.0, frigid temperatures, mesic or thermic soil temperatures, vertic properties, aquic conditions, saturation of water in any of the horizons for more than 20 days, pumice or pumice like fragments, entire lamille forms, 75 per cent sand in the 75 cm argillic layer, calcic layer in the 100 cm depth of the pedon 6 was classified as Fine-loamy, mixed, isohyperthermic, Typic Haplustlafs. Satyavathi and Suryanarayana Reddy (2004) and Ramprasad and Goverdhan (2011) classified the Alfisols of Telngana under Typic haplustalfs.

## Soil nutrient status

## Macronutrient status

The nutrient status of the study area was presented in table 6. The available nitrogen in the soils under present investigation ranged from 142 to 296 kg/ha. The lowest value of 142 kg $ha^{-1}$ soil was observed in BSS3 horizon of pedon 5. The highest value of 296 kg $ha^{-1}$ soil was noticed in AP horizon of pedon 4. The available nitrogen was found to be maximum in the surface horizons and decreased more or less with depth of the pedons, which might be due to decreasing trend of organic carbon with depth. This observation was in agreement with the results of Sarkar *et al.* (2002) and Satish Kumar and Naidu (2012).

The available phosphorus in soils of the study area varied from 4.5 to 23.5 kg $ha^{-1}$ soil. The lowest value of 4.5 kg $ha^{-1}$ soil was observed in BSS2 horizon of pedon 5. The highest

value of 23.5 kg $ha^{-1}$ soil was noticed in AP horizon of pedon 3. In general, higher available phosphorus was observed in the surface horizons and decreased regularly with depth. The reason for high available phosphorus in surface horizons might possibly be due to the confinement of crop cultivation to the rhizosphere which improves the organic carbon content in surface and supplementing the depleted phosphorus by external sources *i.e.,* fertilizers and presence of small amounts of free iron oxide and exchangeable $Al^{3+}$ in the surface horizons (Thangasamy *et al.* 2005). The available potassium in soils of the study area ranged from 156 to 360 kg $ha^{-1}$ soil. The lowest value of 156 kg $ha^{-1}$ soil was observed in BSS3 horizon of pedon 5 and the highest value of 360 kg $ha^{-1}$ soil was noticed in AP horizon of pedon 3. Most of the pedons exhibited more or less a decreasing trend with depth.

Slow weathering and fixation of released potassium might have resulted in low exchangeable potassium status (Ramprakash and Seshagiri Rao, 2002). Amount and type of clay, organic carbon, soil pH and CEC significantly affects the K-availability in the soil. Similar observations were also noticed by Sharma and Anil Kumar (2003) a significant and positive correlation between clay content and available K as K availability was largely controlled by clay minerals.

## Micro nutrients

The available zinc was ranged for 0.22 to 1.29 mg $kg^{-1}$ soil. The lowest value of 0.22 mg $kg^{-1}$ soil was noticed in BW2 horizon of pedon 1 and the highest value of 1.29 mg $kg^{-1}$ of soil was recorded in AP horizon of pedon 6. The available copper in soils under study area ranged from 0.18 to 3.90 mg $kg^{-1}$ soil. The lowest value of 0.18 mg $kg^{-1}$ soil was observed in BSS3 horizon of pedon 5 and the highest value of 3.90 mg $kg^{-1}$ of soil was noticed in AP horizon pedon 6. The available iron ranged from 3.22 to 12.5 mg $kg^{-1}$ soil. The lowest value of 3.22 mg $kg^{-1}$ soil was recorded in AP horizon of pedon 4 and where as the highest value 12.5 mg $kg^{-1}$ soil was noticed in AP horizon of pedon 1. The available manganese in soils of the study area ranged from 6.5 to 25.2 mg $kg^{-1}$ of soil. The lowest value of 6.5 mg $kg^{-1}$ of soil was noticed in Bt1 horizon of pedon 4 and the highest value of 25.2 mg $kg^{-1}$ soil was observed in AP horizon of pedon 1. The availability of these ions (Zn, Cu, Fe and Mn) increased 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. Similar kind of relationship between Zn and organic carbon was also reported by Mahesh Kumar *et al.* (2011).

In conclusion, based on morphological, physical and physico-chemical properties of Mulugu division of warangal district were neutral to moderately alkaline, non-saline, low to medium in organic carbon and CEC. The exchangeable bases in all the pedons in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ on the exchange complex. Whereas, the soils were low to medium in available nitrogen, low to high in available phosphorus and potassium. Available zinc was deficient to sufficient in all the horizon. The soils were sufficient in available iron, copper and manganese. The soils were classified as Typic Haplustepts, Typic Haplustalfs, Typic Haplusterts, Lithic Haplustalfs, Typic Haplusterts and Vertic Haplustept.

## References

Arun Kumar, V., Natarajan, S and Sivasamy, R. 2002. Characterisation and classification of soils of lower Palar-

Manimuthar watershed of Tamil Nadu. *Agropedology*. 12: 97-103.

Ashokkumar, H. P and Jagdish Prasad. 2010. Some typical sugarcane growing soils of Ahmadnagar district of Maharashtra. Their characterization, classification and nutritional status of soils and plants. *Journal of the Indian Society of Soil Science*. 58(3): 257-266.

Basava Raju, D, Naidu, M. V. S, Ramavatharam N, Venkaiah K, Rama Rao G and Reddy K S 2005 Characterization, classification and evaluation of soils in Chandragiri mandal of Chittoor district, Andhra Pradesh. *Agropedology* 15: 55–62.

Gangopadhyay, S. K, Battacharjee T and Dipak Sarkar 2001 Rubber growing soils of Tripura – their characteristics and classification. *Journal of the Indian Society of Soil Science* 49: 164-170.

Jagdish Prasad, Nagaraju, M.S.S., Srivastava Rajeev, Ray, S.K and Chandran, P. 2001. Characteristics and classification of some orange growing soils in Nagpur district of Maharashtra. *Journal of the Indian Society of Soil Science*. 49:735-739.

Leelavathi, G.P., Naidu, M.V.S., Ramavatharam, N and Karuna Sagar, G. 2009. Studies on genesis, classification and evaluation of soils for sustainable land use planning in Yerpedu mandal of Chittoor district, Andhra Pradesh. *Journal of the Indian Society of Soil Science*. 57: 109-120.

Leelavathi, G.P., Naidu, M.V.S., Ramavatharam, N and Karuna Sagar, G. 2010. Clay mineralogy of soils formed on granite-gneiss of Chittoor district, Andhra Pradesh. *Journal of the Indian Society of Soil Science*. 58(4): 376-383.

Mahesh Kumar, Singh, S.K., Raina, P and Sharma, B.K. 2011. Status of available major and micronutrients in arid soils of Churu district of western Rajasthan. *Journal of the Indian Society of Soil Science*. 59(2): 188-192.

Meena, R.H., Giri, J.D., Chaudhary, S.R and Shyampura, R.L. 2012. Characterization and classification of the soils of Malwa plateau in Banswara district of Rajasthan. *Journal of Soils and Crops.* 22(2): 216-225.

Nasre, R.A., Nagaraju, M.S.S., Rajeev Srivastava, Maji, A.K and Barthwal, A.K. 2013. Characterization, classification and evaluation of soils of Karanji watershed, Yavatmal district of Maharashtra for land resource management using geospatial technologies. *Journal of the Indian Society of Soil Science.* 61(4): 275-286.

Nayak, R., Sahu, G.C and Nanda, S.S.K. 2002. Characterization and classification of the soils of Central Research Station, Bhubaneswar. *Agropedology*. 12: 1-8.

Niranjana, K.V., Anil Kumar, K.S., Arti Koyal., Naidu, L.G.K and Dipak Sarkar. 2013. Major soils of Pulivendla region, Andhra Pradesh and their constraints. *Journal of the Indian Society of Soil Science*. 61(2): 140-142.

Patil, R. B and Jagdish Prasad 2004 Characteristics and classification of some sal (Shorea robusta) supporting soils in Dindari district of Madhya Pradesh Journal of the Indian Society of Soil Science 52 (2): 119-125.

Ram Prakash, T and Rao, S.M. 2002. Characterization and classification of some soils in a part of Krishna district, Andhra Pradesh. *The Andhra Agricultural Journal*. 49: 228-236.

Ramprakash, T. 2005. Thesis submitted to Acharya N. G. Ranga Agricultural University titled"Optimum land use planning for Ramannapet watershed using GIS and remote sensing techniques"

Ramprasad, M. Govardhan V, Praveenrao, V., and Bhave, M. H. V. 2013. Characterization and classification of rice growing soils of central Telangana region of Andhra Pradesh. *Journal of Research, ANGRAU* 41(2) 52-58.

Sarkar, D., Gangopadhyay, S. K and Velayutham, M. 2001. Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau. *Agropedology* 11: 29-36.

Satish Kumar, Y.S and Naidu, M.V.S. 2012a. Characteristics and classification of soils representing major landforms in Vadamalapeta mandal of Chittoor district, Andhra Pradesh. *Journal of the Indian Society of Soil Science*. 60(1): 63-67.

Satyavathi, P. L. A and Reddy M 2004. Soil site suitability for six major crops in Telangana region of Andhra Pradesh. *Journal of the Indian Society of Soil Science*. 52(3): 220-225.

Sharma, R. C., Mandal, A. K., Singh, R and Singh, Y. P. 2011. Characteristics and use potential of sodic and associated soils in CSSRI experimental farm, Lucknow, Utter Pradesh. *Journal of the Indian Society of Soil Science.* 59(4): 381-387.

Sidhu, M.S and Vatta, K. 2008. Development experience of Indian agriculture: An appraisal of post-reform period. *Southern Economist*. 11: 9-14

Sitanggang, M., Rao, Y. S., Nayan Ahmed and Mahapatra, S. K., 2006, Characterization and classification of soils in watershed area of Shikohpur, Gurgaon district, Haryana. *Journal of the Indian Society of Soil Science*. 54: 106–110.

Thangasamy, A, Naidu M V S, Ramavatharam N and Raghava Reddy, C. 2005. Characterization, classification and evaluation of soil resources in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh for sustainable land use planning. *Journal of the Indian Society of Soil Science*. 53: 11–21.

**How to cite this article:**

Narsaiah, E., T. Ramprakash, M. Chandinipatnaik, D. Vishnuvardhan Reddy and Bhupal Raj, G. 2018. Soil Physical, Physico-Chemical Properties of Mulugu Division Soils of Warangal District, India. *Int.J.Curr.Microbiol.App.Sci.* 7(06): 2735-2748.
doi: https://doi.org/10.20546/ijcmas.2018.706.322