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**“CHARACTERIZATION AND CLASSIFICATION OF
SOILS OF AGRICULTURAL RESEARCH STATION,
BADNAPUR”**

BY

SUNIL CHOUREY

B.Sc. (Agri.)

Dissertation

Submitted to

*The Vasant Rao Naik Marathwada Krishi Vidhyapeeth,
Parbhani In Partial Fulfillment Of The Requirements For The
Degree Of*

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MASTER OF SCIENCE

(AGRICULTURE)

IN

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COLLEGE OF AGRICULTURE, BADNAPUR

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PARBHANI-431 402 (M.S.) INDIA

2016

*Dedicated to
My Beloved
Parents
and brother*



CANDIDATES DECLARATION

I hereby declare that the dissertation

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Previously submitted by

Me for a degree of

Any University.

Place: Badnapur

Date: 30 /05 /2016


(SUNIL CHOUREY)

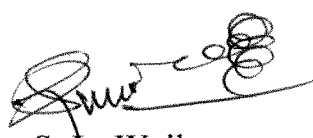
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This is to certify that the dissertation entitled “**Characterization and Classification of soils of Agricultural Research Station, Badnapur**” submitted by **Mr. Sunil Chourey** to the **Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** is record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.


I also certify that the dissertation or part there has not been previously submitted by him for a degree of any university.

Place: Parbhani
Date: 30/05/2016



Dr. S. L. Waikar
Research guide and chairman
Advisory committee

CERTIFICATE – II

This is to certify that the dissertation entitled “**Characterization and Classification of soils of Agricultural Research Station, Badnapur**” submitted by **Mr. Sunil Chourey** to the **Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** has been approved by the student’s advisory committee after viva-voce examination in collaboration with the external examiner.



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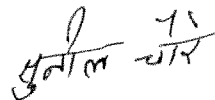
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Date: 30/05/2016.


(SUNIL CHOUREY)

Reg No. 25MB/2013A

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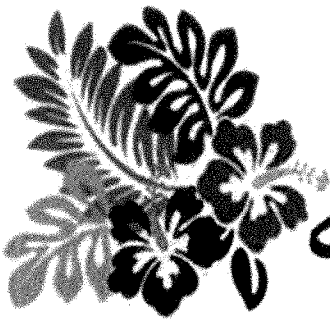
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ABBREVIATIONS

/	per
%	per cent
°C	Degree centigrade
cc	Cubic centimeter
cm	Centimeter
dSm ⁻¹	Desi simen per metre
EC	Electrical conductivity
<i>et al.</i>	And others
etc.	Etceteras
Fig.	Figure
g	gram(s)
ha	hectare(s)
i.e.	That is
K	Potassium
kg ha ⁻¹	kilogram per hectare
kg	kilogram
m	meter
mg kg ⁻¹	milligram per kilogram
mm	millimeter
N	Nitrogen
No.	number
P	Phosphorus
viz.,	namely
CO ₃ ⁻	Carbonate
HCO ₃ ⁻	Bicarbonate
Cl ⁻	Chloride
Ca ⁺⁺	Calcium
Mg ⁺⁺	Magnesium
Na ⁺⁺	Sodium
RSC	Residual Sodium Carbonate
SAR	Sodium Absorption Ratio
ARS	Agricultural Research Station
USDA	Unites state departement of Agriculture
NBSS & LUP	National Buero of soil science & land use planning

*Thesis
Abstract*



DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, BADNAPUR

Research Title : **“Characterization and Classification of soils of Agricultural Research Station, Badnapur”**

Name of Guide : Dr. S. L. Waikar
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ABSTRACT

In the present investigation entitled “Characterization and Classification of soils of Agricultural Research Station, Badnapur” the study was aimed at characterization and classification of soils of Agricultural research station, Badnapur.

Agricultural Research Station, Badnapur is situated at 19.50⁰ and 47.53 longitudes, with an altitude of 520 meters. It is on Aurangabad-Jalna road at a distance of 2.5 km from Badnapur railway station on Manmad-Secundrabad route of south central railway. The total area of this research station initially was 141.43 ha. The area under building is 11.25 ha, roads 5.90 ha, canal 7.44 ha, grazing area 3 ha, wells 2.10 ha. Now it is 84.14 ha.

The area is covered by the basaltic lava flows. Same layers of the lava flows are the result of intense volcanic activity during cretaceous Eocene period (almost seventy years ago). When the lava flows were ejected through long narrow fissures on the earth surface. This area has shallow cover of gravelly sediment over a hard basaltic contact within 50 cm of the surface.

The area falls under semi-arid tropics. The average annual precipitation is 565.7 mm, mostly concentrated during the monsoon months from June to December. The daily mean maximum and minimum temperature 28.50⁰ C and 20.17⁰ C, respectively. The mean minimum and maximum relative humidity varied between 71.8 to 57.23 per cent, respectively. Badnapur is grouped under assured rainfall zone.

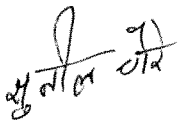
The soils of Agricultural research station, Badnapur are very deep (more than 120 cm). Most of the soils of Agricultural research station, Badnapur were very dark brown (10 YR 2/2) to light yellowish brown (10 YR 6/4) in colour. Structure varied from medium, moderate, granular to medium, moderate, angular blocky. Consistency varied from slightly hard to very hard in dry condition, friable to extremely firm in moist condition and slightly sticky slightly plastic to very sticky very plastic in wet condition. The coarse fragment of the soil varied from 8.56 to 21.23 per cent. The bulk density of these soils varied from 1.19 to 1.55 Mg m⁻³. The per cent porosity varied from 41.51 to 55.26 per cent. The soils of study area are clay in nature.

The soils of studied area are moderately alkaline in reaction with pH ranged from 7.79 to 8.55. The electrical conductivity varied from 0.26 to 0.98 dSm⁻¹. This is well

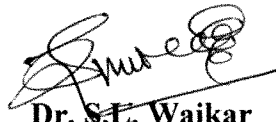
within safe to normal limit of electrical conductivity range, designated for normal soil (Richards, 1954) and all soils comes under non-saline class. The organic carbon content of studied soil is varied from 0.25 to 0.98 per cent in various depths. This shows that the soils of studied area are low to moderate in organic carbon. The soils of studied area are medium to very high in calcium carbonate ranged from 4.1 to 14.8 per cent.

The available nitrogen content in soils of Agricultural research station, Badnapur is varied from 109.76 to 269.70 kg ha⁻¹. The data indicates that soils of studied area are very low to medium in available nitrogen content. In general, the available nitrogen content decreased with depth. The available phosphorus content of these soils varied from 15.75 to 25.95 kg ha⁻¹. The data indicates that soils of studied area are medium to moderate in available phosphorus content. In general, the available phosphorus content decreased with depth. The available potassium content of these soils varied from 177.74 to 575.01 kg ha⁻¹. The data indicates that soils of studied area are medium to very high in available potassium content.

Taxonomically the soils of Agricultural research station, Badnapur are classified into order Vertisols. Further these soils were classified under the sub-order Usterts, great group Haplusterts, sub-group Typic Haplusterts and family Clay, montmorilonitic.



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Introduction



CHAPTER I

INTRODUCTION

The study of soils as naturally occurring phenomena is called pedology (from the Greek word pedon, meaning soil or earth). Pedology takes into account factors and processes of soil formation, soil characteristics, and distribution of soil types.

A soil profile is a vertical cross section of a soil. It is divided into a number of distinct layers, referred to as horizons. The horizons are normally designated by symbols and letters. The presence or absence of particular horizons allows pedologists (soil scientists) to classify the soil. In addition, the organic or O horizon can form above the mineral soil commonly in forested areas, resulting from the dead plant and animal remains.

The horizons may be further subdivided. For example, in this soil profile the A horizon has been divided into 4 further pedological horizons: (L) leaf litter, (F) fermenting leaf litter, (H) humus, (E) alluvial.

Soil colour is determined by the amount of organic matter and the state of the iron. Soil colour is also related to soil drainage, with free draining, well aerated soils (with pore space dominated by oxygen) having rich brown colours. In contrast, poorly draining soils, often referred to as gleys, develop under anaerobic conditions (the pore space dominated by water) and have grey or blue-grey colours. Soils with periodic water logging are imperfectly drained and are often highly mottled with blotches of contrasting colour. Mottles are often rusty in colour and are due to iron concentration.

Classification is the grouping of objects in some orderly and logical manner. It is based on the properties of objects for the purpose of their identification and separation. These are termed as differentiating characteristics or differentiate and serve to separate one class from others. For instance, soils are classified on the basis of their texture as sandy, loamy or clayey soils. For classifying the individuals of a large and widely varying population, such as soils, it is useful to group individuals into classes, and further into five classes. This kind of grouping is called multi-categorical or hierarchical system of classification. The individual soils are grouped into classes of lower category (e.g. Soil Series) which are further grouped into classes of higher categories (e.g. Soil Orders). The lower categories are defined by a large number of differentiating characteristics and higher categories by a few such characteristics. Within each class, there is a central core or nucleus to which the individual members are related in varying degrees. It is called *typic*, the central concept or an idealized individual, which typified the class.

Soil texture is a term used to describe the distribution of the different sizes of mineral particles in a soil. Textures ranged from clay, sand, and silt at the extremes, to a loam which has all three sized fractions present. The main influence of texture is on permeability which generally decreases with decreasing particle size. Soil clod on right (above) is dense with a poor texture and leads to a poor structure if badly managed. Due to continual compaction it is blue-grey in colour due to low oxygen conditions. It is a poor environment for root development. Soil clod on left has been well managed and is relatively loose with ample pore space for good, healthy root development.

Agricultural Research Station, Badnapur is located in the Jalna district of Maharashtra. Badnapur is a Taluka headquarter which is located at a distance of 40 km from Aurangabad on Aurangabad-Jalna National Highway. Unfortunately many of the farmers are not familiar with the information about morphological, physical and chemical properties of soils. Kipping in view the present investigation was undertaken on topic "Characterization and Classification of soils of Agricultural Research Station, Badnapur" with following objectives.

1. To know the morphological features of soils of Agricultural research station, Badnapur.
2. To determine depth wise physical and chemical properties of soil of Agricultural research station, Badnapur.
3. To classify soil of Agricultural research station, Badnapur.



*Review of
Literature*



CHAPTER II

REVIEW OF LITERATURE

A brief review of literature for present investigation is grouped under the following heads.

- 2.1 Soil characteristics
- 2.2 Morphological properties
- 2.3 Physical properties
- 2.4 Chemical properties
- 2.5 Classification of soils

2.1 Soil characteristics

Soil and climate are the most important factors for cultivation of the crops. The important soil characteristics which directly or indirectly affect on crop growth and soil characteristics are described as below.

Walkar *et al.* (1968) reported that landform parameter such as slope, length and direction, curvation, distance from the hill slope summit and its relative elevation influence the soil profile development. They also observed the influence of the slope, length and its direction on horizon development.

Ghatol (1972) studied the four profile sample and sixty surface sample collected from millet, old and new farms of Marathwada Krishi Vidyapeeth, Parbhani and reported that out of four profiles undertaken for study, three have shown inclination towards heavy clay texture, containing about 70 to 80 per cent of the finer fraction. Majority of the surface samples are heavy clay, medium clay, clay loam and sandy clay loam. The surface samples are adequate in content of calcium carbonate, which favours good structural condition in spite of high content of clay in these soils.

Landey *et al.* (1982) reported that black soil and associated soils were found on various micro land form units both erosional and depositional. The depositional features are generally residual hill ranges directed means of butte, escarpment and pediments while the depositional features are visible in piedmont plain margin gradually with the valley floor. They were also observed that the texture of black soil were usually fine and varied from clay loam, silt clay to clay. The clay content varies from 35 to 60 per cent. They also observed that the bulk density was normally high in black soils and the normal range estimated with dry clod method ranged between 1.5 to 1.8 Mg m⁻¹.

Mungare and Pharande (1982) reported that soil texture is the main factor of soil moisture. They established highly significant correction between clay content and clay plus silt content with sand content.

Vadivelu *et al.* (1983) and Bhattacharya *et al.* (1989) reported that soil site and climate characteristics changes with geomorphic unit which is turn influence on land use pattern, they observed that hill ridges with shallow soil were mostly under forest with patches of rainfed crops. The pediments surface with shallow to deep soils were cultivated to sorghum and soybean and pearl millet, while the soils occurring on pediment plain and flood plains were very deep and cultivated to sorghum, pigeon pea, safflower under rainfed condition.

Bharambe and Ghonsikar (1985) studied the soils in jayakwadi command area and reported that calcium carbonate content in these soils ranged from 1.12 to 16.61 per cent, pH of the very deep soil, deep soil and medium soils were neutral to alkaline in nature and varied from 7.19 to 9.30, 7.85 to 9.12 and 7.33 to 9.20, respectively and bulk density of very deep soil, deep soil and medium soil and shallow soils are 1.18 to 1.52, 1.23 to 1.50, 1.20 to 1.50 and 1.20 to 1.61 Mg m⁻¹,

respectively. Total porosity of very deep soil, deep soil and medium soil and shallow soils ranged from 37 to 58, 43 to 54 and 38 to 53 per cent, respectively.

Pal and Deshpande (1987) reported that basalt rocks reality weathers to fine clay and this could be the reason for high clay and low content of sand in deep black soil.

Ganure (1987) investigated 30 soil profiles having different soil depth from Jayakwadi, Purna, Penganga commands and scarcity zone of Maharashtra and reported that the soil colour ranged from very dark brown (10YR 2/2) to dark yellowish brown (10YR 4/4). Majority of soils were very dark greyish brown (10YR 3/2) and dark greyish brown (10YR 4/2). The clay content varied in the range of 25.00 to 59.00 per cent. The high per cent of clay was observed in deep soils Jayakwadi, Purna and Penganga command areas and lowest in shallow soils of scarcity zone of Marathwada. Texture varied from sandy clay to clay. The finer fractions like clay-silt account more than 50 per cent of the mechanical composition in all the soils. The bulk density of all the soils varied from 1.12 to 1.48 g/cm³ in surface layers and it increased to extent of 1.52 g/cm³ at lower depths. Porosity of soils varied from 44.15 to 57.73 per cent in surface layers and decreased with depth.

Bhattacharya *et al.*, (1989) carried out soil survey in the Junnar tehsil of Pune district, Maharashtra to identify basic soil and land use patterns. Eighteen soil series were identified, classified and mapped at the level of series association. Nearly 50% of the area has shallow soils, 15% moderately deep soils and 25% very deep soils. Shallow soils are under forest, moderately deep soils are on pediments under a single crop and deep soils are on intensively cultivated plains.

Palaskar *et al.*, (1990) analyzed the surface feel technique for determining soil texture in the field was compared with the laboratory method (Black

1965) in order to assess its accuracy for different Maharashtra soils. Although field estimations of the basic textural classes (clay, silt loam, silty clay, loam, sandy loam and clay loam) were found to be accurate, errors were observed for soils of the Konkan region which contained high organic matter, iron oxides and kaolinitic clay, leading to under estimation of clay content. Surface feeling of soils in the black soil region showed high accuracy (82%).

Kadam (1991) conducted an investigation on soils of majalgaon command area (Jayakwadi Project stage III) and revealed that the soils colour ranged from very dark brown to very dark greyish brown, majority of soils were very dark greyish brown. The clay content varied in the range of 30.2 to 58.8 per cent in different soil types. The highest amount of clay was observed in deep soils and lowest in shallow soils. Texturally, all the soil types were clay and finer fraction like clay + silt accounted for more than 70 per cent of the mechanical composition. The bulk density of all soil groups varied from 1.33 to 1.40 g/cm³ in surface layers and increased to the extent of 1.53 g/cm³ in lower depth. Porosity of soils varied within very narrow range of 44.1 to 49.9 per cent in surface layer and decreased with the depth.

Srivastava *et al.* (1991) studied the soils of Ujjain district of Madhya Pradesh and observed that the soils on hill and ridge were shallow, excessively drained with problem of severe erosion soils on gently sloping to undulating lands were as deep to very deep, well drained and were suitable for arable crops if irrigation was provided. Soils on gentle sloping land were very deep, moderately well drained calcareous and were under cultivation.

Rakhunde *et al.*, (1993) studied morphological, physical and chemical properties of six soils from the Vengurla and Sawantwadi areas in Maharashtra, India

and reported that Mangoan-1 (Alfisols) soils of flat-topped hills and Mangoan-2 (Typic Ustropepts) soils of the escarpments, had strong brown to yellowish red colours and were strong to medium acid (pH 5.4 to 5.9). Both had developed *in situ* from parent rock through laterization. Nirwade (Alfisols) soils developed on lateritic colluvial material and contained appreciable amounts of colluvial material in the profile and on the surface. These and Venglura soils (Lithic Ustropepts), developed on pediments, had dark brown to reddish brown colours, were well drained and strong to medium acidic (pH 5.0 to 5.8). Mangoan-3 soils (Alfisols) occurred in the valleys and Aravali soils (Alfisols) of the coastal lowlands had olive brown and lightish-yellow brown to grey colours and were strongly to slightly acid (pH 5.2 to 6.2). Soils of the coastal plain were very coarse, had low CEC and no horizon development.

Sharma *et al.* (1996) reported that the soils at elevated topography were shallow to moderate deep, clayey to loamy skeletal and yellowish brown, while the soils at lower topography were deep to very deep, fine to fine loamy and greyish. The influence of topography was marked on soil properties such as pH, CaCO₃, clay content, Vertic properties and exchangeable cations.

Padole (1997) studied Central Demonstration Farm, PDKV, Akola, Maharashtra state, India and reported that the soils from pedon 1 were shallow, from pedon 2 and pedon 3 were deep and pedon 4 were very deep. The soil textures were clay to clay loam, with moderately well drained conditions and calcareous.

Chinchmalatpure *et al.* (1998) observed that Entisols are the dominant soils on hill top and have erosional surface, Vertisols are the dominant soils, occurring on concave slope of basaltic transect.

Patil *et al.*, (2001) collected sample from eight pedons of Varkhed watershed in Akola district of Vidarbha region of Maharashtra, India, were studied to

characterize and classify the soils of the watershed area. The soils, in general, were shallow to deep, non to slightly eroded to severely eroded, well to moderately well drained, gravelly clay to clay in texture, slightly acidic to moderately alkaline in reaction, low to moderately high in organic carbon content with calcium as the dominant cation among the major exchangeable cations. The bulk density of soils ranged from 1.06 to 1.28 tonnes m⁻³.

Ilorkar and Totey (2002) studied on the Navegaon National Park (Maharashtra, India). Six soil profiles were excavated under the three plant communities. Physico-chemical and morphological properties of soils were studied and they were classified accordingly. The soils under the plant community *Tectona-Pterocarpus-Buchanania* are very deep and dark brown to yellowish brown in colour with abundance of silica and iron concretion. These are moderately drained with silty loam to loamy in texture. The soils under the plant community *Cleistanthus-Ougeinia-Tectona* are shallow to medium in depth and dark yellowish brown to dark reddish brown in colour and silty clay loam in texture. The soils under the plant community *Cleistanthus-Terminalia-Lagerstroemia* are deep silty loam in texture and dark brown in colour, acidic in neutral.

Kadao *et al.*, (2003) analyzed eight typical pedons (P1-P8) supporting banana [*Musa paradisiacal*] in Wardha district of Maharashtra, India and reported that the soils are developed in basaltic alluvium, deep and calcareous and brown to very dark greyish brown in colour (10 YR). The texture of pedons ranged from loamy sand to clay (10.7-65.4% clay) in different horizons.

Kadu *et al.* (2003) reported that evaluation of Vertisols for deep rooted crops on the basis of hydraulic conductivity alone may help in planning and management of Vertisols under semi-arid climate in India.

Maji *et al.*, (2005) investigated the landform and soil characteristics of Ringnabodi watershed of Nagpur district in sub-humid tropics of central India for their characterization, classification and analysis of their relationships. The slope varies from level to nearly level (0-1%) to steeply sloping (30-50%) land. With changing topographic position, the depth of soil changed from 33 to 140 cm and the coarse fragments decreased from 61 to 2%. The soils developed on topographically higher elevation have dark brown (7.5 YR hue) and those developed on lower elevation have dark brown to very dark gray and very dark grayish brown (10 YR hue) color. Soils at higher elevation have clay loam texture, whereas the low-lying areas have clayey textural class. Higher available water holding capacity (AWC 199 mm) is found in low-lying area and low to medium (AWC 68 mm) is noticed in the soils developed on higher elevation.

Yadav Y. V. (2005) conducted an experiment on soil resource mapping of Agriculture College Farm, Latur in 2003-04 and reported that the soil of college farm are very shallow to very deep, clayey, sub-angular blocky, very dark grayish brown to black. The Vertisols are more porous (51.57 per cent) than Inceptisols and Entisols. The farm soils are slight to moderately alkaline in reaction, safe in total soluble salt concentration and calcareous in nature. These parameters increased with depth of soil. The Vertisols and Inceptisols group of soils were more alkaline than Entisols.

Sitanggang *et al.*, (2006) analyzed the soils of Watershed area of Shikohpur, Gurgaon district, Haryana and reported that textural class of the soils varies from sandy loam to clay loam. Soils on the hill top (P1) and hill side (P2) have relatively higher clay content (23.40 to 34.90%) with 12.50 to 87.50% coarse

fragments as they occur on hill slopes. Soils having high percentage of sand or gravel have more bulk density than those having high clay content.

Balpande *et al.*, (2007) characterized and classified the grape growing soils in Nasik district, Maharashtra and reported that the clay, silt and sand varied from 28.5 to 67.0, 18.7 to 28.6 and 20.0 to 48.4%, respectively in different horizons of pedons. The bulk density of soils ranged from 1.23 to 1.73 Mg m⁻³.

Jagdish Prasad *et al.*, (2007) studied four each of banana and associated non-banana-growing soils in Jalgaon district of Maharashtra, India, classified and assessed for their suitability for banana and sugarcane crops. All the pedons are more than 100 cm deep in the hue of 7.5 YR and developed over basaltic alluvium of river Tapi and its tributaries. The soils are slightly to strongly alkaline, calcareous (Typic/Vertic Haplustepts/Typic Haplusterts), clay in texture with fine/very-fine particle-size class family and smectic mineralogy.

Sarade *et al.*, (2007) analyzed the six typical pedons supporting guava, representing Betala (P1), Sukali (P2), Ghatkurora (P3 and P4), Khamari (P5) and Surewara (P6) sites, developed in recent alluvium (floodplain) of river Wainganga, in Bhandara district, Maharashtra, India, and characterized for their physical and chemical properties and taxonomically classified. These pedons are deep (>100 cm) and had their Munsell colour notation in 10 YR with value 3 to 5 and chroma 2 to 6 (yellowish brown to very dark grayish brown). The dominant structure is moderate medium sub-angular blocky barring few exceptions. In general, the sand, silt and clay content ranged from 5.6 to 81.7, 1.2 to 34.1 and 15.2 to 60.3%, respectively. Pedon 1 and 2 are relatively coarser than others and that reflected in their bulk density (1.35-1.79 tonnes m⁻³).

Sinha *et al.*, (2008) determined the physico-chemical properties of soils sampled from different depths (0-15, 15-30, 30-60, 60-90, 90-120 and 120-150 cm) in upland, mid-level, and lowland areas in Bihar, India. The clay content in the 0-15-cm depth increased from the upland area down to the lowland area. The highest clay content at the 90- to 120 cm depth in the upland and mid-level areas was 26.7 and 29%, respectively. In the lowland area, the highest clay content was recorded in the 0 to 15 cm depth. Macro-aggregates in the soil profile were 53.8, 58.1 and 61.6% in the upland, mid-level and lowland area, respectively. Bulk density (1.55 g cm^3) was highest in the lowland area at the 30 to 45 cm depth. In both upland and mid-level area, the highest bulk density values (1.53 and 1.51 g/cm^3 , respectively) were recorded in the 15 to 30 cm depth.

Todmal *et al.*, (2008) conducted soil resource inventory at the Agricultural College Farm, Kolhapur (Maharashtra, India) to study the morphological, physical and chemical properties of soils and classify them taxonomically. The soils were classified as Lithic Ustorthent, Typic Haplustert and Vertic Haplustept. The Lithic Ustorthent soils were sandy clay to sandy loam in texture with gravel percentage from 18.89 to 46.11, Vertic Haplustepts were clayey in texture with gravel percentage ranged from 14.6 to 41.7 and Typic Haplusterts were clayey with gravel percentage from 1.54 to 21.38, respectively.

Jagdish Prasad *et al.*, (2009) carried out a detailed soil survey of Selsura KVK research farm of PDKV, Akola in Wardha district, Maharashtra. There were nine soil series and thirteen mapping units. The soils were very dark gray to very dark greyish brown in hue 10YR, calcareous and clayey but differed in depth and are classified under Entisols, Inceptisols and Vertisols.

Dhale and Prasad (2009) studied the sweet-orange growing soils of Jalna district, Maharashtra. Seven pedons were characterized for their physical, chemical properties, nutritional status of soil and leaves. These pedons were shallow (P2), moderately deep (P1, P3, P4) and others were deep to very deep and had their Munsell colour notation in 10 YR / 7.5 YR / 5 YR hue with value 3 to 4 and chroma 1 to 4. The dominant structure was moderate, medium, sub-angular blocky in Inceptisols (P1 to P3) but angular blocky structure in sub-soils of Vertisols (P4 to P7). In general, sand, silt and clay content ranged from 14.4 to 46.9, 8.1 to 27.3 and 38.1 to 66.3% in different horizons, respectively. Bulk density ranged from 1.29 to 1.96 Mg m⁻³ and increased with depth.

Ashok kumar H. P. and Jagdish Prasad (2010) conducted a study based on variation in physiography, soils and cane yield, six pedons namely, Vadala Mahadev (P1), Umbare (P2), Kendhal (P3), Nandgaon (P4), Khedle (P5) and Sonai (P6) in Ahmadnagar district of Maharashtra were characterized for their physical and chemical properties, and nutritional status of soils and leaves. These pedons are shallow (P1), very shallow (P2), moderately deep (P6) and others are very deep and have their Munsell colour notation in 10YR / 7.5YR hue with value 3 to 4 and chroma 1 to 4. The dominant structure is moderate, medium, sub-angular blocky type, but angular blocky structure is a common feature in slickenside zone of Vertisols. Sand, silt and clay content ranged from 24.2 to 62.5, 5.6 to 45.2 and 5.0 to 70.2% in different horizons and bulk density from 1.54 to 1.95 Mg m⁻³. These soils are moderately to strongly alkaline in reaction.

Ram *et al.*, (2010) studied the soils of flood-prone eastern plains of Rajasthan. Eleven profiles (P1 to P11) were dug and soil samples from each horizon were drawn with the help of sectional core sampler for determination of various soil

properties and reported that the hue of soil matrix varied from 2.5 YR to 10 YR with value ranging from 6 to 3 and chroma from 6 to 2 when moist. Texture varied from loamy sand to clay loam with granular to sub-angular blocky and prismatic structure. Sand content of the soils ranged from 28.3 to 78.7% and it was more in surface horizons. Clay content varied from 9.3 to 37.8%. It increased with the depth indicating downward translocation, which was more pronounced in P1, P3, P4, P5, P6, P7 and P8 suggesting development of an Argillic horizon. Bulk density of the soils ranged from 1.32 to 1.61 Mg m⁻³. It slightly decreased in horizons just below the Ap layer except in P2, P3, P4 and P10 and then increased with depth in all the profiles which could be attributed to decreased organic matter content and secondary accumulation of illuviated clays but further orientation of clay in pore space increased the bulk density value in C horizon (Walia and Rao 1996). Particle density of these soils varied from 2.36 to 2.64 Mg m⁻³. Total porosity and capillary porosity of the soils ranged between 37.70 to 46.36 and 15.26 to 19.56%, respectively. Profiles P2, P9, P10 and P11 had less capillary porosity in comparison to others due to their coarse texture.

Niranjana *et al.*, (2010) collected sample from six pedons, three on inter-hill basin (P1, P2 and P3) and three on gently sloping uplands (P4, P5 and P6) of Pulivendla region and characterized, classified and evaluated for growing banana crop. The pedons on inter-hill basin are moderately shallow to very deep, very dark grayish brown clay to dark reddish brown to dark red sandy clay loam to clay loam soils. The pedons of gently sloping uplands are moderately shallow to deep, dark brown to dark yellowish brown clay to dark reddish brown to dark red sandy clay to gravelly clay soils.

Shalima Devi and Anil Kumar (2010) characterized and classified the coffee growing soils of Karnataka and presented the data. The soil depths of all, except two sites were more than 150 cm. Most soils were well drained. The slope varied from 1 to 3% to 25 to 33%. The colour of the surface layer varied from reddish brown to very dark greyish brown. The dark colour of the surface layer may be due to the high amount of organic matter found in the coffee growing areas. The texture of the soils varied from sandy clay loam to clay. In pedons 1 and 4, there were no coarse fragments present; whereas in pedons 3, 5 and 6 these were found in the lower layers. In others coarse fragments were present almost throughout the profile. The structure of all the soils was sub-angular blocky, except in pedon 2, where it was granular. This could be attributed to the high amount of organic matter in these soils. Except in pedons 2 and 9, thin patchy clay cutans were observed in all the pedons indicating the formation of Argillic sub-surface horizon and good soil profile development.

Likhar and Prasad (2011) studied based on variation in physiography, parent material, soils and productivity of orange, six pedons were characterized and evaluated in Nagpur district of Maharashtra for their physical and chemical properties, and nutritional status of soil and leaves. These pedons were shallow underlain by saprolite (P3, P4 and P5) and deep soils (P1, P2 and P6) had their Munsell colour notation in 10 YR / 2.5 Y / 7.5 YR / 5 YR hue with value 3 to 4 and chroma 2 to 4. The dominant structure was moderate, medium, sub-angular blocky (P3, P4 and P5) to angular blocky in sub-soils (P1, P2 and P6). In general, sand, silt and clay content ranged from 0.6 to 46.1, 19.3 to 40.0 and 24.1 to 68.2% in different horizons, respectively. Bulk density ranged from 1.4 to 2.0 Mg m⁻³.

Meena *et al.*, (2011) studied the six typical pedons on different places in part of Wardha river valley of Maharashtra during 2008. The soils had clayey

texture, sub-angular blocky to angular blocky structure and moderately alkaline reaction. The soils had well developed slickensides in sub-surface horizons. On the basis of soil characteristics these soils were classified under order- Vertisols, sub-order- Usterts, great group- Haplusterts and subgroup- Sodic Haplusterts.

Satish Kumar and Naidu (2012) studied on the soils of Vadamalalpet Mandal of Chittoor district, Andhra Pradesh and reported that the P1, P2, P3, P4 and P7 were located in plains while the P5 and P6 occurred on uplands. The soils are moderately deep to very deep and imperfectly to well drain. The soils of upland were yellowish red (5YR 4/6) to dark red (2.5YR 3/6) and in the plains reddish yellow (7.5YR 6/8) to yellowish brown (10YR 5/4). The soils of Vadamalalpet Mandal showed wide textural variations clay to sand. The wide textural variation might be due to variation in parent material, topography, *insitu* weathering and translocation of clay. The structure of the soils is crumb, sub-angular blocky, angular blocky and single grain. The P1 and P7 profiles showed thin/thick and patchy or continuous cutans and P4 and P5 exhibited cambic sub-surface diagnostic horizon. The physical characteristics of the soils indicated that clay content varied from 2.74 to 43.84%.

Hirey *et al.*, (2013) classified the soils from Tuljapur tahsil of Osmanabad district. These soil samples were analyzed for physico-chemical properties. Average particle density, bulk density and porosity of Vertisols soils were 2.44 gcc⁻¹, 1.49 gcc⁻¹ and 38.14 %, Inceptisols soils were 2.44 gcc⁻¹, 1.50 gcc⁻¹ and 37.51 % respectively. The soil color was black, light brown and dark brown in Vertisols, Inceptisols and Entisols, respectively.

Patil *et al.* (2013) studied on the soils of Osmanabad district and reported that these soils are classified as Lithic Ustorthent, Typic Ustorthent and Typic Haplusterts. The morphological, physical and chemical properties of soils are

differing in relation to topographic position of soil profile. The different soil site attribute responsible for yield difference in soybean and pigeon pea are PAWC, clay content, soil depth, CEC and stoniness.

Snehal Shilewant (2013) investigated two soil profiles from the BSP farm (Khanapur Block-B) for rational Land Use Planning. MKV, Parbhani was carried out during the year 2012. The results emerged out from the present investigation revealed that soils of BSP farm (Khanapur Block- B) are dark brown to black in color and clay in texture.

2.2 Morphological properties

Soils developed from variety of parent material occurring on various land form units widely distributed through out of the country and have wide difference in their morphological characteristics.

Mehta and Shankarnaraynan (1961) found that stones and gravels to the extent of more than 10-20 per cent by volume on the surface adversely affect the root growth and water retention.

Sehgal (1991) reported that soil depth is an important criteria for land evaluation. Most of the crops produce excellent yield with an effective soil depth of 90 to 100 cm (Sys. 1985).

Dipak sarkar *et al.* (1997) reported that the soils of the hilly terrain are very shallow to shallow, yellowish red to dark reddish brown, gravelly sandy loam to sandy clay loam in texture with A-C and A-B-C horizon sequence are classified as Lithic Ustorthents and Lithic Ustochrepts.

Gabhane *et al.* (2006) studied on Beluru watershed Akola district, Maharashtra and reported that the soils are grouped under Typic Haplusterts. The Vertisols soils showed well developed slickenside. This slickenside zone and well

developed wedge shaped structure aggregates and angular blocky structure. This may be due to the swell shrink phenomenon of smectic clay (Ahmad 1983).

Patil *et al.* (2008) studied on the soils of college of Agriculture farm Pune, Maharashtra and reported that soil colour varies from brown (10 YR 4/4) to dark brown (10 YR 3/3), clay in texture and medium, moderate, sub-angular blocky in structure.

Leelavati *et al.* (2009) studied the soil depth varies from deep to very deep and the soil colour on very gentle slopping land varies from yellowish brown (10 YR 5/6) to dark red (2.5 YR 3/6) and in flat land soils showed very pale brown (10 YR 7/3) to reddish gray (5 YR 5/2) colour.

Ashok kumar and Jagdish Prasad (2010) studied typical sugarcane growing soils of Ahmednagar district of Maharashtra were characterized and reported that the soils were very shallow to very deep and have their Munsell colour notation in 10 YR to 7.5 YR hue with value 3 to 4 and 1 to 4 chroma. The dominant structure is moderate, medium, sub-angular blocky type, but angular blocky structure is a common feature in slickenside zone of Vertisols.

Patil (2011) reported that soils of Osmanabad tahsil were yellowish brown (10 YR 5/6) to black (10 YR 2.5/1) in colour, very shallow to very deep, granular to angular blocky in structure, sandy clay loam to clay in nature.

Mane (2013) reported that the soils of Osmanabad district were very black (10 YR 2.5/1) to dark yellowish brown (10 YR 6/4) in colour, clay to sandy loam in nature, granular to angular blocky in structure.

Pawar (2013) reported that the soils of Osmanabad district were very dark greyish brown (10 YR 3/2) to light yellowish brown (10 YR 6/4) in colour, loam

to clayey in texture, granular to sub-angular blocky in structure, friable non sticky non plastic to firm very sticky to very plastic consistency.

Vaidya *et al.* (2014) reported that the soils at farm college of Agriculture, Osmanabad were the pedon situated on elevated position are reddish brown (5 YR 5/4) to yellowish red (5 YR 5/6) and the pedon situated on lower topography the soil colour varies from dark brown (10 YR 4/3) to yellowish brown (10 YR 5/8). The soil structure is granular to sub-angular blocky and soil texture sandy to clayey.

2.3 Physical properties

Bharambe *et al.* (1986) reported that higher value of saturated hydraulic conductivity (6 to 39 mm hr⁻¹) for shallow soils and lower values (2 to 30 mm hr⁻¹) for deep black soils of the Jayakwadi and Purna command area.

Kanwar and Virmani (1986) and Vaidya and Pal (2002) obtained significant positive correlation between clay content and water holding capacity in Vertisols.

Yule (1986) reported the bulk density of swell shrink soils has been observed to change with moisture content.

Walia and Rao (1997) reported that clay content in Khraud and Bharatkup soils varied from 15.4 to 39.8 per cent and such variation could be due to change in depositional pattern as indicated by abrupt change in sand/silt ratio and bulk density varied from 1.46 to 1.96 Mg m⁻³ increases with depth.

Gabhane *et al.* (2006) studied on the soils of Belura watershed Akola district and reported that the soils were clay in texture with clay content ranging from 34.4 to 73.4 per cent and which was increased with depth.

Patil *et al.* (2008) studied on the soils of College of Agriculture, Pune and reported that the soils are gravelly sandy clay loam to clay in texture and high bulk density 1.83 Mg m^{-3} .

Leelavathi *et al.* (2009) reported that the clay content varied from 42.13 to 55.32 per cent and silt content in all pedons exhibited an irregular trend with depth and sand constituted the bulk of mechanical fraction, which could be attributed to the dominance and alluvial sandy parent material and the bulk density in different pedons varied from 1.15 to 1.61 Mg m^{-3} and showed an increasing trend with depth which might be due to more compaction, low organic matter and less aggregation.

Kharche and Pharande (2010) studied on soils of Mula command area Ahmednagar district Maharashtra and reported that the clay content in different horizon varied from 36.2 to 57.2 per cent. Bulk density of soils varied from 1.32 to 1.65 Mg m^{-3} .

Vaidya and Dhavan (2010) reported that the soils of Kini farm college of Agriculture, Osmanabad were clay loam to sandy clay loam in texture and its bulk density (1.67 to 2.11 Mg m^{-3}) varies with depth.

Patil *et al.* (2013) studied on the soils of Osmanabad district, Marathwada region of Maharashtra and reported that the soils are sandy clay loam to clayey in texture.

2.4 Chemical properties

Ghatol (1972) studied the four profile sample and sixty surface samples collected from millet, old and new farms of Marathwada Krishi Vidyapeeth, Parbhani and reported that the nitrogen and organic carbon content tends to be decreased, according to depth in profile samples. 83.33 per cent of samples are account for medium in total nitrogen. Most of the soils contain 0.0724 to 0.0848 per

cent and 0.412 to 0.585 per cent of P_2O_5 and K_2O , respectively. Therefore majority of samples can be considered as medium in nitrogen and P_2O_5 and all the soils are rich in K_2O . In surface samples, available nitrogen varied from 0.0028 to 0.007 per cent, P_2O_5 content varied from 0.0024 to 0.009 per cent and K_2O content varied from 0.025 to 0.07 per cent. In general most of the samples have medium power of supplying nitrogen and P_2O_5 and high supplying power in case of K_2O .

Ganure (1987) investigated 30 soil profiles having different soil depth from Jayakwadi, Purna, Penganga commands and scarcity zone of Maharashtra and reported that the soil reaction ranged from 7.49 to 8.80 in different soils and showed increasing trend with depth in most of the soils. Electrical conductivity was in the range of 0.21 to 2.75 mmhos/cm and increased with depth. Organic carbon and organic matter content of soils ranged from 0.28 to 0.98 percent and 0.62 to 1.68 per cent, respectively in their surface layers and decreased with depth.

Kadam (1991) conducted an investigation on soils of Majalgaon command area (Jayakwadi Project stage III) and reported that the soil reaction varied from 7.55 to 8.98 in different soil types and showed increasing trend with depth in most of the profiles. Electrical conductivity was in the range of 0.15 to 0.69 mmhos/cm. The free calcium carbonate varied from 3.0 to 19.0 per cent thereby imparting calcareous nature to these soils. Organic carbon ranged from 0.21 to 0.81 per cent in all soil group and decreased with soil depth. The total Nitrogen ranged from 0.028 to 0.068 per cent in different profile and decreased with depth. Available Phosphorus varied from 9.6 to 28.8 kg/ha in medium to deep black and 9.6 to 28.8 kg/ha in shallow soils and decreased with the depth.

Moharkar *et al.*, (1992) described physical and chemical properties of Vertisols in Maharashtra, India. The soils are very clayey, slightly alkaline and well

structured. Irrigation resulted in some variations in nutrients availability. Organic carbon, available P and K decreased with depth under both irrigated and dry farming conditions.

Rakhunde *et al.*,(1993) studied the morphological, physical and chemical properties of six soils from the Vengurla and Sawantwadi areas in Maharashtra, India and reported that Mangoan-1 (Alfisols) soils of flat-topped hills and Mangoan-2 (Typic Ustropepts) soils of the escarpments, had strong brown to yellowish red colours and were strong to medium acid (pH 5.4 to 5.9). Both had developed *in situ* from parent rock through laterization. Nirwade (Alfisols) soils developed on lateritic colluvial material and contained appreciable amounts of colluvial material in the profile and on the surface. These and Venglura soils (Lithic Ustropepts), developed on pediments, had dark brown to reddish brown colours, were well drained and strong to medium acidic (pH 5.0 to 5.8). Mangoan-3 soils (Alfisols) occurred in the valleys and Aravali soils (Alfisols) of the coastal lowlands had olive brown and lightish-yellow brown to grey colours and were strongly to slightly acid (pH 5.2 to 6.2). Soils of the coastal plain were very coarse.

Babrekar and Ravankar (1993) assessed the available K status of soils of Maharashtra (India) for the period 1981-91 showed that soils of 9 talukas had moderate, 40 talukas moderately high, and all the remaining talukas high to very high in available K. Comparison with ratings for 1969 and 1976 show a build up in available K status in different districts.

Patil (1993) analyzed the status of Maharashtra soils, India, for water soluble K, exchangeable K and available K was assessed. Lateritic and non-lateritic soils of the humid region are comparatively low in available potassium. Swell-shrink soils with marginal variation in soil properties show differential potassium

availability. K supply capacity ranges from 98.4 to 310.6 and 136.0 to 294.7 ppm K for lateritic and medium black soils, respectively. Soil samples collected over the period 1981-91 shows that eight talukas in western Maharashtra and one taluka in Marathawada have moderate available K status, while soils of 22 talukas in the western part and 18 talukas in Bhandara and Chandrapur districts are moderately high. Soils of the remaining talukas of the State are high to very high in available potassium.

Patil and Sonar (1994) analyzed total and available nutrient and trace element status in twenty swell-shrink soils from Maharashtra, India and reported that the soils were low in N, very low to moderate in P, and moderate to very high in K.

Agarkar and Padole (1996) studied morphological and physico-chemical properties of 4 representative profiles from the Central Research Station, PDKV, Akola and reported that the soils from profiles 1 and 3, located on gently sloping landscapes, were shallow, moderately well drained, non-calcareous and fine-textured. Soil pH varied from 7.8 to 8.1. These soils are low to medium in organic carbon and available N, low in available P_2O_5 and medium to high in available K_2O . Profile 2 soil is deep, well-drained and fine-textured. The pH of the soil vary from 7.8 to 8.1. These soils are low to medium in organic carbon and available N, low in available P_2O_5 and high in available K_2O . The soil from profile 4 is very deep, dark greyish brown, imperfectly drained and fine-textured. The soil pH ranged from 8.2 to 8.6. The soils are medium to low in organic carbon, and available N, low in available P_2O_5 and medium to high in available K_2O .

Pharande and Sonar (1996) investigated the distribution of potassium (K) in 5 soil series of Vertisols of Maharashtra, India, in relation to soil properties. The water soluble, exchangeable and non-exchangeable K were 5-25, 148-415 and

130-830 mg/kg soil, respectively, while lattice and total soil K were 0.12-1.1 and 0.15-1.23%, respectively. Although exchangeable K was high at all soil depths, total K reserve was poor, indicating low K bearing minerals in soils. In general, the water soluble, exchangeable and non-exchangeable K were higher in the surface (Ap) layer and decreased in the C layer, except in the Nimone series. No definite trend in distribution of lattice and total K was noticed.

Kale and Chavan (1996) analyzed twenty four surface soil samples from randomly selected fields from the Kumbhave-5 soil series (Fluventic Ustropepts) were collected from the Konkan region of Maharashtra state. The analytical data showed that these soils are silty clay loam to loam in texture, with an average bulk density of 1.15 t/m³ and maximum water holding capacity of 58.55%. The soils are slightly acidic (pH 5.9), non-calcareous, with EC 0.083 dSm⁻¹, high in organic carbon (2.33%), medium in available N (182.75 ppm) and low in available phosphorus (P₂O₅, 3.94 ppm). The available potassium was low to medium, ranging from 36 to 162 p.p.m. K₂O. and free CaCO₃ and non-exchangeable-K. However, a significant negative relationship was observed between organic carbon and total-K.

Padole (1997) studied Central Demonstration Farm, PDKV, Akola, Maharashtra state, India and reported that the pH and EC ranged from 7.7 to 8.2 and 0.12 to 0.75 dS/m respectively. Soil cation exchange capacity ranged from 34.4 to 48.0 cmol/kg and base saturation was 78.06 to 95.29%, respectively. Clay mineralogical studies indicated that the soils were dominated by smectite, though vermiculite, chlorite, mica, kaolinite and quartz were also present. The soils were classified as Lithic Ustorthent, Vertic Ustorthent, Vertic Ustochrept and Aridic Haplustert.

Raskar and Pharande (1997) studied vertical distribution of different forms of K in five Vertisols and four Alfisols soil series of Western Maharashtra, India and analyzed that The amount of water soluble, exchangeable, non-exchangeable, lattice and total K in profiles of different Vertisols soil series ranged from 3-31.8, 54-278, 83-787, 1243-7387 mg/kg and 0.14-0.82%, respectively. Alfisol soil series showed higher content of lattice K and total K than Vertisols. In general, the surface horizon (Ap) of Vertisols and Alfisols soil series had a higher content of water soluble, exchangeable and non-exchangeable K than lower horizons. Among the soil series, Kolhapur (Vertisols) and Pali (Alfisol) soil series were low in all the forms of K. All the forms of soil K in Vertisols were positively and significantly correlated with each other. In Alfisols, all the forms of K were positively correlated with each other except water soluble K.

Malewar *et al.*, (1999) analyzed oilseed-based cropping sequences in Maharashtra, India behaved differently in influencing soil physico-chemical properties after two cycles over initial values. Cotton-Groundnut sequences improved the porosity, water stable aggregates and organic carbon in soil as compared to other systems. Each oilseed-based crop sequence showed differential effect on the availability of N, P and K in soil. The Cotton-Groundnut rotation was better at increasing soil available N, P and K. However, net losses of 35.43 kg N, 3.90 kg P₂O₅ and 23.05 kg K₂O ha⁻¹ occurred under the cotton-sunflower rotation.

Bhattacharyya *et al.*, (2000) estimated the organic and inorganic carbon stocks of the black cotton soils (BCS) of Maharashtra, India. BCS can be grouped broadly into 3 categories: deep black soils (>100 cm depth - Vertisols), medium black soil (Vertic intergrades of Inceptisols) and shallow black soils (<50 cm depth - Lithic Ustorthents). Out of the total 25.7 M ha area under BCS in

Maharashtra, deep, medium, and shallow soils occur in 7.3, 11.0 and 7.4 M ha accounting to 28, 43 and 29% of the total BCS of the state, respectively. Low soil organic carbon (SOC) and high amounts of inorganic carbon, mostly in the form of calcium carbonate (CO₃-C) in the BCS are due to rapid decomposition of OC and precipitation of calcium carbonate in the prevailing arid and semiarid climates. The study suggests that the estimation of SOC and CO₃-C stocks and their inverse relationship with soil depth can help land resource managers in their efforts to restore productivity of BCS.

Kaskar *et al.*, (2001) investigated thirty soil samples representing Inceptisols of West Coast of Maharashtra, India. The water soluble, exchangeable, available, non-exchangeable and lattice K contributed 0.04, 1.39, 1.43, 3.95 and 94.61% towards total soil K in the given soils. Highly significant positive relationships amongst different fractions of soil K indicated existence of equilibrium between different forms of K in these soils.

Ghosh *et al.*, (2002) studied the soils of Gotera Mouza (Block-Chakdah, district-Nadia) and reported that morphologically the soils did not vary greatly in different arsenic contaminated zones. Soils were mostly neutral to alkaline in reaction, low to medium in organic matter.

Sharma *et al.*, (2004) analyzed six typical pedons representing cultivated soils of Neogal watershed in North-West Himalayas occurring on river terraces and hill slopes *viz.* Baun, Talinu, Phata, Gopalpur, Bhattu and Mahadev. The soils are acidic in reaction. The soil texture, pH (1:2.5), organic carbon, CEC, base saturation, water retention at 33 and 1500 kPa ranged from loamy sand to clay loam, 5.2 to 6.2, 3.2 to 9.5 g kg⁻¹, 4.9 to 14.3 cmol (p⁺) kg⁻¹, 46 to 77%, 4.2 to 31.2% and 2.6 to 16.8%, respectively.

Pagar *et al.*, (2004) study on shallow to moderately deep, clay to clay loam textured soils at Futala farm, College of Agriculture, Nagpur, Maharashtra, India and reported that the soil properties like bulk density, pH, free lime increased with depth while EC, organic carbon, CEC, exchangeable bases decreased with depth. In all the spacings and plantation, bulk density and pH of the soil decreased while organic carbon content improved. The percentage improvement in these soil properties is more in narrow spacing as compared to wider spacing.

Kawde *et al.*, (2005) analyzed the soil samples of 5 pedons from Keliveli (Akola district, Maharashtra, India) to assess the nature of salt affected soil. The soils are clay textured, very deep, calcareous, poorly to very poorly drain with high swelling-shrinkage. Soils are moderately to very strongly alkaline (pH 7.5 to 9.7) in reaction. Electrical conductivity ranged from 0.17 to 0.80 dSm⁻¹. CaCO₃ was 8.32 to 18.36%, which increased with depth, and organic C content ranged from 0.18 to 0.69%, which decreased with depth.

Yadav Y. V. (2005) conducted an experiment on soil resource mapping of Agriculture College Farm, Latur in 2003-04 and reported that the soil of college farm are rich in organic carbon, available N, K, Cu and Mn. The available Phosphorus and zinc was moderately high to high. These two nutrients become serious and cause nutrient imbalance if not regularly fortified with other nutrients.

Bodle (2005) carried out soil resource mapping of demonstration farm of Marathwada Agricultural University, Parbhani during the year 2005-06. The results emerged out from the present investigation revealed that the soils of demonstration farm are slightly to moderately alkaline in reaction, calcareous in nature, poorly supplied with organic carbon and in total soluble salt concentration. In all 92.02 per cent of soils are low and 7.69 per cent soils were placed as moderately low in

available N content. Available P content found very low in 50 per cent soils while 42.85 per cent low and only 7 per cent soils are moderate in P content.

Chalwade *et al.*, (2006) analyzed one hundred twenty surface (0-30 cm) soil samples from the sugarcane growing areas of the five talukas viz., Gangakhed, Palam, Ahmadpur, Loha and Kandhar of Parbhani and Nanded districts, Maharashtra, India, for their available N, P and K. The data revealed that most of the soil samples have low available nitrogen, low to medium available phosphorus, and high available potassium. Soil pH is slightly alkaline with low organic carbon.

Shilpa *et al.*, (2007) analyzed fourteen profiles from five districts of Central and Eastern Vidarbha region of Maharashtra for studied the potassium fraction distribution and their inter-relationship between forms of potassium. The soils of Wardha, Nagpur, Chandrapur and Bhandara districts were slightly calcareous neutral to alkaline in reaction and the soils of Gondia district was non calcareous and slightly acidic in reaction. The available, water soluble, exchangeable, and non-exchangeable and lattice K contributed 1.97, 0.12, 1.88, 11.25 and 86.76 per cent towards total K. The increase in available K significantly correlated with exchangeable K ($r=0.9964^{**}$) in Central Vidarbha where as total and lattice K was highly significant and positively correlated with each other in Vidarbha ($r=0.9954^{**}$) and Eastern Vidarbha ($r=0.9946^{**}$).

Todmal *et al.*, (2008) conducted soil resource inventory at the Agricultural College Farm, Kolhapur (Maharashtra, India) to study the morphological, physical and chemical properties of soils and classify them taxonomically. The soils were slightly acidic to alkaline in nature (6.3 to 8.4 pH) with very low salt content (electrical conductivity: 0.04 to 0.36 dSm^{-1}), organic carbon content was low to high (0.10 to 0.81%), CaCO_3 content varied from 0.46 to 14.86%, cation exchange

capacity ranged from 20.8 to 54.8 C mol (p+) kg⁻¹. Available nitrogen content varied from very low to low (72 to 272 kg ha⁻¹), available P was very low to moderately high (3.16 to 28.6 kg ha⁻¹) available K was low to very high (104 to 350 kg ha⁻¹).

Waghmare *et al.*, (2008) studied to determine the status of available micronutrient in relation to the chemical properties in soils of AUSA tahsil of Latur district, Maharashtra, India. For this purpose, 100 surface soil samples were collected from 20 villages. Data showed that these soils were neutral to alkaline in reaction, safe in terms of electrical conductivity (EC), has low to medium organic carbon (OC) content, and non-calcareous to calcareous in nature.

Gable *et al.*, (2008) conducted a field experiment in Akola, Maharashtra, India, during the *Kharif* and *Rabi* seasons of 2005-06 to study the effect of integrated nutrient management in Maize-Chickpea cropping system on physico-chemical properties of soil. Results revealed that available nutrient status (NPK) after harvest of maize and also after chickpea was improved by 100% recommended dose of fertilizer followed by 75% RDF+25% N through leucaena lopping+biofertilizer. Physico-chemical properties of soil like pH, electrical conductivity, bulk density, field capacity and permanent wilting point were improved significantly due to application of N through *leucaena lopping* and use of *Azotobacter* for seed treatment. Yield of maize was the significantly highest with 100% recommended dose of fertilizer followed by 75% RDF+25% N through leucaena lopping+biofertilizer.

Sinha *et al.*, (2008) determined the physico-chemical properties of soils sampled from different depths in upland, mid-level, and lowland areas in Bihar, India and reported that soil pH, no definite vertical or horizontal variation was observed. The highest electrical conductivity value was found in the upland area at the 0 to 15 cm depth. Soil organic carbon content was highest in the mid-level area. The

average value of calcium carbonate in the soil profile (0-150 cm depth) decreased from the upland area to the mid-level area and to the lowland area.

Nirawar *et al.*, (2009) conducted a laboratory experiment to know the status of available N, P and K in relation to physico-chemical properties of soils from Ahemadpur tahsil of Latur district, Maharashtra, India. The analysed samples showed that these soils were neutral to moderately alkaline in reaction, safe limit in EC, low to high in organic carbon and non-calcareous to calcareous in nature. The results further indicated that soils were low to medium in available N and P while, available K was medium to high range.

Jibhakate *et al.*, (2009) analyzed one hundred and twenty surface soil samples from fifty two villages in eleven soil series from Katol tahasil, for their physico-chemical properties and available nutrient status and reported that all the soils under study were clay to clay loam in texture, bulk density ranged between 1.1 to 1.8 mg m^{-1} with the highest value recorded in Karla-Muserkhapa (Krl-Msk) series and the lowest in Malgaon-Muserkhapa (Mlg-Msk) series. The soil reaction is neutral to medium alkaline. Regarding the nutrient status, all the soils are low in organic carbon and available nitrogen content, however medium in available phosphorus and high to very high in available potassium.

Patil *et al.*, (2009) studied to evaluate seasonal variation in physico-chemical parameters of soil samples collected from Dhule district region (M. S.). The soil characterization was carried out for parameters like pH, electrical conductivity, total alkalinity, moisture contents, bulk density and heavy metal contents like Fe, Cr, Cd, Ni etc. During the course of study period, fluctuation in various parameters was recorded. This effect may be due to different uptake tendency of growing plants in the fields.

Humayun (2010) studied to estimate the percentage of free lime of agriculture soil in Amravati district (M.S.). Two hundred and seventy five soil samples were collected from different locations of 30 villages of 6 Talukas (M.S.). The result showed that 50% soil samples were having moderately high lime percentage and 42% soil samples were having very high lime percentage. Amount and reactivity of free lime not only influence the availability of micronutrients, phosphate but also raises the pH of soil.

Ashok kumar and jagdish Prasad (2010) carried out a study based on variation in physiography, soils and cane yield, six pedons namely, Vadala Mahadev (P1), Umbare (P2), Kendhal (P3), Nandgaon (P4), Khedle (P5) and Sonai (P6) in Ahmadnagar district of Maharashtra and reported that majority of surface and sub-surface layers had relatively higher organic carbon content than underlying ones. The available N, P, and K ranged from 47.0 to 228.9, 0.6 to 28.6 and 80.3 to 760.3 kg ha⁻¹, respectively. The DTPA extractable-Fe, Mn, Cu and Zn ranged from 7.2 to 17.9, 7.9 to 25.0, 1.2 to 4.0 and 0.2 to 0.9 mg kg⁻¹ respectively, in different pedons. These soils are medium in N, low in P, medium to high in K and deficient in Mn, Cu, and Zn.

Shalima Devi and Anil Kumar (2010) characterized and classified the coffee growing soils of Karnatka and presented the data. The presented data showed that soil reaction in all the profiles ranged from slightly acidic to moderately acidic except in one where it was highly acidic with pH varying from 4.1 to 6.3. This acidic pH may be due to acidic parent material and leaching of bases due to the high rainfall prevalent in this area. The variation in pH with depth may be due to weathering and leaching of bases from sloping landforms. The organic carbon content in the surface layers of the profiles ranged from 1.47 to 5.29%, whereas in the sub-soil horizon it decreased in almost all the horizons with increasing depth except in pedon 8 where it

increased in the lower most horizon. The high soil organic carbon content may be due to the slow organic matter decomposition at higher altitudes, where temperature is low and rainfall is high.

Narkhede *et al.*, (2011) studied to evaluate seasonal variation in physico-chemical parameters of soil samples collected from 'Chorwad' Tehsil-Bhusawal, Dist. Jalgaon (M.S.). The soil characterization was carried out for parameters like pH, electrical conductivity, total chloride, total alkalinity, sulphate, bulk density, moisture content, organic matter, calcium, magnesium, sodium and potassium. During the course of study period, fluctuation in the various parameters were recorded.

Deshmukh (2012) studied to evaluate the soil fertility status from Sangamner area, Ahmednagar district, Maharashtra, 62 surface soil samples were analyzed for various soil fertility parameters like pH, EC, organic matter, available NPK and boron by standard procedures. pH ranged from 8 to 9.7 reflecting alkaline nature of soils. The Higher EC in the down-stream part reflecting low flushing rate and sluggish ground water movement in the area. Organic carbon ranges from 0.165 to 1.575% in the soils. 29.03% and 48.38% of soils showed low and medium status of organic carbon, respectively. Soils showed low contents of available nitrogen and phosphorus, while available potassium was high.

Kadam *et al.*, (2012) analyzed the pH of soil of Majalgaon command area, India and reported that pH of the studied soils varied from 7.55 to 8.98 in different soil types and showed increased trend with depth in most of the profiles.

Pandurang Patil *et al.*, (2013) analyzed for evaluate soil fertility status of the soils from Dapoli tahsil, Ratnagiri district of Maharashtra and reported that the pH of the soils ranges from 5.77 to 7.95 reflecting slightly alkaline nature of the soil.

The EC ranged from 0.09-0.19 mS/cm. EC of the soil samples indicates the salt free nature of the soil in all samples. The values of the OC range from 0.57 to 2.06% in the soils of tahsil. Majority of the villages 72.72% have low proportion of the N and 54.54% villages having medium proportion of P. The proportion of K is high in 72.72% villages and medium in 27.27%.

Pooja Sawant (2013) analyzed the physico-chemical properties of samples of soil from areas in Dapoli, Maharashtra, India, where finger millet had been cultivated. The soil samples from the finger millet fields were sandy clay loam and moderately acidic, with high organic C content and low electrical conductance. Before and after the harvesting of finger millet, N availability was moderate and low, respectively. P availability was low before and after harvesting, whereas K availability was high and moderately high.

Prabhavathi *et al.*, (2013) studied to assessment of the soil fertility status in a watershed as carried out for efficient soil management and cropping systems for sustainable yields. Soil samples were analyzed for pH, electrical conductivity, organic carbon, available N, P₂O₅ and K₂O and micronutrients Zn, Cu, Fe and Mn. Results revealed that Nutrient Index of organic carbon (g/kg), available N (kg/ha) and zinc (mg/kg) were very low and nutrient index was medium for available P₂O₅ and K₂O in the watershed. The extent of deficiency of organic carbon, nitrogen and zinc was 63%, 86% and 58%, respectively. The study indicated that the low organic carbon and nitrogen in soils were attributed to low application rates of organic material, high temperature and low rate of application of N fertilizers, especially in the rainfed areas.

Selvaraj and Naidu (2013) have undertaken a reconnaissance soil survey in Renigunta mandal of Chittoor district, Andhra Pradesh to evaluate the land

capability classification and suitability of soils for Paddy, Groundnut, Red gram, Sugarcane, Vegetables and Mango. The data pertaining to soil characteristics of different landforms of the pedon P1 to P7 are presented. In pedon 1, the soil pH between 7.00 to 7.87 with the mean of 7.46 showed slightly alkaline in reaction. The organic carbon content varied from 1.1 to 3.2 g/kg (mean of 1.97 g/kg) indicating the soil was low in organic content. In pedon 2, the soil pH varied from 6.16 to 7.17 with the mean of 6.74 it showed slightly acidic in reaction. The organic carbon of soils was low and ranged between 0.6 to 5.2 g/kg with mean value of 2.01g/kg. In pedon 3, the soils were slightly acidic in reaction with pH ranged from 6.67 to 6.79 with a mean of 6.71. The organic carbon content was medium and varied from 1.7 to 4.3 g/kg mean of 2.77 g/kg. In pedon 4, the soils were showed slightly to moderately alkaline in reaction with pH 7.22 to 8.94 (mean of 8.25). The organic carbon content varied from 0.4 to 1.9 g/kg with mean of 0.9 g/kg. In pedon 5, the soil reaction was normal and pH ranged from 6.20 to 7.80 with mean value of 6.91. The organic carbon value ranged between 1.1 to 2.6 g/kg with mean of 1.55 g/kg. In pedon 6, the soils showed moderately alkaline reaction and pH ranged from 7.82 to 8.96 with mean value of 8.34. The organic carbon value varied from 1.1 to 3.3 g/kg with mean of 2.16 g/kg. In pedon 7, the soil exhibited moderately alkaline reaction with pH value 7.85 to 8.69 (mean value of 8.33). The organic carbon was low in this profile soil that ranged from 0.4 to 1.3 g/kg (0.94 g/kg).

Snehal Shilewant (2013) investigated two soil profiles from the BSP farm (Khanapur Block-B) for rational Land Use Planning. MKV, Parbhani was carried out during the year 2012. The results emerged out from the present investigation revealed that soils of BSP farm (Khanapur Block- B) are slightly to moderately alkaline in nature, safe in total soluble salt concentration, moderately

calcareous to calcareous and moderately high supply with organic carbon. Typic Haplusterts have higher alkalinity than rest of the great groups. In all 88.28 per cent soil samples are placed as very low in available N content. Available phosphorus content found to be low in 7.27 % while 50 % medium and 42.73 % soils are moderately high. The availability of potassium found to be very high in BSP farm.

2.5 Classification of soils

Prasad *et al.*, (1995) studied three typical pedons developed at different altitude on different parent materials and under different climatic conditions in Nasik district, Maharashtra, India. Soils developed from basalt on a Western Ghat spur under a hot, humid climate were dark reddish brown, with an Argillic horizon, and were classified as Typic RhodustalFs. Soils developed on interfluves under a sub-humid climate were very deep, clayey, with a reddish brown colour, and were classified as Typic Ustropepts. The piedmont plain soils developed under a semi-arid climate were very deep, moderately well drained and clayey, and were classified as Chromic Haplusterts.

Agarkar and Padole (1996) studied morphological and physico-chemical properties of 4 representative profiles from the Central Research Station. The soils were classified as Lithic Ustorthent, Vertic Ustorthent, Vertic Ustochrept and Aridic Haplustert.

Rao *et al.*, (1997) carried out a detailed soil survey of high intensity at Central Demonstration Farm of PDKV, Akola to characterize and classify the soils. Based on their morphological and physico-chemical characteristics, six different soils were identified. Three soils belong to order Vertisols while others are Inceptisols and Entisols, respectively.

Jagdish Prasad *et al.*, (2001) analyzed four typical swell-shrink orange supporting soils of Nagpur district and reported that the Selu and Gondkhairi (P3) soils are grouped under Typic Ustorthents whereas Ninji and Gondkhairi (P4) soils are classified as Typic Haplustept and Typic Haplustert, respectively. The high clay content, CaCO₃ and poor drainage of deep swell-shrink soils limit the productivity of orange.

Patil *et al.*, (2001) collected soil samples from eight pedons of Varkhed watershed in Akola district of Vidarbha region of Maharashtra, India, were studied to characterize and classify the soils of the watershed area. These soils were classified as Typic Ustorthents, Vertic Ustochrepts and Typic Haplusters, based on the variations in their morphological and physico-chemical properties, as per the guidelines in "Keys to Soil Taxonomy". The basic data obtained in present investigation may be useful to suggest the capability and suitability of soils for obtaining the potential yields on a sustainable basis.

Satyavathi and Suryanarayan (2003) studied on the soils of northern telangana zone in Andhra Pradesh. Soils were classified as Shallow red soil pedon of Karimnagar keyed out as Entisols order, Psamment at sub-order, Ustipsamments at great-group. At sub-group level, the soils had been keyed out as Typic Ustipsamments. At family level, the mineralogy class is mixed. Medium deep red soil in Malyal and deep red soil in Aswaraopet have an argillic horizon and hence, they keyed out as Alfisols. They were keyed out as Ustalfs sub-order, Haplustalfs great-group. At sub-group level, these two soils had been keyed out as Typic Haplustalfs. At family level, the particle size class is fine loamy. Mineralogy class is mixed. Shallow black soil in Wyra and medium deep black soil in Madhira keyed out as Inceptisols as per key to soil-orders. Since they have Ustic moisture regime, they

keyed out as Ustepts. Wyra pedon keyed out as Calcustept as it has a Calcic horizon with its upper boundary within 100 cm of the mineral soil surface. Madhira pedon keyed out as Haplustepts great group. Both soils were qualified for "Vertic" subgroup. Deep black soil in Adilabad keyed out as a Vertisols.

Waikar *et al.*, (2003) analyzed four pedons from different parts of drought prone south central Maharashtra (India) during 1998-99 for characterization and classification of soils. The soils were characterized and classified on the basis of USDA system as Inceptisols with Ustept and Haplustert as sub-order and great-group for pedon Bhagur and Nawargaon, respectively with Vertic Haplustept as sub group belongs to fine montmorillonitic isohyperthermic calcareous family of Vertic Haplustept. Other two pedons belonged to family very fine, montmorillonitic, isohyperthermic, calcareous family of Typic Haplustert with order Vertisols, sub-order Ustert, Haplustert as great group and sub group as Typic Haplustert. The soils were classified as Typic Haplustert and Vertic Haplustept.

Thangasamy *et al.*, (2005) analyzed of soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh. The soils have been classified as Aquic Ustorthents, Typic Ustipsamments, Typic Ustifluvents, Typic Haplustepts, Vertic Haplustepts, Typic Haplustalfs and Typic Rhodustalfs. On the basis of the major soil constraints, sustainable land use plan for the micro-watershed has also been suggested for their better management.

Bodle (2005) carried out soil resource mapping of demonstration farm of Marathwada Agricultural University, Parbhani during the year 2005-06. The results emerged out from the present investigation revealed that the soils of demonstration farm are Typic Haplusterts (46%), Vertic Ustochrepts (29%) and Lithic Ustorthents (25%).

Balpande *et al.*, (2007) studied to characterize and classify the grape-growing soils in Nasik district, Maharashtra, India. P1 and P3 did not show any profile development and hence were keyed out under order Entisols and sub-order Orthents and Ustorthents at the group level.

Todmal *et al.*, (2008) conducted soil resource inventory at the Agricultural College Farm, Kolhapur (Maharashtra, India) to study the morphological, physical and chemical properties of soils and classify them taxonomically. The soils were classified as Lithic Ustorthent, Typic Haplustert and Vertic Haplustept.

Sharma *et al.*, (2008) studied sand dune areas in the semi-arid and arid agro-ecological sub-region covering a part of central and south-western Punjab and reported that soils from semi-arid sub-region were classified as mixed, hyperthermic family of Typic Ustipsamments whereas that of arid sub-region keyed out as mixed, calcareous, hyperthermic family of Ustic Torripsamments.

Mahesh Kumar *et al.*, (2009) studied soils of Churu district, Rajasthan and reported that Molasar, Modasar, Devas and Dune complex were classified as Typic Torripsamments, while Naurangpura series as Typic Torrifluents sub-groups of Entisols soil order. Chirai series was classified as Typic Haplocalmbids, while Masitawali and Saroopdesar were placed in Fluventic Haplocambids sub-groups of Aridisols soil order.

Niranjana *et al.*, (2010) collected sample from six pedons, three on inter-hill basin (P1, P2 and P3) and three on gently sloping uplands (P4, P5 and P6) of Pulivendla region and characterized, classified and evaluated for growing banana crop. Soils of P1 and P4 were classified as very fine, calcareous Vertic Haplustepts. Soils of P2 and P3 were classified under fine-loamy, Typic Rhodustalfs and Typic

Paleustalfs. Soils of P5 and P6 were classified as clayey-skeletal/fine, calcareous, Typic Haplustafs.

Agarkar *et al.*, (2012) studied on some cotton growing soils of Wardha district of Vidharbha region (M.S., India) during 2005. The profile often soil sites on different micro topographic condition chosen at Selsura, Krishi Vigyan Kendra farm of Panjabrao Deshmukh Krishi Vidyapeeth, Akola were examined for soil site properties such as climate, depth, texture, structure and drainage. Out of ten pedon, P1 belonged to Typic Haplustepts, P2 belonged to Lithic Haplustepts, P3 and P10 belonged to Leptic Haplusterts and P4, P5, P6, P7, P8 and P9 belonged to Typic Haplusterts. The soils were classified as sub-order Ustepts and Ustert in the order Inceptisols and Vertisols. They qualified for great group Haplusterts. The soils were classified as Lithic Haplustepts, Typic Haplustepts, Leptic Haplusterts and Typic Haplusterts at great group level. Soil profile when correlated with yield it was concluded that Leptic Haplusterts (P3, P10) and Typic Haplusterts (P4, P5, P9) belonging to order Vertisols were best soils for cotton growing.

Hirey *et al.*, (2013) classified the soils from Tuljapur tahsil of Osmanabad district as per the USDA classification based on soil characteristics into Vertisols, Inseptisols and Entisols. Among the 180 soil samples collected from 30 villages of Tuljapur tahsil during the year 2011-12, 34 % were grouped as Vertisols, while 47 % and 19 % as Inseptisols and Entisols, respectively.



*Material and
Methods*



CHAPTER III

MATERIALS AND METHODS

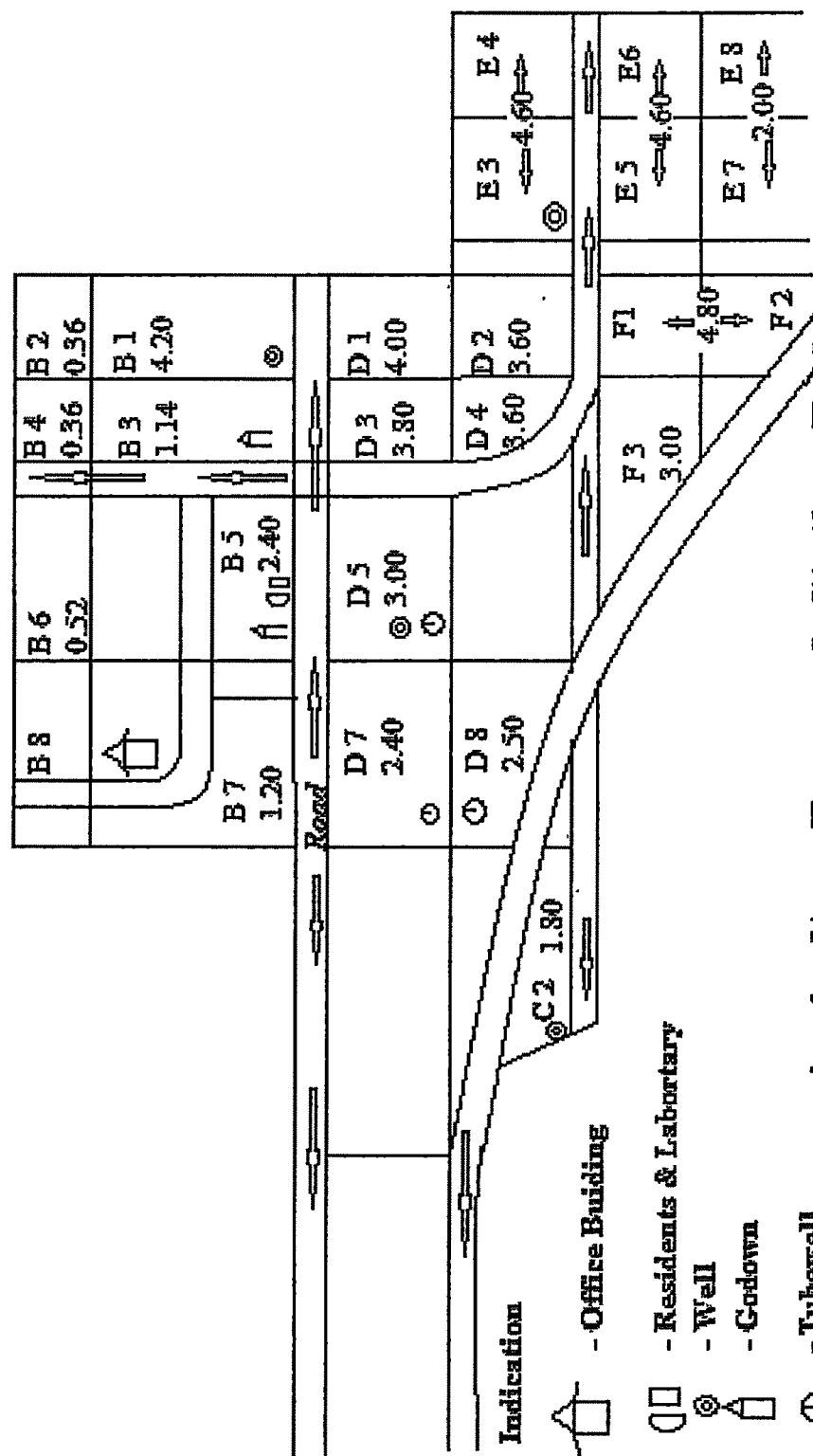
The soil, a natural resource even today is less understood and less recognized in comparison to plant and animals. It's an unconsolidated mineral matter on the surface of the earth, is influenced by parent material, climate, micro and macro organisms, topography and time. Various soils forming factors and processes influence the variations in characteristics of different soils. In the present project effort has been made to describe soils of Agricultural Research Station, Badnapur. The method adopted and materials used are described in this chapter under following heads.

- 3.1 Site and Location
- 3.2 Geology and parent material
- 3.3 Climate and Rainfall
- 3.4 Major crop of the region
- 3.5 Cropping Pattern
- 3.6 Natural vegetation
- 3.7 Opening of soil profile
- 3.8 Collection of soil samples
- 3.9 Processing of soil samples for analysis
- 3.10 Soil Analysis

3.1 Site and Location

Geographically, Agricultural Research Station, Badnapur is situated at 19.50⁰ and 47.53 longitudes with an altitude of 520 meters. It is on Aurangabad-Jalna road at a distance of 2.5 km from Badnapur railway station on Manmad-Secundrabad route of south central railway.

Aurangabad to Jalna road



Indication

- Office Building
- Residents & Laboratory
- Well
- Godown
- Tubewell

Agriculture Research Station, Badnapur

The total area of this research station initially was 141.43 ha. The area under building is 11.25 ha, roads 5.90 ha, canal 7.44 ha, grazing area 3 ha, wells 2.10 ha. Now it is 84.14 ha.

Table 1 Blockwise Soil Area ARS, Badnapur

Block	Sub block	Area (ha)	Total Area
B	B1	4.20	10.7
	B2	0.36	
	B3	1.14	
	B4	0.36	
	B5	2.40	
	B6	0.52	
	B7	1.20	
	B8	0.52	
C	C2	1.80	1.80
D	D1	4.00	22.9
	D2	3.60	
	D3	3.80	
	D4	3.60	
	D5	3.00	
	D7	2.40	
	D8	2.50	
E	E3	4.60	11.3
	E4		
	E5	4.60	
	E6		
	E7	2.00	
	E8		
F	F1	4.80	12.6
	F2	4.80	
	F3	3.00	

3.2 Geology and parent material

The area is covered by the basaltic lava flows. Some layers of the lava flows are the result of intense volcanic activity during cretaceous Eocene period (almost seventy years ago). When the lava flows were ejected through long narrow fissures on the earth surface. This area has shallow cover of gravelly sediment over a hard basaltic contact within 50 cm of the surface.

3.3 Climate and Rainfall

Climatically, there are three seasons *Kharif* season starts from middle June to middle of September, *Rabi* from October to January and *Summer* from February to May. The area falls under semi-arid tropics. The average annual precipitation is 565.7 mm, mostly concentrated during the monsoon months from June to December. The daily mean maximum temperature varied from 28.50⁰ C where the daily mean minimum temperature ranged from 20.17⁰ C in the month of June and December, respectively. The mean minimum and maximum relative humidity varied between 71.8 to 57.23 per cent, respectively.

Sehgal *et al.*, (1990) established agro-ecological regions of Maharashtra South central Maharashtra falls under agro-ecological region No. 6 and further sub regions are 6.1, 6.2 and 6.3. Region No. 6.1 of south central part of Maharashtra plateau is hot, dry semiarid eco-sub-region with shallow and medium black soils (deep clayey black soils as inclusion), medium to high AWC and LPG of 90 to 120 days. Under this sub-region part of Aurangabad, Jalna and part of Parbhani falls.

Region No. 6.2 is central and western Maharashtra plateau hot moist semiarid eco-sub-region with shallow and medium loamy to clayey black soils (medium to clayey deep black soils as inclusion) medium to high AWC and LPG 120-

150 days and this region includes major part of Jalna, Parbhani and Nanded district and part of Aurangabad district. Region No. 6.3 is eastern Maharashtra plateau, hot moist semiarid eco-sub-region with medium and deep clayey black soils (shallow loamy to clay black soils as inclusion), medium to high AWC and LPG of 120 to 150 days. Majorly forest cover of Nanded district falls under this eco-sub-region (Challa *et al.*, 1995).

3.4 Major crop of the region

The major *Kharif* crops of the region are cereals (Sorghum, Maize and Pearl millet), oilseeds (Soybean, Sunflower and Sesamum) and cash crops (Cotton and Sugarcane). In *Rabi* season chickpea, wheat, sorghum, sunflower, safflower, linseed, and in *summer* season groundnut and mung are grown. Fruit crops like sweet-orange, mango, grapes, banana, and pomegranate are also grown.

3.5 Cropping Pattern

The important cropping pattern followed in the region is mung/urdbean followed by *Rabi* sorghum. Hybrid sorghum, pearl millet, maize followed by wheat and chickpea, and cotton, pigeonpea followed by summer groundnut. The chickpea is also grown generally either on residual moisture or where irrigation is limiting factor. The two major intercropping systems followed in the region are cereals+pulses (sorghum/pearl millet+pigeonpea). Pigeonpea is grown on large scale as a strip cropping with cotton. Since last few years pigeonpea+mung/urd/soybean is becoming popular. Strip cropping of safflower with chickpea is also practiced by many farmers in *Rainfed* areas.

3.5.1 Cultivated crops

Various crops cultivated on the Research Station during last three years are listed in table No. 3.1. in addition to agronomical crops various fruit plantation crop like mango, guava, sapota, tamarind, lime and custard apple also grown.

3.6 Natural vegetation

Agricultural Research Station, Badnapur is supported with the variety of trees and shrubs which includes Neem, Acacia, Ber, Mango, Australian Babul and shrubs of lantana, Tarota and hekalt.

3.7 Opening of soil profile

Agricultural Research Station, Badnapur is divided into 5 units, these five units further divided into 24 blocks on the basis of slope, soil depth and drainage basin. Eight profiles are exposed from the mungbean-sorghum, urdbean-sorghum, pigeonpea-chickpea, sorghum-chickpea cropping system (two profiles from each cropping system) by digging out up to 120 cm during the year 2014-15. The horizon in each profile were identified and studied as per the procedure and proforma supplied by NBSS & LUP, Nagpur (Sehgal, 1992).

3.8 Collection of soil samples

The Agricultural Research Station, Badnapur is spread over 141.43 ha. The area under building is 11.25 ha, roads 5.90 ha, canal 7.44 ha, grazing area 3 ha, wells 2.10 ha. The net cultivated area is 84.14 ha in different blocks viz. B, C, D, E and F. The soil samples were collected from upper part of Block D4 (mungbean-sorghum cropping system), lower part of Block D4 (urdbean-sorghum cropping system), Block D5 (pigeonpea-chickpea cropping system) and Block D7 (sorghum-chickpea cropping system). Total 64 soil samples were collected from the different depth by digging out the eight profiles from four blocks up to 120 cm (eight samples

from each profile). The collected samples were mixed thoroughly by hand on clean piece of cloth and about 1.5 kg composite representative samples were retained by quartering the soil. The soil boundaries were work out by observing each plot of the research station by actually traversing along the bunds of each plot and by collecting co-related information regarding soil depth, soil color and profile sampling. The plots and boundaries already existed on the farm.

3.9 Processing of soil samples for analysis

Collected soil samples were dried pounded in wooden mortar and pastel and was passed through 2 mm sieve. Each sample was thoroughly mixed to make it homogeneous and preserved in properly labeled polythene bags for a laboratory analysis (for determination of bulk density and free CaCO₃, soil samples were retained before pounding the soil).

3.10 Soil Analysis

The soil samples were used for estimation of density of soil, porosity, pH, EC, organic carbon, free calcium carbonate, available nitrogen, available phosphorus and available potassium. Soil color and soil texture were determined in situ. The details of procedure adopted and references are given bellow.

3.10.1 Soil physical and physico-chemical properties analysis

3.10.1.1 Soil colour

The soil color was determined in situ by using Munsell names and Munsell notations from Munsell soil color chart (Das and Agrawal 1997).

3.10.1.2 Bulk density

Bulk density of soil was estimated by clod method (Das and Agrawal 1997).

3.10.1.3 Porosity of soil

It was calculated from bulk density and particle density as per the formula,

$$\text{Percent porosity} = \frac{1 - \frac{d_b}{d_p} \times 100}{d_p}$$

Where,

d_b = bulk density g cm^3

d_p = particle density g cm^3

3.10.1.4 Soil texture

Soil texture was determined by hydrometer method by piper 1966.

3.10.1.5 Soil pH

It was determined in soil:water suspension (1:2.5) using glass electrode pH meter (Jackson, 1979).

3.10.1.6 Electrical conductivity

Electrical conductivity was estimated in (1:2.5) soil:water suspension after settlement of solids using conductivity bridge and expressed in dSm^{-1} (Jackson, 1979).

3.10.1.7 Organic carbon

The organic carbon of soil was determined by wet oxidation method suggested by walkley and black (Jackson, 1958).

3.10.1.8 Free CaCO_3 per cent

Free calcium carbonate equivalent was determined by rapid titration method (Piper, 1950) using 0.5 N HCl.

3.10.2 Macronutrient analysis

3.10.2.1 Available nitrogen

Available nitrogen was determined by the alkaline potassium permanganate method given by Subbiah and Asija, 1956.

3.10.2.2 Available phosphorus

It was determined by Olsen's method using 0.5 M NaHCO₃ (pH 8.5) as extracting reagent (Jackson, 1967).

3.10.2.3 Available potassium

The available potassium was determined by soil treated with Neutral Normal Ammonium Acetate and potassium in extract was determined by emission spectroscopy by flame photometer (Jackson, 1967).

*Result and
Discussion*



CHAPTER-IV

RESULT AND DISCUSSION

The results of the field and laboratory investigation carried out on soil sample collected from Agricultural research station, Badnapur have been presented and discussed in this chapter under following heads.

4.1 Soil site characteristics

4.1.1 Morphological properties of soil

4.1.2 Physical properties of soil

4.1.3 Chemical properties of soil

4.2 Fertility status of soil

4.2.1 Available macronutrient

4.3 Soil classification

4.4 Relationship between physical and chemical properties of soil.

4.1 Soil site characteristics

Soil site characteristics such as location, landform, slope and erosion were also studied and recorded in (Table 2).

4.1.1 Morphological properties of soil

Agarkar and Padole (1996) studied morphological and physico-chemical properties of 4 representative profiles from the Central Research Station, PDKV, Akola and reported that the soils from profiles 1 and 3, located on gently sloping landscapes, were shallow, moderately well drained, non-calcareous and fine-textured.

Balpande *et al.* (2007) studied the Grape-growing soils of Nashik district, Maharashtra and reported that the soils have developed over basalt except P₃ (basaltic alluvium) and occur at an elevation ranging from 550 to 700 m and above

MSL. P2, 5 and 6 were moderately well drained and others were well drained. P1, P3 and P6 were found to occur on plain/valley (1-3 % slope) and others on undulating lands (3-8 % slope) except P6.

The morphological characteristics of different pedons studied during present investigation and presented in (Table 3).

Soils are studied only in the field and can be best evaluated in situ examination of soil profile. However, in laboratory soil samples are analyzed for further interpretation. Soil description is based on classifying soil in defined categories in the profile. Various soil horizons were studied. Each horizon was observed and described in respect of various characteristics such as depth, colour, texture, consistency etc as per the norms of NBSS & LUP, Nagpur.

Table 2. Soil sites landform characteristics of soil of Agricultural research station, Badnapur.

Location	Land form	Parent Material	Slope (%)	Runoff	Drainage	Erosion
Pedon 1 Lower part of Block D4 (ARS, Badnapur)	Level plain	Weathered basalt	0-1	Medium	Well drained	Moderate
Pedon 2 Lower part of Block D4 (ARS, Badnapur)	Moderately sloping, Nearly level plain	Weathered basalt	1-3	Medium	Well drained	Moderate
Pedon 3 Upper part of Block D4 (ARS, Badnapur)	Gently to moderately sloping	Weathered basalt	1-3	Medium	Well drained	Moderate
Pedon 4 Upper part of Block D4 (ARS, Badnapur)	Nearly level plain	Weathered basalt	1-3	Medium	Well drained	Moderate
Pedon 5 Block D5 (ARS, Badnapur)	Moderately sloping	Weathered basalt	0-1	Medium	Well drained	Moderate
Pedon 6 Block D5 (ARS, Badnapur)	Nearly level plain	Weathered basalt	1-3	Medium	Well drained	Moderate
Pedon 7 Block D7 (ARS, Badnapur)	Level plain	Weathered basalt	0-1	Medium	Well drained	Moderate
Pedon 8 Block D7 (ARS, Badnapur)	Moderately sloping, Nearly level plain	Weathered basalt	1-3	Medium	Well drained	Moderate

A brief description of soil is given below. Salient morphological characteristics of the typifying pedon are described as under:

Pedon-1 (P₁)

- Location : Lower part of Block D4 (Agricultural research station, Badnapur)
- Land form and slope : 0-1%, level plain
- Present land use : Urdbean
- Previous land use : Sorghum
- Date of sample collection : 05/06/4014
- Drainage : Well drained
- Natural vegetation : Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt
- Parent material : Weathered basalt
- Climate : Hot sub-humid
- Annual rainfall : 565.5 mm
- Annual Temperature : The daily mean maximum temperature varied from 28.50⁰ C where the daily mean minimum temperature ranged from 20.17⁰ C in the month of June and December, respectively.
- Agro-climatic zone : Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-21	Very dark brown (10 YR 2/2) ; clay; moderate, medium, sub-angular blocky structure; hard, friable, sticky and plastic; very fine many pores; common plenty roots; violent effervescence; clear smooth boundary.
Bw	21-42	Very dark brown (10 YR 2/2); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; very fine many pores; plenty roots; slight effervescence; clear smooth boundary.



Plate. 1. Profile view of Pedon P₁, Lower part of Block D4 (ARS, Badnapur)



Plate. 2. Profile view of Pedon P₂, Lower part of Block D4 (ARS, Badnapur)

Bss1	42-65	Very dark brown (10 YR 2/2); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; very fine many pores; fine roots; slight effervescence; clear smooth boundary.
Bss2	65-91	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence; clear smooth boundary.
Bss3	91-113	Dark brown (10 YR 3/3); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence; clear smooth boundary.
Bss4	113-120	Dark brown (10 YR 3/3); clay; medium, strong, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence.

Pedon-2 (P₂)

Location	: Lower part of Block D4 (Agricultural research station, Badnapur)
Land form and slope	: 1-3%, moderately sloping, nearly level plain
Present land use	: Urdbean
Previous land use	: Sorghum
Date of sample collection	: 05/06/4014
Drainage	: Well drained
Natural vegetation	: Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.
Parent material	: Weathered basalt
Climate	: Hot sub-humid

Annual rainfall : 565.5 mm

Annual Temperature : The daily mean maximum temperature varied from 28.50⁰ C where the daily mean minimum temperature ranged from 20.17⁰ C in the month of June and December, respectively.

Agro-climatic zone : Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-19	Dark gray (10 YR 4/1) ; clay; medium, strong, sub-angular blocky structure; slightly hard, friable, sticky and plastic; very fine many pores; fine plenty roots; violent effervescence; clear smooth boundary.
Bw	19-39	Very dark gray (10 YR 3/1) ; clay; medium, strong, sub-angular blocky structure; hard, friable, sticky and plastic; very fine many pores; fine plenty roots; slight effervescence; clear smooth boundary.
Bss1	39-68	Very dark brown (10 YR 2/2); clay; medium, weak, angular blocky structure; hard, firm, sticky and very plastic; very fine many pores; very fine plenty roots; violent effervescence; clear smooth boundary.
Bss2	68-95	Dark brown (10 YR 3/3); clay; medium, weak, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very fine plenty roots; slight effervescence; clear smooth boundary.
Bss3	95-104	Very dark brown (10 YR 2/2); clay; medium, weak, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence; clear smooth boundary.
Bss4	104-120	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence.

Pedon-3 (P₃)

Location	: Upper part of Block D4 (Agricultural research station, Badnapur)
Land form and slope	: 1-3%, gently to moderately sloping
Present land use	: Mungbean
Previous land use	: Sorghum
Date of sample collection	: 05/06/4014
Drainage	: Well drained
Natural vegetation	: Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.
Parent material	: Weathered basalt
Climate	: Hot sub-humid
Annual rainfall	: 565.5 mm
Annual Temperature	: The daily mean maximum temperature varied from 28.50 ⁰ C where the daily mean minimum temperature ranged from 20.17 ⁰ C in the month of June and December, respectively.
Agro-climatic zone	: Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-23	Dark grayish brown (10 YR 4/2) ; clay; medium, moderate, sub angular blocky structure; hard, friable, sticky and plastic; very fine many pores; medium plenty roots; violent effervescence; clear smooth boundary.
Bw	23-46	Dark brown (10 YR 3/3) ; clay; medium, moderate, sub angular blocky structure; hard, friable, sticky and plastic; very fine many pores; medium plenty roots; slight effervescence; clear smooth boundary.
Bss1	46-70	Very dark brown (10 YR 2/2); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; fine roots; slight effervescence; clear smooth boundary.
Bss2	70-93	Dark brown (10 YR 3/3); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very fine roots; slight effervescence; clear smooth boundary.



Plate. 3. Profile view of Pedon P₃, Upper part of Block D4 (ARS, Badnapur)



Plate. 4. Profile view of Pedon P₄, Upper part of Block D4 (ARS, Badnapur)

Bss3	93-107	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence; clear smooth boundary.
Bss4	107-120	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, extremely firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence.

Pedon-4 (P₄)

Location	:	Upper part of Block D4 (Agricultural research station, Badnapur)
Land form and slope	:	1-3%, nearly level plain
Present land use	:	Mungbean
Previous land use	:	Sorghum
Date of sample collection	:	05/06/4014
Drainage	:	Well drained
Natural vegetation	:	Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.
Parent material	:	Weathered basalt
Climate	:	Hot sub-humid
Annual rainfall	:	565.5 mm
Annual Temperature	:	The daily mean maximum temperature varied from 28.50 ⁰ C where the daily mean minimum temperature ranged from 20.17 ⁰ C in the month of June and December, respectively.
Agro-climatic zone	:	Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-16	Dark grayish brown (10 YR 4/2) ; clay; medium, moderate, sub angular blocky structure; hard, friable, sticky and plastic; very fine many pores; medium plenty roots; slight effervescence; clear smooth boundary.

Bw	16-28	Very dark grayish brown (10 YR 3/2) ; clay; medium, moderate, sub angular blocky structure; hard, friable, sticky and plastic; very fine many pores; common plenty roots; slight effervescence; clear smooth boundary.
Bss1	28-53	Dark brown (10 YR 3/3); clay; medium, moderate, sub angular blocky structure; very hard, firm, sticky and plastic; very fine many pores; plenty roots; slight effervescence; clear smooth boundary.
Bss2	53-78	Dark brown (10 YR 3/3); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; very fine many pores; fine roots; slight effervescence; clear smooth boundary.
Bss3	78-103	Very dark brown (10 YR 2/2); clay; medium, strong, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence; clear smooth boundary.
Bss4	103-120	Very dark brown (10 YR 2/2); clay; medium, strong, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence.

Pedon-5 (P₅)

Location	: Block D5 (Agricultural research station, Badnapur)
Land form and slope	: 3-8%, moderately sloping
Present land use	: Pigeonpea
Previous land use	: Chickpea
Date of sample collection	: 05/06/4014
Drainage	: Well drained
Natural vegetation	: Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.
Parent material	: Weathered basalt
Climate	: Hot sub-humid
Annual rainfall	: 565.5 mm
Annual Temperature	: The daily mean maximum temperature varied from 28.50 ⁰ C where the daily mean minimum temperature ranged from 20.17 ⁰ C in the month of June and December, respectively.
Agro-climatic zone	: Drought prone zone



Plate. 5. Profile view of Pedon P₅, Block D5 (ARS, Badnapur)

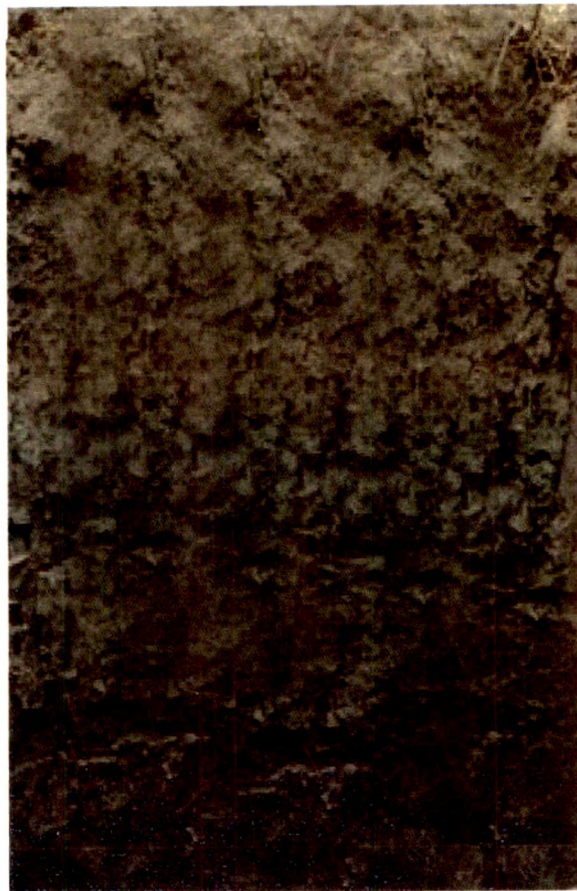


Plate. 6. Profile view of Pedon P₆, Block D5 (ARS, Badnapur)

Horizon	Depth (cm)	Description
Ap	0-16	Grayish brown (10 YR 5/2) ; clay; medium, strong, sub angular blocky structure; slightly hard, friable, sticky and plastic; very fine many pores; common plenty roots; violent effervescence; clear smooth boundary.
Bw	16-31	Very dark grayish brown (10 YR 3/2) ; clay; medium, strong, sub angular blocky structure; hard, firm, sticky and plastic; very fine many pores; common plenty roots; violent effervescence; clear smooth boundary.
Bss1	31-57	Very dark gray (10 YR 3/1); clay; medium, moderate, angular blocky structure; very hard, firm, very sticky and very plastic; very fine many pores; plenty roots; violent effervescence; clear smooth boundary.
Bss2	57-83	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; very fine many pores; fine roots; slight effervescence; clear smooth boundary.
Bss3	83-104	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence; clear smooth boundary.
Bss4	104-120	Very dark brown (10 YR 2/2); clay; medium, moderate, angular blocky structure; very hard, extremely firm, very sticky and very plastic; fine many pores; very few roots; slight effervescence.

Pedon-6 (P₆)

Location	: Block D5 (Agricultural research station, Badnapur)
Land form and slope	: 1-3 %, nearly level plain
Present land use	: Pigeonpea
Previous land use	: Chickpea
Date of sample collection	: 05/06/4014
Drainage	: Well drained
Natural vegetation	: Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.

Parent material : Weathered basalt

Climate : Hot sub-humid

Annual rainfall : 565.5 mm

Annual Temperature : The daily mean maximum temperature varied from 28.50⁰ C where the daily mean minimum temperature ranged from 20.17⁰ C in the month of June and December, respectively.

Agro-climatic zone : Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-16	Grayish brown (10 YR 5/2); clay; medium, moderate, angular blocky structure; slightly hard, friable, sticky and plastic; very fine many pores; medium plenty roots; violent effervescence; clear smooth boundary.
Bw	16-29	Very dark grayish brown (10 YR 3/2); clay; medium, strong, sub angular blocky structure; hard, friable, sticky and plastic; very fine many pores; medium plenty roots; violent effervescence; clear smooth boundary.
Bss1	29-54	Very dark gray (10 YR 3/1); clay; medium, strong, sub angular blocky structure; very hard, firm, very sticky and very plastic; very fine many pores; plenty roots; violent effervescence; clear smooth boundary.
Bss2	54-89	Very dark brown (10 YR 2/2); clay; medium, strong, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; fine few roots; violent effervescence; clear smooth boundary.
Bss3	89-108	Dark brown (10 YR 3/3); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; violent effervescence; clear smooth boundary.
Bss4	108-120	Brown (10 YR 5/3); clay; medium, moderate, sub angular blocky structure; very hard, extremely firm, very sticky and very plastic; fine many pores; very few roots; violent effervescence.

Pedon-7 (P₇)

Location	: Block D7 (Agricultural research station, Badnapur)
Land form and slope	: 0-1 %, level plain
Present land use	: Sorghum
Previous land use	: Chickpea
Date of sample collection	: 05/06/4014
Drainage	: Well drained
Natural vegetation	: Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.
Parent material	: Weathered basalt
Climate	: Hot sub-humid
Annual rainfall	: 565.5 mm
Annual Temperature	: The daily mean maximum temperature varied from 28.50 ⁰ C where the daily mean minimum temperature ranged from 20.17 ⁰ C in the month of June and December, respectively.
Agro-climatic zone	: Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-14	Dark grayish brown (10 YR 4/2); clay; medium, moderate, granular structure; hard, friable, slightly sticky and slightly plastic; very fine many pores; common plenty roots; violent effervescence; clear smooth boundary.
Bw	14-29	Very dark yellowish brown (10 YR 4/4); clay; medium, moderate, granular structure; hard, firm, sticky and plastic; very fine many pores; medium plenty roots; violent effervescence; clear smooth boundary.
Bss1	29-57	Brown (10 YR 5/3); clay; medium, weak, angular blocky structure; very hard, firm, sticky and plastic; fine many pores; plenty roots; violent effervescence; clear smooth boundary.
Bss2	57-83	Pale brown (10 YR 6/3); clay; medium, weak, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; few fine roots; violent effervescence; clear smooth boundary.



Plate. 7. Profile view of Pedon P₇, Block D7 (ARS, Badnapur)



Plate. 8. Profile view of Pedon P₈, Block D7 (ARS, Badnapur)

Bss3	83-107	Light yellowish brown (10 YR 6/4); clay; c medium, weak, angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; very few roots; violent effervescence; clear smooth boundary.
Bss4	107-120	Pale brown (10 YR 6/3); clay; medium, moderate, sub angular blocky structure; very hard, extremely firm, very sticky and very plastic; fine many pores; very few roots; violent effervescence.

Pedon-8 (P₈)

Location	:	Block D7 (Agricultural research station, Badnapur)
Land form and slope	:	1-3 %, moderately sloping, nearly level plain
Present land use	:	Sorghum
Previous land use	:	Chickpea
Date of sample collection	:	05/06/4014
Drainage	:	Well drained
Natural vegetation	:	Neem, Ber, Babul, Acacia, Mango, Australian babul, shrubs of lantana, tarota and hekalt.
Parent material	:	Weathered basalt
Climate	:	Hot sub-humid
Annual rainfall	:	565.5 mm
Annual Temperature	:	The daily mean maximum temperature varied from 28.50 ⁰ C where the daily mean minimum temperature ranged from 20.17 ⁰ C in the month of June and December, respectively.
Agro-climatic zone	:	Drought prone zone

Horizon	Depth (cm)	Description
Ap	0-15	Dark grayish brown (10 YR 4/2); clay; medium, moderate, granular structure; slightly hard, friable, slightly sticky and slightly plastic; very fine many pores; medium plenty roots; violent effervescences; clear smooth boundary.

Table 3. Morphological characteristics of soils of Agricultural research station, Badnapur.

Horizon	Depth	Boundary	Matrix colour	Texture	Structure	Consistence	Pores	Roots	Efferves cence
1	2	3	4	5	6	7	8	9	10
Pedon - P ₁ Lower part of Block D4 (ARS, Badnapur)									
Ap	0-21	cs	10 YR 2/2	c	m2 sbk	h, fr, s, p	vfm	common plenty	ev
Bw	21-42	cs	10 YR 2/2	c	m2 sbk	vh, vfi, vs, vp	vfm	plenty roots	e
Bss1	42-65	cs	10 YR 2/2	c	m2 sbk	vh, vfi, vs, vp	vfm	fine roots	e
Bss2	65-91	cs	10 YR 2/2	c	m2 abk	vh, vfi, vs, vp	fm	very few roots	e
Bss3	91-113	cs	10 YR 3/3	c	m2 abk	vh, vfi, vs, vp	fm	very few roots	e
Bss4	113-120	-	10 YR 3/3	c	m3 abk	vh, vfi, vs, vp	fm	very few roots	e
Pedon - P ₂ Lower part of Block D4 (ARS, Badnapur)									
Ap	0-19	cs	10 YR 4/1	c	m3 sbk	sh, fr, s, p	vfm	fine plenty roots	ev
Bw	19-39	cs	10 YR 3/1	c	m3 sbk	h, fr, s, p	vfm	fine plenty roots	ev
Bss1	39-68	cs	10 YR 2/2	c	m1 abk	h, fi, s, p	vfm	very fine plenty roots	ev
Bss2	68-95	cs	10 YR 3/3	c	m1 abk	vh, vfi, vs, vp	fm	very fine plenty roots	e
Bss3	95-104	cs	10 YR 2/2	c	m1 abk	vh, vfi, vs, vp	fm	very few roots	e
Bss4	104-120	-	10 YR 2/2	c	m2 abk	vh, vfi, vs, vp	fm	very few roots	e
Pedon - P ₃ Upper part of Block D4 (ARS, Badnapur)									
Ap	0-23	cs	10 YR 4/2	c	m2 sbk	h, fr, s, p	vfm	medium plenty roots	ev
Bw	23-46	cs	10 YR 3/3	c	m2 sbk	h, fr, s, p	vfm	medium plenty roots	e
Bss1	46-70	cs	10 YR 2/2	c	m2 sbk	vh, vfi, vs, vp	fm	fine roots	e
Bss2	70-93	cs	10 YR 2/2	c	m2 abk	vh, vfi, vs, vp	fm	few fine roots	e
Bss3	93-107	cs	10 YR 2/2	c	m2 abk	vh, vfi, vs, vp	fm	very few roots	e
Bss4	107-120	-	10 YR 2/2	c	m2 abk	vh, efi, vs, vp	fm	very few roots	e

Horizon	Depth	Boundary	Matrix colour	Texture	Structure	Consistence	Pores	Roots	Efferves cence
1	2	3	4	5	6	7	8	9	10
Pedon - P ₄ Upper part of Block D4 (ARS, Badnapur)									
Ap	0-16	cs	10 YR 4/2	c	m2 sbk	h, fr, s, p	vfn	medium plenty roots	e
Bw	16-28	cs	10 YR 3/2	c	m2 sbk	h, fr, s, p	vfn	common plenty roots	e
Bss1	28-53	cs	10 YR 3/3	c	m2 sbk	vh, fi, s, p	vfn	plenty roots	e
Bss2	53-78	cs	10 YR 3/3	c	m2 sbk	vh, vfi, vs, vp	vfn	fine roots	e
Bss3	78-103	cs	10 YR 2/2	c	m3 sbk	vh, vfi, vs, vp	fm	very few roots	e
Bss4	103-120	-	10 YR 2/2	c	m3 sbk	vh, vfi, vs, vp	fm	very few roots	e
Pedon - P ₅ Block D5 (ARS, Badnapur)									
Ap	0-16	cs	10 YR 5/2	c	m3 sbk	sh, fr, s, p	vfn	common plenty roots	ev
Bw	16-31	cs	10 YR 3/2	c	m3 sbk	h, fi, s, p	vfn	common plenty roots	ev
Bss1	31-57	cs	10 YR 3/1	c	m2 abk	vh, fi, vs, vp	vfn	plenty roots	ev
Bss2	57-83	cs	10 YR 2/2	c	m2 abk	vh, vfi, vs, vp	vfn	fine roots	e
Bss3	83-104	cs	10 YR 2/2	c	m2 abk	vh, vfi, vs, vp	fm	very few roots	e
Bss4	104-120	-	10 YR 2/2	c	m2 abk	vh, efi, vs, vp	fm	very few roots	e
Pedon - P ₆ Block D5 (ARS, Badnapur)									
Ap	0-16	cs	10 YR 5/2	c	m2 abk	sh, fr, s, p	vfn	medium plenty roots	ev
Bw	16-29	cs	10 YR 3/2	c	m3 sbk	h, fr, s, p	vfn	medium plenty roots	ev
Bss1	29-54	cs	10 YR 3/1	c	m3 sbk	vh, fi, vs, vp	vfn	plenty roots	ev
Bss2	54-89	cs	10 YR 2/2	c	m3 sbk	vh, vfi, vs, vp	fm	few fine roots	ev
Bss3	89-108	cs	10 YR 3/3	c	m2 sbk	vh, vfi, vs, vp	fm	very few roots	ev
Bss4	108-120	-	10 YR 5/3	c	m2 sbk	vh, efi, vs, vp	fm	very few roots	ev

Horizon	Depth	Boundary	Matrix colour	Texture	Structure	Consistence	Pores	Roots	Efferves cence
1	2	3	4	5	6	7	8	9	10
Pedon - P ₇ Block D7 (ARS, Badnapur)									
Ap	0-14	cs	10 YR 4/2	c	m2 gr	h, fr, ss, sp	vfm	Common plenty roots	ev
Bw	14-29	cs	10 YR 4/4	c	m2 gr	h, fi, s, p	vfm	Medium plenty roots	ev
Bss1	29-57	cs	10 YR 5/3	c	m1 abk	vh, fi, s, p	fm	Plenty roots	ev
Bss2	57-83	cs	10 YR 6/3	c	m1 abk	vh, vfi, vs, vp	fm	Few fine roots	ev
Bss3	83-107	cs	10 YR 6/4	c	m1 abk	vh, vfi, vs, vp	fm	Very few roots	ev
Bss4	107-120	-	10 YR 6/3	c	m2 sbk	vh, efi, vs, vp	fm	Very few roots	ev
Pedon - P ₈ Block D7 (ARS, Badnapur)									
Ap	0-15	cs	10 YR 4/2	c	m2 gr	sh, fr, ss, sp	vfm	Medium plenty roots	ev
Bw	15-34	cs	10 YR 4/4	c	m2 gr	h, fi, s, p	fm	Common plenty roots	e
Bss1	34-59	cs	10 YR 5/3	c	m2 gr	vh, fi, s, p	fm	Plenty roots	e
Bss2	59-87	cs	10 YR 5/3	c	m2 sbk	vh, vfi, vs, vp	fm	Fine roots	e
Bss3	87-109	cs	10 YR 6/4	c	m2 sbk	vh, vfi, vs, vp	fm	Fine few roots	e
Bss4	109-120	-	10 YR 6/3	c	m2 sbk	vh, vfi, vs, vp	fm	Very few roots	e

Abbreviations:-

cs	:	Clear smooth	h	:	hard	vp	:	very plastic
c	:	Clay	fr	:	Friable	efi	:	extremely firm
m2 sbk	:	medium, moderate, sub-angular blocky	s	:	sticky	vs	:	very sticky
m3 sbk	:	medium, strong, sub-angular blocky	p	:	plastic	vfi	:	very firm
m1 abk	:	medium, weak, angular blocky	fi	:	firm	fm	:	fine many
m2 abk	:	medium, moderate, angular blocky	ss	:	slightly sticky	vfm	:	very fine many
m3 abk	:	medium, strong, angular blocky	sh	:	slightly hard	e	:	slight effervescences
m2 gr	:	medium, moderate, granular	vh	:	very hard	ev	:	violent effervescences

Bw	15-34	Dark yellowish brown (10 YR 4/4); clay; medium, moderate, granular structure; hard, firm, sticky and plastic; fine many pores; common plenty roots; slight effervescences; clear smooth boundary.
Bss1	34-59	Brown (10 YR 5/3); clay; medium, moderate, granular structure; very hard, firm, sticky and plastic; fine many pores; plenty roots; slight effervescences; clear smooth boundary.
Bss2	59-87	Brown (10 YR 5/3); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; fine roots; slight effervescences; clear smooth boundary.
Bss3	87-109	Light yellowish brown (10 YR 6/4); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; fine few roots; slight effervescences; clear smooth boundary.
Bss4	109-120	Pale brown (10 YR 6/3); clay; medium, moderate, sub angular blocky structure; very hard, very firm, very sticky and very plastic; fine many pores; fine few roots; slight effervescences.

4.1.1.1 Soil Depth

The soil depth is an important factor in the crop production which influences the crop yield in general, increase in yield with increase in soil depth (De La Rosa 1981; Bhaskar *et al.* 1987). Soil depth is a central characteristic in land evaluation as it partly control the water storage, available water capacity, storage of nutrients and providing volume for the production of root biomass in the root zone. Soil depth data presented in (Table 3) indicated that all profiles *viz.* P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈ are deep >120 cm.

Similarly, Walkar *et al.* (1968) reported that landform parameters of slope gradient, slope length direction, curvature, distance from the hill slope summit, and elevation relative to the summit were recorded with soil profile observations

across small loess and drift landscapes in Iowa. Slope length direction was also an important parameter for A horizon thickness and subsoil mottle features. When two of the sites were subdivided into convex and concave areas, significant regressions were again obtained. Nevertheless, considerable soil variation remained unaccounted for. This may result from the relict nature of some of the subsoil features, or in the case of A horizons, from faunal activity.

Sehgal (1991) reported that soil depth is an important criteria for land evaluation. Most of the crops produce excellent yield with an effective soil depth of 90 to 100 cm (Sys. 1985).

Sharma *et al.* (1996) reported that the soils at elevated topography were shallow to moderate deep.

4.1.1.2 Soil colour

Soil colour is one of the most important morphological characteristics used for soil identification in the field and it helps in soil classification. Although it has little bearing on the function of the soil, a number of important aspects like wetness, organic matter content and the relative age of the soils can be inferred from soil colour.

The black colour of soil usually indicates the presence of titaniferous magnetite and organic matter: red colour indicates the presence of free iron oxides common in well oxidized soils and commonly found in tropical region.

The soils of the Agricultural research station, Badnapur had colours in the hue ranging from 10 YR, values ranging from 2 to 6 chroma of 1-4. The hue, value and chroma denote dominant spectral colour, lightness or darkness of a colour and strength of colour respectively.

The low chroma indicates poor drainage of the soils and the dark colour of the soils may be due to high dark coloured ferromagnesium minerals.

The data presented in (Table 3) indicates that most of the soils were very dark brown (10 YR 2/2) to light yellowish brown (10 YR 6/4) in colour. The pedon P₁ soils colour varies from 10 YR 2/2 to 10 YR 3/3 corresponds to the very dark brown to dark brown. The pedon P₂ soils colour varies from 10 YR 2/2 to 10 YR 4/1 corresponds to the very dark brown to dark gray. The pedon P₃ and P₄ soils colour varies from 10 YR 2/2 to 10 YR 4/2 corresponds to the very dark brown to dark grayish brown. The pedon P₅ soils colour varies from 10 YR 2/2 to 10 YR 5/2 corresponds to the very dark brown to grayish brown. The pedon P₆ soils colour varies from 10 YR 2/2 to 10 YR 5/3 corresponds to the very dark brown to brown. The pedon P₇ and P₈ soils colour varies from 10 YR 4/2 to 10 YR 6/4 corresponds to the dark grayish brown to light yellowish brown. The dark colour of these soils may be attributed to domination of highly dispersed forms of humus and smectite minerals (Zonn 1986).

Walia and Rao (1996) reported that the variation in colour is because of release of iron oxides and their occurrence in various hydrated forms due to difference in drainage of the soils.

4.1.1.3 Soil structure

The soil structure refers to aggregation of primary soil particles in to large units known as peds. Also it can be defined as the arrangement of primary soil particles into secondary units. The secondary units are characterized and classified on the basis of size, shape and degree of distinctness into size, classes, types and grades respectively.

The data presented in (Table 3) showed that the soils of study area have structure varies from medium, moderate, granular to medium, moderate, angular blocky. The pedon P₁ and P₃ soils structure varies from medium, moderate sub-angular blocky to medium, moderate, angular blocky. The pedon P₂ soils structure varies from medium, strong, sub-angular blocky to medium, weak, angular blocky. The pedons P₄ and P₅ soils structure varies from medium, moderate, sub-angular blocky to medium, strong, sub-angular blocky. The pedon P₆ soils structure varies from medium, strong, sub-angular blocky to medium, moderate, angular blocky in structure. The pedon P₇ and P₈ soils structure varies from medium, moderate, granular to medium, moderate, sub-angular blocky.

The Vertisols possess inherently poor structure which is greatly influenced by water regimes. Krishna and Perumal (1948) described the formation of a 'lentillike' (resembling lentil seed) structure having the shape of a double-convex lens in the subsurface of black cotton soils from the Hyderabad (India) area. The lentils formed are stable and of different sizes, which break into irregular or prismatic clods. Studies of the Blue Nile clay plains of Sudan indicated that the unequal pressures which result from the swelling and shrinkage processes are responsible for the aggregated structure (De Vos and Virgo 1969)

4.1.1.4 Soil consistency

Vertisols offer extremes of consistence they are very hard when dry and very sticky and plastic when wet (Jewitt *et al.* 1979). Extreme hardness when dry and stickiness and loss of trafficability when wet, permit tillage and seedbed preparation only within a very narrow range of moisture contents. The cultivation of Vertisols when too dry or too wet may therefore result in poor tilth due to cloddy or

puddled structure, respectively (Dudal 1965; Krantz and Sahrawat 1974; Krantz *et al.* 1978).

The data presented in (Table 3) shows that the consistency of the studied soils varies from slightly hard to very hard in dry condition, friable to extremely firm in moist condition and slightly sticky slightly plastic to very sticky very plastic in wet condition. The consistency in pedon P₁ & P₄ varies from hard to very hard in dry condition, friable to very firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₂ varies from slightly hard to very hard in dry condition, friable to very firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₃ varies from hard to very hard in dry condition, friable to extremely firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₅ & P₆ varies from slightly hard to very hard in dry condition, friable to extremely firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₇ varies from hard to very hard in dry condition, friable to extremely firm in moist condition slightly sticky slightly plastic to very sticky very plastic in wet condition. The consistency in pedon P₈ varies from slightly hard to very hard in dry condition, friable to very firm in moist condition and slightly sticky slightly plastic to very sticky very plastic in wet condition.

4.1.2 Physical characteristics of the soil

4.1.2.1 Coarse fragments

The data presented in (Table 4) indicates that the coarse fragment of the soil varies from 8.56 to 25.81 per cent. The coarse fragments is varies from 9.23 to 14.65, 9.13 to 15.57, 8.56 to 19.94, 8.83 to 14.84, 14.08 to 20.28, 10.72 to 19.83, 9.27 to 21.23 and 9.48 to 25.81 per cent in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈,

Table No. 4 Physical characteristics of the soils of Agricultural research station, Badnapur

Horizon	Depth	Coarse fragment (%)	Bulk Density (Mg m ⁻³)	Porosity (%)	Particle size distribution		
					Sand %	Silt %	Clay %
Pedon - P₁ Lower part of Block D4 (ARS, Badnapur)							
Ap	0-21	9.23	1.19	55.26	5.7	30.7	63.6
Bw	21-42	11.42	1.30	50.94	6.9	40.0	53.2
Bss1	42-65	10.24	1.36	48.68	12.1	26.1	61.8
Bss2	65-91	12.67	1.37	48.43	10.5	29.0	60.6
Bss3	91-113	9.89	1.39	47.55	11.7	28.6	59.7
Bss4	113-120	14.65	1.48	44.15	8.6	38.2	53.3
Pedon - P₂ Lower part of Block D4 (ARS, Badnapur)							
Ap	0-19	12.87	1.20	54.72	6.7	37.9	55.4
Bw	19-39	14.56	1.23	53.69	5.5	38.0	56.6
Bss1	39-68	12.34	1.32	50.19	12.9	24.6	62.6
Bss2	68-95	9.13	1.39	47.55	11.4	31.0	57.7
Bss3	95-104	10.76	1.38	47.92	16.9	20.5	62.6
Bss4	104-120	15.57	1.41	46.79	16.8	21.3	62.0
Pedon - P₃ Upper part of Block D4 (ARS, Badnapur)							
Ap	0-23	8.56	1.22	53.88	9.8	28.4	61.8
Bw	23-46	10.22	1.43	46.04	13.9	27.2	59.0
Bss1	46-70	13.87	1.41	46.79	9.1	27.2	63.8
Bss2	70-93	10.49	1.41	46.79	8.5	29.0	62.6
Bss3	93-107	9.40	1.45	45.28	12.9	29.2	58.0

Horizon	Depth	Coarse fragment (%)	Bulk Density (Mg m ⁻³)	Porosity (%)	Particle size distribution		
					Sand %	Silt %	Clay %
Pedon - P₄ Upper part of Block D4 (ARS, Badnapur)							
Ap	0-16	9.68	1.23	53.46	6.9	34.5	58.6
Bw	16-28	9.28	1.30	50.94	5.9	32.5	61.7
Bss1	28-53	12.94	1.44	45.66	6.1	32.3	61.7
Bss2	53-78	14.41	1.45	45.28	5.5	30.7	63.8
Bss3	78-103	8.83	1.49	43.77	9.9	25.6	64.5
Bss4	103-120	14.84	1.48	44.15	14.8	26.4	58.9
Pedon - P₅ Block D5 (ARS, Badnapur)							
Ap	0-16	14.08	1.20	54.72	6.4	38.8	54.8
Bw	16-31	15.81	1.42	46.33	5.9	36.3	57.8
Bss1	31-57	19.62	1.41	46.79	10.9	28.0	61.2
Bss2	57-83	14.76	1.43	46.04	8.9	32.5	58.7
Bss3	83-104	20.28	1.47	44.53	7.5	33.7	58.9
Bss4	104-120	18.69	1.52	42.64	15.9	23.9	60.3
Pedon - P₆ Block D5 (ARS, Badnapur)							
Ap	0-16	10.72	1.19	55.06	7.8	39.6	52.6
Bw	16-29	12.82	1.43	45.91	6.2	38.0	55.8
Bss1	29-54	10.48	1.49	43.87	9.1	28.4	62.6
Bss2	54-89	18.92	1.52	42.64	10.5	29.0	60.6
Bss3	89-108	16.24	1.53	42.26	12.8	26.7	60.6
Bss4	108-120	19.83	1.55	41.51	10.1	31.7	58.3

Horizon	Depth	Coarse fragment (%)	Bulk Density (Mg m ⁻³)	Porosity (%)	Particle size distribution		
					Sand %	Silt %	Clay %
Pedon - P₇ Block D7 (ARS, Badnapur)							
Ap	0-14	9.27	1.20	54.72	6.5	31.7	61.8
Bw	14-29	12.53	1.29	51.32	8.5	30.3	61.3
Bss1	29-57	15.82	1.32	50.19	16.9	26.4	56.8
Bss2	57-83	10.88	1.35	49.06	11.9	34.6	53.6
Bss3	83-107	17.23	1.39	47.55	20.2	23.4	56.4
Bss4	107-120	21.23	1.42	46.42	12.5	38.3	49.3
Pedon - P₈ Block D7 (ARS, Badnapur)							
Ap	0-15	12.57	1.22	53.88	5.8	35.6	58.6
Bw	15-34	9.48	1.26	52.45	7.1	33.3	59.6
Bss1	34-59	15.50	1.38	47.92	13.6	31.9	54.6
Bss2	59-87	19.48	1.40	47.17	12.1	28.9	59.1
Bss3	87-109	21.57	1.44	45.66	10.4	36.7	53.0
Bss4	109-120	25.81	1.55	41.51	9.4	35.8	54.8

respectively. It is further noticed that the presence of coarse fragments decrease down the slope. Therefore, it is obvious that the presence of coarse fragments is related with topographic situation.

4.1.2.2 Bulk density

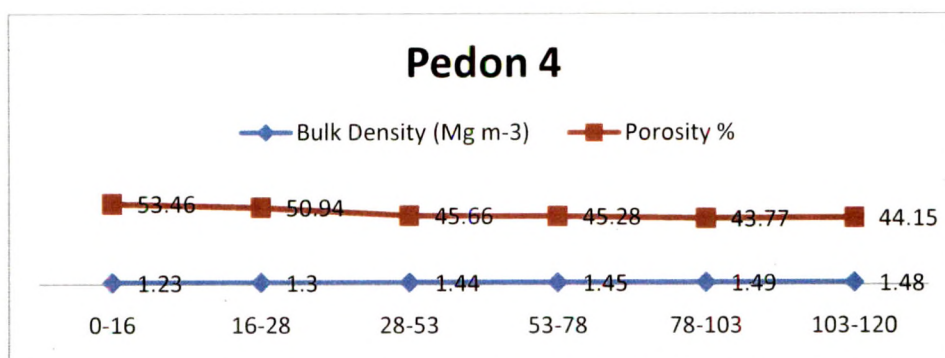
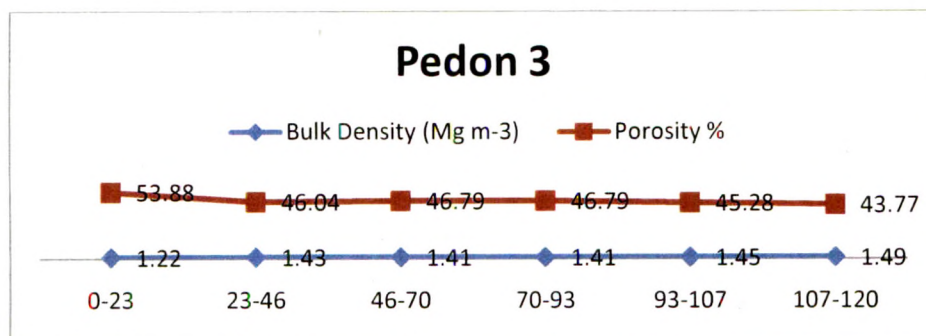
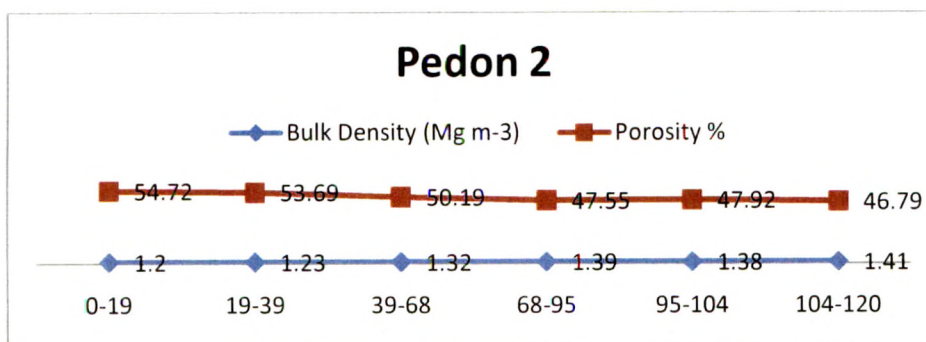
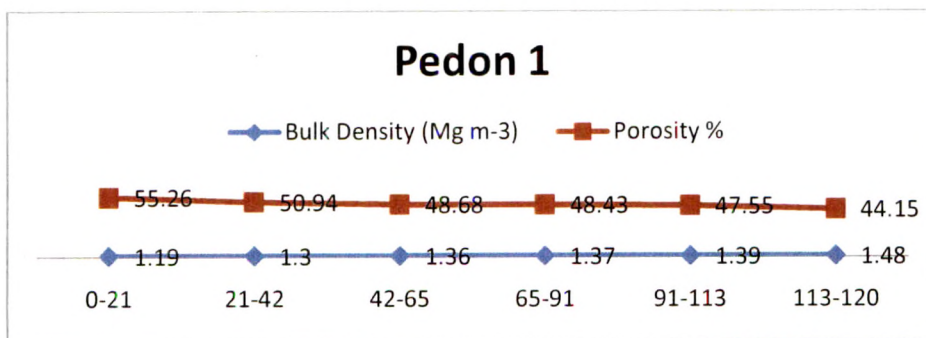
Bulk density is the mass of soil per unit volume, including pore spaces (Hillel, 1980) as the bulk density relates to combined volume of the solids and pore spaces, it serves as a guide to assess the soil compaction and porosity. It can be used as an indicator for root penetration and soil aeration.

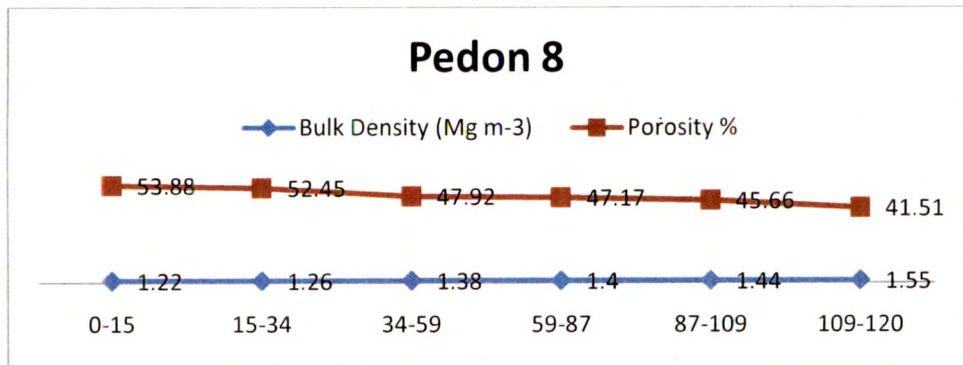
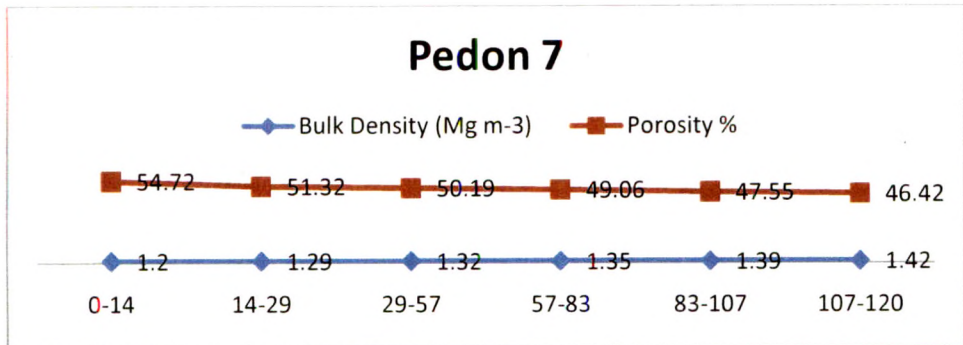
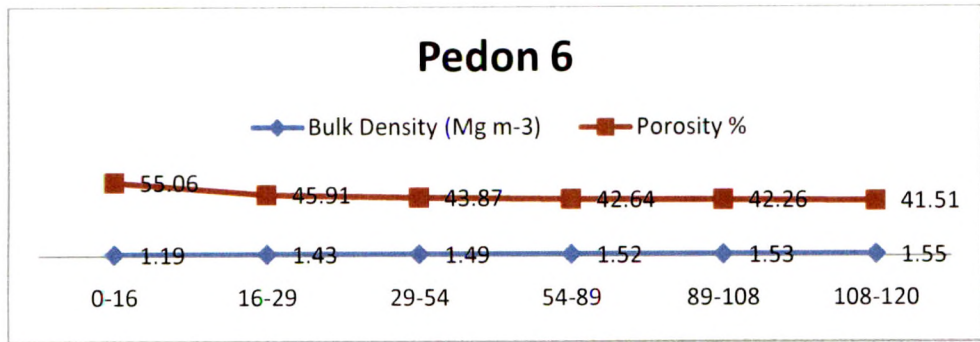
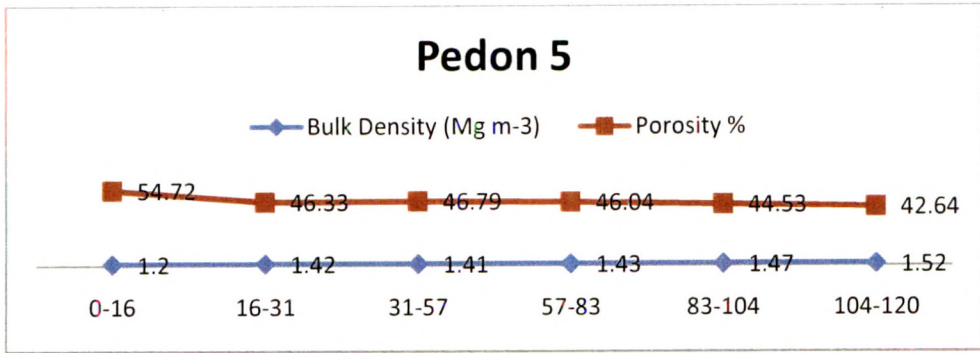
The bulk density of Vertisols varies greatly because of their swelling and shrinking nature with changes in soil moisture content. The soils have high bulk density when these are dry, and low values when in a swollen stage. According to Jewitt *et al.* (1979), the bulk density of a Vertisols may vary from approximately 1 to 2 g/cm³ depending on the moisture content.

The data presented in (Table 4) indicates that the bulk density of soils of Agricultural research station, Badnapur is varied from 1.19 to 1.55 Mg m⁻³ which may be due to presence of organic carbon and/or coarse fragments. The highest (1.55 Mg m⁻³) bulk density was observed in pedon P₆ & P₈ in lower depth. The bulk density of pedon P₁ varies from 1.19 to 1.48 Mg m⁻³, pedon P₂ is 1.20 to 1.41 Mg m⁻³, pedon P₃ 1.22 to 1.49 Mg m⁻³, pedon P₄ is 1.23 to 1.48 Mg m⁻³, pedon P₅ 1.20 to 1.52 Mg m⁻³, pedon P₆ is 1.19 to 1.55 Mg m⁻³, pedon P₇ 1.20 to 1.42 Mg m⁻³ and pedon P₈ is 1.22 to 1.55 Mg m⁻³, respectively. The Bss horizon of all the pedons had higher bulk density than the surface and sub-surface horizons which may be due to high clay content resulting in greater compaction in swelling clay soils (Ahuja *et al.* 1988).

In general, the bulk density increased with soil depth and with amount of clay. Surface soils show lower bulk density in compare to subsurface soils. It may

Figure. 2. Graphical representation of depth wise Bulk density and Porosity of the soils of Agricultural research station, Badnapur.





be due to high organic carbon and disturbance due to intercultural operations. High value in subsurface layers may be due to smectite clay and over burden leading to compaction, slickensides, caused strong structural aggregate formation and high bulk density and root development have the inverse relationship.

4.1.2.3 Porosity

Soil porosity is the percentage pore space to total volume of soil. Porosity refers to that percentage of soil volume, which is occupied by pore space.

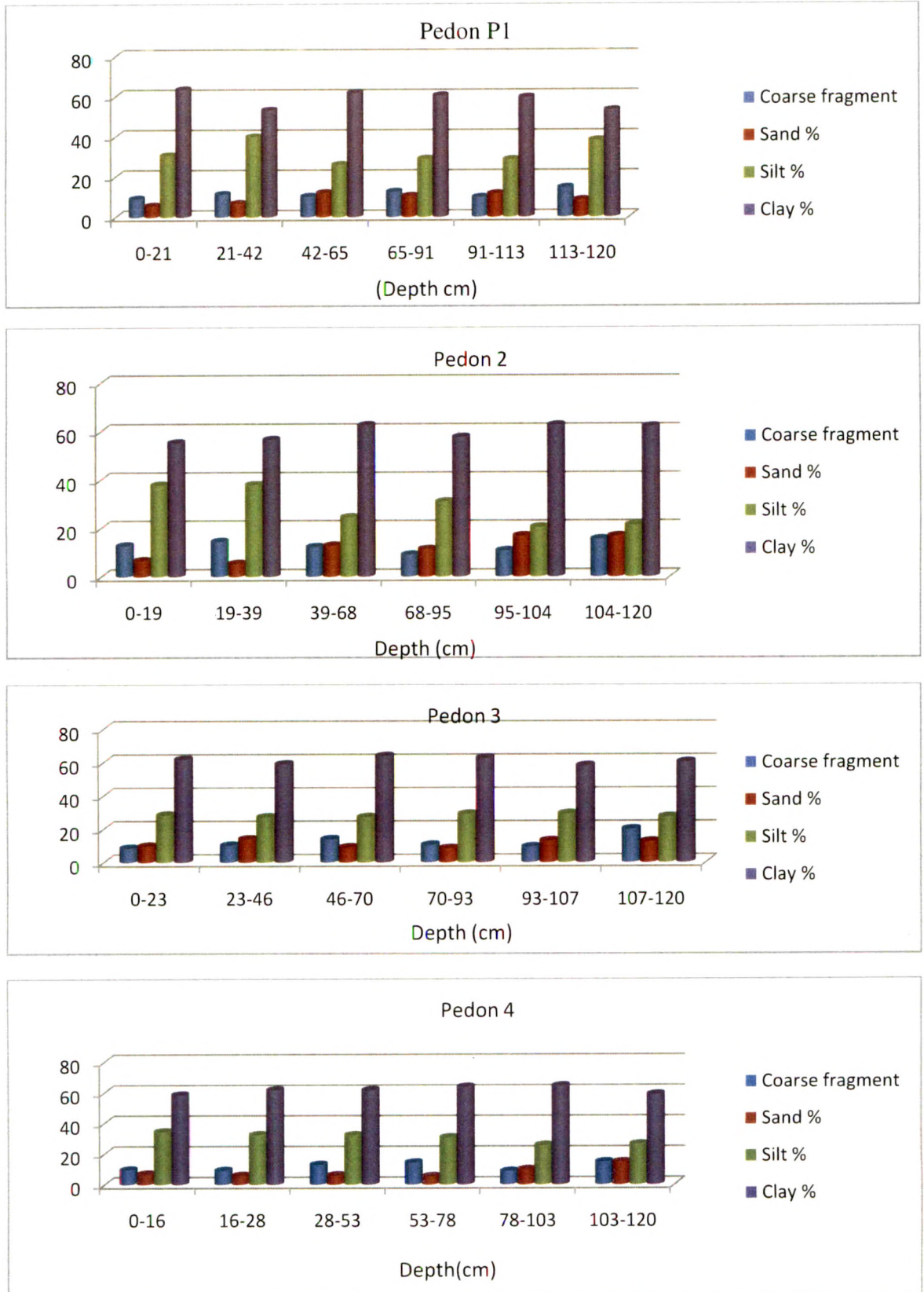
The data presented in (Table 4) shows that the per cent porosity of soils of studied area is varies from 41.51 to 55.26 per cent. Highest porosity estimated in surface soil 55.06 and 55.26 per cent in pedon P₆ and P₁, respectively. The per cent porosity of soils estimated in different horizon varies from 44.15 to 55.26 per cent, 46.79 to 54.72 per cent, 43.77 to 53.88, 44.15 to 53.46 per cent, 42.64 to 54.72 per cent, 41.51 to 55.06 per cent, 46.42 to 54.72 per cent, 41.41 to 53.88 per cent in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. Soil porosity is inversely related with soil bulk density. Soil porosity decreases as increases in bulk density. Soil texture, soil structure, arrangement of soil particle, organic matter, macro organisms, depth of soil and cropping affect the per cent porosity of soils. Increase in organic matter content in the soil, increase in percentage of pore space. Pore space in the sub-soil has been found to decrease in compare to surface soil.

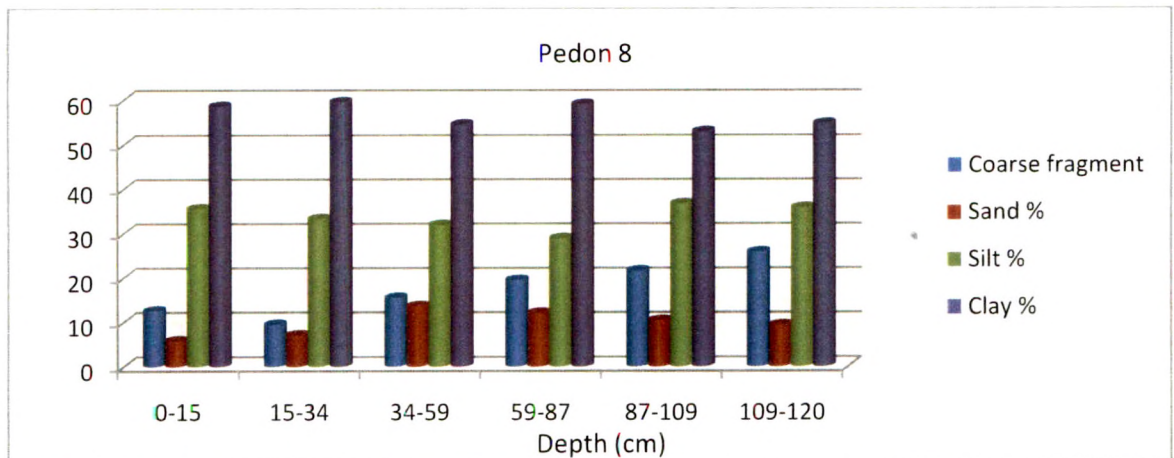
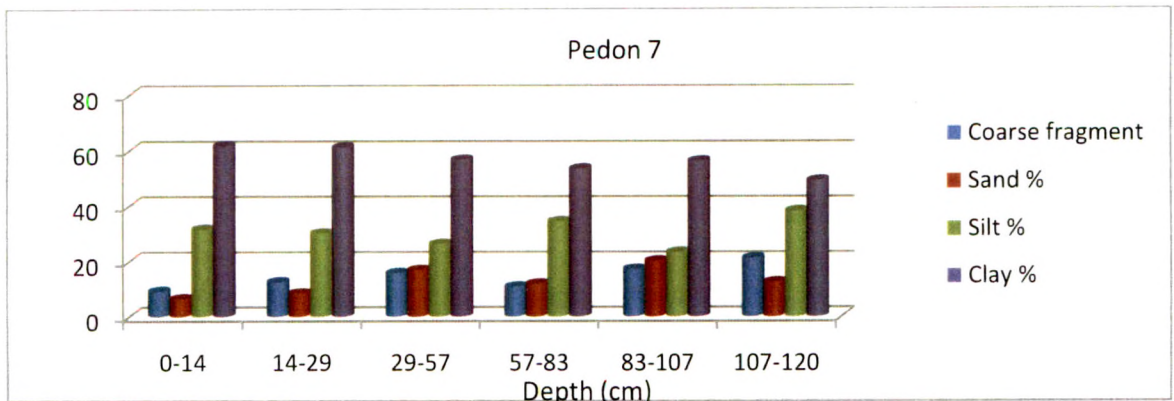
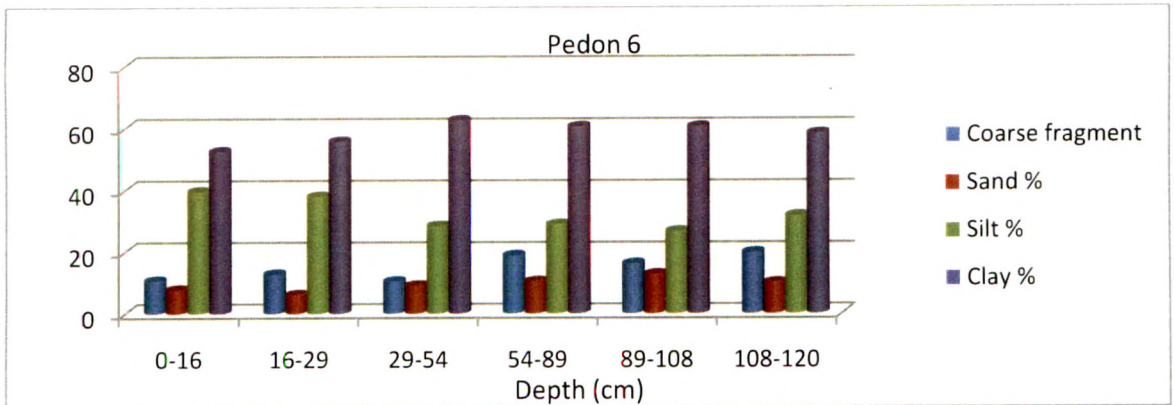
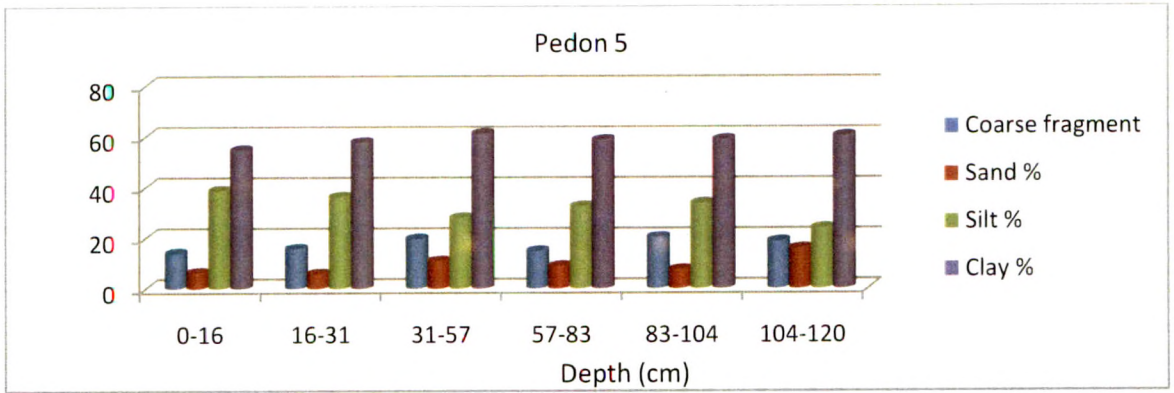
4.1.2.3 Particle size distribution

Particle size distribution is defined as the fractions of the various soil separates in a soil sample, often expressed as mass percentages.

The data presented in (Table 4) indicates that the particle size distribution analysis indicates the general picture of physical nature of soil and also gives insight into its chemical and biological potentials. The particle size distribution

Figure 3. Graphical representation of depth wise Particle size distribution in the soils of Agricultural research station, Badnapur.





related directly or indirectly to plant growth and provides understanding in respect of soil water retention and their availability, workability, drainage, condition and crop suitability.

The soils of study area are developed on basaltic parent material and the soil developed on basalt produces high amount of clay on weathering (Eswaran *et al.* 1988).

The data presented in (Table 4) indicates that the soils of study area are clay in texture. The highest clay content found 64.50 % in pedon P₄. Clay content ranged from 53.15 to 63.60 per cent in P₁, 55.40 to 62.60 per cent in P₂, 57.95 to 63.75 per cent in P₃, 58.60 to 64.50 per cent in P₄, 54.80 to 61.15 per cent in P₅, 52.60 to 62.60 per cent in P₆, 49.25 to 61.80 per cent in P₇ and 52.95 to 59.60 per cent in P₈, respectively.

There is lithological discontinuity in the studied soils as evidenced from marked variation in sand/silt ratio (Sidhu *et al.* 1976; Ray and Reddy 1997)

4.1.3 Chemical properties

4.1.3.1 Soil reaction

As in the case of physical properties, the chemical nature of Vertisols occurring in diverse environments is somewhat similar (Hoskings 1935; Roy and Barde 1962; Virgo and Munro 1978; Jewitt *et al.* 1979). The Vertisols occurring in India, Australia, Sudan, Ethiopia and other parts of Africa generally have soil pH ranging between 7.5 and 8.5 in the soil profile. Factors which contribute to high soil pH are the presence of CaCO₃ and high contents of bases, especially calcium and magnesium, in the profile. The high pH of Vertisols favors gaseous loss of ammonia when urea or ammonium fertilizers are applied to the surface (Terman 1979; Sahrawat 1980).

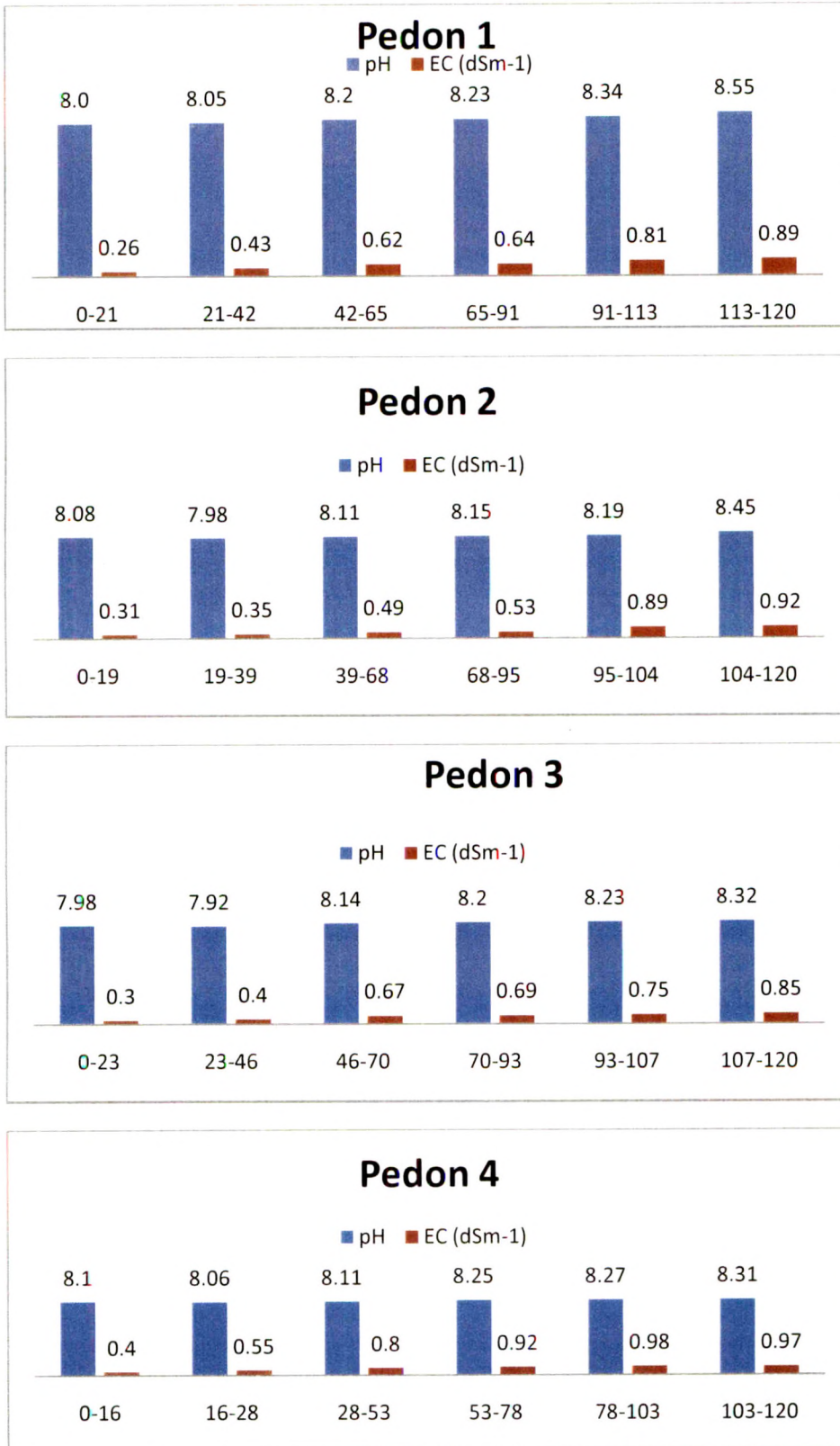
Table No. 5 Chemical characteristics of the soils of Agricultural research station, Badnapur

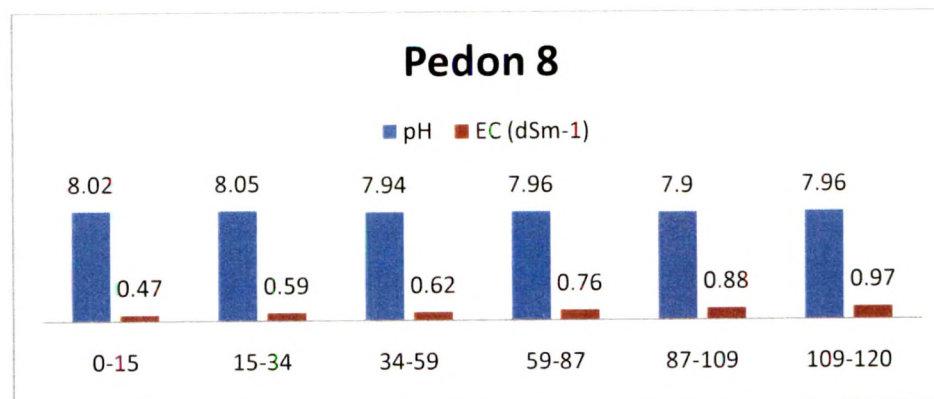
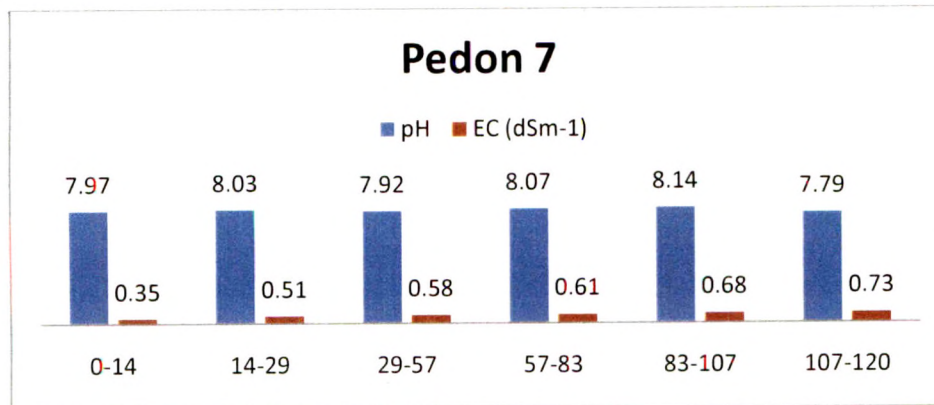
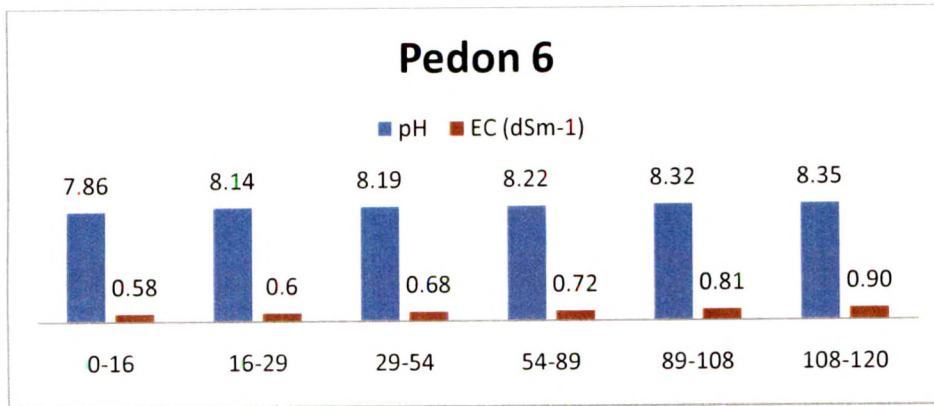
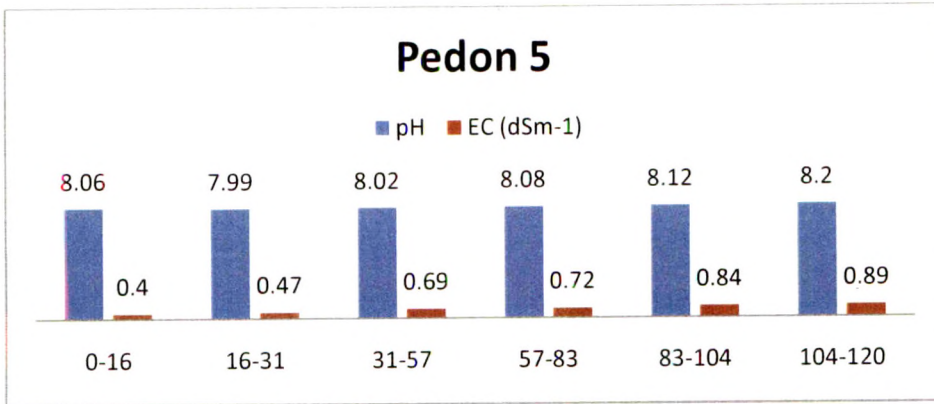
Horizon	Depth	pH	EC (dSm ⁻¹)	Organic Carbon (%)	CaCO ₃ (%)
1	2	3	4	5	6
Pedon - P₁ Lower part of Block D4 (ARS, Badnapur)					
Ap	0-21	8.00	0.26	0.98	4.5
Bw	21-42	8.05	0.43	0.89	5.2
Bss1	42-65	8.20	0.62	0.57	10.5
Bss2	65-91	8.23	0.64	0.45	12.1
Bss3	91-113	8.34	0.81	0.34	10.1
Bss4	113-120	8.55	0.89	0.31	12.2
Pedon - P₂ Lower part of Block D4 (ARS, Badnapur)					
Ap	0-19	8.08	0.31	0.92	6.3
Bw	19-39	7.98	0.35	0.85	6.9
Bss1	39-68	8.11	0.49	0.53	8.2
Bss2	68-95	8.15	0.53	0.35	8.5
Bss3	95-104	8.19	0.89	0.31	9.1
Bss4	104-120	8.45	0.92	0.29	9.9
Pedon - P₃ Upper part of Block D4 (ARS, Badnapur)					
Ap	0-23	7.98	0.30	0.89	4.9
Bw	23-46	7.92	0.40	0.84	5.5
Bss1	46-70	8.14	0.67	0.72	6.3
Bss2	70-93	8.20	0.69	0.69	7.6
Bss3	93-107	8.23	0.75	0.47	8.4
Bss4	107-120	8.32	0.85	0.40	9.5

Horizon	Depth	pH	EC (dSm ⁻¹)	Organic Carbon (%)	CaCO ₃ (%)
1	2	3	4	5	6
Pedon - P₄ Upper part of Block D4 (ARS, Badnapur)					
Ap	0-16	8.10	0.40	0.91	5.3
Bw	16-28	8.06	0.55	0.81	5.7
Bss1	28-53	8.11	0.80	0.64	6.3
Bss2	53-78	8.25	0.92	0.62	7.3
Bss3	78-103	8.27	0.98	0.43	8.2
Bss4	103-120	8.31	0.97	0.26	8.5
Pedon - P₅ Block D5 (ARS, Badnapur)					
Ap	0-16	8.06	0.40	0.86	4.1
Bw	16-31	7.99	0.47	0.81	4.8
Bss1	31-57	8.02	0.69	0.72	6.9
Bss2	57-83	8.08	0.72	0.58	7.2
Bss3	83-104	8.12	0.84	0.39	8.3
Bss4	104-120	8.20	0.89	0.36	9.1
Pedon - P₆ Block D5 (ARS, Badnapur)					
Ap	0-16	7.86	0.58	0.92	5.2
Bw	16-29	8.14	0.60	0.89	5.9
Bss1	29-54	8.19	0.68	0.53	5.7
Bss2	54-89	8.22	0.72	0.49	6.1
Bss3	89-108	8.32	0.81	0.35	6.8
Bss4	108-120	8.35	0.90	0.31	8.9

Horizon	Depth	pH	EC (dSm ⁻¹)	Organic Carbon (%)	CaCO ₃ (%)
1	2	3	4	5	6
Pedon - P₇ Block D7 (ARS, Badnapur)					
Ap	0-14	7.97	0.35	0.84	6.4
Bw	14-29	8.03	0.51	0.75	12.9
Bss1	29-57	7.92	0.58	0.69	13.2
Bss2	57-83	8.07	0.61	0.67	14.6
Bss3	83-107	8.14	0.68	0.40	14.8
Bss4	107-120	7.79	0.73	0.30	14.7
Pedon - P₈ Block D7 (ARS, Badnapur)					
Ap	0-15	8.02	0.47	0.77	5.9
Bw	15-34	8.05	0.59	0.71	10.3
Bss1	34-59	7.94	0.62	0.59	13.1
Bss2	59-87	7.96	0.76	0.55	14.2
Bss3	87-109	7.90	0.88	0.43	14.4
Bss4	109-120	7.96	0.97	0.38	14.2

Figure. 4. Graphical representation of depth wise pH and Electrical conductivity of the soils of Agricultural research station, Badnapur.





The data presented in (Table 5) indicates that the soils of studied area are moderately alkaline in reaction with pH ranged from 7.79 to 8.55. The highest soil pH is estimated in P₁ in lower depth. The pH of soil of pedon P₁ ranged from 8.00 to 8.55, pedon P₂ 7.98 to 8.45, pedon P₃ 7.92 to 8.32, pedon P₄ 8.06 to 8.20, pedon P₅ 7.99 to 8.20, pedon P₆ 7.86 to 8.35, pedon P₇ 7.92 to 8.03 and pedon P₈ 7.90 to 8.05, respectively.

4.1.3.2 Electrical conductivity

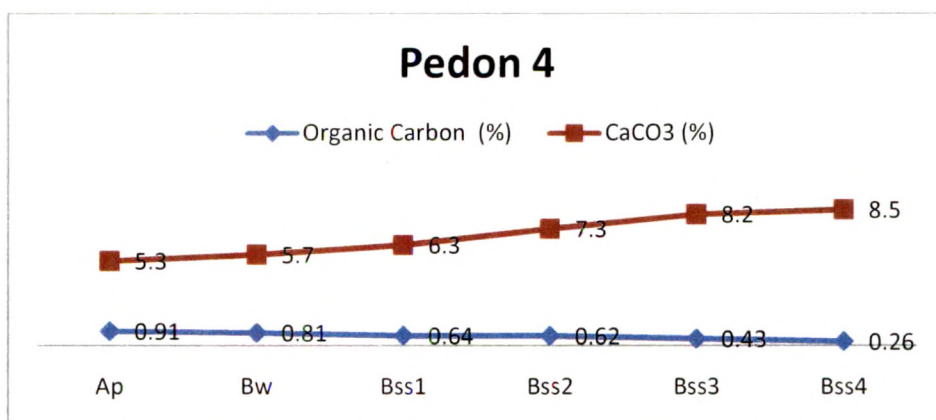
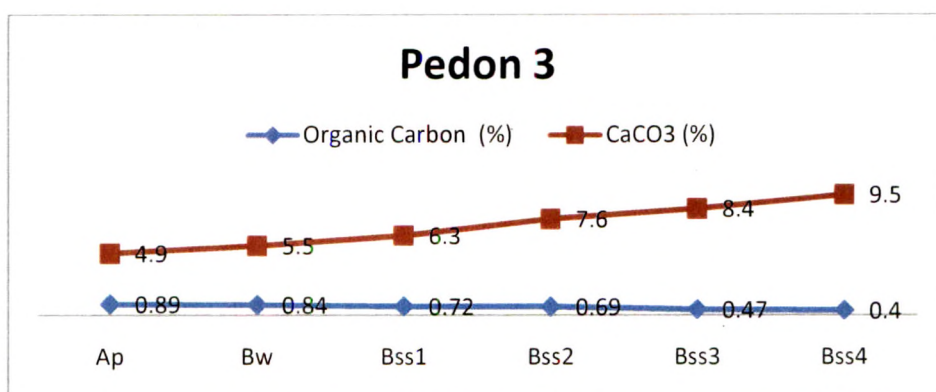
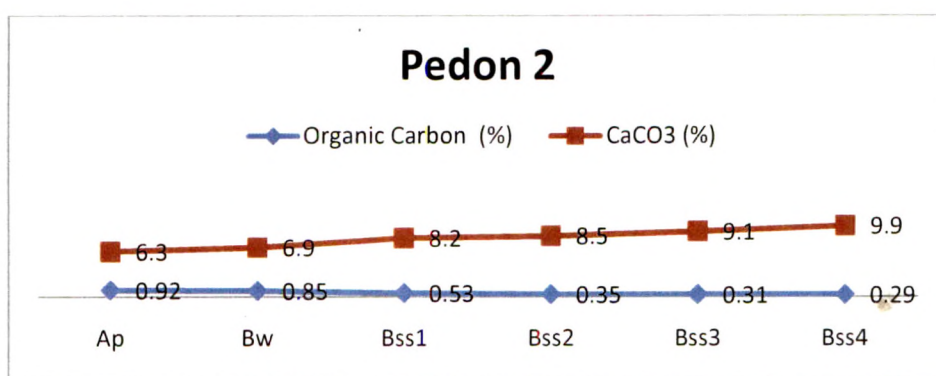
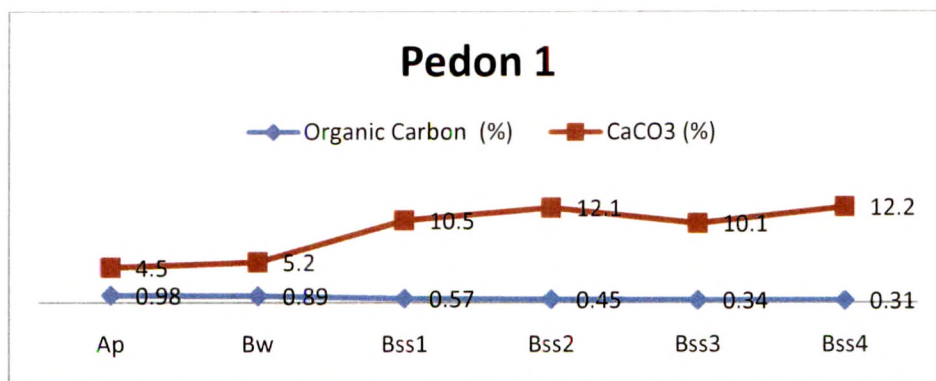
The data presented in table (Table 5) is indicated that the electrical conductivity of the soils of study area is varies from 0.26 to 0.98 dSm⁻¹. This is well within safe to normal limit of electrical conductivity range, designated for normal soil (Richards, 1954) and all soils comes under non-saline class. The EC value of pedon P₁ ranged from 0.26 to 0.89 dSm⁻¹, pedon P₂ 0.31 to 0.92 dSm⁻¹, pedon P₃ 0.30 to 0.85 dSm⁻¹, pedon P₄ 0.40 to 0.98 dSm⁻¹, pedon P₅ 0.40 to 0.89 dSm⁻¹, pedon P₆ 0.58 to 0.90 dSm⁻¹, pedon P₇ 0.35 to 0.73 dSm⁻¹ and pedon P₈ 0.47 to 0.97 dSm⁻¹, respectively.

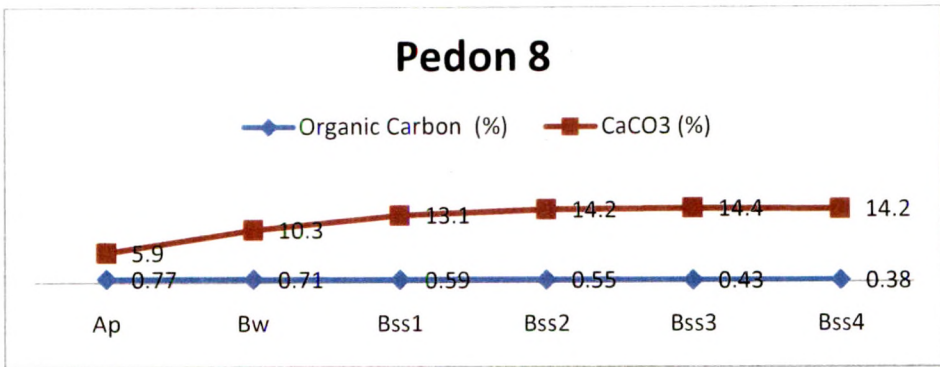
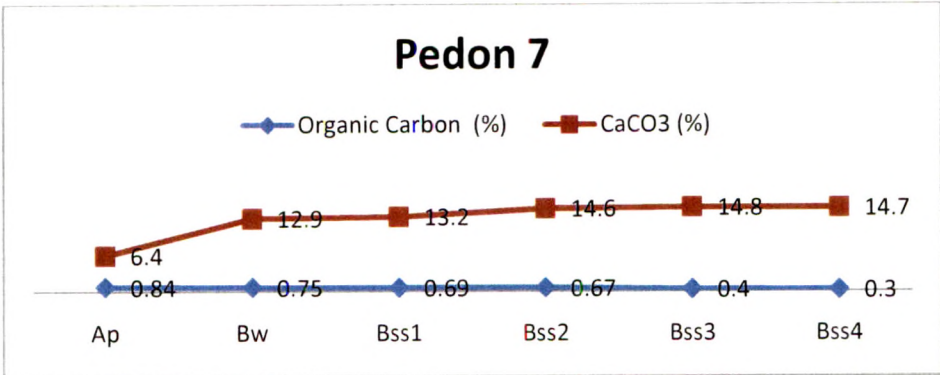
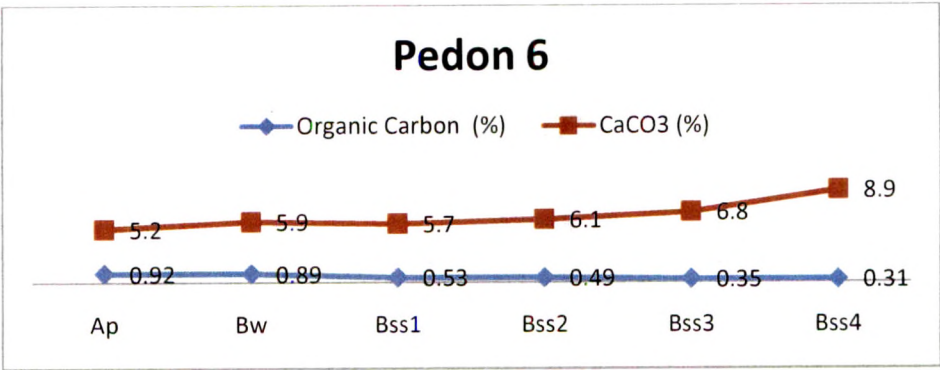
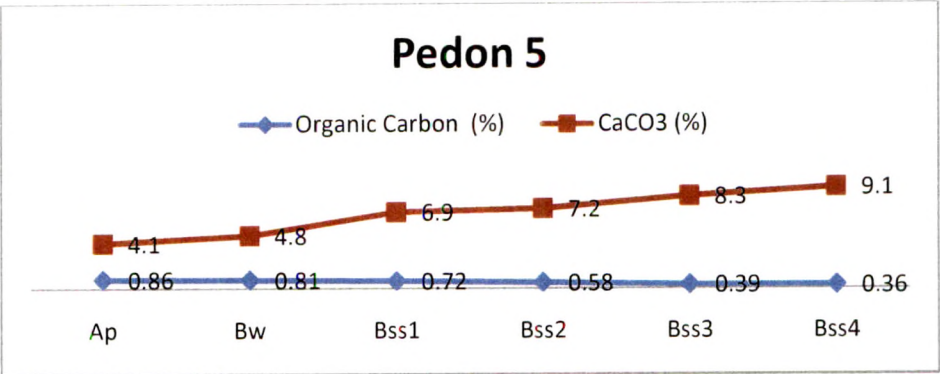
4.1.3.3 Organic carbon

Soil organic matter plays a very important role in maintenance and improvement of soil properties as well as nutrient status of soil. In addition to this, it also improves soil structure, infiltration rate, hydraulic conductivity, water and nutrient storage capacity and reduces soil erosion (Smith and Elliott 1990).

The dark colour of the Vertisols was earlier suspected to be an indicator of high organic matter content but this was disproved by Singh (1954). Most of the black cotton soils of India rarely have organic matter exceeding 1.0% (Roy and Barde 1962)

Figure. 5. Graphical representation of horizon wise distribution of per cent Organic carbon and CaCO₃ content in the soils of Agricultural research station, Badnapur.





The data presented in (Table 5) is indicated that the organic carbon content of studied soil is varied from 0.25 to 0.98 per cent in various depths. This shows that the soils of studied area are low to moderate in organic carbon. The highest organic carbon estimated in pedon P₁ (0.98 per cent) in surface layer. The organic carbon content of soils of studied area is ranged from 0.31 to 0.98 per cent, 0.29 to 0.92 per cent, 0.40 to 0.89 per cent, 0.26 to 0.91 per cent, 0.36 to 0.86 per cent, 0.31 to 0.92 per cent, 0.30 to 0.84 per cent and 0.38 to 0.77 per cent in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. P₇ and P₈ are very low in organic carbon in compare to other pedons. It was observed that as depth increases, per cent organic carbon decreased.

Similarly, Manwar (2014) reported that sugarcane growing soils of Latur district were low to moderate in organic carbon content. They also observed that organic carbon decreases as depth increases.

Ashok kumar and Jagdish Prasad (2010) also reported that Organic carbon content of soils ranged from 1.3 to 11.4 g kg⁻¹ and decreased with depth. Organic carbon was lower in pedons having high pH and CaCO₃ (Bhattacharyya *et al.* 2004).

4.1.3.4 Calcium carbonate (CaCO₃)

Most of the Vertisols are calcareous. The distribution of CaCO₃ may be either uniform throughout the profile or may increase in the lower horizons (Raychaudhuri *et al.* 1963; De Vos and Virgo 1969). The content of CaCO₃ in Indian Vertisols may vary from nil to 10% or more in the profile (Roy and Barde 1962). Their calcareous nature along with dominance of montmorillonite clay influences greatly the plant availability of nutrients such as phosphate (Kanwar and Grewal 1960; Nad *et al.* 1975; More *et al.* 1978).

The data presented in (Table 5) indicates that soils of studied area are medium to very high in calcium carbonate ranged from 4.1 to 14.8 per cent. Highest CaCO_3 content is observed in P₇ (14.8 per cent) in lower depth. The calcium carbonate content of soils of studied area is ranged from 4.5 to 12.2, 6.3 to 9.9, 4.9 to 9.5, 5.3 to 8.5, 4.1 to 9.1, 5.2 to 8.9, 6.4 to 14.8 and 5.9 to 14.4 in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. P₇ and P₈ are very high in calcium carbonate in compare to other pedons. It was observed that calcium carbonate content increases as increases in depth. It may be due to attributed to the leaching of $(\text{HCO}_3)_2$ which get precipitate down to the slope as well as at lower horizon, the high calcium carbonate in soil affect the available water capacity of soil which has a great influence on crop production under rainfed conditions. High calcium carbonate affects the physical and chemical properties of soil and may prevent the root penetration (Sys 1985).

Similarly, Balpande *et al.* 1996; Vaidya and Pal 2002 reported the high CaCO_3 in the soils may be due to semi-arid climate which is responsible for the pedogenetic processes resulting in the depletion of Ca^{2+} ions from the soil solution in the form of calcretes with the concomitant increase in ESP with depth.

4.2 Available macro-nutrient

4.2.1 Available Nitrogen

The data presented in (Table 6) indicated that the available nitrogen content in soils of Agricultural research station, Badnapur is varied from 109.76 to 269.70 kg ha⁻¹. The data indicates that soils of studied area are very low to medium in available nitrogen content. In general, the available nitrogen content decreased with depth. The highest amount of available nitrogen is observed in pedon P₂ (269.70 kg ha⁻¹).

Table No.6. Available macronutrient status of soils of Agricultural research station, Badnapur

Horizon	Depth	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
1	2	3	4	5
Pedon - P₁ Lower part of Block D4 (ARS, Badnapur)				
Ap	0-21	254.02	22.05	349.78
Bw	21-42	238.34	20.80	314.72
Bss1	42-65	232.06	20.32	295.68
Bss2	65-91	200.70	19.55	367.36
Bss3	91-113	175.62	17.30	386.40
Bss4	113-120	153.66	16.43	273.28
Pedon - P₂ Lower part of Block D4 (ARS, Badnapur)				
Ap	0-19	269.70	25.08	413.28
Bw	19-39	257.15	22.53	323.46
Bss1	39-68	216.38	20.84	248.98
Bss2	68-95	194.43	20.37	233.30
Bss3	95-104	150.53	17.73	205.41
Bss4	104-120	144.26	15.57	190.18
Pedon - P₃ Upper part of Block D4 (ARS, Badnapur)				
Ap	0-23	244.61	24.65	450.58
Bw	23-46	219.52	22.57	227.70
Bss1	46-70	166.21	19.98	188.94
Bss2	70-93	156.80	19.59	194.21
Bss3	93-107	150.53	19.20	216.61
Bss4	107-120	144.26	17.34	223.89

Horizon	Depth	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
1	2	3	4	5
Pedon - P₄ Upper part of Block D4 (ARS, Badnapur)				
Ap	0-16	232.06	25.95	232.51
Bw	16-28	222.66	25.17	331.97
Bss1	28-53	200.70	23.35	229.15
Bss2	53-78	185.02	22.62	207.65
Bss3	78-103	163.07	21.23	226.46
Bss4	103-120	147.39	18.72	250.21
Pedon - P₅ Block D5 (ARS, Badnapur)				
Ap	0-16	254.02	21.28	455.50
Bw	16-31	232.06	20.89	377.10
Bss1	31-57	178.75	20.41	320.77
Bss2	57-83	153.66	20.02	256.59
Bss3	83-104	134.85	19.63	190.18
Bss4	104-120	122.30	19.03	177.74
Pedon - P₆ Block D5 (ARS, Badnapur)				
Ap	0-16	241.47	22.92	320.32
Bw	16-29	225.79	22.23	276.30
Bss1	29-54	163.07	20.93	345.07
Bss2	54-89	156.80	20.06	283.70
Bss3	89-108	144.26	19.50	254.69
Bss4	108-120	137.98	18.94	190.29

Horizon	Depth	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
1	2	3	4	5
Pedon - P₇ Block D7 (ARS, Badnapur)				
Ap	0-14	228.93	22.66	575.01
Bw	14-29	219.52	21.62	264.88
Bss1	29-57	169.34	21.32	233.86
Bss2	57-83	131.71	19.94	211.90
Bss3	83-107	122.30	19.29	215.15
Bss4	107-120	116.03	18.64	179.09
Pedon - P₈ Block D7 (ARS, Badnapur)				
Ap	0-15	232.06	22.14	383.71
Bw	15-34	222.66	22.18	279.22
Bss1	34-59	156.80	20.84	231.06
Bss2	59-87	134.85	20.97	237.66
Bss3	87-109	112.90	20.45	251.44
Bss4	109-120	109.76	18.59	225.46

Presented data indicates that available nitrogen content ranges from 153.66 to 254.02 kg ha⁻¹ in pedon P₁, 144.26 to 269.70 kg ha⁻¹ in pedon P₂, 144.26 to 244.61 kg ha⁻¹ in pedon P₃, 147.39 to 232.06 kg ha⁻¹ in pedon P₄, 122.30 to 254.02 kg ha⁻¹ in pedon P₅, 137.98 to 241.47 kg ha⁻¹ in pedon P₆, 116.03 to 228.93 kg ha⁻¹ in pedon P₇ and 109.76 to 232.06 kg ha⁻¹ in pedon P₈.

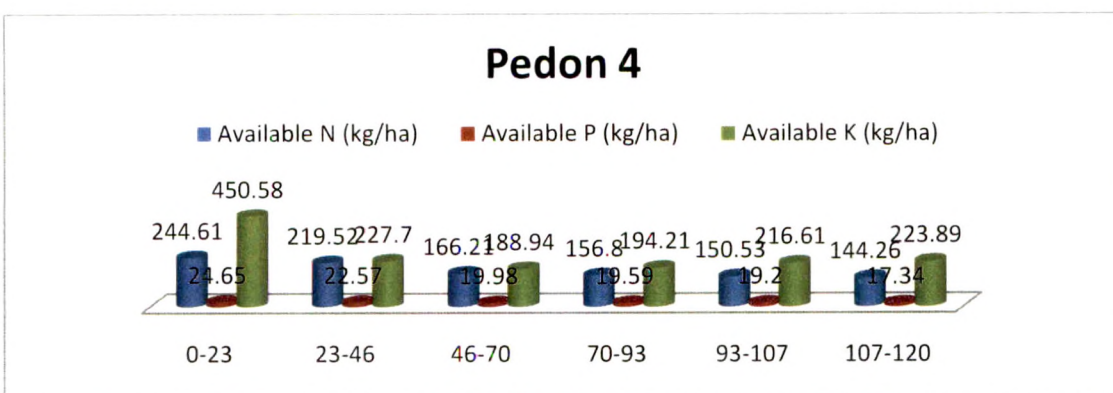
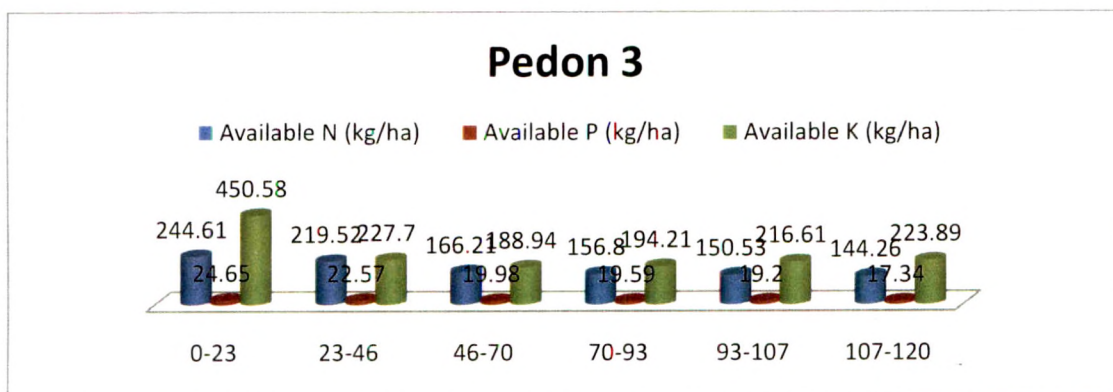
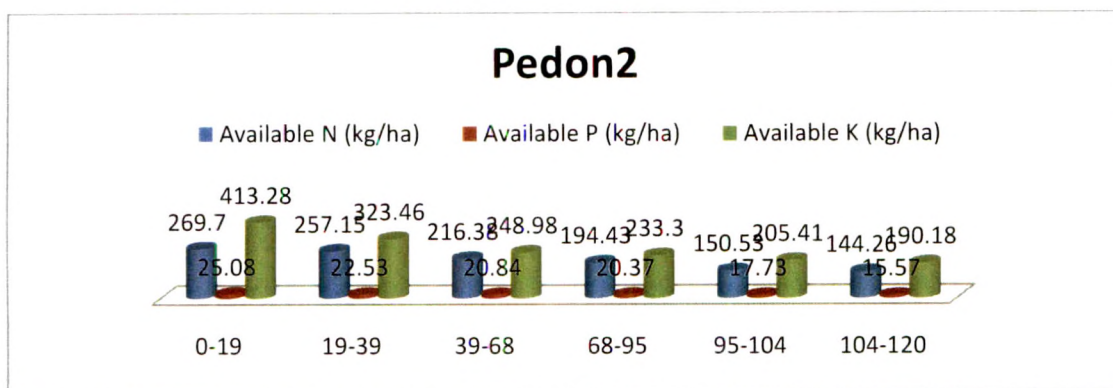
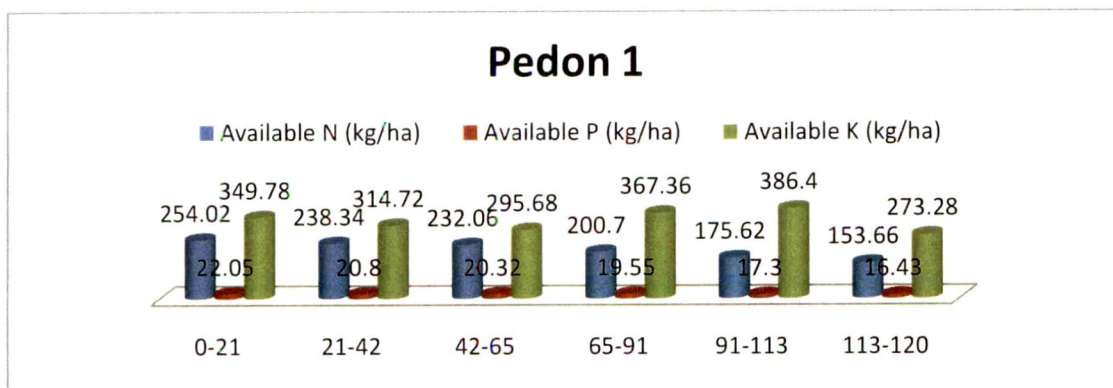
4.2.2 Available Phosphorus

The data presented in (Table 6) indicated that the available phosphorus content in soils of Agricultural research station, Badnapur is varied from 15.75 to 25.95 kg ha⁻¹. The data indicates that soils of studied area are medium to moderate in available phosphorus content. In general, the available phosphorus content decreased with depth. The highest amount of available phosphorus is observed in pedon P₄ (25.95 kg ha⁻¹) in surface layer.

The presented data indicates that available phosphorus content ranges from 16.43 to 22.05 kg ha⁻¹ in pedon P₁, 15.57 to 25.08 kg ha⁻¹ in pedon P₂, 17.34 to 24.65 kg ha⁻¹ in pedon P₃, 18.72 to 25.95 kg ha⁻¹ in pedon P₄, 19.03 to 21.28 kg ha⁻¹ in pedon P₅, 18.94 to 22.92 kg ha⁻¹ in pedon P₆, 18.64 to 22.66 kg ha⁻¹ in pedon P₇ and 18.59 to 22.14 kg ha⁻¹ in pedon P₈. Surface layer of soil found to be rich in phosphorus than surface layer, possibly due to fertilization. Similar trend was also reported by Dehsmukh *et al.* (1982) and Vaidya *et al.* (2014).

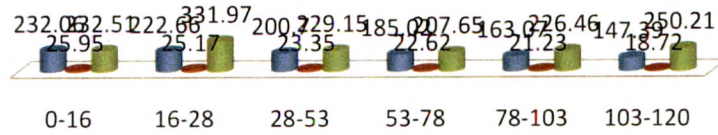
Thangasamy *et al.* (2005) reported that the highest available phosphorus content was observed in the surface horizons and decreased with depth. It might be due to the addition of phosphatic fertilizers. The lower phosphorus content in sub-surface horizons could be attributed to the fixation of released phosphorus by clay minerals and oxides of iron and aluminium.

Figure. 6. Graphical representation of depth wise Available Macronutrients viz N, P, K (kg ha^{-1}) in the soils of Agricultural research station, Badnapur.



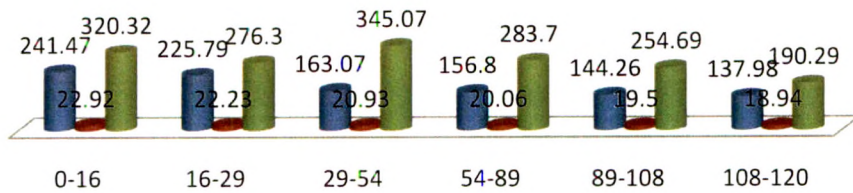
Pedon 5

Available N (kg/ha) Available P (kg/ha) Available K (kg/ha)



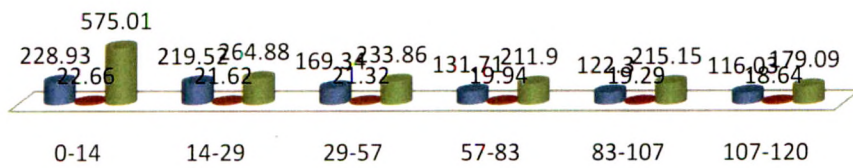
Pedon 6

Available N (kg/ha) Available P (kg/ha) Available K (kg/ha)



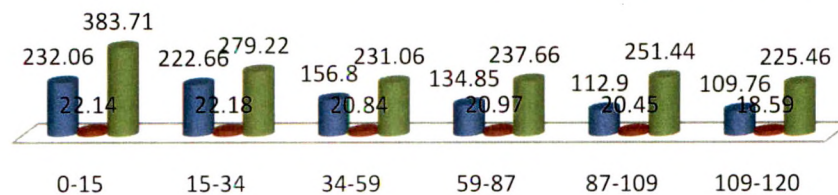
Pedon 7

Available N (kg/ha) Available P (kg/ha) Available K (kg/ha)



Pedon 8

Available N (kg/ha) Available P (kg/ha) Available K (kg/ha)



4.2.2 Available Potassium

The data presented in (Table 6) indicated that the available potassium content in soils of Agricultural research station, Badnapur is varied from 177.74 to 575.01 kg ha⁻¹. The highest available potassium content observed in P₇ (575.01 kg ha⁻¹). The data indicates that soils of studied area are medium to very high in available potassium content.

The presented data indicates that available potassium content ranges from 273.28 to 386.40 kg ha⁻¹ in pedon P₁, 190.18 to 413.28 kg ha⁻¹ in pedon P₂, 188.94 to 450.58 kg ha⁻¹ in pedon P₃, 207.65 to 331.97 kg ha⁻¹ in pedon P₄, 177.74 to 455.50 kg ha⁻¹ in pedon P₅, 190.29 to 345.07 kg ha⁻¹ in pedon P₆, 179.09 to 575.01 kg ha⁻¹ in pedon P₇ and 225.46 to 383.71 kg ha⁻¹ in pedon P₈.

4.3 Soil classification

Classification is the grouping of objects in some orderly and logical manner. It is based on the properties of objects for the purpose of their identification and separation. These are termed as differentiating characteristics or differentiae and serve to separate one class from others. For instance, soils are classified on the basis of their texture as sandy, loamy or clayey soils. For classifying the individuals of a large and widely varying population, such as soils, it is useful to group individuals into classes, and further into five classes. This kind of grouping is called multi-categorical or hierarchical system of classification. The individual soils are grouped into classes of lower category (e.g. Soil Series) which are further grouped into classes of higher categories (e.g. Soil Orders). The lower categories are defined by a large number of differentiating characteristics and higher categories by a few such characteristics. Within each class, there is a central core or nucleus to which the individual members are related in varying degrees. It is called typic, the central concept or an idealized individual, which typified the class.

Based on field morphology and laboratory characterization the soils of Agricultural research station, Badnapur are classified according to U.S. comprehensive system of soil classification (Soil Survey Staff 1994 & 2006). The soils of studied area are belonging to order Vertisols.

These soils were very deep (more than 120 cm), black coloured, clayey (> 49.25) and characterized by deep and wide cracks, well developed slickenside and pressure faces. Thus these soils were classified under the order Vertisols, sub-order Usterts, great group Haplusterts, sub-group Typic Haplusterts and family Clay, montmorillonitic.

Vertisols are generally found on sedimentary plains as the result of thousands of years eroding the clay content out of the surrounding hills. They can also be found on level land and in depressions. H. Jenny (1980) also reported that Vertisols are typically developed on alluvial material in flat inland areas.

4.4 Relationship between physical and chemical properties of soil.

The coefficient of correlation (r) values given in (Table 7) clearly established the relationship between physical and chemical properties of soil.

There was inter relationship between physical and physico-chemical properties were intimately associated. pH was positively and significantly correlated with EC ($r=0.534^{**}$) and clay ($r=0.364^{**}$), while negatively significantly correlated with organic carbon ($r= -0.251^*$), available N ($r= -0.281^*$), available P ($r= -0.539^{**}$) and silt ($r= -0.400^{**}$). pH content positively correlated with sand but it could not reached the statistical significant level. Electrical conductivity was positively and significantly correlated with CaCO_3 ($r= 0.440^{**}$) and sand ($r=0.403^{**}$), while negatively significantly correlated with organic carbon ($r= -0.782^{**}$) available N ($r= -0.825^{**}$), available P ($r=-0.675^{**}$), available K ($r= -0.618^{**}$) and silt ($r= -0.340^*$). Organic carbon was positively and significantly correlated with available N ($r=0.890^{**}$), available P ($r=0.775^{**}$) and available K ($r= 0.583^{**}$) while negatively

Table No. 7. Relationship between physical and chemical properties of soils of Agricultural research station, Badnapur.

Character	pH	EC	Organic Carbon	CaCO ₃	Available N	Available P	Available K	Sand	Silt	Clay
pH	1.000	0.534**	-0.251*	-0.039	-0.281*	-0.539**	-0.220	0.201	-0.400**	0.364**
EC		1.000	-0.782**	0.440**	-0.825**	-0.675**	-0.618**	0.403**	-0.340*	0.073
Organic Carbon			1.000	-0.776**	0.890**	0.775**	0.583**	-0.587**	0.262	0.223
CaCO ₃				1.000	-0.642**	-0.476**	-0.429**	0.533**	-0.121	-0.369**
Available N					1.000	0.703**	0.667**	-0.600**	0.352*	0.108
Available P						1.000	0.413**	-0.565**	0.349*	0.078
Available K							1.000	-0.466**	0.309*	0.032
Sand								1.000	-0.709**	-0.013
Silt									1.000	-0.696**
Clay										1.000


* Significant at 1% level

** Significant at 5% level


significantly correlated with CaCO_3 ($r = -0.776^{**}$) and sand ($r = -0.587^{**}$). CaCO_3 was positively and significantly correlated with sand ($r = 0.533^{**}$), while negatively significantly correlated with available N ($r = -0.642^{**}$), available P ($r = -0.476^{**}$), available K ($r = -0.429^{**}$) and clay ($r = -0.369^{**}$). Available N was positively and significantly correlated with sand available P ($r = 0.703^{**}$), available K ($r = 0.667^{**}$) and silt ($r = 0.352^*$), while negatively significantly correlated with sand ($r = -0.600^{**}$). Available P was positively and significantly correlated with available K ($r = 0.413^{**}$) and silt ($r = 0.349^*$), while negatively significantly correlated with sand ($r = -0.565^{**}$). Available K was positively and significantly correlated with silt ($r = 0.309^*$), while negatively significantly correlated with sand ($r = -0.466^{**}$). Sand content was negatively significantly correlated with silt ($r = -0.709^{**}$). Silt content was negatively significantly correlated with clay content ($r = -0.696^{**}$). Higher degree of correlation was observed in between organic carbon and available N ($r = 0.890^{**}$) and organic carbon and available P ($r = 0.775^{**}$). Clay is positively correlated with EC, organic carbon, available N, available P and available K but it could not reached the level of statistical significant.

Similarly, Ashok kumar and Jagdish Prasad (2010) reported that the pH had strong positive correlation with CaCO_3 ($r = 0.55^{**}$) and negatively influenced by organic carbon ($r = -0.39^*$). The CaCO_3 content was strong negative correlation with OC ($r = -0.49^*$).

Satish Kumar and Naidu (2012) also reported that available K had a significant and positive correlation with organic carbon ($r = 0.453$).



*Summary and
Conclusion*



CHAPTER-V

SUMMARY AND CONCLUSION

Soil is a key element of agriculture. Without it we wouldn't be able to grow plant, which are used as food for both human and animals. There are different definitions of soil. Depending on the approach we want to take. From the agricultural point of view, it is an unconsolidated mineral or organic material that is on the surface of the earth in which we grow plants. From a geological point of view, we would probably look at how it was formed and what kind of layers it has. As far as food is concerned it is important to study a couple of its properties that are fundamental for plant growth. In the present investigation morphological, physical and chemical properties of soils of Agricultural research station, Badnapur have been studied and classified according to it.

Geographically, Agricultural Research Station, Badnapur is situated in Badnapur taluka of Jalna district at 19.50⁰ and 47.53 longitudes with an altitude of 520 meters. It is on Aurangabad-Jalna road at a distance of 2.5 km from Badnapur railway station on Manmad-Secundrabad route of south central railway. The total area of this research station initially was 141.43 ha. The area under building is 11.25 ha, roads 5.90 ha, canal 7.44 ha, grazing area 3 ha, wells 2.10 ha. Now it is 84.14 ha.

On our planet we have 12 different soil types known as orders. Each one of them leads a different treatment and farmers should know about these practices. How a farmer manages the farm can have crucial impacts on environment. Unfortunately many of the farmers are not familiar with the information about morphological, physical and chemical properties of soils. Kipping in view the present investigation was undertaken on topic "Characterization and Classification of soils of Agricultural Research Station, Badnapur" with following objectives.

- To know the morphological features of soils of Agricultural research station, Badnapur.
- To determine depth wise physical and chemical properties of soil of Agricultural research station, Badnapur.
- To classify soil of Agricultural research station, Badnapur.

With above objectives in view the present study was undertaken on 4 Block of Agricultural research station, Badnapur. The eight (08) soil profiles were finalized for profile examination. Horizon wise soil sample from the soil profiles were collected for laboratory analysis and classified as per soil Taxonomy (Soil Survey Staff 1994 & 2006).

Soil depth of the soils of Agricultural research station, Badnapur is more than 120 cm in all pedons correspond to very deep.

Most of the soils of Agricultural research station, Badnapur were very dark brown (10 YR 2/2) to light yellowish brown (10 YR 6/4) in colour. The pedon P₁ soils colour varies from 10 YR 2/2 to 10 YR 3/3 corresponds to the very dark brown to dark brown. The pedon P₂ soils colour varies from 10 YR 2/2 to 10 YR 4/1 corresponds to the very dark brown to dark gray. The pedon P₃ and P₄ soils colour varies from 10 YR 2/2 to 10 YR 4/2 corresponds to the very dark brown to dark grayish brown. The pedon P₅ soils colour varies from 10 YR 2/2 to 10 YR 5/2 corresponds to the very dark brown to grayish brown. The pedon P₆ soils colour varies from 10 YR 2/2 to 10 YR 5/3 corresponds to the very dark brown to brown. The pedon P₇ and P₈ soils colour varies from 10 YR 4/2 to 10 YR 6/4 corresponds to the dark grayish brown to light yellowish brown.

Soil structure of the studied soils were varies from medium, moderate, granular to medium, moderate, angular blocky. The pedon P₁ and P₃ soils structure varies from medium, moderate sub-angular blocky to medium, moderate, angular

blocky. The pedon P₂ soils structure varies from medium, strong, sub-angular blocky to medium, weak, angular blocky. The pedons P₄ and P₅ soils structure varies from medium, moderate, sub-angular blocky to medium, strong, sub-angular blocky. The pedon P₆ soils structure varies from medium, strong, sub-angular blocky to medium, moderate, angular blocky in structure. The pedon P₇ and P₈ soils structure varies from medium, moderate, granular to medium, moderate, sub-angular blocky.

Consistency of the studied soils varies from slightly hard to very hard in dry condition, friable to extremely firm in moist condition and slightly sticky slightly plastic to very sticky very plastic in wet condition. The consistency in pedon P₁ & P₄ varies from hard to very hard in dry condition, friable to very firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₂ varies from slightly hard to very hard in dry condition, friable to very firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₃ varies from hard to very hard in dry condition, friable to extremely firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₅ & P₆ varies from slightly hard to very hard in dry condition, friable to extremely firm in moist condition and sticky plastic to very sticky very plastic in wet condition. The consistency in pedon P₇ varies from hard to very hard in dry condition, friable to extremely firm in moist condition slightly sticky slightly plastic to very sticky very plastic in wet condition. The consistency in pedon P₈ varies from slightly hard to very hard in dry condition, friable to very firm in moist condition and slightly sticky slightly plastic to very sticky very plastic in wet condition.

The coarse fragment of the soil varies from 8.56 to 25.81 per cent. The coarse fragments is varies from 9.23 to 14.65, 9.13 to 15.57, 8.56 to 19.94, 8.83 to 14.84, 14.08 to 20.28, 10.72 to 19.83, 9.27 to 21.23 and 9.48 to 25.81 per cent in

pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. It is further noticed that the presence of coarse fragments decrease down the slope. Therefore, it is obvious that the presence of coarse fragments is related with topographic situation.

The bulk density of soils of Agricultural research station, Badnapur is varied from 1.19 to 1.55 Mg m⁻³. The highest (1.55 Mg m⁻³) bulk density was observed in pedon P₆ & P₈ in lower depth. The bulk density of pedon P₁ varies from 1.19 to 1.48 Mg m⁻³, pedon P₂ is 1.20 to 1.41 Mg m⁻³, pedon P₃ 1.22 to 1.49 Mg m⁻³, pedon P₄ is 1.23 to 1.48 Mg m⁻³, pedon P₅ 1.20 to 1.52 Mg m⁻³, pedon P₆ is 1.19 to 1.55 Mg m⁻³, pedon P₇ 1.20 to 1.42 Mg m⁻³ and pedon P₈ is 1.22 to 1.55 Mg m⁻³ respectively. In general, the bulk density increased with soil depth and with amount of clay. Surface soils show lower bulk density in compare to subsurface soils. It may be due to high organic carbon and disturbance due to intercultural operations. High value in subsurface layers may be due to smectite clay and over burden leading to compaction, slickensides, caused strong structural aggregate formation and high bulk density and root development have the inverse relationship.

The per cent porosity of soils of studied area is varies from 41.51 to 55.26 per cent. Highest porosity estimated in surface soil 55.06 and 55.26 per cent in pedon P₆ and P₁, respectively. The per cent porosity of soils estimated in different horizon varies from 44.15 to 55.26 per cent, 46.79 to 54.72 per cent, 43.77 to 53.88, 44.15 to 53.46 per cent, 42.64 to 54.72 per cent, 41.51 to 55.06 per cent, 46.42 to 54.72 per cent, 41.41 to 53.88 per cent in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. Soil porosity is inversely related with soil bulk density. Soil porosity decreases as increases in bulk density. Soil texture, soil structure, arrangement of soil particle, organic matter, macro organisms, depth of soil and cropping affect the per cent porosity of soils. Increase in organic matter content in the soil, increase in

percentage of pore space. Pore space in the sub-soil has been found to decrease in compare to surface soil.

The soils of study area are developed on basaltic parent material and the soil developed on basalt produces high amount of clay on weathering (Eswaran *et al.* 1988). The soils of study area are clay in texture. The highest clay content found 64.50 % in pedon P₄. Clay content ranged from 53.15 to 63.60 per cent in P₁, 55.40 to 62.60 per cent in P₂, 57.95 to 63.75 per cent in P₃, 58.60 to 64.50 per cent in P₄, 54.80 to 61.15 per cent in P₅, 52.60 to 62.60 per cent in P₆, 49.25 to 61.80 per cent in P₇ and 52.95 to 59.60 per cent in P₈, respectively.

The soils of studied area are moderately alkaline in reaction with pH ranged from 7.79 to 8.55. The highest soil pH is estimated in P₁ in lower depth. The pH of soil of pedon P₁ ranged from 8.00 to 8.55, pedon P₂ 7.98 to 8.45, pedon P₃ 7.92 to 8.32, pedon P₄ 8.06 to 8.20, pedon P₅ 7.99 to 8.20, pedon P₆ 7.86 to 8.35, pedon P₇ 7.92 to 8.03 and pedon P₈ 7.90 to 8.05, respectively.

The electrical conductivity of the soils of study area is varies from 0.26 to 0.98 dSm⁻¹. This is well within safe to normal limit of electrical conductivity range, designated for normal soil (Richards, 1954) and all soils comes under non-saline class. The EC value of pedon P₁ ranged from 0.26 to 0.89 dSm⁻¹, pedon P₂ 0.31 to 0.92 dSm⁻¹, pedon P₃ 0.30 to 0.85 dSm⁻¹, pedon P₄ 0.40 to 0.98 dSm⁻¹, pedon P₅ 0.40 to 0.89 dSm⁻¹, pedon P₆ 0.58 to 0.90 dSm⁻¹, pedon P₇ 0.35 to 0.73 dSm⁻¹ and pedon P₈ 0.47 to 0.97 dSm⁻¹, respectively.

The organic carbon content of studied soil is varied from 0.25 to 0.98 per cent in various depths. This shows that the soils of studied area are low to moderate in organic carbon. The highest organic carbon estimated in pedon P₁ (0.98 per cent) in surface layer. The organic carbon content of soils of studied area is ranged from 0.31 to 0.98 per cent, 0.29 to 0.92 per cent, 0.40 to 0.89 per cent, 0.26 to 0.91

per cent, 0.36 to 0.86 per cent, 0.31 to 0.92 per cent, 0.30 to 0.84 per cent and 0.38 to 0.77 per cent in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. P₇ and P₈ are very low in organic carbon in compare to other pedons. It was observed that as depth increases, per cent organic carbon decreased.

The soils of studied area are medium to very high in calcium carbonate ranged from 4.1 to 14.8 per cent. Highest CaCO₃ content is observed in P₇ (14.8 per cent) in lower depth. The calcium carbonate content of soils of studied area is ranged from 4.5 to 12.2, 6.3 to 9.9, 4.9 to 9.5, 5.3 to 8.5, 4.1 to 9.1, 5.2 to 8.9, 6.4 to 14.8 and 5.9 to 14.4 in pedon P₁, P₂, P₃, P₄, P₅, P₆, P₇ and P₈, respectively. P₇ and P₈ are very high in calcium carbonate in compare to other pedons. It was observed that calcium carbonate content increases as increases in depth. It may be due to attributed to the leaching of (HCO₃)₂ which get precipitate down to the slope as well as at lower horizon, the high calcium carbonate in soil affect the available water capacity of soil which has a great influence on crop production under rainfed conditions. High calcium carbonate affects the physical and chemical properties of soil and may prevent the root penetration (Sys 1985).

The available nitrogen content in soils of Agricultural research station, Badnapur is varied from 109.76 to 269.70 kg ha⁻¹. The data indicates that soils of studied area are very low to medium in available nitrogen content. In general, the available nitrogen content decreased with depth. The highest amount of available nitrogen is observed in pedon P₂ (269.70 kg ha⁻¹). Presented data indicates that available nitrogen content ranges from 153.66 to 254.02 kg ha⁻¹ in pedon P₁, 144.26 to 269.70 kg ha⁻¹ in pedon P₂, 144.26 to 244.61 kg ha⁻¹ in pedon P₃, 147.39 to 232.06 kg ha⁻¹ in pedon P₄, 122.30 to 254.02 kg ha⁻¹ in pedon P₅, 137.98 to 241.47 kg ha⁻¹ in pedon P₆, 116.03 to 228.93 kg ha⁻¹ in pedon P₇ and 109.76 to 232.06 kg ha⁻¹ in pedon P₈.

The available phosphorus content in soils of Agricultural research station, Badnapur is varied from 15.75 to 25.95 kg ha⁻¹. The data indicates that soils of studied area are medium to moderate in available phosphorus content. In general, the available phosphorus content decreased with depth. The highest amount of available phosphorus is observed in pedon P₄ (25.95 kg ha⁻¹) in surface layer. The presented data indicates that available phosphorus content ranges from 16.43 to 22.05 kg ha⁻¹ in pedon P₁, 15.57 to 25.08 kg ha⁻¹ in pedon P₂, 17.34 to 24.65 kg ha⁻¹ in pedon P₃, 18.72 to 25.95 kg ha⁻¹ in pedon P₄, 19.03 to 21.28 kg ha⁻¹ in pedon P₅, 18.94 to 22.92 kg ha⁻¹ in pedon P₆, 18.64 to 22.66 kg ha⁻¹ in pedon P₇ and 18.59 to 22.14 kg ha⁻¹ in pedon P₈. Surface layer of soil found to be rich in phosphorus than surface layer, possibly due to fertilization. Similar trend was also reported by Desmukh *et al.* (1982) and Vaidya *et al.* (2014).

The available potassium content in soils of Agricultural research station, Badnapur is varied from 177.74 to 575.01 kg ha⁻¹. The highest available potassium content observed in P₇ (575.01 kg ha⁻¹). The data indicates that soils of studied area are medium to very high in available potassium content. The presented data indicates that available potassium content ranges from 273.28 to 386.40 kg ha⁻¹ in pedon P₁, 190.18 to 413.28 kg ha⁻¹ in pedon P₂, 188.94 to 450.58 kg ha⁻¹ in pedon P₃, 207.65 to 331.97 kg ha⁻¹ in pedon P₄, 177.74 to 455.50 kg ha⁻¹ in pedon P₅, 190.29 to 345.07 kg ha⁻¹ in pedon P₆, 179.09 to 575.01 kg ha⁻¹ in pedon P₇ and 225.46 to 383.71 kg ha⁻¹ in pedon P₈.

Based on field morphology and laboratory characterization the soils of Agricultural research station, Badnapur are classified according to U.S. comprehensive system of soil classification (Soil Survey Staff 1994 & 2006). The soils of studied area are belonging to order Vertisols. These soils were very deep (more than 120 cm), black coloured, clayey (> 49.25) and characterized by deep and

wide cracks, well developed slickenside and pressure faces. Thus these soils were classified under the order Vertisols, sub-order Usterts, great group Haplusterts, subgroup Typic Haplusterts and family Clay, montmorillonitic.

From the present study the following conclusion are drawn:

- The soils of Agricultural research station, Badnapur are very deep (more than 120 cm).
- Most of the soils of Agricultural research station, Badnapur were very dark brown (10 YR 2/2) to light yellowish brown (10 YR 6/4) in colour.
- Soil structure of the studied soils were varies from medium, moderate, granular to medium, moderate, angular blocky.
- Consistency of the studied soils varies from slightly hard to very hard in dry condition, friable to extremely firm in moist condition and slightly sticky slightly plastic to very sticky very plastic in wet condition.
- The coarse fragment of the soil varies from 8.56 to 25.81 per cent.
- The bulk density of soils of Agricultural research station, Badnapur is varied from 1.19 to 1.55 Mg m⁻³.
- The per cent porosity of soils of studied area is varies from 41.51 to 55.26 per cent.
- The soils of study area are clay in texture.
- The soils of studied area are moderately alkaline in reaction with pH ranged from 7.79 to 8.55.
- The electrical conductivity of the soils of studied area is varies from 0.26 to 0.98 dSm⁻¹. This is well within safe to normal limit of electrical conductivity range, designated for normal soil (Richards, 1954) and all soils comes under non-saline class.
- The organic carbon content of studied soil is varied from 0.25 to 0.98 per cent in various depths. This shows that the soils of studied area are low to moderate in organic carbon.
- The soils of studied area are medium to very high in calcium carbonate ranged from 4.1 to 14.8 per cent.

- The available nitrogen content in soils of Agricultural research station, Badnapur is varied from 109.76 to 269.70 kg ha⁻¹. The data indicates that soils of studied area are very low to medium in available nitrogen content. In general, the available nitrogen content decreased with depth.
- The available phosphorus content in soils of Agricultural research station, Badnapur is varied from 15.75 to 25.95 kg ha⁻¹. The data indicates that soils of studied area are medium to moderate in available phosphorus content. In general, the available phosphorus content decreased with depth.
- The available potassium content in soils of Agricultural research station, Badnapur is varied from 177.74 to 575.01 kg ha⁻¹. The data indicates that soils of studied area are medium to very high in available potassium content.
- Taxonomically the soils of Agricultural research station, Badnapur are classified into order Vertisols. Further these soils were classified under the sub-order Usterts, great group Haplusterts, sub-group Typic Haplusterts and family Clay, montmorillonitic.



Literature Cited



LITERATURE CITED

- Agarkar, D. V., Ingle, S. R. and Hemant Khambalkar (2012). Characterization of some cotton growing soils of Wardha district of Vidharbha region (M.S., India). *Journal of Soils and Crops*; **22**(1):159-167.
- Agarkar, S. C. and Padole, V. R. (1996). Morphology and classification of soils of Central Research Station, PDKV, Akola. *PKV Research Journal*; **20**(2):140-145.
- Ahuja, L. R., Naney, J., Williams, W. R. D. and Ross, J.R. (1988) Vertical variability of soil properties in a small watershed. *Journal of Hydrology* **99**, 307-318.
- Ashok kumar, H. P. and Jagdish Prasad (2010). Some typical sugarcane growing soils of ahmadnagar districts of Maharashtra : Their characterization and classification and nutritional status of soils and plants. *Journal of the Indian Society of Soil Science*. Vol. **58**(3):257-266.
- Babrekar, P. G. and Ravankar, H. N. (1993). Changes in available potassium status of soils in Maharashtra. *Use of potassium in Maharashtra agriculture. Proceedings of Workshop held on March 20, 1993, Konkan Krishi Vidyapeeth, Dapoli.*; 38-45.
- Balpande, H. S., Challa, O. and Jagdish Prasad (2007). Characterization and classification of grape - growing soils in Nasik district, Maharashtra. *Journal of the Indian Society of Soil Science*. **55**(1):80-83.
- Balpande, S.S., Deshpande, S.B. and Pal, D.K. (1996) Factors and processes of soil degradation in Vertisols of Purna valley, Maharashtra, India. *Land Degradation and Development* **7**, 313-324.
- Bharambe, P.R. and Ghonsikar, C.P. (1985). Physico-chemical characteristics of soil in Jayakwadi command. *Journal of Maharashtra Agricultural Universities*. **10** (3):247-249.
- Bharambe, P.R., Awasmal, B.C. and Ghonsikar, C.P. (1986). Physical properties of soil in Jayakwadi and Purna command. Agricultural development of

Jayakwadi and Purna command areas. *Publ. Marathwad Agric. Univ.* 10 :137-147.

Bhaskar, K. S., Lal, S., Challa, O. and Madavi S. H. (1987). Effect of soil depth on cotton yield. *J. Maharashtra Agric. Univ.* 12(1):139.

Bhattacharya, T., Deshmukh, S. N. and Roychaudhary, C. (1989). Soils and land use of Junnar tehasil, Pune district, Maharashtra. *Journal of Maharashtra Agricultural Universities.* 14(1):1-4.

Bhattacharyya, T., Pal, D. K., Velayutham, M. Chandran, P. and Mandal, C. (2000). Soil organic and inorganic carbon stocks in the management of black cotton soils of Maharashtra. *Clay Research*;20(1):11-20.

Bhattacharyya, T., Pal, D.K., Chandran, P., Mandal, C., Ray, S.K., Gupta, R.K. and Gajbhiye, K.S. (2004) Managing Soil Carbon Stocks in the Indo-Gangetic Plains, India, Rice-Wheat Consortium for the Indo-Gangetic plains, New Delhi, India. pp 44.

Bodle (2005). Soil resource mapping of demonstration farm of Marathwada Agricultural University, Parbhani. M. Sc. Agri. Thesis, VNMKV University, Parbhani.

Chalwade, P. B., Kulkarni, V. K. and Ghuge, S. D. (2006). Physico-chemical and macronutrient status of soils. *Journal of Soils and Crops*;16(1):127-130.

Challa, O., Vadivelu, S. and Sehgal, J. (1995). Soils of Maharashtra for optimum land use. NBSS Publ. 54b, 1995, p 112+6 sheets of map.

Chinchmalatpure, A.R., Gowrisankar, D., Challa, O. and Sehgal J. (1998). Soil site suitability of micro-watershed of Wunna catchment near Nagpur. *Journal of the Indian Society of Soil Science* 46 (4), 657-661.

Das, P. K. and Agrawal, R. P. (1997). Physical properties of soil, fundamental of soil science, 2002. ISSS publ., 71-72.

De la Rosa, D., Cardona, P. and Almorza, J. (1981). Crop yield prediction based on properties of soil in Sevilla, Spain. *Geoderma.* 25:267-174.

- De Vos, J.H. & Virgo, K.J. (1969). *J. Soil Sci.* **20**, 189.
- Deshmukh, K. K. (2012). Evaluation of soil fertility status from Sangamner area, Ahmednagar district, Maharashtra, India. *Rasayan Journal of Chemistry*; **5(3)**:398-406.
- Dhale, S.A. and Jagdish Prasad (2009). Characterization and Classification of Sweet Orange-growing Soils of Jalna District, Maharashtra. *Journal of the Indian Society of Soil Science*, Vol. **57**, No.1, pp 11-17.
- Dipak Sarkar, Sahoo, A.K. and Nayak, D.C. (1997). Evaluation of pedological development through field morphology rating system. *Journal of the Indian Society of Soil Science* **45** (1), 141-146.
- Dudal, R. (1965); Dark Clay Soils of Tropical and Subtropical Regions. *Agric. Dev. Paper 83, FAO, Rome, Italy*. 161 p.
- Eswaran, H. and Gathrie, R. L. (1988). International technical assistance in soil survey and classification abstract. *Voluntary paper 12th international congress of soil science*. New Delhi, India.
- Gabhane, V.V., Jadhao, V.O. and Nagdeve, M. B. (2006). Land evaluation for Land use planning of a micro watershed in vidarbha region of Maharashtra. *Journal of the Indian Society of Soil Science* **54** (3), 307-315.
- Gable, D. B., Kubde, K. J., Katore, J. R., Fiske, A. V. and Deshmukh, M. R. (2008). Physico-chemical properties of soil as affected by integrated nutrient management treatments in maize-chickpea cropping system. *Journal of Soils and Crops*; **18(2)**:462-468.
- Ganure, C. K. (1987). Study on important physical properties and available moisture storage capacity of Jayakawadi, Purna, Penganga command areas and scarcity zone of Maharashtra. M. Sc. Agri. Thesis, VNMKV, Parbhani.
- Ghatol, S. G. (1972). Physico-chemical properties of soils of farm under Marathwada Krishi Vidyapeeth campus, Parbhani. M. Sc. Agri. Thesis, VNMKV, Parbhani.

- Ghosh, A. K., Dipak Sarkar, Sanyal, S. K. and Nayak D. C. (2002). Status and Distribution of Arsenic in Alluvium Derived Soils of West Bengal and their Interrelationship with Some Soil Properties. *Journal of the Indian Society of Soil Science* ;Vol 50. No.1.65.
- H. Jenny, "The Soil Resource," Springer, New York, 1980.
- Hillel, D. (1980). Fundamentals of soil physics academic press, Inc. New York.
- Hirey, O. Y., Takankhar, V. G. And Cheke A.S. (2013). Physico-chemical properties in soils from Tuljapur tahsil of Osmanabad district. *Bioinfolet* 10(4B) : 1373-1375
- Hoskings, J.S. (1935); Trans. Proc. Roy, Soc., S. Australia. 59, 169.
- Humayun Khan (2010). Status of free lime in agriculture soil. of Amravati District, Maharashtra. *Annals of Plant Physiology*; 24(1):38-40.
- Ilorkar, V. M. Totey, N. G. (2002). Characterization of soils of Navegaon National Park (Maharashtra). *Indian Journal of Forestry*. 25(1/2):127-135.
- Jackson, M. L. (1958) Soil Chemical Analysis, Prentice Hall, Englewood Cliffs, New Jersey. 498.
- Jackson, M. L. (1967) Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi, pp 205.
- Jackson, M. L. (1979) Soil Chemical Analysis, Prentice Hall Pvt. Ltd., New Delhi.
- Jackson, M. L. (1979) Soil Chemical Analysis- Advanced course, 2nd edn. Publ. by the author, Univ. Of Wisconsin, Madison, USA.
- Jagdish Prasad, Chaudhari, N. B., Kadao, S. H., Gajbhiye, K. S. and Potdar, S. S. (2007). Characterisation of some typical banana (*Musa paradisiaca*) and associated non-banana-growing soils of Jalgaon district, Maharashtra and their suitability evaluation for banana and sugarcane (*Saccharum officinarum*). *Agropedology*; 17(2):88-96.
- Jagdish Prasad, M. S. S. Nagaraju, Rajeev Srivastava, S. K. Ray and P. Chandran (2001). Characteristics and Classification of Some Orange

Growing Soils in Nagpur District of Maharashtra. *Journal of the Indian Society of Soil Science* ;Vol 49, No 4.

Jagdish Prasad, Ray, S. K., Gajbhiye, K. S. and Singh, S. R (2009). Soils of Selsura research farm in Wardha district, Maharashtra and their suitability for crops. *Agropedology*; 19(2):84-91.

Jewitt, T.N., Law, R.D. & Virgo, K.J. (1979). Outlook on Agriculture 10, 33.

Jibhakate, S. B. Bhende, S. N. Kharche, V. K. and Selvalakshmi, V. (2009). Physico-chemical status of soils of Katol Tahasil in Nagpur District. *Journal of Soils and Crops*; 19(1):122-128.

Kadam, S. G. (1991) Characterization of soils of Majalgaon command area (Jayakwadi project stage III). *M. Sc. Agri. Thesis, VNMKV, Parbhani*.

Kadam, S. G., Ugle, B. J., Rathod, G. M., Pathan, D. M. and Bhambe, P. R. (2012). pH of soil of Majalgaon command area (Jayakwadi project stage-III), India. *Current Botany*, 3(2): 24-26.

Kadao, S. H. Jagdish Prasad, and Gajbhiye, K. S. (2003). Characterization and classification of some typical banana growing soils of Wardha district of Maharashtra. *Agropedology*; 13 (2):28-34.

Kadu, P.R., Vaidya, P.H., Balpande, S.S., Satyavathi, P.L.A. and Pal, D.K. (2003) Use of hydraulic conductivity to evaluate the suitability of Vertisols for deep-rooted crops in semiarid parts of central India. *Soil Use and Management* 19, 208-216.

Kale, V. B. and Chavan, A. S. (1996). Physico-chemical characteristics of Kumbhave-5 soil series of Konkan region of Maharashtra state. *PKV Research Journal*; 20(2):136-139.

Kanwar, J.S. & Grewal, J.S. (1960). *J. Indian Soc. Soil Sci.* 8, 211.

Kanwar, J. S. & Virmani, S. M. (1986). Management of Vertisols for improved crop production in SAT: A plan for technology transfer network in Africa.

First regional seminar of management of vertisols under SAT. IBSRAM Proc. No. 6, Nairobi, Kenya: 157-172.

Kaskar, D. R. Salvi, V. G. Mayekar, B. S. and Dabke, D. J. (2001). Forms of potassium, their interrelationship and relationships with other soil properties of Inceptisols of West Coast of Maharashtra. *Journal of Potassium Research*; 17(1/4):23-27.

Kawde, A. D., Ravankar, H. N. and Padole, V. R. (2005). Physico-chemical properties and classification of salt-affected soils of Keliveli (Dist.-Akola) from Purna Valley. *Journal of Soils and Crops*; 15(1):139-143.

Kharche, V. K. and Pharande, A. L. (2010). Land degradation assessment and land evaluation in mula command of irrigation agro-ecosystem in Mahaarashtra. *J. Indian Soc. Soil Sci.*, 58 (2): 221-227.

Krantz, B.A. & Kampen, J, (1978). In Soil resource data for agricultural development (ed. L. D. Swindale). Hawaii Agric. Expt. Stn., Honolulu Hawaii, USA.

Krantz, B.A., Sahrawat, K.L. (1974). In Proc. FAI-FAO Seminar on Optimising Agricultural Production under Limited Availability of Fertilisers, Fertiliser Association of India, New Delhi, India, pp. 313-320.

Krishna, P.G. & Perumal, S. (1948). *Soil Sci.* 66, 29.

Landey, R.J., Hirekerur, L.R. and Krishnamoorthy, P. (1982). Morphology genesis and classification of black soil. In review of soil research in India Part II. 12th Intl Congr. Soil Sci. New Delhi. Pp484-497.

Leelavathi, G.P., Naidu, M.V.S., Ramavatharam, N. And Kurana Sagar, G. (2009). Studied 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 (2), 109-120.

Likhar Chetna K. and Jagdish Prasad (2011). Characteristics and Classification of Orange-growing Soils Developed from Different Parent Materials in

Nagpur district, Maharashtra. *Journal of the Indian Society of Soil Science*. Vol. 59, No. 3, pp 209-217.

Mahesh Kumar, S.K. Singh, and B.K. Sharma (2009). Characterization, Classification and Evaluation of Soils of Churu District, Rajasthan. *Journal of the Indian Society of Soil Science*, Vol. 57, No. 3, pp 253-261.

Maji A. K., Obi reddy G.P., Thayalan S. and Walke N. J. (2005). Characterization and Classification of Landforms and Soils over Basaltic Terrain in Sub-humid Tropics of Central India. *Journal of the Indian Society of Soil Science*, Vol. 53, No. 2, pp 154-162.

Malewar, G. U. Ganure, C. K. Rudraksha, G. B. and Ismail, S. (1999). Impact of oilseed-based cropping systems on physico-chemical properties, soil nutrient dynamics and nutrient balance. *Journal of Maharashtra Agricultural Universities*; 24(2):125-127.

Mane, R.D. (2013). Assessment of soil quality for grape growing soils in Osmanabad district Maharashtra. *M. Sc. Agri. Thesis, VNMKV, Parbhani*.

Manwar S. G. (2014) Soil-site suitability evaluation for sugarcane growing soils of Latur district. *M. Sc. Agri. Thesis, VNMKV, Parbhani*.

Meena, R. B., Balpande, S. S., Babhulkar, V. P. and Mandle, M. G. (2011). Characteristics and classification of water logged soils in Upper Wardha Command Area of Maharashtra. *Journal of Soils and Crops*. 21(1):90-94.

Mehta, K.M. and Shankarnarayana, H.S. (1961). Rating of lands for irrigation- Jawai project area. *Journal of the Indian Society of Soil Science*. 9: 71-76.

Moharkar, P. F. Deoras, C. M. and Kadwe, R. S. (1992). Characterization of soils in relation to long term well water irrigation in Chouras area of Bhandara district of Maharashtra (India). *Journal of Soils and Crops*; 2(2):45-48.

More, S.D. Kachhave, K.G. & Varade, S.B. (1978). *J. Indian Soc. Soil Sci.* 26, 403.

Mungare and Pharande (1982). Soil moisture retention to some properties of soil- A review. *J. Maharashtra Agric. Univ* 7(3):207-210.

- Nad, B.K., Goswami, N.N. & Leelavathi, C.R. (1975). *J. Indian Soc. Soil Sci.* 23, 315.
- Narkhede, S. R., Bhirud, S. R., Patil, N. S. and Chaudhari, R. R. (2011). Physico-chemical analysis of soil collected from Chorwad, Tehsil-Bhusawal, Dist. Jalgaon (M.S.). *International Journal of Chemical Sciences*;9(4):1973-1978.
- Niranjana K.V., Ramamurthy V., Hegde Rajendra, Srinivas S., Koyal Arti, Naidu, L.G.K. and Sarkar Dipak (2010). Characterization, Classification and Suitability Evaluation of Banana Growing Soils of Pulivendla Region, Andhra Pradesh. *Journal of the Indian Society of Soil Science*.Vol. 59 (1):1-5.
- Nirawar, G. V. Mali, C. V. and Waghmare, M. S.(2009). Physico chemical characteristics and status of available N, P and K in soils from Ahemedpur tahsil of Latur district. *Asian Journal of Soil Science*;4(1):130-134.
- Padole, V. R. (1997). Morphology, genesis, clay mineralogy and classification of soils of the Central Demonstration Farm, PDKV, Akola. *PKV Research Journal*; 21(1):6-12.
- Pagar, P. C., Gabhane, V. V. and Nitu Khobragade (2004). Effect of plant density on physico-chemical properties of soils and growth of teak. *Indian Journal of Agroforestry*; 6(1):45-49.
- Pal, D.K. and Deshpande, S.B. (1987). Characterization and genesis of minerals in some benchmark Vertisols of India. *Pedology*. 37(3): 259-275.
- Palaskar, M. S., More, S. D. and Varade, S. B. (1990). Accuracy of field determination of soil texture in command areas of Maharashtra. *Journal of Maharashtra Agricultural Universities*;15(1):90.
- Pandurang Patil, Prashant Andage, Ashok Bhise and Praveen Saptarshi (2013). To assess fertility status of soils from paddy fields in the dapoli tahsil of Ratnagiri district, Maharashtra (India). *Review of Research Journal*; 2(12):404-ROR-404.

- Patil, B. A. (2011). Evaluation of soils and ground water quality in basaltic area of Osmanabad tahsil. *M. Sc. Agri. Thesis, VNMKV, Parbhani*.
- Patil, B.A., Vaidya, P.H. and Dhawan, A.S. (2013). Characterization, classification and evaluation of soils and irrigation water in Osmanabad tahsil. *J. Soil and crop* **23** (2): 401-408.
- Patil, C. L. Deore, H. O. and Lokhande, R. S. (2009). Physico-chemical analysis of soil collected from Dhule district (Maharashtra state). *International Journal of Chemical Sciences*; **7**(2):1412-1420.
- Patil, G.D., Khedkar, V.R., Tathe, A.S. and Deshpande, A.N. (2008). Characterization and classification of soils of Agricultural college farm, Pune. *J. Maharashtra Agric. Univ.* **33** (2):143-148.
- Patil, M. D. (1993). Available potassium status of soils in Maharashtra. *Use of potassium in Maharashtra agriculture. Proceedings of Workshop held on March 20, 1993, Konkan Krishi Vidyapeeth, Dapoli.*;31-37.
- Patil, M. N., Gabhane, V. V. and Dangore, S. T. (2001). Characterization and classification of soils of Varkhed watershed in Akola District of Vidarbha Region of Maharashtra. *PKV Research Journal*; publ. 2003. **25**(1):9-15.
- Patil, Y. M. and Sonar, K. R. (1994). Status of major and micronutrients of swell-shrink soils of Maharashtra. *Journal of Maharashtra Agricultural Universities*; **19**(2):169-172.
- Pawar, Y. S. (2013). Soil quality evaluation for pomegranate in Osmanabad district of Maharashtra. *M. Sc. Agri. Thesis, VNMKV, Parbhani*.
- Pharande, A. L. and Sonar, K. R. (1996). Depth wise distribution of different forms of potassium in important vertisol soil series of Maharashtra. *Journal of Potassium Research*; **12**(2):127-134.
- Piper, C. S. (1950). *Soils and plant analysis*. The university of Adelaide, Adeliade, 368p.

- Piper, C. S. (1966). *Soils and plant analysis*, IVth Edn. 135-200 Univ. of Adelaide, Australia.
- Piper, C. S. (1966). *Soils and plant analysis*. Hans' publication Bombay.
- Pooja Sawant, Nirmala Yenagi and Vaidya, K. P. (2013). Influence of physico-chemical properties of soil on nutritional quality of finger millet grown in Konkan region of Maharashtra. *Journal of Agriculture Research and Technology*;38(2):297-300.
- Prabhavathi, M., Patil, S. L. and Raizada A. (2013). Assessment of soil fertility status for sustainable crop production in a watershed of Semi-AridTropics in Southern India. *Indian Journal of Soil conservation*.Vol. 41, No. 2, pp 151-157.
- Prasad, J., Satyavathi, P. L. A., Srivastava, R. and Nair, K. M. (1995). Characterisation and classification of soils of Nasik district, Maharashtra. *Agropedology*; 5:25-28
- Rakhunde, S. B., Khaladkar, B. V. and Khairnar, S. M. (1993). Soils of southern Sindhudurg District, Maharashtra-their characterisation and classification. *Red and lateritic soils of India-resource appraisal and management*.;68-72.
- Ram, D. Ram, T. and Subhash Chand (2010). Characterization and Classification of Flood-prone Soils of Eastern Plains of Rajasthan for their Corrective Measures. *Journal of the Indian Society of Soil Science*, Vol. 58, No. 2, pp 228-232.
- Rao, R. V. S., Mahapatra, S. K., Verma, T. P. and Raja, P. (1997). Land capability classes and management practices for some vertisols of Maharashtra for sustainable agriculture: a case study. *Annals of Agricultural Research*; 18(3):295-299.
- Raskar, B. N. and Pharande, A. L. (1997). Different forms of potassium and their distribution in some important soil series of Vertisol and Alfisol of Western Maharashtra. *Journal of Potassium Research*; 13(1):21-30.

- Ray S.K. and Reddy, R.S. (1997). Quaternary soil formations in some Godavari delta region. *Journal of the Indian Society Soil Science*.45, 208-211.
- Raychaudhuri, S.P., Roy, B.B., Gupta, S.P. & Dewan, M.L. (1963). Slack soils of India. *National Institute of Science of India, India*.
- Richard, L. A. (1954). Diagnosis and improvement of saline alkaline soils. US Department of Agriculture, Hand book No.60, 160p.
- Roy, B.B. & Barde, N.K. (1962). *Soil Sci.* 93, 142.
- Sahrawat, K.L. (1980). *Pl. Soil.* 57, 335.
- Sarade, S. D. and Jagdish Prasad (2007). Characterization and classification of guava growing soils in Bhandara District, Maharashtra and their suitability evaluation. *Acta Horticulturae*. (735):441-450
- Satish Kumar, Y.S. and Naidu, M.V.S. (2012). Characteristics and Classification of Soils Representing Major Land forms in Vadamalalpeta Mandal of Chittoor District, Andhra Pradesh. *Journal of the Indian Society of Soil Science*, Vol. 60, No. 1, pp 63-67.
- Satyavathi, P. L. A. and Suryanarayan Reddy, M. (2003). Characterization and classification of shallow, medium deep and deep red and black soils of northern telangana zone in andhra pradesh. *Journal of Tropical Agriculture* .41: 23-29.
- Sehgal, J.L. (1991). Soil-site suitability evaluation for cotton. *Agroedology* 1:49-65.
- Sehgal, J. (1992). Soil Series Criteria and Norms, Tech. Bull. No. 36, NBSS & LUP, Nagpur.
- Sehgal, J., D. K. Mondal, C. Mondal and S. Vadi (1990). Agro-ecological regions of India. NBSS Tech. Bull. No. 24. NBSS & LUP, Nagpur. 73p.
- Selvaraj and Naidu, M.V.S. (2013) Land characterization and soil-site suitability for the major crops for Reniguntamandal in Chittoor District, Andhra Pradesh. *Indian Journal of Soil Conservation*. Vol. 41, No. 1, pp 41-46.

- Shalima Devi, G. M. and Anil Kumar, K. S. (2010) Characterization and Classification of Coffee-growing Soils of Karnataka. *Journal of the Indian Society of Soil Science*, Vol. **58** (1) pp 125-131.
- Sharma, B. D., Jassal, H. S. and Raj Kumar (2008). Sand Dune Soils of Semi-arid and Arid Agro-ecological Sub-regions of Punjab and their Characterization and Management. *Journal of the Indian Society of Soil Science* ;Vol 56, No 4.
- Sharma, S. S., Tetawat, K. L. and Shyampura, R.L. (1996). Characterization and classification of soils in a toposequence over basaltic terrain. *J. Indian Soc. Soil Sci.* **44** (3):470-475.
- Sharma, V. K., Sharma, P. D., Sharma, S. P., Acharya, C. L. and Sood, R. K. (2004). Characterization of Cultivated Soils of Neogal Watershed in North-West Himalayas and their Suitability for Major Crops. *Journal of the Indian Society of Soil Science* ; Vol **52**, No 1.
- Shilpa Babar, Rathod, P. K., Narkhede, A. H., Rathod, S. D. and Yewale, A. C. (2007). Studies on forms of Potassium and Nutrients status of soil in central and Eastern Vidarbha region of Maharashtra. *Asian Journal of Bio Science*; **2**(1/2):102-109.
- Sidhu, P.S., Hall, G.F. and Sehgal, J.L. (1976) Studies on some soils at varying stages of pedogenic development in the central Punjab. *Journal of Research Ludhiana* **13**, 23-33.
- Singh, S. (1954). *J. Soil Sci.* **5**, 289.
- Sinha, A. K. Singh, R. K. Singh, H. K. Ashok Kumar and Rajendra Prasad (2008). Variation of physico-chemical properties of soil in Deopar Chaur (Bihar). *Journal of Research, Birsa Agricultural University*; **20**(1):107-111.
- Sitanggang, Masri, 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*; Vol. **54**, No.1, pp 106-110.

- Smith, J. L. and Elliott, L. F. (1990). Tillage and residual management effect on soil organic matter dynamics in semi-arid region. *Adv. Soil sci.* 13:69-85. Soil chemical analysis prentice hall of India Pvt. Ltd. New Delhi, pp498
- Snehal Shilewant (2013). Characterization, classification and evaluation of soil water quality of BSP Farm (Khanapur Block- B) for Rational Land Use Planning. MKV, Parbhani. M. Sc. Agri. Thesis, VNMKV, Parbhani.
- Soil Survey Staff (2006). Key to soil taxonomy 8th edition SMSS Technical Monograph No. 19 Blacksburg Virginia poeahontas Press Inc-556.
- Srivastava, R., Prasad, J. and Tomgade, D. B. (1991). Soil physiography relationship in Ujjain district of M.P. *Land use planning* 37 (3):246-252.
- Subbiah, B. V. and Asija, G.L. (1956). Rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci.* 25: 259-260.
- Sys, C. (1985). Land Evaluation Part I, II, III State Univ. Ghent Publ., Belgium, 343p.
- Terman, G.L. (1979). *Adv. Agron* . 31, 189.
- Thangasamy, A., Naidu, M. V. S., Ramavatharam, N. and Raghava Reddy C. (2005). Characterisation, 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*, Vol. 53, No. 1, pp 11-21.
- Todmal, S. M. Patil, B. P. Tamboli, B. D. (2008). Characterisation and classification of soils in agriculture college farm, Kolhapur. *Journal of Maharashtra Agricultural Universities.* 33(3):287-291.
- Vadivelu (1983). Soil physio-graphic relationship and its impact on land use. *J. Maharashtra Agric. Univ.* 8 (1):16-19.
- Vaidya, P. H., Dhavan, A. S. and Mali, C. V. (2014). Characterization and classification of soils and ground water farm College of Agriculture, Osmanabad. *J. Agric. Res. Technol.*, 39 (1) 145-148.

- Vaidya, P.H. and Dhawan, A.S. (2010). Soil-site suitability of Agriculture farm, College of Agriculture, Osmanabad. *State level seminar on soil resources management for sustainable soil health and food security*. Dr. P.D.K.V. Akola 82.
- Vaidya, P.H. and Pal, D.K. (2002) Microtopography as a factor in the degradation of Vertisols in Central India. *Land Degradation and Development* 13, 429-445.
- Virgo, K.H. & Munro, R.N. (1978). *Geoderma* 20, 131.
- Waghmare, M. S., Indulkar, B. S., Mali, C. V., Takankhar, V. G. and Bavalgave, V. G. (2008). Chemical properties and micronutrient status of some soils of Ausa tahsil of Latur, Maharashtra. *Asian Journal of Soil Science*; 3(2):236-241.
- Waikar, S. L., Malewar, G. U. and Kausadikar, H. K. (2003). Characterization and classification of soils of drought prone south central part of Maharashtra. *Journal of Soils and Crops*; 13(2):262-266.
- Walkar, P. H., Hall, G. F. and Portz, R. (1968). Relation between landform parameter and soil properties. *Soil Sci. Soc. Am. J.* 32: 29-38.
- Walia, C.S. and Rao, Y.S. (1997) Genesis, characteristics and taxonomic classification of some red soils in Bundelkhand region of Uttar Pradesh. *Journal of the Indian Society of Soil Science* 44, 476.
- Yadav, Y. V. (2005). Soil resource mapping of Agriculture farm, Latur. M. Sc. Agri. Thesis, VNMKV, Parbhani.
- Yule, D. F. (1986). Water management in Vertisols in the semi-arid tropics, *IBSRAM Proc.* No. 6, Nairobi, Kenya, pp. 104-107.
- Zonn, S.V. (1986) Tropical and Subtropical Soil Science (Translated from the Russian), *Mir Publishers, Moscow*, pp. 260.



Appendix



Appendix-I

Ratings of various nutrients according to six tier system

Sr.No	Parameter	Strongly Acidic	Moderately Acidic	Slightly Acidic	Neutral	Moderately Alkaline	Strongly Alkaline
1	pH	<4.5	4.5-5.5	5.5-6.5	6.5-7.5	7.5-8.5	>8.5
		Safe		Normal		Unsafe	
2	EC	<0.8		0.8-2.5		>2.5	

Sr.No	Parameter	Very Low	Low	Moderate	Moderately High	High	Very High
1	Org.C (gm kg ⁻¹)	<2	2-4	4.1-6	6.1-8	8.1-10	>10
2	CaCO ₃ (gm kg ⁻¹)	<5	5-10	10-20	20-50	50-100	>100
3	Av. N (kg ha ⁻¹)	<140	140-280	280-420	420-560	560-700	>700
4	Av. P (kg ha ⁻¹)	<15	15-30	30-50	50-65	65-80	>80
5	Av. K (kg ha ⁻¹)	<120	121-180	181-240	241-300	301-360	>360

Sr.No	Parameter	Deficient	Sufficient
1.	Av.S (Mg kg ⁻¹)	<12.8	>12.8

Parker, 1951

Appendix-II

Rating of NIV:

Sr. No.	Category	Value
1.	Low	< 1.67
2.	Medium	1.67 – 2.33
3.	High	> 2.33

Ramamoorthy and Bajaj (1969)

Appendix-III

Meteorological data recorded during the course of investigation at Badnapur.

(2014-15)

M.W.	Date	Total rain fall (mm)	Rainy days (No.)	Temperature °C		Relative Humidity (%)	
				Min	Max.	Mor.	Eve.
23	4-10 June	0	0	26.1	37.6	28	17
24	11-17 June	0	0	23.6	34.7	52	30
25	18-24 June	0	0	23.1	33.6	52	41
26	25Jun-1Jul	0	0	21.3	30.3	67	49
27	2-8 July	15.0	01	21.8	30.9	63	46
28	9-15 July	45.0	02	20.6	29.2	78	57
29	16-22 July	20.0	02	21.7	30	71	46
30	23-29 July	35.0	03	21.1	29	77	67
31	30Jully-5 Aug	4.0	01	21.6	29.6	70	59
32	6-12Aug	21.0	02	20.8	28.8	75	62
33	13-19Aug	26.0	02	21	28	77	71
34	20-26Aug	104.5	04	21.3	30.5	73	63
35	27Aug-2 Sept	129.0	02	20.5	28.4	70	64
36	3-9Sept	50.0	02	19.6	25.1	86	69
37	10-16Sept	44.5	02	20.4	24.9	85	76
38	17-23Sept	0	0	20.2	26.3	79	73
39	24-30Sept	0	0	19.7	27	73	60
40	1-7 Oct	0	0	19.9	28.5	69	49
41	8-14Oct	0	0	19.7	26.4	85	72
42	15-21Oct	36.5	02	20.2	26.8	80	67
43	22-28 Oct	0	0	20.1	26.5	80	68
44	29 Oct-4 Nov	7.7	01	20.1	26.6	80	68
45	5-11Nov	0	0	14.9	26.4	71	40
46	12-18Nov	0	0	19.3	26.8	78	62
47	19-25Nov	0	0	19.3	26.8	79	63
48	26 Nov-2 Dec	27.5	02	19.1	26.7	79	62
49	3-9 Dec	0	0	14.6	28.7	55	46
50	10-16Dec	0	0	18.2	26.9	75	58
51	17-23Dec	0	0	17.9	27	74	57
52	24-31Dec	0	0	17.6	27.1	73	55
Total		565.7	28	20.17	28.50	71.8	57.23