

CHARACTERIZATION, CLASSIFICATION AND LAND EVALUATION OF COTTON GROWING SOILS OF HARYANA

BY

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DOCTOR OF PHILOSOPHY

in

SOIL SCIENCE

College of Agriculture

CCS Haryana Agricultural University

HISAR

**Dedicated
To My
Respected Parents**

CERTIFICATE - I

This is to certify that this dissertation entitled "Characterization, Classification and Land evaluation of cotton growing soils of Haryana" submitted for the degree of Ph.D., in the subject of Soil Science, of the CCS Haryana Agricultural University, is a bonafide research work carried out by Shri Rishi Raj Dahiya under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged


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CERTIFICATE - II

This is to certify that this dissertation entitled "Characterization, Classification and Land evaluation of Cotton growing soils of Haryana "submitted by Shri Rishi Raj Dahiya to the CCS Haryana Agricultural University in partial fulfilment of the requirements for the degree of Ph.D., in the subject of Soil Science, has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner

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CHAPTER - I

INTRODUCTION

The primary interest of mankind in soils rest on their capacity to support plants that provide food and fibre. Production of food and fibre retains first place even in the highly industrialized nations of the world. The Indian soils are required to produce much in a sustained manner to overcome the food and fibre shortage of the country. It is, therefore, important to have scientific inventory of soils for higher agricultural production.

Soil constitutes one of the basic resources of a country and is the key factor governing the use of land (Kellogg; 1961; Vink 1963). There are no two opinions that agricultural production starts with soil under a given agro climatic zone and the differences in the soils and their ability to produce crops have been recognised since ancient times. In order to understand the complex nature of soils developed under different environments, it is essential to determine the nature and properties of soils for predicting their behaviour under different management systems.

Soils differ greatly in their physical, chemical and mineralogical properties. These differences affect the response of soil to management inputs. In order to quantify crop responses, there is a great need for detailed soils information on the extensively occurring agricultural soils within a particular tract. This is also needed for a basic understanding of soil characterization, development and classification as well as for land use purposes. The importance of soil physical and chemical properties in the domain of agriculture and forestry can not be over emphasized. These properties are related to field morphology and regulate to a considerable degree, the qualitative and quantitative aspects of plant growth.

Mineralogical make up of soil has an important bearing on soil plant relationship. Mineralogy of sand fraction is important in nutrient release as well as in soil genesis studies. On the other hand, clay, the most reactive mineral fraction of soil, controls to a large degree the fixation and release of nutrients; retention of moisture; adsorption of pesticides and herbicides; base exchange phenomenon; expansion and contraction; structure; plasticity and permeability etc. It is also important to determine the kinds and rates of mineralogical transformation under given soil and climatic conditions and to relate these transformation to management practices. Increasing pressure on land for food and fibre necessitates assessment of land productivity, its suitability for different purposes. Most land evaluation studies require physical resource surveys such as inventory of soils, water, forest resources and ecological data etc. A clear understanding of the limitations presented by these native and environmental factors is essential for rational land use planning (Mcrae and Bunham, 1981). The productivity ratings of different soils under defined management systems have been considered rewarding (Storie, 1976, 1983). Riquier *et.al.*, 1970; FAO, 1976). Most useful expression of soil productivity indices indicates the adoption of various crops in different soils (Bertelli; 1978).

The soils of Haryana developed on alluvium vary with respect to texture, degree of profile development, drainage, salt and calcium carbonate and effective soil depth. The major crops grown include cotton which covers about 20 per cent of the cropped area. In general, while growing cotton, no proper consideration is given to soil and site properties resulting in overall low yield. Therefore, a need is felt to develop a strategy to evaluate and determine soil suitabilities in terms of crop performance qualitatively and quantitatively for better utilization of our soil resources for cotton

cultivation. The information on these aspects is lacking, therefore, the present study was undertaken with the following objectives :

1. To characterize soils using morphological, physico-chemical and mineralogical parameters.
2. To classify the soils according to Soil Taxonomy.
3. To evaluate the soils for alternate land use planning.

CHAPTER - II

REVIEW OF LITERATURE

The problem under investigation has been reviewed under the following heads:

- 2.1 Morphological characteristics
- 2.2 Physico-chemical characteristics
- 2.3 Mineralogical characteristics
- 2.4 Soil classification
- 2.5 Land evaluation

2.1 Morphological characteristics :

The morphological characters like colour, texture and structure etc. depend upon various soil forming factors. For studying the soil morphology various workers gave different morphological characters in soil, but colour is thought to be important macro-morphological property and is the resultant of various factors. Several workers have compiled the morphology of alluvial soils of the Indo-Gangetic plains. The Indo-Gangetic plains are among the most extensive alluvial plains of the world. Of great significance to the country's agricultural production, the area comprises in Punjab, Haryana, Rajasthan, Uttar Pradesh, Bihar and West-Bengal (Wadia, 1964). The investigations by Sehgal *et.al.* (1968) distinguished the soils of the Sutlej flood basin in Punjab. The soils were young alluvial, light grey to yellowish brown, shallow, coarse textured, well drained and neutral alkaline in reaction. Similar results were obtained by Satyanarayana and Dhir (1968) while studying the soils of Nawanshahar, (Punjab).

Mehrotra *et. al.* (1972) described the soils of Agra and Meerut districts, (U.P.) morphologically. The texture of the soil varied from loamy sand to clay loam with sub-angular blocky structure. Karale *et. al.* (1974) studied the soils of Meerut district, (U.P.) and observed that the clay coatings and clay in the sub surface horizons are invariably associated with an argillic horizon. Micro-morphological studies of sub surface horizons showed moderately to strongly oriented argillans in an Aeric ochraqualf and Typic natrustalf in conformity with designation of argillic and natric horizon in the field descriptions.

Gawande *et. al.* (1980) studied the soils in Attah district, (U.P.) and established seven series. The colour of the soils varied from yellowish brown (10 YR 5/4) to dark brown (10 YR 4/3). The texture varied from loamy sand to loam. In some of the series, the surface salinity was very high with salt incrustation on the surface.

Sehgal *et. al.* (1973) reported that there was an absence of prismatic structure but ESP was very high (60 ESP) in the salt affected soils of Indo-Gangetic alluvial plain morphologically. The soils were poorly drained and showing platy structure. The different land forms were observed on the soils of Malwa alluvial plain i.e. the flood plains, channels and flat plains. The flat plains showed medial profile development with a structural B (Cambic horizon) and blocky structure, those developed on the old channels and flood plains showed no profile development and exhibited A.-C. profiles with no structure. (Anand *et. al.* 1977).

Bhargava and Sharma (1982) studied the soils of Indo-Gangetic alluvial plain of North Bihar morphologically. The soils were calcareous and owe their origin mainly due to lime stone rocks. They occupied soil scape position within the upland plain

where the geochemical process of salt accumulation continued. Talati *et. al.* (1979) characterized the flood plain desert soils of North West Rajasthan. These soils were highly stratified with texture ranging from sand to clay. Chakraborty *et. al.* (1984) examined some alluvial soils of Assam morphologically and reported that upland levelled soils were devoid of mottlings and concretions and moderately developed. Soils affected by shallow water table, resulting in the formation of iron concretions and mottlings were weakly developed.

Several workers have studied the soils of Haryana (Kuhad, 1973; Sangwan, 1978; Goyal, 1981; Malik *et. al.*; 1984; Shanwal, 1984). They observed that texture varied from sand to clay loam. Colour of the profile was yellowish brown (10YR 5/4) to olive brown (2.5 YR 4/4). Soil structure was mainly subangular blocky. The pale brown colour in soils of Hisar district of Haryana is mainly due to the presence of iron-oxides and ferro-magnesium minerals and the light grey colour is due to calcium carbonate content (Sehgal *et. al.* 1968). Similar findings were made by Sangwan (1978) and Goyal (1981). The distribution of calcium carbonate in a profile in arid and semi-arid climate is an important parameter for judging the initiation of weathering.

Kuhad (1973) observed wide variations in soils of six bio-climatic zones of Haryana. The texture varied from drift sands to silty clays. The most common surface horizon in these soils was an Ochric epipedon with a textural B (cambic) horizon in most of the profiles of different zones. Based on morphology of the profiles and physiography, the soils of Haryana were grouped into nine main zones : i) siwalik hills ii) dissected rolling plain iii) inter-fluvial plain iv) active and recent flood plain v) table and water divide vi) ancient chautang flood plain vii) relict wedge plain ix) low land

plain. (Ahuja *et al.* 1978). Similarly, based on morphology of profile and physiography, the Rajasthan soils were grouped into nine zones : i) sandy arid plain ii) alluvial plain of mid west iii) plain of interior drainage iv) ghaggar plain v) aravali range vi) eastern plain vii) chhapan plain viii) north-east hilly region ix) south-east hadoti plateau. (Lodha *et al.* 1982).

The soils of North-East Punjab were divided on the based of soil morphology and physiography into eight land forms. i) foot hills ii) alluvial fans iii) sand bars iv) covered flood plain v) upper terrace vi) lower terrace vii) channel viii) river flood plain. The soils on unstable surfaces were coarse-textured, those on stable surfaces were fine textured. (Sharma and Dev, 1985).

Courty (1986) described the morphology of soil surface crusts in semi-arid conditions (Hisar region, N.W. India). He further reported that well developed surface crusts on sandy loam and loamy sand. Aridisols are of sedimentary type, appearing either when the soils are flooded for irrigation or during the monsoon period. Courty and Fedoroff (1985) studied the micro-morphology of recent and buried soils in a semi-arid region of North-West India. Major features of both soils were attributed to biological activity, reflected in extensive channeling and additions of excrements throughout profiles. Evidence of biological activity become progressively weaker from older to younger profiles soil development seems to have weakend over that period as well.

Manchanda and Hilwig (1983) studied the micro morphology of the soils of North-West, India under different moisture regime having same physiography and age. They observed sufficient clay skins to qualify for argillic horizon in the pedons having rainfall - 1000mm. Pedons with 500 mm rainfall lacked the clay cutans. Ahuja and

Khanna (1983) grouped the soils of Ghaggar river basin into i) relict channel course ii) levees and bars iii) relict channels iv) plain undifferentiated and v) old basin. The soils of Yamuna alluvial plain were grouped into four major plains : i) recent flood plain ii) young meander plain iii) old meander plain iv) old alluvial plain. The soils of old alluvial plains showed the signs of profile development but that of recent flood plain were quite immature. (Shanwal 1984). The soils of North-Eastern part of Ambala district of Haryana developed on Siwalik foot hills were divided into three major land forms : i) hills ii) piedmont plains iii) plains. Soils of hills and piedmont plains were lighter in texture and plains were heavier in texture. (Kumar, 1987).

2.1.1 Genesis of soils :

Pedogenic evolution in soil involves the comparison of the solum with the parent material. It concerns that phase of pedology that deals with the factors and processes of soil formation. The pedogenic processes include gains and losses of materials from a soil body in accordance with aggradational, degradational or intermediate geomorphic characters of the site as well as translocations within the soil body (Simonson, 1959). The knowledge about pedogenesis is helpful for better understanding of the magnitudes of changes that may have taken place during development of soils. The consideration in evaluating pedogenesis is the establishment of the parent material uniformity and assessing the degree of weathering.

Wang and Arnold (1973) suggested that the estimates for uniformity should be based on many lines of evidence including field observations and distribution of assumed mobile constituents. The location of discontinuities in the profile is commonly associated with concomitant changes in texture, structure and consistence, nature of

boundaries and matrix changes such as reaction and carbonate. Soil colour may also lend additional support to the field judgements.

An evaluation of the extent and nature of attraction of soil material during pedogenic development and redistribution either in solution or in colloidal form can be made assuming that certain constituents remain inert and immobile enabling thereby the use of stable mineral or of their component elements as internal standards as means of establishing the original uniformity of a deposit and of evaluating quantitatively changes which have occurred during soil development. Pedogenesis of soils from various land forms in the central Punjab was found to be affected by topography (Sharma *et al.*, 1979). The differences among the soils developed on different physiographic positions are primarily due to topography and to some extent age.

Bhargava *et al.* (1981), studied the soils of Indo-Gangetic alluvial plain of Haryana and U.P. and reported that release of salts in the Siwalik / piedmont zone and the plains through alkali hydrolysis during the weathering of alumino-silicate minerals and their repeated convergence into micro-depressions lead to the genesis of sodic soils at the surface where good quality ground water occurred in the substratum. Manchanda and Khanna (1981) studied soil landscape relationship in Haryana and observed that there was mechanical illuviation of clay in the soils of upland with wedges, where soils were impregnated with salts. Uniformity of the soil texture was found in case of plain undifferentiated and aeolian cover, having no development.

Soil survey staff (1975) gave an explanation for the movement of clay i.e. the parent material must contain very fine clays or weathering must produce them. Clay tends to disperse due to its negative charge. Such dispersed clay is believed to move

with percolating water and to stop where percolating water stops. Wetting a dry soil favours dispersion of the clay when soil dries, cracks form in which gravitational water or water held at low tension can percolate the halting of percolating water by capillary withdrawal is favoured by the strong tendency for a dry soil to take up moisture.

Sharma and Dev (1985) studied the genesis of soils on different geomorphic surfaces in a riverine plain of Punjab and reported that the soils developed on foot hills, alluvial fans, sandbars, lower terrace and flood plains were stratified, show A.-C. profiles and soil properties were mostly inherited from the parent materials but the soil profiles in upper terrace and channels showed the formation of an altered B or cambic horizon, blocky structure, redistribution and reorganization of mobile soil constituents as evidenced by mottles and / or iron manganese nodules and translocation of alkaline cations. Sehgal and Stoops (1972) described that the accumulation of pedogenic calcite in the soils of arid and semi-arid regions of the Indo-Gangetic alluvial of erstwhile Punjab and found that all types of calcite formations seemed to be secondary origin. However, Manchanda *et al.* (1983) and Ahuja and Khanna (1983) studied the genesis of nodules in Haryana and Ghaggar river basin, respectively and reported that the CaCO_3 conversion in the profile were inherited from the parent rocks and were not of secondary origin.

Another important morphological soil feature in the process of genesis is the mottling which indicates certain aspects of the moisture regime. Soil mottles within a soil profile are generally used as indicators for the degree of soil wetness, periodic soil saturation and ultimately presence of a water table. (Soil Survey Staff, 1975). Presence of an oxidation and reduction mottles in soil profiles of Indo-Gangetic alluvial plain

indicating the poor and impeded drainage have been reported by several workers (Kumar, 1987; Ahuja *et al.*, 1983; Vepraska *et al.*, 1974). The physical significance of soil mottling in soils can be derived from an analysis of morphological features formed of reduction and oxidation of iron and manganese compounds. The reducing conditions during rainy season in the soils of alluvial plain of Punjab solubilized originally insoluble forms of Fe and Mn in the upper horizons (Sidhu *et al.*, 1978). The iron-manganese concretions in the soils of Yamuna alluvial plain were studied by Shanwal and Ghosh (1987). They reported that concretions were absent in the recent flood plains (<100 years) and depth of concretions in the profiles increased from meander plain (Holocene) to old alluvial plain (Pleistocene).

2.2 Physico-chemical characteristics :

The physico-chemical characterization has direct bearing on the aspects of salt movement and movement of water leading to water logging and salinity. It also relates to soil-plant relationships. Ghildyal and Satyanarayana (1965) reported that coarse textured soils are more susceptible to compaction because of the presence of macro-voids, which are destroyed during puddling resulting in marked decrease in infiltration rate. Soils are expected to be relatively more deficient in nutrients, water holding capacity, fertility status, organic carbon content and high calcium carbonate in view of their coarse texture as compare to fine-textured soils (Takkar and Randhawa, 1978; Katyal and Sharma, 1979). The increase in cation exchange capacity relates to the fineness of soil which enhances the availability of certain micro nutrients (Tarafdar *et al.*, 1989).

Sharma (1970) observed better relation between water holding capacity and

clay content, bulk density, particle density and type of clay minerals in block soils of Hisar district. Kuhad *et al.*, 1975 observed that physiography of the area and the texture of different horizons, in the soil profile, mainly governed the moisture retention and storage capacity of soils in Haryana, and fine loamy classes retained higher amounts of available moisture as compared to those of coarse loamy. Other workers also have reported that finer the texture, more is the water retained at a given suction. (Ghosh 1976; Tripathi and Ghildyal 1976; Gupta *et al.*, 1981). Thomas and Moody (1962) found that the Na montmorillonite contains more moisture than any other clay. They found no effect of type of clay and exchangeable cation except sodium in the water retention by clay at 15 atmosphere. They also observed that water held at 1/3rd atmosphere was closely related to clay type and cation saturation. Importance of organic matter in water retention at different tensions was pointed out by number of workers (Kuhad, 1973; Gupta *et al.*, 1981). Zonn (1959) reported that texture was a basic factor in moisture retention, but it was modified by organic matter. Kemper (1958) found that water retention increased on additions of organic matter, but it decreased with an increase in exchangeable sodium; whereas Abrol *et al.* (1978) showed that with increasing exchangeable sodium percentage moisture retention increased but infiltration rate, hydraulic conductivity and soil water diffusivity under went sharp decreased. The soils in the Siwalik foot hills of Haryana having fine loamy particles retained higher amounts of available moisture as compared to those which qualified for coarse loamy (Kumar *et al.*, 1989).

2.2.1 Soil fertility status :

To supply the proper doze of nutrients to the crops, it becomes necessary to know the fertility status of the soils. Mahazan and Kanwar (1974) analysed the

saline-alkali soils of Punjab and Haryana and found that total nitrogen, nitrate nitrogen and ammonical nitrogen varied from 27 to 291, 7 to 22.5 and 0 to 7 ppm respectively. Ruhal and Shukla (1979) conducted field studies on the effect of continuous application of varying levels of FYM under pearl millet-wheat rotation and found that the available N, P and K contents decreased from 200.0 to 147.2, 13.0 to 9.6 and 498 to 318 kg/hac., respectively due to continuous cropping without FYM. Minhas and Boora (1982) found that with the increase in the altitude, the total, available, ammonical and nitrate nitrogen increased. A highly significant correlation (0.951) existed between organic carbon and total nitrogen in the soils.

Brar (1980) reported that available phosphorus status of the soils of Punjab generally ranged from 12.5 to 22.5 kg/hac. It was in the low range (12.5 kg /hac.) in parts of Punjab soil and was estimated that about 27-57 per cent soils of different districts are deficient in phosphorus. Tamhane *et al.* (1959) studied the soils of community project area of arid and semi-arid regions of India. They found that available nitrogen was practically low to medium. For phosphorus, all were on the average near medium side; available potash being medium in practically all the cases except Alipur (Delhi) soils. The difference between the characteristics of alluvium soils in the tropical and temperate regions was reported by Edelman and Vander (1963). According to them temperate region was characterised by high natural fertility, illite type of clay minerals, presence of calcium carbonate, high cation exchange capacity, high organic matter content and late formation of soil while the tropical region was characterised by low natural fertility, absence of calcium carbonate, kaolinite type of clay minerals, low organic matter content, low cation exchange capacity and early formation of soils.

Ghabru and Ghosh (1980) characterised the soils of Dhauladhar range of middle Siwaliks (HP) and observed the soils of high rainfall and low temperatures are rich in organic matter, acidic in pH, medium in N, P and K fertility status. Sangwan (1980) studied the soils of southern part of Mahandergarh district and found that fertility status and relationship of micro nutrient with physico-chemical characteristics of soils in a land form is low. Sharma *et al.* (1992) studied the distribution of micro nutrients in arid zone of Punjab and reported that DTPA extractable micro nutrients increased with an increase in organic carbon, cation exchange capacity, silt and clay and decreased with an increase in sand content, whereas Mn decreased with an increase in sand and calcium carbonate content. Total content of all micro nutrients increased with an increase in silt and clay, whereas Zn and Fe increased with an increase in organic carbon content. As physiography changed from alluvial terrace to sand dune, the available forms of micro nutrients decreased. Analysis of surface soils revealed widespread deficiency of Zn and Fe, particularly in sand dune soils.

Sangwan and Singh (1993) reported that the micro nutrients present in semi arid soils of Haryana are related to the other soil properties. The available Fe and Mn were influenced by pH and CaCO₃ content. The clay and CEC controlled the availability of soil Cu. Accordingly the availability of Zn, Cu, Mn and Fe decreased as the soils become aridic; contrarily their total contents increased. Similar reports were given by Chaudhari *et al.* (1990) and Kuhad *et al.* (1986) while studying the arid zone soils of Rajasthan and semi arid and arid regions of Western Haryana.

2.3. Mineralogical characteristics :

Sand mineralogy : Mineralogical studies have been used in evaluating the

pedogenesis of soil, recognising depositional differences, lithological discontinuities, realizing weathering trend and classifying soils. The mineralogical make up of soils is helpful in determining the source of parent material of the alluvium derived soils (Hasemann and Marshall, 1945) and is also important in predicting the response of soils to management and manipulation. Several workers have studied the mineralogy of sand fractions and arrived at various conclusions. The fine sand fractions in the soils of Hisar constituted of biotite, chlorite, epidote, garnet, sphene, zircon, tourmaline and opaque iron oxides as heavy minerals and quartz, muscovite and feldspars as the light minerals. (Roonwal *et al.*, 1967) It was further concluded that these are drift soils and the source of parent material is sedimentary or para metamorphic areas. Similar observations were also reported in various soils of Haryana (Kuhad 1973; Ahuja *et al.*, 1984; Sangwan, 1978) and Punjab (Pundeer *et al.*, 1974).

Pundeer *et al.* (1978) reported the dominance of quartz and muscovite as the light minerals in the sand fractions of Sutlej alluvium (Punjab). Biotite, tourmaline, garnet, kaynite, and sphene were heavy minerals. The mineralogical make up of heavy sand fractions suggests a dominant metamorphic and a subsidiary and igneous terrain in the source area. All the minerals encountered in these soils were present in the Siwalik and Himalayan formations. Similar observations were made by Sidhu and Gilkes (1977). Minerals present in the sand fractions of different soil series of Punjab viz. Gurdaspur, Jalalabad, and Fajewal were muscovite, biotite, microcline and orthoclase feldspars as potassic minerals (Sidhu and Dhillon 1985).

Barua *et al.*, (1990) observed the dominance of quartz followed by feldspars, mica and calcite in light sand fractions of some salt-affected soils of Punjab. In heavy sand fractions, the dominant mineral was biotite. Other minerals present were chlorite,

interstratified biotite-vermiculite, amphiboles, zircon, tourmaline and kyanite.

The sand fractions of the alluvium derived soils of Haryana contained quartz, muscovite, albite, tourmaline, hornblende, biotite, chlorite etc. Other accessory minerals in soils of Haryana were zircon, garnet, kaolinite, rutile and apatite. (Ahuja *et al.*, 1978; Shanwal 1984). The soils of Ghaggar river basin constituted of quartz followed by muscovite in the light fine sand fractions. Other minerals present were albite oligoclase, orthoclase-microcline, sericite and calcite. The heavy minerals observed were hornblende, iron ores, biotite, chlorite, epidote, apatite, garnet and sphene. (Ahuja *et al.*, 1984). Similar observations were made by Goyal *et al.* (1985).

The soils of different bioclimatic zones of Haryana contained quartz and muscovite in the light sand fractions. The presence of quartz in abundance was mainly due to weathering resistance to the prevailing conditions. The high percentage of muscovite accounted for the rich status of potash in these soils. Among heavy minerals observed were mainly, biotite, epidote, chlorite, garnet, zircon, hornblende, tourmaline, kyanite, apatite, limonite and hematite. Iron minerals were found well distributed in the form of hematite and limonite as coatings, cracks filling, globules and stains on various mineral grains (Kuhad *et al.*, 1983). Manchanda *et al.* (1982) studied the soils of different landforms in a part of Indo-Gangetic plain in Haryana and reported the predominance of quartz followed by muscovite and albite as the light fraction minerals. Calcite was present in all types of soils with higher percentage in salt affected pedons. Heavy minerals were hornblende, chlorite, iron ores, biotite, tourmaline and zircon.

Clay mineralogy : In relation to the dynamics of pedological processes the clay minerals together with the oxides and hydroxides follow closely behind soil organic

matter in reactivity and insensitivity to various factors of soil formation. Mineralogical composition of soil clays is a function of weathering reactions during the process of soil development controlled by the pedogenic factors. The distribution of clay minerals in soils is expected to bear a close relation with the climate and zonal distribution of soils.

The presence of illite, kaolinite, vermiculite, smectite, metahalloysite, hydrobiotite and chlorite was reported in Sutlej alluvium and Indus basin soils of Punjab (Pundeer *et al.*, 1978; Sidhu and Sehgal 1978). Sharma (1981) investigated the clay mineralogy of soils from different landforms of Punjab and reported the dominance of smectite in all the pedons. Earlier reports have shown that this mineral is abundant only in certain specific soils such as some salt-affected soils (Sehgal 1971a; Sidhu and Gilkes, 1977) and flood plain soils (Pundeer *et al.*, 1978). The abundance of this mineral in all the studied soils which show only limited pedogenesis (development of a cambic horizon) suggested that it was inherited from the parent material. Anand and Sehgal (1977) reported the dominance of illite in soils of Malwa alluvial plain of Punjab. The other minerals found were montmorillonite, vermiculite and kaolinite.

The soil profiles developed on different parent materials in Simla, Kulu and Palampur in Himachal Pradesh were reported to contain illite, smectite with occasional presence of mixed layer minerals in clay fraction (Ghosh and Tomar 1973; Krishnamurti *et al.*, 1973). Satyanarayan *et al.*, (1974) suggested the dominance of illite with good amount of smectite in the soil clays from different sources of alluvial parent materials in N.W. India. Kapoor *et al.*, (1982) reported that illite, mixed layer minerals, smectite / chloritized smectite, chlorite and vermiculite were found in the aridic soils of Haryana. Shanwal *et al.* (1988) made quantitative studies on some soils of H.A.U. farm and

reported the presence of illite, kaolinite, chlorite with small amount of smectite, vermiculite, feldspar and quartz. The clay mica (illite) decreased with depth from flood plain to old alluvial plain in Indo-Gangetic alluvial plain of Haryana. (Shanwal and Ghosh, 1987). Appreciable amount of smectite (15-20%) was observed in sub-surface soils of old alluvial plain. Vinayak et al. (1984), Sharma and Dev (1985) and Dhaliwal et al., (1993) studied the geographic distribution of clay mineral in different parts of Punjab and reported that soil contained high amount of smectite in addition to illite.

Mineral transformations : The study of clay minerals in Punjab soils (Sehgal, 1970) indicated three prominent reflections at 14, 10 and 7.1Å d-spacing. In ustic moisture regime areas, the 14Å component (vermiculite) increased and 10Å component decreased with depth upto lower part of B horizon. This changes was explained as a result of in place weathering of illite to vermiculite. It was also concluded that the probable weathering trend of clay minerals in Punjab soils is as follows :

Mica - illite - illite-vermiculite - illite montmorillonite and / or Vermiculite - Chloritized vermiculite / montmorillonite.

Sehgal (1974a) suggested that in the Indo-Gangetic plains tri-octahedral illite was alteration product of biotite. Contrary to this, Sidhu and Gilkes (1977) reported that both muscovite in the coarse fractions and illite in the clays of some soils of western Indo-Gangetic plain were of the 2M₁ polytype, indicating that the illite was derived from muscovite by the mechanism of loss of part of interlayer potassium during transportation, sedimentation and pedogenesis following deposition. The expanding minerals belonging to smectite and vermiculite groups are essentially weathering product of micas. The occurrence of vermiculite in the soils has been reported (Anand and Sehgal,

1977) as a minor component and as an intermediate stage in the weathering of micas to smectite. Sahu and Ghosh (1977) observed that mica weathers to smectite through intermediate stages of mica-vermiculite following the sequence.

Mica - Mica - Vermiculite - Vermiculite



Montmorillonite

The same sequence was postulated by Kapoor *et al.* (1980), Shanwal and Ghosh (1984, 1987) and Shanwal *et al.*, (1989a). Recently, Shanwal (1992) observed high charge smectite transformed from illite in paleosoils of pleistocene period in Indo-Gangetic alluvial plain, Haryana.

Kapoor *et al.* (1981) suggested that in the initial stages of weathering, leaching and hydration would selectively alter the defect layers in biotite by replacing the interlayer K by the hydrated Mg or Ca ions present in the soil solution, leading to the formation of two component mixed-layer minerals. Vinayak *et al.* (1984) reported that the salinity and the sodicity may be attendant factors rather than the cause of smectite formation under poor drainage conditions. Higher level of exchangeable sodium and calcium in soil cause the displacement of interlayer K from celadonite mica to form Fe-rich smectite (Reid *et al.*, 1988).

2.4 Soil classification :

The objective of soil classification is to organise the knowledge about soils in such a way that their properties are clearly conceived and their relationships can easily be understood. Taxonomy also aids in reducing the number of individual soils studied to a few well defined classes or units. For good classification, precise criteria

and objective description of individual soils are very necessary. The grouping of soils into distinct units or taxa is based on the determination of measurable morphological and analytical soil properties. The development of modern comprehensive system of soil classification above the level of soil series is based on a sequence of approximations. The 7th Approximation was published in 1960 (Soil Survey Staff, 1960), followed by supplements published in 1964, 1967 (Soil Survey Staff, 1964, 1967). Finally, soil taxonomy, a basic system of soil classification for understanding and interpreting soil surveys (Soil Survey Staff, 1975) was published. This system seems to be an open system and can be modified to fit all the soils of the world.

Sehgal *et al.*, (1975) classified the soils of Indo-Gangetic plain in N.W. India into Aquic Calcorthids, Camborthids and Haplustalfs on the basis of high salts, esp, pH, chromas and hues. Anand *et al.*, (1977) classified the soils of Malwa alluvial plain as Typic Ustochrepts, Aeric Fluvaquents and Aquic Ustifluvents, respectively. Sidhu *et al.*, (1976b) classified the soils developed on terraces of Jullundur district in central Punjab as Udic Ustochrepts and Udic Haplustalfs and those of flood-plain as Aeric Fluvaquants. Kuhad (1973) while characterizing and classifying soils of various bioclimatic zones of Haryana observed that within the bioclimatic zone physiography and drainage of the area appeared to have influenced the development of soil profile and its characteristics. Soil moisture regime as influenced by physiographic positions was noticed as responsible for the differences in profile development and characteristics. Srinivason (1976) proposed epialic, natric and halic subgroups in the Alfisols of saline-alkali soils of Karnal district. Sangwan (1978) classified the soils of Southern part of Mahendergarh district (Haryana) based on their morphological and physico-chemical characteristics. Goyal *et al.*, (1978) proposed a new sub group "Aquic Vertic Camborthids

in the basinal areas of Gurgaon district. Manchanda and Khanna (1981) proposed epihalic, epinatric and epihalonatric subgroups in saline-alkali soils of Jind and Karnal districts.

Sawhney *et al.*, (1992) studied the relationship of genesis to physiography in semi-arid and arid tracts of Punjab and revealed three distinct stages of pedogenic development : A-C, A-Bw-C and A-Bt-C profiles. The young and stratified soils from unstable landforms, representing newer alluvium were classified as Typic Ustipsamments. The severely eroded and shallow soils of foothills were classified as Typic Ustorthents. The soils developed on relatively stable landforms show development of cambic horizon and were classified as Ustochreptic Camborthids. The soils developed on old alluvial terraces show the development of argillic horizons.

Sidhu and Sharma (1990) classified the arid zone soils of Punjab and revealed that the soils developed on sand dunes were coarser in texture, lack subsurface diagnostic horizons and were classified as Ustic Torripsamments. The soils developed on alluvial terraces were relatively finer in texture, showed the development of cambic horizon, and classified as Ustochreptic Camborthids. The soils of interdunal areas were intermediate in texture and were classified as Ustochreptic Camborthids.

2.5 Land evaluation :

The performance of any crop is largely dependent on soil parameters (i.e. depth, texture, drainage, etc.) as conditioned by climate and topography. The study of soil-site characteristics for predicting the crop performance of an area forms land evaluation. According to Van Wambeke and Rossiter (1987) land evaluation is the ranking of soil units on the basis of their capabilities (in prevailing circumstances and manage-

ment and socio-economic levels) to produce optimum returns per unit area.

Many of the approaches and methods employed in land evaluation originated in developed countries. The earliest methods were developed in United States and recent advances have been made particularly in the European countries. The Food and Agricultural Organisation of the United Nations has taken an important role of co-ordinating land evaluation methods. Selected approaches and methods to land classification in the appraisal of soil productivity are reviewed below:

1. USDA Land capability classification : The land capability classification of USDA is the best known example of interpretative groupings of soils and the one most widely used and adapted (Klingbiel and Montgomery, 1961) all over world.

The system is intended as a means of grouping soil mapping units. Other features of land, i.e. slope angle, climate and frequency of flooding are taken into account. The main concept used is that limitations, land characteristics which adversely affect the land use. Two types of limitations, permanent (slope angle, soil depth and climate) and temporary (soil nutrient content, minor drainage, impedance, etc.,) are used. This system involves three category classification.

- i) A capability class is a grouping of capability sub classes that have the same relative degree of limitation hazard. Classes are indicated by Roman numbers from class I to class VIII.
- ii) A capability sub class is a grouping of capability units that have the same kinds of limitation or hazard. These kinds are indicated by lower-case letter subscripts, of which the original system gives four erosion hazard (e), excess water (w), soil root zone limitations (s) and climatic limitations (c).

- iii) A capability unit is a grouping of soil mapping units that have the same potential, limitations and management responses. Units are shown by Arabic numerals, as IIIe₁, IIIe₂. This is a qualitative, general purpose land evaluation system for current suitability, it does not take adequate account of the requirements of major kind of land use other than arable (Young, 1976).

2. USBR Land classification for irrigated land use :

The most widely used system where irrigation projects are being assessed is that of US Bureau of Reclamation (1953). This classifies land specifically in terms of its suitability for irrigation. Six land classes are defined in terms of suitability for irrigated farming.

Class 1 Arable lands that are highly suitable for irrigation, being capable of producing sustained and relatively high yields of a wide range of crops at reasonable cost.

Class 2 Arable lands of moderate suitability for irrigation, being lower than Class 1 in productive capacity, adapted to a somewhat lower range of crops, more expensive to prepare for irrigation or more costly to farm. These lands have an intermediate payment capacity.

Class 3 Arable land that are suitable but approaching marginality for irrigation.

Class 4 Limited arable or special use. These lands may either have excessive deficiencies susceptible of correction at high cost, but are suitable for irrigation of high-value crops such as vegetables or fruits.

Class 5 Non-arable. These lands are non-arable under existing conditions, but have a potential value sufficient to warrant segregation for special study; or their arability is dependent upon additional project construction.

Class 6 Non-arable. These lands do not have sufficient payment capacity to warrant consideration for irrigation.

The final allocation of land to a particular class is based on economic considerations, specifically payment capacity. This means the capacity of the land to provide an acceptable income for the farmer and at the same time to pay water charges sufficient to amortize the capital costs of development. This is thus a single purpose economic evaluation system.

3. Soil capability classification of Canada¹⁹⁶⁹: In this system a greater number of soil limitations as compared to that in USDA system, are taken into account to estimate the value of the tracts of land that are recognised.

4. The multipurpose land classification system of Iran : Soil Survey Institute of Iran (1970) the multipurpose land classification is based on land resources and land potentiality surveys for double purposes : (a) the selection of the most suitable land for a given use; and (b) the determination of the suitable uses for a given tract of land.

5. Parametric methods of land classification : The parametric methods of land classification aim at expressing the suitability of land entirely in quantitative terms. They tend to follow an opposite approach. In these methods, instead of working with limitations, use is made of the land and / or soil features which are thought to be of paramount importance to make certain land uses of land utilization types of possible.

Variations in quality or influence on productivity of the features used land and / or soil characteristics are rated and expressed in a certain numerical scale. The rated values are combined together they reflect the end result in the productivity index. With the help of master rating these index values can be transferred in terms of suitability classes.

6. The storie index method : Another land evaluation system developed in the United States is the Storie Index Rating, of which a series of revisions exists (Storie 1976, 1983). It is devised for the agricultural rating of soils for purposes of land tax assessment and land use zoning. The approach can be characterized as a multiplicative parametric method to express the joint influence of soil factors on suitability for and productivity of agricultural crops.

The storie Index is assessed by assigning percentage ratings to each factor and then multiplying these ratings. $\text{Storie Index} = A \times B \times C \times X$

where factor A = soil profile factor determined by depth, permeability and gravel content of the soil

B - texture factor, C - slope factor, X - miscellaneous factor

7. System of Riquier, Bramao and Cornet (1970) : The term productivity index is expressed as a percentage of the optimum yield per hectare of the same crop grown on the best soil. $\text{The productivity Index} = H \times B \times P \times T \times N \text{ or } S \times O \times A \times M$ where the nine factors are respectively moisture, drainage, effective depth, texture / structure, base saturation or soluble salt concentration, organic matter, cation exchange capacity / nature of clay and mineral reserves. The main difference between this index and storie's is in the actual choice of productivity factors.

8. The framework for land evaluation (F.A.O., 1976) : The Food and Agricultural Organisation of the United Nations, in its efforts to co-ordinate the different land evaluation methods, chalked out a frame work for land evaluation in the year 1976. The frame work as such does not constitute an evaluation system but is primarily designed to provide tools for the construction of local, national or regional evaluation systems in support of rural land use planning. The two basic means are land improvement and land management improvement to achieve the goal of land evaluation.

The frame work defines six principles that are fundamental to land evaluation:

- i) Land suitability is assessed and classified with respect to specified kinds of use.
- ii) The suitability classes are defined by economic criteria.
- iii) A multidisciplinary approach is required.
- iv) Evaluation should take into account the physical, economic, social and political context of the area concerned
- v) Suitability refers to land use on a sustained basis.
- vi) Evaluation involves comparison of two or more alternative kinds of use. The Framework recommends four classes : S1, highly suitable; S2, moderately suitable; S3 marginally suitable; and N, not suitable.

Land suitability sub classes; are divisions of classes distinguished by the nature of the limitations eg., wetness, topographic etc.

Land suitability units : are divisions of sub classes which differ in minor aspects of management requirements. Different methods have been taken into consid-

eration to evaluate the productivity of soils for different crops. The concept of soil productivity is based on properties that affect root ramification and supply of moisture and nutrients (Bertelli, 1978). Sopher and McCracken (1973) studied the relationship between soil properties, management practices and corn yields in South Atlanta and revealed that most important factors affecting yields were soil moisture holding capacities, certain combinations of clay and sand, extractable phosphorous, per cent base saturation, properties controlling acidity and cation exchange capacity, plant population and planting dates. Applied nutrients also appeared to be important.

Alexander and Paschke in (1972) satisfactorily used soil characteristics like soil depth, slope, permeability, available moisture capacity, natural fertility and acidity of surface soil to group soil mapping units into the management units.

Soil suitability evaluation of Indian soils :

In India, sporadic attempts have been made from time to time to evaluate the productivity of soils using both qualitative and quantitative approaches. Kuhad *et al.*, (1988) modified the approaches of land suitability and its uses in the field of Agriculture, forestry, water resources, mining etc.

Manchanda *et. al.* (1982) studied soils and land use in Patna area (Bihar) using aerial photos of 1:25,000 scale and identified three major systems i.e. Ganges, Gandak and Interfluvial plain. They further evaluated the soils of the area for different land utilization types such as upland crops, low land crops and habitation. For paddy 73.3 per cent area was found suitable and 27.7 per cent unsuitable, where 81.2 per cent area was suitable for upland crops and 18.2 per cent unsuitable. For habitation 57 per cent was suitable and 43 per cent unsuitable.

The cropwise productivity indices of five mollisols of Tarai in U.P. based on yield data obtained from farm records have been worked out (Sinha, 1974; Sinha *et al.*, 1977). The maximum productivity indices obtained for paddy, wheat and maize were 62.2 per cent (Beni silty clay loam), 57.8 per cent (Haldi loam) and 54.9 per cent Haldi loam respectively. They concluded that this information can help in proper land use planning of the classified and mapped soils in a particular area. Using additive approach, Nanda and Bastia (1982) calculated productivity of five mapping units by summation of marks assigned to six soil characteristics. Four soil characteristics viz. texture, available water holding capacity, nutrient status and permeability which affect the productivity most were assigned 20 marks each and pH and cation exchange capacity were assigned 10 points each against a total of 100 marks. Each mapping unit was rated for its productivity expressed as per cent of the actual yield to the standard optimum yield.

The parametric approach of Riquier *et al.*, (1970) has been found useful for productivity evaluation of Indian soils by many workers (Iyer *et al.*, 1972; Anand *et al.*, 1977; Kumar and Saxena, 1985). The calculations of productivity and potentiality using all the nine or three factors viz. total available moisture, base saturation and organic matter for the soils of Doon Valley were found to be equally comparable (Iyer *et al.*, 1972). Similarly, Anand *et al.* (1977) computed the productivity index of soils of a part of Malwa alluvial plain in Punjab using five soil characteristics viz. texture, calcium carbonate, salinity, sodium saturation. Sharma *et al.*, (1980) using modified FAO limitation approach and the criteria outlined in the suitability tables for wheat (Sehgal, 1986) evaluated the soils of kandi area in Hoshiarpur district for their suitability for wheat. Their results suggest that all the soils in kandi area are not suitable for growing

wheat. The ustochrepts developed on terraces are comparatively the best suitable (S2-moderately suitable) followed by Ustifluvents developed on foot hills and piedmont plain (S3-marginally suitable). The Ustipsamments developed on 'cho'-bed area are least suitable (U1-unsuitable but potentially suitable) for wheat crop.

Ahuja *et al.*, (1987) evaluated the soils of Ghaggar river area on the basis of physiographic positions and the soil properties, the land qualities ratings were found for paddy, wheat, cotton, sugarcane and forestry. Based on the suitability of land for different purposes and the present land use, five potential land resources regions were identified and mapped. Purnell (1986) gave an outline on the methods proposed by F.A.O. frame work for land evaluation for rainfed agriculture and for forestry with particular reference to those applicable for conservation and similarly for land use planning on slopping land and discussed the advantages and limitations of the method briefly. Rao (1987) evaluated Madurai district on the basis of irrigation, cropping pattern and physical attributes and suggested measures to increase the productivity to meet the growing demand of timber and industrial needs.

The soils of Rania block, Sirsa district were evaluated and soil suitability classes were made by interpreting the agro-pedological data on the basis of framework for land evaluation. The percentage of highly suitable S_1 , moderately suitable S_2 , marginally suitable S_3 and currently not suitable N_1 land with respect to the specified land utilization type found was 8.0, 39.3, 20.8 and 29.6 respectively (Dahiya and Kuhad, 1983). Based on soil characteristics, interpretations in respect of present productivity and predicted potentiality of individual soil series for cotton and sorghum crops in different soil series of Nagpur district, Maharashtra was reported in terms of highly significant values of correlation coefficient ($-r$) for sorghum (0.975) and cotton (0.954)

under similar management conditions (Kumar *et al.*, 1984), Sehgal (1988) developed the soil-site evaluation criteria for eucalyptus plantation in different agro-climatic zones of Iraq. The soils of lower Mesopotamian plains have high soil salinity, low organic matter content, moderate fine texture with weak structure, shallow and saline underground water and were low in eucalyptus growth with low survival rate was reported as compared to the soils of Valley plain having limiting soil depth, low salinity, high organic matter content and were good for eucalyptus plantation.

Bhaskar *et al.*, (1988) evaluated the soil suitability for cotton at agricultural research station Kutki, Wardha district and found that all soils are not suitable for cotton cultivation. Shanwal *et al.*, (1988) studied the alluvial plain (Sonepat) of Haryana and identified four major landforms and thirty three land mapping units. These mapping units were evaluated for forestry and agriculture by various land evaluation systems i.e. FAO, land capability classification and land irrigability classification. Based on the land evaluation system the land mapping units had been grouped into various classes and land use pattern suggested. The soil potential ratings for sugarcane in the area of sugar factory, Palwal, Haryana was evaluated and a two stage approach was adopted. All the mapped land units were evaluated for their suitability in qualitative terms and for their potential suitability after considering possible land improvements. (Kuhad *et al.*, 1991).

Sehgal.(1991) evaluated the soils of swell-shrink areas of Maharashtra and Gujarat for cotton crop and showed that all the soils are not equally-suitable for cotton cultivation. Some are moderately suitable, while the others are marginally suitable, or even unsuitable for cotton cultivation.

The soil-site suitability for wheat in different agro-climatic regions of Punjab was evaluated and the productivity indices of the soils were calculated by giving the ratings for different limiting soil characteristics. It was observed that for wheat, the well drained, medium textured, deep soils were highly suitable whereas the saline, calcareous, poorly drained and shallow depth soils were having low productivity. (Sharma and Sharma, 1991).

Walia and Chamuah (1992) evaluated the suitability of land for agricultural crops on the basis of limitations of moisture, erosion and acidity of soil in the flood affected soils of Brahmaputra Valley. Same workers (1994) evaluated the riverine plain soils in Arunachal Pradesh based on major limitations. The soils with good profile development, moderate texture, well drained were suitable for all types of crops, followed by the soils with no diagnostic horizon, stratified, young soils resulting in poor productivity. Pundari Kakshudu *et al.* (1992) also showed the greater moisture relation and higher seed cotton yield in deep soils as compared to medium deep and shallow soil. The beneficial effect of increasing clay content was not only the increased water holding capacity but also increased CEC and nutrient supply. Diwakar and Singh (1993) assessed the productivity and potentially ratings of different soils of Tal land of Bihar and reported that the old alluvial soils (chromusterts) and young alluvial soils (Ustorthents) were having average productivity due to poor organic matter content, high amount of shrink-swell types of clays, hard structure and poor drainage. The assessment of productivity of these soils revealed that it can be raised by 1.8 to 2.1 times. Same workers (1994) evaluated the productivity and potentially ratings of Vertisols and other soils of Bihar. These soils were low in productivity and were monocropped due to long severe dry period. The low productivity was due to poor drainage, poor texture and drought

conditions. Similar findings have also been reported by Kumar *et al.* (1984) for Vertisols and Entisols. The soils occurring on different physiographic units in Raichur district of Madhya Pradesh were evaluated and the suitability of these soils was assessed in terms of productivity potential, coefficient of improvement and nature of improvement. (Deshmukh and Bapat, 1993).

The production potential of different soils in saongi watershed in Nagpur district of Maharashtra was assessed by employing parametric approaches of land evaluation with respect to cotton and sorghum production. The shallow depth soils with poor drainage were found to have low productivity index as compared to deep, well drained soils. (Kharche and Gaikwad, 1993).

Yadav *et al.* (1994) studied the effect of soil-site parameters on growth and yield of cotton of khapri watershed of Nagpur district of Maharashtra and reported that the soils experiencing heavy rainfall, higher total plant available water capacity, higher soil depth and fine texture were responsible for higher root-shoot and matter production and in turn the seed cotton yield was high whereas the soils with shallow-depth, poor texture, poor drainage, calcareous and low total plant available water capacity were low yielding of cotton seed. The soils of dominant terraces, piedmont, filled up channels and flood plains in ustic and arid zones of Punjab were evaluated for their suitability for rice. The productivity was evaluated using parametric limitation approaches and was found to be high in moderately well drained, medium / fine textured soils showing the development of argillic / cambic horizon. (Sharma *et al.*, 1994). Similarly, Srivastava *et al.* (1994) evaluated the soil-site suitability of some dominant soils of Bardhaman district of West Bengal by using limitations and parametric approaches. The soils with

steep and undulating slopes having shallow rooting depth, gravelly texture, low nutrient and water retention capacity were not suitable for rice cultivation whereas the soils developed on lower alluvial plain and meander flood plains were highly suitable for rice cultivation due to flooding and impeded drainage. The soils of Banaswara district of Rajasthan were evaluated for their suitability for maize production and it was reported that the soils with very shallow depth, having very high clay content, poor drainage or excessive slopes were unsuitable whereas the soils with deep depth having sandy clay loam to clayey structure and with a good drainage were more suitable for maize (Giri *et al.*, 1994).

No single approach has emerged as a universal approach that works well in all situations. Crop yields might be preferred methods of expressing productivity if crop yield data are available.

From the foregoing review, it may be observed that many methods for site quality evaluation have been developed from time to time. At first glance the existing results from different soil-site seem confusing. But this confusion is more apparent than real because all direct and indirect methods of site evaluation are in many ways complementary rather than contradictory. The theme that unifies the several methods of site evaluation is that they all have a common goal that of predicting and classifying land productivity for different crop growth.

It is seen from the review that even though attempts have been made to characterize, classify and map the soils of the different administrative units in the state. Among these studies, none evaluates the suitability of the classified soils for the major crops of the region. In view of this, the present study was undertaken for characterization, classification and land evaluation of the cotton growing regions of the state.

CHAPTER - III

MATERIALS AND METHODS

General Description of the study Area : ✓

Haryana state lies between 27° 39' to 30° 55'N latitude and 74° 29'8" to 76° 36'5"E longitude and constituting NW part of India. The study area is situated between 28° 36' to 30° 22'N latitude and 74° 29' to 76° 56'E longitude (Table-1) and the area comprises of the districts Hisar, Sirsa, Bhiwani, Jind and Rohtak where the cultivation of cotton crop is done extensively (Fig. 1). The area is a part of the Indo-Gangetic alluvial plain.

Climate :

The climate is very hot in summer and markedly cool in winter. It has a sub-tropical, semi dry, continental, monsoonal climate (Fig.2-4 Table-2). The distribution of rainfall is almost same of the studied area and it varies from 167.0mm to 232.2mm. The data (Table-2) showed that a greater portion (more than 75%) of the total rainfall is received during summer monsoons in the month of July, August and September which coincides well in the mean annual temperatures of the different stations (Table 2). The mean monthly maximum temperature (June) is as high as 35.9°C while the mean monthly minimum temperature (January) is low as 12.85°C. The MAST of the area is more than 22°C at all the stations qualifies the area for hyperthermic temperature regime. Although the soils remain sufficiently moist (because of summer monsoon) to growth one crop a year without artificial irrigation. This excludes the area from aridic soil moisture regime. The soil also do not remain moist throughout the year and as such do not qualify for udic moisture regime. They represent Ustic soil moisture regime

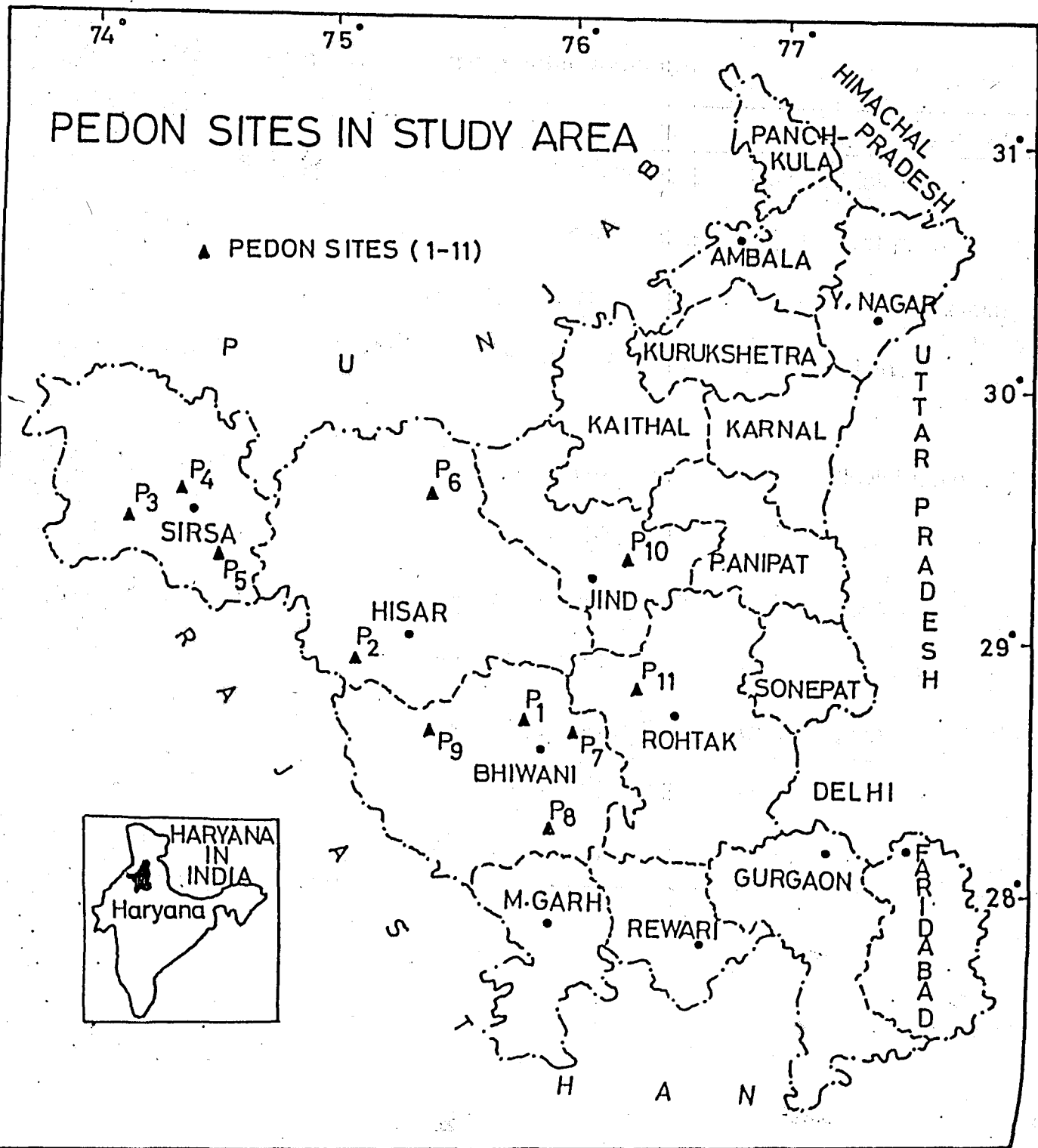


FIG. 1

Table Pedon sites and their geographic location.

Profile site	Profile No.	District	Lat. and Long.	Physiographic regions
Dhani Alkhpur	1	Bhiwani	28° 42'N-75° 43'E	Upland Plains
Bhiwani Rohilla	2	Hisar	29° 42'N-75° 32'E	Sandy level plain
Bakria wali	3	Sirsa	29° 30'N-74° 46'E	Aeolian cover alluvium
Cotton Research Station	4	Sirsa	29° 42'N-75° 32'E	Aeolian plain
Bhavdin	5	Sirsa	29° 50'N-74° 32'E	Upper alluvial plain
Dhani Prem Nagar	6	Hisar	29° 42'N-75° 32'E	Upland plain
Tigrana	7	Bhiwani	28° 42'N-75° 43'E	Upland plain
Pentawas	8	Bhiwani	28° 42'N-75° 43'E	Aravali rock out crops
Mundhal	9	Bhiwani	29° 42'N-75° 32'E	Upland plain
Gulkani	10	Jind	28° 18'N-76° 4'E	Plain
Bahu-Akbarpur	11	Rohtak	28° 42'N-75° 42'E	Plain

because of the summer monsoon rains.

Selection of Sites :

The existing soil survey information of the area was used for the selection of profile sites representing dominant soil series from extensively cotton growing areas of the state. The basic information about the soil sites is given in Table 1.

On the basis of morphological properties e.g. soil colour, mottlings, texture, concretions etc. different horizons were demarcated in each of the profile in the field. Representative soil samples from each horizon were collected for laboratory analysis.

Soil samples were air dried, weighed and ground with a wooden pestle and mortar. The ground samples were passed through 2 mm. sieve for the determination of physical properties and 0.5 mm. sieve for chemical properties.

Methods i) Soil suitability evaluation for cotton :

- a) **Selection of pedons :** Eleven profiles representing dominant soils of alluvial plains in the ustic and aridic zones varying in texture, drainage, CaCO_3 , salts and profile development were exposed upto a depth of 1.5 to 2.0 m, studied according to the procedure and horizon wise soil samples collected for analysis.
- b) **Criteria and approaches used :** Productivity was evaluated using the parametric approach of Riquier *et al.* (1970), limitation approach of FAO (1976) and Sys 1981. The variables like climate, moisture, drainage, texture/structure; nature of clay/exchange capacity; organic matter; CaCO_3 ; Na saturation; texture, structural; soluble salts were

Table 2 : Average rainfall and temperature data for year 1993.

Monthly average rainfall (mm) - 1993

District	J	F	M	A	M	J	J	A	S	D	N	D	Total
Hisar	14.2	0.0	1.0	1.2	0.0	34.5	41.2	71.0	1.6	0.0	0.0	4.6	169.9
Sirsa	0.0	10.3	0.0	0.0	26.2	43.7	62.4	0.0	69.1	0.0	0.0	0.0	211.7
Bhiwani	0.0	16.0	7.0	7.0	7.0	64.0	361.0	28.0	90.0	0.0	0.0	0.0	
Jind	27.2	0.4	0.0	0.0	0.0	45.3	27.2	112.4	2.0	0.0	1.0	10.3	225.9
Rohtak	10.3	0.0	7.4	0.0	0.0	4.4	41.8	99.1	17.1	0.0	5.1	7.1	192.3

Mean monthly temperature (°C) of different districts of year 1993.

District	J	F	M	A	M	J	J	A	S	D	N	D
Hisar	12.85	16.95	18.55	25.8	32.3	33.4	30.35	31.6	28.55	24.5	19.95	14.15
Sirsa	13.0	17.0	18.15	27.85	31.5	33.6	30.20	32.1	28.60	24.35	19.8	14.4
Bhiwani	12.94	16.4	17.9	29.2	31.3	35.9	32.3	29.7	29.5	26.6	19.93	15.1
Jind	13.49	16.2	19.6	28.9	32.1	34.8	31.8	30.8	28.90	25.8	19.7	14.8
Rohtak	13.9	16.3	20.3	27.6	31.8	34.4	30.0	30.4	28.3	24.9	20.4	15.2

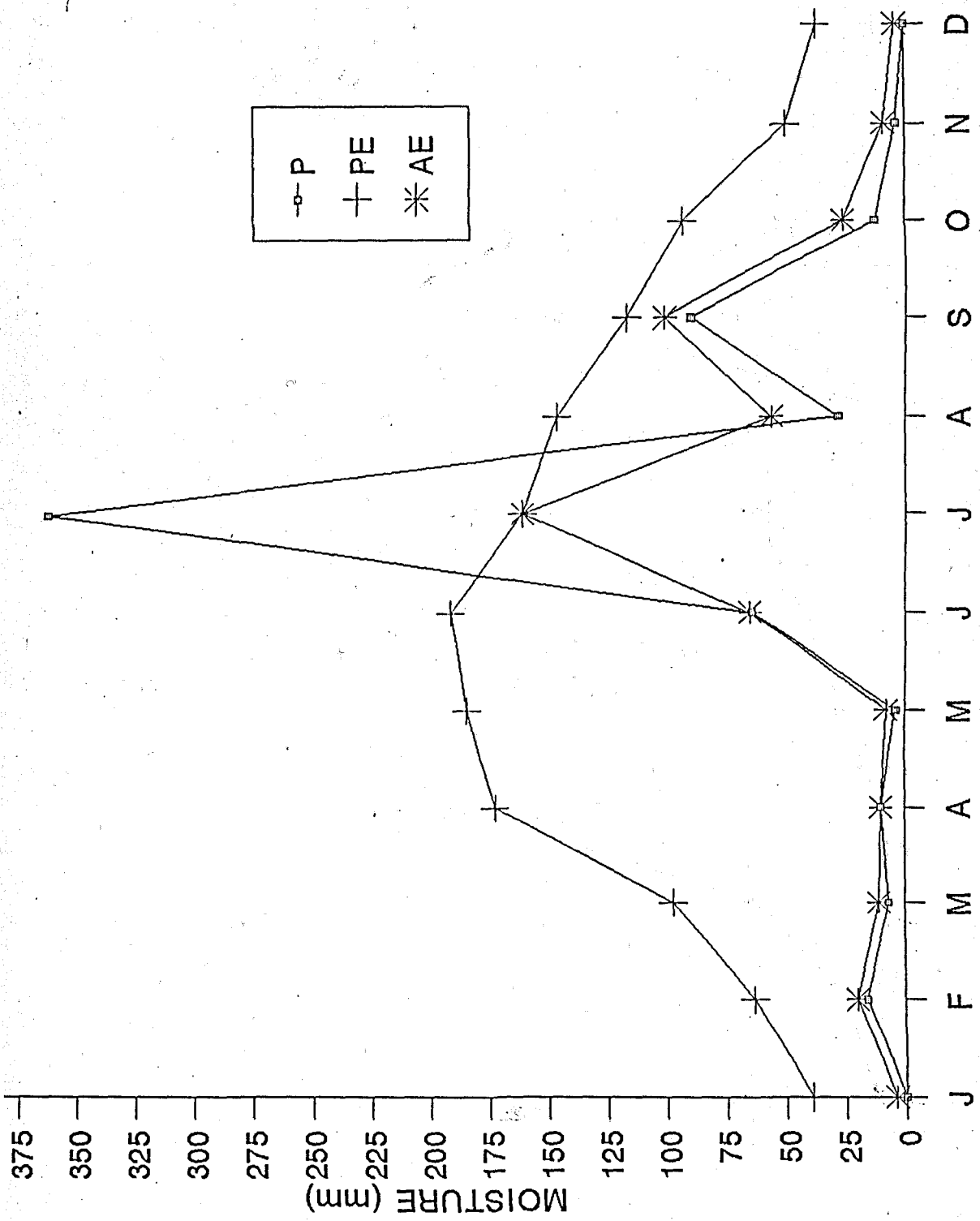


FIG.2 WATER BALANCE DIAGRAM FOR BHIWANI

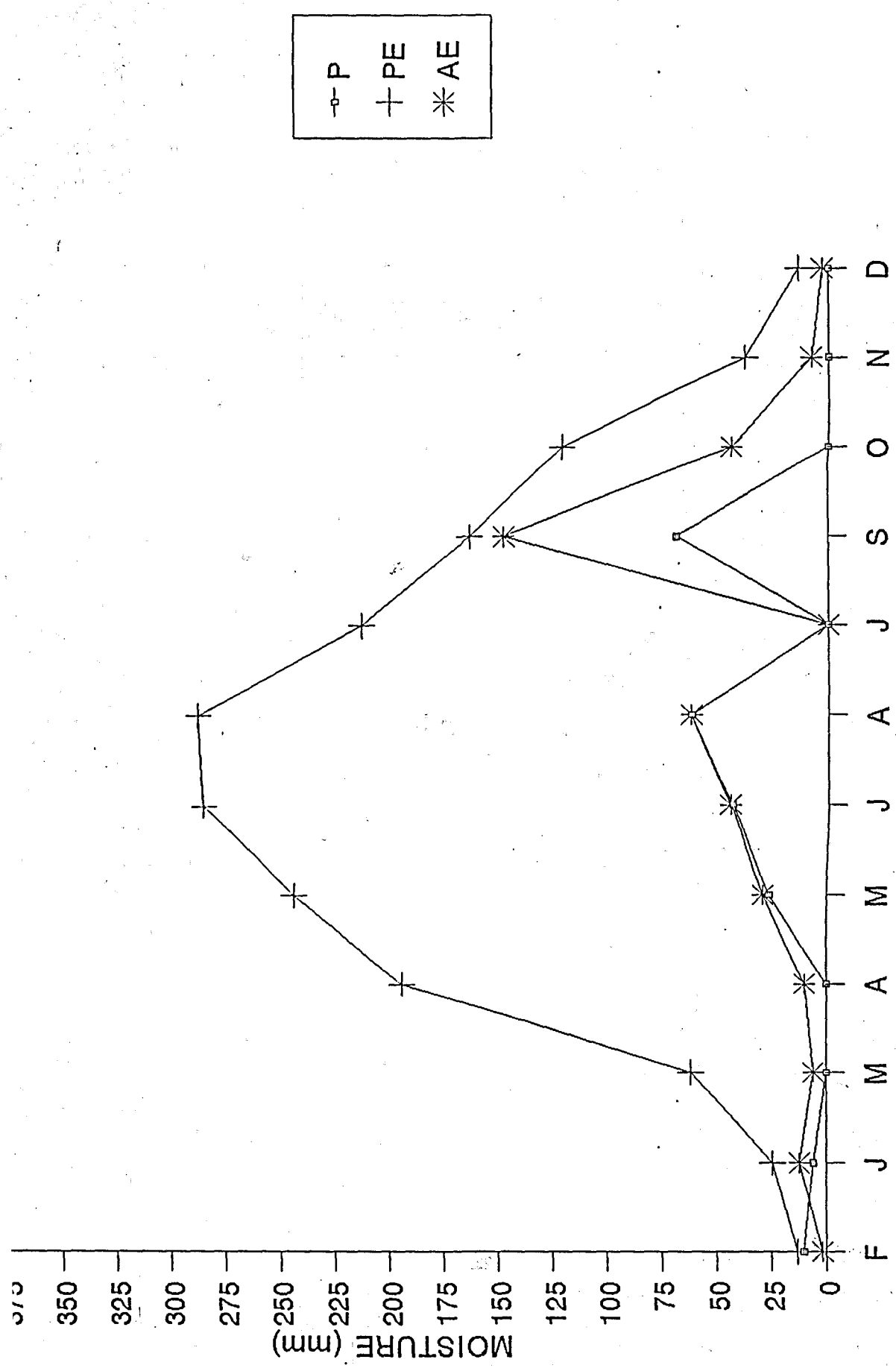


FIG.3 WATER BALANCE DIAGRAM FOR SIRSA

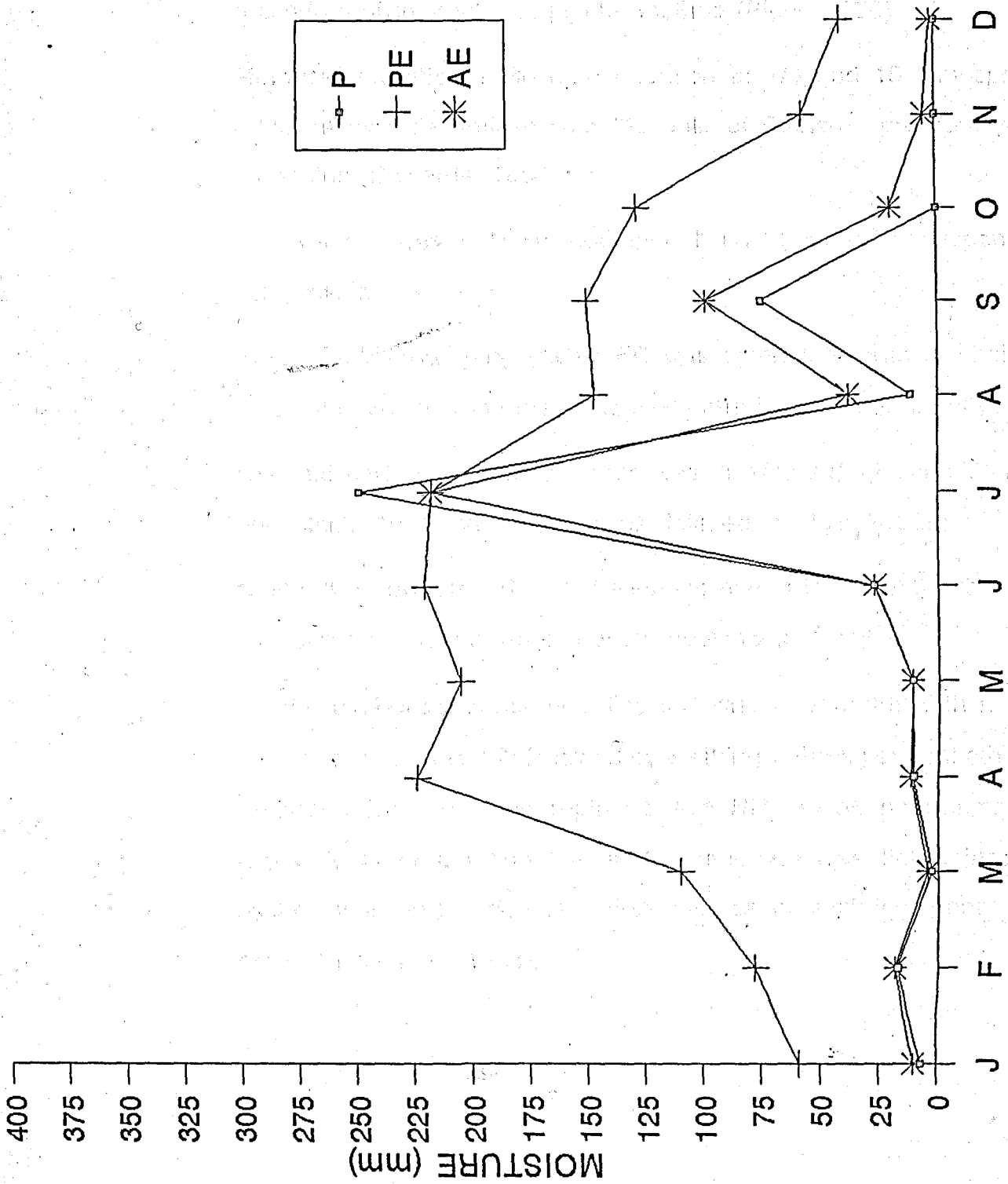


FIG.4 WATER BALANCE DIAGRAM FOR HISAR

used to evaluate the productivity of soils for cotton.

Laboratory analysis : Following laboratory analysis were conducted

Mechanical analysis : Particle size fraction was carried by using the procedure of International pipette method (Piper, 1966).

Moisture retention : Moisture retention at 1/3 and 15 atmosphere pressure was determined with the help of Richards pressure plate apparatus (Richards, 1954).

Soil reaction (pH) : pH was determined in a 1:2 soil water suspension using digital pH meter.

Electrical conductivity (EC) : EC was determined with the help of solubridge conductivity meter as described by Richards (1954).

Organic carbon : Organic carbon was determined by using Walkley and Black (1934) rapid titration as detailed by Piper (1966).

Calcium carbonate : Rapid titration method of Puri (1930) was used for estimation of calcium carbonate equivalent of soil.

Cation exchange capacity : The soil was equilibrated with normal sodium acetate (pH 8.2) followed by washing with 95 per cent ethanol. Adsorbed Na^+ was then replaced with NH_4^+ using neutral normal ammonium acetate and Na^+ in the leachate was determined by systronics flame-photometer to determine cation exchange capacity of the soil (Richards, 1954).

Exchangeable cations : Soil was extracted with 1N neutral ammonium acetate following the procedure by Jackson (1973). The extractant was analysed for Na and K by using Systronic flame photometer for Ca and Mg by versenate titration method (Barrows and Simpson, 1962).

Soluble salts : Saturation paste was prepared and extract was collected by using suction and preserved for analysis. Electrical conductivity of saturation extract was determined with the help of solubridge conductivity meter. pH of the extract was estimated using digital pH meter. Na^+ and K^+ were determined by using Systronic flame photometer and Ca^{++} and Mg^{++} were analysed by versenate titration method. CO_3^{--} , HCO_3^- , Cl^- and SO_4^{--} ions were estimated as per the procedures outlined by USDA Hand book No. 60 (Richards 1954).

Available nutrient status : Available nitrogen was determined by alkaline permagnate method. Available phosphorous extraction with alkaline sodium bicarbonate method (Olsen *et al.*, 1954) Available potassium by ammonium acetate method (Piper 1950) and Available sulphur was estimated with morgan's reagent extractable method.

Available Zn, Cu, Mn and Fe were extracted by DTPA (Lindsay and Norvell, 1978) and estimated on atomic absorption spectrophotometer.

X-ray diffraction analysis :

- i) **Clay analysis :** 300 mg of the clay samples were washed once with NaOAC buffered at pH 4.5 and then divided into two parts of 100 mg and 200 mg. One hundred mg set of clay samples was saturated with

potassium and 200 mg set of clay samples with magnesium (Jackson, 1976). Enough care was taken not to allow the clay samples to dry at any stage. Finally, the volume was made to 10 ml with distilled water.

Parallel oriented aggregate specimens of the Mg and K-saturated clays were prepared by spreading uniformly over a 4.5 x 2.5 cm glass slide 1 per cent suspension of the clay. Slides were dried at room temperature under controlled humidity. The samples were subjected to X-ray diffraction analysis. The diffractograms were recorded with the following treatments.

- a) Mg-saturated, b) Mg-saturated and Glycerol solvated.
- c) K-saturated, d) K-saturated and heated to 550°C,
- e) HCl-treated and Mg-saturated

The X-ray diffractograms were recorded with Ni-filtered Cu K-radiation ($\lambda=1.5418 \text{ \AA}$) obtained at 30 kv and 20mA from a philips PW 1390 X-ray generator with time constant 4, attenuation 1 and at 1000 CPS.

Interpretation of x-ray diffractograms :

Identification of clay minerals : The purpose of qualitative interpretation of X-ray diffraction pattern is the identification of each crystalline species or series of spacing in the samples. The diffraction of X-rays obeys Bragg's scattering law ($n\lambda = 2d \sin\theta$) and the diffraction pattern of each crystal species is a unique sequence of diffraction maxima, like a "finger print", the pattern serves the purpose of identification of each species present unless the diffraction intensity is

inadequate. For the qualitative identification the method is based on one to three intense diffraction peaks from basal planes. The chief qualitative errors occur because of difference in particle size and complex inter stratification of layer silicate species. The 'd' values are calculated for all the diffraction maxima recorded in the X-ray diffractograms using tables for conversion of 2θ values to $hk1$ for the atomic spacing for various X-ray tube target material such as Cu, Fe or Co (X-ray power data file, published by American Society of Testing Materials, Philadelphia). The basal spacings of layer silicates vary within limits, with the nature of interlayer cations and the solvation procedure employed. The intensity of the diffraction maxima also changes with nature of cations. The diagnostic criteria for the important clay mineral groups are listed below :

- a) **Mica group** : This group of minerals is recognised by three strong peaks at 10, 3.3 and 5Å (Basal-reflections) on Mg-saturation as well as on glycerol solvation. In soil clay mica the 10Å peak is often asymmetrical with tailing towards low angle. This is because of mica degradation (Brown, 1954) and are common in Indian soil clays. The dioctahedral and trioctahedral mica is identified by the ratio of (001/002). A high ratio of 10Å/5Å confirms the dioctahedral then trioctahedral (Grim, 1954). Further information concerning whether the mica is dioctahedral or trioctahedral is obtained by observing reflection (060). The (060) peak of dioctahedral mica appears at about 1.53Å and of trioctahedral at 1.52Å and 1.56Å in case of biotite (Grim, 1954).

- b) **Chlorite group** : This group of mineral is identified by a series of basal reflections at 14, 7, 4.7 and 3.5Å which persist on heating the specimens at 550°C. The iron rich chlorite poses problem, particularly in presence of kaolinite, whereas the 001 and 003 reflections are weak, the 002 and 004 reflections are relatively stronger, overlapping the 001 and 002 reflections of kaolinite. In clay chlorites a series of defects are generally produced as a result of weathering (Bradley, 1954). Defect in structure may also cause partial expansion with glycerol (Stephens and McEwans, 1949) as found in the so called "swelling-chlorite". This type of imperfect chlorites are identified by the 18Å spacing in glycerol and 14Å spacing on heating at 550°C, chloritised montmorillonite/vermiculite formed by fixation of iron/Al hydroxide in interlayer space (Tamura, 1956, 1958) under said conditions of weathering is also common in Indian soils (Ghosh *et al.*, 1962; Sehgal and Coninck, 1971). This interlayer materials can be removed by treating either with NH_4F or Na-citrate or NaOH (Rich and Obenstain, 1955; Tamure, 1957). Prior to this treatment, these minerals give a 14Å peak and do not collapse to 10Å on k-saturation and heating but after the interlayer material has been removed the resultant mineral either gives a 14Å spacing (Rich, 1960; Sawhney, 1960) or and 18Å spacing (Tamura, 1957; Dixon and Jackson, 1959) on glycerol solvation.
- c) **Koalin group** : Minerals in this group was identified by strong basal reflections at 7.0 and 3.5Å which disappear on heating the sample to 550°C. The heat treatment also distinguishes it from true chlorites,

many soil chlorites also get decomposed or lose the 7Å peak on heating at 550°C or even at low temperature (Grim and Johns, 1954; Rolfe, 1954; Murray and Sayyab, 1955). Under such conditions, the dilute HCl (warm) treatment leads to correct identifications. The warm HCl dissolves the chlorite along with some trioctahedral montmorillonite and vermiculite. *Meta halloysite* gives a spacing 7.2Å and hydrated halloysite gives 10.7Å. Heating to 400°C decreases the spacing to 7.2Å (Brindley, 1954). Inter-relation of kaolinite and halloysite with KOAC gives a 14Å spacing and this can be decreased to a diagnostic 11.6Å spacing on washing with 10N NH₄NO₃ solution (Andrew et al, 1960).

- d) **Smectite group** : This group gives a strong reflection at 14Å on Mg-saturation and can be isolated from rest of the 14Å spacing on treatment with glycol or glycerol when it gives 17.7Å and 18Å, respectively (McEwans, 1944; Walker, 1958). The spacing decreases on k-saturation frequently giving reflection at 12Å. This reflection shifts to 10Å and is usually enhanced to give a sharp peak on heating at 300°C. A broad 10Å peak even after heating at 300°C indicates that the material has Al hydroxide or oxide interlayer countering the layer charge and causing resistance of the mineral to the thermal collapse (Sawhney and Jackson, 1958).
- e) **Vermiculite** : Mg saturated vermiculite give a peak between 14.2-14.4Å, k- saturated vermiculite can be distinguished from smectite or chlorite by its non expansability on glycerol solvation and collapsibility

on k-saturation. Even the low charge vermiculite will collapse on k-saturation and heating to 300°C. True vermiculite gives only a very weak second order peak at 7.0Å-7.1Å and medium intensity peaks at 7.0-7.1Å and medium intensity peaks at 4.79Å and 3.60Å.

f) **Interstratified minerals** : Generally two types of interstratification are found in soils.

i) a regular or ordered alteration of mineral layers in definite sequence for which the resulting super lattice spacing is additive of the basal spacing of the minerals present and their different orders.

ii) a completely random interstratifications in which the layers do not repeat themselves in any sequence but are randomly distributed in the complex. Random mixtures can be of binary, ternary or quaternary interstratification involving two three or four minerals. Binary random mixtures can be identify (McEwan *et al.*, 1961).

g) **Primary and accessory minerals** :

i) **Quartz** : It usually gives two fairly strong peaks at 3.34 and 4.26Å. Quartz gives a number of (hkl) peaks which are quite sharp. In general, more than 5 per cent quartz must be present to give a noticeable 4.23Å peak,.

ii) **Feldspar** : Feldspars give sharp peaks at 3.18 and 3.24Å and are usually present in mixture, doublets (two peaks very close to each other) are obtained in many species.

Semiquantitative estimation of clay minerals : The semi-quantitative measurement of clay minerals present in the clay samples was done according to the procedures of Gjems (1967) with some modification as suggested by Ghosh and Datta (1974). This procedure involves the measurement of areas of 1st order basal reflection peaks for different clay minerals after appropriately setting of the background line. The peak areas are further corrected for the instrument geometry effects and polarization factor, and then compared with each other for relative percentage of each component in the sample.

CHAPTER - IV

RESULTS AND DISCUSSION

The result of the present study have been dealt under the following heads :

4.1. Morphological characteristics of soils

4.1.1 Soil colour and mottling

4.1.2 Soil texture

4.1.3 Soil structure

4.2 Physio-chemical characteristics of soils

4.2.1 Particle size distribution

4.2.2 Moisture retention characteristics

4.2.3 pH, E.C., Org. Carbon and CaCO_3

4.2.4 CEC and exchangeable cations

4.2.5 Available nutrient status

4.2.6 Saturation extract analysis

4.3 Clay mineralogy

4.4 Soil classification

4.5 Land evaluation

4.1 Morphological characteristics of soils :

Brief morphological characteristics of the studied pedons are summarised in Table 3 and the detailed descriptions are given in Appendix I.

4.1.1 Soil colour and mottling :

The colour of the studied pedons varied between the hues of 2.5 Y and 10YR, with a dominant hue of 10YR. The values ranged from 3 to 8, whereas chromas were 6 or less (Table 3).

The P1 soil showed brown (10YR 4/3) matrix in the surface and substratum (7.5 YR 4/4) horizons. Few fine mottles were also observed in C1 (72-107 cm) horizon. The colour of the mottles was light brown (10YR 6/2). Yellowish brown (10YR 5/4) colour was observed in the surface horizon followed by dark yellowish brown (10YR 4/4) colour in the C1 (17-38 cm) horizon in P2 soil. Dark yellowish brown (10YR 4/4) colour was observed in surface and subsurface horizons followed by light yellowish brown (10YR 5/4) colour in the lower most horizon in P3 soil. P4 soil was dark brown (10YR 4/3) at the surface and sub-surface horizons. Few fine mottles were observed in the lower most horizon. The colour of the mottles was (10YR 7/4) dark yellowish brown. Dark Brown (7.5 YR 4/2) colour was observed in the surface and sub-surface horizons followed by light brown colour (7.5 YR 5/4) in the lower horizons in P5 soil. P6 soil showed yellowish brown (10YR 5/4) in the surface horizon followed by dark brown (10YR 3/4) in B12 (45-105 cm) and C1 (105+ cm) horizon. Dark yellowish brown (10YR 4/4) surface horizon and brown (10YR 6/4) C1 horizon (75-120 cm) were observed in P7 soil.

The P8 and P9 soils had brown (10YR 4/3) and (10YR 3/6) matrix colour in the surface horizons. However pedon 8 showed brown coloured mottles (2.5Y 8/8) in the lower most horizons. P10 soil showed brown (10YR 5/3) surface horizon, where in p11 soil, the dark yellowish brown (10YR 4/4) colour was observed in the surface horizon followed by light yellowish brown (10YR 6/4) in A13 horizon (38-72 cm) and lower most horizon.

4.1.2 Soil texture :

The texture of the studied pedons varied from Loamy sand to silty clay loam (Table 3). The soils of the area are of alluvial origin and exhibit a great deal of heterogeneity with respect to texture. The pedons P2, 3, 7, 8, 9 and 11 were dominantly sandy loam and did not show marked variation in texture with depth. P1 was predominantly sandy clay loam. Variation in texture within a profile was observed in pedons P4, 5, 6 and 10.

The wide variations in texture found in the area seem to be controlled by geomorphological processes governing the deposition of sediments. (Kuhad, 1973).

4.1.3 Soil structure :

The structure of the studied pedons was dominantly massive and weak, fine subangular blocky to moderate medium subangular blocky (Table 3). P1 soil had weak, fine to medium subangular blocky structure on the surface, moderate medium subangular blocky in A-C (42-72 cm) horizon, whereas, P2 soil showed single grain structure in the profile. The structure of P3, 7 and 11 soils was uniformly weak, fine subangular blocky throughout the profile, whereas, P4 soil had moderate, medium subangular blocky structure throughout the profile. The structure of P5 soil was weak,

Table 3 Brief Morphological characteristics of the studied pedons.

DEPTH (cm)	HR	MAT.	MOTT.	TEXT.	STR.	CONS.	LIMENOD.	ROOTS	REACT.	B.RY	P.TY
1	2	3	4	5	6	7	8	9	10	11	12
PEDON-1 (ALKHPUR- BHIWANI)											
0-20	Ap	10YR4/3	-	SCL	1F-m,sbk	dh	nil	c,m	nil	ds	m,covs
20-43	A12	7.5YR4/4	-	SCL	1F-m,sbk	dh	nil	c,f	nil	ds	m,covs
43-72	AC	7.52YR4/4	-	SCL	2F-m,sbk	dh	nil	c,f	nil	ds	m,covs
72-107	C	17.5YR4/4	10YR6/2	SCL	2F-m,sbk	dh	nil	f,f	st	ds	m,m,vs
107-135	C2	10YR3/6	-	SCL	2m,sbk	dh	ff	f,f	mo	cs	m,m,vs
PEDON-2 (BHIWANI ROHILLA- HISAR)											
0-17	Ap	10YR5/4	-	SL	Single grain	dh	nil	c,m	cf	ds	c,f,in
17-38	C1	10YR4/4	-	SL	Single grain	mfr	nil	c,f	cf	cs	c,f,in
38-62	C2	10YR5/4	-	SL	Hard Pan	dh	f,c	f,f	cf	cw	c,f,in
62-140	C3	10YR6/4	-	LS	Single grain	dh	f,f	f,f	ef	ds	m,f,in
PEDON -3 (BAKRIAWALI - SIRSA)											
0-20	Ap	10YR4/4	nil	LS	1F,sbk	ml	nil	cf	wk	ds	ccovs
20-50	C1	10YR4/4	nil	SL	1F,sbk	ml	nil	c,m	nil	cs	ccovs
50-137	C2	10YR4/4	nil	SL	1F,m,sbk	mfm	ff	cf	cf	cs	ccovs
137+	C3	10YR4/3	-	SCL	1F,m,sbk	mfm	ff	cf	cf	cs	ccovs
PEDON -4 (COTTON RESERCH STATION - SIRSA)											
0-20	Ap	10YR4/3	-	SCL	2m,sbk	dvh	nil	c,f	cf	ds	c f in
20-120	BC	10YR4/3	-	SL	2m,sbk	dh	vf	f,f	cf	cs	c f in
120+	C1	10YR5/3	10YR7/4	L	2m,sbk	mfr	c	f,f	cf	cs	m f in
PEDON - 5 (BHAVDIN - SIRSA)											
0-22	Ap	7.5YR4/2	NIL	SCL	1F,sbk	dh	NIL	m,f	st	cs	c covs
22-60	IC	7.5YR4/2	NIL	L	1F,sbk	dh	NIL	c,f	mo	cs	c covs
60-90	IIC	7.5YR3/4	NIL	SCL	1F,sbk	dh	NIL	f,f	wk	as	c covs
90-125	IIIC	7.5YR5/4	NIL	L	massive	dh	NIL	f,f	wk	cs	m covs
125+	IVC	7.5YR4/4	NIL	SL	massive	dh	NIL	f,f	wk	cs	m covs
PEDON - 6 (DHANI PREM NAGAR -HISAR)											
0-15	Ap	10YR5/4	nil	SL	Single grain	dh	nil	m,c	cf	gs	m fn tb
15-45	B11	10YR4/4	nil	SL	f,m,sbk	mfr	nil	m,c	wk	ds	m fn tb
45-105	B12	10YR3/4	nil	SCL	2m-sbk	mfr	nil	m,c	wk	ds	m fn tb
105+	C1	10YR4/4	nil	SCL	2m-sbk	dh	nil	m,c	wk	cs	m fn tb

Contd....

DEPTH (cm)	HR	MAT.	MOTT.	TEXT.	STR.	CONS.	LIMENOD.	ROOTS	REACT.	B.RY	P.TY
1	2	3	4	5	6	7	8	9	10	11	12
PEDON - 7 (TIGRANA- BHIWANI)											
0-15	Ap	10YR4/4	nil	SL	1F-m,sbk	dh	nil	m,f	mo	cs	c covs
15-37	A12	10YR4/6	nil	SL	1F-m,sbk	mfr	nil	c,f	mo	cs	c covs
37-75	AC	10YR5/4	nil	SL	1F-m,sbk	mfr	nil	c,f	wk	cs	c covs
75-120	C1	10YR6/4	nil	SL	1F-m,sbk	mfr	m	c,f	wk	cs	c covs
120-150	C2	10YR5/4	nil	SL	1F-m,sbk	mfr	m	c,f	wk	cs	c covs
PEDON - 8 (PENTAWAS - BHIWANI)											
0-15	Ap	10YR4/3	nil	SL	1F-m,gr	dh	nil	c,m	st	ds	c mdvs
15-30	A12	10YR3/2	nil	SCL	1F-m,gr	dh	nil	c,f	mo	cs	c mdvs
30-90	AC	10YR4/3	nil	SL	2F-m,gr	mfr	nil	c,f	wk	cs	c mdvs
90-135	C1	10YR4/4	nil	SL	massive	mfr	ff	c,f	wk	cs	c mdvs
135-180	C2	2.5Y5/4	2.5Y8/8	SL	massive	mfr	ff	f,f	wk	cs	c mdvs
PEDON-9 (MUNDHAL- BHIWANI)											
0-20	Ap	10YR3/6	-	SL	1F-msbk	mfr	nil	c,m	st	cs	m co tb
20-60	B1	10YR3/4	-	SL	2F, sbk	mfr	nil	m,f,c	st	cs	m co tb
60-150	B12	10YR5/4	-	SL	massive	mfr	cf	c,f	mo	cs	m co tb
105-150	C	10YR6/4	-	SL	massive	mfr	cf	c,f	wk	cs	m co tb
PEDON -10 (GULKANI-JIND)											
0-18	Ap	10YR5/3	-	SCL	1F-m,sbk	dh	nil	c,m	ef	cs	c covs
18-43	A12	10YR5/4	-	SCL	1F-m,pl	dh	mf	c,f	ef	cs	c covs
43-65	IC	7.5YR4/4	-	CL	2F-m,gr	mfr	ff	c,f	st	cw	c covs
65-135	IIC	7.5YR4/4	-	SiL	2F-m,gr	mfr	ff	c,f	mo	cs	c covs
PEDON-11 (BAHUAKBARPUR - ROHTAK)											
0-15	Ap	10YR4/4	-	SL	1F-m,sbk	dh	nil	c,m	st	cs	c,f,in
15-38	A12	10YR5/4	-	SL	1F-m,sbk	dh	nil	c,f	st	cs	c,f,in
38-72	A13	10YR5/4	-	SL	1F-m,sbk	mfr	nil	c,f	mo	cs	c,f,in
72-110	C1	10YR5/4	-	SL	1F-m,sbk	mfr	ff	f,f	ef	cw	c,f,in
110-145	C2	10YR6/4	-	LS	1F-m,sbk	mfr	ff	f,f	st	cs	m,f,in

Texture : s = sand, ls = loamy sand, sl = sandy loam
 : sil = silt loam l = loam, scl = sandy clay loam
 : cl = clay loam

Structure : grade : 1 = weak, 2 = moderate
 class : m = massive, gr = granular
 sbk = subangular blocky; cpr = columnar
 pl = platy
 type : f = fine, m = medium

Consistence : dh = dry hard, deh = dry extremely hard
 mfr = moist friable, mfm = moist firm

Carbonate : abundance : f = few; size : f = fine
 nodules

Roots : abundance : f = few, c = common, m = many
 size : f = fine, m = medium, c = coarse

Reaction : mo = moderate, ef = effervescence violet
 wk = weak, st = strong

Boundary : distinctness : a = abrupt, c = clear, g = gradual
 topography : s = smooth, w = wavy, b = broken

fine, subangular blocky in the surface and sub surface horizon followed by massive structure in the lower most horizon. P6 soil had single grain structure on the surface horizon, moderate medium subangular blocky in the lower horizons. The P8 soil had weak, fine medium granular structure in the surface and sub surface horizon followed by massive structure in the lower most horizon whereas P9 soil had weak fine, subangular blocky followed by massive structure in the lower most horizon. P10 soil had weak, fine to medium subangular blocky on the surface horizon, platy structure in the A12 horizon followed by granular structure in the lower most horizon.

The soils are low in organic matter, devoid of CaCO_3 and thus lack structural peds. The alternate wet (monsoon) and dry (summer) periods favour the formation of structural peds in these soils. (Sharma and Dev, 1985). The presence of blocky structure in soils indicates the alternation of original material by pedogenic factors and processes.

4.2 Particle size distribution :

Sand : The particle size distribution data (Table 4 and Figs. 5-8) showed wide variations among the studied pedons. The total sand content in Pedon 1 decreased from 59.8 per cent in the surface horizon to 57.6 per cent in A-C horizon followed by an increase to 61.2 per cent in lower horizon. The total sand content in pedon 2 increased from 71.8 per cent in surface horizon to 83.2 in the lower most horizon. The total sand content in pedon 3 decreased from 82.0 per cent in the surface horizon to 74.9 percent in C2 horizon and again increased to 77.6 per cent in lower most horizon. The depth distribution of total sand in pedon 4 showed irregular distribution with an increase from 64.4 per cent in surface horizon to 72.8 per cent in sub

surface horizon and again decrease to 43.2 per cent in lower most horizon, where as, P5 showed an increased of total sand from 50.2 per cent in the surface horizon to 72.8 per cent in IIC horizon and gradual decrease to 70.6 per cent in the lower most horizon. The gradual decrease of total sand was observed from 66.2 per cent in the surface to 57.2 per cent in B12 horizon and again decrease to 55.0 per cent in the lower most horizon in P6. P7 showed an increase of total sand from 69.4 per cent in surface to 71.2 per cent increased in C1 horizon and further increased to 77.0 per cent in C2 horizon, where as, P8 showed the decreasing trend from 79.5 per cent in surface to 71.0 in A-C horizon and further 70.8 per cent in C2 horizon.

In P9 soil, the total sand content decreased from 72.2 per cent in surface to 64.4 per cent in sub surface horizon followed by an increase to 71.5 per cent in the lower most horizon. The lowest amount of total sand content was observed in P10 soil ranging from 57.7 per cent in the surface horizon to 28.6 per cent 1C(43-65 cm) horizon which again increased to 36.6 per cent in lower most horizon. The increasing trend of total sand content was observed in P11 soils ranging from 67.7 per cent in the surface horizon to 73.8 per cent in A13 (38-72 cm) horizon which further increased to 82.1 per cent in lower most horizon.

Silt : The data on silt content of soils are given in (Table 4 and figs, 5-8). The profiles representing different units contained variable amounts with irregular distribution of silt . The silt content in P1 soil decreased gradually from 20.0 percent in surface horizon to 19.6 per cent in A-C (43-72 cm) horizon and further decreased to 18.4 per cent in lower most horizon . Similarly the silt content in P2 soil decreased gradually from 10.6 percent in the surface horizon to 9.0 per cent in C2 (38-62)horizon

and further decreased to 6.0 percent in the lower most horizon where as in P3 soil ; the silt content increased from 6.2 per cent in surface horizon to 7.1 per cent in C2 horizon which further increased to 8.0 percent in the lower most horizon.

In P4 soil, the silt content varied between 10.0 per cent to 46.3 per cent. The wide variation and irregular distribution of silt with depth was observed in P5 soils ranging from 6.4 per cent to 43.8 per cent and P10 soils ranging from 20.0 per cent to 48.0 per cent. P6 soils showed the silt content increasing from 15.8 per cent in the surface horizon to 21.8 per cent in B12 (45-105 cm) horizon which again decreased to 17.0 per cent in lower most horizon. The depth distribution of silt in P7 soils was almost uniform ranging from 14.5 per cent in the surface horizon to 14.1 per cent in A-C (37-75 cm) horizon which was also uniform (14.6 per cent) in the lower most horizon.

However, P8 soils showed an increasing trend of silt content ranging from 5.7 per cent in the surface horizon to 11.1 per cent in A-C (30-90 cm) horizon which further increased to 16.7 per cent in the lower most horizon. The depth distribution of silt content in P9 soils showed an increasing trend from 12.1 per cent in surface horizon to 12.8 per cent in B12 (60-105 cm) horizon which further increased to 13.0 per cent in lower most horizon, whereas, P11 soils showed the decreasing trend with depth. The silt content in P11 soils decreased from 13.2 per cent in the surface horizon to 12.4 per cent in A13 (38-72 cm) horizon which further decreased to 7.3 per cent in lower most horizon.

The wide variations and irregular distribution of silt with depth in similar soils of the region have been reported to be controlled by the heterogenous nature of the parent material and topographic differences (Sehgal *et al.*, 1968). The geomorpho-

logical processes governing the deposition of sediments may also be responsible for the wide variations with irregular distribution of silt in soils.

Clay : The distribution of clay in different profiles is shown in (Table 4 and Figs. 5-8). The depth distribution of clay in P1 soils showed an increasing trend from 20.2 per cent in surface horizon to 22.8 per cent in A-C horizon and then slight decrease to 20.4 per cent in lower most horizon indicating relative maturity of the profile. In P2 soil, it was observed that clay content was higher in surface horizon ranging from 17.6 per cent to 10.0 per cent in lower most horizon. Depth distribution of clay showed an increase from 11.8 per cent in surface horizon to 18.0 per cent in C2 horizon of P3 soil. The clay content in P4 soil showed a decreasing trend ranging from 20.6 per cent in the surface horizon to 10.4 per cent in the lower most horizon. Clay content also decreased from 27.2 per cent in the surface horizon to 20.8 per cent in IIC (60-90 cm) horizon which further decreased to 15.6 per cent in the lower most horizon of P5 soil. Whereas, the P6 soil showed an increasing trend ranging from 18.0 per cent in the surface horizons followed by 21.0 per cent in B12 (45-105 cm) horizon to 28.0 per cent in the lower most horizon. The P7 soil showed an irregular distribution of clay content ranging from 16.1 per cent in the surface horizon which increased to 17.0 per cent in A-C (37-75 cm) horizon and again decreased to 8.4 per cent in the lower most horizon. Similarly the P8 soil also showed the irregular distribution of clay content increasing from 14.8 per cent in the surface horizon to 17.9 per cent in A-C (30-90 cm) horizon and then decreased to 12.5 per cent in the lower most horizon.

More or less uniform depth distribution of clay was observed in P9 soil ranging from 15.7 per cent in the surface horizon followed by 16.9 per cent in B12 (60-105) horizon which decreased to 15.5 per cent in the lower most horizon. P10 soil

Table 4 Particle size distribution of the studied pedons

DEPTH (cm)	HORIZON	-----%-----			TEXT CLASS	BASE SATURATION
		SAND	SILT	CLAY		
1	2	3	4	5	6	7
PEDON-1 (ALKHPUR-BHIWANI)						
0-20	Ap	59.8	20.0	20.2	SCL	97
20-43	A12	59.4	19.2	21.4	SCL	96
43-72	AC	57.6	19.6	22.8	SCL	96
72-107	C1	56.8	22.0	21.2	SCL	97
107-135	C2	61.2	18.4	20.4	SCL	97
PEDON-2 (BHIWANI ROHILLA-HISAR)						
0-17	Ap	71.8	10.6	17.6	SL	98
17-38	C1	74.0	11.2	14.8	SL	96
38-62	C2	78.0	9.0	13.0	SL	97
62-140	C3	83.2	6.8	10.0	LS	97
PEDON-3 (BAKRIAWALI-SIRSA)						
0-20	Ap	82.0	6.2	11.8	LS	85
20-50	C1	78.2	6.0	15.8	SL	95
50-137	C2	74.9	7.1	18.0	SL	96
137+	C3	77.6	8.0	14.4	SL	97
PEDON-4 (COTTON RESEARCH STATION-SIRSA)						
0-20	Ap	64.4	15.0	20.6	SCL	97
20-120	BC	72.8	10.4	16.8	SL	96
120+	C1	43.2	46.4	10.4	L	98
PEDON-5 (BHAVDIN-SIRSA)						
0-22	Ap	50.2	22.6	27.2	SCL	98
22-60	IC	36.4	35.6	28.0	L	98
60-90	IIC	72.8	6.4	20.8	SCL	97
90-125	IIIC	41.8	43.8	14.4	L	95
125+	IVC	70.6	13.8	15.6	SL	100
PEDON-6 (DHANI PREM NAGAR-HISAR)						
0-15	Ap	66.2	15.8	18.0	SL	96
15-45	B11	63.6	16.8	19.6	SL	99
45-105	B12	57.2	21.8	21.0	SCL	99
105+	C1	55.0	17.0	28.0	SCL	94

Contd....

DEPTH (cm)	HORIZON	SAND SILT CLAY			TEXT CLASS	BASE SATURATION
		-----%-----				
1	2	3	4	5	6	7
PEDON-7 (TIGRANA-BHIWANI)						
0-15	Ap	69.4	14.5	16.1	SL	98
15-37	A12	70.9	12.7	16.4	SL	98
37-75	AC	68.9	14.1	17.0	SL	99
75-120	C1	71.2	18.3	10.5	SL	98
120-150	C2	77.0	14.6	8.4	SL	99
PEDON-8 (PENTA WAS-BHIWANI)						
0-15	Ap	79.5	5.7	14.8	SL	98
15-30	A12	62.2	14.8	23.0	SCL	97
30-90	AC	71.0	11.1	17.9	SL	100
90-135	C1	73.9	15.4	10.7	SL	100
135-180	C2	70.8	16.7	12.5	SL	98
PEDON-9 (MUNDHAL-BHIWANI)						
0-20	Ap	72.2	12.1	15.7	SL	100
20-60	B11	64.6	17.0	18.4	SL	99
60-105	B12	70.3	12.8	16.9	SL	100
105-150	C	71.5	13.0	15.5	SL	100
PEDON-10 (GULKANI-JIND)						
0-18	Ap	57.5	20.1	22.2	SCL	97
18-43	A12	47.4	27.8	24.8	SCL	97
43-65	IC	28.6	41.2	30.2	CL	100
65-135	IIC	36.6	48.0	15.4	SIL	99
PEDON-11 (BAHUAKBARPUR-ROHTAK)						
0-15	Ap	67.6	13.2	19.2	SL	99
15-38	A12	71.4	12.3	16.3	SL	99
38-72	A13	73.8	12.4	13.8	SL	98
72-100	C1	77.5	10.8	11.7	SL	93
110-145	C2	82.1	7.3	10.6	LS	96

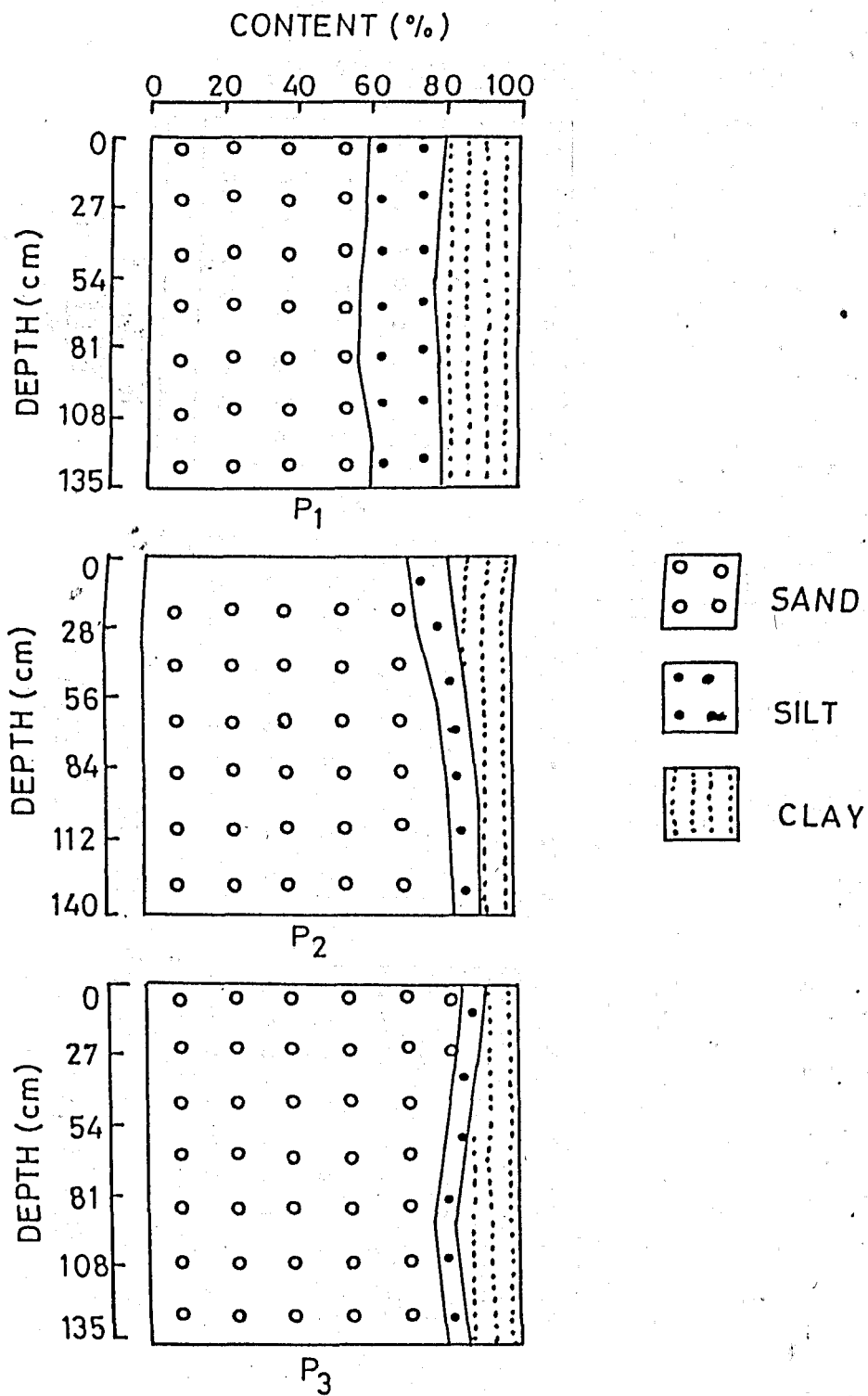


FIG.5 PARTICLE SIZE DISTRIBUTION WITH DEPTH IN PEDONS 1, 2 AND 3

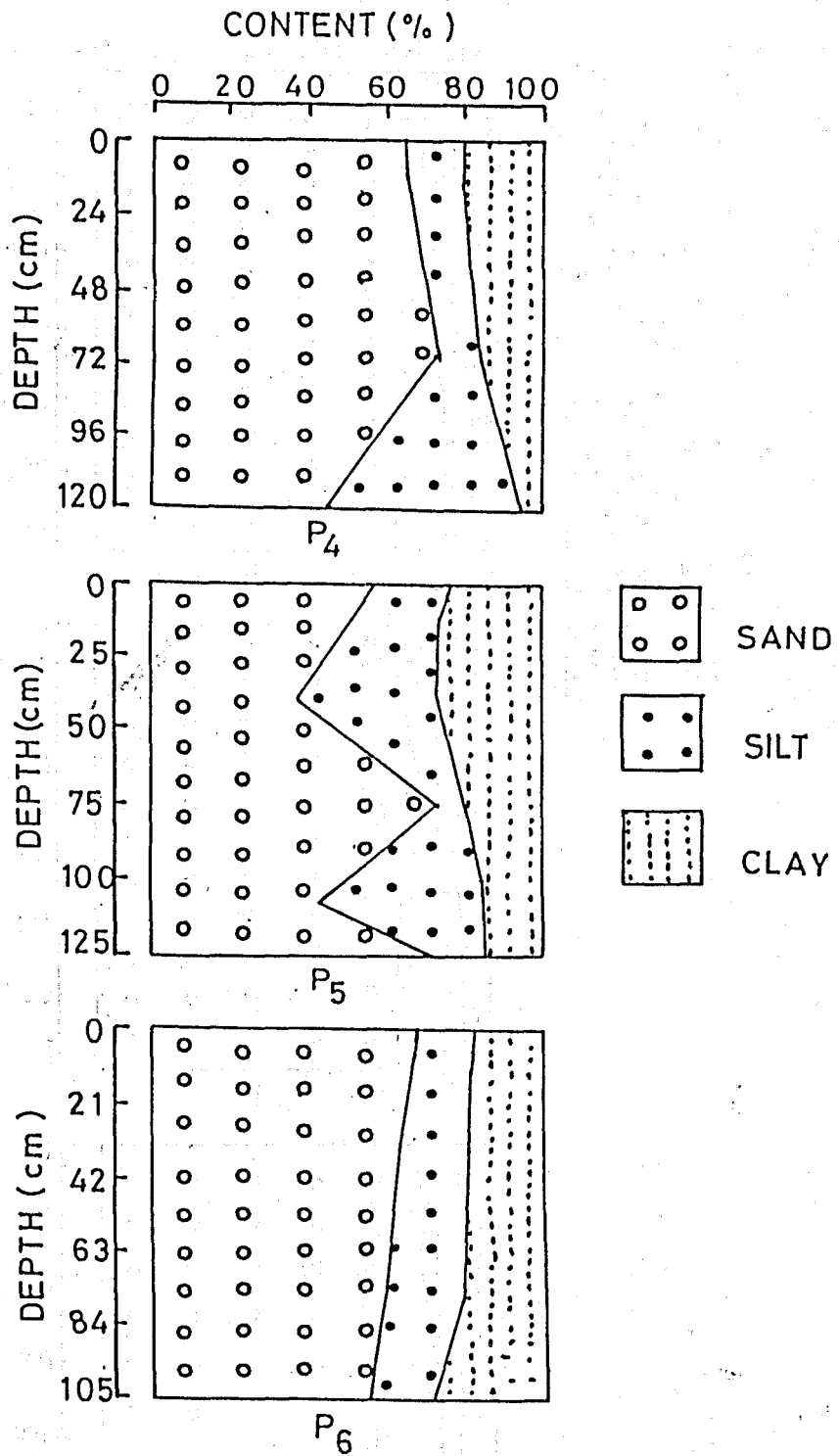


FIG.6 PARTICLE SIZE DISTRIBUTION WITH DEPTH IN PEDONS 4,5 AND 6

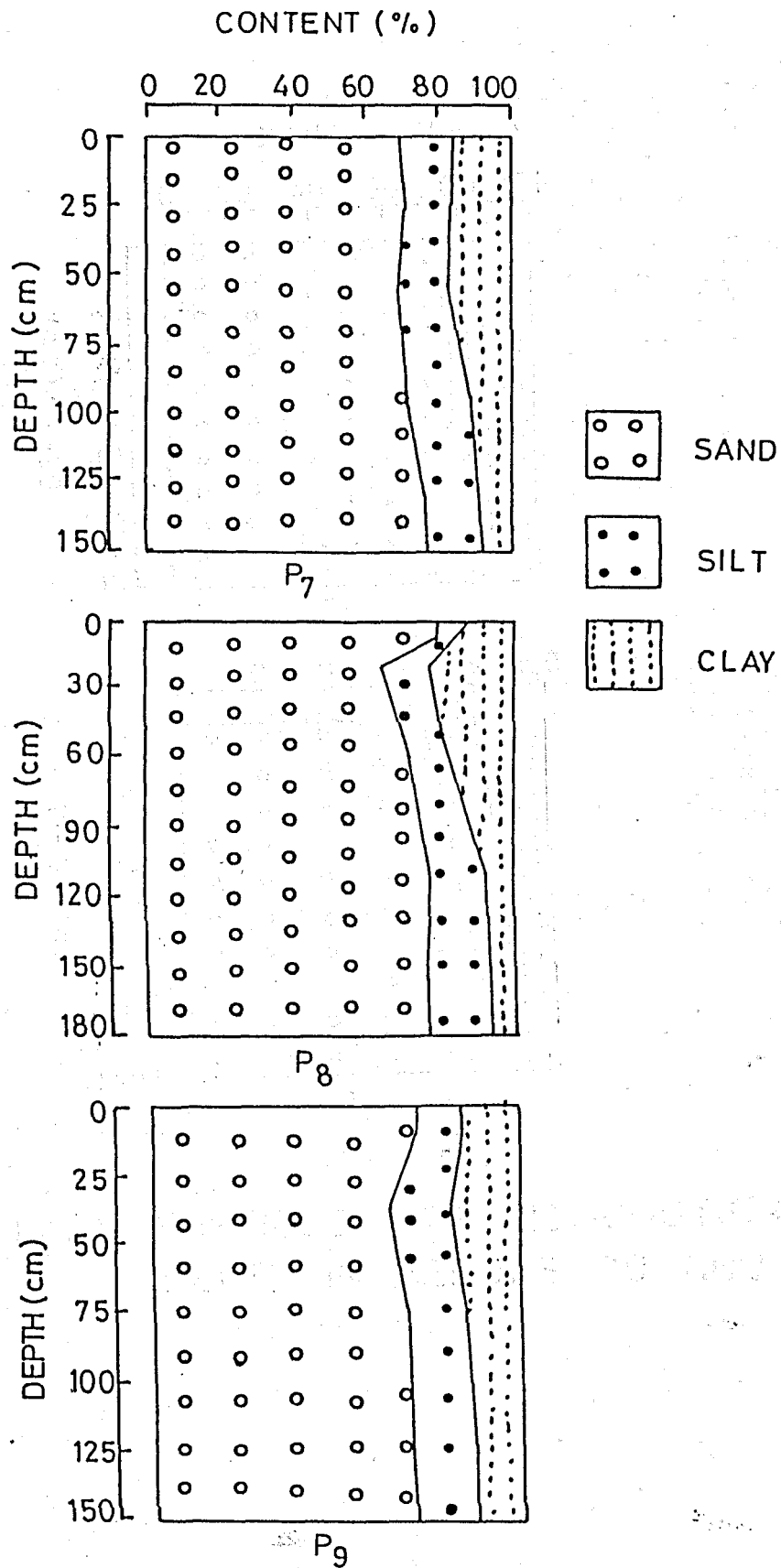


FIG. 7 PARTICLE SIZE DISTRIBUTION WITH DEPTH IN PEDONS 7, 8 AND 9

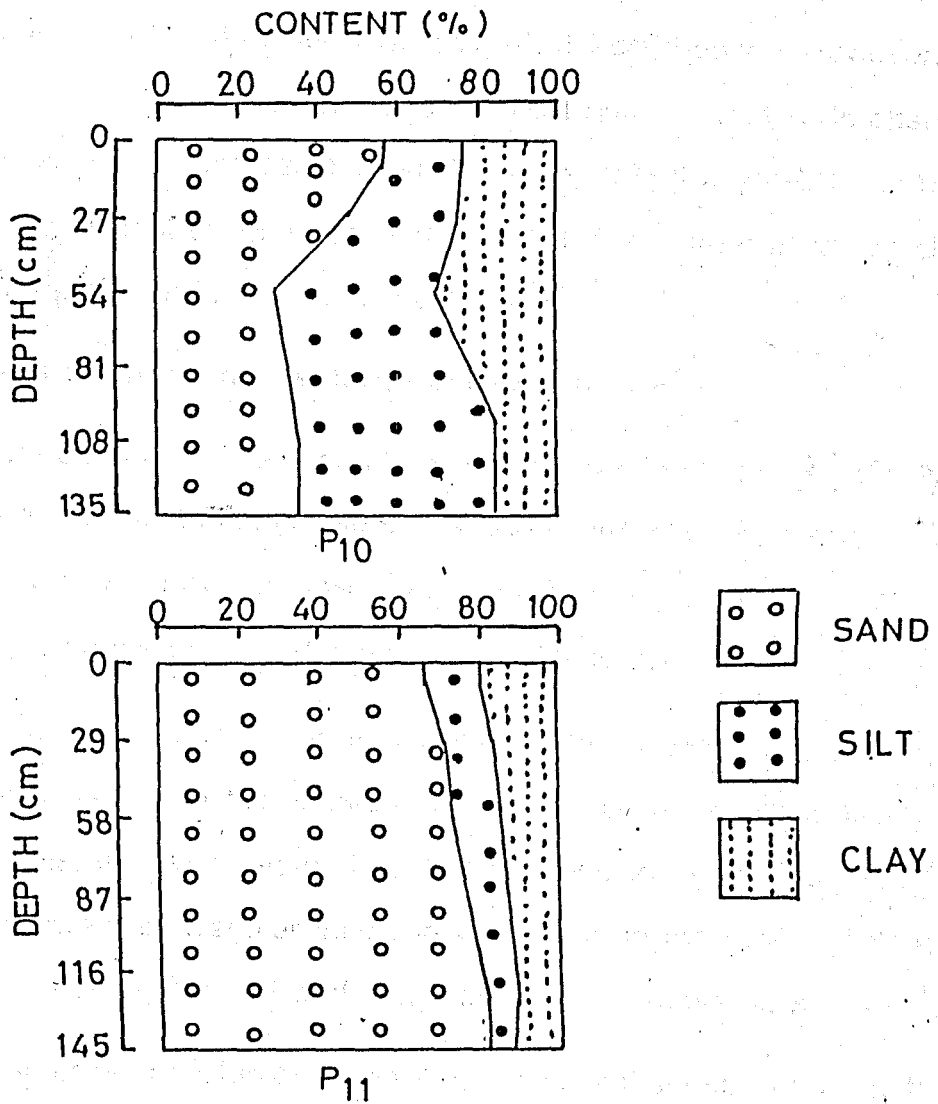


FIG. 8 PARTICLE SIZE DISTRIBUTION WITH DEPTH IN PEDONS 10 AND 11

showed depth distribution of clay content in the increasing order ranging from 22.2 per cent in the surface horizon to 30.2 per cent in 1C (43-65 cm) horizon. However, the clay content decreased to 15.4 per cent in the lower most horizon. P11 soils observed the depth distribution of clay in decreasing trend. The clay content was more on the surface ranging from 19.2 per cent to 13.8 per cent in A13 (38-72 cm) horizon which further decreased to 10.6 per cent in the lower most horizon.

4.2.2 Moisture retention and storage capacity of soils :

The data on moisture retention by soil of different horizons at different atmospheric tensions are presented in (Table 6) . Available water is expressed as percentage on weight basis and also as cm of water for each horizon. The total available moisture in the soil profile up to a depth of 1.5 meter is also shown in (Table 6).

It was observed for all soils that the moisture retained at various tensions decreased regularly as the suction increased from 1/3 to 15 atmospheres. (Table 6). For most of the soils, moisture retained at different tensions and also the amount of available water followed an irregular increase with depth in the profile. This might be due to an increased amount of silt and clay with depth in these soils.

A clear inter-relationship between the mechanical constituents and the water relations of soils were brought out in (Table 5) which gives the values of 'r' the coefficient of correlation between the mechanical constituents and the available water, it was observed that clay and silt fractions of soil had a positive and significant correlation with available water ('r' being 0.473 and 0.538, respectively). These relations are in accord with those reported by Jamison and Kroth (1958); Bertelli and Peters (1958); Lund (1959); Abrol and Bhumbra (1966); Kuhad (1973); and Kumar *et al.*, (1989). But

available water showed a negative and significant correlation with sand fractions of soil (-0.07). Kuhad (1973); Gupta *et al.*, (1986) and Kumar *et al.*, (1989).

Table 5 Values of 'r' between some soil characteristics and available water

S. No.	Soil Characteristics	Values of 'r'
1	Clay	0.473
2.	Silt	0.538
3.	Sand	-0.075
4.	Organic Carbon	0.12
5.	Cation exchange capacity	0.37

Several workers have recognised the role of organic matter in influencing the moisture characteristics. Salter and Howorth (1961) found that application of farm yard manure to a soil led to the increased available moisture capacity of soils. Kumar *et al.*, (1989) reported a positive and significant correlation ($r=0.27$) between available water and organic matter. The possible effect of organic matter in increasing the available water capacity of soils, results in the aggregation of clay into units of the size of silt and very fine sand.

Cation exchange capacity of soils was also found to have a highly significant and positive correlation ($r=0.37$) with the available water. Kuhad (1973) also reported a positive and significant correlation ($r=0.625$) between cation exchange capacity and available water. This is due to the direct dependence of cation exchange capacity on organic matter and clay content of soil. Similar results were also reported by Ahuja (1981); Shanwal (1985); and Kumar *et al.*, (1989) in different parts of Haryana.

Table 6 Moisture retention characteristics

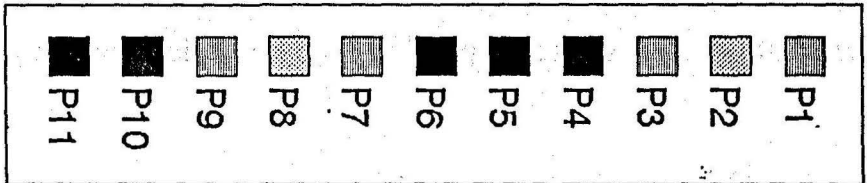
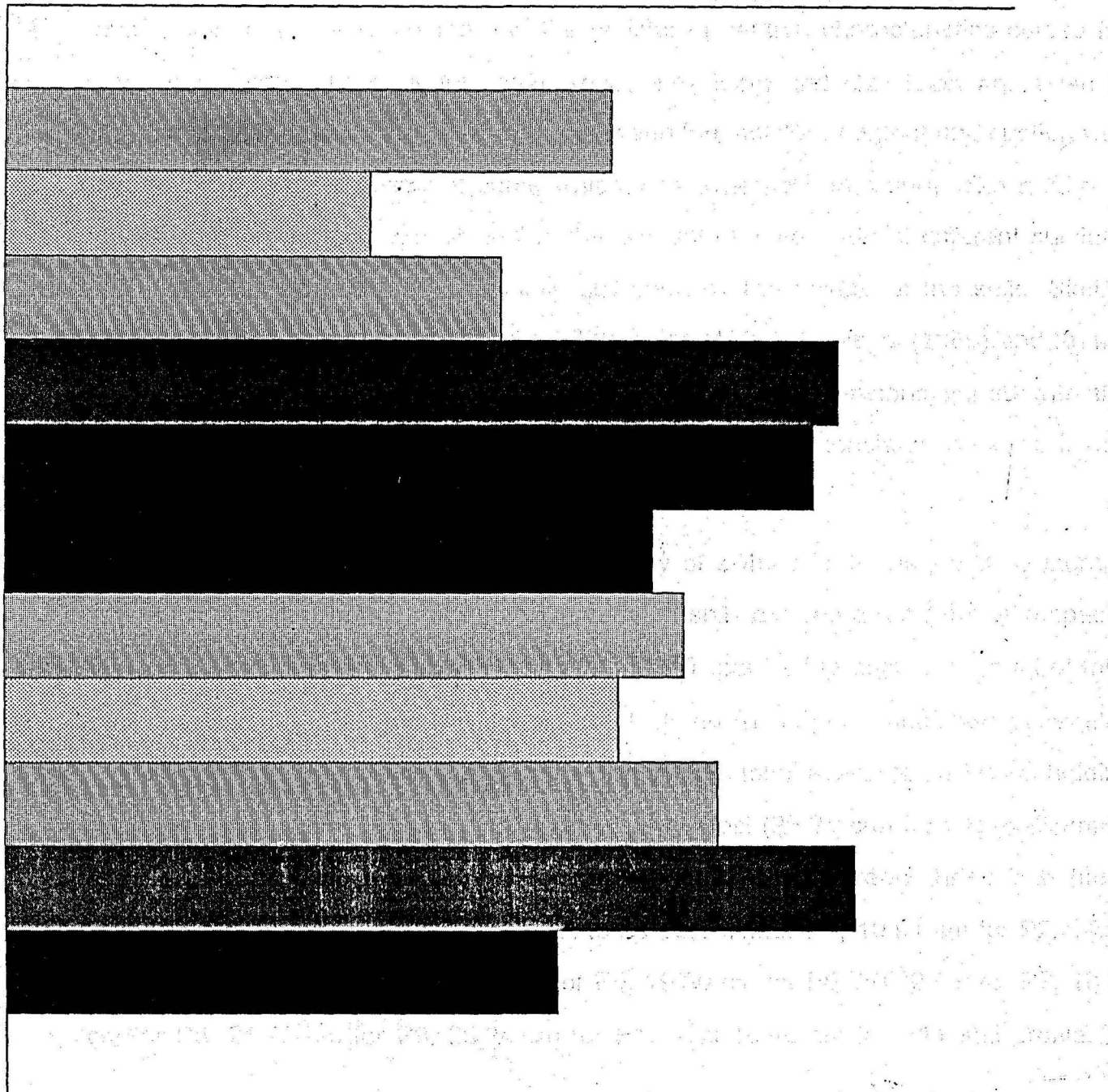
DEPTH (cm)	HR.	PERCENT MOISTURE RETAINED		AVAILABLE AVAILABLE		AWSC (CM)
		0.3 BAR	15 BAR	WATER (WT)	WATER (CM) 6	
1	2	3	4	5	6	7
PEDON - 1(ALKHPUR - BHIWANI)						
0-20	Ap	11.96	3.67	8.29	2.45	18.1
20-43	A12	13.62	4.57	9.05	3.08	
43-72	AC	14.86	5.23	9.63	4.13	
72-107	C1	14.70	5.15	9.55	4.94	
107-135	C2	12.32	3.86	8.46	3.50	
PEDON - 2 (BHIWANI ROHILLA - HISAR)						
0-17	Ap	10.85	2.25	8.60	2.16	10.91
17-38	C1	9.44	1.85	7.59	2.35	
38-62	C2	8.84	1.12	7.72	2.74	
62-110	C3	6.16	1.00	5.16	3.66	
PEDON - 3 (BAKRIAWALI- SIRSA)						
0-20	Ap	8.52	2.28	6.24	1.84	14.81
20-50	C1	9.81	3.31	6.50	2.88	
50-137	C2	11.68	4.82	6.86	8.83	
137+	C3	10.44	3.86	6.58	1.26	
PEDON - 4 (COTTON RESEARCH STATION- SIRSA)						
0-20	Ap	14.83	4.63	10.20	3.01	24.79
20-120	BC	12.94	2.86	10.08	14.91	
120+	C1	23.84	8.36	15.48	6.87	
PEDON - 5(BHAVDIN - SIRSA)						
0-22	Ap	15.96	5.34	10.62	3.45	24.05
22-60	1C	17.68	6.47	11.21	6.30	
60-90	IIC	15.32	4.67	10.65	4.72	
90-125	IIIC	13.87	3.38	10.49	5.43	
125+	IVC	17.16	5.93	11.23	4.15	
PEDON - 6 (DHANI PREM NAGAR - HISAR)						
0-15	Ap	10.84	3.07	7.77	1.72	19.3
15-45	BII	12.14	3.77	8.37	3.71	
45-105	B12	13.15	4.52	8.63	7.66	
105+	C1	14.21	4.88	9.33	6.21	

Contd....

DEPTH (cm)	HR.	PERCENT MOISTURE RETAINED		AVAILABLE	AVAILABLE	AWSC (CM)
		0.3 BAR	15 BAR	WATER (WT)	WATER (CM) 6	
1	2	3	4	5	6	7
PEDON - 7 (TIGRANA- BHIWANI)						
0-15	Ap	14.51	5.03	9.43	2.10	20.22
15-37	A12	14.62	4.52	10.10	3.28	
37-75	AC	16.10	5.64	10.46	5.88	
75-120	C1	12.21	3.51	8.70	5.70	
120-150	C2	10.37	3.02	7.35	3.26	
PEDON - 8 (PENTAWAS - BHIWANI)						
0-15	Ap	10.03	2.45	7.58	1.68	18.28
15-30	A12	15.78	5.23	10.55	2.34	
30-90	AC	13.20	4.20	9.0	7.99	
90-135	C1	9.31	2.28	7.03	4.68	
135-180	C2	9.85	2.65	7.20	1.59	
PEDON - 9 (MUNDHAL - BHIWANI)						
0-20	Ap	12.65	3.27	9.38	2.77	21.20
20-60	A11	15.39	5.47	9.92	5.87	
60-105	A12	14.57	4.83	9.74	6.48	
105-150	C	12.23	3.10	9.13	6.08	
PEDON - 10 (GULKANI - JIND)						
0-18	Ap	19.34	6.47	12.87	3.42	25.24
18-43	A12	20.24	7.14	13.10	4.84	
43-65	1C	22.62	9.23	13.39	4.35	
65-135	11C	15.46	3.26	12.20	12.63	
PEDON - II (BAHU AKBARPUR - ROHTAK)						
0-15	Ap	14.85	5.15	9.70	2.15	16.4
15-38	A12	12.96	3.67	9.29	3.16	
38-72	A13	10.84	3.10	7.74	3.89	
72-10	C1	9.02	2.65	6.37	3.58	
110.145	C2	8.78	1.79	6.99	3.62	

AVAILABLE WATER CM/METER

0 5 10 15 20 25 30



Moisture retention characteristics curves : Moisture release patterns for various soils have been studied and the moisture retention characteristics curves for sand, loamy sand, sandy loam, loam, sandy clay loam and clay loam are given in (Fig. 10) In all the cases the relationship between the moisture content and suction was governed by a smooth and flat curve which was hyperbolic in nature. The nature of curves for different soils with regard to the amount of water held at different suctions and the slope of the curve was mainly governed by the texture of the soils. Similar results were also reported by Kuhad (1973); Ahuja (1981); Shanwal (1985) and Kumar *et al.*, (1989). The availability of the moisture at different tensions varied with the texture of soils. The influence of texture was less at lower tensions, whereas it was more at higher tensions.

Available moisture storage capacity of soils : From the moisture storage data presented in (Table 6) , it was observed that soils differed greatly in their capacity to store available moisture. In the last column of (Table 6), the data on amount of total available water is presented, which was calculated for upper meters for all profiles assuming a constant bulk density of 1.4 g/cc. The total available moisture holding capacity was lowest (10.91 cm) for P2 soil and highest (25.24 cm) for P10 soil profile. Rest of the profiles retained total available moisture between these two limits (Table-6 Fig. 9). The values worked out to be 18.1 cm for P1, 10.91 cm for P2, 14.81 cm for P3, 24.79 cm for P4, 24.05 cm for P5, 19.30 cm for P6, 20.22 cm for P7, 18.28 cm for P8, 21.20 cm for P9, 25.24 cm for P10 and 16.40 cm for P11 soil profile.

All the eleven soil profiles can be arbitrarily grouped into different categories based on their total available moisture holding capacity Soil profiles with available

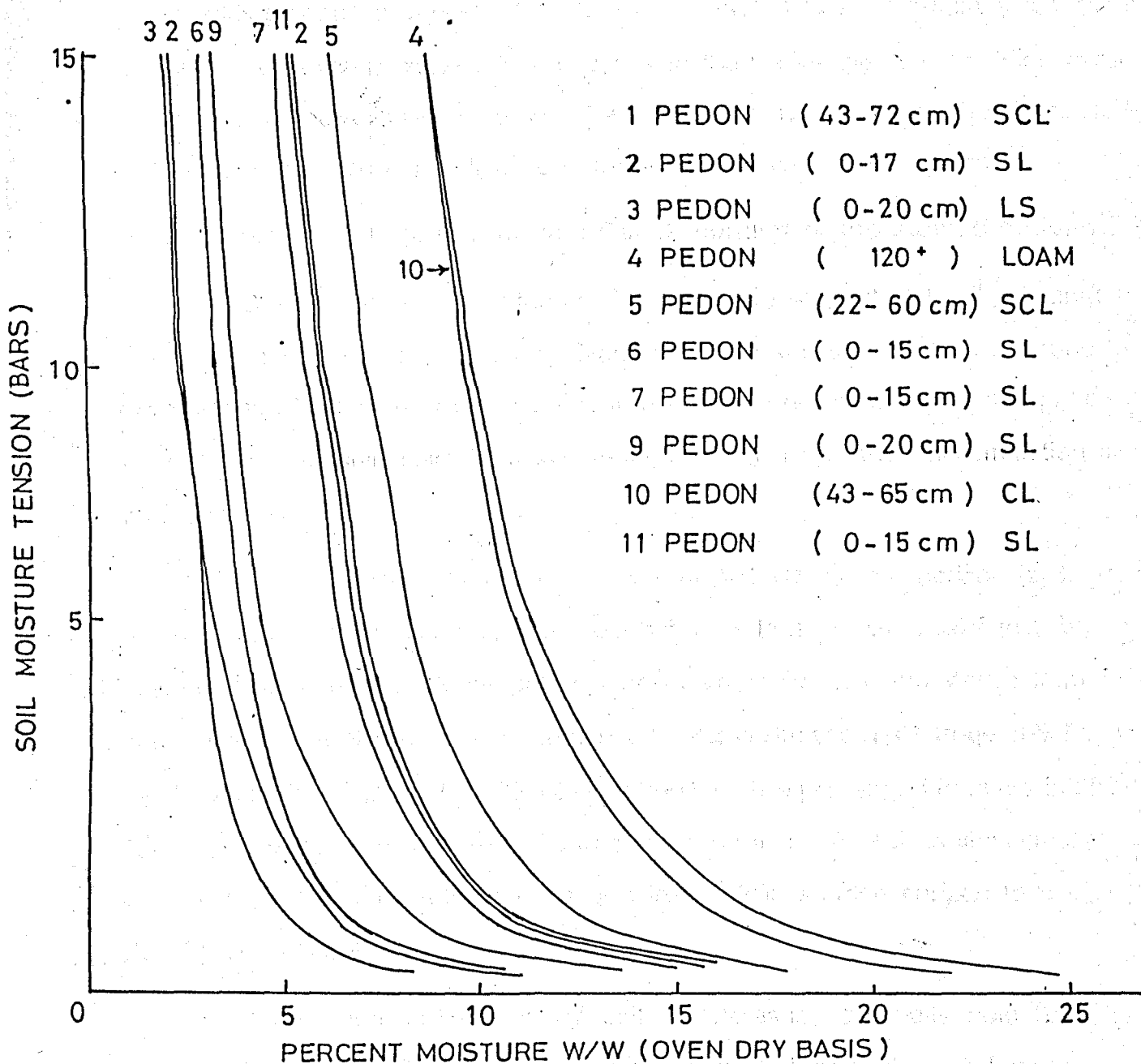


FIG.10 MOISTURE RETENTION CHARACTERISTICS CURVE OF SOILS VARYING IN TEXTURE

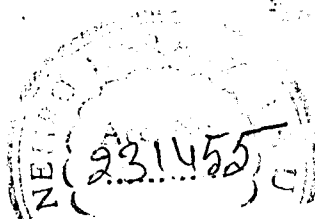
water holding capacity less than 20 cm were considered as low in available water, while those having between 20 and 30 cm as medium and more than 30 cm as high in available water. Thus, soil profiles P1, P2, P3, P6, P8 and P11 were low in available water holding capacity whereas, P4, P5, P7, P9 and P10 were medium. Thus, the soil profiles of a particular zone differed greatly in their available water holding capacity depending on the texture of the soil. The content of available moisture decreased or increased with depth depending upon the texture of the various horizons.

4.2.3 pH , E.C. Org. Carbon and CaCO₃ content of the studied pedons :

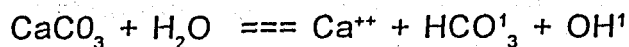
Soil pH : A perusal of the pH data (Table 7) suggest that soil pH varies from 7.9 to 9.1. The pH in the surface horizons of all the studied pedons was found to be lower except P1, P6 and P8 soils. The lower pH in the surface horizons may be due to removal of soluble salts from the surface horizons and their accumulation in the lower horizons.

In P1 soil, the pH varied from 7.9 in A-C (43-72 cm) horizon to 8.2 in the surface horizon. In P2 soil it ranged from 8.5 in surface horizon to 8.7 in sub surface horizon. Comparatively higher pH was observed in P3 soil and varied from 8.4 in surface horizon to 8.7 in sub surface horizon. P4 soil showed a pH range of 8.3 in lower most horizon to 8.6 in the BC (20-120 cm) horizon. The pH ranged from 8.1 in IIIC (90-125 cm) horizon to 8.6 in IIC (60-90 cm) horizon in P5 soil. P6 soil exhibit comparatively uniform pH within the profile and ranged from 8.2 in surface horizon to 8.1 in B12 (45-105 cm) horizon.

It was observed that in P7 soil pH increased gradually from 8.3 in A12 (15-37 cm) horizon to 8.7 in the lower most horizon whereas the pH decreased from



8.2 in the surface horizon to 7.9 in A-C (30-90 cm) horizon in P8 soil. The depth distribution of pH in P9 soil ranged from 8.3 in the B11 (20-60 cm) horizon to 8.5 in B12 (60-105 cm) horizon. The increasing trend of pH with depth was observed in P10 and P11 soils. In P10 soil the pH ranged from 8.4 in the surface horizon to 9.1 in C1 (43-65 cm) horizon. Similarly, the pH ranged from 8.3 in surface horizon to 8.7 in C1 (72-110 cm) horizon in P11 soil profile. The increase of pH with depth may be attributed to downward leaching of soluble salts. Besides, the increase in pH with depth may be due to the liberation of free OH ions as a result of hydrolysis and dessionication of calcium carbonate (Lloyd and Peterson, 1964) as follows:



The soils were neutral to moderately alkaline in reaction (pH 7.0-8.4). The alkaline pH in these soils might be due to presence of soluble bicarbonates.

Electrical conductivity : The electrical conductivity of 1:2 soil-water extract (Table 7) varied between 0.08 to 1.20 dsm^{-1} in all the studied pedons. Pedons 1, 2, 3, 5 and 10 showed high EC in the surface horizons and decreased downwards. On the other hand pedons 4, 6, 7 and 8 exhibited on increase in EC in the lower horizons from surface horizons, whereas, P9 and P11 showed a uniform E.C. throughout the profile.

The results showed these soils are free from any salinity hazard. The well drained, coarse to medium textured soils have a more active eluviation process resulting in leaching of salts. These results are in conformity with the observations reported by Kuhad (1973).

Organic carbon : The results given in (Table 7 and Figs. 11-14) showed that all the studied pedons were low in organic carbon content (less than 1%) except the surface horizons. Low organic carbon content was observed in P3 soil ranging from 0.08 per cent in C2 (50-137 cm) to 0.33 per cent in lower most horizon. Similarly in P2 soil, organic carbon content varied from 0.09 per cent in C3 (62-140 cm) to 0.15 per cent in C1 (17-38 cm) horizon. Relatively higher organic carbon content was observed in P1 soil ranging from 0.02 per cent in C2 horizon (107-135 cm) to 0.27 per cent in surface horizon. Whereas in P4 soil, the organic carbon content varied from 0.07 per cent in BC (20-120 cm) horizon to 0.42 per cent in the lower most horizon. The content of organic carbon in P5 varied from 0.05 to 0.10 per cent. The P6 soil observed the organic carbon content from 0.10 per cent in C1 (105⁺) horizon to 0.21 per cent in the surface horizon.

Organic carbon content ranged from 0.07 to 0.25 per cent in P7 soil. In P8 soil, the organic carbon content varied from 0.10 per cent to 0.33 per cent. The organic carbon content in P9 soil varied from 0.20 to 0.54 per cent. Relatively higher organic carbon content was observed in P10 soil ranging from 0.18 to 0.83 per cent. Similarly in P11 soils, the organic carbon content varied from 0.21 to 0.42 per cent.

The low content of organic carbon is because of decomposition of organic matter due to higher temperature. The organic carbon content was maximum at surface and decreased with depth. The decrease with depth was irregular indicating the fluventic characters of these soils. (Goyal, 1981)

Calcium carbonate : The data on distribution of calcium carbonate in these soils are given in (Table 7 and Figs. 15-18) and showed variations among the studied pedons.

Table 7 pH, Electrical conductivity, Organic carbon and Calcium carbonate of the studied pedons.

DEPTH (cm) 1	HORIZON 2	PH (1:2) 3	E.C. (dsm-1) 4	ORGANIC CARBON % 5	CaCO ₃ % 6
PEDON-1 (ALKHPUR-BHIWANI)					
0-20	Ap	8.2	1.20	0.27	NIL
20-43	A12	8.0	0.94	0.10	NIL
43-72	AC	7.9	0.80	0.09	NIL
72-107	C1	8.2	0.52	0.03	0.30
107-135	C2	8.3	0.60	0.02	0.25
PEDON-2 (BHIWANI-ROHILLA-HISAR)					
0-17	Ap	8.5	0.20	0.10	0.65
17-38	C1	8.7	0.16	0.15	2.70
38-62	C2	8.6	0.15	0.12	2.45
62-140	C3	8.5	0.17	0.09	1.00
PEDON-3 (BAKRIAWALI-SIRSA)					
0-20	Ap	8.4	0.28	0.08	0.10
20-50	C1	8.7	0.13	0.10	NIL
50-137	C2	8.3	0.36	0.08	1.70
137+	C3	8.5	0.30	0.33	2.25
PEDON-4 (COTTON RESEARCH STATION-SIRSA)					
0-20	Ap	8.4	0.08	0.10	0.90
20-120	BC	8.6	0.12	0.07	1.55
120+	C1	8.3	0.20	0.42	2.10
PEDON-5- (BHAVDIN-SIRSA)					
0-22	Ap	8.4	0.60	0.08	0.85
22-60	IC	8.5	0.50	0.10	1.05
60-90	IIC	8.6	0.26	0.06	NIL
90-125	IIIC	8.1	0.31	0.07	NIL
125+	IVC	8.4	0.33	0.05	NIL
PEDON-6 (DHANI PREM NAGAR-HISAR)					
0-15	Ap	8.2	0.70	0.21	0.15
15-45	B11	8.1	0.72	0.13	0.10
45-105	B12	8.1	0.85	0.13	0.10
105+	C1	8.2	0.80	0.10	0.25

Contd....

DEPTH (cm) 1	HORIZON 2	PH (1:2) 3	E.C. (dsm-1) 4	ORGANIC CARBON % 5	CaCO ₃ % 6
PEDON-7 (TIGRANA-BHIWANI)					
0-15	Ap	8.4	0.37	0.25	0.95
15-37	A12	8.3	0.49	0.15	0.45
37-75	AC	8.4	0.36	0.10	0.80
75-120	C1	8.5	0.40	0.13	3.40
120-150	C2	8.7	0.31	0.07	2.50
PEDON-8 (PENTA WAS-BHIWANI)					
0-15	Ap	8.2	0.30	0.33	0.30
15-30	A12	8.1	0.30	0.23	0.70
30-90	AC	7.9	0.50	0.15	2.00
90-135	C1	8.0	0.20	0.12	5.25
135-180	C2	8.1	0.27	0.10	5.75
PEODN-9 (MUNDHAL-BHIWANI)					
0-20	Ap	8.4	0.20	0.54	0.30
20-60	B11	8.3	0.30	0.35	0.30
60-105	B12	8.5	0.20	0.28	4.70
105-150	C	8.4	0.30	0.20	5.10
PEDON-10 (GULKANI-JIND)					
0-18	Ap	8.4	0.23	0.83	0.30
18-43	A12	9.0	0.17	0.30	1.10
43-65	IC	9.1	0.17	0.27	1.20
65-135	IIC	8.9	0.15	0.18	1.70
PEDON-11 (BAHUAKBARPUR-ROHTAK)					
0-15	Ap	8.3	0.25	0.42	1.00
15-38	A12	8.4	0.25	0.28	0.90
38-72	A13	8.7	0.23	0.27	0.45
72-110	C1	8.7	0.22	0.21	2.50
110-145	C2	8.6	0.26	0.36	0.85

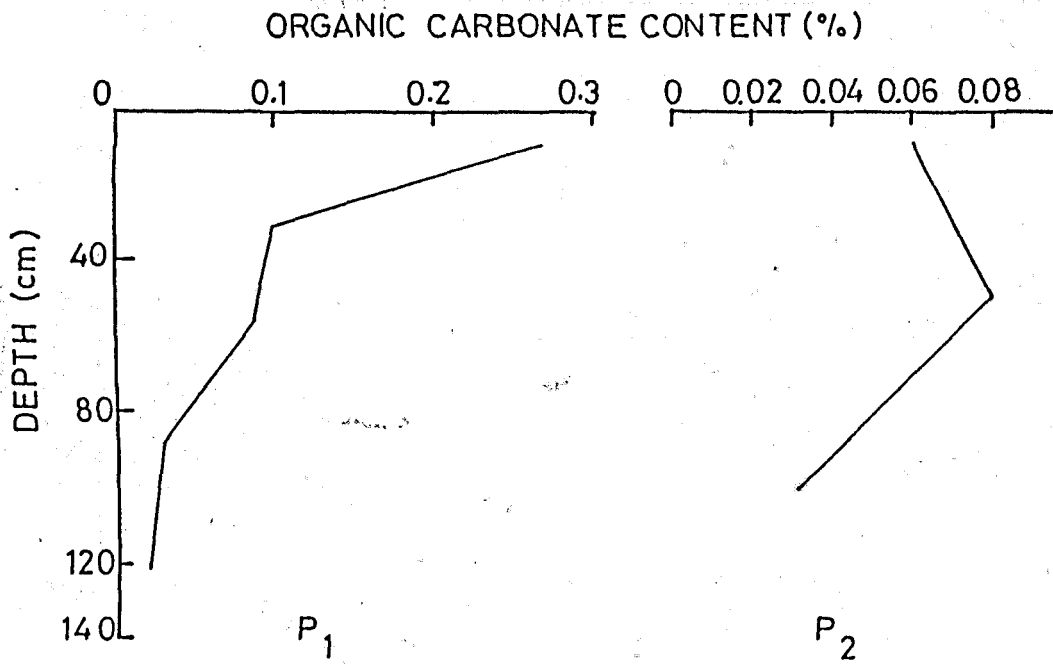


FIG. 11 DEPTH DISTRIBUTION OF ORGANIC CARBON IN PEDONS 1 AND 2

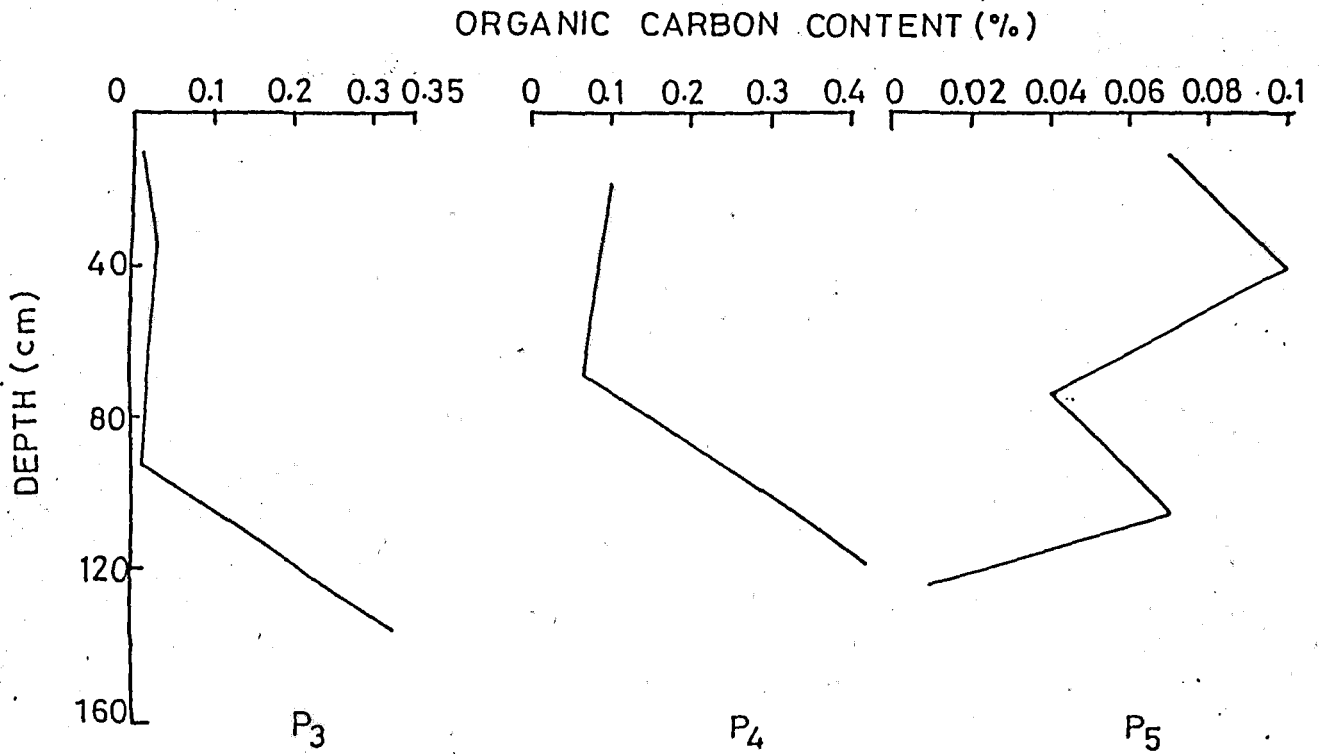
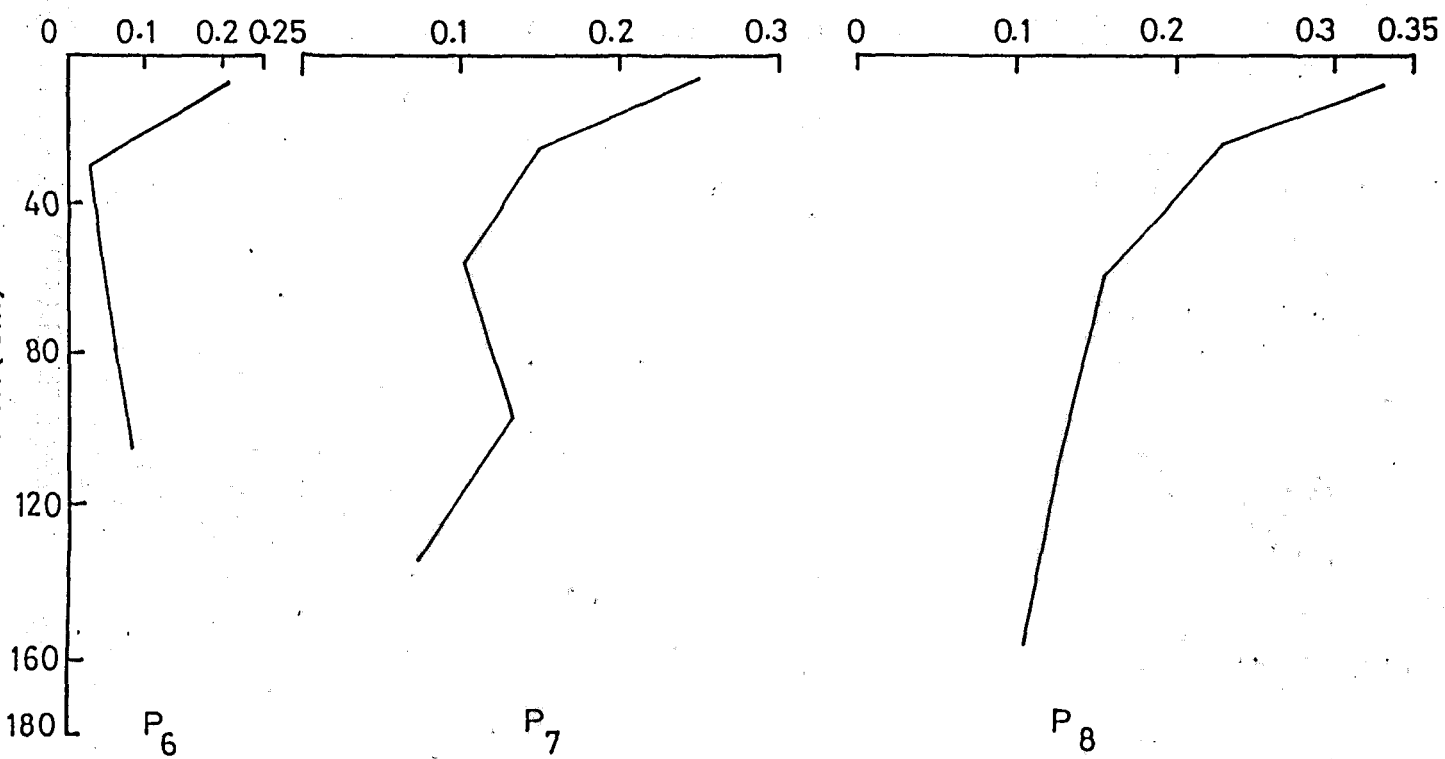


FIG.12 DEPTH DISTRIBUTION OF ORGANIC CARBON IN PEDONS 3, 4 AND 5

ORGANIC CARBON CONTENT (%)



13 DEPTH DISTRIBUTION OF ORGANIC CARBON IN PEDON 6, 7 AND 8

ORGANIC CARBON CONTENT (%)

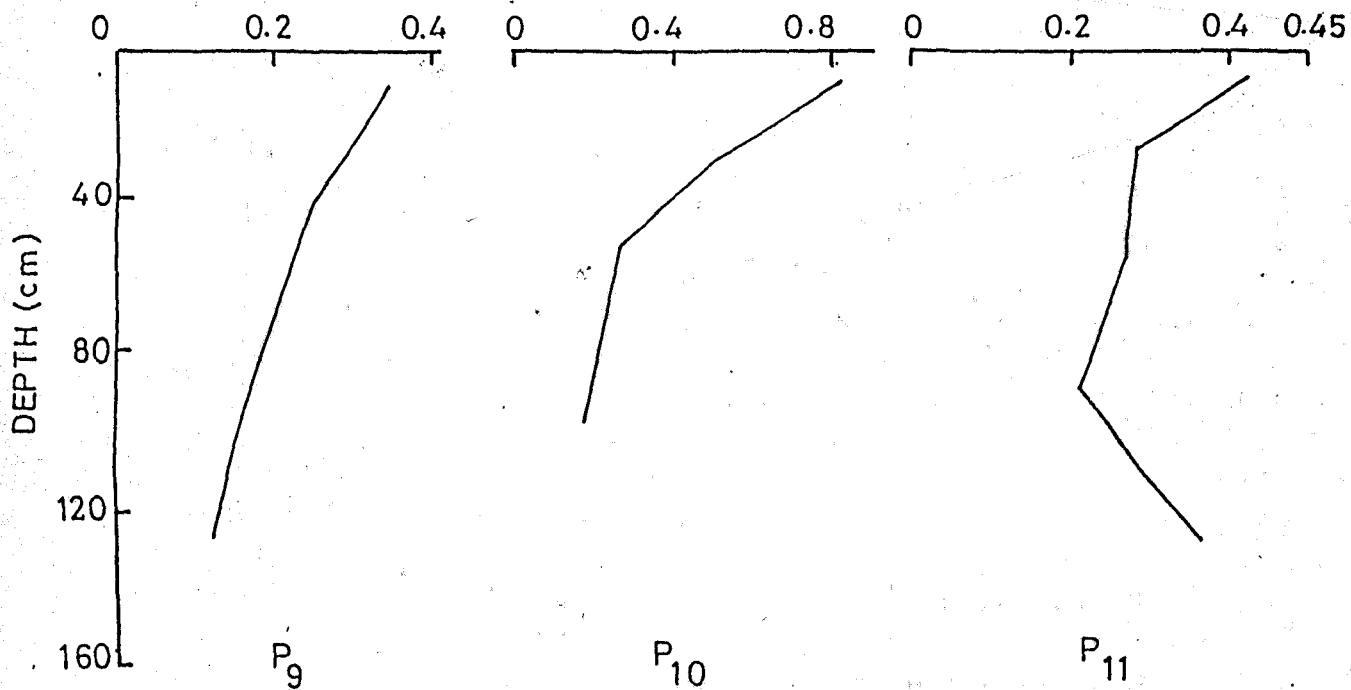


FIG.14 DEPTH DISTRIBUTION OF ORGANIC CARBON IN PEDONS 9, 10 AND 11

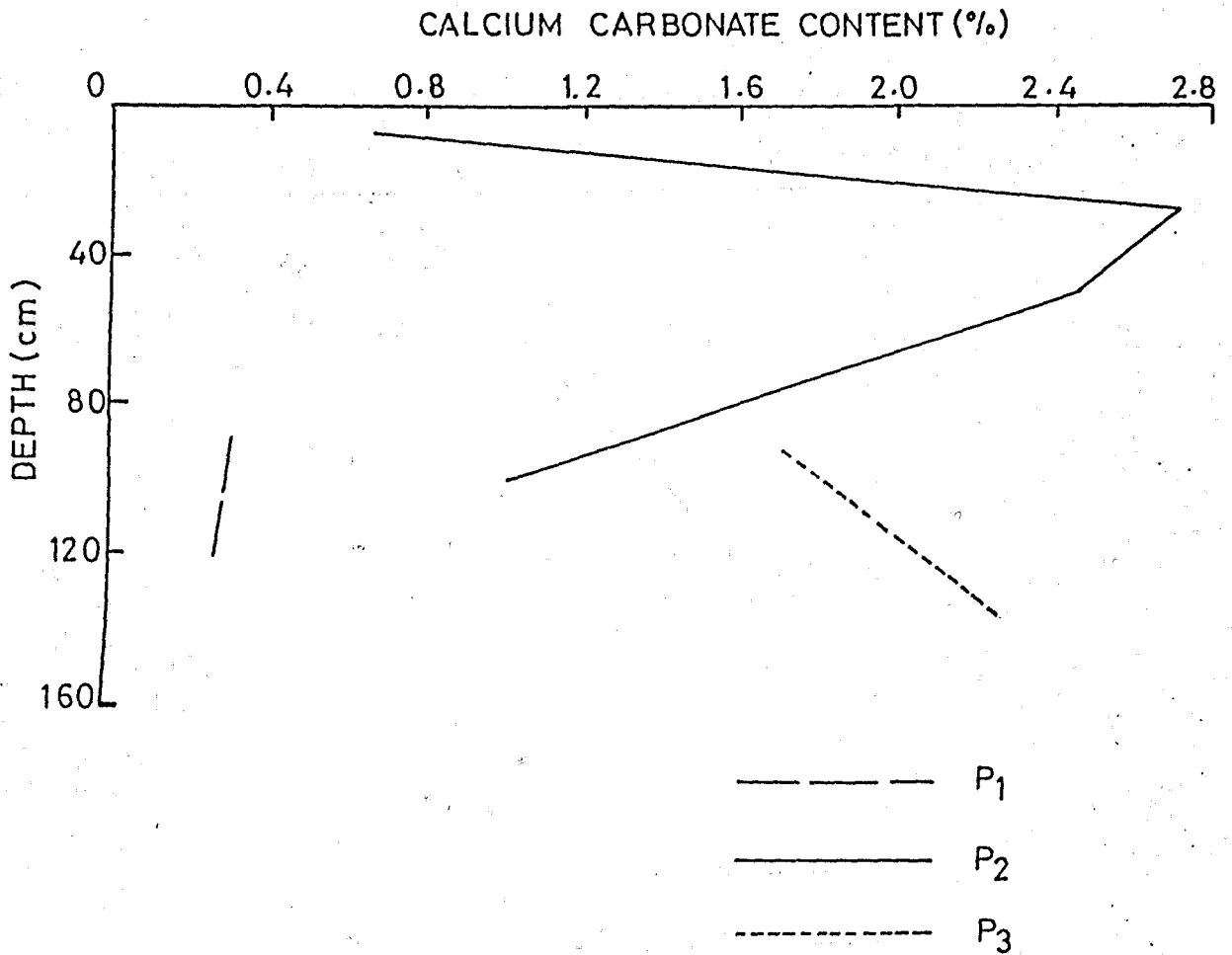


FIG.15 DEPTH DISTRIBUTION OF CALCIUM CARBONATE IN PEDONS 1, 2 AND 3

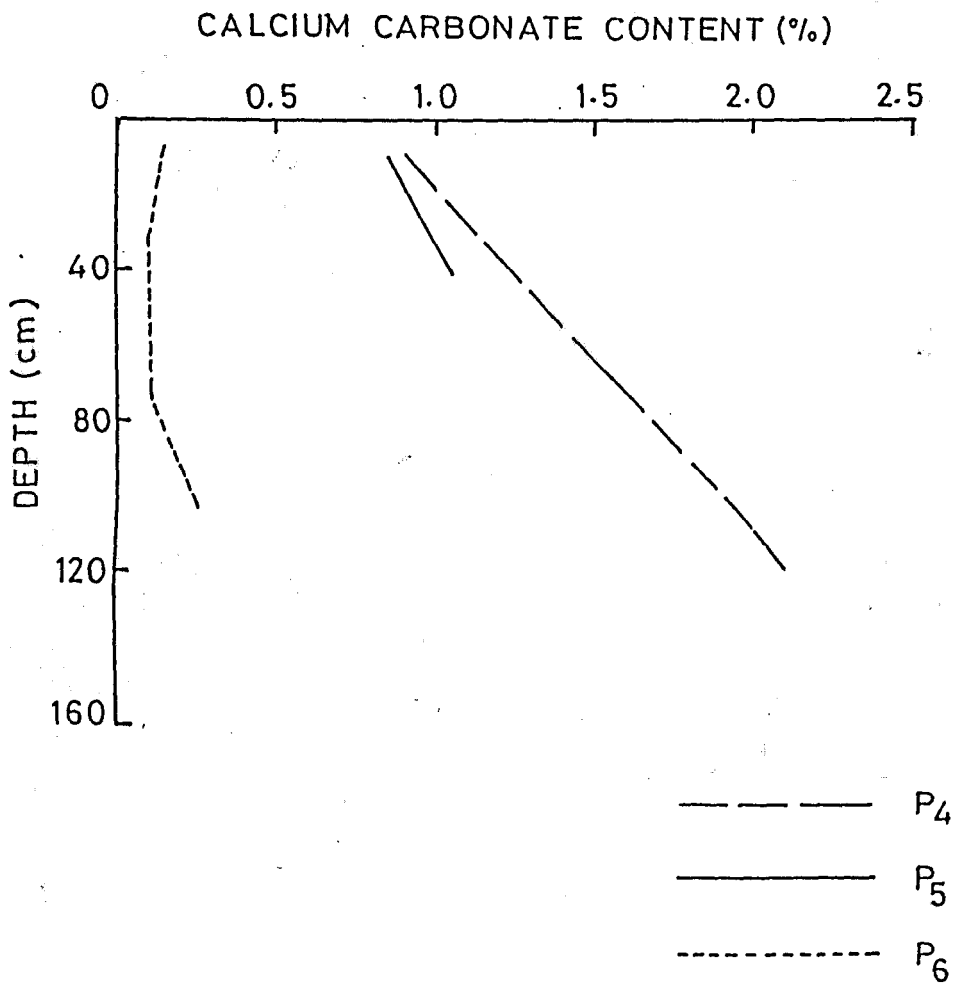


FIG.16 DEPTH DISTRIBUTION OF CALCIUM CARBONATE IN PEDONS 4, 5 AND 6

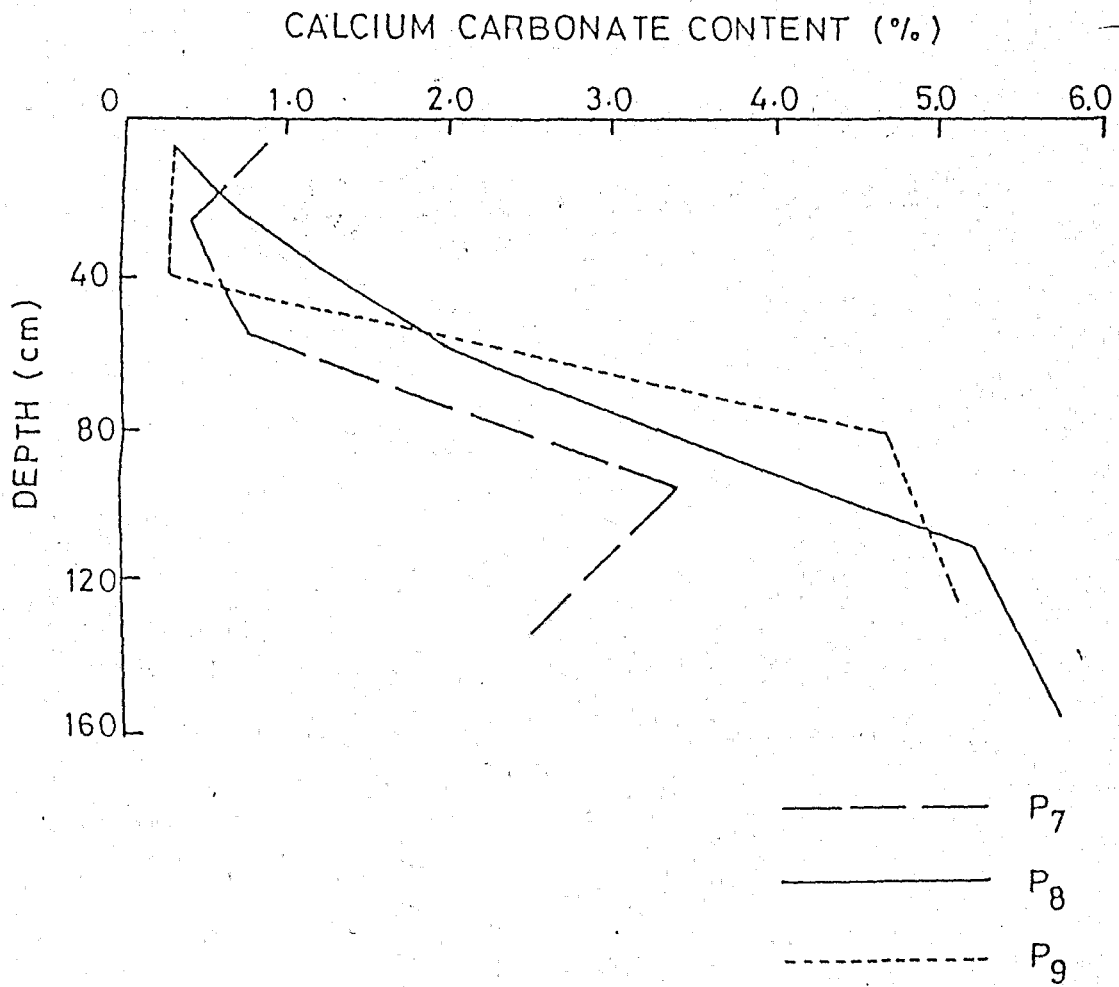


FIG.17 DEPTH DISTRIBUTION OF CALCIUM CARBONATE IN PEDONS 7, 8 AND 9

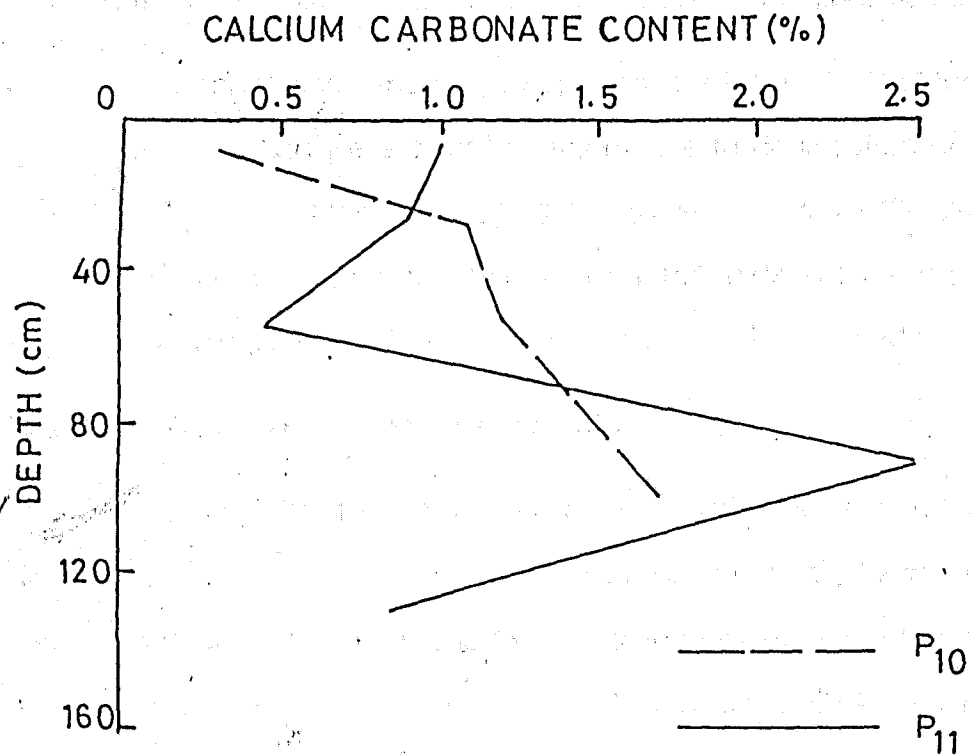


FIG.18 DEPTH DISTRIBUTION OF CALCIUM CARBONATE IN PEDONS 10 AND 11

The soils were either devoid of free CaCO_3 , indicating that either sediments on which these soils have been formed were free from CaCO_3 or it has been leached to deeper layers. These results show that none of CaCO_3 enriched horizon in these soils qualify for calcic horizon, as the CaCO_3 equivalent to less than 15 per cent.

Sehgal and Stoops (1972) suggested that CaCO_3 concretions in soils of the Indo-Gangetic plain were of orthic nature due to desiccation of the soil material during March to June followed by wetting by monsoon rains from July to September, thus facilitating the movement of solutions from the voids into the dry soil material surrounding it and precipitation of CaCO_3 in the form of lime nodules.

4.2.4 CEC and exchangeable cations :

The studied pedons from different regions have a wide variation in cation-exchange capacity (Table 8), which may be attributed to the nature of material now comprising the soil profiles and to the differences in amount of clay and organic matter and type of clay minerals in the soils. The value of CEC of various horizons indicate that its maxima correspond to the maxima of clay content within the profile. The coarse loamy soils have low CEC in the control section.

In view of the wide variation in CEC of the pedons, the CEC has been used as the criteria for evaluating the productivity of soils. The correlation coefficients between CEC and Clay ($r=0.92$), CEC and silt ($r=0.24$) and CEC and organic carbon (0.14) suggest that clay fraction is the main contributor to CEC of these soils (Bear, 1964; Sharma, 1979 and Kumar 1987). A low positive correlation between silt and CEC and organic carbon and CEC indicated limited contribution of these fractions towards CEC of the studied soils.

The cation-exchange capacity of the soils ranged from 6.17 to 21.91 cmol (p+) kg. The P10 soil profile had highest CEC (21.91 cmol kg⁻¹) followed by P5 soil (21.36 cmol kg⁻¹). On the other hand, the lowest CEC was observed in the coarse textured P3 soil (6.17 cmol kg⁻¹) followed by P7 soil (6.70 cmol kg⁻¹). The cation exchange capacity of P1 soil varied between 16.04 to 17.68 cmol kg⁻¹. CEC, ranging from 8.32 to 13.86 cmol kg⁻¹ was observed in P2 soil. The P4 soil had a CEC ranged from 8.60 to 16.40 cmol kg⁻¹ soil.

P6 soil observed CEC ranging from 12.94 to 21.20 cmol kg⁻¹. CEC with a range from 8.60 to 18.8 cmol kg⁻¹ was observed in P8 soil. P9 soil showed a CEC range from 10.90 to 14.56 cmol kg⁻¹ soil. P11 had a CEC range of 8.30 to 13.34 cmol kg⁻¹.

Exchangeable cations : Data (Table 8) on exchangeable cations showed that almost all the horizons of different pedons were saturated with Ca⁺⁺ and Mg⁺⁺. The exchangeable Na⁺ and K⁺ were observed rather in low amounts. The highest amount of calcium was observed in P5 soil ranging from 2.9 to 10.9 cm(p+)kg⁻¹ followed by magnesium in P5 soil ranging from 1.4 to 8.1 cm(p+)kg⁻¹. The sodium was present in low amount and varied between 0.50 to 2.67 followed by potassium ranged from 0.02 to 0.28 cm(p+)kg⁻¹.

These conflicting trends may be due to differences in parent material, maturity of profile, texture and intensity of leaching or aridity. (Kuhad, 1973).

Exchangeable sodium percentage and base saturation of soils : The base saturation was very high in the soils of all the studied profiles and varied between 85 to 100 per cent of the cation exchange capacity of soil. The highest value of ESP was observed in P4 soil which varied widely between 8.35 to 19.76 per cent.

Table 8 Cation exchange capacity and exchangeable cations of studied pedons.

DEPTH (cm)	HR	CEC cm(p+)kg-1	EXCHANGEABLE CATIONS cm(p+)kg-1				ESP %
			Ca ^{**}	Mg ^{**}	Na ⁺	K ⁺	
1	2	3	4	5	6	7	8
PEDON-1 (DHANI ALKHPUR-BHIWANI)							
0-20	Ap	16.04	8.10	5.60	1.81	0.09	11.28
20-43	A12	17.56	9.30	6.05	1.43	0.05	8.14
43-72	AC	17.68	7.40	8.20	1.27	0.07	7.18
72-107	C1	17.41	8.40	7.30	1.15	0.05	6.60
107-135	C2	16.08	7.70	6.80	1.00	0.05	6.21
PEDON-2 (BHIWANI ROHILLA-HISAR)							
0-17	Ap	13.86	7.5	5.3	0.69	0.05	4.97
17-38	C1	12.94	7.2	4.6	0.64	0.04	4.94
38-62	C2	9.95	5.2	3.8	0.61	0.02	6.13
62-140	C3	8.32	5.9	1.3	0.60	0.02	7.21
PEDON-3 (BAKRIAWALI-SIRSA)							
0-20	Ap	6.17	3.4	1.0	0.53	0.08	8.58
20-50	C1	7.26	4.3	2.0	0.50	0.09	6.88
50-137	C2	12.26	6.7	3.8	1.11	0.05	9.05
137+	C3	9.86	5.1	3.1	1.22	0.02	12.37
PEDON-4 (COTTON RESEARCH STATION-SIRSA)							
0-20	Ap	16.40	6.8	7.5	1.37	0.12	8.35
20-120	BC	11.53	7.0	2.1	1.90	0.06	16.47
120+	C1	8.60	4.3	2.2	1.70	0.04	19.76
PEDON-5 (BHAVDIN-SIRSA)							
0-22	Ap	19.20	9.4	7.5	1.41	0.12	7.34
22-60	IC	21.36	10.9	8.1	1.43	0.09	6.69
60-90	IIC	17.34	9.3	6.2	1.32	0.08	7.62
90-125	IIIC	10.40	6.4	2.5	0.85	0.05	8.16
125+	IVC	9.52	5.9	2.5	1.00	0.05	10.50
PEDON-6 (DHANI PREM NAGAR-HISAR)							
0-15	Ap	12.94	6.8	3.6	1.66	0.08	12.82
15-45	B11	15.11	7.3	4.7	2.67	0.05	17.67
45-105	B12	16.20	7.8	5.5	2.43	0.05	15.00
105+	C1	21.20	10.2	7.8	2.32	0.05	10.94

Contd....

DEPTH (cm)	HR	CEC cm(p+)kg-1	EXCHANGEABLE CATIONS cm(p+)kg-1				ESP %
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	
1	2	3	4	5	6	7	8
PEDON-7 (TIGRANA-BHIWANI)							
0-15	Ap	13.30	7.3	4.4	0.82	0.06	6.16
15-37	A12	13.47	6.7	4.8	0.68	0.04	5.04
37-75	AC	14.40	7.5	5.4	0.84	0.03	5.88
75-120	C1	8.75	4.7	2.9	0.87	0.03	9.94
120-150	C2	6.70	2.9	2.4	0.88	0.03	13.13
PEDON-8 (PENTA WAS-BHIWANI)							
0-15	Ap	10.9	6.8	2.6	0.78	0.28	7.15
15-30	A12	18.8	8.8	7.4	0.87	0.09	4.62
30-90	AC	14.7	8.9	4.7	1.00	0.06	6.80
90-135	C1	8.6	4.7	2.7	0.96	0.05	11.16
135-180	C2	7.34	4.3	1.4	0.97	0.03	13.21
PEDON-9 (MUNDHAL-BHIWANI)							
0-20	Ap	12.93	7.67	4.11	0.84	0.06	5.76
20-60	B11	14.56	9.20	4.45	0.69	0.05	4.73
60-105	B12	11.21	7.43	3.11	0.63	0.03	5.61
105-150	C	10.90	5.94	3.21	0.53	0.03	4.80
PEDON-10 (GULKANI-JIND)							
0-18	Ap	18.37	7.5	7.4	2.20	0.43	11.21
18-43	A12	19.62	9.3	6.5	2.54	0.37	12.94
43-65	IC	21.91	9.9	8.9	2.54	0.21	11.59
65-135	IIC	12.40	6.4	3.6	2.00	0.17	16.12
PEDON-11 (BAHUAKBARPUR-ROHTAK)							
0-15	Ap	13.34	6.1	4.4	1.27	0.24	9.52
15-38	A12	12.26	5.2	5.4	1.00	0.06	8.15
38-72	A13	10.33	4.1	5.1	0.90	0.02	8.71
72-110	C1	9.71	4.2	3.8	1.00	0.02	10.29
110-145	C2	8.30	3.5	3.4	0.91	0.03	10.96

4.2.5 Available nutrient status of soils :

The data revealed that the studied soils showed a wide variation in the nutrient status of the soils. Among the macro nutrients, the available N, P, K and S content of the studied soils was analysed. The content of the nutrients decreased with depth in soil (Table 9).

Available nitrogen : Data (Table 9) revealed that the studied soils are more or less deficient in available nitrogen content. The nitrogen content decreased with depth. The soil profiles P1, P2, P3, P5, P8 and P11 ranged widely from low to medium and their values ranged from 60.3 to 271 kg ha⁻¹. The available nitrogen in pedons P4, P6, P7, P9 and P10 from medium to high and their values ranged from 123.8 to 334.9 kg ha⁻¹. Generally the surface horizons of all the profiles had higher contents of available N which in most cases decreased with depth. The higher content of available N in surface horizons might be due to their higher organic carbon content. Similar findings were corroborated by Kumar (1989); Singh and Ahuja (1990).

Available phosphorous : The studied soils varied widely and the content of available phosphorous varied between 4.5 to 52.1 kg ha⁻¹ (Table 9). The soil profiles P1 and P2 were having low to medium phosphorous, whereas, soil profiles P3, P4, P5, P6, P7, P8, P9, P10 and P11 were having medium to high phosphorous ranged from 10.0 to 52.1 kg ha⁻¹. The available phosphorous status was in low to medium range and the pattern of distribution with depth varied among the profiles. In general, maximum accumulation of available P. was found in surface layers which decreased with depth or showed irregular pattern of distribution. Singh and Ahuja (1990).

Available potassium : The studied soils showed that the available

potassium present in the soils ranged widely from 91.4 to 949 kg ha⁻¹ (Table 9). The soil profiles P2, P3, P5, P6, P7, P8, P9 and P11 were low in available potassium whereas the soil profiles P1, P4 and P10 were sufficient in the available potassium content. It was observed that the distribution of available potassium was irregular with depth. Similar observations were reported by Singh and Ahuja, 1990.

Available sulphur : Available sulphur content in the profiles varied from 0.07 to 14.60 ppm (Table 9). The light textured soils were having low available sulphur and its content decreased with depth. Singh *et al.*, (1990). The soil profiles P2, P3, P5, P9 and P11 were deficient in available sulphur and were below 10 ppm whereas the soil profiles P1, P4, P6, P7, P8 and P10 were sufficient in the available sulphur having more than 10 ppm. Relationship of available sulphur with soil properties showed that the deficiency of available sulphur decreased with the increase in organic carbon content of the soil, but it has no systematic relation with soil pH and CaCO₃ content. (Gupta *et al.*, 1992).

Available micronutrients in soil profiles :

DTPA Zn : The content of DTPA-Zn in studied soils varied from 0.20 to 3.64 mg kg⁻¹ (Table 9). A highly significant coefficient of correlation ($r=0.60$) was observed between organic matter and DTPA-extractable Zn. Presumably, organic matter supplies complexing agents that promote the availability of certain elements (Hodgson 1963). DTPA-Zn was significantly correlated with silt ($r=0.15$), an observation supporting the findings of Katyial and Sharma (1991). Negative significant coefficient of correlation between DTPA-Zn and sand ($r=-0.13$) suggests that Zn availability decreased with an increase in sand content. A significant decrease in DTPA-extractable Zn in soils of

Table 9 Available nutrient status of the pedons.

DEPTH (cm)	HR	N	P	K	S	DTPA EXTRACTABLE			
						Zn	Cu	Mn	Fe
1	2	3	kg/hac 4	5	ppm 6	7	mg /kg 8	9	10
PEDON- 1(ALKHPUR - BHIWANI)									
0-20	Ap	211.8	23.5	598.6	14.60	0.94	1.14	12.48	2.80
20-43	A12	169.9	11.2	587.4	14.06	0.68	0.60	8.32	2.04
43-72	AC	149.7	5.70	531.4	10.30	0.43	0.60	8.88	1.98
72-107	C1	115.6	10.10	442.6	6.56	0.30	0.68	10.36	1.80
107-135	C2	95.8	6.90	365.7	11.95	0.36	0.48	7.02	1.44
PEDON - 2 (BHIWANI ROHILLA- HISAR)									
0-17	Ap	160.0	4.50	165.7	0.23	0.68	0.40	4.92	1.16
17-38	C1	162.4	11.20	123.2	0.46	0.68	0.464.86	1.16	
38-62	C2	149.3	13.40	139.7	0.26	0.62	0.34	3.16	0.94
62-140	C3	109.4	11.20	162.4	0.43	0.38	0.30	2.56	1.06
PEDON-3(BAKRIAWALI - SIRSA)									
0-20	Ap	122.0	31.4	231.4	2.81	0.88	0.60	7.76	1.44
20-50	C1	143.7	18.5	280.0	1.56	0.96	0.46	5.02	1.44
50-137	C2	112.4	11.2	114.2	9.92	0.58	0.26	3.56	1.00
137+	C3	86.2	10.1	91.4	6.56	0.40	0.34	4.08	1.44
PEDON - 4 (COTTON RESERACH STATION - SIRSA)									
0-20	Ap	219.7	19.6	438.6	4.76	0.68	0.70	5.16	2.32
20-120	BC	208.4	10.1	257.6	11.56	0.66	0.74	4.76	1.66
120+	C1	242.6	18.5	253.8	14.37	0.34	0.70	3.86	1.74
PEDON - 5 (BHAVDIN - SIRSA)									
0-22	Ap	213.7	25.7	369.7	8.75	0.68	1.34	5.86	6.28
22-60	1C	219.8	23.5	321.0	4.77	0.48	0.78	7.28	3.16
60-90	IIC	204.2	16.4	313.6	6.55	0.32	0.56	5.86	2.72
90-125	IIIC	213.7	17.3	157.4	4.25	0.56	0.32	6.00	1.36
125+	IVC	197.6	16.2	135.0	2.16	0.46	0.40	5.84	2.30
PEDON - 6 (DHANI PREM NAGAR- HISAR)									
0-15	Ap	147.7	22.6	224.6	11.17	0.98	0.58	10.98	9.96
15-45	B11	102.6	10.7	162.4	12.81	0.66	0.66	10.66	7.92
45-105	B12	86.3	8.8	168.0	13.90	0.48	0.66	8.86	8.22
105+	C1	42.4	7.3	124.4	13.42	0.56	0.54	6.72	5.82

Contd....

DEPTH (cm)	HR	N	P kg/hac	K	S ppm	DTPA EXTRACTABLE			
						Zn	Cu mg /kg	Mn	Fe
1	2	3	4	5	6	7	8	9	10
PEDON - 7 (TIGRANA - BHIWANI)									
0-15	Ap	144.6	21.4	175.4	3.82	1.18	0.66	4.90	2.28
15-37	A12	123.4	17.9	114.2	12.81	0.66	0.54	4.84	1.76
37-75	AC	84.6	14.7	112.1	8.77	0.44	0.44	4.30	1.62
75-120	C1	67.4	8.9	97.0	3.12	0.28	0.42	3.48	1.48
120-150	C2	44.3	7.6	74.6	1.58	0.28	0.38	3.32	1.44
PEDON - 8 (PENTAWAS - BHIWANI)									
0-15	Ap	176.7	27.6	392.0	8.08	0.96	0.62	9.56	2.24
15-30	A12	150.3	10.8	231.4	8.78	0.88	0.90	7.32	2.34
30-90	AC	131.2	24.6	119.4	9.14	0.62	0.86	5.94	2.16
90-135	C1	70.8	13.4	113.4	9.14	0.42	0.80	4.30	2.00
135-180	C2	60.3	10.6	91.4	11.53	0.52	0.40	2.56	1.54
PEDON - 9 (MUNDHAL - HISAR)									
0-20	Ap	273.4	17.3	194.1	0.07	0.92	0.68	9.80	3.06
20-60	B11	253.2	10.6	162.4	0.25	0.88	0.70	5.98	2.40
60-105	B12	208.4	11.2	134.4	0.26	0.52	0.50	4.40	1.76
105-150	C	196.3	29.1	112.0	0.27	0.74	0.40	3.70	1.78
PEDON-10 (GULKANI - JIND)									
0-18	Ap	334.9	52.1	949.0	13.43	3.64	5.8	16.46	9.51
18-43	A12	271.2	22.4	761.0	11.96	0.98	1.42	12.56	6.87
43-65	1C	224.3	34.1	796.5	8.04	0.64	1.24	11.18	4.71
65-135	11C	123.8	27.4	561.0	5.87	0.58	0.78	8.24	3.66
PEDON -11 (BAHU AKBARPUR - ROHTAK)									
0-15	Ap	171.0	25.9	328.5	1.09	0.28	0.92	6.24	3.49
15-38	A12	124.6	14.5	259.8	1.40	0.30	0.60	5.14	2.30
38-72	A13	98.2	17.3	235.2	0.79	0.26	0.50	3.82	1.80
72-110	C1	72.8	10.8	205.2	0.57	0.36	0.60	8.08	2.88
100-145	C2	42.4	7.4	194.1	0.48	0.20	0.26	2.30	0.98

sand dunes as compared to alluvial terraces is explained by a concomitant decrease in organic matter and clay (Gupta *et al.*, 1986; Sharma *et al.*, 1992).

DTPA-Cu : DTPA-extractable Cu varied between 0.26 to 1.38 mg kg⁻¹ soil (Table 9). DTPA extractable Cu was significantly correlated with organic matter ($r=0.64$), CEC ($r=0.36$), clay ($r=0.32$) and silt ($r=0.17$). DTPA Cu availability decreased in the coarse textured soils as compare to fine textured soils. Similar results were reported by Singh *et al.*, (1990). Negative significant correlation was observed between DTPA Cu and sand ($r=-0.27$).

DTPA Fe : The content of DTPA-Fe ranged from 0.9 to 9.96 mg kg⁻¹ soil (Table 9). The Fe content was related to texture. As the texture become finer, the mean iron content increased. The significant correlation between DTPA-Fe and Clay ($r=0.51$) showed that the fine textured soils contain high amount of DTPA-Fe. Similar findings were supported by Gupta *et al.*, 1986; Kuhad *et al.*, 1986 and Sharma *et al.*, 1992.

DTPA-Mn : The content of DTPA-Mn varied between 2.30 to 16.46 mg kg⁻¹ soil. (Table 9). The coarser the texture, the lower was the Mn concentration. The positive correlation coefficient was observed between DTPA-Mn and Clay ($r=0.55$) which implies that DTPA-Mn is more available in fine textured soils as compared to coarse textured soils. Similar results were corroborated by Benbi and Brar (1992) and Sharma *et al.*, (1992).

4.2.6 Saturation paste and extract analysis :

Saturation percentage is directly related to field capacity, clay content and clay minerals of soils. It equals approximately four times and two times the moisture held at wilting point and field capacity respectively (USDA Handbook no. 60).

The data as described in (Table 10) showed that the saturation percentage ranged from 19.5 to 40.5 per cent and have significant position correlation with the clay and silt content.

The pH of saturation paste (pHs) ranged between 6.16 to 8.8. The CEE ranged between 0.37 to 9.92 dsm^{-1} . Calcium followed by sodium and chloride followed by sulphate and bicarbonates dominated among the cations and anions in the saturation extract. Calcium ranged from 5.3 to 139.8 me/l followed by Na^+ with a range from 3.30 to 87.40 me/l. Mg^{++} varied from 1.8 to 66 me/l. The K^+ was present in low amount ranging from 0.25 to 4.70 me/l. These cations do not have any definite trend with respect to their depth distribution in the studied pedons. Generally, the depth distribution of cations first decreases and again increases in the lower horizons in same soil profiles. The high amount of soluble salts in the deeper layers may be due to calcareous nature of the parent material and also the result of leaching down from the solum to the lower depths.

Sodium is another dominant cation followed by potassium in the saturation extract. Sodium and potassium do not have any definite trend with respect to their depth distribution in these pedons, but it has been observed that sodium is much higher in salt-affected soils as compared to the pedons not affected by salinity and water logging.

Carbonates are absent in all the soils. Bicarbonates are present in all the soils under study with relatively low content in the soils which are not affected by salinity. Chloride and sulphate are the dominant anions followed by bicarbonates. Similar observation were reported by Kumar, 1987.

Table 10 Analysis of saturation extract of the studied pedons.

DEPTH (cm)	HR	SAT. %	PH	E/Ce ₁ dsm ⁻¹	SOLUBLE CATIONS				SOLUBLE ANIONS			
					Ca ⁺⁺	Mg ⁺⁺	Na ⁺	k ⁺	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻
1	2	3	4	5	6	7	8	9	10	11	12	13
PEDON - 1 (ALKHPUR - BHIWANI)												
0-20	Ap	30.0	8.07	5.44	100.0	66.0	24.34	1.75	-	47.9	128.3	14.0
20-43	A12	32.5	7.10	3.58	47.7	11.8	26.47	0.98	-	22.5	53.4	9.8
43-72	AC	33.25	6.95	2.86	12.1	9.4	7.52	0.74	-	8.0	13.6	6.3
72-107	C1	31.75	6.16	2.68	15.8	6.8	6.42	0.52	-	9.2	12.8	7.4
107-135	C2	30.75	7.30	1.95	18.6	8.2	8.43	0.68	-	10.8	20.9	4.6
PEDON - 2 (BHIWANI ROHILLA - HISAR)												
0-17	Ap	29.75	7.42	2.12	28.7	8.3	30.40	1.91	-	24.2	38.2	6.4
17-38	C1	26.50	7.90	1.27	14.8	11.2	23.81	0.82	-	9.4	37.6	2.3
38-62	C2	26.0	8.04	0.95	9.44	2.0	16.30	0.97	-	8.9	17.6	1.6
62-140	C3	22.0	8.14	0.86	17.0	4.0	15.21	0.96	-	9.8	22.4	2.4
PEDON - 3 (BAKRIAWALI - SIRSA)												
0-20	Ap	22.5	8.39	0.91	15.6	6.4	4.95	0.64	-	6.4	17.2	4.3
20-50	C1	26.75	8.09	0.14	17.5	7.6	6.91	0.82	-	8.2	19.6	6.7
50-137	C2	32.05	7.90	0.23	34.9	9.7	7.84	0.33	-	12.8	30.3	9.4
137+	C3	28.25	7.70	0.21	29.3	6.2	10.43	0.94	-	9.6	32.8	4.9
PEDON - 4 (COTTON RESERCH STATION - SIRSA)												
0-20	Ap	30.05	8.30	2.78	15.4	5.6	23.26	1.68	-	10.8	30.6	6.7
20-120	BC	29.25	8.05	4.68	24.8	7.8	34.43	2.70	-	19.70	41.3	8.9
120+	C1	38.75	7.91	4.78	19.6	7.3	47.82	0.91	-	16.06	46.7	9.4
PEDON-5 (BHAVDIN - SIRSA)												
0-22	Ap	34.00	8.76	2.32	24.9	8.2	20.6	1.55	-	17.30	31.6	4.7
22-60	IC	38.25	8.32	2.30	8.7	4.4	9.13	0.88	-	6.80	14.3	3.9
60-90	IIC	32.75	8.40	1.02	6.6	2.3	6.65	0.33	-	6.07	8.9	2.3
90-125	IIIC	28.05	8.10	0.92	15.8	7.4	8.14	0.44	-	9.40	17.4	2.6
125+	IVC	29.75	8.08	0.82	19.4	6.7	9.64	0.44	-	9.10	24.8	4.6
PEDON-6 (DHANI PREM NAGAR - HISAR)												
0-15	Ap	28.5	8.40	2.42	33.6	8.9	53.69	2.69	-	33.0	53.6	9.8
15-45	A11	30.25	8.40	1.66	11.3	3.2	44.65	1.79	-	22.8	33.5	7.4
45-105	A12	32.50	8.10	1.43	24.7	6.8	49.78	1.46	-	30.7	46.0	7.8
105+	C1	35.25	8.30	1.32	30.7	7.4	40.68	0.76	-	28.9	39.6	6.3

Contd....

DEPTH (cm)	HR	SAT.	PH	E/Ce_1 dsm ⁻¹	SOLUBLE CATIONS				SOLUBLE ANIONS			
					Ca ^{**}	Mg ^{**}	Na ⁺ cmolp*kg	k ⁺	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻
PEDON - 7(TIGRANA - BHIWANI)												
0-15	Ap	25.75	8.40	2.34	10.8	4.2	23.47	1.89	-	12.1	22.3	6.8
15-37	A12	29.50	8.40	2.11	16.10	6.9	33.52	1.94	-	18.8	36.4	4.2
37-75	AC	30.25	8.40	1.68	18.05	8.9	22.60	0.94	-	14.7	34.6	6.3
75-120	C1	22.50	8.10	1.84	10.07	3.8	26.68	0.87	-	15.6	21.6	2.9
120-150	C2	19.50	8.30	1.41	10.6	3.9	23.60	0.66	-	9.8	23.4	6.4
PEDON - 8 (PANTAWAS - BHIWANI)												
0-15	Ap	24.5	8.5	1.32	29.8	4.7	10.86	2.70	-	10.4	38.6	2.4
15-30	A12	30.25	8.2	3.44	74.9	7.6	17.39	1.94	-	14.6	81.6	4.2
30-90	AC	29.75	7.9	4.66	139.8	22.6	42.39	1.89	-	18.4	176.6	6.3
90-135	C1	21.75	7.9	4.58	136.7	30.8	78.26	1.36	-	57.9	186.6	2.9
135-180	C2	23.50	7.8	4.58	132.6	25.9	73.86	1.95	-	53.6	175.4	6.4
PEDON - 9 (MUNDAL - BHIWANI)												
0-20	Ap	21.75	8.2	1.33	81.4	59.6	10.86	4.70	-	53.4	98.4	5.6
20-60	B11	27.25	8.4	1.01	29.2	9.3	4.04	2.30	-	13.2	27.6	4.3
60-105	B12	26.25	8.4	0.86	18.2	7.8	3.30	2.21	-	9.7	19.4	1.6
105-150	C	24.50	8.4	0.50	14.4	5.6	13.04	1.36	-	12.3	19.8	1.4
PEDON - 10 (GULKANI - JIND)												
0-18	Ap	35.0	8.2	4.62	20.1	8.4	87.40	2.70	-	13.9	98.6	6.7
12-43	A12	37.25	8.6	2.26	25.2	5.9	56.52	1.95	-	10.4	74.4	4.2
43-65	IC	40.50	8.3	1.68	8.3	2.9	15.21	1.84	-	7.8	17.8	2.4
65-135	IIC	29.50	8.2	0.59	6.9	1.8	7.10	0.85	-	5.9	9.6	1.8
PEDON -11 (BAHU AKBARPUR - ROHTAK)												
0-15	Ap	28.75	8.8	1.46	7.2	3.8	12.28	1.46	-	8.6	13.9	2.3
15-38	A12	26.50	8.6	1.23	10.8	6.7	14.63	1.38	-	9.3	21.6	3.8
38-72	A13	22.33	8.4	1.35	7.9	5.4	16.26	0.88	-	11.5	16.8	2.6
72-110	C1	23.50	8.5	0.38	6.7	4.8	20.56	0.34	-	13.8	16.1	3.1
110-145	C2	20.75	8.3	0.37	5.3	4.6	8.62	0.25	-	7.1	10.77	0.9

4.3 Clay Mineralogy :

From the X-ray diffractograms shown in (Figs. 19 -29), it is observed that the overall mineralogy of the profiles of the studied area is more or less similar and mixed except quantitative distribution of minerals (Table 11) . The dominant clay mineral is illite ranging between 25-57 per cent. Other associated minerals in clay fractions were kaolinite, chlorite, vermiculite, smectite and interstratified minerals. Small amount of quartz and feldspars were also observed.

High amount of smectite and vermiculite (Table 11) in the sub-surface horizons of the profiles showed the increasing trend with depth, whereas mica content decreased in the same direction. This is obviously due to translocation of smectite and vermiculite with fine clays to sub-surface layers rather than transformation of mica to smectite in these layers. The high amount of swelling type of minerals is contrary to the findings of earlier workers (Shanwal, 1984; Shanwal *et al.*, 1988; Shanwal and Ghosh 1985; Shanwal and Ghosh, 1987; Shanwal and Ghosh, 1989; Shanwal *et al.*, 1989a; Shanwal *et al.*, 1993; Kapoor *et al.*, 1980; 1981, 1982) on the alluvium of Indo-Gangetic Plain in Haryana. This unexpected high amount of swelling type of clay minerals (smectite and vermiculite) may be attributed to the irrigation (canal as well tubewell) introduced in the cotton growing areas which is ultimate responsible for the chemical weathering of the alluvium. The transformation of mica has apparently been taken place in epipedon.

This is also supported by the presence of inter stratified minerals in fair amount (7 to 12 per cent).

The weathering of mica may have followed the sequence :

Table 11 Semi-quantitative (%)estimation of minerals in clay fraction (<2.0) of soils.

DEPTH	HR	Mica(illite)	Kaolinite	Chlorite	Smectite	Vermiculite	Quartz	Feldspar	Inter stratified min.
1	2	3	4	5	6	7	8	9	10
PEDON - 2 (BHIWANI ROHILLA - HISAR)									
0-17	Ap	35	10	8	15	14	3	4	11
38-62	C2	39	11	6	12	11	4	5	12
PEDON - 4 (COTTON RESERCH STATION - SIRSA)									
0-20	Ap	57	12	8	5	3	3	3	9
120+	C1	50	10	7	12	7	3	2	9
PEDON - 5 (BHAVDIN - SIRSA)									
0-22	Ap	42	13	6	10	11	6	5	7
60-90	IIC	32	11	8	16	17	5	3	8
PEDON- 8 (PENTAWAS - BHIWANI)									
0-15	Ap	36	12	6	18	10	4	4	10
30-90	AC	25	12	7	21	20	4	2	9
PEDON 9 (MUNDHAL - BHIWANI)									
0-20	Ap	49	11	7	5	8	6	5	9
105-150	C	44	12	7	8	12	5	4	8
PEDON - 10 (GULKANI- JIND)									
0-18	Ap	60	8	7	6	4	4	4	7
65-135	IIC	41	12	8	14	7	4	6	8

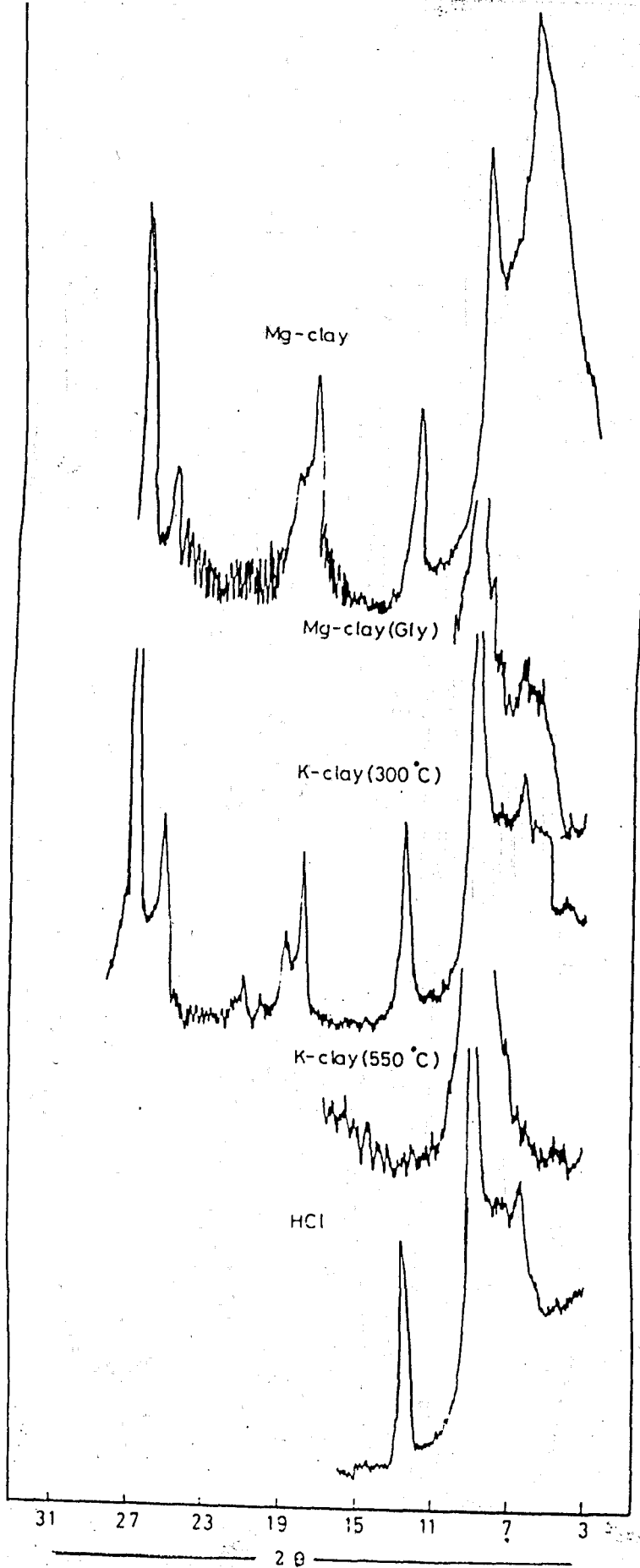


FIG.19 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 2 (SURFACE)

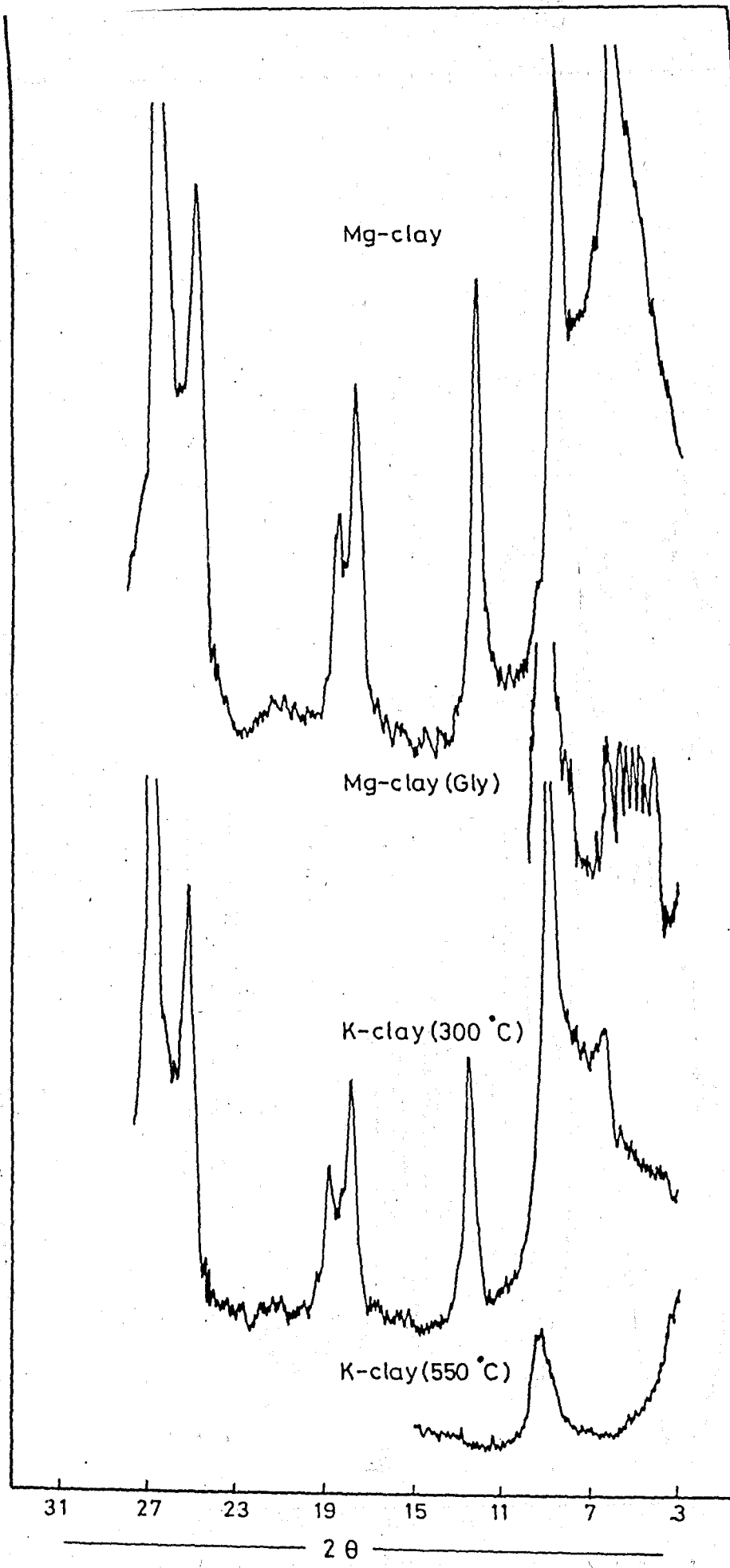


FIG.20 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 2 (SUB-SURFACE)

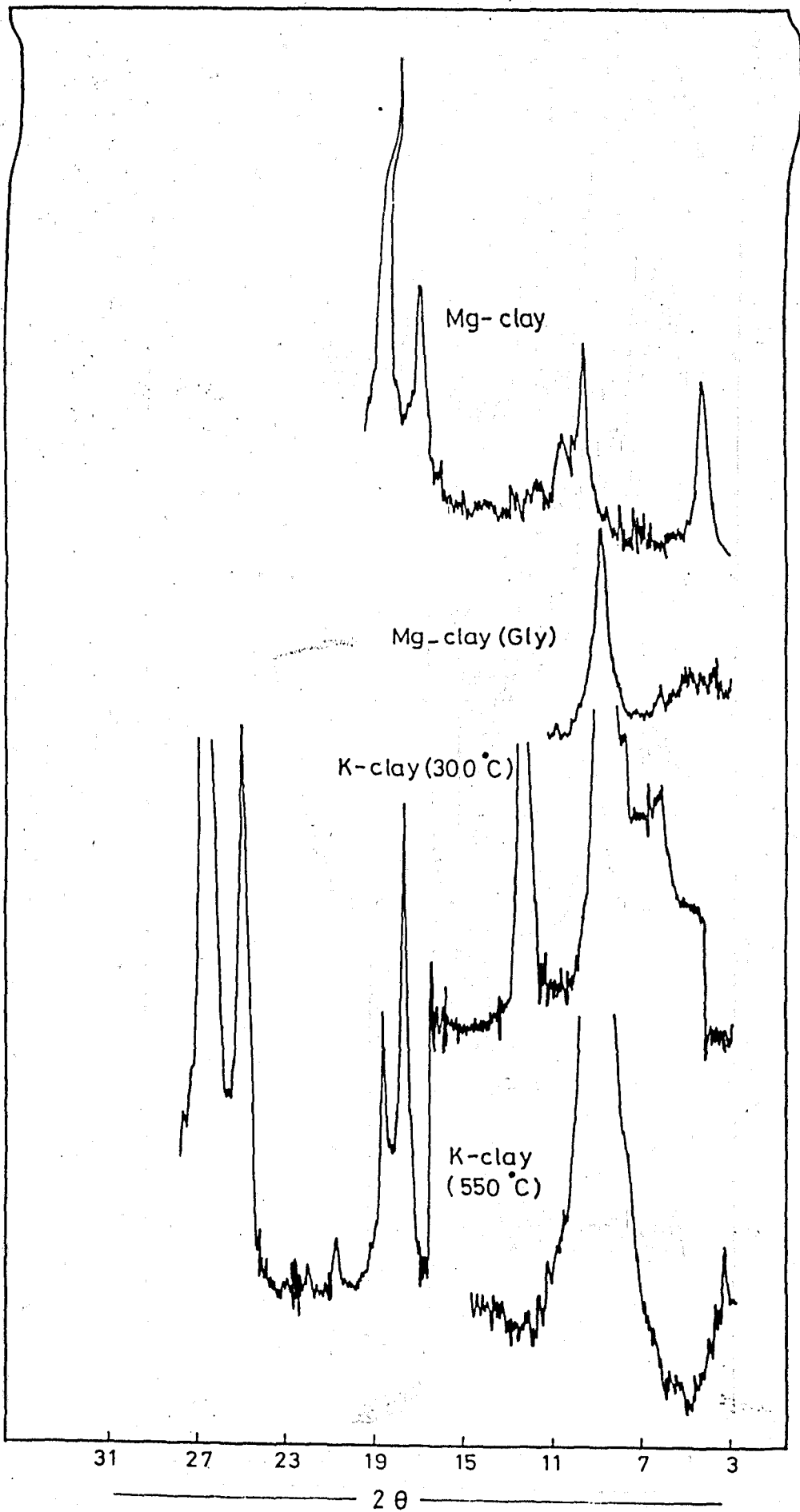


FIG. 21. X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 4 (SURFACE).

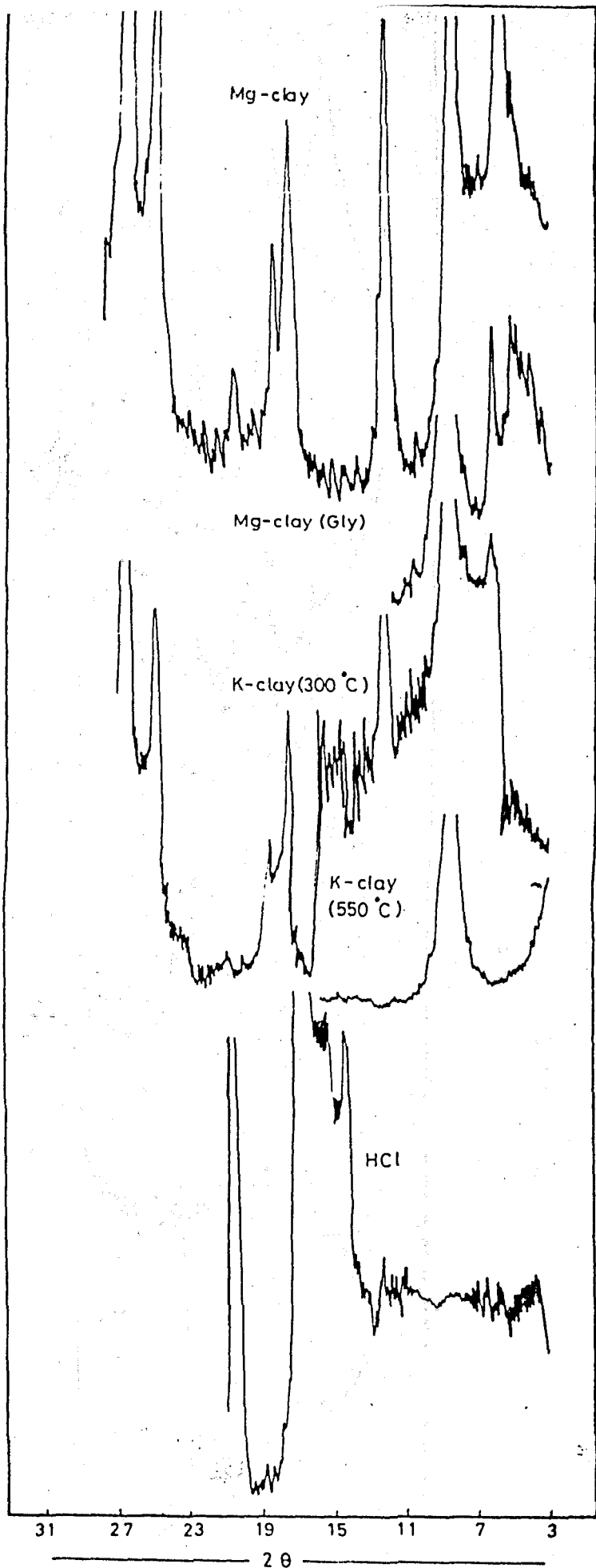


FIG.22 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 4 (SUB-SURFACE)

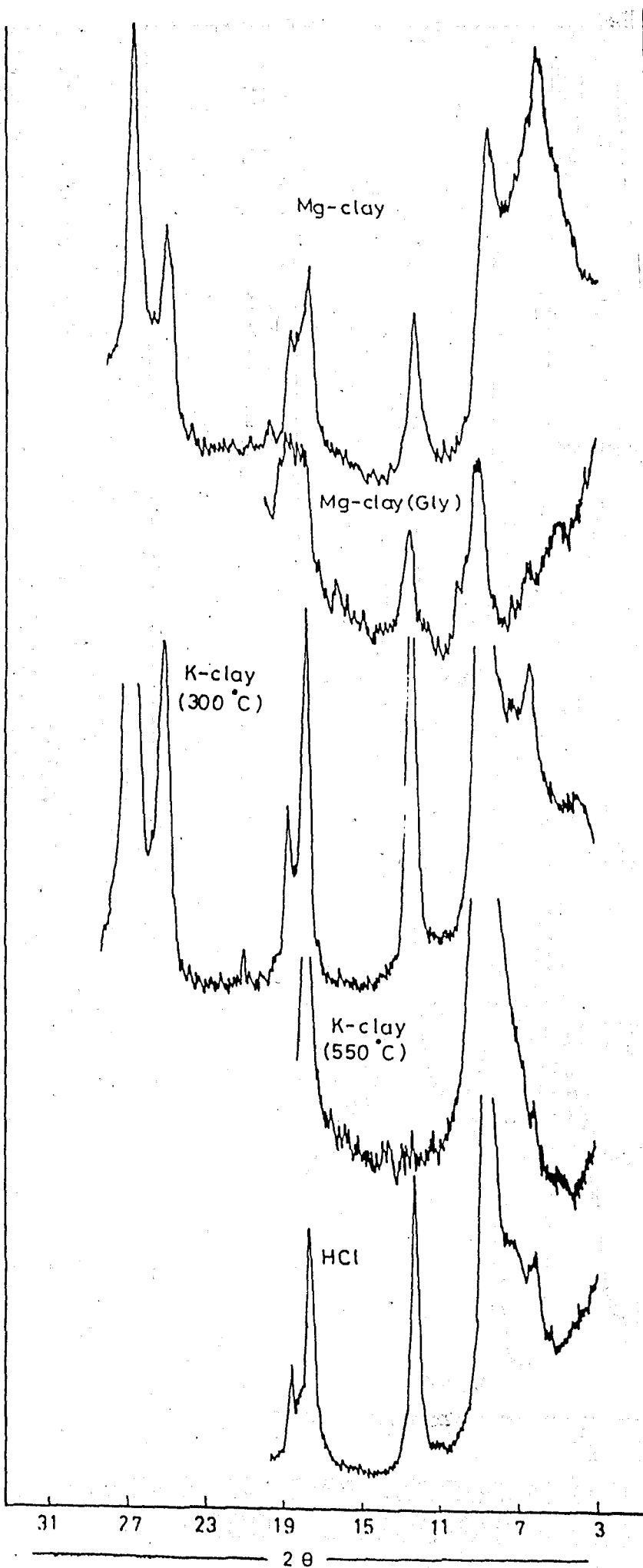


FIG.23 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 5 (SURFACE)

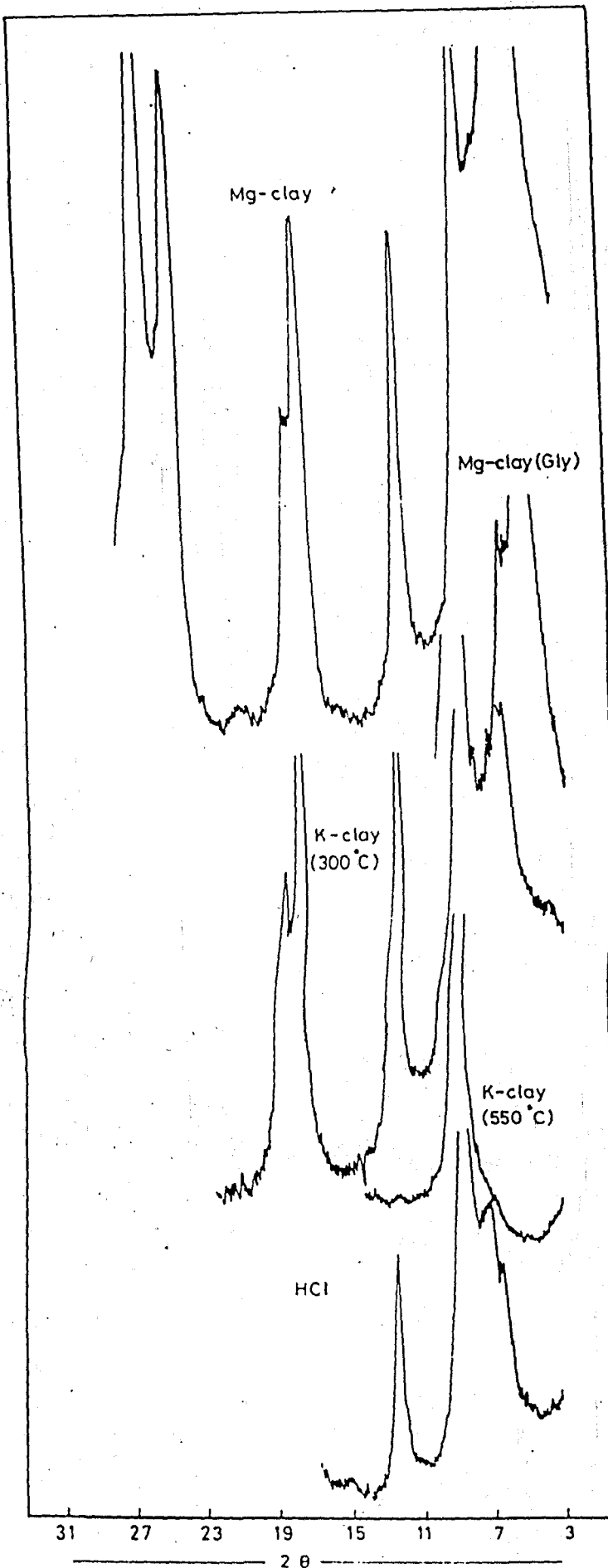


FIG.24 X RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 5 (SUB-SURFACE)

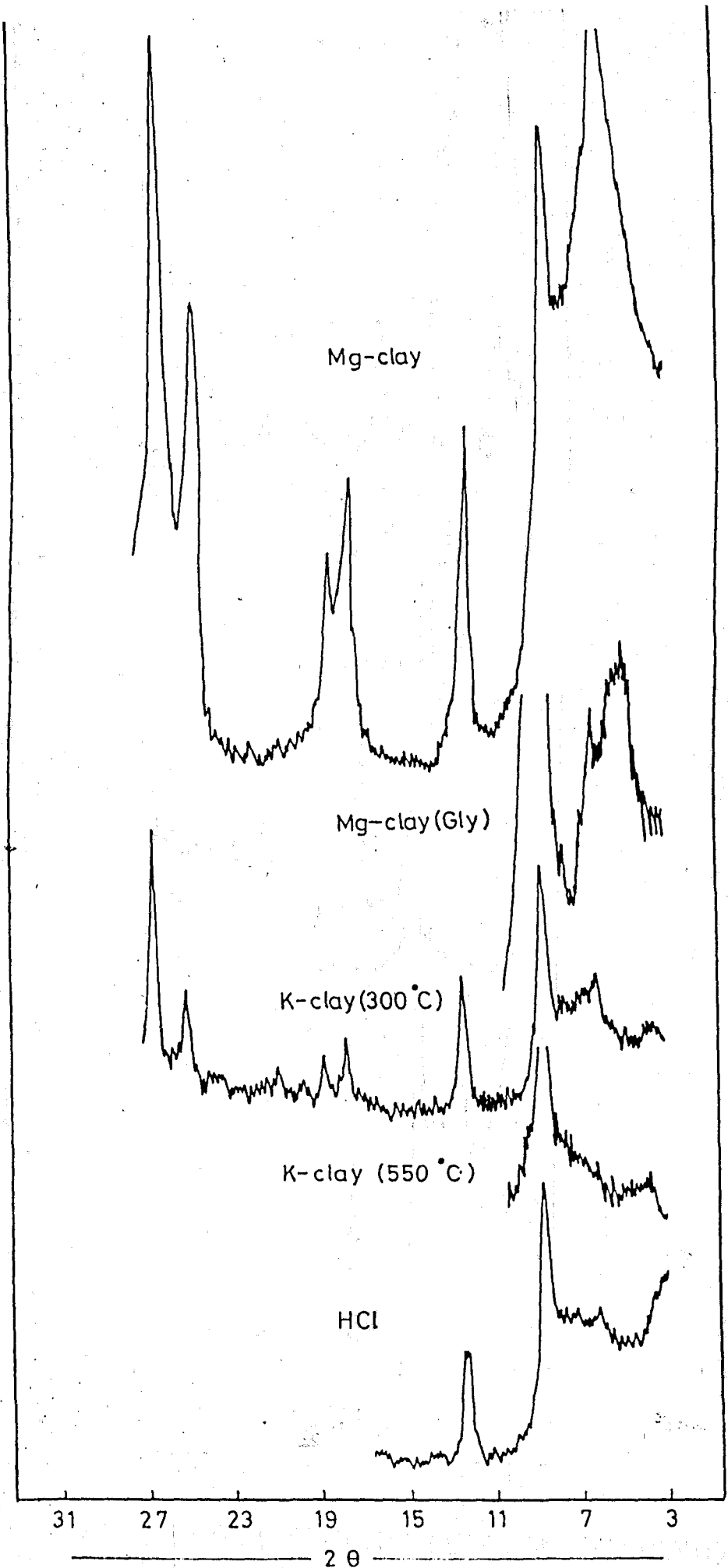


FIG.25 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 8 (SURFACE)

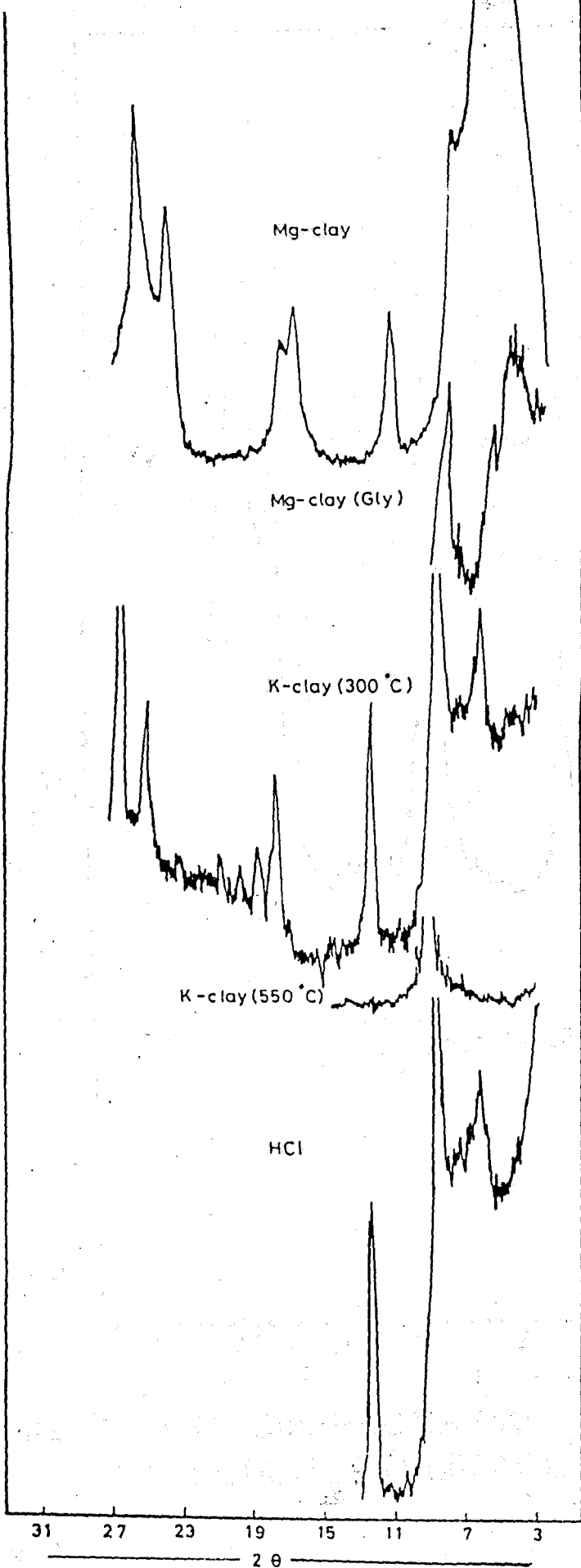


FIG.26 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 8 (SUB-SURFACE)

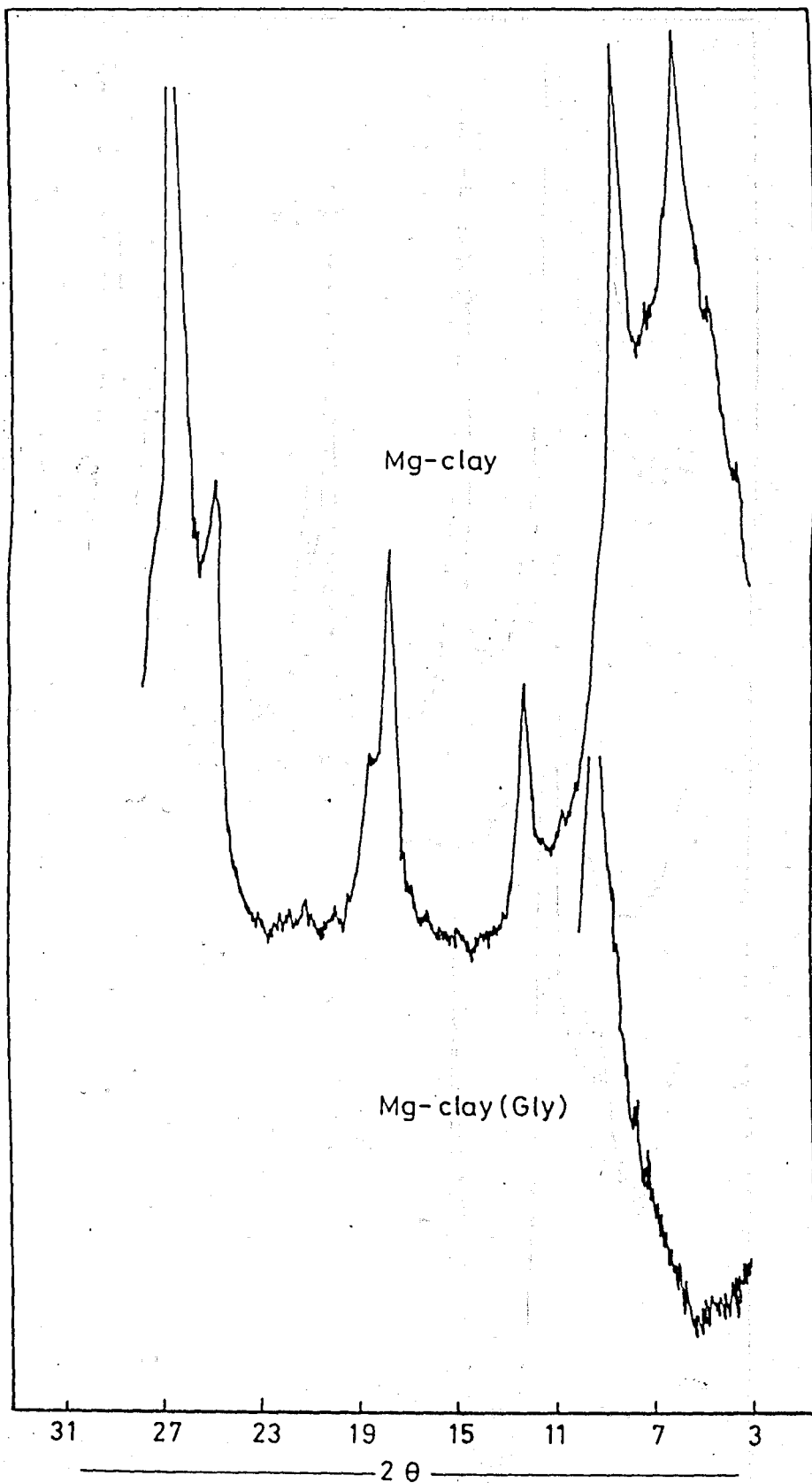


FIG.27 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 9 (SURFACE)

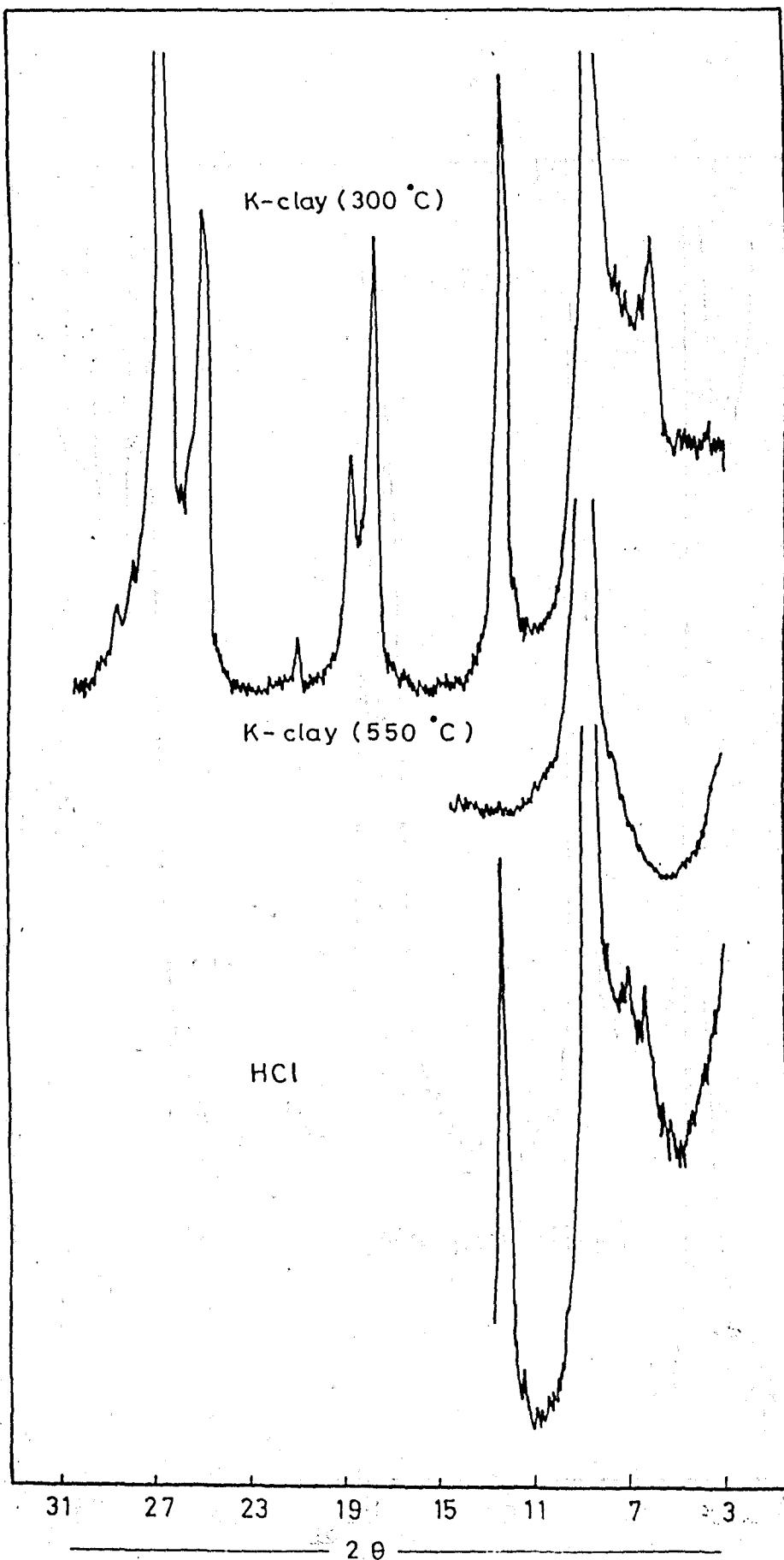


FIG.28 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 10 (SURFACE)

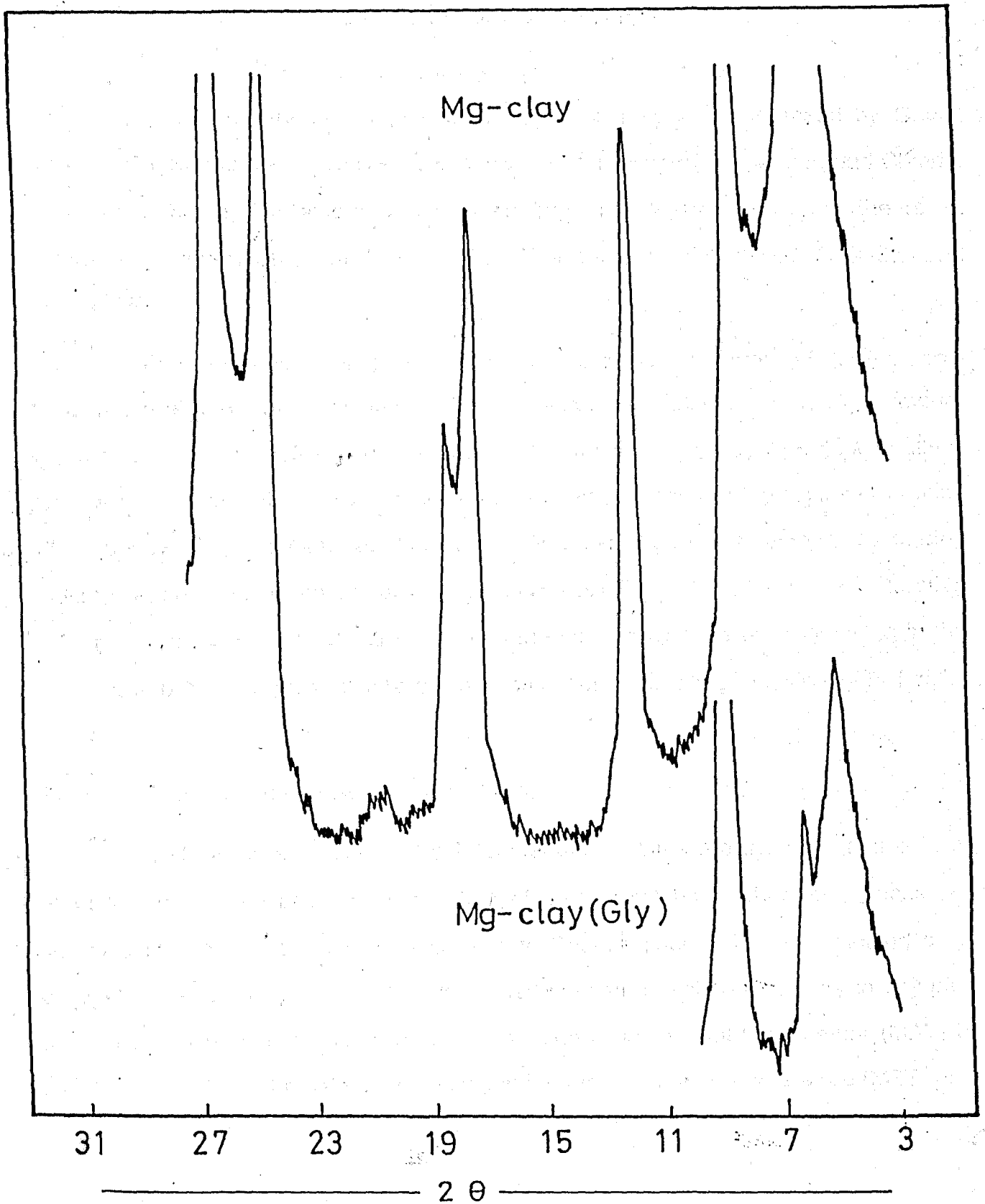
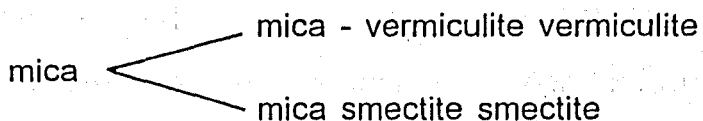


FIG.29 X-RAY DIFFRACTOGRAM OF CLAY FRACTION IN PEDON 10 (SUB-SURFACE)



Similar weathering sequence of mica has also been proposed by Ghosh *et al.*, 1976; Kapoor *et al.*, 1981 and Shanwal and Ghosh 1986). Kaolinite and Chlorite appears to be of detrital origin. These findings are in agreement with the result of earlier studies (Shanwal 1984; 1992; Shanwal and Ghosh, 1987, Sidhu and Gilkes 1977).

From the above mineralogical study it is evident that the soil forming processes like eluviation and illuviation are very active as indicated by the high amount of smectite and vermiculite in sub-surface diagnostic horizons. The chemical weathering seem to be still at low level as indicated by the presence of high amount of mica and detrital origin of chlorite and kaolinite. This is expected in the alkaline weathering environment of the soils characterized by alkaline pH (7.9 to 9.1), high base saturation (>85 per cent) and salt concentration. Thus the soils appears to be very young in the time scale but still represent intermediate stage of weathering showing high fertility status.

4.4 Soil Classification :

Soil moisture regime and soil temperature regime are the important parameters for soil classification. Determination of these regimes is, therefore, necessary before classification of the soils according to Soil Taxonomy. In these studied soils except for the region of pedon³ the soil moisture control section is not dry in any part for as long as 90 cumulative days in a year. The mean annual temperature (MAT) is more than 22°C and the differences between the mean summer temperature (MST) and

mean winter temperature (MWT) is more than 5°C (Table 12). So the areas qualify for ustic moisture regime and hyperthermic temperature regime

Based on measurable morphological, physico-chemical, mineralogical characteristics and climate data, the soils have been classified according to the criteria of Soil Taxonomy (Soil Survey Staff, 1975) into three orders i.e. Entisols, Inceptisols and Aridisols. (Table 12).

The pedons P1, P4, P7, P8 and P11 qualified for the order Entisols due to lack of diagnostic horizon at sub-surface level. Owing to the presence of light coloured surface horizon with little organic carbon and further classified as ustorthents at great group level due to ustic soil moisture regime. Because of mixed mineralogy and hyperthermic temperature regime these soils belong to mixed, hyperthermic family of Ustorthents.

The pedons P2 and P3 are characterised by the presence of coarser texture and classified as psamments at the sub order level. At the great group level the pedon P2 is classified as Ustipsamments because of Ustic moisture regime whereas the pedon P3 is characterised by torric moisture regime qualify for Torripsamments. Due to mixed mineralogy and hyperthermic temperature regime, these soils belong to mixed, hyperthermic family.

Pedon 6 showed the development of blocky structure due to alternate wetting and drying cycles is suggestive of alternation of original sediments and development of cambic horizon. The light coloured soils with ochric epipedon underlain by cambic horizon having torric moisture regime is classified in order Aridisol, suborder Orthids, great group camborthids and sub group Typic.

The pedons P5 and P10 are classified as Entisols because of absence of diagnostic horizons except for ochric epipedon are qualified for Fluvents at suborder level, Ustifluvents at great group level. P9 soil profile is classified into Inceptisols due to few diagnostic features at order level and characterised by ochrepts. Because of the presence of thin, light coloured surface horizons with little organic matter and further classified as Ustochrepts at great group level due to Ustic soil moisture regime.

Table 12 Classification of studied pedons.

Pedon	Order	Suborder	Great group	Sub group	Family
P1	Entisols	Orthents	Ustorthents	Typic Ustorthents	Fine, Loamy, Mixed hyperthermic
P2	Entisols	Psamments	Ustipsamments	Typic Ustipsamments	-do-
P3	Entisols	Psamments	Torrripsamments	Typic Torrripsamments	-do-
P4	Entisols	Orthents	Ustorthents	Typic Ustorthents	-do-
P5	Entisols	Fluvents	Ustifluvents	Typic Ustifluvents	-do-
P6	Aridisols	Orthids	Camborthids	Typic Camborthids	-do-
P7	Entisols	Orthents	Ustorthents	Typic Ustorthents	-do-
P8	Entisols	Orthents	Ustorthents	Typic Ustorthents	-do-
P9	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	-do-
P10	Entisols	Fluvents	Ustifluvents	Typic Ustifluvents	-do-
P11	Entisols	Orthents	Ustorthents	Typic Ustorthents	-do-

4.5 Land evaluation :

The profile characteristics of soils (Table 14) from different climatic zones suggest that studied soils vary in respect of drainage conditions, texture, profile development, fertility status, lime and salt content.

Rating tables for the soils and site parameters for cotton (Table 13) have been prepared taking into account the rating tables given by Riquier *et al.*, (1970), Sys (1981) FAO framework (1976) and Sehgal (1986). Using class criteria out lined in suitability tables for cotton the land characterisables of studied pedons were expressed in terms of degree of limitation from 0 to 4 and rating assigned to each parameter and the productivity index or land coefficient calculated using the procedure outlined by Riquier *et al.*, (1970). The soil-site characteristics were evaluated based on the criteria of FAO framework (1976), Sys (1981) and expressed in terms of their degree of limitations.

Basic soil parameters such as drainage, depth, texture, carbonates etc. as well as meterologic factors like rainfall and temperature were evaluated.

Soil depth is an important criterion for land evaluation. Most crops produce excellent yields with an effective root zone depth of 90-100 cm. Sys (1981). It is evident that cotton is successfully grown in deep soils. The field studies on soils (NBSS Staff, 1986; Bhaskar et al, 1987; Sehgal *et al.*, 1989) suggested that a depth of 100-120 cm is optimum for cotton cultivation.

The soils having 60-100 cm depth support good crop; and others having less than 60 cm depth are not economical to grow cotton (Bhaskar *et al.*, 1987). The depth of 50 cm was considered critical below which cultivation of cotton becomes marginally economical or uneconomical.

Table 13 Climatic and soil-site suitability requirements of cotton at different degrees of limitation.

Soil-Site Characters	Range in the degree of limitation				
	0 S1	1 S2	2 S3	3 N1	4
Topography (t)					
Slope (%)	0-1 (100)	1-2 (90)			
Climatic Requirements					
Mean Temp. during growing season (°C)	28-26	26-24	24-22	22-20	20
Mean Max. Temp. during growing season °C	35-32	32-28	28-26	26-24	24
Mean R.H. in growing season	50	50-60	60-70	70-80	80
Characteristics of wetness limitations					
1. Med & fine textured soils	Well (100)	Moderate (90)	Imperfect (80)	Poor (70)	20
2. Coarse textured soils	Imperfect (100)	Moderate (90)	Well (70)		
Physical soil condition	Sil, Scl 100	SI+II 90	SI-SC (80)	Ls, SIC 5(45)	Stc, (40)
Lime (%)					
Stoniness	5 (100)	5-15 (90)	15-40 (80)	40-80 (60)	+80 (25)
Soil Depth. (cm)	+120 (100)	80-120 (90)	50-80 (75)	20-50 (55)	-20 (30)
Fertility (+) (Profile Development)	Bw (100)	A-C (90)	Bt (80)	Bn	-

Contd....

Soil-Site Characters	Range in the degree of limitation				
	0 S1	1 S2	2 S3	3 N1	4
Characteristics with regard to fertility					
Org. carbon % (0-15 cm)	0.6 (100)	0.6-0.64 (90)	0.4-0.2 (80)	0.2 (70)	
CEC (cmol(p+)kg) (Bhorizon)	16 (100)	16-12 (90)	12-8 (80)	8-4 (70)	
Available water					
AWC mm/m	150	100-150	75-100	50-75	50
Salinity and alkalinity					
E.C. (dsm ⁻¹)	0-2 (100)	2-4 (90)	4-6 (85)	6 (80)	
Na-saturation (ESP)	20 (100)	20-30 (90)	30-40 (85)	40 (80)	
Base-saturation	All the soils are saturated with bases				

Source : Sys, C. 1981

Table 14 Characteristics of the studied pedons.

Drainage (m)	Texture		Lime %	CEC cmol kg ⁻¹ O.C. (sur) %	Fertility	Salinity (ECe)		Profile Dev
	Sur.	Sub-Sur (50-100 cm)				Sur.	Sub-Sur	
Pedon-1	Mod. Well	SCL (20-22) SCL (21-23)	0.2-0.3	17.4	0.27	6.0	1.96-3.6	AC
Pedon-2	Imperfect	SL (13-17) SL (10-17)	2.4	9.10	0.06	2.2	0.86-1.27	C1
Pedon-3	Well	LS (11-15) SL (14-18)	2.2	10.20	0.01	0.91	0.14-0.21	C1
Pedon-4	Mod. Well	SCL (16-20) L (10-16)	1.5	11.40	0.10	2.8	4.6-5.0	BC
Pedon-5	Mod. Well	SCL (27) L (14-28)	1.0	19.40	0.07	2.5	0.82-2.3	IIC
Pedon-6	Well	SL (18-21) SCL (18-28)	0.2	16.20	0.21	2.5	1.3-1.7	A11
Pedon-7	Well	SL (15-17) SL (8-17)	0.9	11.62	0.25	2.5	1.4-2.2	BC
Pedon-8	Imperfect	SL (14) SL (10-23)	5.7	11.64	0.33	1.3	3.4-4.6	AC
Pedon-9	Well	SL (15) SL (15-18)	5.1	12.24	0.34	1.4	0.50-1.1	B11
Pedon-10	Mod. Well	SCL (22) CL (30)	2.2	16.43	0.83	4.7	0.59-2.3	A12
Pedon-11	Mod. Well	SL (19) SL (10-19)	2.5	9.62	0.42	1.5	0.37-1.3	A13

Free lime has an antagonistic effect on the availability of some plant nutrients, high lime content in soils, in general, is considered one of the major determinants of crop yield. (Landon, 1984).

The yield response to moisture storage in the solum indicate that maximum yield of cotton could be obtained at 220 mm of available water capacity. Cotton being a long duration crop, even with its deep rooting system, it experiences significant decline in yield in soils having low (100 mm) moisture storage. Texture is considered important and its influences can be modified by structure. (Table 13).

Based on the above considerations the studied soils are matched with the soil-site criteria for cotton. The kind and degree of limitations and suitability class were determined and evaluated (Table 13). It showed that all the soils are not equally suitable for cotton. Some are well suitable, others moderately suitable or even suitability is low for cotton.

Productivity ratings for cotton :

Data in (Table 15) showed that the productivity ratings for the studied soils for cotton varied widely (29 to 81 per cent). The productivity rating index is highest in P10 and P11 soils as the soils are well drained and medium textured (SI//SCI) except for P10 soils which have clay loam texture in the deep soil. They qualify for ustic zone in semi arid region with hyperthermic temperature regime. These medium textured soils favour unrestricted development of roots, good aeration and hence higher productivity. The productive index of P10 and P11 soils was 81 and 72 per cent followed by yield of cotton 25 and 23 qha⁻¹, respectively at the recommended level of management (Fertilizer, Water etc.).

Table 15 Evaluation of soil types for cotton according to soil-site characteristics.

Profiles	Drainage		Texture		Lime %	Fertility		Profile Dev.	Salinity	Land Coeff.	Yield qha ⁻¹
	Sur.	Sub-Sur	Sur.	Sub-Sur		CEC	O.C.				
P1	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	2 (80)	1 (90)	2 (80)	58	17
P2	2 (80)	0 (100)	1 (90)	0 (100)	1 (90)	2 (80)	3 (70)	2 (80)	1 (90)	29	9
P3	1 (90)	2 (80)	1 (90)	1 (90)	0 (100)	1 (90)	3 (70)	1 (90)	0 (100)	37	7
P4	0 (100)	0 (100)	0 (100)	1 (90)	0 (100)	1 (90)	3 (70)	1 (90)	1 (90)	46	14
P5	0 (100)	0 (100)	0 (100)	0 (100)	1 (90)	0 (100)	3 (70)	0 (100)	1 (90)	57	17
P6	0 (100)	1 (90)	0 (100)	0 (100)	0 (100)	0 (100)	2 (80)	0 (100)	1 (90)	65	20
P7	0 (100)	1 (90)	1 (90)	1 (90)	1 (90)	1 (90)	2 (80)	0 (100)	1 (90)	46	15
P8	2 (80)	1 (90)	1 (90)	0 (100)	1 (90)	1 (90)	2 (80)	1 (90)	0 (100)	42	13
P9	0 (100)	1 (90)	1 (90)	1 (90)	2 (85)	1 (90)	2 (80)	0 (100)	0 (100)	50	16
P10	0 (100)	0 (100)	0 (100)	0 (100)	1 (90)	0 (100)	0 (100)	0 (100)	1 (90)	81	25
P11	0 (100)	1 (90)	1 (90)	1 (90)	0 (100)	1 (90)	0 (100)	0 (100)	0 (100)	72	23

The P1, P5 and P6 soils with productive rating index varied between 57 to 65 have light to medium texture (S/I/L) in the surface horizons and relatively heavy texture (SCL/L) in the sub-surface horizons. They qualify for fine loamy family. They have blocky structure in the sub soil. These soils show the characteristics of low organic carbon content, high lime content and high salinity. The productive rating index of P6 soil was 65 per cent with good profile development and heavy texture (Scl/I) at the sub surface horizon produced yield of 20qha⁻¹ whereas the productive rating index of P1 and P5 was 57 and 58 with cotton yield 17 qha⁻¹, respectively. (Table 15).

The soil profiles P7 and P9 are poor in surface and sub-surface texture with moderate drainage. The major limitations are low cation exchange capacity and low fertility characteristics. The productive index of P7 and P9 was 46 and 50 per cent with yield varied from 15 to 16 qha⁻¹, respectively, (Table 15). Considerable reduction of cotton yield had been reported by Sehgal (1991) due to limitations regarding, salinity, low fertility and drainage characteristics.

The P4 and P8 soils with poor texture at surface, moderate drainage, low fertility characteristics and high salinity conditions resulting in the low productivity rating index of 46 and 42 with the yield of cotton in these two soils 14 and 13 qha⁻¹ respectively. (Table 15).

Low yields in P2 and P3 soils with the poor drainage showing the poor profile development with low fertility conditions suffering from high salinity. The two pedons have low clay content in the surface and sub-surface horizons. The productivity index of P2 and P3 was 29 and 37 with cotton yield 6 and 7 qha⁻¹ respectively. (Table 15).

It may be concluded that medium textured, well drained with good profile development having low salinity level soil of P10 and P11 having coefficient between 72 to 81 are best suited for cotton cultivation. The soil profiles P1, P5, P6, P4, P8 are marginally suitable for cotton whereas P2 and P3 are low suitable for cotton cultivation due to increase in the degree of limitations.

The validity of land coefficients (LC) is supported by the linear regression equation, $Y_c = -3.79 + 0.368 LC$ ($r = 0.97$) relating to yield of cotton (Y_c) obtained under recommended package of practices.

Highly significant positive correlation at 1 per cent probability level between cotton yields and land coefficients suggests that the soil parameters used for calculating land coefficients are responsible for variation in crop productivity.

CHAPTER V

SUMMARY AND CONCLUSION

The environment and soil characteristics have profound influence on the growth of crops and their yield capacity. Optimum production potential of crops is controlled by crop genetic factor, edaphic environment features, agro management and soil-site factors. The land capacity system as such finds little application for judging crop suitability of soils. Other productivity indices and suitability ratings using parametric and limitation approaches thus need to be tested for major crop of the region like cotton in relation to actual yields under defined management practices. In view of this, present study was undertaken to characterize, classify and evaluate suitability of the dominant soils for cotton in different places of Haryana.

Eleven soil profiles representing cotton growing soils under simple fertilizer practices varying in texture, drainage, lime content, salts and profile development were studied for morphological, physico-chemical and mineralogical characteristics and classified. The productivity of the soils was evaluated using parametric and limitation approaches and ratings for variables like moisture, drainage, organic matter, CaCO_3 , sodium saturation, texture/structure, nature of clay/exchange capacity and soluble salts. The correlations between the productivity index ratings and average yields were worked out to find out the reliability of these ratings.

5.1 Morphological characteristics :

Soil colour : The colour of the studied pedons varied between the hues of 2.5Y and 10YR with a dominant hue of 10YR. The values ranged from 3 to 8, whereas chromas were 6 or less. Few fine mottles were present in the lower horizons. The

colour of the studied pedons depend on drainage conditions, profile development and fertility status of the soils.

Texture : The texture of the studied pedons varied from loamy sand to clay loam. The wide variations in texture found in the area seem to be controlled by geomorphological process governing the deposition of sediments.

Structure : The structure of the studied pedons was dominantly massive in the subsurface horizons with surface horizons having weak to moderate, fine to medium subangular blocky. The soils with blocky structure indicates the alternation of original material by pedogenic factors and process.

5.2 Physico-chemical characteristics :

Particle size distribution : The studied soils showed appreciable variation in particle size distribution. The sand content was highest in P2 soil (83.2%) followed by lowest in P10 (28.6%) soil. The silt content was highest in P10 (48.0%) soil with lowest in P3 (6.0%) soil. The clay content was highest in P10 (30.2%) soil with lowest in P2 (10.0) soil.

Moisture retention and available water storage capacity : Cotton growing soils were found to differ in their available water storage capacity depending upon the texture and organic carbon of various horizons in their profile. On the basis of total available water holding capacity, these soils were grouped into the categories : (i) low, available water holding capacity less than 20 cm which includes P1, P2, P3, P6, P8 and P11 soil profiles (ii) medium, available water holding capacity between 20 to 30 cm. having P4, P5, P7, P9 and P10 soil profiles.

Typical moisture retention curves for ten different textural classes have been presented and its relationship with moisture tension and availability discussed.

Clay and silt fractions of soils were found to have a positive and significant correlation with available water (r' being 0.473 and 0.538, respectively). Positive and significant correlation coefficient ($r = 0.37$) was observed between available water and cation exchange capacity.

Soil reaction (pH) and electrical conductivity : The pH values (1:2) of the studied soils varied from 7.9 to 9.1 and in general, increased with depth. Comparatively, low pH values in the surface horizons might be due to the removal of soluble salts from the surface horizons with percolating water, crop removal and root exudation.

The electrical conductivity (1:2) of the studied soils was low (0.08 to 1.20 dsm^{-1}) indicating that the soils were free from any salinity hazard.

Organic carbon : These soils were low in organic carbon content (<1%) due to existing hyperthermic temperature regime ($\text{MAT} > 22^\circ\text{C}$) which results in fast decomposition of the organic carbon. Relatively higher organic carbon was observed in surface horizons, which gradually decreased with depth.

Calcium carbonate : The soils were either devoid of free CaCO_3 , indicating that either sediments on which these soils have been formed were free from CaCO_3 or it has been leached to deeper layers. These results show that none of CaCO_3 enriched horizons in these soils qualify for calcic horizon, as the CaCO_3 equivalent to less than 15 per cent.

Cation exchangeable capacity and exchangeable cations : The CEC varied widely in the studied pedons, ranging from 6.17 to 21.91 $\text{cmol p}^+\text{kg}$. Depth distribution

of CEC attributed to nature of parent material and to the differences in content of clay and silt in the soils. Highly significant correlation between clay and CEC ($r = 0.92$) indicate that CEC of these soils is controlled mainly by clay content.

Exchange complex of all the studies soils was dominated by Ca^{++} and Mg^{++} . The exchangeable Na^+ and K^+ were present in low amounts. The high per cent base saturation in all the soil profiles may be due to youthful nature of soils.

Available nutrient status : Among macro nutrients, most of the profiles were low in available nitrogen and potassium whereas phosphorous was medium to high in most of the profiles. The available sulphur was also low more or less in all the profiles. The available nitrogen was low in soil profiles P1, P2, P3, P5, P8 and P11, whereas, soil profiles P4, P6, P7, P9 and P10 were medium in available nitrogen. The available phosphorous was low in P1 and P2 whereas other profiles were sufficient. Available potassium was low in amount in the soil profiles P2, P3, P5, P6, P7, P8, P9 and P11 whereas the soil profiles P1, P4, and P10 were having sufficient potassium. The available sulphur was sufficient in soil profiles P1, P4, P6, P7 and P10 whereas P2, P3, P5, P9 and P11 were deficient.

Micronutrients (Zn, Cu, Mn, Fe) were present in sufficient amount in all the soil profiles.

Saturation extract analysis : The results of saturation extract of the soils revealed that calcium was the dominant cation followed by magnesium and sodium in most of the profiles. Among anions, carbonates were absent and chlorides were the dominant anions in the saturation extract followed by bicarbonates and sulphates. Thus the nature of the dominant salts present in the area may be CaCl_2 , NaCl , NaHCO_3 , Na_2SO_4 , CaSO_4 .

5.3 Clay mineralogy :

Clay mineralogy investigated by X-ray diffraction technique indicated dominated occurrence of illite (25 to 57%). The second dominant mineral was smectite (5 to 21%). Other minerals present were kaolinite (8 to 13%), vermiculite (3 to 20%) and chlorite (6 to 8%).

The relative similarities in the mineralogy of these alluvium derived soils irrespective of the degree of pedogenesis suggested that all the clay minerals were inherited from parent material with very little insitu transformation under prevailing conditions.

5.4 Soil classification :

The studied soils are classified into three orders i.e. Entisols, Inceptisols and Aridisols. The soil profiles P1, P4, P7, P8 and P11 qualified for the order Entisols due to lack of diagnostic horizons at sub surface level. Due to presence of Ustic soil moisture regime the soils were classified as Ustorthents at great group level. Because of mixed mineralogy and hyperthermic temperature regime, these soil profile belong to mixed, hyperthermic family of Ustorthents. The soil profiles P2 and P3 were classified as psamments at sub-order level. At the great group level the pedon P2 was classified as Ustipsamments because of Ustic moisture regime whereas P3 qualified for Torripsamments due to presence of Torric soil moisture regime.

The pedon 6 was classified for Aridisol at order level, sub-order Orthids and great group Camborthids and sub-group Typic. The pedons P5 and P10 were classified as Entisols at order level, Fluvents at sub-order level, Ustifluvents at great group level. The soil profile P9 was classified into Inceptisols at order level and Ochrepts at

sub-order level. Because of the presence of thin, light coloured surface horizons with low organic matter and presence of Ustic soil moisture regime, it qualified for Typic Ustorthents at great group level.

5.5 Land evaluation :

Productivity indices for the studied soils have been calculated giving ratings for different limiting soil characteristics. It is seen that for cotton, (P10 and P11) the well drained, medium textured with low lime content and high fertility status soils are highly productive; soil profiles P1, P5, P6, P7 and P9 with two or three limitations have moderate productivity; P4 and P8 soils have low to moderate productivity and P2 and P3 soils are least productive.

The validity of the land coefficient (LC) ratings was supported by linear regressions relating yields of cotton obtained under recommended package of practices suggesting the reliability of these parameters for soil-site suitability evaluation.

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APPENDIX - 1

Detailed Morphological Description

PEDON - 1	:	Alkhpur (Bhiwani)
Location	:	From the field of Balwan Singh S/o Sh. Fateh Singh
Physiography	:	Up land plain
Drainage Class	:	Moderately Well
Parent Material	:	Alluvium
Human Influence	:	Cultivated
Land use	:	Cotton-Wheat
Classification	:	

Horizon	Depth (cm)	Morphological Description
Ap	0-20	Dark brown (10YR 4/3, M); Sandy Clay Loam; Weak, fine to medium subangular blocky, dryhard, common, medium roots; no effervescence; no cutans; diffuse, smooth boundary; pH 8.2,
A12	20-43	Dark brown (7.5 YR 4/4, M); Sandy Clay Loam; Weak, fine to medium subangular blocky, dryhard, common, fine roots; no effervescence; no cutans; diffuse, smooth boundary; pH 8.0,
AC	43-72	Dark brown (7.5 YR 4/4, M); Sandy Clay Loam; moderate medium subangular blocky, dryhard, common fine roots; no effervescence; no cutans; diffuse, smooth boundary; pH 7.9,
C1	72-107	Dark Brown (7.5 YR 4/4, M) ; Sandy Clay Loam; moderate medium subangular blocky, dryhard, few fine roots; strong effervescence; no cutans; diffuse, smooth boundary; pH 8.2,
C2	107-135	Dark yellowish brown (10 YR 3/6, M); Sandy Clay Loam; moderate, coarse subangular blocky, dryhard, few nodules, few fine roots; moderate effervescence; clear smooth; boundary; few cutans; pH 8.3,

PEDON - 2 : Bhiwani Rohilla (Hisar)
 Location : From the field of Sh. Zile Singh S/o Sh. Chajju Ram
 Physiography : Sandy Level Plain
 Drainage Class : Imperfect
 Parent Material : Alluvium calcareous
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-17	Yellow brown (10YR 5/4, M); Sandy loam; Single grain; dry hard, common, medium roots; violent effervescence; no cutans; diffuse, smooth boundary; pH 8.5,
C1	17-38	Dark Yellow brown (10YR 4/4, M); Sandy loam; Single grain; moist friable, common fine roots; violent effervescence; no cutans; clear smooth boundary; pH 8.5,
C2	38-62	Yellow brown (10YR 5/4, M); Sandy loam; hard pan; dry hard; few fine roots; violent effervescence; many coarse lime nodules; no cutans; clear wavy boundary; pH 8.6,
C3	62-140	Light yellow brown (10YR 6/4, M); loamy sand; Single grain; dry hard, few fine roots; violent effervescence; few fine lime nodules; no cutans; diffuse, smooth boundary; pH 8.5.

PEDON - 3 : Bakriawali (Sirsa)
 Location : From the field of Sh. Raj Singh S/o Sh. Puran Singh
 Physiography : Aeolian Plain
 Drainage Class : Well
 Parent Material : Aeolian cover alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-20	Pale brown (10YR 6/3, D); Dark yellowish brown (10YR 4/4, M), Loamy Sand; non coherent; weak fine subangular blocky; common fine roots; weak effervescence; no cutans; diffuse smooth boundary; pH 8.4,
C1	20-50	Pale brown (10YR 6/3, D); Dark yellowish brown (10YR 4/4, M), Sandy loam; non coherent; weak fine subangular blocky; common medium roots; no effervescence; no cutans; clear smooth boundary; pH 8.7,
C2	50-137	Dark yellowish brown (10YR 4/4, D); Sandy loam; moist firm; weak fine granular; common fine roots; strong effervescence; no cutans; clear smooth boundary; pH 8.3,
C3	137+	Yellowish brown (10YR 5/4, D); Sandy loam; moist firm; weak fine subangular blocky; common fine roots; few fine carbonate nodules; violent effervescence; no cutans; clear smooth boundary; pH 8.5.

PEDON - 4 : Cotton Research Farm (Sirsa)
 Location : From the field of Cotton Research Farm (Sirsa)
 Physiography : Aeolian Plain
 Drainage Class : Moderately Well
 Parent Material : Alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat, Raya-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-20	Pale brown (10YR 6/3, D); Dark brown (10YR 4/3, M), Sandy clay loam; dry, very hard; moderate subangular blocky; common fine roots; violent effervescence; no cutans; diffuse smooth boundary; pH 8.4,
BC	20-120	Pale brown (10YR 6/3, D); Dark yellowish brown (10YR 4/3, M), Sandy loam; dry hard; moderate subangular blocky; few, fine roots; violent effervescence; no cutans; clear, smooth boundary; pH 8.6,
C1	120+	Loam (10YR 5/3; D); moist friable; (10YR 7/4, M); moderate subangular blocky; few, fine roots; violent effervescence; white mottles; coarse lime nodules clear, smooth boundary; pH8.3.

PEDON - 5 : Bhavdin (Sirsa)
 Location : From the field of Sh. S. Pritam Singh
 Physiography : Upper alluvial plain
 Drainage Class : Moderately Well
 Parent Material : Alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-22	Dark brown (7.5 YR 7/2, D); Brown (7.5 YR 4/2, M), Sandy clay loam; weak; coarse angular blocky; dry hard; medium, fine roots; strong effervescence; no cutans; diffuse smooth boundary; pH 8.4,
IC	22-60	Dark brown (7.5 YR 7/2, D); Brown (7.5 YR 4/2, M), loam; weak; subangular blocky; dry hard; common, fine roots; moderate effervescence; no cutans; diffuse smooth boundary; pH 8.5,
IIC	60-90	Dark brown (7.5 YR 7/2, D); Light Brown (7.5 YR 3/4, M), Sandy clay loam; weak, subangular blocky; dry hard; few, fine roots; weak effervescence; no cutans; diffuse smooth boundary; pH 8.6,
IIIC	90-125	Brown (7.5 YR 6/4, D); Light Brown (7.5 YR 5/4, M), Loam; massive; dry hard; few fine roots; weak effervescence; no cutans; diffuse smooth boundary; pH 8.1,
IVC	125+	Brown (7.5 YR 4/4, D); Sandy loam; loose friable; dry hard; few fine roots; weak effervescence; no cutans; diffuse smooth boundary; pH 8.4.

PEDON - 6 : Dhani Prem Nagar (Barwala-Hisar)
 Location : From the field of Manphool Singh S/o Sh. Baksa Ram
 Physiography : Upland plain
 Drainage Class : Well
 Parent Material : Alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-15	Yellowish brown (10 YR 5/4, D); Sandy loam; Single grain; dry hard; many coarse roots; tubular pores; violent effervescence; no cutans; gradual, smooth boundary; pH8.2,
B11	15-45	Light brown (10 YR 4/4, D); Sandy loam; fine to medium subangular blocky; moist friable; many coarse roots; tubular pores; weak effervescence; no cutans; diffuse, smooth boundary; pH8.1,
B12	45-105	Dark brown (10 YR 3/4, D); Sandy clay loam; moderate subangular blocky; moist friable; many coarse roots; tubular pores; weak effervescence; no cutans; diffuse, smooth boundary; pH8.1,
C1	105+	Dark brown (10 YR 4/4, D); Sandy clay loam; moderate subangular blocky; moist friable; many coarse roots; tubular pores; weak effervescence; no cutans; diffuse, smooth boundary; pH8.2.

PEDON - 7 : Tigrana (Bhiwani)
 Location : From the field of Sh. Balbir Singh S/o Sh. Sardara Ram
 Physiography : Upland plain
 Drainage Class : Well
 Parent Material : Alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-15	Light yellowish brown (10 YR 6/4, D); Dark yellowish brown (10 YR 4/4, M); Sandy loam; weak, fine subangular blocky; dry hard; many fine roots; moderate effervescence; no cutans; clear, smooth boundary, pH 8.4,
A12	15-37	Brown (10 YR 6/4, D); Sandy loam; weak, fine subangular blocky; moist friable; common roots; moderate effervescence; no cutans; clear, smooth boundary, pH 8.3,
C1	75-120	Brown (10 YR 6/4, D); Sandy loam; weak, fine subangular blocky; moist friable; common roots; weak effervescence; no cutans; clear, smooth boundary, pH 8.5,
C2	120-150	Brown (10 YR 5/4, D); Sandy loam; weak, fine subangular blocky; moist friable; common fine roots; weak effervescence; no cutans; clear, smooth boundary, pH 8.7.

PEDON - 8 : Pentawas (Bhiwani)
 Location : From the field of Sh. Ishwar S/o Sh. Jugual Kishore
 Physiography : Aravali rock outcrops
 Drainage Class : Imperfect
 Parent Material : Aravali Rocks
 Human Influence : Cultivated
 Land use : Cotton-Sarson
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-15	Brown (10 YR 5/3, D); (10 YR 4/3, M); Sandy Loam; dry hard; weak fine to medium, granular; common medium roots; strong effervescence; no cutans; diffuse smooth boundary, pH 8.2,
A12	15-30	Brown (10 YR 4/3, D); (10 YR 3/2, M); Sandy Loam; dry hard; weak fine to medium, granular; common fine roots; moderate effervescence; no cutans; diffuse smooth boundary, pH 8.1,
AC	30-90	Brown (10 YR 4/3, D); Sandy Loam; moist friable; moderate medium, granular; common medium roots; weak effervescence; no cutans; diffuse smooth boundary, pH 7.9,
C1	90-135	Brown (10 YR 4/4, D); Sandy Loam; moist friable; massive; few fine line nodules; common fine roots; weak effervescence; clear smooth boundary, pH 8.0,
C2	135-180	Brown (2.5 YR 5/4, D); Mottles (2.5 YR 8.8); Sandy Loam; moist friable; massive; few fine lime nodules; few fine roots; weak effervescence; clear smooth boundary, pH 8.1.

PEDON - 9 : Mundhal (Bhiwani)
 Location : From the field of Dalvir Singh S/o Mange Ram
 Physiography : Upland plain
 Drainage Class : Well
 Parent Material : Alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification : Typic Ustochrepts

Horizon	Depth (cm)	Morphological Description.
Ap	0-20	Brown (10 YR 3/6, M); Sandy Loam; moist friable; weak fine to medium subangular blocky; common medium roots; strong effervescence; no cutans; clear smooth boundary, pH 8.4,
A11	20-60	Brown (10 YR 3/4, M); Sandy Loam; moist friable; moderate medium subangular blocky; common medium roots; many coarse, tubular pores; strong effervescence; no cutans; clear smooth boundary, pH 8.3,
A12	60-105	Brown (10 YR 5/4, M); Sandy Loam; moist friable; structure less; common, fine roots; many coarse tubular peres; coarse CaCO ₃ nodules; moderate effervescence; no cutans; clear smooth boundary, pH 8.5,
C	105-150	Brown (10 YR 6/4, M); Sandy Loam; moist friable; structure less; common, fine roots; many coarse tubular pores; coarse CaCO ₃ nodules; weak effervescence; no cutans; clear smooth boundary, pH 8.4.

PEDON - 10 : Gulkani (Jind)
 Location : From the field of Sher Singh S/o Sh. Man Singh
 Physiography : Plain
 Drainage Class : Moderately Well
 Parent Material : River Deposited
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-18	Brown (10 YR 6/2, D); Brown (10 YR 5/3, M) Sandy clay loam; dry hard; massive; common medium roots; violent effervescence; no cutans; clear smooth boundary, pH 8.4,
A12	18-43	Brown (10 YR 7.5, D); Brown (10 YR 5/4, M) Sandy clay loam; dry hard; common fine roots; whitish mottling, ; common medium roots; violent effervescence; no cutans; clear smooth boundary, many fine lime nodules; pH 9.0,
IC	43-65	Brown (7.5 YR 4/6, D); Brown (7.5 YR 4/4, M) Clay loam; moist friable; moderate fine to medium granular; whitish mottling; common, fine roots; strong effervescence; clear wavy boundary, pH 9.1,
IIC	65-135	Brown (7.5 YR 4/6, D); Brown (7.5 YR 4/4, M) Silt loam; moist friable; moderate fine to medium granular; many fine concretions; clear smooth boundary, pH 8.9.

PEDON - 11 : Bahu Akbarpur (Rohtak)
 Location : From the field of Sh. Manna Ram S/o Sh. Raj Singh
 Physiography : Plain
 Drainage Class : Moderately Well
 Parent Material : Alluvium
 Human Influence : Cultivated
 Land use : Cotton-Wheat
 Classification :

Horizon	Depth (cm)	Morphological Description
Ap	0-15	Dark yellowish brown (10 YR 4/4, M); Sandy loam; dry hard; weak, fine to medium subangular blocky; common medium roots, no cutans; strong effervescence, clear, smooth boundary pH 8.3,
A12	15-38	Yellowish brown (10 YR 5/4, M); Sandy loam; dry hard; weak, fine to medium subangular blocky; common fine roots; strong effervescence, clear, smooth boundary pH 8.4,
A13	38-72	Light yellowish brown (10 YR 6/4, M); Sandy loam; moist friable weak, fine to medium subangular blocky; common medium roots; moderate effervescence, clear, smooth boundary pH 8.7,
C1	72-110	Yellowish brown (10 YR 5/4, M); Sandy loam; moist friable; weak, fine to medium subangular blocky; few fine lime nodules; few fine roots; violent effervescence, clear, wavy boundary pH 8.7,
C2	110-145	Light yellowish brown (10 YR 6/4, M); Sandy loam; moist friable, weak, fine to medium subangular blocky; few fine roots; strong effervescence, clear smooth boundary pH 8.6.

CHARACTERIZATION, CLASSIFICATION AND LAND EVALUATION OF COTTON GROWING SOILS OF HARYANA

BY

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The present investigation was undertaken to characterize, classify and to evaluate the cotton growing soils of Haryana. The study area includes Hisar, Sirsa, Bhiwani, Jind and Rohtak districts of Haryana. The climate of the area is semi-arid and hot and qualifies for ustic soil moisture regime and hyperthermic temperature regime.

Morphological, physico-chemical and mineralogical characteristics of eleven soil profiles, were investigated to assess their suitability for cotton. Matrix colour of the studied soils varied between the hues of 2.5 Y and 10YR with a dominant hue of 10YR and values ranged from 3 to 8 and chromas were 6 or less. The structure varied from massive, weak to moderate, fine to medium subangular blocky. The soil texture was loamy sand to clay loam.

The depth distribution of various soil-separates indicated parent material heterogeneity among all the studied pedons. The clay and silt fractions of different soil profiles have a significant positive correlation with available water. The studied soils were low in organic carbon content and the soils were free from any carbonate layer. The CEC varied from 6.17 to 21.91 cmolp*kg. Calcium and magnesium were the dominant cations on the exchange complex.

The soils were low to medium in available, nitrogen, potassium and sulphur followed by medium content in available phosphorous. Micronutrients (Zn, Cu, Mn, Fe) were present in sufficient amount in all the profiles. The soil saturation extract analysis revealed the presence of calcium, magnesium and sodium as the dominant cations followed by chlorides, bicarbonates and sulphates as the anions.

The clay fraction of the soil profiles comprised of illite followed by smectite, kaolinite, vermiculite and chlorite. The soils under cotton were classified as Entisols, Inceptisols and Aridisols. Due to the presence of Ustic soil moisture regime, hyperthermic temperature regime and low organic matter content, the soils were grouped into, Typic Ustorthents, Typic Camborthids and Typic Ustipsamments.

The productivity indices for different soils was calculated and the different soil profiles were evaluated into high productive soils, medium productive soils and low productive soils. The validity of the land coefficient (LC) is supported by the linear regression equation, $Y_c = -3.79 + 0.368 LC$ ($r = 0.97$) relating to yield of cotton (Y_c) obtained under recommended package of practices.

Highly significant positive correlation at 1 per cent probability level between cotton yields and land coefficients suggests that the soil parameters used for calculating land coefficients are responsible for variation in crop productivity.

