GENERAL
INTRODUCTION
The term soil is derived from Latin word “Solum” which means floor. According to Hilgard (1892), “Soil is more or less a loose and friable material in which plants, by means of their roots find a foothold for nourishment as well as for other conditions of growth”. This definition emphasizes the soil as a medium for crop growth, which is not always true because there are some soils (highly sodic or severely acidic), which may not be capable of producing anything; nevertheless they are soils.

According to the glossary of soil science terms (Soil Science Society of America, 1970), “Soil is (i) the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants, (ii) the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro- and microorganism and topography, all acting over a period of time and
producing a product that is soil, that differs from the material from which, it is derived in many physical, chemical, biological and morphological properties and characteristics”.

**COMPOSITION OF SOIL**

Soil is mainly composed of solid, liquid and gaseous phases in varying proportion. The approximate composition of an ideal surface soil is given below:

![Soil Composition Diagram]

**Solid phase:**

Composition of solid phase of soil comprises (i) inorganic materials and (ii) organic matter.
(i) Inorganic materials:

The constituent of inorganic materials in soils is composed of small rock fragments and minerals of various kinds, which have been formed by physical and chemical weathering. They are extremely variable in size. The smallest constituent of materials is clay (<0.002mm), which is the most active and reactive portion of soil (Baver, 1948). The smallest clay particle has colloidal properties (Grim, 1953; Mackenzie, 1957; Olphen, 1963; Marshal, 1964) and is composed of few simple building units. Some important and most frequently occurring clay minerals in soil are:

**Montmorillonite:**

Montmorillonite has the 2:1-type (Fig. 1 and 2) mineral layers, which is made up of an octahedral (alumina) sheet sandwiched between two tetrahedral (silica) sheets (Hofmann et al., 1983). These layers are loosely held together by very weak oxygen-to-oxygen and cation-to-oxygen linkage. Exchangeable cations and associated water molecules are attracted between the interlayer spaces, causing expansion of the crystal lattice. Montmorillonite exhibit high plasticity, cohesion and marked swelling when wet and shrinkage on drying. Cation exchange capacity of montmorillonite is high, that varies from 60 to 150 Cmol (p+) per kg (or meq g⁻¹)soil (Daji, 1990).

**Kaolinite:**

Kaolinite is the most prominent member of 1:1-type (Fig. 3 and 4) crystal among the isomers, halloysite, nacrite and dickite. The layers of
Schematic sketch of crystal structure of montmorillonite clay mineral

Montmorillonite (2:1-type expanding minerals)
Montmorillonite (2:1-type expanding minerals)

Layer structure of montmorillonite clay mineral
silicate are made up of one tetrahedral (silica) sheet combined with one octahedral (alumina) sheet (Pauling, 1930; Ross and Kerr, 1931; Grunar, 1932). The tetrahedral and octahedral sheets in a layer of kaolinite crystal are held together tightly by oxygen atoms, which are mutually shared by the silicon and aluminium cations in their respective sheets. These layers in turn, are held together by hydrogen bonding. In contrast with other silicate groups, kaolinite exhibit very little plasticity, cohesion, shrinkage and swelling. It has restricted surface and limited adsorptive capacity for cations and water molecules. The cation exchange capacity is very low and varies from 5 to 15 Cmol (p+) per kg soil (Daji, 1990).

**Illite:**

Illite has 2:1-type (Fig. 3 and 4) mineral layers and is very similar to that of montmorillonite structure. The major source of charge is due to the isomorphous replacement of ions in the tetrahedral sheet (Grim et al., 1937; Bolt et al., 1963) where about 20% of the silicon sites are occupied by aluminum atoms. This result in the balance of net negative charge of the tetrahedral sheet. To satisfy this charge, potassium ions are strongly attracted in the interlayer space that act as a bridging agent, preventing the expansion of the crystal layers. Cation exchange capacity of illite is 20 to 40 Cmol (p+) per kg soil.
Schematic sketch of crystal structure of kaolinite and illite clay minerals
Kaolinite (1:1-type mineral)

Octahedral sheet
7.2 Å
Tetrahedral sheet

Hydrogen bonding

6 (OH) -6
4 Al +12
4 O +2 (OH) -10

4 Si +16
6 O -12

Net charge 0

Illite (2:1-type expanding mineral)

Tetrahedral sheet

10 Å

yK
deficiency charge is balanced by K ions

6 O -12
4 (Si, Al) +16 or less

4 O +2 (OH) -10
4 (Al, Fe, Mg) +12 or less
4 O +2 (OH) -10
4 (Si, Al) +16 or less
6 O -12

Net charge 0 or less e.g. -1

Layer structures of kaolinite and illite clay minerals

Fig. 4
Chlorite:

Chlorite is basically iron-magnesium silicate associated with some aluminium (Donahue et al., 1977). In a typical chlorite clay crystal, 2:1-type layers are formed. The crystal unit contains two silica tetrahedral sheets and two magnesium-dominated trioctahedral sheets, giving rise to the term 2:1:1 or 2:2-type structure. There is no water adsorption between the chlorite crystal units, which accounts for the non-expanding nature of this mineral. Chlorite has low cation exchange capacity and varies from 10 to 40 Cmol (p+) per kg soil.

Amorphous clay:

Amorphous clay is the mixture of silica and alumina, containing weathered oxides of iron etc. that has not formed very well oriented crystals. These are common in soils and exist in varying proportions. Their properties are uncommon usually shown by well-defined clay. On the contrary, they possess some times positive charge, which is responsible for anion exchange property, which is governed by the pH and the nature of salt solution in soil medium.

(ii) Organic matter:

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by the soil microbes. They are also
called humus. Organic matter binds the mineral particles into granules that are largely responsible for the loose and easily manageable condition of the productive soils with good water holding capacity. The humus is usually dark black or brown in colour and is colloidal in nature. It possesses high cation exchange properties and go up to 350 Cmol (p+) per kg soil. Humus may be divided into following main groups:

**Humic substances:**

Transformed products bearing little or no resemblance to the anatomical structures from which they are derived.

**Non-humic substances:**

Unaltered remains of plant and animal tissues and also organic compounds that have definite characteristics.

According to their solubility in alkali and acids, the humic substances can further be sub-divided into three sub-groups.

**Humic acids:** Soluble in alkali and insoluble in acids.

**Fulvic acids:** Soluble in both alkali and acids.

**Humin:** Insoluble in both alkali and acids.

Accumulation patterns of humic and fulvic acid fractions have been studied by various workers (Syers et al., 1970; Schnitzer and
Khan, 1972; Goh et al., 1976; Kilham and Alexander, 1984) to show that the humic acid gets accumulated principally in the surface of immediately below the surface horizon while fulvic acid fraction extends to much lower depth and is hardly precipitated from its alkaline extract by acid because of the presence of more functional groups (Stevenson and Goh, 1971) in the structure.

**Liquid phase:**

It is mainly composed of soil water. Soil water is an important component of soil. It has the property of solubilizing the plant nutrients in their usable or ionic forms (Brady, 1974). The osmotic pressure on the hair like roots is also controlled by the quantity of water or salt concentration. Soil water, therefore, becomes one of the limiting factors in crop production.

The total water present in the soil is not utilized by plants. The water that can be absorbed by the plant is termed as available water and that water, which is not absorbed by the plant, is termed as non-available water.

**Gaseous phase:**

Composition of gaseous phase in soil is soil air, which is dynamic and varies greatly from place to place within a given soil (Russel and Appleyard, 1915; Jong, 1981). It contains a number of gases, of which
nitrogen, oxygen, carbon dioxide and water vapour are the most important constituents. The soil air contains a much greater proportion of carbon dioxide and lesser amount of oxygen than atmospheric air. This is due to respiratory activity of the roots, soil flora and fauna. Soil air is essential for the respiration of soil microorganisms and underground parts of the plants.

The content and composition of soil air are determined largely by the water content of the soil, since the air occupies those soil pores, which are not filled up with water.

**SOIL MICROORGANISMS AND THEIR ACTIVITIES**

The various microorganism, that inhibit the soil forms are one of the important components of all soils. It has been estimated that one gram of soil may contain 1 to 100 million microorganisms, forming a very small fraction (<1%) of soil mass (Donahaue et al., 1977; Sehgal, 1996). They are considered to be present in soil from the top to a depth of few inches. The density of microbial population and their normal activities depend on many factors, such as the availability of food and energy supply, moisture, temperature, light, air, soil condition, soil reaction and the antagonistic and associative effect of the microorganism themselves. However, soil acidity (pH 4.5-5.5) is favorable to the development of fungi; soil bacteria prefer neutral conditions (pH 6.5-7.5), and actinomycetes thrive well in slightly alkaline condition.
Microorganisms play an important role in biochemical transformations, such as organic matter decomposition, humification, nitrogen fixation, ammonification, nitrification, oxidation and reduction (Bollag and Henninger, 1976; Gowda et al., 1976; Vlassak, 1975; Gaur and Misra, 1977;). Thus, they help the soil development and tend to maintain the soil fertility. (Russel, 1973). Soil microorganisms are classified as (i) microflora and (ii) microfauna.

(i) Microflora:

It comprises of the following:

**Bacteria:**

Bacteria, single-cell organisms, are one of the simplest and smallest forms of life known. Soil bacteria are either autotrophic or heterotrophic. Autotrophic bacteria have the ability to oxidize (or reduce) the selected chemical elements in soil. Thus, through nitrification, selected bacteria oxidize ammonium compounds to the nitrate form, and others complete the oxidation to the nitrate form. Other bacteria are responsible for oxidation and/or reduction of sulphur, iron, manganese and carbon monoxide, etc.

**Fungi:**

Fungi are plants without seed, stem, leaf and root and have no chlorophyll. Their biomass varies with the kind of soil. They take part in
a number of processes, of which their role in the decomposition of complex organic substances is the most important. They also play a dominant role in the synthesis of lignoprotein complex and in the formation of other new compounds, such as polysaccharides, gums, chitin, etc. They also decompose proteins and convert them into amino acids and ammonia. The ammonifying capability of soil fungi, is greater than that of many bacteria.

**Actinomycetes:**

Actinomycetes are filamentous and branched. They are similar to bacteria, in that they are unicellular and have about the same diameter. In soils, they are involved in the decomposition of all sorts of organic substances. They have the capability of breaking down cellulose. Proteins and amino acids are broken down and ultimately converted into ammonia.

**Algae:**

Most algae are chlorophyll-bearing organisms. These are capable of performing photosynthesis like higher plants. Soil algae are divided into four general groups: blue-green, green, yellow green, and diatoms. Blue-green algae are commonly available in large numbers in rice soils, and when such land is flooded, appreciable amounts of atmospheric nitrogen are fixed or changed to a combined form by these organisms.
Blue-green algae, growing within leaves of the aquatic fern *Azolla*, are able to fix nitrogen in significant quantities for rice production.

(ii) **Microfauna:**

Microfauna comprises of the following (Sehgal, 1991):

**Nematodes:**

Nematodes are microscopic, unsegmented and thread like worms. The most numerous and varied forms of nematodes are those that live on decaying organic matter (saprophytes). But, some nematodes, especially those of the genus *Heterodera*, can infest the roots of practically all plant species.

**Protozoa:**

Protozoa are probably the simplest form of animal life and are the most varied and numerous of all the micro animals in soils. Protozoa include amoebae, ciliates and flagellates. The various kinds of chemical reactions in soil such as oxidation-reduction (Charles and Paul, 1958), solubilization and fixation of plant nutrients in soils (Singhal et al., 1975), denitrification and nitrification of soil nitrogen (Noggle and George, 1977) are all mostly controlled as a result of chemical and microbial activities in soil (Singhal et al., 1976).
The microbial activities are largely responsible for the maintenance of soil fertility (Martin, 1973) as well as in governing soil properties (Katznelson and Bose, 1959).

**PHYSICO-CHEMICAL PROPERTIES OF SOIL**

The physico-chemical properties of soil may be discussed as (i) mechanical composition (ii) pH (iii) electrical conductivity (iv) exchangeable cations and (v) cation exchange capacity.

(i) **Mechanical composition:**

The first information required about a soil is its mechanical composition. Mechanical composition or texture means the particles of various sizes such as gravel (> 2mm), sand (0.02-2mm), silt (0.002-0.02) and clay (<0.002mm) fractions. The particle size distribution in soils influences its chemical, physical and biological properties. Clay particles, which have a large surface area, determine most of its chemical properties. Particle size distribution in soils also influences its water holding capacity and water supply to plants. It influences the strength and compressibility of soils. The success of any mechanical analysis depends firstly upon the preparation of the sample to ensure complete dispersion of all aggregates into their individual primary particles without breaking up the particles themselves, and secondly upon the accurate fractionation of the sample into various separates.
(ii) pH:

Soil pH is one of the most important soil property, which is a measure of the acidity or alkalinity of the soil. It gives an idea about acidic, basic or neutral character of a soil and is defined as -log [H⁺]. Soil pH affects the availability of plant nutrients. Macronutrients tend to be less available in soil with low pH. However, if the soil pH is high the micronutrients tend to be less available due to their precipitation. In pH range 6.0 to 6.5, nutrients are more readily available to plants. Soil microbial population also increases in this range of soil pH.

Various soil particles, especially the clays, are saturated with different cations. The nature and extent of cations varies from soil to soil having different clay minerals and is reflected from their cation exchange properties. The soil pH is also governed by the nature of soluble salt cations saturating the soil particles over their exchangeable sites. For instance, soils containing aluminium as its dominant cations mostly be acidic, ranging from 3.8-5.8 in pH. On the other hand, soils containing a lot of sodium ions will tend to be basic ranging from 8.5-10.5 in pH.

(iii) Electrical conductivity:

It gives an idea about the total soluble salt content in soil. Soil salinity can be measured by extent of soluble salt especially the NaCl
and Na₂SO₄. For saline soil, the salt content is more than 0.3% or E.C. > 4.0 mmhos cm⁻¹. EC of a solution increases approximately 2% per degree centigrade. E.C of the irrigation water may vary from 0.1-0.75 mmhos cm⁻¹ or below. High salinity hazard is increased in case of irrigation water having conductance much above this range.

(iv) Exchangeable cations:

The exchangeable cations, normally present in agricultural soils, are Ca²⁺, Mg²⁺, K⁺, Na⁺, NH₄⁺ and H⁺ ions. During the processes of weathering and clay formation, the water in the immediate vicinity of the decomposing primary mineral is rich in Ca²⁺, Mg²⁺, K⁺ and Na⁺ ions. The newly formed clay mineral reacts with these ions and adsorbs them on its surface. Ordinarily, calcium ions are adsorbed to a much greater extent than the other ions giving rise to calcium clay. The source of H⁺ ion on the clay surface may be due to the decomposition of carbonic and other acids. In addition to those, the clay minerals also found to adsorb other cations such as iron, aluminium, manganese, zinc, copper and other minor elements though in smaller quantity.

Cation adsorption is a function of the clay mineral; the amount of total exchangeable cation varying with the amount of colloidal content or clay present in soil. Hence, clay and clayey soils contain a greater amount of total exchangeable cations than sands and sandy soils.
(v) Cation exchange capacity:

The cation exchange capacity is related to the fundamental properties of soil, that represents the total quantity of negative charge, available to attract positively charged cations in solution. It is one of the most important chemical properties of soil, and strongly influences in preserving the nutrients availability. The CEC of soil is expressed in terms of milli equivalent of negative charge per 100 gm of soil (meq 100 g⁻¹) or in terms of centimole of negative charge per kg of soil (Cmol(p+) kg⁻¹). The CEC also represents the total meq 100 g⁻¹ or Cmol (p+) kg⁻¹ of cations held on the negative sites.

The CEC of soil varies with the nature and extent of clay and organic matter contents. In case of soil, which contains very little organic matter, the CEC may be taken to vary with the clay content of a soil. Soils rich in montmorillonite clay possess high CEC, while those having kaolinite as the predominant clay mineral, have low exchange capacity.

SOIL ADSORPTION

Soil adsorption may be defined as the excess solute concentration at the liquid soil interface over the concentration in the bulk of the solution regardless of the nature of the interface region or of the interaction between the solute and the solid surfaces (Mingelgrin
and Gerstl, 1983). The rate and extent to which a substance distributes itself between the solid and solution phase over a soil are determined by several physical and chemical properties of both the adsorbing substance and the soil as well as by environmental conditions (Bailey and White, 1964; Greenland, 1965; Bailey et al., 1968) prevailing on them.

Colloidal particles of soil possess the power of adsorbing gases, liquids and even solids from their suspensions. The phenomenon of adsorption is confined to the surface of the colloidal particles. The dynamic nature of the colloidal particles of the soil is manifested prominently in clay and humus. Because of their extremely small particle size, they have a large surface area per unit weight. They also exhibit surface charges that attract polar molecules and charged ions as well as water (Weber and Weed, 1968; Bisada and Johns, 1969; Hower, 1970; Singhal and Singh, 1976). Such attraction is of particular significance for negatively charged colloids. Ions found in soil solutions are in the process of ion exchange between the soil colloids and can be replaced in equivalent amounts by other ions. For example, a hydrogen ion released into the soil solution by plant root can exchange readily with the potassium ion adsorbed on the colloidal surface. The potassium ion is then available in the soil solution for uptake by the roots of the growing crop plants (Brady, 1995).
The property of adsorption plays an important role in maintaining the soil fertility. It is due to this property that a soil is able to hold water and plant nutrients; keeps them available for plant use. It enables the soil colloids to function as a reservoir of nutrients for plant use. Soluble substances added to the soil in the form of fertilizers are retained in it because of the power of adsorption that soil colloids possess. Thus, properties of adsorption or ion exchange are the main criteria for assessing the fertility status of the soil.

SOILS OF INDIA

India, constituting a part of the "Asian Continent", lies to the north of equator. It has a geographical area of 329 m ha and lies between latitude of 08° 04' and 37° 06'N and longitudes of 68° 07' and 97° 25'E (Sehgal, 1996). The nature and properties of its soil vary greatly depending upon the variation in soil-forming factors and processes. Due to the variations in different soil parameters, India has a large variety of soils. The variety is so diverse that, India represents all the major soil groups of the world.

Agriculture in India is highly dependent on bioclimatic conditions, which in combination with soils, physiography and other factors, decides the agro-ecological zones. Agro-ecological zoning is, therefore, important for macro-scale planning, particularly in area where rainfed-farming is practiced, which accounts for nearly three-fourth of cultivated
area in India. Based on the relevant parameters, the National Bureau of Soil Survey and Land Use Planning (Sehgal et al., 1992) has identified 20 agro-ecological regions, which have been found to be useful for macro-scale planning.


The Soil groups of India give the salient characteristics, potential, constraints and equivalents in the US soil Taxonomy (Soil Survey Staff, 1975) and FAO legend (1991). The NBSS and LUP has been engaged in preparing a comprehensive soil resource inventory of different states (Sehgal, 1990) by using a latest technology to highlight the areas of political problems (Sehgal, 1995).

On the basis of the efforts made by the National Bureau of Soil Survey and Land Use Planning, the soil of India is classified into following major genetic groups:

**Alluvial soils:**

Alluvial soils represent the most fertile land and occupy an
estimated area of about 75 m ha in the Indo-Gangetic plain and Brahmaputra Valley. These soil are widely distributed in northern, north-western and NE parts of India, including Punjab, Haryana, UP, Delhi, MP, Assam, Bihar, WB, and coastal regions of Orissa, Gujrat, TN, Kerala, etc. They are inherently rich in plant nutrients. These soils are generally alkaline in reaction, but may become acidic as in NE regions where the rainfall (> 2000 mm per annum) generally exceeds potential evapotraspiration. These soils are further classified into Khadar (young alluvial) and Bhangar (old alluvial). According to US soil Taxonomy (Soil Survey Staff, 1994), such soils may be divided into various order such as entisols, inceptisols, alfisols and aridisols.

**Black soils:**

Black soils occupy an area of about 72 m ha (Sehgal and Bhattacharjee, 1988). These soils are observed in the central, western and southern part of India, including Maharashtra, western parts of MP, Gujrat and some parts of AP, Karnataka and TN. These soils are highly argillaceous, varying from 30 to 80 percent clay content. They have high cation exchange capacity (33-55 Cmol (P+) per kg). These soils, in the Genetic System, were classified in the order: intrazonal (grumusols) and azonal (regosols and alluvial soils). According to soil Taxonomy, the medium and deep black soils are grouped in the order of vertisols.

**Red soils:**

The red soils are widely present in the southern part of Peninsula
comprising the states of TN, Karnataka, Maharashtra, AP, MP, Goa and the Union Territory of Pondicherry, Dadra Nagar Haveli, Daman and Diu. In the north and NE regions, these soils are occasionally observed in parts of Bihar, WB, Assam, and UP. The red and lateritic soils, according to the recent survey, occupy 70 m ha (Sehgal et al., 1993). These soils are generally deficient in nitrogen and phosphorous; but are well supplied in potassium. According to the US soil Taxonomy (1975 and 1994), they may be classified into the following orders: alfisols, ultisols, entisols and inceptisols.

**Laterites and lateritic soils:**

The well developed laterites are observed on hill-tops and Plateau of Orissa, Maharashtra, Kerala, TN and NE regions; such soils are locally observed in AP, Karnataka and Assam. The lateritic soils occupy 25 m ha of the total geographical area. Kaolinite is the dominant clay mineral in these soils. The laterite and lateritic soils have been classified, according to US soil Taxonomy, in the orders of: oxisols and ultisols.

**Saline and alkali soils or salt affected soils:**

In India, these soils are mainly confined to the arid and semi-arid and subhumid regions. The salts deposited are of sodium, carbonate, bicarbonate, sulphate and chloride with little calcium and magnesium
contents. These soils are observed in UP, Haryana, Rajasthan, Maharashtra and Karnataka. In the new US Soil Taxonomy, these soils have been classified in the following orders: aridisols, inceptisols, alfisols, entisols and vertisols.

Desert or arid soils:

These soils are fine sandy to loamy fine sand in texture. They are generally poor in plant nutrients with low water holding capacity. These soils are found in western Punjab, southern Haryana and south west Punjab. On the basis of soil Taxonomy they are grouped into orders of: aridisols and entisols.

Forest and hill soils:

The total forest area in India is estimated as 75 m ha, which constitutes a major geographical area. The major forest areas are covered by tropical deciduous coniferous and tropical evergreen forests and occur in the states of HP, J&K, UP, Arunachal Pradesh, Nagaland, Assam, Meghalaya, Mizoram, Manipur, Orissa, MP, Maharashtra, Kerala and Andaman and Nicobar Island. These soils have been formed under acidic conditions in the presence of acid humus and low base status or under slightly acidic or neutral and high base status conditions. Some other soil formation in the forest areas, developed on sandstone, limestone or colluvium under slightly acidic to neutral
condition and in sub-humid environment. These soils are neutral to acidic (pH ranging from 4.5 to 7.0). Some soils, developed on calcareous and stones, show pH up to 8.0. The organic matter is varied from 1 to 3.5%. These soils may be divided into following orders: inceptisols, alfisols, mollisols, ultisols and entisols.

**Peaty and marshy soils:**

These soils occupy a limited area in localized pockets of Kerala and NE region, and are dark to almost black in colour with abundant organic matter contents (20-40%). They are very strongly acidic (pH as low as 3.5 to 4.0). This may be due to the decomposition of organic matter. As per soil Taxonomy these soils are classified into following orders: histisols, inceptisols and entisols.

**GENERAL DISCRIPTION OF ALIGARH SOILS**

Aligarh covers an important area among the districts of Uttar Pradesh. The Aligarh district lies towards north of the Ganga-Yamuna doab within the parallels 27°29' and 28°11' north latitude and 77°29' and 78°38' east latitude. Aligarh district acquires an area of 5000 sq. km. (including newly created Hathras district). Its alluvial deposits have a gentle slope from north-west to south-east. There are several depressions apart from those formed by the river valleys and drainage lines. Topographically the district presents a trough like appearance
with high Ganga and Yamuna river banks at both extreme rims. It has a semi-desert type of climate. Soils of the Aligarh district are alluvial with little leaching and considerable accumulation of salts on the surface (Agrwal and Mehrotra, 1951). The alluvial beds varying from reddish brown to ash grey in colour passing through successive layers of sands, sandy silt and clay with occasional compact beds of kankar of an indurate character. In some places, pisolitic small concentration of hydrated iron and manganese oxides is disseminated in the soil beds.

Salt problem in UP was recognized as early as 1876 and a commission was set to investigate the deterioration of soils in Aligarh district where a vast area of over 3 million acres (about 15% of the total) consists of barren lands. Leather (1897) showed that the injurious salts, which were the decomposition products of igneous rock under natural weathering process and got deposited within the soil profiles. He called such land as ‘Usar’. The soil factor in the district, such as nearness of water table and/or impedance of drainage due to the hard kankar pan, caused intensification in the area of ‘Usar’ patches. The ‘Usar’ reclamation committee of UP (1938) reported that the alkaline conditions in the soil of the district were mainly due to the presence of carbonate and bicarbonate of sodium. The alkaline layers extended on an average to a depth of 3-4 ft. deep. The distribution of saline soil, though comparatively less also covered a considerable area of the district. These soils were characterized by the presence of sodium
chloride and sodium sulphate with an open texture and existed in a state of flocculation. The alkali soils could be classed as ‘solonetz’ and the saline soils as ‘solon-chaks’.

According to the order of geneses of the principal soil types, the district of Aligarh has been grouped into six natural soil regions as indicated on the attached soil map of the district (vide fig. 5). The chief characteristics of these soils, as investigated till the time of undertaking the present work, are briefly indicated in the table I, II and III.

**COLLECTION OF SOIL SAMPLES**

According to an axiom; analysis can be no better than the sample. This is all the more true in the collection of soil samples. The general problem of soil sampling has been summarized by the Association of Agricultural Chemists as follows “In view of the variability of soils, it seems impossible to devise an entirely satisfactory method for sampling”. During the collection of soil sample hereunder described, the importance of taking representative composite sample was kept in mind and variations in color, texture, slope and cropping pattern were all adequately considered. The grass and other matters were removed from the surface soil. The soil samples (0-30 cm depth) from at least ten well described spots in fields were collected and then mixed well. The different samples were collected from the following mentioned area:
1. **Aligarh Type I (Ganga Khadar):**

   This soil is distributed in narrow belt of recent alluvial tract of the Ganga in the northeastern corner of the district in tehsil Atrauli. The sample was collected from the field in the neighborhood of Sankra bus-stand about two furlong from the river bank.

2. **Aligarh Type II (Eastern Uplands):**

   This soil covers almost the entire tehsil of Atrauli except for a thin strip of Ganga Khadar. The sample was collected from the field of Malhepur village, situated on the Aligarh-Ramghat Road.

3. **Aligarh Type III (Central Lowlands):**

   This soil occurs widely in the central low lying tracts of the district in tehsil Koil and tehsil Sikandra Rao, and is underlain by the thick pan of kankar; at some places form a stiff imperviable rock in the bottom layers. The sample was collected from the barren field around the Aligarh Muslim University.

4. **Aligarh Type IV (Western Uplands):**

   The soil is mainly distributed in the tehsil of Khair, Iglas and Hathras and forms numerous sandy ridges. The sample was collected from Talaspur village.
Table – I

Some general characteristics of Type I (Ganga Khadar) and Type II (Eastern Uplands) soils of Aligarh district

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Type I (Ganga Khadar)</th>
<th>Type II (Eastern Uplands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile development</td>
<td>Immature</td>
<td>Mature</td>
</tr>
<tr>
<td>Colour</td>
<td>Ash gray</td>
<td>Light brown</td>
</tr>
<tr>
<td>Concretion</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Texture</td>
<td>Sandy to silty loam</td>
<td>Sandy-loam, friable</td>
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<tr>
<td>Lime</td>
<td>High (slightly calcareous)</td>
<td>Low (non-calcareous)</td>
</tr>
<tr>
<td>Soluble salts</td>
<td>High</td>
<td>Very low</td>
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<tr>
<td>Salt efflorescence</td>
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<td>Nil</td>
</tr>
<tr>
<td>pH</td>
<td>8.5</td>
<td>7.2</td>
</tr>
<tr>
<td>Clay</td>
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<td>Moderate</td>
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<tr>
<td>Drainage</td>
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<td>Good</td>
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<tr>
<td>Water table</td>
<td>About 8 ft.</td>
<td>About 22 ft.</td>
</tr>
<tr>
<td>Main crops</td>
<td>Millet, Wheat, and Barley</td>
<td>Oat, Maize, Black gram, Barley, Wheat and Pea</td>
</tr>
</tbody>
</table>
Table – II

Some general characteristics of Type III (Central Lowland) and Type IV (West Uplands) soils of Aligarh district

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Type III (Central Lowlands)</th>
<th>Type IV (West Uplands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile development</td>
<td>Mature</td>
<td>Mature</td>
</tr>
<tr>
<td>Colour</td>
<td>Whitish gray</td>
<td>Reddish brown</td>
</tr>
<tr>
<td>Concretion</td>
<td>Thick kankar pan</td>
<td>No</td>
</tr>
<tr>
<td>Texture</td>
<td>Clayey loam, compact</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>Lime</td>
<td>High (calcareous)</td>
<td>Low (faintly alkaline)</td>
</tr>
<tr>
<td>Soluble salts</td>
<td>High</td>
<td>Very low</td>
</tr>
<tr>
<td>Salt efflorescence</td>
<td>Present</td>
<td>Nil</td>
</tr>
<tr>
<td>pH</td>
<td>9.2</td>
<td>7.9</td>
</tr>
<tr>
<td>Clay</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Drainage</td>
<td>Very poor</td>
<td>Excessive</td>
</tr>
<tr>
<td>Main crops</td>
<td>Sugar cane, Barley and Paddy</td>
<td>Oat, Maize, Barley, Wheat and Pea</td>
</tr>
</tbody>
</table>
Table – III

Some general characteristics of Type V (Yamuna Khadar) and Type VI (Trans Yamuna Khadar) soils of Aligarh district

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Type V (Yamuna Khadar)</th>
<th>Type VI (Trans Yamuna Khadar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile development</td>
<td>Not fully mature</td>
<td>Mature</td>
</tr>
<tr>
<td>Colour</td>
<td>Dark gray</td>
<td>Brownish gray</td>
</tr>
<tr>
<td>Concretion</td>
<td>Kankar at bottom</td>
<td>Kankar at lower depth</td>
</tr>
<tr>
<td>Texture</td>
<td>Clay</td>
<td>Loam</td>
</tr>
<tr>
<td>Lime</td>
<td>Rich (moderately calcareous)</td>
<td>Average (non-calcareous)</td>
</tr>
<tr>
<td>Soluble salts</td>
<td>very high</td>
<td>Average</td>
</tr>
<tr>
<td>Salt efflorescence</td>
<td>Present</td>
<td>Not prominent</td>
</tr>
<tr>
<td>pH</td>
<td>8.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Clay</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Drainage</td>
<td>Poor</td>
<td>Restricted</td>
</tr>
<tr>
<td>Water table</td>
<td>About 5 ft.</td>
<td>About 12 ft.</td>
</tr>
<tr>
<td>Main crops</td>
<td>Wheat and Gram</td>
<td>Pea, Barley and Maize</td>
</tr>
</tbody>
</table>
5. **Aligarh Type V (Yamuna Khadar):**

The overflow of Yamuna in the extreme of north-west of the district has given rise to the formation of this type of soil in Khair tehsil. The soil is hard with cloddy structure and gets puddled up when wet. The sample was collected from Tappal Town, situated on the bank of Yamuna river.

6. **Aligarh Type VI (Trans Yamuna Khadar):**

The tract of land containing this soil lies parallel to the Yamuna Khadar in the form of narrow belt about six miles wide. The soil is associated with *kankar* and is slightly stiff. The sample was collected from Jattari Town in Khair tehsil.

**PLANT NUTRIENTS**

The seventeen chemical elements, that are important for proper growth of plants, are called plant nutrients. Deficiency of these elements causes several diseases and affects the life processes of plants (Arnon, 1950). The physiological function of these elements depends on their concentration. Too much of some plant nutrients, may cause a nutrient imbalance in plants and adversely effects the population of microflora and microfauna (Kuster and Grun, 1984). The essential elements are divided into two main groups: non-mineral and mineral nutrients.
Non-mineral nutrients:

The non-mineral nutrients are hydrogen, oxygen and carbon. They are found in the form of air and water. Plants use the energy from the sun to change carbon dioxide and water into starch and sugars.

Mineral nutrients:

Out of the essential elements, thirteen mineral nutrients, which usually come from the soil, are dissolved in water and absorbed through the plant’s roots. The mineral nutrients are further divided into two groups (i) macronutrients and (ii) micronutrients.

(i) Macronutrients:

Macronutrients are divided into two more groups (a) primary and (b) secondary nutrients.

(a) Primary nutrients:

The primary nutrients are:

Nitrogen:

Nitrogen is a critical component of enzymes, amino acids and proteins, which control the metabolic processes, required for plant growth. It is also an integral part of the chlorophyll molecule and thus, plays a key role in the photosynthesis. An adequate supply of nitrogen
is associated with vigorous growth and dark green colour of the plant. Nitrogen deficiency is characterized by reduced plant growth and a pale green or yellow colouring in leaves (Chapman, 1968). If the deficiency is severe, the affected area of the leaf eventually turns brown and dies.

**Phosphorus:**

Phosphorus is a critical component of nucleic acids. So, it plays an important role in plant reproduction, of which grain production is an important consideration. This mineral is often found in large quantities in seed and fruit. Phosphorus is essential in the biological energy transfer process (Mengel, and Kirkby, 1982), which is of vital significance for the life and growth of plants (Khasawneh, 1980). Adequate phosphorus is characterized by improved crop quality, greater straw strength, increased root growth, and earlier crop maturity. Phosphorous deficiency is indicated by reduced plant growth, delayed maturity and smaller fruit size. These symptoms may be revealed through purple colouring, particularly in young plants.

**Potassium:**

Potassium in plants stays in a mobile form rather than as an integral part of any fixed components. It helps to maintain self-permeability, aids in the translocation of carbohydrate (Webster and Varner, 1954), keeps iron more mobile in the plant and increases the resistance to certain diseases. It also helps in the building of protein,
photosynthesis, fruit quality and reduction of diseases. High potassium in solution also affects the osmotic pressure of the soil solution and makes the water less available for plant use. Deficiency of potassium is reflected in plants by white spots on the leaf edges, chlorosis and necrosis. Potassium deficiency can also occur in young leaves at the top of high yielding and fast maturing crops.

(b) Secondary nutrients:

The secondary nutrients are:

**Calcium:**

Calcium is an integral part of plant cell walls. It provides for normal transport and retention of other elements as well as strength in the plant. Sources of calcium are dolomitic lime, gypsum and super phosphate. Calcium deficiency causes reduction in crop growth but, are rare in agricultural soils.

**Magnesium:**

Magnesium is a key component of chlorophyll, essential for photosynthesis. It also activates many plant enzymes, needed for growth of plants. Magnesium is best supplied by limestone that contains this nutrient. White strips between the leaf veins characterize the magnesium deficiency.
Sulphur:

Sulphur is a common component of proteins and vitamins, which are essential for plant and animal growth (Tabatabai, 1986). It also helps in chlorophyll formation. Sulphur improves root growth and seed production. Rainfall supplies significant amounts of sulfur. Sulfur also occurs in volatile compounds, responsible for the characteristic taste and smell of plants in the mustard and onion families. Sulfur deficient plants have a general yellowing and are very spindly.

(ii) Micronutrients:

Micronutrients are those elements, which are needed in only very small quantities for plant growth (Nicholas and Egan, 1975). There is considerable variation in the specific role of the various micronutrients (Mengel and Kirkby, 1982) in plants and microbial growth processes. The micronutrients are:

Boron:

Boron helps in the utilization and regulation of other nutrients. Boron is essential for seed and fruit development. Sources of boron are organic matters and borax. A boron deficiency decreases the rate of water absorption, root growth and translocation of sugars in plants.

Copper:

Copper is important for reproductive growth and is involved in
photosynthesis and respiration (Arnon, 1949). It also stimulates lignification of plant cell walls and helps in the utilization of proteins. Deficiency of copper has been reported in numerous plants, although they are more prevalent among crops growing in peat and muck soils. In corn, copper deficiency causes yellowing and stunted to the youngest leaves.

Iron:

Iron is structural component of porphyrin molecules such as, cytochromes, hemes, hemating, ferrichrome and leghemoglobin. These substances are involved in the oxidation-reduction reactions in respiration and photosynthesis. It involves in chlorophyll formation and degradation and also in the synthesis of proteins, contained in the chloroplasts. Source of iron are the soil, iron sulphate and iron chelate. A deficiency of iron is indicated in the young leaves of plants. Iron deficiency also reduces the chlorophyll production, which results in the characteristic chlorosis symptoms of iron stress. An excess amount of iron is hazardous to plants.

Manganese:

Manganese is considered to be essential for photosynthesis, respiration and nitrogen metabolism (Stiles, 1961). It also takes part in oxidation-reduction process and in decarboxylation and hydrolysis reactions. Soil is a source of manganese. Its deficiency causes gray speck of oats, marsh spots of peas and speckled yellow of sugar beets.
Wheat plants grown in low manganese, are often more susceptible to root rot diseases. Excessive amounts of manganese are also harmful to plants.

**Molybdenum:**

Molybdenum is a component of the enzyme nitrogenase, which is essential for the process of nitrogen fixation. It is also present in the enzyme nitrate reductase, which is responsible for the reduction of nitrates in soil and plants. Small grains and some row crops are more tolerant to low levels of available molybdenum.

**Zinc:**

Zinc plays a vital role in protein synthesis, in the formation of some growth regulating hormones like indole acetic acid and in the reproductive process of certain plants. Reduced growth hormone production is common in zinc deficient plants and causes the shortening of internodes and smaller than normal leaves.

**Chloride:**

Chloride is known to influence photosynthesis and root growth. A useful function of chloride is as the counterion during rapid potassium fluxes, thus contributing to turgor of leaves and other plant parts. Chlorosis in younger leaves and overall wilting of the plants are the two most common symptoms of chloride deficiency.
Cobalt:

Cobalt is essential for the symbiotic fixation of nitrogen. In addition, legumes and some other plants have a cobalt requirement, independent of nitrogen fixation, although the amount required is small as compared to that for the nitrogen-fixation process. Cobalt is also essential for the growth of symbiotic microorganisms, which are responsible in the formation of vitamin $B_{12}$. Improved growth, transpiration and photosynthesis with application of cobalt have been observed in many plants.

SOIL THIN-LAYER CHROMATOGRAPHY

Thin-layer chromatography (TLC) is considered as powerful tools for the separation and identification of organic and inorganic compounds from their complex mixture. It gives a satisfactory result, where other methods fail. The TLC is simple, rapid, inexpensive, sensitive and selective and it requires very little working materials. The technique of TLC was first introduced actively for the separation of fatty esters by Kirchner et al. (1951) and now it has become one of the most important technique employed in virtually every branch of chemistry for the separation, identification and isolation of pure compounds. Some useful and comprehensive text on the application of TLC for organic compounds has been compiled by Stahl (1966). A variety of literature is also available describing the TLC of lipid molecules (Bobbitt et al.,

Helling and Turner (1968) first introduced the soil TLC for the determination of pesticides movement using different types of soils as static phase. Rhodes et al. (1970) used soil TLC for the determination of agrochemicals in soil. Chapman et al. (1970) also used soil TLC for measuring the relative mobility of herbicides. The work was further compiled by Helling (1971) in three reports dealing with pesticides mobility in soils (1) parameters of TLC (2) application of soil TLC and (3) influences of soil properties.

Soil TLC method has been successfully used by Singhal and Singh (1977) for the mobility of trace metals, Singhal et al. (1978) for the mobility of amino acids, Khan et al. (1982) for the mobility of heavy metals, Khan et al. (1985) for the effect of organic acids and bases on the heavy metals mobility, Khan and Khan (1986) for the mobility of organophosphorous insecticides in soils as affected by soil parameters and Khan et al. (1999) for the mobility of amino acids in soil as affected by some pesticides. Soil TLC technique has now become an important analytical tool in describing the mechanism involved in the mobilization process of organic and inorganic compounds through soils.

Soil TLC is an adsorption chromatography, where the adsorbent is a thin-layer of soil deposited on a glass plate. The soil components
provide an adsorptive or static phase, where adsorption and desorption takes place very rapidly and reversibly. Thin layer, prepared by spreading the slurry of soil as uniform film (0.15-2.0 mm) with the help of an applicator, is allowing to stand overnight for drying (Bremner et al., 1961; Bremner et al., 1962; Michalec et al., 1962). Better results are obtained if the layer is thin, because the spray reagent is much more sensitive when it does not have to search for tiny amounts of substance in a large amount of adsorbent. On the contrary, when the work is preparative in nature, it is advisable to use a thick layer (Cerny et al., 1961) so that the maximum amount of material can be separated in a single chromatogram. The amount of substances applied depends upon thickness of the layer and visualization procedure, which are inversely proportional to each other and also on the nature of adsorbent. The compound under investigation is spotted at fixed scribed place (about 4 cm above from the bottom) on the plate with the help of micropipette. The mobile phase level in the closed glass jar always remains about one cm below the spots.

Chromatograms are then developed in a closed chamber using selected developer. After the solvent ascends up to scribed line (up to 10 cm from the base line of the plate), the plate is removed, dried and detected by spraying a suitable chemical as detector. The mobility in terms of $R_f$ value can be calculated by the formula.

$$R_f \text{ value} = \frac{\text{Distance moved by solute}}{\text{Distance moved by developer}}$$
AMINO ACIDS

There are twenty naturally occurring amino acids that build animal proteins. Amino acids constitute a very important group of organic compounds conforming the general formula, R-CH(NH₂)COOH (except proline). Amino acids in solution at isoelectric pH are mainly dipolar ions, called zwitter ions; the molecules are left with no net charge. These are classified as: acidic, basic, neutral-polar and neutral non-polar. Because the alpha carbon of an amino acid is an asymmetric carbon, each amino acids can exist in the form of two enantiomers. These enantiomers are called L-isomers and D-isomers. Amino acids, present in living systems, are almost exclusively L-isomers except some D-isomers (Bege et al., 1993).

With some exception, bacteria and plants can synthesize all of amino acids the need from simpler substances. If the proper raw materials are available, the cells of humans and animals can manufacture some, but not all, of the biologically significant amino acids (Russel, 1996). Those, that humans and animals cannot synthesize, must be obtained through their diet, known as essential amino acids.

The nitrogenous organic compounds in the soil are derived from plant and animal residues, root exudats and microbial cells (Verhoeven et al., 1956; Hale and Moore, 1979). Among these nitrogenous organic
compounds, the amount of the free amino acids, that can be detected in soils, is very small (Sperber, 1958), attesting to the fact that these compounds are rapidly immobilized or transformed. Paul and Schmidt (1960 and 1961) showed that the total amount of free amino acid nitrogen in soils rarely exceeds 2 µg per gm of soil. The amounts of free amino acid nitrogen are related to the level of microbial activity (Putman, 1959; Paul and Schmid, 1960;). It is likely that, some of the combined amino acids in soil remain in the form of mucopeptides and teichicholic acids and these compounds are essential constituent of bacterial cell wall. Some growth stimulators of plants contain amino acids (Takahashi, and Okano, 1999)

In soils with high clay content, there is a greater tendency to preserve potentially labile compound such as amino acids (Sorenson, 1972; Sorenson, 1975; Balesdent et al., 1988). The use of fertilizers affects the contents of free amino acids in soils (Udaipur et al., 1998), which favours the growth of amino acid decomposing, ammonifying and nitrifying bacteria. Amino acid contents have been found highest in both extremities of plants, grown under the conditions of the maximum photosynthesis in soils with moisture content of above 36% of saturation (Lagun, 1972). The amino acid contents of the soil decreased at end of the growth period.

Talibuddin (1955) studied the adsorption of some amino acids by montmorillonite at pH 2.5 and 4 and concluded that the amount of
adsorbed amino acids was a function of basicity and size of the amino acid molecules. Sieskind and Wey (1959) observed that the adsorption of amino acids found a linear relationship between the amount of adsorbed amino acids in meq 100 g⁻¹ montmorillonite at pH 2. Singhal et al., (1978) observed that the pH, particle size and types of soils affect the mobility of amino acids. It has been observed that amino acids mobility was affected by pesticides in soil (Khan et al., 1999).

PESTICIDES

The term pesticide include any substance intended for preventing, destroying, attracting, repelling or controlling any pest including unwanted species of plants and animals during production, storage, distribution and processing of food, agricultural modities or animal feed (Ware 1978). These are the largest group of poisonous substance, available in gaseous, liquid and solid forms. When applied at recommended rates, the concentration of pesticides present in soil does not significantly alter the microbial activity that are important to soil fertility.

At present more than 10,000 different pesticides are widely used to control or destroy the different types of unwanted pests and weeds. Pesticides may be classified into following major categories: insecticides, herbicides, fungicides, rodenticides, nematicides, acricides etc., which are in commonly used:
Insecticides:

Chemical substances, which are used for killing insects are known as insecticides. According to their mode of action, they are usually classified as: stomach insecticides which are lethal only to insects that ingest them, contact or external insecticides which destroy the insect simply by external bodily contact and fumigants which act on the insect through respiratory system. On the basis of chemical nature of insecticides, they may be classified as (i) inorganic (ii) natural and (iii) organic insecticides.

(i) Inorganic insecticides:

Before the introduction of modern insecticides, the inorganic insecticides as well as those of plant origin were extensively utilized for plant protection. In recent years, inorganic insecticides have been generally replaced by organic formulations in various applications. The major disadvantage of inorganic insecticides is in their toxicity to man and other warm-blooded animals. Some inorganic insecticides are: lead arsenate, calcium arsenate, paris green, sulphur and compounds of halogen, copper, phosphorus, mercury, sulphur, etc.

(ii) Natural insecticides:

Plant materials yield some of the most widely used insecticides. Nicotine, rotenone, allethrin etc., are well known examples of natural insecticides.
(iii) Organic insecticides:

Organic insecticides include: organo-phosphorous and chlorinated hydrocarbons.

Organo-phosphorus hydrocarbons:

These have generally a very short residual action. They control a wider range of pests than chlorinated hydrocarbons. They are, however, rarely used for the control of soil pests. These insecticides are poisonous to mammals and should, therefore, be handled with great caution. Parathion, malathion, dimethoate, tetraethylpyrophosphate (TEPP), dichlorvos, phosphamidon, etc., are some common examples of organo-phosphorus hydrocarbons.

Chlorinated hydrocarbons:

They have generally a long residual action and are generally less toxic to mammals than phosphorous compounds. DDT was the first to be used as a synthetic chlorinated hydrocarbon. Although, DDT was prepared by O Zeidler in 1874 but, its insecticidal properties were discovered by a Swiss Chemist, Paul Muller in 1939. Some common chlorinated hydrocarbons are: benzenehexachloride (BHC), endosulfan, methoxy-chlor, chlordane (1068), heptachlor, aldrin, dieldrin, endrin, toxaphene, etc.
Herbicides:

Herbicides are used to control unwanted weeds in cultivated crop plants. The biological activity of herbicide molecules is a reflection of their ability to penetrate into plant tissues, resist detoxication (or be transformed into toxic products), and interfere to particular physiological or biological processes in plants. However, many herbicides, which are effective to monocots, are injurious to dicots. For example, atrazine and diuron interfere the photosynthesis while glyphostate, sulfonyleureas and imidazolone block the synthesis of essential amino acids (Mehta et al., 1993). Herbicides include (i) triazine (ii) substituted ureas (iii) carbanilates (iv) phenoxyalkanoic acids (v) chlorinated aliphatic acids and (vi) amitrole.

(i) Triazines:

The triazine pesticides are among the most widely used agricultural pesticides. These are primarily used as pre-emergent herbicides. They conform to the general formula:

\[
\begin{array}{c}
\text{N} \\
\text{C} \\
\text{N} \\
\text{C} \\
\end{array}
\]

where,

\[ R_1 \text{ and } R_2 \text{ are lower alkyls and } x \text{ is a chloro (-Cl) or methoxy (-OCH}_3\text{) or} \]

thio methyl (-SCH₃), etc. Some of the commonly used triazine herbicides are: simazine, cyanazine, atrazine, prometone, ametryne, prometryne, etc.

(ii) Substituted ureas:

The asymmetric phenylureas constitute one of the most important groups of herbicides that are being used. They are non-volatile, non-corrosive and non-flammable organic compounds. They are absorbed by plants from the soil and translocated up to the tops through the transpiration stream (Minshall, 1954). At low dosage, they are selective and are used to control the seedling growth of weeds in certain crops. At higher dosage, they are used as soil sterilants in non-agricultural areas. Some commonly used substituted ureas are: phenyldimethylureas and chlorophenyldimethylureas.

(iii) Carbanilates:

They are used as pre-emergence and post emergence herbicides. These compounds are readily degradable by microorganisms. They are lost through volatilization, if they are applied to wet soil. Some of the most extensively used compounds of this group are: swep, propham, chlorpropham, barban, etc.

(iv) Phenoxyalkanoic acids:

These are generally employed as pre-emergence treatment in
conjunction with other herbicides, because of their short residual life. The members of this group are used in foliar treatment. Some of the important phenoxyalkanoic acid herbicides are: 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), 2-methyl-4-chlorophenoxyacetic acid (MPC), silvex, etc.

(v) Chlorinated aliphatic acids:

Various chlorinated aliphatic acids such as 2,2-dichloropropionic acid (dalapan), trichloroacetic acid (TCA) and 2,2-dichloroisobutyric acid (FW-450), etc. have been used as chlorinated aliphatic herbicides.

(vi) Amitrole:

It is a substituted triazole (3-amino-1,2,4-triazole) herbicide, which is used primarily due to its resistivity towards microorganisms (Ashton, 1961). However, it was later observed that chemical as well as microbial degradation both may be experienced in this compound.

Some other compounds, which are used as herbicides are: N-aliphatic carbamates, dipyridyls, etc.

Fungicides:

Fungicides have been used for the control of plant pathogens. Fungicides, on application to various plant parts, are absorbed by the plant tissues and translocated either upwards or downwards and control
diseases away from the site of application. They may be described under the following categories:

(i) **Benzimidazoles and thiophanates:**

These are used as foliar sprays, seed, soil and post-harvest dip treatment (Delp and Klopping, 1968).

(ii) **Oxathiim derivativas:**

They possess marked activity against basidioomycetes i.e., stunt and rust fungi in particular (VonSchmeling and Kulka, 1966).

(iii) **Organophosphorus fungicides:**

These are used against blast of rice, powdery mildews, soil-borne diseases, etc.

(iv) **Phenylamides:**

The phenylamides on the whole are very effective against oomycetous fungi.

(v) **Hydroxy pyrimidines:**

The hydroxy pyrimidines have been used on cereals, cucurbits, roses and apples, against their respective powdery mildews.

(vi) **Ergosterol biosynthesis inhibitors:**

They are very selective in their mode of action and are particularly by effective against rust, bunts and mildews of cereals.
Rodenticides:

These are used to control and kill rats, mice, squirrels, ground hogs, field rodents, etc. Warfarin, sodium fluoroacetate, nor-bromide, calcium cyanide, etc., are the common chemicals that are used as rodenticides. Warfarin acts as anticoagulant and depresses prothrombin level, which is a blood protein required for blood clotting. Sodium fluoroacetate, an extremely hazardous rodent killer, causes hyperstimulation of central nervous system and affects hearts action. Nor-bromide constricts small peripheral blood vessels of rats (Sharma and Kaur, 1995).

Nematicides:

Nematicides are used for controlling underground practice nematodes that attack on the root hairs of plants. Nematode problem occurs in all areas of the world where crops are grown. It causes more damage in “old tired soil”, that is those, which have been cultivated for a long period of time. The application of nematicidal chemicals may decrease crop losses (Evan, 1973; Blunt, 1975; Hummel, 1983). Nematicides are of two types (i) fumigants and (ii) non-fumigants.

(i) Fumigants:

Soil fumigants give protection to crop plants for prolonged period, posses a high proportion of active ingredients with effectiveness
against plants (Hollis, 1958). These are usually formulated as liquids, which vaporize and move through air spaces in soil after vaporizing. Some of the important fumigants are: methylbromide (MB), 1,3-dichloropropane, methydisoocyanate, etc.

(ii) Non-fumigants:

They are also called as systemic nematicides. They are often formulated in the form of granules but, some are also available in liquid forms for spraying on soil or foliage. Some common examples of non-fumigant nematicides are: carbofuran, fenamiphos, oxamyl etc.

Acricides:

These are generally employed for the control of pests like mites and ticks, which are actually parasites living on juices sucked from fruit and other parts of plants. Tetraethyl pyrophosphate, nemagon, ilexone, oxamyl, etc., are commonly used acricides.

Although, the use of pesticides is necessary for the modern agrotechnology but, they also affect to non-target organisms (Audns, 1970; Ojha et al., 1992; Ignacimuthu and Sarvana, 1994; Murugappan and Guna, 1996; Zhou et al., 1997; Xing et al., 1998). Recent reports have indicated that our environment is chronically polluted by pesticides (Heuper and Conway, 1964; Viswanathan, 1997; Rath et al., 1998; Zhu and Hu, 1997; Xing et al., 1998), which is increasing tremendously in
various parts of the world. Therefore, there is an urgent need to control and prevent the environmental pollution, posed by pesticides, through a scientific approach.

**SURFACTANTS**

Surfactants are surface-active agents that dissolve partly in water and partly in organic solvents. Surfactants are divisible into three main groups: anionic, cationic and non-ionic.

Anionic surfactants are characterized by the possession of a long non-polar portion to the molecule attached with the compact hydrophilic, ionized group at the end. For example,

\[
\begin{array}{c}
R \\
\end{array} \left[ \begin{array}{c}
\overset{\mathrm{S}}{\overset{\mathrm{O}}{\mathrm{O}}} \\
\end{array} \right] \\
\overset{\mathrm{N}^+}{\mathrm{Na}}
\]

Alkyl benzene sulphonate (LBS)

\[
\begin{array}{c}
R \\
\end{array} \left[ \begin{array}{c}
\overset{\mathrm{S}}{\overset{\mathrm{O}}{\mathrm{O}}} \\
\end{array} \right] \\
\overset{\mathrm{N}^+}{\mathrm{Na}}
\]

Linear alkyl sulphonate (LAS)

where,

\[R = \text{Hydrocarbon chain 12-19 carbons}.\]
Cationic surfactants are usually quaternary ammonium salts. For example,

\[
\begin{array}{c}
\text{R}_1 \\
\text{R}_2 \\
\text{R}_3 \\
\text{R}_4 
\end{array}
\begin{array}{c}
\text{N} \\[+]
\text{X}
\end{array}
\]

where,

R₁, R₂ and R₃ are short hydrocarbon chain and R₄ is aromatic. X is halogen or acid group.

Non-polar surfactants are more soluble in hydrocarbons and similar oily liquids. The most common feature of the non-ionic surfactants is:

\[\text{R-O-(CH}_2-\text{CH}_2\text{-O)}_n\text{-H}\]

Pre-alkyl polyoxyethylene alcohol.

\[\text{CH}_3-(\text{CH}_2)_8-O-(\text{CH}_2-\text{CH}_2\text{-O)}_n\text{-H}\]

Polyoxyethylenenonyl phenolate.

Surfactants lower the surface tension of the liquid in which they are dissolved. They give stable emulsions or suspensions with soil particles that need removal (Yeom et al., 1996). Consequently, surfactants are used for remediation (Lee, 1998; Doong et al., 1998; Yuan and Jafvert, 1995; Nivas et al., 1996; Huang et al., 1997) and bioremediation (Tiehm et al., 1995; Volkering et al., 1998; Boopathy and
A number of aliphatic acids such as, oxalic, citric, formic, acetic, malic, etc., have been found in soils and litters (Stevenson, 1967; McKeague et al., 1986; Tan, 1986). It has been suggested that they are important in the podzolization process (Aritovskaya and Zykina, 1977; Lundstrom et al., 1995). In addition, these compounds have a high carboxyl contents, may therefore be important for the buffering capacity of the soil solutions.

TRACE ELEMENTS AND THEIR EFFECTS

Out of the seventeen elements to be essential for plant growth; eight are required in very small amounts, and are called trace elements or micronutrients (Nicholas and Egan, 1975; Stevenson, 1986). These are iron, manganese, zinc, copper, boron, molybdenum, cobalt and chlorine. The dominant form of trace elements, that remained in the soil solutions, are found mainly iron as Fe$^{2+}$, Fe$^{3+}$, Fe(OH)$_2$$^+$, Fe(OH)$_2$$^+$; manganese as Mn$^{2+}$; zinc as, Zn$^{2+}$, Zn(OH)$^+$; copper as Cu$^{2+}$, Cu(OH)$^+$; molybdenum as MoO$_4^{-2}$, HMoO$_4^{-}$; boron as, H$_3$BO$_3$, H$_2$BO$_3^{-}$; cobalt as Co$^{2+}$ and chlorine as Cl$^-$ (Lindsay, 1972). Plants as well as microorganisms require traces of these elements. Non-availability of these elements in soils may result in the manifestation of specific symptoms in plants.

There is a considerable variation in the specific roles of the various trace elements in plants and microbial growth processes.
(Mengal and Kirkby, 1982; Marschner, 1986). Some of them are found to participate in their cellular enzymes activities and other important processes. For example, copper, iron and molybdenum are capable of acting as "electron carriers" in enzyme systems that bring about oxidation-reduction reaction in plants. These trace metals are required in such type of reactions, as are essential for plant development and reproduction. Zinc and manganese are needed in the function of enzymes, systems necessary for important reaction in plants metabolism. Molybdenum is essential for certain nitrogen transformation in microorganisms as well as in plants (Stiles, 1961). Cobalt is essential for nitrogen fixing microorganisms. Cobalt is also needed in nodules of legumes and alder as well as in nitrogen fixing algae. Chloride acts as countarian during rapid K fluxes, which may have important biochemical and/or biophysical consequences. Boron plays an essential role in the development and growth of new cell in the plant meristem.

The physiological function of trace elements depends on concentration. These are essential for physiological function at low concentration. On the other hand, they have a deleterious effect on living organisms at higher concentrations (Dijkshoorn et al., 1979; Khan and Khan, 1983; Brookes and McGrath, 1984; Brookes et al., 1984; Sharaf, 1996; Anuradha and Raju, 1996; Doelman, 1998; Baath et al., 1998), at which they may be termed as toxic. For example,
molybdenosis, a disease in cattle is caused by an imbalance of molybdenum and copper in their diet. It is reported in literature that Cu, Zn, Fe, Mn, Co, Mo, Cr, Sn, Si, Ni, I, Se, F, V, and As are essential for animal health (Underwood, 1977). Many of these, Cu, Zn, Fe, Mn, Co, Mo, Cr, Sn, Ni, V and As are heavy metals. There is increasing evidence that nickel may be essential for the growth and reproduction of plants (Hutchinson, 1981; Walker et al., 1985). The chemical behaviour of trace elements has been extensively studied in relation to soils and plants (Bowman et al., 1981; Hodgson, 1963; Tiller et al., 1979; Zhu and Liu, 1986).

Utilization of sewage and industrial wastes as a source of micronutrients in most of the developing countries is very common. Composition of these huge waste materials has been studied by various workers (Stover et al., 1976; Anderson and Nilsson, 1972). It was found that harmful metals constitute a major part of its composition along with some useful micronutrients. Metals added in soils remained in the upper layer extended to few inches (Page and Chang, 1975; Williams et al., 1980), because of various immobilizing mechanisms like precipitation and specific adsorption on metal oxides, clay minerals and organic matters. Considering the sludge and wastes as a complex mixture of organic an inorganic species, various available forms of trace metals exist in soil (Tills and Alloway, 1983; Gregson and Alloway, 1984).
It is also important to understand the free ion activity of these trace metals in soil solution and their adsorption-desorption equilibria over soil particles. This gives information regarding the uptake and supply of various elements by plants. Thus, there are dynamic equilibria between various ions in solutions and the solid phase of the soil particles (Sillen and Martell, 1971). The literature available on the role of trace elements under Indian climatic conditions is lamentably inadequate. More attention on the judicious utilization of trace elements is required in the near future.

**FLY ASH**

Coal burning is a major source of energy production in India. Large quantities of solid residues are generated each year (Muraka et al., 1987) from coal burning as a byproduct containing FA (Rehage and Holcambe, 1990). Around 60-70 million tones of FA is produced every year from different thermal power plants in India (Saxena and Ashokan, 1998). Increasing release of FA is becoming a problem for its disposal. The most common methods of FA disposal are land filling and settling ponds (Suloway et al., 1983).

Fly ash contains some useful nutrients such as Ca\(^{2+}\), Mg\(^{2+}\), Cu\(^{2+}\), Zn\(^{2+}\), SO\(_4^{2-}\), PO\(_4^{3-}\), Cl\(^{-}\), etc., (Leonard and Davidson, 1959; Cope, 1962; Hodgson and Holiday, 1966; Saxena et al., 1997) which are essential for plant growth. Therefore, it has agronomic potential (Sikka and
Kansal, 1994) either as liming agent to neutralize soil acidity (Hodgson et al., 1982; Masti and Keramida, 1999), boron fertilizer (Plank and Martens, 1974; Masti and Keramida 1999) and as a physical amendments for soils (Doyle, 1976; Chang et al., 1977) or as a soil modifier (Saxena et al., 1996). Addition of FA to the soil also improves the porosity of the soil and thus, increases the water retention capacity (Campbell, 1983; Saxena et al., 1997).

Many research workers have recommended the use of FA for increasing the crop yield of alfalfa, barley, white clover, rice, wheat and swiss chard (Page et al., 1979; Elseewi et al., 1980; Hill and Lamp 1980; Sikka and Kansal 1995; Summer et al., 1998) and for improving the physical and chemical characteristics of the soils. Hill and Lamp (1980) suggested that FA may be used as Mg fertilizer for pasture. Elseewi et al. (1978) observed that plants grown on sulphur deficient soils responded favourably to incorporation of FA into the soil. The main contraints are still posing strains due to its high alkalinity and salt contents (Adriano et al., 1980) and potentially harmful trace elements like As, Cd, Pb, Sb etc. content (Kleir and Andren, 1975; Bel and Phung, 1979; Thicke, 1988; Chandra 1997) of coal ash which are phytotoxic and inhibit crop growth and cause deterioration to soil. However, there is a tremendous scope for conducting research in relation to soil-FA amendments in the fields of agriculture.
SOIL POLLUTION

Mankind is dependent on the soil either directly or indirectly for food, clothing and shelter. But, increasing world population and the increasing usage of chemical doses, leads to ecological problems because of wide dispersal of these chemicals into the soil environment. Recent research has shown that most of the dispersed toxic, persistent and bioaccumulative chemicals occur widely throughout the global environment. Increasing evidence is coming forward that these substances are having deleterious effect on biological systems (Perrin, 1998; Silant’ev et al., 1998). These substances remain in direct contact with the soils for relatively longer periods. Thus, soil is getting heavily polluted day by day by toxic materials and dangerous microorganisms, which enter into the air, water and the food chain. For all this, man is the original and basic polluting agent responsible for pollution hazards and toxic effects. Soil pollution mainly results from the following sources:

- Industrial wastes and sludges.
- Urban wastes.
- Radioactive pollutants.
- Agricultural practices.
- Chemical and metallic pollutants.
- Biological agents.
Disposal of industrial wastes is the major problem responsible for soil pollution. These industrial pollutants are mainly discharged from pulp and paper mills, chemical industries, oil refineries, sugar factories, tanneries, textiles, steel, distilleries, fertilizers, pesticides industries, coal and mineral mining industries, metal processing industries, drugs, glass, cements, petroleum and engineering industries, etc. Industrial wastes mainly composed of organic compounds along with inorganic complexes and non-biodegradable materials (Baldwin *et al.*, 1983; Jacob *et al.*, 1994; Grosser *et al.*, 1995; Goodin and Webber, 1995; Bechmann and Grunewald, 1995). These pollutants affect and alter the chemical and biological properties of soils. As a result, hazardous chemicals can enter into human food chain from the soil or water and may disturb the biochemical processes and finally lead to serious health hazards.

The industrial wastes consist of calcium salts, fuel gases and several toxic volatile elements such as arsenic, selenium, mercury, lead and cadmium, which pose detrimental affects on environment (William and David, 1973; Tyler, 1981; Lee, 1985).

Urban wastes comprises both commercial and domestic wastes consisting of dried sludge of sewage. Urban domestic wastes, though disposed off separately from the industrial wastes, can still be dangerous. This is so because they can not be easily degraded. The
leachates from the dumping sites and disposal tanks of sewage, mixed with industrial effluents and wastes, are extremely harmful and toxic.

Radioactive substances resulting from explosions of nuclear devices, atmospheric fall out from nuclear dust and radioactive wastes that penetrate into the soil create soil pollution. Radionuclides of radium, thorium, uranium, isotopes of potassium (K-40) and carbon (C-14) are very common in soils, rocks, water and air. Radioactive wastes contain several radionuclides such as strontium-90, iodine-129, caesium-131 and isotopes of iron, which are most injurious. Recently it has been indicated that some plants such as lichen and mushroom can accumulate Cs-137 and other radionuclides, which get concentrated in grazing animals.

Modern agricultural practices are also responsible for the soil pollution to a large extent. Today, with the advancing agro-technology, huge quantities of chemical fertilizers, pesticides and soil conditioning agents are employed to increase the crop yield. Although, the fertilizers are used to fortify the soil, yet they are also found to contaminate the soil with their toxic impurities. For instance, cadmium is the main source of low-grade rock phosphate. When the fertilizers are contaminated with other synthetic organic pollutants, the water present in the soil may also get polluted. Different kinds of pesticides used to control pests and pest born diseases, are causing a stress in the natural environment. Pesticides may get absorbed by soil colloids,
which may contaminate root crops, grown on such soils. In addition to
the fertilizers and pesticides, soil conditioners and fumigants are also
employed to the land system to increase and protect the soil fertility as
well as to kill the hazardous insects. These chemical agents are
reported to cause alteration in both agricultural and horticultural soil
areas. Animal wastes containing several pathogenic bacteria and
viruses enter into plant metabolism and ultimately reach human beings.

Synthetic chemicals and fertilizers containing trace metals
(Swaine, 1962; Tiller, 1983) are added to the soil either deliberately or
as an impurity. Metallic contaminants in soil are considered to be the
indestructible poisons and their accumulation in plants and water may
be highly dangerous.

Soil gets large quantities of human, animal and bird excreta,
which constitute the major source of land pollution by biological agents.
These biological agents are also highly responsible for huge
contamination of soils and crops by pathogens.

THE PROBLEM

The significance of soil science and agricultural chemistry are of
paramount importance in India as it is mainly an agricultural country,
where more than 80% of the population, out of 1000 millions, depends.
In order to feed, a large population the search for a greater output in
food crop production with a low cost indigenous technology is needed
and therefore, different types of materials such as chemical fertilizers, pesticides, fly ash, sewage sludge and industrial waste have been and are being extensively tried to ascertain their feasibility the crop production. But, excessive use of these materials has resulted in a decline in the quality and quantity of crops due to imbalance in the nutrient concentration and microbes in soil.

The aim of the present study was to build a ground structure and to give a fillip to research of national and international importance in field of soil science and Agricultural Chemistry. The thesis has been divided into following parts:

**Part I, general introduction**, covers a brief account of present and past literature in related fields of soil research.

**Part II, chapter I**, describes the role of pesticides such as parathionmethyl, dimethoate, carbendazim, chloroyrifos endosulfan and methyldemeton on the mobility of amino acids through soil TLC.

**Part III, chapter II**, describes the behaviour of fly ash on the mobility of amino acids, such as lysine, glycine, alanine and valine as examined through soil TLC.

**Part IV, chapter III**, describes the effect of surfactants such as CTAB, Triton X-100 and SDS on the mobility of trace metals viz. Pb, Cu, Ag, Zn and Co through soil TLC.
Part V, chapter IV, reports the effect of fly ash on the physiological parameters such as seed germination, number of leaves, shoot length, root length and fresh and dry shoot weight and metals uptake of barley and wheat plants.

Part VI, chapter V, describes the effect of endosulfan pesticide on the physiological parameters such as seed germination, number of leaves, shoot length, root length and fresh and dry shoot weight and nutrients uptake of fenugreek plant, which is used as spices and medicine.
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