CHARACTERIZATION, CLASSIFICATION AND NUTRIENT INDEXING OF SAFFRON GROWING SOILS OF DISTRICT PULWAMA

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(2007-196-D)

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THESIS

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DOCTOR OF PHILOSOPHY IN AGRICULTURE
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Dedicated

to my beloved Parents

&

Late Brother (Mr. Tariq A. Bhat)

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Soil Science,
Shalimar Campus, Srinagar – 191 121
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CERTIFICATE – I

This is to certify that the thesis entitled, **"Characterization, Classification and Nutrient Indexing of Saffron Growing soils of district Pulwama"** submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Agriculture (Soil Science)**, to the **Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Mohammad Iqbal Bhat (Regd. No. 2007-196-D)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

(Dr.G.R.Najar)
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Certificate – II

We, the members of the Advisory Committee of **Mr. Mohammad Iqbal Bhat (Regd. No. 2007-196-D)**, a candidate for the degree of **Doctor of Philosophy in Agriculture (Soil Science)**, have gone through the manuscript of the thesis entitled, **"Characterization, Classification and Nutrient Indexing of Saffron Growing soils of district Pulwama"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

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CERTIFICATE – III

This is to certify that the thesis entitled, **“Characterization, Classification and Nutrient Indexing of Saffron Growing soils of district Pulwama”** submitted by **Mr. Mohammad Iqbal Bhat (Regd. No. 2007-196-D)**, to the **Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Agriculture (Soil Science)** was examined and approved by the Advisory Committee and External Examiner on …………….

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Title of the Thesis	:	**Characterization, Classification and Nutrient Indexing of Saffron Growing Soils of District Pulwama**

ABSTRACT

A systematic and scientific appraisal of natural resources, especially soils is important and helpful to augment food production. Soil resource inventory is, therefore, basic for rationalizing land use according to its potentiality. Since no two soils are alike and have their own potential and/or problems and behave differently to management inputs, therefore, their use as per their potential is imperative for sustainable agriculture production.

On the basis of physiography the soils of Kashmir valley have been categorized into high altitude (Kandi), mid altitude (*Karewa*) and the low altitude (Valley basin). The mid altitude saffron growing *karewas* are the Pleistocene and post-pleistocene deposits of lacustrine origin with an altitude of 1582-1800 m (amsl). The commercial importance of these soils for the saffron crop in particular necessitates their characterization classification and nutrient indexing for agro-technological transfer. In order to address the above objective 15 representative soil profiles were selected from whole of the saffron belt in the Pulwama district on the basis of variation in apparent soil colour, topography and aspect. The excavated soil profiles were thoroughly examined for morphological characteristics and horizon wise soil samples were collected for laboratory analysis. The profiles were found to be of A-B or A-C type, with either well developed sub-surface diagnostic argillic horizon (B_t) in profiles on near level lands facing north and the cambic horizon in profiles facing south. The profiles on higher elevation with very gentle slope did not show any profile development. The texture showed variation with increase in the depth of the soil pedon. Generally the soil texture changed from silt clay/loam to clay loam except in profiles P_{10}, P_{11} and P_{12} where it changed from loam to sandy loam, clay loam to loam and silt loam to clay loam/silt loam. The pH was slightly acidic to alkaline in pedons facing northern aspect and alkaline in the southern aspect facing pedons. The $CaCO_3$ was found only at the sub-surface horizons giving an indication of calcareous nature of the parent material. Electrical conductivity in all the profiles was in normal range. The organic carbon content in the leveled land profiles facing north was found higher as compared to south facing pedons. The cation exchange capacity of north facing pedons was also found higher than south facing pedons and it showed generally an increasing trend with the depth of soil pedon. The exchange complex was dominated by Ca^{2+} followed by Mg^{2+} and K^{+}, respectively. Clay mineralogy revealed the dominance of illite followed by mixed layer, hydroxyl interlayered vermiculites, smectite, chlorite, kaolinite and some amount of quartz and feldspar. All the micro-nutrient were found in sufficient range and among the primary macro-nutrients N and K varied from medium to higher range and available phosphorus was found in the lower range (deficit). Among the micronutrient Zn, Fe, and Mn showed significant positive correlation with organic carbon and negative significant correlation coefficient with soil pH. The soils are classified as Eutrochrepts, Udorthents and Hapludafls, respectively. Nutrient indexing for N, P and K, too revealed that these soils are deficient in phosphorus and require phosphorus along with nitrogen and potassium management for sustainable saffron yields.

Keywords: Alfisols, Argillans, Cambic, Characterization, Classification, Clay cutans, Illites, Mineralogy, Nutrient indexing, Udorthents

Signature of the Student | Signature of Major Advisor

Dated…………………. | Dated……………………..

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Mohammad Iqbal Bhat

Place : Shalimar, Srinagar
Dated :

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CHAPTER – 1

INTRODUCTION

Soil is the most precious natural resource. Maintaining soil in a state of high productivity on sustainable basis is important for meeting the basic needs of the people and livestock. It is particularly important in a country like India, which is largely dependent on agriculture. During the past few decades, we have made significant strides to achieve self-sufficiency in food production. In order to meet the challenge of increasing food requirement for the ever increasing population and to maintain the quality of the environment we live in, it is essential that the soil and water resources are used rationally and in a way so as not to affect adversely the productivity and ensure to leave a better heritage for the posterity.

A systematic and scientific appraisal of natural resourses, especially soils is important and helpful to augment food production. Soil resource inventory is basic for rationalising land use according to its potentiality. Since no two soils are alike and have their own potential and/or problems and behave differently to management inputs, therefore, their use as per their potential/capability is imperative for sustainable agriculture production.

The state of Jammu and Kashmir is located in the north western corner of India between 32°15′ and 37°05′ N latitudes and 72°35′ and 80°20′ E longitudes. It covers an area of 22.2 m ha and accounts for 6.7 per cent of total geographical area of the country (India). The average height of the valley (Kashmir) is 1,850 meters above sea level (Anonymous, 2008).

Saffron, the legendary crop of Kashmir, belongs to the family *irridaceae* and genus *crocus*, of which about 80 species are so far known. Its cultivation in the world extends through 0-90°E longitude (Spain to Kashmir) and 30-45°N latitude (Persia to England).

In India, most of the saffron production is limited to the state of Jammu and Kashmir, and is chiefly grown in the districts of Pulwama, Budgam, Anantnag, Srinagar and Kishtwar (Mir, 1992 and Zargar, 2001).

The total area under saffron cultivation in Iran increased almost four fold during the last 12 years with a mean annual growth rate of 22.4 per cent. However, total saffron production during the same period increased 2.8 times, with a mean annual growth rate of 13 to 7 per cent (Anonymous, 2002). This trend was converse in India during the past 10 to 15 years, as is evident from the fact that till 1997-98 the total area under saffron cultivation in the valley was 5361 ha and the annual production output was approximately 17 mt of dry yield while in 2002-03 the total cultivated area was 2710 ha and the production was approximately 6 mt the decline in cultivation area and production since 1997-98 is 49 per cent and 64 per cent respectively (Molafilabi, 1994; Zargar, 2001 and Anonymous, 2008).

The valley of Kashmir is physio-graphically categorised into high altitude (Kandi), mid altitude (Karewa) and the low altitude (Valley basin). *Karewas* are the flat-topped like features in Kashmir valley and occur in the districts of Baramulla, Budgam and Pulwama and have developed on the morainic deposits of Pleistocene glaciation. These are formed from clay, silt and sand of lacustrine origin. The *Karewas* are moderately to highly dissected. The limited knowledge and under standing of these soils could not be extended for their practical application and proper utilization.

The occurrence of diverse soil type due to variation in climate, relief, slope, aspect, parent material, temperature etc. necessitates their characterization and systemic ordering – classification, in order to understand their potential and problems and to make use of such information for land resource management and also to make easier the transfer of agro-technology among different locations belonging to same agro-ecological zone/regions.

Clay is an important soil constituent that controls its properties and also influences its management and productivity (Davies *et al.*, 1972).

Considering the influence of clay mineralogy on the soil physico-chemical behaviour, its quantitative and qualitative characterization can provide important information for the improvement of soil management practices.In general, detailed mineralogical investigation can indicate the most probable fate of the plant nutrients added to a soil and can also support a better understanding of the soil genesis and the electro-chemical behaviour.

Keeping in view, the declining productivity and production of world's spice (Saffron), the present investigation entitled "Characterization, Classification and Nutrient Indexing of Saffron Growing Soils of District Pulwama", was under taken with following specific objectives :

- To characterize and classify the saffron growing soils as per soil taxonomy.
- To investigate the mineralogical build up of saffron growing soils.
- To study the nutrient status of these soils.
- To find out the relationship between soils characteristics and available nutrients.

CHAPTER – 2

REVIEW OF LITERATURE

The review of literature pertaining to the present investigation, “Characterization, Classification and Nutrient Indexing of Saffron Growing Soils of District Pulwama” has been broadly discussed under the following headings:

2.1 Morphological characterization of soils

2.2 Physico-chemical characterization of soils

2.3 Mineralogical composition

2.4 Soil classification

2.5 Nutrient status of saffron soils

2.6 Relationship of available nutrients and some important physico-chemical properties

2.1 Morphological characterization of soils

The soils can best be evaluated from the in-situ examination of the soil profiles. Soil description form the basis for classifying soils into defined categories. It is, therefore imperative that a recently excavated profile, large enough for observation is studied. The soil profile study begins with a demarcation of soil horizon boundaries. Each horizon is then carefully observed, studied and described in respect of various morphological characteristics, such as colour, texture, structure, consistence, mottling, roots, pores, boundary, cations, nodules and several other features of the horizons of soil profiles as can be perceived in the fields which signify the inherent characteristics of soil development during soil genesis.

Shinde *et al.* (1984) studied some typical soils of lacustrine deposits of Jammu and Kashmir and reported that the colour of the soils were light yellowish brown (10 YR 6/4D) to darker yellowish brown (10 YR 5/4D) with clay loam to silty clay loam texture. The structure was found to be moderately developed angular to sub-angular blocky.

Shinde and Talib (1984) studied saffron growing soils of Pampore and Kishtwar *Karewa*s, reported the rooting zone (2-75 cm) of these soils were moderate to strong, coarse to medium, subangular to angular blocky in structure varying from clayloam to silty clay loam in texture. According to Pal and Deshpande (1987) two pedons namely Gogji Pather and Wathora of Kashmir valley were dark brown, yellowish brown and dark greyish brown in colour, the texture of these soils was generally silty loam to silty clay loam with moderately developed granular, angular to sub-angular blocky structure.

Verma *et al.* (1990) while studying the forest soils of Kashmir valley and observed that the surface soils were dark brown to very dark grey colour 10 YR hue,with a chroma of 1-3 and value 3. The soil structure was weak to moderate granular in the surface and moderate to strong sub-angular blocky in the sub-surface horizons. The texture of the soil was silty loam and soil consistence was loose, soft friable, in dry and moist conditions, respectively. Singh *et al.* (1991) while studying the soils of Mizoram in relation to altitude, found that the colour in surface horizons were very dark grey (10 YR 3/1) to dark brown (10 YR 1/3), while in subsurface horizons it was yellowish brown (10 YR 5/4) to strong brown (7.5 YR 5/6) at higher altitude, but at the lower altitudes the colour of surface and sub-surface horizons was mostly olive brown (2.5 YR 4/4). The soils at higher and lower altitudes were found to have sandy clay loam and loam texture with angular blocky and blocky structure, respectively.

Kaishta and Gupta (1993) reported that the soils of subhumid temperate high lands had a colour value of 3 to 4, chroma of 2 to 3 and hue of 10 YR. The soils were loamy or silty loam in texture with granular to angular/sub-angular blocky structure. Mushki (1994), while studying the soils of Kashmir, found that the *Karewa* soils had colour value of 4 to 7, chroma 2 to 4 and hue of 10 YR. The soils were silty-loam to clay loam in texture with angular to sub-angular blocky structure. The colour of the surface and sub-surface soils of Soan river valley of Himachal Pradesh, varied from brown to dark yellowish brown with texture of sand to sandy loam. The presence of calcium carbonate was evident by strong to violet effervescence and the consistency in surface soils was reported as friable, non-sticky and non-plastic (Sharma *et al.*, 1994).

According to Singh and Mishra (1996) the soils of command area of Bihar were grey with hue of 2.5 to 5 YR in the surface horizons, whileas the subsurface horizons showed increase of chroma as compared to surface horizons. The texture of soils varied from loamy sand to silty clay loam with medium moderate angular blocky structure. Chamuah *et al.* (1996) while characterizing the soils of Jorhat district of Assam on hilly slopes, reported yellowish brown (10 YR 5/6), brownish yellow (10 YR 6/8), brown (10 YR 4/3), light brown grey (10 YR 6/2) and light grey (10 YR 7/1) colours. The texture varied between loam to clay loam with moderate sub-angular blocky to massive structure. Gupta and Tripathi (1996) observed black (10 YR 2/1) or yellowish red (5 YR 5/8) colour in the surface horizons and brown (10 YR 4/3) or strong brown (7.5 YR 5/6) in the subsurface horizons in North-west Himalayan soils. The soils were silty clay loam, clayey in texture with granular to blocky/subangular blocky structure of different grades and sizes.

Sidhu *et al.* (1999) while characterizing and classifying some dominant soils of Jammu region, observed that the colour of the soils varied from brown (10 YR 4/3), dark greyish brown (10 YR 3/2) to reddish brown (5 YR 4/4) and yellowish brown (10 YR 5/4) in the surface horizons, whereas it varied from dark yellowish brown (10 YR 4/6), brown (10 YR 4/3), dark brown (7.5 YR 4/4) and the reddish brown (5 YR 4/4) in the sub-surface horizons. The soils in general were fine textured with medium to moderate sub-angular blocky structure. While studying the soils of Ladakh, Walia *et al.* (1999) found a wide range of colour values from 3 to 5, chroma 2 to 4 with a hue of 10 YR. The soils were coarse to moderately coarse textured with granular to blocky structure.

Mahapatra *et al.* (2000), while working with the soils of Kashmir valley, observed that the altitude and relief have signficiant bearing on the soil properties like colour, texture, structure and consistency. The high altitude soils have a colour value ranging from 3 to 4, chroma 3 to 4 with a hue of 10 YR, whereas the *Karewa* valley soils had a value of 2 to 4, chroma 2 to 4 with mostly a common hue of 10 YR. The soils were medium textured (silt loam) to fine textured (silty clay loam, clay loam) with angular/subangular blocky structure. Singh *et al.* (2000), found that the colour of the surface horizons were yellowish brown (10 YR 5/8), light olive grey (2.5 YR 5/4), whereas, in the subsurface horizons it was pinkish grey (5 YR 6/2). The soils in general were fine textured (clay loam) with granular or blocky/subangular block structure, in case of the older alluvium area. Katoo (2001) reported that the soil colour varied from 10 YR ¾ to 10 YR 3/2 in surface horizon and 10 YR 4/3 to 10 YR 4/4 in the sub-surface with clay loam texture and subangular blocky structure.

Nayak *et al.* (2001) reported that the colour of three out of five pedons of Central Research Station, Bubaneshwar ranged from light yellowish brown to yellowish red on the surface to red in sub-surface horizons. Soil structure varied from subangular blocky on the surface and angular blocky in the surface horizon. The colour of other two pedons varied from pinkish grey to grey and light grey to light brownish grey for surface and subsurface soils.

While studying the soils belonging to three different physiographic land slopes, Khademi and Mermut (2003), observed that colour (moist) varied from 10 YR 5/4 to 5 YR 4/6, 10 YR 4/4 to 5 YR 8/1 and 10 YR 4/3 to 10 YR 5/4 with soil structure massive to angular blocky structure, massive, granular to subangular blocky and a texture of loam to clay loam, silty clay loam and silty clay loam to silty clay, in colluvial fans, plateaus and alluvial fans, respectively. Marathe *et al.* (2003) observed that the soils on plateau have shallow soil depth (27 cm) with abundance of coarse fragments (10-14%). The soil was dark greyish brown (10 YR 4/2) in colour with subangular blocky and loam in structure and texture, espectively.

A reconnaissance soil survey of the Neogal Watershed in North-west Himalayas was undertaken by Sharma *et al.* (2004) to characterized the soil on the basis of effect of slope and reported that the colour, texture and consistence ranged from brown to dark yellowish brown, loamy sand to loam and loose to hard in surface and strongly brown to yellowish brown, sand to clay loam and loose to very hard in subsurface horizons, respectively. The soil structure observed was granular to subangular blocky in surface and subsurface horizons. Darmody *et al* (2005) reported while working with Holocene maraines, that the soils were coarse textured with weak horizon development. Soil colours tended to be dark grey and dull, chromos were 1 or 2 and values ranged from 2 to 4. Soil hues were typically 2.5 Y to 5 Y.

Sitanggang *et al.* (2006) while studing a micro-shed in Gurgaon district (Haryana) revealed that the soils in the study area ranged from 35 to more than 150 cm in depth due to variation in topography and slope gradient. Except pedon seven (P7) which was darker in colour, soils in the study had lighter colour in the surface horizons than the sub-surface horizons. The structure was massive in surface horizons while massive to subangular blocky structure in case of subsurface horizons. From a detailed soil survey of the Kiar-Nagali micro-watershed in North-west Himalayas, Tripathi *et al.* (2006) observed a considerable homogeneity in profile development of Nagali-II, Kiar and Kundla (AP-A2-BW-BC) in contrast to Nageli-I (A1-A2-2C1). The soils were well to excessively drained. The horizon boundaries were clear to diffuse in distinctness and smooth to wavy in topography. The colour of the surface horizons vaired from dark brown (10 YR 3/3) to yellowish brown (10 YR 5/4) while the subsurface horizons were brown (10 YR 4/3) to dark yellowish brown (10 YR 4/4). The texture, structure and consistency ranged from silty loam to loam; weak to moderate, fine to medium granular; soft to hard, friable to firm, slightly sticky to sticky, and slightly plastic in surface horizon, respectively. Whereas, the respective characteristics in sub-surface horizons ranged form loam to silty loam; subangular blocky to angular blocky; slightly hard to hard, friable to very firm, slightly sticky to very sticky, and very plastic to plastic.

Rasmussen *et al.* (2007) studied a series of well-drained soils across an elevation gradient (between 150 and 2800 m) on the western slope of the

Sierra Nevada in California and observed that differences in soil genesis resulting from variation in parent materials are small relative to the effects of climate. The colour value (moist) varies 10 YR 2/2 to 7.5 YR 3/3 and 10 YR 5/3 to 5 YR, in surface and sub-surface horizons, respectively along an elevation and climate gradient. The texture reported varied from loamy to clayey one.

The examination of selected soils from south Tripura district of North-eastern India by Gangopadhyay *et al.* (2008) revealed considerable profile development in pedon-1 (Gokulpur) while the pedon-3 (Dhaganagar) and pedon-5 (Kakrabon) show homogeneity in profile development in contrast to that of Pedon-2 (Khilpara) and Pedon-3 (Chhataria) which showed lithological discontinuity. The colour of the soils varied from dark brown to dark grayish brown at the surface and dark greyish brown to reddish brown at the sub-surface horizons. The soils were fine loamy in texture except the Pedon-3 (Chattaria) soils which were fine loamy over coarse loamy in texture. The consistency of the soils (moist) was friable in all the soils but the consistency (wet) varied from slightly sticky and slightly plastic to sticky and plastic. The structure observed varied from massive to subangular blocky in surface horizon and moderately sub-angular blocky in all sub-surface horizons. Rao *et al.*

(2008) studied typical pedons representing major land forms of Ramachandrapuram mandal in Chittor district of Andra Pradesh viz. plain, upland and hill slope developed from alluvium and granite-gneiss occurring under varying land use and observed that these soils were moderately deep to very deep in depth, soil colour varied from very dark grayish brown (10 YR 3/8) to brown (7.5 YR 4/4) in plains, brown (10 YR 4/3) to dark red (2.5 YR 3/6) in upland and very dark grayish brown (10 YR 3/2) to dark red (2.5 YR 3/6) on hill slope. The soils showed wide variation in texture i.e. from sandy to clay loam (plain), sandy loam to clay loam (upland) and sandy clay loam (hill slope). The structure of the soils was single-grained, crumb, subangular to angular blocky in plains, subangular to angular blocky in upland and subangular blocky in hill slope. The consistency of the soils occurring on plains varied from loose to hard (dry), loose to very firm (moist) and non-sticky and non-plastic to sticky and plastic (wet) whereas the soils in upland exhibited loose to hard (dry), very friable to firm (moist) and non-sticky and non-plastic to slightly sticky and slightly plastic. Further, soils located on hills slope were reported slight hard to very hard (dry), friable to firm (moist) and slightly sticky and slightly plastic to sticky and plastic in consistence.

In order to assess the effect of slope and aspect on soil characterization a study was undertaken by Verma *et al.* (2008) in the Tehri-Garhwal district of Uttrakhand. The observation revealed the colour of the surface horizon of the northern aspects was darker with value 2 to 3 and chroma 2 whereas south facing pedons had lighter colour with value 4 to 6 and chroma 3 to 4. The subsurface horizons of north facing pedons were in hue 5 YR, whereas it varied from 5 YR to 7.5 YR on south-facing pedons. However, former had values 2 to 4 and chroma 2 to 3 wheras latter had values 3 to 5 and chroma 4 to 6. The texture of surface horizon was clay loam in all the pedons observed in northern aspect whereas it vaired from loam to silt loam in southern aspect. The texture of subsurface horizon also varied in both the aspects viz. loam to silt clay loam in north-facing pedons and sandy loam to silt loam in south-facing pedons. The structure in north-facing pedons ranged from very fine granular to moderately strong subangular blocky whereas in south-facing pedons it varied from fine, weak, crumb to medium, moderately subangular blocky. The consistency was also observed to vary in both the aspects. Similarly, Najar (2009) reported that the altitude and aspect play a significant role on the morphological characters of the soil. The colour values of the soils varied form 3 to 6, chroma 1 to 4 with the common hue of 10 YR. Soils on the northern aspect were either dark brown/brown or pale brown at the surface whereas, in the subsurface they were yellowish brown. Contrary to this the soils on the southern aspect both in the surface and subsurface have various shades of grey colour. The soils on southern aspect was observed to pass moderately fine to fine texture where as those of northern aspect had medium to moderately finer texture. The soils of the surface horizons developed granular structure, friable consistency at higher altitudes on both the aspects, whereas at lower altitudes these were reported to have sub-angular blocky structure on both the aspects. In subsurface horizons, the soils developed angular blocky to subangular blocky structure on both the aspects.

2.2 Physico-chemical characteristics of soils

2.2.1 Soil reaction (pH)

The degree of soil acidity or alkalinity, expressed as soil pH, is a "*master variable*" that affects a wide range of soil properties – chemical, biological and indirectly, even physical. Jalali *et al.* (1989) found a pH value ranging from 5.4 to 6.7, 6.2 to 8.3 and 6.6 to 7.8 in high altitude, *Karewa* and valley basin soils of Kashmir. Verma *et al.* (1990) observed that pH in the surface soils of Kashmir valley was 5.6 to 6.0 with a slight increase in subsurface horizons in Duksam and Yus locations. Mushki (1994) observed a pH variation of 6.5 to 6.7 in the apple orchard soils of Kashmir. Farida (1997) reported a pH range of 7.6 to 7.8 in some *Karewa* soils of Kashmir valley. Ganai *et al.* (1999) observed that almond growing soils of Kashmir were slightly acidic to neutral in reaction and pH values varied from 6.2 to 8.3 with mean pH values showing slight increase with depth. Sharma *et al.* (2004) found that the soils of Neogal Watershed in North-west Himalayas varied in pH from 5.2 to 6.2; with a slight variation along the depth of a pedon. Similarly, Thangasamy *et al.* (2004) found a pH variation of 5.83 to 8.47 across the pedons of micro-watershed of Chittor district in Andhra Pradesh.

According to Kirmani (2004) the soil reaction of lacustrine deposits were acidic to alkaline in nature and exhibited a slight increase with the depth of the pedon. Tripathi *et al.* (2006) reported that the soils of Kiar-Nagal; micro-watershed in North-west Himalayas, were neutral to slightly alkaline (7.2 to 7.6) and showed slight increase with depth. Verma *et al.* (2008) while evaluation the influence of slope, aspect and altitude on soil characteristics in Garhwal Himalayas, observed the surface soils of north facing pedons had higher pH values (6.3 to 6.7) as compared to south facing pedons (5.4 to 6.0). The maximum difference in surface and subsurface horizons were found on higher altitude of north aspect. Najar *et al.* (2009) observed the pH of the apple growing soils varied from 6.7 to 7.2 in surface horizons with a slight increase in subsurface horizons. The soils in northern aspect were found slightly less alkaline in nature than the soils in the southern aspect.

2.2.2 Electrical conductivity (EC)

Mushki (1994) observed that the electrical conductivity range from 0.15-0.39 $dsm^{-1}$and 0.10 to 0.43 dsm^{-1}in surface and subsurface layers of apple orchard soils of Kashmir respectively. Wani (1994) found that the electrical conductivity in the *Karewa* soils of Kashmir was in the range of 0.09 to 0.32 dsm^{-1}. Dar (1996) while working on cherry orchards of Kashmir reported that electrical conductivity of the surface soils ranged from 0.11-0.48 $dsm^{-1}$with a mean value of 0.24 $dsm^{-1}$and in subsurface soils it varied from 0.08 to 0.36 $dsm^{-1}$with a mean value of 0.17 dsm^{-1}.

Farida (1997) observed that the electrical conductivity in high altitude, *Karewa* and valley basin soils of Kashmir varied from 0.14 to 0.15, 0.15 to 0.24 and 0.30 to 0.42 dsm^{-1}, respectively. Ganai (2001) reported that the electrical conductivity of saffron growing soils of Kashmir valley ranged from 0.09 to 0.32 $dsm^{-1}$with mean value of 0.16 dsm^{-1}. Electrical conductivity in normal range of 0.11 to 0.40 dsm^{-1}in Lethpora command area was also reported by Katoo (2001). Kirmani (2001) reported that the electrical conductivity of 0.08 to 0.17 dsm^{-1} in some of the lacustrine surface soils of Kashmir valley. Thangasamy *et al.* (2004) found that the electrical conductivity varied form 0.02 to 0.26 dsm^{-1} which was in the normal range. Rao *et al.* (2008) observed that electrical conductivity ranged from 0.01 to 0.04 dsm^{-1} in surface horizons and 0.02 to 0.12 dsm^{-1} in subsurface horizons, respectively and also showed a variation down the slope gradient. Similarly, Dhale and Prasad (2009) found a variation in the electrical conductivity which ranged 0.15 to 0.40 dsm^{-1} and 0.15 to 0.54 dsm^{-1}in the surface and sub-surface horizons of the analysed pedons, respectively. Najar *et al.* (2009) from his study revealed a variation in electrical conductivity but it remained well under normal range. It ranged from 0.20 to 0.56 dsm^{-1} in pedons facing south and 0.15 to 0.40 dsm^{-1} in pedons facing north.

2.2.3 Calcium carbonate ($CaCO_3$)

Wani (1994) observed that $CaCO_3$ content in *Karewa* soils of Kashmir ranged from 1.00 to 5.50 per cent. Gupta and Tripathi (1996) reported 1.5 to 7.6 per cent calcium carbonate in North-west Himalayan soils of Kangra district of Himachal Pradesh. The $CaCO_3$ content varied from 0.20 to 0.40, 1.40 to 1.90 and 0.50 to 0.80 per cent in high altitude, *Karewa* and valley basin soils of Kashmir, respectively (Farida, 1997). Ganai *et al* (2000) reported that the $CaCO_3$ content varied from 1.25 to 10.82 per cent in the saffron growing soils of Kashmir showing an increase alongwith the depth of the pedon.

The upland soils have no free $CaCO_3$ while it ranged from 2.8 to 8.2 per cent in lowland soils of Soan basin (Bihar) (Singh *et al.*, 2000). Najar (2002) observed 1.2 to 8.60 per cent calcium carbonate in some surface soils of *Karewa*s, whileas it ranged from 4.6 to 10.50 per cent in subsurface, an increasing trend was observed with depth. Ahmad (2003) observed the increasing trend of calcium carbonate with depth, with range of 3.32-4.67 per cent in surface and subsurface while studying the orchard soils of district Baramulla. Kirmani (2004) reported zero to 1.40 per cent $CaCO_3$ in surface and zero to 17.80 per cent calcium carbonate in subsurface horizon of the pedons in the lacustrine belt of Kashmir valley. The free $CaCO_3$ was observed in all the soils examined and the content ranged from 5.0 to 100 g kg^{-1}. The highest content was found in pedon on piedmont plain (P4) followed by pedon on ravinous area (P_3) and alluvial plain (P6), respectively (Sitanggang *et al.*, 2006). The $CaCO_3$ content varied from 0.85 to 1.83 g kg^{-1} (plains), 0.53-1.40 g kg^{-1} (uplands) and 0.50 to 0.85 g kg^{-1} (hill slope). Sub-surface horizons showed higher content of $CaCO_3$ as compared to surface horizons (Rao *et al.*, 2008).

2.2.4 Organic carbon

Handoo (1983) reported that the organic content varied from 0.45-

4.83 per cent in Kashmir valley soils with high content in surface horizons. The organic carbon content of 0.21 to 0.99, 0.30 to 0.99 and 0.60 to 1.77 per cent in the valley basin, *Karewa*s and high altitude soils of Kashmir was reported by Jalali *et al.* (1989). The organic carbon content in apple orchard soils of Kashmir ranged from 0.90-3.18 and 0.15-2.16 per cent of surface and sub-surface horizons (Mushki, 1994). While studying saffron growing soils of Kashmir, Wani (1994) observed that the organic content in surface and sub-surface was in the range of 0.18-0.87 and 0.15-0.54 per cent, respectively.

According to Farida (1997), the organic content of some bench mark soils of Kashmir at different altitudes varied from 0.63 to 1.27 per cent. Mahapatra *et al.* (2000) observed that the organic carbon content varied from 0.2 to 1.6 per cent in some pedons of Kashmir valley. The organic carbon content of 4.11 to 0.36 per cent was reported in pedons of forest, pasture orchard and arable lands of south Kashmir (Dandroo, 2001). The organic carbon content in the saffron growing soils of Kashmir ranged from 0.18 to 0.87 with an average mean of 0.59 per cent (Ganai, 2001). Khademi and Mermut (2003) observed a varied organic carbon content in the Argids of Iran. The organic carbon content ranged from 0.50 to 11.7 g kg^{-1} of soils, which showed a decreasing trend, with the depth of the pedon. Soil organic carbon content has been shown to be related to particle size distribution. The organic carbon content in the Neogal Watershed of North-west Himalayas varied from 3.2 to 9.5 g kg^{-1} of soil. The organic carbon content showed a definite relationship with the slope and altitude of the area, besides the type of vegetation (Sharma *et al.*, 2004).

According to Patil and Prasad (2004) organic carbon content varied from 33 to 2 g kg^{-1} with depth, being higher in surface layers than in the subsurface horizons and topography, slope and type and amount of vegetation showed a very well established relationship. The organic carbon content of Kiar-Nagali Microwatershed in North-west Himalayas varied from 11.7 to 23.5 g kg^{-1}in surface and 4.5 to 16.2 g kg^{-1} in subsurface soils, respectively. The carbon content observed, was relatively higher in forest soils as compared to those under cultivation (Tripathi *et al.*, 2006). Singh *et al.* (2006) observed that the organic carbon ranged from 0.23 to 1.20 per cent in different soil layers. The upper most soil layer (0-5 cm) had higher organic carbon as compared to 5-15 and 15-30 cm soil layers. Wills *et al.* (2007) reported that there is significant difference between the soil organic carbon content of varied land uses. Soil organic carbon content ranged from 0 to 48.2 g kg^{-1} in the agricultural field and 0 to 165.7 g kg^{-1} in the prairie. Najar *et al.* (2009) while studying the effect of aspect and slope on some apple orchard growing soils of Kashmir valley, observed higher content of organic carbon in northern facing pedons that ranged from 1.6 to 35.0 g kg^{-1} soil where as in southern aspect it ranged from 1.0 to 24.0 g kg^{-1}, respectively.

2.2.5 Cation exchange capacity (CEC)

The cation exchange capacity of Kashmir soils vary from 20.0 to 33.0 meq/100 g of soil (Gupta *et al.*, 1980 and Handoo, 1983). Shinde *et al.* (1984) reported that the CEC of saffron growing soils of Kashmir ranged from 15.0 to 22.0 meq/100 g soil. Verma *et al.* (1990) found slightly lower values of 7.1 to 9.2 meq/100 g of soil in some pedons of Kashmir. While studying apple orchards of Kashmir valley, Mushki (1994) observed cation exchange capacity between 5.90 and 11.90 cmol (P^+) kg^{-1} soils. Farida (1997) reported that the CEC estimates ranged between 20.70 to 21.20, 14.00 to 18.20 and 11.30 to 12.80 (cmol (P^+) kg^{-1}] in high altitude, *Karewa* and valley basis soils of Kashmir. Sidhu *et al.* (1999) reported 3.7 to 19.1 cmol (P^+) kg^{-1} in some dominant soils of Jammu region. The CEC in the range of 16.0 to 20.5 cmol (P^+) kg^{-1} was observed in the saffron soil of Kashmir valley (Ganai *et al.*, 2001). Kirmani (2001) noticed 13.0 to 18.0 cmol (P^+) kg^{-1} soil CEC in some surface layers of lacustrine soils. The orchard soils of Kashmir showed CEC in the range of 16.6 to 20.8 and 18.9

to 20.5 (cmol (P^+) kg^{-1}) soil in surface and sub-surface horizons, respectively (Ahmad, 2003). The CEC of 4.9 to 14.3 cmol (P^+) kg^{-1} soil was observed in the soils of Neogal watershed in the North-west Himalayas (Sharma *et al.*, 2004). The CEC associated with iso-hyperthermic and ustic moisture regime was found to be in the range of 1.5 to 45.1 cmol (P^+) kg^{-1} soil (Thangasamy *et al.*, 2004).

The cation exchange capacity varied from 9.8 to 14.8 cmol (P^+) kg^{-1} which decreased with depth (Tripathi *et al.*, 2006). Darmody *et al.* (2005) observed low cation exchange capacity in the storbreen glacial foreland and the adjacent hill slope soils that ranged from 2 to 25 cmol (P^+) kg^{-1}. According to Sitanggang *et al.* (2006) CEC of the soils from hill slope to alluvial plain ranged from 6.00 to 12.57 cmol (P^+) kg^{-1}. The CEC were high in north facing pedons than south facing pedon and it ranged from 15.2 to 74.8 and 14.0 to 20.3 cmol (P^+) kg^{-1} soil, respectively. In addition with increase in altitude CEC also increases (Verma *et al.*, 2008). Najar *et al.* (2009) observed that the cation exchange capacity of north-facing soil was higher [17.20 to 22.6 cmol (P^+) kg^{-1}]. The CEC was also found lowest at the lower altitude.

2.2.6 Exchangeable calcium

Shinde *et al.* (1984) reported a varied range for exchangeable calcium in the saffron growing soils of Kashmir valley that ranged 11.2 to 18.2 me 100^{-1} g soil. Wani (1994) observed that exchangeable calcium is some saffron growing soils of Kashmir ranged from 12.5 to 17.1 and 13.7 to 18.0 cmol (P^{+}) kg^{-1} with mean values of 14.8 and 15.9 cmol (P^{+}) kg^{-1} soil in surface and subsurface layers, respectively. The exchangeable calcium in apple orchard soils of Kashmir ranged from 6.20 to 16.80 and 5.60 to 18.0 cmol (P^{+}) kg^{-1} soil in surface and subsurface layers, respectively (Mushki, 1994).

Peer (1994) observed that exchangeable calcium was a dominant cation varying from 12.96 to 15.10 cmol (P^{+}) kg^{-1} soil in soils of Kashmir. Exchangeable calcium as a dominant cation in the soils of Kangra district Himachal Pradesh, ranged from 3.10 to 11.0 cmol (P^{+}) kg^{-1} (Gupta and Tripathi, 1996). Sidhu *et al.* (1999) observed exchangeable calcium varied from 2.3 to3.6 cmol (P^{+}) kg^{-1} and did not exhibited any trend with increase in soil depth. According to Ganai (2001) exchangeable calcium ranged from 12.5-17.1 cmol (P^{+}) kg^{-1} soil in some saffron growing soils of the Kashmir valley. Patil and Prasad (2004) while studying the effect of elevation alongwith vegetation on soil, observed that the exchangeable calcium dominated the exchange complex of the soil and varied from 35.18 to 4.87 cmol (P^{+}) kg^{-1} soil from the surface to subsurface horizons. Kirmani (2004) reported that the exchange complex of *Karewa* soil of Kashmir valley was dominated by exchangeable calcium cation and ranged from 5.12-8.73 and 6.23-9.86 $cmol_c\ kg^{-1}$ soil in surface and subsurface horizons, respectively. Najar *et al.* (2009) observed that the exchangeable calcium was the dominant cation in soils of both aspects and varied from 12.8 to 5.4 and 11.3 to 9.2 cmol $(P^+)\ kg^{-1}$ soil in the northern and southern aspect, respectively.

2.2.7 Exchangeable magnesium (mg^{2+})

The content of exchangeable magnesium in the termperate subhumid high land soils of Himachal Pradesh were found to vary from 0.1 to 4.2 cmol $(P^+)\ kg^{-1}$ soil (Kaishtha and Gupta, 1993). Wani (1994) reported that the exchangeable magnesium in saffron growing soils of Kashmir ranged from 1.5-2.8 and 1.2-3.0 cmol $(P^+)\ kg^{-1}$ soil with mean value of 2.2 and 2.3 $cmol_C\ kg^{-1}$ soil in surface and subsurface layers, respectively. Peer (1994) observed that the exchangeable magnesium in Kashmir soils ranged from 2.45-3.45 $cmol_C\ kg^{-1}$ soil. According to Gunjoo (1994) the exchangeable magnesium in mid hill soils of Jammu region was 2.74 $cmol_C\ kg^{-1}$ soil.

Das *et al.* (1997) reported that exchangeable magnesium varied from 0.2-1.7 $cmol_C\ kg^{-1}$ in some alfisols of Meghalaya. Surekha *et al.* (1997) reported a range of 2.8 to 12.6 $cmol_C\ kg^{-1}$ of exchangeable magnesium in some soils of Andhra Pradesh. Sidhu *et al.* (1999) found that the contents of exchangeable magnesium is some soils of Jammu ranged between 0.4 to 2.0 $cmol_C$ kg^{-1} soils. Ganai (2001) reported that the exchangeable magnesium was found in the range of 1.5-2.9 $cmol_C$ kg^{-1} soil, in some saffron growing soils of the Kashmir valley. Ahmad (2003) while studying apple orchard soils of Baramulla district reported that the available magnesium content ranged from 140.2 to 178.8 ppm in surface soils and 126 to 188.6 ppm in subsurface soils.

Kirmani (2004) reported that the exchangeable magnesium was found in the range of 1.58-2.5 $cmol_C$ kg^{-1} soil and 1.86-2.85 $cmol_C$ kg^{-1} soil in surface and subsurface of lacustrine deposits of the Kashmir valley. Verma *et al.* (2008) found that the amount of the exchangeable magnesium was higher in northern pedons as compared to the southern ones and their value decreased with soil depth and by and large increased with altitude. The exchangeable magnesium ranged from 3.8 to 3.5 and 3.9-1.0 $cmol_C$ kg^{-1} soil in surface and subsurface horizons of northern pedons and 3.8-1.8 and 3.4-1.8 cmol (P^+) kg^{-1} soil in surface and subsurface horizons of southern pedons, respectively. Najar *et al.* (2009) reported that exchangeable magnesium observed an increasing trend with depth in north-facing soils and no such trend was observed in south-facing soils. The exchangeable magnesium varied from 2.1 to 1.2 and 3.2-1.0 cmol (P^+) kg^{-1} soil in surface and subsurface horizons of northern pedons and 2.9-2.1 and 3.3-1.8 cmol (P^+) kg^{-1} soil in southern pedons, respectively.

2.2.8 Exchangeable potassium

The exchangeable potassium content varied from 0.4 to 1.7 cmol (P^+) kg^{-1} in alluvium derived soils of Jammu and Kashmir (Gupta *et al.*, 1988). In forest soils of Kashmir valley, exchangeable potassium of 0.28 to 1.33 $cmol_C$ kg^{-1} in different horizons was found (Verma *et al.*, 1990). Singh *et al.* (1991) found exchangeable potassium in the range of 0.0 to 0.5 C mol_C kg^{-1} in different soil pedons of northwest Himalayan region of Himachal Pradesh. Surekha *et al.* (1997) observed the exchangeable potassium in the range of 0.13 to 0.84 cmol (P^+) kg^{-1} in some soils of Andhra Pradesh. Sidhu *et al.* (1999) reported that the exchangeable potassium contents ranged from 0.04 to 0.6 cmol (P^+) kg^{-1} in some soils of Jammu region.

According to Dandroo (2001) the soils of lower Munda Watershed showed overall range of 0.32 to 0.75 cmol (P^+) kg^{-1} with average value of 0.62 cmol (P^+) kg^{-1}. Kirmani (2004) reported that the exchangeable potassium ranged from 0.44-0.96 and 0.29-1.04 in the surface and subsurface horizons of lacustrine deposits in the Kashmir valley. Rao *et al.*

(2008) while evaluating the soils on the basis of altitude and physiography, observed that the exchangeable potassium vary from 1.0-0.4 cmol (P^+) kg^{-1} soil. The content observed decreasing trend with the depth of soil pedon but increased with the altitude. Najar *et al.* (2009) reported that the exchangeable potassium varied from 0.24 to 0.58 cmol (P^+) kg^{-1} and 0.28 to 0.56 cmol (P^+) kg^{-1} in northern and southern pedons, respectively.

2.2.9 Base saturation

Reddy and Shivprasad (1999) while working on, characterization and evaluation of potato growing soils of Karnataka, reported higher base saturation in different soil textural classes. Kirmani (2004) while characterizing some *Karewa* soils of Kashmir valley reported that the base saturation varied from 73.5-81.1 per cent and 72.1-78.7 per cent with the average mean of 77.75-75.88 in the surface and subsurface horizons, respectively. Sharma *et al.* (2004) while studying the soils of Neogal Watershed in North-west Himalayas reported that the base saturation varied from 46 to 77 per cent.

According to Tripathi *et al.* (2006), the base saturation varied from 58.6-66.3 and 56.6-74.3 per cent in surface and subsurface soils of Kiar-Nagali microwatershed in north-west Himalayas. Sarade and Prasad (2008) reported the base saturation in the range of 69.8-93.8 per cent in the recent alluvium derived soils of Maharashtra. Najar *et al.* (2009) reported that the base saturation of apple growing soils of the Kashmir valley vary in the range of 62.1-72.2 and 64.1-75.3 per cent in surface and subsurface horizons, respectively.

2.3 Mineralogical characteristics

Clay is an important soil constituent that control its properties and also influences its management and productivity (Davies *et al.*, 1972). Considering the influence of clay mineralogy on the soil physicochemical behaviour, its quantitative characterization can provide important data for the improvement of soil management practices. Since, in general detailed mineralogical investigation can indicate the most probable fate of the plant nutrients added to a soil and can also support a better understanding of the soil genesis and the electro-chemical behaviour.

Gupta *et al.* (1980) while studying some cultivated and uncultivated soils of Rajouri and Poonch districts of Jammu and Kashmir identified the illite, chlorite and smectite as main minerals in these soils. Gupta *et al.* (1988) reported that some alluvium derived soils of Jammu and Kashmir had mica followed by chlorite as the dominant minerals. Gupta and Banerjee (1991) observed the dominance of mica followed by chlorite, smectite, kaolnite and mixed layer minerals while studying clay mineralogy of soils of Jammu and Kashmir. Gupta and Tripathi (1996) reported illite as the dominant mineral in the north-west Himalayan soils of Himachal Pradesh.

Dey and Sehgal (1997) revealed higher contents of chlorite followed by mica in some alluvial derived soils of Assam. Mall and Mishra (2000) reported mica as the dominant clay mineral, while working on Alfisols of Bihar. Dandroo (2001) observed the dominance of illite followed by chlorite, vermiculite, kaolinite and mixed layers in the soils of Lower Munda watershed. Najar (2002) while studying the clay mineralogy of apple orchard soil reported the dominance of illite followed by the chlorite, vermiculite, kaolinite and mixed layers. Kirmani (2004) reported the dominance of quartz followed by plagioclase and mica in sand fractions of some profiles and dominance of plagioclase followed by quartz and orthoclase. Clay fractions were dominated by illite followed by mixed layer minerals, vermiculite and then chlorite. Katoo (2001) reported the dominance of illite in clay fraction where as, quartz was the dominant primary mineral in sand and silt fractions of Letpora command area.

Patil and Prasad (2004) observed the dominance of smectite mineralogy in some pedons and the dominance of mixed mineralogy in some pedons. In smectite dominate mineralogy, smectite was followed by kaolin, mica and fieldspar. Thangasamy *et al.* (2004) reported the dominance of smectite in the clay fractions of the Sivagiri Microwatershed of Chittoor district, Andhra Pradesh. Fontes and Carvalho (2005) observed that the typical minerals of highly weathered tropical soils were dominated by iron oxides, kaolinite and gibbisite, respectively. Souza *et al.* (2008) in the mangrove forests of SaoPaulo, Brazil, identified quartz, feldspars, gibbisite, kaolinite, illite, and vermiculite in silt fractions and smectite, kaolinite, illite, gibbisite, quartz, and feldspars in the clay fractions of the soil, respectively. Gupta *et al.* (2009) reported the dominance of quartz, feldspar and muscovite-mica in the light sand fraction and opaque type of minerals vis-à-vis zircon, tourmaline, augite, hornblende and biotite in heavy fractions of sand and the dominance of mica or illite as the dominant mineral followed by chlorite, smectite and mixed layer minerals in clay fractions was also observed in the same acid soils of Jammu division of Jammu and Kashmir.

2.4 Soil Classification

Man has a natural tendency and urge to classify the naturally occurring objects on the basis of certain distinguishing properties/ characters. This help in the detailed study of the individuals in comparison to each other, soil being the collection of natural bodies is therefore, no exception. In 1975, United States Department of Agriculture (USDA) developed taxonomic system of classification which was designed to meet the needs of soil survey, besides enabling soil scientists to communicate and transfer information at the international level.

Gupta *et al.* (1984) while working with soils of Kashmir classified high altitude and *Karewa* soils into Haplumbrept and Udorthents, respectively. Shinde *et al.* (1984) studied the saffron growing soils of Jammu and Kashmir and classified them as Vertic Hapludalfs and Typic Eutrochrepts. Sehgal *et al.* (1985) have classified and characterised mountain soil on slopes formed on chloritic schist and valley soils from gneisses under Typic Hapludolls and Mollic Hapludalfs, respectively in central Himalayas. Biswas (1985) classified some typical soils from Dader and Nagar Havelli under Vertisols, Alfisols and Entisols.

Pal and Despande (1987) studied the two bench mark soils of Kashmir valley and classified them as Mollic Hapludalf (Gogji Pather) and Mollic Haplaquents (Wathora). Gupta *et al.* (1988) while studying the characteristics and genesis of some soils of Jammu and Kashmir, reported the presence of Eutrocrepts, Haplaquents, Ustorthents and Ustrochrepts, respectively. Jalali *et al.* (1989) had classified the soils developed on various physiographic zones of Kashmir valley viz., high altitude, *Karewa* and valley basis as Agriudolls, Hapludalfs and Ochraqualf, respectively. The soils under forests of Kashmir Valley were classified as Typic Hapludoll, and Typic Agriudolls (Verma *et al.*, 1990).

While under taking a detailed survey of mid altitude soils of outer Himalayas, Singh *et al.* (1991) observed that these soils were developed on similar groups of rocks overlain by infrakarol and Karol series of the carboniferrous lower Mesozoic period under Monsoon climate as conditioned by undulating topography and peculiar natural drainage system and were classified in the order of Alfisols, Inceptisols and Entisols, respectively. Mushki (1994) classified orchard soils of Kashmir valley into Dystrochrepts, Hapludalfs and Argiudolls. Gupta and Chera (1996) from their detailed survey of middle Shiwalik observed that these soils developed on southern aspect and taxonomically characterised and classified them into Inceptisols.

Sharma *et al.* (1997) while studying the Inceptisols of North-West India classified these soils as Dystric Eutrochrepts and Typic Eutrochrepts. Ganai *et al.* (2000) classified saffron growing soils of Kashmir valley as Hapludalfs. Mahapatra *et al.* (2000) while working with the soils of Kashmir, of different physiographic units classified soils into Udorthents, Hapludalfs and Eutrochrepts, respectively. Katoo (2001) classified soils of

Lethpora command area as Hapludafs and Eutrochrepts. Ahmad (2003) classified some upland orchard soils of Baramullah district in Hapludalfs.

Kirmani (2004) while under taking the Reconnaissance survey of lacustrine deposits of Kashmir valley, classified these soils into typic Hapludalfs and Ruptic-Alfic Eutrudepts, respectively. Sharma *et al.* (2004), classified soils of Neogal water shed in North-West Himalayas as Typic Udipsmments, Udorthents, Dystrudepts and Hapludalfs, respectively. Darmody *et al.* (2005) while studying the effect of glaciation on Norwegian soils, classified these soils into Typic Cryorthents and Oxyaquic Dystrocrepts, respectively.

Tripathi *et al.* (2006) while studying the soils of Kiar-Nagali micro water shed of Himachal Pradesh in North- West Himalayas, classified these soils into Typic Udorthents, Dystric Eutrudepts and Typic Dystrudepts, respectively. Verma *et al.* (2008) while examining the effect of aspect and altitude on soil characterization in Garhwal Himalayas, classified these soils into Typic Agriudolls and Typic Hapludolls, respectively. Bhushan et al (2009) characterized soils of Kukar-Suha water shed in lower Shiwaliks of Punjab as Typic Ustipsamments and Typic Ustorthents. Najar *et al.* (2009) classified apple growing orchard soils of Kashmir valley in Agriudolls, Hapludalfs, Hapludolls, Eutrochrepts and Udorthents, respectively.

2.5 Nutritional status and soil fertility

2.5.1 Available nitrogen

Among the major plant nutrients, nitrogen is the most important and has been subjected to lot of studies. Kaistha *et al.* (1990) found that available nitrogen content in a horizon of all zones of Himachal Pradesh was higher than underlying horizons indicating a regular decrease with the increase in soil depth. Mandal *et al.* (1990) also observed highest nitrogen content in surface soils and it regularly decreased with depth in mid hill and upper hill forest soils of Himalayas. Verma *et al.* (1990) reported that the available nitrogen content ranged from 36.0 to 205.0 ppm with a mean value of 118.0 ppm in some alluvial soils of Kashmir. Sharma and Bhandari (1992) observed that available nitrogen content ranged from 92.0 to 231.0 and 27.0 to 210.0 ppm with a mean value of 158.0 and 137.9 ppm in the surface and subsurface soils, respectively in Himachal Pradesh.

The available nitrogen content in some apple orchard soils of Kashmir varied form 56.0 to 140.00 and 22.5 to 117.60 ppm in the surface and subsurface horizons, respectively (Mushki, 1994). Wani (1994) observed that available nitrogen content in the surface and subsurface layers of *Karewa* soils of Kashmir varied from 125.54 to 336.63 and 149.45 to 373.63 and 149.45 to 373.63 kg $ha^{-1,}$ respectively. Dar (1996) reported that the available nitrogen content in surface soils from 131.6 to 193.2 ppm with a mean value of 164.7 ppm, where as, in the subsurface soils it varied from 61.6 to 137.2 ppm with a mean value of 89.9 ppm in cherry growing soils of Kashmir. Ganie *et al.* (1999) reported that the available nitrogen varied from 64.8-226.4 mg kg^{-1} with mean value of 137.0 mg kg^{-1} in surface samples of some almond growing soils of Kashmir valley. The available nitrogen content in the range of 124.54 to 336.63 kg ha^{-1} with a mean value of 238.82 kg ha^{-1} was reported by Ganai (2001) for saffron growing soils of Jammu and Kashmir. Najar (2002) reported that available nitrogen content in the surface soils of *Karewa* varied from 82.0 to 142.1 with a mean value of 116.56 ppm, respectively.

The available nitrogen content in the surface samples of Ramachandrapuram Mandal ranged from 54.0 to 178.0 kg ha^{-1} with a mean value of 121.5 kg ha^{-1}, respectively (Rao *et al.*, 2008). Sharma *et al.* (2008) reported that the available nitrogen in the surface soil samples of Amritsar district of Punjab varied in the range of 63 to 170 kg ha^{-1} with a mean value of 117 kg ha^{-1}, respectively.

2.5.2 Available phosphorus

The available phosphorus in a soil represents a fraction of about 0.01 per cent of the total phosphorus which is liable for absorption by growing plants. Jaggi *et al.* (1990) noticed that the available phosphorus in surface and subsurface soils of Himachal Pradesh ranged from 10.5 to 40.5 and 6.5 to 34.3 ppm with the mean value of 25.5 and 17.9 ppm, respectively. Singh and Ahuja (1990) while studying the distribution of available phosphorous, reported low to medium phosphorous status with maximum accumulation of available phosphorus in the surface layers of Ghagger river basin soils. Ganai et al (1991) reported that the available phosphorus in the cherry orchards of Kashmir ranged from 6.6 to 14.5 ppm, respectively. Sharma and Bhardari (1992) observed that the available phosphorus in surface and subsurface soils of Kinnaur district of Himachal Pradesh varied from 14.0 to 52.0 ppm. The available phosphorus in some apple orchard soils of Kashmir ranged from 10.0 to 20.0 and 9.0 to 26.0 ppm in the surface and subsurface layers, respectively (Mushki, 1994). Farida (1997) observed that the available phosphorus content varied from 16.8 to 19.0 ppm in *Karewa* soils of Kashmir.

The available phosphorus contents in the surface and subsurface layers of *Karewa* soils ranged from 12.0 to 19.10 ppm and 8.0 to 17.20 ppm, respectively (Najar, 2002). Dwivedi *et al.* (2005) reported that the available phosphorus ranged from 2.35 to 25.66 and 2.5 to 137.4 Kg ha^{-1} in the surface soils of Leh and Kargil districts of Jammu and Kashmir, respectively. Rao *et al.* (2008) observed that the available phosphorus content in the surface samples of Rama Chandrapuram mandal ranged from 9.3 to 23.9 kg ha^{-1} with a mean value of 18.0 kg ha^{-1}. Sharma *et al.* (2008) noticed a range of 9.38 to 84.9 kg ha^{-1} averaging to 37.3 kg ha^{-1} for available phosphorus in the Amritsar district of Punjab. Singh and Bansal (2009) reported that the available phosphorus in the Berpura alluvial soil series of Indo-Gangetic plains ranged from 9.0 to 153 mg kg^{-1} in surface soil samples with an average mean of 41.7 mg kg^{-1}, respectively.

2.5.3 Available potassium

The total potassium content of soil is usually many times higher than the amount taken by growing plants, revealing that only a small fraction of it is available to plants. Mandal *et al.* (1990) reported a range of 47.2 to 289.3 ppm of available potassium in some forest soils of East Himalayas. Sharma and Bhandri (1992) observed that the available potassium in some soils of Himachal Pradesh ranged from 182.0 to 540.0 ppm with a mean value of 263.7 ppm in surface soil samples. Singh and Bhandari (1992) noticed that the apple orchard soils of Kinnour district of Himachal Pradesh were high in available potassium and it varied from 120.0 to 170.0 ppm. Mir (1994) reported that the available potassium in some orchard soils of Kashmir ranged from 108.40 to 207.75 and 67.32 to 151.84 ppm in surface and subsurface soils, respectively with the maximum amount in the surface horizons. Dar (1996) observed that the available potassium content in cherry orchard soils of Kashmir ranged between 135.0 to 205.0 ppm with a mean value of 168.3 ppm in the surface and from 80.0 to 17.0 ppm with a mean value of 111.8 ppm in subsurface soils. Farida (1997) observed that the available potassium varied between 156.0 to 180.0 ppm in *Karewa* soils of Kashmir valley.

The available potassium ranged from 11 to 496 and 103 to 861 mg kg^{-1} in soil surface sample of Leh and Kargil districts, respectively of Ladakh region (Dwivedi *et al.* (2005). Najar *et al.* (2005) reported that the available potassium content in surface soil of *Karewas* varied in the range of 93.6 to 280.8 ppm with a mean value of 183.2 ppm, respectively. Wani *et al.* (2007) reported that the soils of Zaingir command area of north Kashmir were medium in available potassium, that ranged from 134-158 mg kg^{-1}. Rao *et al.* (2008) reported that the available potassium in the surface samples of Ramachandrapuram Mandal soils, in the range of 135-320 kg ha^{-1} with mean value of 237 kg ha^{-1}, respectively. Sharma *et al.* (2008) observed that the available potassium content ranged from 84 to 700 kg ha^{-1} with a mean value of 340 kg ha^{-1} in the surface soil samples at Amritsar district in Punjab. Wani *et al.* (2009) reported that the available potassium in some soils of lesser Himalayas ranged from 0.18-0.44, 0.14-0.18, 0.12 - 0.18 with the mean values of 0.18, 0.16 and 0.17 cmol kg^{-1}, respectively. Shaista and Wani (2009) observed that the plant available potassium in some soils of Kashmir valley ranged from 0.10 to 0.37 cmol K kg^{-1} soil with a mean value of 0.23 C mol K kg^{-1} soil.

2.5.4 Micronutrient cation distribution

Micronutirent cations are held in the soils in various forms. Viet (1962) prefer to view these nutrients in terms of pools. Micronutrient cations occur in five pools in soils, viz., water soluble, exchangeable, chelated or complexed, secondary and primary minerals. The first three pools of micronutrient cations are in reverse equilibrium with one other.

Water soluble ⇔ Exchangeable ⇔ chelated/complexed

These three forms are subjected to removal through different extractants and are considered readily available to the plants. Whereas fourth and fifth fractions of the pool are not in reversible equilibrium with each other as well as with first three forms and it is difficult to separate them with ordinary chemical methods.

All these five forms constitute the total content of an element in the soil. But here we will confine ourselves to the work done/review on the exchangeable form of an element. It is that fraction of labile pool which is largely adsorbed on the exchange complex of the soil and is susceptible to exchange reaction with weak exchanger like NH_4OAC or $Mg(NO_3)_2$ etc. It also include water soluble fraction.

2.5.4.1 Zinc (Zn)

Singh *et al.* (1988) observed that exchangeable zinc ranged from 1.0 to 1.5 mg kg^{-1} in some calcareous soils of India. Jalali *et al.* (1989) reported that the DTPA-extractable zinc in high altitude soils ranged from 0.35-0.65 mg kg^{-1} and was higher than that of *Karewa* and valley basin soils of Kashmir. Sharma and Bhandari (1992) reported that the available zinc in apple orchard soils of Himachal Pradesh ranged from 0.75-4.60 with mean values of 2.6 \mg kg^{-1} in surface layers, respectively. According to Mushki (1994) DTPA-extractable zinc in apple orchard soils of Kashmir varied from 0.47-0.66 mg kg^{-1} soil. Dar (1996) observed that DTPA-extractable zinc in cherry orchard soils of district Srinagar ranged from 0.33-1.82 mg kg^{-1} soil. Mamgain *et al.* (1998) reported that the available zinc content in apple orchard soils of Himachal Pradesh ranged between 2.73-3.66 mg kg^{-1} with a mean value of 2.99 mg kg^{-1} soil. Ganai *et al.* (1999) reported that the DTPA-extractable zinc content varied from 0.55-1.50 mg kg^{-1} soil with mean value of 0.88 in surface of almond growing soils of the Kashmir valley.

Ganai (2001) reported that DTPA-extractable zinc in some saffron growing soils was in the range of 0.35-1.14 mg kg^{-1} soil. Kirmani (2004) while studying *Karewa* soils of Kashmir valley noticed that the DTPA extractable zinc varied in the range of 1.45-4.00 mg kg^{-1} soil with mean value of 2.26 kg^{-1} soil in surface soil. Sharma (2004) reported the DTPA-extractable zinc varied form 0.20 to 2.36 mg kg^{-1} in some inceptisols of Punjab. Dhale and Prasad (2009) reported that the DTPA-extractable zinc content ranged from 0.18 to 1.49 mg kg^{-1} and, in general, Ap horizons had more DTPA-zinc than underlying horizons.

2.5.4.2 Copper (Cu)

Jalali *et al.* (1989) reported that the DTPA-extractable copper in the *Karewa* soils of Kashmir valley ranged from 0.07-0.33 mg kg^{-1} soil. The available copper in apple orchards of Himachal Pradesh varied from 1.4-9.7 mg kg^{-1} soil with mean value of 4.4 mg kg^{-1} soil in surface layers, respectively (Sharma and Bhandari, 1992). Mushki (1994) observed that the DTPA-extractable in apple orchard soils of Kashmir valley varies in the range of 1.52-1.80 mg kg^{-1} soil. Wani (1994) while working with *Karewa* soils of Kashmir, found that the DTPA-extractable copper decreased with profile depth and its content ranged from 0.07 to 0.37 mg kg^{-1} soil with mean value of 0.20 mg kg^{-1} soil in surface horizons.

Dar (1996) revealed that the DTPA-extractable copper content in the cherry orchard soils of district Srinagar ranged from 0.88 to 2.89 mg kg^{-1} soil. Mamgain *et al.* (1998) reported that the copper content in Himachal Pradesh soil varied in the range of 2.86-4.13 mg kg^{-1} soil with mean value of 3.38 mg kg^{-1} soil. Ganai *et al.* (1999) observed that the DTPA extractable copper ranged from 1.61 to 3.81 mg kg^{-1} soil with mean value of 2.30 mg kg^{-1} soil in surface soils, respectively. Kirmani (2004) while evaluating *Karewa* soils for micronutrient distribution, reported that the DTPA-extractable copper in these soils were in the range of 1.29-2.87 mg kg^{-1} soil with mean value of 1.95 mg kg^{-1} soil in surface layers, respectively. While studying Mollisols and Inceptisols, Patil and Prasad (2004) observed that the DTPA-extractable copper varied in them from 2.6-14.1 and 4.3-8.7 mg kg^{-1} soil, respectively. Rao *et al.* (2008) reported that the DTPA-extractable copper was found in the range of 0.21-1.04 mg kg^{-1} soil with mean value of 0.58 mg kg^{-1} soil in surface soils.

2.5.4.3 Iron (Fe)

Jalali *et al.* (1989) reported that the DTPA-extractable iron was higher in high altitude and valley basin soils than in *Karewa* soils, and it ranged from 24-124, 6-116 and 3-21 mg kg^{-1} soil, respectively. Sharma and Bhandhari (1992) observed that available iron varied from 18.0-22.6 mg

kg^{-1} soil in surface soils of apple orchards of Himachal Pradesh. Mushki (1994) found that DTPA extractable iron in some apple orchard soils of Kashmir varied from 15.0-12.0, 51.0-97.0 and 40.0-97.0 mg kg^{-1} soil in surface soils of valley basin, *Karewa* and high altitude, respectively.

Tripathi *et al.* (1994) found that available iron ranged from 6.2 to 41.2 mg kg^{-1} soil in some soils of Himachal Pradesh and its content decreased with the increase in soil depth. In saffron growing soils of Kashmir available iron content ranged from 8.0-72.0 mg kg^{-1} soil in surface soils with mean value of 23.0 mg kg^{-1} soil in surface soils (Wani, 1994). Dar (1996) observed that the DTPA-extractable iron in cherry orchard soils of district Srinagar vary in the range of 9.9-57.4 mg kg^{-1} in surface layer soils. Ahmad (2003) reported that the DTPA-extractable iron in orchard soils of Baramulla varied in the range of 42.8-58.33 mg kg^{-1} soil with an average value of 47.79 mg kg^{-1} soil in surface soils, respectively. The Inceptisols of Punjab contained DTPA extractable iron in the range of 0.91-32.0 mg kg^{-1} soil (Sharma *et al.*, 2004). Rao *et al.* (2008) observed that the DTPA-Fe content ranged from 1.09-5.82 mg kg^{-1} soil in Alfisols, Entisols and Inceptisols of Andhra Pradesh. The DTPA-extractable iron in Vertisols of Maharashtra was found to vary in the range of 7.85-13.99 mg kg^{-1} soil (Dhale and Prasad, 2009).

2.5.4.4 Manganese (Mn)

Jalali *et al.* (1989) reported that *Karewa* and high altitude soils contained more available manganese than valley basin soils. It varied in the range of 7-62, 6-88 and 7-24 mg kg^{-1} soil in valley basin, *Karewa* and high altitude soils, respectively. Sharma and Bhandari (1992) observed that available manganese in apple orchard soils of Himachal Pradesh ranged from 8.0-68.0 mg kg^{-1} soil in surface soils, respectively. The DTPA-extractable manganese in apple orchard soils of Kashmir varied from 19.30-28.9 mg kg^{-1} soil (Mushki, 1994). Wani (1994) observed that DTPA-extractable manganese in saffron growing soils of Kashmir ranged from 2.0-78.0 mg kg^{-1} soil with mean value of 17.88 mg kg^{-1} soil in surface layers, respectively. In cherry orchard soils of Srinagar DTPA-extractable manganese content varied from 10.7-61.0 mg kg^{-1} soil (Dar, 1996). Khan *et al.* (1997) observed that the manganese content in bench mark soils of Bangladesh ranged from 7.0-79.0 mg kg^{-1} soil. Mamgain *et al.* (1998) observed that the DTPA-extractable manganese ranged between 13.5-26.9 mg kg^{-1} soil with mean of 22.1 mg kg^{-1} soil in soils of Himachal Pradesh. Ganai *et al.* (2001) reported that the DTPA-extractable manganese in almond soils ranged from 49.3 to 85.2 mg kg^{-1} soil with mean value of 68.3 mg kg^{-1} soil in surface soils. Najar (2002) reported that the available manganese content in apple orchards in *Karewa* soils varied from 29.0-64.0 mg kg^{-1} soil with the mean value of 24.66 mg kg^{-1} soil in the surface layers, respectively. Kirmani (2004) observed that the DTPA-extractable manganese content in *Karewa* soils ranged from 12.56-28.34 mg kg^{-1} soil with mean values of 21.86 mg kg^{-1} soil in surface horizons, respectively. In recent alluvium soils of Maharashtra the DTPA-extractable manganese showed a varied range of 14.74-81.56 mg kg^{-1} soil in surface layers, respectively (Sarade and Prasad, 2008).

2.5.5 Nutrient indexing (Nutrient Index Value)

There is a real need for obtaining a comprehensive and reliable data on the nutrient status of soils. A general picture of the nutrient status of soils would aid research workers in orienting their research. The data would give educational and action agencies, a sound basis for evaluating or promoting their respective programs.

Dwivedi *et al.* (2005) while studying the status of available nutrients in soils of cold arid region of Ladakh, observed that these soils are medium in organic carbon with nutrients index value of 1.66 and 1.78 for Leh and Kargil districts, respectively. These soils were deficient in phosphorus with nutrient index of 1.42 (Leh) and 1.74 (Kargil). For available potassium the nutrient index was high i.e. Leh (2.27) and Kargil (2.50), which indicated the sufficiency of potassium in this region. Rao *et al.* (2008) reported that the over all nutrient index (NI) for Ramachandrapuram Mandal of Chittor district of Andhra Pradesh was 1.00 for available nitrogen, 1.96 for available phosphorus and 2.37 for available potassium which indicated that these soils were low in nitrogen, medium in available phosphorus and high in available potassium, respectively. Singh and Bansal (2009) observed that Berpura alluvial soil series of the Indo-Gangetic plains was low in organic carbon with a nutrient index value (NIV) of 1.05, high in available phosphorus with a nutrient index value (NIV) of 2.93 and low in available potassium with a nutrient index value (NIV) of 1.15 respectively.

2.6 Relationship between physico-chemical properties and available nutrients

2.6.1 Influence of soil pH

A negatively significant correlation between available nitrogen and soil pH was reported by Singh and Ahuja (1990), Narboo (1994), Yeresheemi *et al.* (1998) and Najar (2002). On the other hand, Singh (1987), Kaistha *et al.* (1990) and Mushki (1994) did not find any relationship between available nitrogen and soil pH, available phosphorus was found significantly and negatively correlated with soil pH by Singh (1987), Mushki (1994), Yeresheemi *et al.* (1998) and Najar (2002). However, Ramesh *et al.* (1994) and Patagundi and Channol (1996) did not observe any relationship between soil pH and available phosphorous. Prakash and Singh (1985), Singh and Ahuja (1990) and Girish and Badrinath (1996) have revealed a negative but non-significant relationship between available potassium and soil pH. Available potassium observed a positive but non-significant correlation with the soil pH (Najar, 2002).

Many workers have reported negative and significant relationship between micro-nutrient cations and soil pH (Jalali *et al.*, 1989; Katyal and Sharma, 1991; Jahiruddin *et al.*, 1992; Bhogal *et al.*, 1993 and Ramesh *et al.* (1994). Ganai *et al.* (1999) reported the negative and significant correlation between soil pH and micro-nutrient cations while working with almond soils of Kashmir. Ahmad (2003) also reported the negative and significant relationship between Micronutrient cations and soil pH. Kirmani (2004) while studying Lacustrine deposit of Kashmir valley, reported the negative and significant correlation between Fe, Mn and Cu with soil pH and the relationship between Zn with soil pH was although negative but non-significant Sharma *et al.* (2004) reported negative and significant relationship between Fe and Mn with soil pH in some Inceptisols of Punjab.

2.6.2 Influent of organic carbon

A number of research workers have reported a significant and positive relationship between organic carbon and available nitrogen

(Minhas and Bora, 1982; Kanthaliya and Bhatt, 1991 and Ramesh *et al.*, 1994). However, Singh and Ahuja (1990) did not found any significant correlation between organic carbon and available phosphorus and available potassium. Najar (2002) observed a significant positive correlation between the organic carbon and available nitrogen in soil and the correlations between organic carbon with available phosphorus and potassium were positive and negative, respectively but were not upto the level of significance.

The micro-nutrient cations were found to be significantly and positively correlation with organic carbon (Katyal and Sharma, 1991; Ganai *et al.*, 1999; Sharma *et al.*, 1999 and 2004). Wani (1994) reported the significant and positive relationship between organic carbon and zinc and copper while working on saffron growing soils of Kashmir valley. Khan *et al.* (1997) observed a positive but non-significant correlation between organic carbon and micronutrients. Najar (2002) while studying apple growing soils of Kashmir valley, observed that there was a significant and positive correlation of zinc, copper and Iron with organic carbon. Ahmad (2003) also reported positive and significant positive linear relationship of organic carbon with all the micronutrient cations in surface soils of Baramulla district. Kirmani (2004) reported that all the micronutrient cation showed positive and significant coefficient of correlation with organic carbon in Lascustrine soils of Kashmir valley.

2.6.3 Influence of calcium carbonate

A negatively significant relation between calcium carbonate and available nitrogen and phosphorus had been observed by Minhas and Bora (1982) and Mir (1994). However, a positive and significant correlation between calcium carbonate and available potassium had been observed in some soils (Kadrekar and Kibe, 1972 and Jassal *et al.* (2000). Singh and Ahuja (1990) did not find any relationship between calcium carbonate and available nitrogen, phosphorus or potassium. Najar (2002) reported a non-significant negative correlation between available nitrogen, phosphorus and potassium with calcium carbonate in some apple orchard soils of Kashmir. Sharma et al (2008) while studying the soils of Amritsar district of Punjab, observed the negatively significant relationship of available nitrogen, phosphorous and potassium with calcium carbonate content in soil.

Prasad and Sakal (1991) found significant negative correlation between Iron and calcium carbonate. Mahapatra and Sahu (1996) did not find any relationship between calcium carbonate and micronutrients. Wani (1994) found significantly negative correlation between calcium carbonate and manganese only. Khan *et al.* (1997) observed a positive but non-significant relationship between calcium carbonate and available micronutrient cations. Ganai *et al.* (1999) reported the negative and significant linear relationship between calcium carbonate and all the micronutrient cations in almond growing soils of Kashmir valley. Najar (2002) and Ahmad (2003) found negative and significant relationship between copper and calcium carbonate only. Sharma *et al.* (2004) reported a negative and significant relationship between Iron, manganese and copper with calcium carbonate. Singh *et al.* (2008) observed an inverse relationship of different forms of zinc, copper, iron and manganese with calcium carbonate in some Vertisols. Yadav and Meena (2009) reported positively significant correlation of iron, copper, manganese and zinc with calcium carbonate.

2.6.4 Influence of cation exchange capacity (CEC)

The available nitrogen was positively and significantly correlated with the cation exchange capacity (Khera and Pradhan, 1980; Mandal *et al.*, 1990; Yeresheemi *et al.*, 1998). Mandal *et al.* (1990) observed a positive and significant relationship between cation exchange capacity and available phosphorus. On the other hand, an inverse and non-significant linear relationship between phosphorus and cation exchange capacity was observed by Battacharyya *et al.* (1998). Prakash and Singh (1985), Kumar *et al.* (1987) and Yeresheemi *et al.* (1998) have reported a significant positive correlation between available potassium and cation exchange capacity. However, Girisha and Badrinath (1996) revealed a positive but non-significant linear relationship between cation exchange capacity and available potassium Sharma *et al.* (2008) reported significant and positive correlation of available nitrogen and available potassium with cation exchange capacity and the linear relationship between available phosphorus and cation exchange capacity was although positive but not upto the level of significance.

Micronutrients cation were reported to have non-significant negative linear relationship with cation exchange capacity (Yeresheemi *et al.*, 1998). Non significant relationship between cation exchange and micronutrients was observed by Najar (2002). Kirmani (2004) while working with *Karewa*s of Kashmir valley, reported a non-significant negative correlation of manganese with cation exchange capacity and non-significant positive linear relationship between zinc, copper and Iron with cation exchange capacity. Sharma *et al.* (2004) reported a positive and significant correlation of cation exchange capacity with zinc and copper, while it showed negative relationship with manganese and positive with iron, but both were not upto the level of significance. Yadav and Meena (2009) observed a significant and positive correlation of zinc, copper, manganese and iron with cation exchange capacity of soils.

2.6.5 Influence of texture (clay)

The available nitrogen and potassium exhibited a positive and significant correlation with clay but a significant negative linear relationship was found between available phosphorus and clay (Sharma *et al.*, 2008). Wani *et al.* (2009) reported a positive but non-significant correlation between available potassium and clay content.

Clay and silt fractions of soil are dominated by micronutrient cations than sand fractions. Katyal and Sharma (1991) reported positive and significant correlation between iron and clay. Sharma *et al.* (2000) in some Indo-Gangetic plains of India observed a significant but negative correlation between manganese and clay. Positive and significant correlation of zinc and copper with clay was reported by Sharma et al (2004). Singh *et al.* (2008) reported a positive correlation of zinc, copper, iron and manganese with clay. Yadav and Meena (2009) observed a positive and significant linear relationship of zinc, copper, iron and manganese with clay content of the soil.

CHAPTER – 3

MATERIALS AND METHODS

3.1 Brief geographical description and conditions of the area

3.1.1 Location and extent

The state of Jammu and Kashmir mostly a mountainous area occupies almost a central position in the Asian continent, and has been divided into nine land forms associated with nine agro-ecological zones and five different agro-climatic zones associated with five land uses. Geographically valley lies on the north flank of Pir Panjal range and southern flank of Great Himalayan range, is located at 33^{o} 30′ N to 34^{o} 30′ N and 74^{o} 10′ E to 75^{o} 03′ E. the average elevation of the valley is above 1500 m (amsl) with following associated information.

Land form	:	Broad valley
Agro-ecological zone	:	Temperate, moist, sub-humid, growing period 150-210 days
Land use	:	Arable land
Agro-climatic zone	:	Mid to high altitude temperate zone

3.1.2 Climate

The climate of valley is sub-humid temperate. The mean annual rainfall/precipitation is about 943.38 mm with mean annual temperature of

13.49^{o}C, the mean winter (December, January and February) and summer (June, July and August) temperature is 3.9 and 22.56^{o}C, respectively. The area therefore, qualifies for mesic temperature regime and udic moisture regime.

3.1.3. Geology

The state is one of the best geologically explored part of the Himalayas and contains within a small geographical compass one of the finest developments of stratified rocks.

The Pleistocene and post-pleistocene deposits, commonly known as "*Karewa*s", occupies nearly half of the valley of Kashmir. These have been held to be the surviving remainants of deposits of a lake which are filled the valley basin from end to end. Lithalogically the '*Karewa*s' are mostly horizontally stratified deposits of lucustrine origin consisting of beds of fine grained, bluish and buff coloured sandy clay, partly compacted conglomerates and embedded moraines. In the *Karewa* group, comprising of 450-500 m thick pile of sediments, the new tree fold classification of *Karewa*s into three sub-groups has been followed. The lower, middle and upper *Karewa* sub-groups show fluvial; lacustrine; aeolian and pedogenetic environments respectively (Pal and Srivastava, 1982).

The middle *Karewa* sub-group was laid down in lacusterine environment and has been divided into two formations i.e. Ruh and Puskar formation comprising one glacial and one inter glacial are divided into Baba Rafi-ud-din Mazar and Kanyalwan members. Their varied nature and a few features in green sands of Pampore represent the glacial stage IV.

3.1.4 Soils

The soils of Kashmir (temperate region) on the basis of altitude, has been classified into three main groups i.e. high altitude (forest) soils, *Karewa* soils and the lower altitude (valley basin) soils (Man and Sharma, 1971). The high altitude soils (Kandi belt) are located within an altitude of 1880-2500 m above amsl stretching from *Karewa*s and bordering forests. These soils are light textured with moderate to severe erosion, deep and excessively drained. The predominant soils in this area are Udalfs, Udolls and Orthents. The *Karewa* soils (mid lands and table lands) are of lacustrine origin within an altitude ranging from 1600 to 1800 m amsl. These include severely to moderately eroded big flat mounds bordering the slopes of mountains. The soils of this area are classified as udalfs and ochrepts. The valley basin soils have mostly resulted from the alluvium deposited by rivers like Jhelum, Sindh and their tributaries and lie at an altitude of 1500 to 1600 m above (amsl). These soils are poorly drained and moderately eroded. Aquepts and udalfs are predominant soils observed in the area.

3.1.5 Physiographic features

Out of the recognised lacustrine belts of Kashmir valley, the import belt viz. Pampore *Karewa* was covered under present study. The area is well drained with good fertility level as being the deposits of Pleistocene and post-pleistocene in nature. The plateau land of Pampore is well known for the cultivation of world's costliest spice i.e. saffron. This area is dominated by flat and gentle slope topography and both were selected for the present study.

3.1.6 Natural vegetation

Vegetation being the active soil forming factor greatly influences soil evolution. The natural vegetation in the study area is scanty and consists of some species of grasses. The *Karewa* tops are studded with apple, pear and almost orchards, besides other fruit trees existing at most of the places in the area.

The common natural vegetations (plants) in the study area are willow (*Salix alba*), popular (*Populus deltoids*), kiker (*Robinia pseudoacacia*), chinar (*Plantanus orientalis*) and walnut (*Juglans regia*).

3.1.7 Land use

Cultivation of saffron (*Crocus sativus*) is the main agricultural activity in the Pampore plateau alongwith the orchards of almonds in the areas of Wuyan, Mueej and Munipur, whileas maize, linseed and walnut trees are found alongwith the cultivation of saffron in the terraces of Shar and Khrew areas. Scarcity of water for irrigation is the main problem, being rainfed has resulted in declining yields of saffron from past few years due to rain deficit.

3.2 Methods of field study

3.2.1 Selection of profile sites

A general reconnaissance of the study area was undertaken and during the course of traversing, the soil map of Jammu and Kashmir prepared by NBSS&LUP (Sehgal, 1994), and the index map of saffron growing areas of Pampore scale of 1:2,50,000 (Soil Survey Organisation, Department of Agriculture, Kashmir) was constantly used. Land use – land cover map of Pulwama district of scale 1:1,00,000 was also used (Fig. 1). On the basis of heterogeneity in apparent soil colour, topography and aspect, the soil profiles were exposed in the study area (*Karewa*s).

3.2.2 Collection of soil samples

Fifteen profiles at respective sites were selected and exposed to a depth of 120 cm and more (Fig. 1). The studies were made according to the methods of the Soil Survey Manual and as per the ‘proforma for soil-site

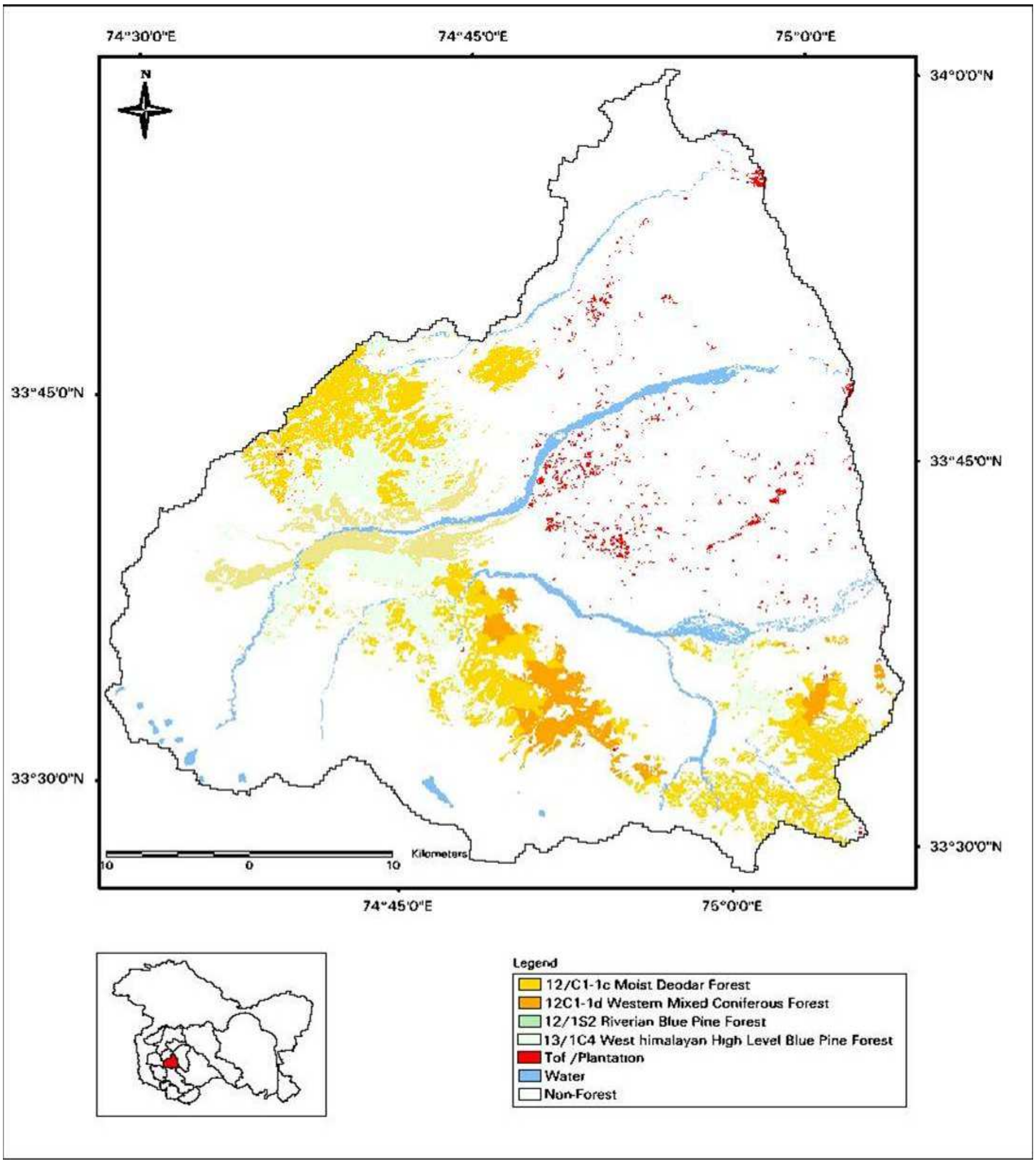

Fig. 1: Land use and Land cover map (1:100,000) of District Pulwama

description and soil characteristics' (Sehgal, 1994). The soils were classified as per 'soil taxonomy' (Soil Survey Staff, 1999) by following 'keys to soil taxonomy' (Soil Survey Staff, 1998). The locations selected were :

S. No.	Location	Profile number	District
1.	Alochibagh	P_1	Pulwama
2.	Samboora	P_2	Pulwama
3.	Borus	P_3	Pulwama
4.	Lethpora	P_4	Pulwama
5.	Chandhore	P_5	Pulwama
6.	Konibal	P_6	Pulwama
7.	Gundibal	P_7	Pulwama
8.	Ladoo	P_8	Pulwama
9.	Shar	P_9	Pulwama
10.	Khrew	P_{10}	Pulwama
11.	Balhama	P_{11}	Pulwama
12.	Munipur	P_{12}	Pulwama
13.	Wuyan	P_{13}	Pulwama
14.	Mueej	P_{14}	Pulwama
15.	Sempur	P_{15}	Pulwama

(A)

(B)

Plate-1:- **Study site giving glimpse of soil development as effected by the aspect**

A : Northern aspect
B : Southern aspect

3.2.3 Morphological Characteristics

The morphological characteristics of soil profiles were studied according to the procedure given in soil survey manual (USDA – Hand book. 18).

The soil colour was compared with Munsen's Soil Colour Notation. The other morphological characteristics like texture, structure, consistency, plasticity and other special features were all described and noted for each profile. Soil samples were collected from different horizons of each soil profile, and were subjected to laboratory analysis.

3.2.4 Collection of soil samples for nutrient indexing (NI)

Samples from all representative areas were taken, mixed and composited after due quatering. Samples numbering five were also taken from these representative sites but not mixed and composited to develop a nutrient index for each nutrient viz. N, P and K, respectively. Composited sample reading were then compared with the reading obtained from simple soil samples to give the better understanding of the variation present at a location.

3.3 Methods of laboratory analysis

The soil samples collected from different horizons and as composite samples were air dried and grounded in a wooden pestle and mortar. Ambient soil was passed through 2 mm sieve for physical, chemical and mineralogical analysis.

3.3.1 Physical and chemical analysis

3.3.1.1 Mechanical analysis

The mechanical composition of soil was determined by International Pipette Method as described by Piper (1966).

3.3.1.2 Soil pH

The pH of soil samples was determined in 1:2.5, soil:water suspension with the help of glass electrode pH meter as described by Jackson (1973).

3.3.1.3 Electrical conductivity (EC)

The electrical conductivity of soil water extract was read with the help of conductivity meter (Jackson, 1973).

3.3.1.4 Organic carbon

Organic carbon was determined by wet digestion method of Walkley and Black (1934) as modified by Walkley (1935).

3.3.1.5 Calcium carbonate ($CaCO_3$)

Estimation of calcium carbonation was done by adopting Rapid Titration Method as described by Piper (1966).

3.3.1.6 Cation exchange capacity (CEC)

It was determined by the centrifuge method using sodium acetate solution (pH 8.2) for leaching and then sodium ions were replaced by ammonium ions using neutral normal ammonium acetate the sodium concentration was measured by flame photometrically and serves the measure of total CEC of the soil (Baruah and Barthakur, 1998).

3.3.1.7 Exchangeable cations

The exchangeable cations viz. sodium, potassium, calcium and magnesium were extracted with neutral normal ammonium acetate. Sodium and potassium were determined by flame photometrically whileas calcium and magnesium were determined by atomic absorption spectroscopy using atomic absorption spectrometer.

3.3.1.8 Available nitrogen

The available nitrogen was estimated by aalkaline permagnate method as given by Subbiah and Asija (1956).

3.3.1.9 Available phosphorus

The available phosphorus was extracted by Olsen's extractant (0.5 N $NaHCO_3$ at pH 8.5) and colour was developed by stannous chloride. The percentage transmittance was measured with the help of spectrophotometer at 660 nm wave length (Jackson, 1973).

3.3.1.10 Available potassium

The available potassium was extracted with one normal neutral ammonium acetate (1 N NH_4 OAC, pH 7.0) and determination was carried out with the help of flame photometer using K-filter (Jackson, 1973).

3.3.2 Micronutrient cation analysis (DTPA-extractable)

For micronutrient estimation, the method of Lindsay and Norvell (1978) was used. Ten grams of soil of each soil sample were shaken for 2 hours with 20 ml of extracting solution consisting of 0.005 M DTPA (di-ethylene triamine penta acetic acid), 0.01 M $CaCl_2$ and 0.1 N TEA (Tri-ethanol amine) buffered at 7.3, the filtrate was analysed for zinc, copper, manganese and iron using atomic absorption spectrometer, after standardizing the instrument with proper standards.

3.3.3 Mineralogical analysis

Three profiles were randomly selected for mineralogical analysis of clay fractions. Soil samples from only sub-surface horizons were selected for fine fraction mineralogy.

3.3.3.1 Separation of clay

For separation of clay fraction, method as out lined by Black (1965) was followed. Briefly it consists of treating the soil with sodium acetate buffer (pH 5.0) for removing calcium carbonate and other salts. Organic matter was removed by treating it with H_2O_2 and sodium bicarbonate-citrate –dithionite was used for removal of free iron oxides (Mehra and Jackson, 1960). The disaggregation was achieved by using 0.1 N NaOH as dispersing agent.

3.3.3.2 Analysis of clay fraction

The analysis of clay fraction was done with X-ray diffraction using Phillips X- ray diffractometer with Ca-K alpha radiations (Goniometer scanning speed of 2^o/minute, voltage of 40 KV, amperage of 20 mA and radiation wave length of 1.54 A^o). The sequence followed for X-ray diffraction in respect of slides followed was: Mg-Saturation, Mg-Saturated and glycolation, K- saturated and K-saturated and heated (550 ^oC).

3.4 Statistical analysis

The data was statistically analysed following the standard procedures outlined by Gomez and Gomez (1984). Coefficient of correlation between the different physico-chemical properties and available nutrients was done using statistical software 'SPSS'.

CHAPTER – 4

EXPERIMENTAL FINDINGS

The results pertaining to the present investigation entitled “Characterization, Classification and Nutrient Indexing of Saffron Growing Soils of District Pulwama” are presented in this chapter under the following headings:

4.1 Characterization of saffron growing soils

4.1.1 Soil site description

4.1.2 Morphological characteristics

4.1.3 Physico-chemical characteristics

4.1.3.1 Particle size distribution

4.1.3.2 Soil reaction

4.1.3.3 Electrical conductivity

4.1.3.4 Organic carbon

4.1.3.5 Calcium carbonate

4.1.3.6 Cation exchange capacity

4.1.3.7 Exchangeable cations and base saturation

4.2 Mineralogical characteristics

4.3 Physcio-chemical and nutrient status of soils (composite samples)

4.3.1 physico-chemical characteristics

4.3.2 Nutrient status of soils

4.3.2.1 Available Nitrogen, Phosphorus and Potassium

4.3.2.2 Micronutrient cation distribution

4.4 Relationship between physico-chemical properties and available nutrients (composite samples)

4.5 Nutrient indexing

4.1 Characterization of saffron growing soils

After conducting a general traversing of the study area viz., district Pulwama, which is dominated by saffron cultivation at commercial scale, 15-profiles were exposed at the representative sites (Map-1) based on heterogeneity in apparent soil colour, topography and aspect. The morphological, physico-chemical and mineralogical properties of these profiles were studied and described here under :

4.1.1 Soil site description

The soil site description was observed following the standard proforma of soil site description of NBSS&LUP soil bulletin No. 23 (Sehgal, 1994). The selected profiles varied in elevation, topography, slope, aspect and natural vegetation. The variation in elevation ranged from 1582 to 1672 amsl (Table-1). The topography was almost nearly level in all the profiles except P_8, P_9, P_{10} P_{11} and P_{12}, respectively. The slope gradient

Table 1: Soil site characteristics of saffron growing areas of Pulwama district

Profile No.	Location	Elevation (amsl)	Topography	Slope (%)	Aspect	Latitude	Longitude	Natural vegetation
P_1	Alochibag	1637	Near level	0-1	Southern	3358°.22′N	7456°.494′E	Willow, kikar, almond, rose, shrubs and grasses
P_2	Samboora	1642	Near level	0-1	Southern	3358°.012′N	7456°.944′E	Poplar, willow, kikar, wild fig, grasses and shrubs
P_3	Borus	1644	Near level	0-1	Southern	3357°.503′N	7458°.930′E	Willow, poplar, fig, rose, bushes and shrubs
P_4	Lethpora	1632	Near level	0-1	Southern	3358°.418′N	3456°.861′E	Willow, poplar, fig, poppy, rose, bushes and shrubs
P_5	Chandhore	1643	Near level	0-1	Southern	3359°.279′N	7457°.234′E	Willow, poplar, wild fig, rose, mulberry, bushes and shrubs
P_6	Konibal	1661	Near level	0-1	Northern	3400°.097′N	7457°.098′E	Willow, poplar, almond, rose, bushes and shrubs
P_7	Gundibal	1632	Near level	1<	Northern	3359°.905′N	7458°.898′E	Willow, kikar, fig, mulberry, rose and other shrubs and grasses
P_8	Ladoo	1648	Very gentle sloping	1-3	Northern	3400°.085′N	7500°.356′E	Almond, kikar, poplar, willow, rose and other shrubs and grasses

Contd…

Table 1 Contd…

P_9	**Shar**	**1672**	**Very gentle sloping**	**1-3**	**Northern**	**3400°.027′N**	**7501°.434′E**	**Almond, kikar, poplar, willow, rose, maize, linseed and other shrubs and grasses**
P_{10}	**Khrew**	**1652**	**Very gentle sloping**	**1-3**	**Northern**	**3401°.242′N**	**7500°.280′E**	**Almond, kikar, poplar, willow, rose and other shrubs and grasses**
P_{11}	**Balhama**	**1617**	**Very gentle sloping**	**1-3**	**Northern**	**3402°.176′N**	**7455°.727′E**	**Almond, kikar, poplar, willow, rose and other shrubs and grasses**
P_{12}	**Mueej**	**1616**	**Very gentle sloping**	**1-3**	**Northern**	**3400°.956′N**	**7456°.591′E**	**Almond, kikar, poplar, willow, rose and other shrubs and grasses**
P_{13}	**Munipur**	**1634**	**Near level**	**0-1**	**Northern**	**3400°.701′N**	**7457°.999′E**	**Willow, kikar, poplar, wild fig, mulberry, rose and other shrubs and grasses**
P_{14}	**Wuyan**	**1623**	**Near level**	**0-1**	**Northern**	**3401°.843′N**	**7454°.598′E**	**Willow, kikar, poplar, pear, wild fig, mulberry, rose, chestnut and other shrubs and grasses**
P_{15}	**Sempur**	**1582**	**Near level**	**0-1**	**Northern**	**3401°.993′N**	**7454°.883′E**	**Willow, kikar, poplar, pear, wild fig, mulberry, rose, chestnut and other shrubs and grasses**

ranged from $\leq$ 1 per cent to 1-3 per cent in near level and very gentle sloping areas. The selected profile were located in Southern and Northern aspect of the District Pulwama and maximum number of these were located in the northern aspect except P_1, P_2, P_3, P_4 and P_5, respectively. The natural vegetation in the area in excess to saffron was viz., willow, almond, popular, kikar, wild rose, poppy, wild fig, mulberry and other shrubs and grasses. The profiles located at higher elevation areas were also dominated in excess to saffron and other vegetation by maize and linseed.

4.1.2 Morphological characteristics

The morphological characteristics of the various soil profiles in terms of colour, texture, structure, consistency, etc. are detailed in Appendix-I and briefly mentioned in Table-2. The colour of the soil in the surface horizons of southern aspect varied from brown(10YR $^5/_3$)/dark brown (10YR $^4/_3$)/dark yellowish brown (10YR $^4/_4$) to pale brown (10YR $^4/_3$)/ yellowish brown (10YR $^5/_4$) while as profiles of northern aspect surface horizons varied from dark brown (10YR $^3/_4$)/very dark brown (10YR $^2/_2$) to dark yellowish brown (10YR $^4/_4$). In the subsurface horizons of the southern aspect the colour varied from brown (10YR $^5/_4$)/dark brown (10YR $^3/_4$)/dark yellowish brown (10YR $^4/_4$) to light yellowish brown (10YR $^6/_4$)/dark greyish brown (10YR $^4/_3$) and yellowish brown (10YR $^5/_4$). While as, the colour in the sub-surface horizons of the northern aspect varied from dark yellowish brown (10YR $^{4}/_{4}$) or yellowish brown (10YR $^{5}/_{4}$)/brown (10YR $^{5}/_{4}$) to dark greyish brown (10YR $^{4}/_{2}$)/very dark grey (10YR $^{3}/_{2}$). The data revealed that the colour of the surface horizons of the northern aspect, was darker with a value of 2 to 5 and chroma of 2 to 4 where as southern aspect profile horizons had lighter colour with a value of 5 to 6 and chroma of 3 to 6.

The texture of surface horizons of southern aspect changed from loam to silty clay loam/clay loam and silt loam to silty clay loam/clay loam where as on the northern aspect, it changed from loam/silt loam to clay loam/sandy loam. However, in P15 it remained clay loam through out the depth. The texture became finner with the increase in depth in most of the profiles.

The structure of north facing profiles was fine, weak/medium granular and medium/coarse moderate angular blocky to sub-angular blocky where as on southern aspect it was weak to moderate angular/sub-angular blocky. The consistency of the soils of studied pedons varied widely. In surface horizons of northern aspect, it was hard/slightly hard when dry and friable/very friable to firm when moist. On the other hand in southern aspect the consistency of soils was slightly hard/hard when dry

Table 2 : Morphological characteristics of soil profiles of Saffron growing areas of district Pulwama

Location (profile No.)	Horizon	Depth (cm)	Colour (moist)	Texture	Structure			Consistence			Boundary		Effervesence with dil. HCl	Cutans		
					Size	Grade	Type	Dry	Moist	Wet	Dist.	Topography		Type	Thickness	quality
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Alochibag (P_1)	Ap	0-20	Brown (10 YR 5/3)	sil	2	m	sbk	h	mfr	wso	c	s	-	-	-	-
	AB	20-52	Brown (10 YR 5/3)	sil	2	m	sbk	h	mfr	wss	c	s	-	-	-	-
	B_1	52-75	Dark brown (10 YR 4/3)	sicl	2	m	sbk	-	mfi	ws	c	s	-	-	-	-
	B_2	75-120	Dark greyish with brown (10 YR 4/2)	sicl	2	m	abk	-	mfi	ws	-	-	es	-	-	-
Samboora (P_2)	AP	0-20	Yellowish brown (10 YR 5/4)	l	1	m	sbk	sh	mfr	wso	c	s	-	-	-	-
	Bw_1	20-35	Light yellowish brown (10 YR 6/4)	cl	2	m	abk	h	mfr	wss	c	s	-	-	-	-
	Bw_2	35-87	Yellowish brown (10 YR 5/4)	cl	2	m	sbk	-	mfi	ws	c	s	es	-	-	-
	Bw_3	87-120	Dark greyish brown (10 YR 4/3)	cl	2	m	abk	-	mfi	ws	-	-	es	-	-	-
Borus (P_3)	Ap	0-25	Yellowish brown (10 YR 5/6)	l	1	m	sbk	h	fr	wso	c	s	-	-	-	-
	AB	25-54	Yellowish brown (10 YR 5/6)	l	1	m	abk	-	fr	wso	c	s	-	-	-	-
	Bw_1	54-85	Dark brown (10 YR 4/3)	cl	2	m	abk	-	fi	wss	g	s	e			
	Bw_2	85-120	Dark brown (10 YR 6/3)	cl	2	m	sbk	-	fi	ws	-	-	es	-	-	-
Lethpora (P_4)	AP	0-20	Pale brown (10 YR 6/3)	sil	1	m	sbk	h	fr	wso	c	s	-	-	-	-
	BA	20-54	Brown (10 YR 5/3)	sil	2	m	sbk	-	fr	wss	d	w	e	-	-	-
	B_1	54-89	Yellowish brown (10 YR 5/4)	sicl	2	m	sbk	-	fi	ws	c	s	es	-	-	-
	B_2	89-120	Dark greyish brown (10 YR 4/2)	cl	2	m	sbk	-	vfi	ws	-	-	ev	-	-	-
Chandhore (P_5)	AP	0-22	Brown (10 YR 5/3)	sil	2	m	sbk	h	mfr	wso	c	s	-	-	-	-
	BA	22-52	Brown (10 YR 5/3)	sil	2	m	sbk	-	fr	wso	c	s	-	-	-	-
	Bw_1	52-88	Yellowish brown (10 YR 5/4)	cl	2	m	abk	-	fi	wss	g	s	-	-	-	-
	Bw_2	88-120	Dark greyish brown (10 YR 4/2)	cl	2	m	sbk	-	fi	ws	-	-	es	-	-	-

Contd…

Symbols used in Morphological characterization (Table 2) of soils

BOUNDARY

c= Clear
g=gradual
s=smooth
i=irregular
w=wavy
d=diffused

STRUCTURE

1=weak
2=moderate
m=medium
c=coarse
f=fine
sbk=sub- angular blocky
abk=angular blocky
gr=granular

EFFERVESCENCE

e=slight
es=strong
ev=voilent

CUTANS

t=Argillans
tn=thin

TEXTURE

l=loam
cl=clay loam
sil=silt loam
sicl=silty clayloam
sl=sandy loam

CONSISTENCE

d=dry
m=moist
w=wet
h=hard
sh=slightly hard
fr=friable
vfr=very friable
mfi=moderatley firm

s=sticky
ss=slightly sticky
vs=very sticky
p=plastic
wso=sticky but non-plastic
fi=firm vfi=very firm
mfr=moderately friable

Table 2 contd…

Location (profile No.)	Horizon	Depth (cm)	Colour (moist)	Texture	Structure			Consistence			Boundary		Effervesence with dil. HCl	Cutans		
					Size	Grade	Type	Dry	Moist	Wet	Dist.	Topography		Type	Thickness	quality
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Konibal (P_6)	Ap	0-15	Dark brown (10 YR 3/4)	l	1	m	gr	sh	fr	wso	c	s	-	-	-	-
	Bw	15-35	Dark yellowish brown (10 YR 3/4)	l	2	m	abk	h	fi	wso	g	s	-	-	-	-
	Bt_1	3-587	Light yellowish brown (10 YR 6/4)	cl	2	m	abk	-	fi	ws	c	w	-	t	tn	Patchy
	Bt_2	87-120	Very dark greyish (10 YR 3/2)	cl	1	m	sbk	-	vfi	wvs	-	-	es	t	tn	Patchy
Gundibal (P_7)	Ap	0-17	Dark brown (10 YR 4/3)	sil	1	m	sbk	sh	fr	wso	c	s	-	-	-	-
	B	17-40	Dark yellowish brown (10 YR 4/4)	cl	2	m	-	h	fi	wss	g	w	-	-	-	-
	Bt_1	40-87	Dark yellowish brown (10 YR 4/3)	cl	2	c	abk	-	fi	ws	g	w	-	t	tn	Patchy
	Bt_2	87-120	Dark greyish brown (10 YR 4/2)	Cl	1	m	sbk	-	vfi	ws	-	-	ev	t	tn	Patchy
Ladoo (P_8)	Ap	0-15	Brown (10 YR 5/3)	l	2	c	abk	h	fi	wss	c	s	-	-	-	-
	A	15-37	Light greyish brown (10 YR 6/2)	cl	2	m	abk	-	vfi	ws	g	s	-	-	-	-
	C_1	37-85	Light greyish brown (10 YR 6/2)	l	1	f	sbk	-	fr	wso	g	s	es	-	-	-
	C_2	85-120	Pale brown (10 YR 6/3)	l	2	c	sbk	-	fr	wso	-	-	ev	-	-	-
Shar (P_9)	Ap	0-20	Brown (10 YR 5/3)	sil	1	m	abk	h	fr	wso	c	s	-	-	-	-
	Ac	20-55	Dark greyish brown (10 YR 4/2)	cl	2	m	abk	h	fi	wss	c	s	-	-	-	-
	C_1	55-90	Dark greyish (10 YR 4/1)	cl	1	m	abk	-	fi	ws	d	i	e	-	-	-
	C_2	90-120	Very dark greyish (10 YR 3/1)	Sl	2	m	abk	-	fr	wso	-	-	es	-	-	-
Khrew (P_{10})	Ap	0-20	Dark brown (10 YR 4/3)	l	1	m	gr	h	fr	wso	d	s	-	-	-	-
	C_1	20-47	Dark yellowish brown (10 YR 4/4)	sl	2	m	sbk	h	fi	wss	d	s	-	-	-	-
	C_2	47-82	Dark yellowish brown (10 YR 4/4)	sl	2	m	sbk	h	fi	wss	d	s	e	-	-	-
	C_3	82-120	Dark yellowish brown (10 YR 4/3)	sl	2	m	abk	-	fr	wso	-	-	es	-	-	-

Table 2 contd…

Location (profile No.)	Horizon	Depth (cm)	Colour (moist)	Texture	Structure			Consistence			Boundary		Effervesence with dil. HCl	Cutans		
					Size	Grade	Type	Dry	Moist	Wet	Dist.	topography		Type	Thickness	quality
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Balhama (P_{11})	Ap	0-15	Dark yellowish brown (10YR 4/4)	cl	1	f	sbk	h	fr	wss	g	s	-	-	-	-
	C_1	15-42	Greyish brown (10YR 5/2)	l	2	m	sbk	sh	fi	wso	g	s	e	-	-	-
	C_2	42-90	Dark brown (10YR 4/3)	l	2	m	sbk	-	fi	wss	g	s	es	-	-	-
	C_3	90-120	Yellowish brown (10YR 5/6)	l	2	m	sbk	-	fi	wso	-	-	es	-	-	-
Mueej (P_{12})	Ap	0-15	Yellowish brown (10YR 5/4)	sil	1	f	sbk	h	fr	wso	c	s	-	-	-	-
	AC	15-35	Dark yellowish brown (10YR 3/4)	cl	1	m	abk	h	fi	wss	c	s	e	-	-	-
	C_1	35-87	Greyish brown (10 YR 5/2)	cl	1	m	sbk	-	vfi	ws	g	i	e	-	-	-
	C_2	87-120	Brownish grey (10 YR 6/2)	sil	1	m	sbk	-	fi	wso	-	-	es	-	-	-
Munipur (P_{13})	Ap	0-28	Very dark brown (10 YR 2/2)	l	1	f	gr	sh	vfr	wss	c	s	-	-	-	-
	Bw	28-72	Dark yellowish brown (10 YR 4/4)	cl	2	m	sbk	h	fr	ws	g	i	-	-	-	-
	Bt_1	72-95	Dark yellowish brown (10 YR 3/4)	cl	2	m	sbk	-	fi	ws	g	i	-	t	tn	Patchy
	Bt_2	95-120	Brown (10 YR 5/3)	cl	2	c	abk	-	fi	ws	-	-	es	t	tn	Patchy
Wuyan (P_{14})	Ap	0-17	Dark yellowish brown (10 YR 4/4)	l	1	f	abk	sh	vfr	wso	g	s	-	-	-	-
	BA	17-45	Dark yellowish brown (10 YR 3/4)	cl	2	m	abk	h	fr	wso	g	i	-	-	-	-
	Bt_1	45-86	Yellowish brown (10 YR 5/4)	cl	2	c	abk	-	fi	wss	c	w	e	t	tn	Patchy
	Bt_2	86-120	Pale brown (10 YR 6/3)	cl	2	c	abk	-	fi	ws	-	-	es	t	tn	Patchy
Sempur (P_{15})	Ap	0-15	Very dark brown (10 YR 2/2)	cl	1	f	sbk	sh	fr	wso	g	s	-	-	-	-
	AB	15-48	Brown (10 YR 4/3)	cl	2	m	sbk	h	fi	wss	g	s	-	-	-	-
	Bt_1	48-85	Yellowish brown (10 YR 5/4)	cl	2	c	abk	-	vfi	ws	g	s	-	t	tn	Patchy
	Bt_2	85-120	Light yellowish brown (10 YR 6/4)	cl	2	c	abk	-	vfi	wvs	-	-	es	t	tn	Patchy

and friable when moist. In the sub-surface horizons of the northern aspect it was slightly hard to hard when dry and very friable/friable to very firm when moist. Whereas on southern aspect the consistency of the sub-surface horizons was hard when dry and friable to firm when moist. On southern as well as on northern aspect, the lower horizons showed effervescence with dil. HCl, indicating the calcareous nature of parent material.

4.1.3 Physico-chemical characteristics

Perusal of the data in Table-3, revealed that the contents of coarse sand varied from 1.30 to 2.40 per cent with mean value of 1.82 per cent in the surface horizons of the profiles on the southern aspect, whereas in northern aspect it varied from 1.60 to 3.70 per cent with a mean value of 2.43 per cent. The coarse sand in the subsurface horizons on southern aspect ranged from 0.40 to 1.80 per cent with a mean value of 1.04 per cent while as on northern aspect it ranged from 0.40 to 3.20 per cent with a mean value of 1.72 per cent in subsurface horizons. The coarse sand in the studied profiles generally decreased with depth. The fine sand in the surface horizons varied from 10.50 to 31.40 per cent with a mean value of 22.86 per cent whereas, in the subsurface horizons it ranged from 9.0 to 36.0 per cent with a mean value of 22.51 per cent on southern aspect. In northern aspect the fine sand in the surface horizons ranged from 20.20 to 46.40 per cent with a mean value of 29.48 per cent. Whereas, in subsurface horizons it varied from 21.50 to 49.60 per cent with a mean value of 30.24 per cent. The contents of fine sand did not depict any trend with depth.

The silt content in the surface and sub-surface horizons on southern aspect varied from 42.70 to 67.50 per cent and 34.90 to 63.40 per cent with a mean value of 53.92 and 48.65 per cent, respectively. On northern aspect the silt content in surface and subsurface horizons ranged from 28.2 to 52.3 and 26.80 to 51.70 per cent with a mean value of 45.79 and 41.20 per cent, respectively. The contents of silt did not show any trend with the increase in the depth. The clay content in surface horizons and sub-surface horizons on southern aspect ranged from 20.30 to 24.20 and 23.10 to 32.20 with a mean value of 21.40 and 27.97 per cent, respectively. The contents of the clay on the northern aspect in surface and sub-surface ranged from 16.60 to 27.50 per cent and 14.50 to 37.90 per cent with a mean value of 22.30 and 26.84 per cent, respectively. The contents of the clay on very gentle sloping lands on northern aspect did not show any trend with depth while as on level land on southern and northern aspect the contents of clay increased with depth. The increase was more on northern aspects than southern aspects.

Table 3 : Soil particle distribution in soil profiles (texture) of Saffron growing areas of district Pulwama

Profile No.	Horizon	Depth (cm)	Soil separates (%)				Texture
			Coarse sand	Fine sand	Silt	Clay	
1	2	3	4	5	6	7	8
Alochibag (P_1)	Ap	0-20	1.5	10.5	67.5	20.5	sil
	AB	20-52	1.3	9.0	63.4	26.3	sil
	B_1	52-75	0.8	10.0	61.2	28.0	sicl
	B_2	75-120	0.6	12.8	58.2	29.6	sicl
Samboora (P_2)	Ap	0-20	1.7	31.4	42.7	24.2	l
	Bw_1	20-35	1.4	28.1	43.3	28.7	cl
	Bw_2	35-87	1.2	27.8	39.8	31.2	cl
	Bw_3	87-120	0.7	30.7	36.4	32.2	cl
Borus (P_3)	Ap	0-25	2.2	31.2	46.3	20.3	l
	AB	25-54	1.6	28.8	46.5	23.1	l
	Bw_1	54-85	1.4	36.0	35.1	27.5	cl
	Bw_2	85-120	0.8	33.0	34.9	31.3	cl
Lethpora (P_4)	Ap	0-20	1.3	16.5	60.5	21.7	sil
	BA	20-54	1.8	9.5	63.0	25.7	sil
	B_1	54-89	0.5	11.2	60.3	27.7	sicl
	B_2	89-120	0.6	24.4	47.1	27.9	cl
Chandhore (P_5)	Ap	0-22	2.4	24.7	52.6	20.3	sil
	BA	22-52	1.6	22.4	51.2	24.8	sil
	Bw_1	52-88	0.9	26.4	45.5	27.2	cl
	Bw_2	88-120	0.4	27.5	43.8	28.3	cl

Condt…..

Table 3- contd……

Profile No.	Horizon	Depth (cm)	Soil separates (%)				Texture
			Coarse sand	Fine sand	Silt	Clay	
1	2	3	4	5	6	7	8
Konibal (P_6)	Ap	0-22	2.2	31.6	46.7	19.5	l
	Bw	22-52	1.7	30.2	46.8	21.3	l
	Bt_1	52-88	1.3	27.8	42.8	28.1	cl
	Bt_2	88-120	0.9	24.2	41.9	33.0	cl
Gundibal (P_7)	Ap	0-17	2.4	30.6	50.4	16.6	sil
	B	17-40	2.1	28.7	42.2	27.0	cl
	Bt_1	40-87	1.8	23.4	41.2	33.6	cl
	Bt_2	87-120	0.9	21.8	39.4	37.9	cl
Ladoo (P_8)	Ap	0-15	2.4	22.7	48.7	26.2	l
	A	15-37	2.0	26.6	39.7	31.7	cl
	C_1	37-85	1.4	28.2	46.9	23.5	l
	C_2	85-120	2.6	29.0	48.8	19.6	l
Shar (P_9)	Ap	0-20	2.8	19.6	51.2	26.4	sil
	AC	20-55	2.1	27.5	41.2	29.2	cl
	C_1	55-90	1.1	25.1	42.3	31.5	cl
	C_2	90-120	0.9	49.3	31.3	18.5	sl
Khrew (P_{10})	Ap	0-20	3.7	46.4	28.2	21.7	l
	C_1	20-47	3.2	49.6	26.8	20.4	sl
	C_2	47-82	2.8	48.7	29.6	18.9	sl
	C_3	82-120	2.7	48.5	29.2	19.6	sl
Balhama (P_{11})	Ap	0-15	1.9	30.6	47.1	20.4	l
	C_1	15-42	2.7	33.1	46.4	17.8	l
	C_2	42-90	2.6	34.3	48.5	14.6	l
	C_3	90-120	2.6	34.7	48.2	14.5	l

Table 3- condt…..

Profile No.	Horizon	Depth (cm)	Soil separates (%)				Texture
			Coarse sand	Fine sand	Silt	Clay	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mueej (P_{12})	Ap	0-15	3.4	20.2	52.3	24.1	sil
	AC	15-35	2.8	28.4	40.7	28.1	cl
	C_1	35-87	2.1	27.2	40.5	30.2	cl
	C_2	87-120	1.6	21.5	51.7	25.2	sil
Munipur (P_{13})	Ap	0-17	2.2	30.4	47.2	20.2	l
	BA	17-45	1.8	29.2	41.4	27.6	cl
	Bt_1	45-86	1.4	26.6	40.6	31.4	cl
	Bt_2	86-120	1.2	29.7	36.1	33.0	cl
Wuyan (P_{14})	Ap	0-28	1.6	35.3	42.7	20.4	l
	Bw	28-72	1.3	34.7	36.2	27.8	cl
	Bt_1	72-95	0.8	24.3	43.6	31.3	cl
	Bt_2	95-120	0.6	26.2	39.5	33.7	cl
Sempur (P_{15})	Ap	0-15	1.7	27.4	43.4	27.5	cl
	AB	15-48	1.4	24.6	45.2	28.8	cl
	Bt_1	48-82	0.8	22.5	44.6	32.1	cl
	Bt_2	82-120	0.4	21.6	42.6	35.4	cl
Southern	**Surface**	**Mean**	**1.82**	**22.86**	**53.92**	**21.40**	
		Range	**1.32-2.40**	**10.50-31.40**	**42.70-67.50**	**23.30-24.20**	
	Subsurface	**Mean**	**1.04**	**22.51**	**48.65**	**27.97**	
		Range	**0.40-1.80**	**9.0-36.0**	**34.9-63.4**	**23.10-32.20**	
Northern	**Surface**	**Mean**	**2.43**	**29.48**	**45.79**	**22.30**	
		Range	**1.60-3.70**	**20.20-46.40**	**28.20-52.30**	**16.60-27.50**	
	Subsurface	**Mean**	**1.72**	**30.24**	**41.20**	**26.80**	
		Range	**0.40-3.20**	**21.50-49.60**	**26.8-51.70**	**14.50-37.90**	

4.1.3.2 Soil reaction

The pH value (Table-4) in the surface horizons on northern aspect varied from 6.70 to 7.60 whereas, it varied from 7.10 to 7.30 on southern aspect. In sub-surface horizons, the pH of the northern aspect soils ranged from 7.10 to 8.10 whereas, on southern aspect it ranged from 7.10 to 7.30. The pH on the northern aspect was slightly acidic whereas on the southern aspect slightly alkaline. The pH of soils on both aspects showed increasing trend with depth.

4.1.3.3 Electrical conductivity

The electrical conductivity of the surface horizons of the southern aspect varied from 0.10 to 0.19 dsm^{-1} with a mean value of 0.136 dsm^{-1} whereas, on northern aspect it varied from 0.04 to 0.22 dsm^{-1} with a mean value of 0.134 dsm^{-1}. The electrical conductivity in sub-surface horizons on northern and southern aspect ranged from 0.08 to 0.25 and 0.10 to 0.19 dsm^{-1} with a mean value of 0.134 and 0.150 dsm^{-1}, respectively. The electrical conductivity was more in subsurface horizons than surface horizons in both aspects. The increase was more pronounced in northern than southern aspect (Table-4).

4.1.3.4 Organic carbon

The data presented in Table-4, indicated that the contents of organic carbon in north facing pedons varied from 11.20 to 19.20 g kg^{-1} soil in surface horizons with a mean value of 14.80 g kg^{-1} soil. Whereas, in south facing pedons it ranged from 14.70 to 17.20 g kg^{-1} soil with a mean value of 16.14 g kg^{-1} soil. The subsurface organic carbon content in northern and southern pedons varied from 1.50 to 8.60 and 1.80-17.60 g kg^{-1} soil with mean value of 4.08 and 6.84 g kg^{-1} soil, respectively. The organic carbon content decreased with depth on both the aspects and varied from 1.50 to 19.2 and 1.80 to 17.20 g kg^{-1} soil in northern and southern aspects, respectively.

4.1.3.5 Calcium carbonate

The contents of calcium carbonate (Table-4) in the subsurface horizons of northern and southern aspect ranged from 0.00 to 7.00 per cent and 0.00 to 5.80 per cent, respectively. The calcium carbonate on both the aspects was found in lower horizons only.

4.1.3.6 Cation exchange capacity

The cation exchange capacity of northern and southern aspect soils showed slight variation and varied from 11.28 to 15.21 and 12.16 to 14.81 ($cmol_c$ kg^{-1} soil) in the surface horizons of north facing pedons and south

Table 4 : Physico-chemical properties of soil profiles of Saffron growing areas of district Pulwama.

Profile No.	Horizon	Depth (cm)	pH	EC	OC (g kg^{-1} soil)	$CaCO_3$ (%)	CEC ($cmol_c$ kg^{-1} soil)	Exchangeable cations ($cmol_c$ kg^{-1} soil))				Base saturation (%)
								Ca^{2+}	Mg^{2+}	K^+	Na^+	
1	2	3	4	5	6	7	8	9	10	11	12	13
Alochibag (P_1)	Ap	0-20	7.2	0.17	16.0	-	13.52	7.82	2.45	0.87	Traces	82.39
	AB	20-52	7.4	0.19	12.1	-	14.71	8.06	2.34	0.78	Traces	76.00
	B_1	52-75	7.6	0.15	7.5	-	16.84	9.87	2.72	0.81	Traces	79.57
	B_2	75-120	7.9	0.20	4.8	3.6	16.93	9.21	2.80	0.78	Traces	75.55
Samboora (P_2)	Ap	0-20	7.3	0.19	14.7	-	14.12	7.96	2.48	0.92	Traces	80.45
	Bw_1	20-35	7.6	0.15	11.5	-	16.56	9.55	2.69	0.81	Traces	78.80
	Bw_2	35-87	7.8	0.17	6.3	0.4	17.00	9.82	2.81	0.81	Traces	79.06
	Bw_3	87-120	8.1	0.20	4.5	4.9	17.18	9.51	2.76	0.86	Traces	76.43
Borus (P_3)	Ap	0-25	7.2	0.12	17.0	-	14.62	8.11	2.46	0.91	Traces	78.93
	AB	25-54	7.1	0.12	17.6	-	14.85	8.26	2.34	0.74	Traces	76.36
	Bw_1	54-85	7.5	0.17	6.7	Traces	16.71	8.45	2.62	0.86	Traces	71.39
	Bw_2	85-120	7.8	0.11	3.6	1.6	15.14	8.76	2.85	0.78	Traces	81.84
Lethpora (P_4)	Ap	0-20	7.2	0.10	15.8	-	12.16	6.85	1.90	0.92	Traces	79.52
	BA	20-54	7.1	0.12	6.8	Traces	14.21	9.11	2.28	0.76	Traces	85.50
	B_1	54-89	7.6	0.17	4.5	0.5	15.95	8.12	2.63	0.72	Traces	71.91
	B_2	89-120	7.9	0.11	3.4	5.8	16.11	9.32	2.25	0.84	Traces	77.03
Chandhore (P_5)	Ap	0-22	7.1	0.10	17.2	-	14.81	8.67	2.16	0.76	Traces	78.26
	BA	22-52	7.2	0.12	6.5	-	16.67	8.81	2.52	0.70	Traces	72.17
	Bw_1	52-88	7.5	0.14	4.1	-	18.29	9.70	2.71	0.78	Traces	72.12
	Bw_2	88-120	7.8	0.15	1.8	1.5	14.80	8.59	2.92	0.72	Traces	83.31
Konibal (P_6)	Ap	0-15	6.7	0.09	18.6	-	15.21	8.04	2.13	0.70	Traces	71.47
	Bw	15-35	7.1	0.10	8.0	-	14.31	8.63	2.51	0.71	Traces	82.81
	Bt_1	35-87	7.8	0.12	3.6	-	17.20	9.90	2.61	0.78	Traces	77.27
	Bt_2	87-120	7.5	0.14	1.8	2.5	18.50	9.72	2.73	0.65	Traces	70.86

Contd……

Table 4 contd…..

Profile No.	Horizon	Depth (cm)	pH	EC	OC (g kg^{-1} soil)	$CaCO_3$ (%)	CEC ($cmol_c$ kg^{-1} soil)	Exchangeable cations ($cmol_c$ kg^{-1} soil))				Base saturation (%)
								Ca^{2+}	Mg^{2+}	K^+	Na^+	
1	2	3	4	5	6	7	8	9	10	11	12	13
Gundibal (P_7)	Ap	0-17	6.7	0.04	19.0	-	12.65	8.67	1.95	0.78	Traces	90.12
	B	17-40	7.2	0.09	7.2	-	14.81	8.81	2.52	0.82	Traces	82.04
	Bt_1	40-87	7.1	0.10	4.5	-	16.50	9.20	2.66	0.98	Traces	77.82
	Bt_2	87-120	7.5	0.12	1.8	4.6	16.90	10.43	2.71	0.97	Traces	83.49
Ladoo (P_8)	Ap	0-15	7.3	0.21	11.5	-	12.15	7.16	1.42	0.86	Traces	77.70
	A	15-37	7.4	0.17	5.8	-	13.76	7.29	1.57	0.75	Traces	69.84
	C_1	37-85	7.6	0.17	2.4	1.5	11.51	7.06	1.37	0.70	Traces	79.32
	C_2	85-120	7.9	0.12	2.1	7.0	10.84	6.84	1.19	0.72	Traces	80.72
Shar (P_9)	Ap	0-20	7.4	0.19	12.1	-	12.31	6.62	1.63	0.92	Traces	74.49
	AC	20-55	7.3	0.14	6.4	-	13.17	7.13	1.84	0.79	Traces	74.11
	C_1	55-90	7.6	0.10	3.0	0.6	13.65	7.15	1.21	0.63	Traces	65.86
	C_2	90-120	7.5	0.09	1.8	2.8	11.60	6.51	1.23	0.69	Traces	72.67
Khrew (P_{10})	Ap	0-20	7.6	0.22	11.2	-	11.28	6.65	1.23	0.80	Traces	76.95
	C_1	20-47	7.9	0.19	5.4	-	11.00	6.21	1.17	0.81	Traces	74.45
	C_2	47-82	7.8	0.16	2.9	0.6	13.46	7.21	1.54	0.71	Traces	70.28
	C_3	82-120	8.1	0.18	1.5	1.5	10.45	6.15	1.01	0.78	Traces	75.98
Balhama (P_{11})	Ap	0-15	7.6	0.10	11.6	-	12.92	7.50	2.09	0.78	Traces	80.26
	C_1	15-42	7.2	0.08	5.7	Traces	10.81	5.80	1.72	0.75	Traces	76.50
	C_2	42-90	7.5	0.08	3.1	1.1	9.40	4.70	1.61	0.80	Traces	75.64
	C_3	90-120	7.8	0.11	1.7	3.2	9.80	4.85	1.80	0.84	Traces	76.42
Mueej (P_{12})	Ap	0-15	7.5	0.19	12.2	-	13.72	7.80	1.62	0.85	Traces	74.85
	AC	15-35	7.3	0.10	6.1	Traces	14.11	8.15	2.08	0.77	Traces	77.96
	C_1	35-87	7.5	0.14	3.2	0.8	15.20	8.21	1.62	0.79	Traces	69.86
	C_2	87-120	7.5	0.09	1.6	1.2	13.80	6.04	1.21	0.71	Traces	57.68

Contd……………

Table 4 contd…..

Profile No.	Horizon	Depth (cm)	pH	EC	OC (g kg^{-1} soil)	$CaCO_3$ (%)	CEC ($cmol_c$ kg^{-1} soil)	Exchangeable cations ($cmol_c$ kg^{-1} soil)				Base saturation (%)
								Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Munipur (P_{13})	Ap	0-17	6.8	0.14	18.3	-	12.33	6.29	1.72	0.76	Traces	71.13
	BA	17-45	7.2	0.17	7.2	-	14.12	7.34	2.27	0.71	Traces	73.09
	Bt_1	45-86	7.8	0.20	2.9	-	15.23	7.61	2.41	0.58	Traces	69.60
	Bt_2	86-120	7.6	0.25	1.7	2.6	16.15	7.92	2.58	0.88	Traces	70.46
Wuyan (P_{14})	Ap	0-28	6.7	0.04	19.2	-	11.75	6.81	2.04	0.70	Traces	81.28
	Bw	28-72	7.4	0.09	8.6	-	12.29	7.09	2.51	0.72	Traces	83.97
	Bt_1	72-95	7.5	0.10	4.7	Traces	15.17	8.27	2.76	0.66	Traces	77.06
	Bt_2	95-120	7.8	0.10	2.0	1.3	16.90	9.08	2.92	0.76	Traces	75.50
Sempur (P_{15})	Ap	0-15	6.7	0.12	14.0	-	11.81	7.42	1.75	0.80	Traces	84.42
	AB	15-48	7.5	0.16	8.1	-	12.65	7.72	1.83	0.78	Traces	81.66
	Bt_1	48-82	7.8	0.18	5.4	0.2	15.17	8.56	2.77	0.81	Traces	80.03
	Bt_2	82-120	7.6	0.19	2.1	2.5	16.51	9.11	2.91	0.67	Traces	76.86
Southern	**Surface**	**Mean**	**7.20**	**0.14**	**16.14**	**-**	**13.85**	**7.88**	**2.29**	**0.89**	**79.91**	
		Range	**7.10-7.30**	**0.10-0.19**	**14.70-17.20**	**-**	**12.16-14.81**	**6.85-8.67**	**1.90-2.48**	**0.76-0.97**	**78.26-82.39**	
	Subsurface	**Mean**	**7.59**	**0.15**	**6.84**	**0.61**	**16.13**	**9.01**	**6.62**	**0.78**	**77.14**	
		Range	**6.70-8.10**	**0.11-0.20**	**1.80-17.60**	**0.00-5.80**	**14.21-18.29**	**8.06-9.87**	**2.25-2.92**	**0.70-0.86**	**71.39-85.50**	
Northern	**Surface**	**Mean**	**7.10**	**0.13**	**14.80**	**-**	**12.61**	**7.30**	**1.76**	**0.80**	**78.27**	
		Range	**6.70-7.60**	**0.04-19.2**	**11.20-19.20**	**-**	**11.28-15.21**	**6.29-8.67**	**1.23-2.13**	**0.70-0.92**	**71.13-90.12**	
	Subsurface	**Mean**	**7.54**	**0.13**	**4.08**	**1.13**	**13.83**	**7.62**	**2.03**	**0.76**	**75.33**	
		Range	**7.10-8.10**	**0.08-0.25**	**1.50-8.60**	**0.00-0.70**	**9.40-18.50**	**4.70-10.73**	**1.01-2.92**	**0.63-0.98**	**57.68-83.97**	

facing pedons, respectively (Table-4). The cation exchange capacity of soil was high in lower horizons than upper horizons and ranged from 9.40 to 18.50 and 14.21 to 18.29 ($cmol_c$ kg^{-1} soil) on northern aspect and south facing pedons, respectively. The cation exchange capacity did not depict any trend with depth on northern aspects with 1-3 per cent slope.

4.1.3.7 Exchangeable cations and base saturation

The data presented in Table-4 indicated that the exchangeable calcium was the dominant cation in the studied soils followed by magnesium and potassium, respectively. The contents of exchangeable calcium in the surface horizons of northern and southern aspects in levelled lands ranged from 6.29 to 8.67 and 6.85 to 8.67 ($cmol_c$ kg^{-1} soil), respectively. Whereas, on north facing pedons with 1-3 per cent slope, it varied from 6.62 to 7.80 ($cmol_c$ kg^{-1} soil). The contents of exchangeable calcium showed increase with the increase in the depth on northern and southern aspect with slope 0-1 per cent, whereas, on northern aspects having 1-3 per cent slope, it did not depict any trend with depth. The contents of exchangeable magnesium in surface hirozon of north and south facing pedons varied from 1.23 to 2.13 and 1.90 to 2.48 ($cmol_c$ kg^{-1} soil), respectively. In subsurface horizons on northern and southern aspects, the soil exchangeable magnesium ranged from 4.70 to 10.43 and 8.06 to 9.87

($cmol_c$ kg^{-1} soil), respectively. The exchangeable magnesium showed increasing trend with depth in north facing pedons, whereas, on south facing pedons, it did not exhibit any trend with depth. The exchangeable potassium in the surface horizons of the studied soils varied from 0.70 to 0.92 and 0.76 to 0.97 ($cmol_c$ kg^{-1} soil) in northern and the southern aspect, respectively. In subsurface horizons of north and south facing pedons it varied from 0.63 to 0.98 and 0.70 to 0.86 ($cmol_c$ kg^{-1} soil) with mean values of 0.76 and 0.78 ($cmol_c$ kg^{-1} soil), respectively. The exchangeable potassium did not depict any trend with depth in any aspect.

The base saturation ranged from 71.13 to 90.12 and 78.26 to 82.39 per cent in north and south facing pedons, respectively. It in subsurface horizons ranged from 57.68 to 83.97 and 71.39 to 85.50 per cent in northern and southern aspect, respectively. In general, it decreased with increase in depth of soil. However, it did not depicted any trend in particular aspect.

4.2 Mineralogical characteristics

The profiles were randomly selected for mineralogical studies through x-ray diffraction. The profiles selected were Samboora (P_2), Khrew (P_{10}) and Sempur (P_{15}). All the profiles selected on the basis of difference in profile morphology and aspect, were subjected to clay mineralogical studies.

The relative abundance of clay minerals obtained by X-ray diffraction analysis of clay samples is present in Table-5. The important 'd-spacing' values with respect to corresponding '2θ' values are presented in Appendix-II. Due to similarity in diffractograms of different clays, only representative ones are described.

The representative soil clay collected from different aspect and topography (levelled and gentle sloping lands) showed strong reflection at 10.0 to 10.02 A^o in magnesium saturated samples with higher order peak at about 5, 4.98, 2.57, 3.34 and 3.33 A^o. The glycolated samples showed the basal reflection of 10.0 to 10.02 A^o. Upon heating the samples, the spacing did not expand but the reflection become more intense, indicating the presence of illite. The $10A^o$ reflections did not show asymmetrical broading towards 2θ angle suggesting the presence of illite (almost pure and unweathered with good amount of K) (Figs. 2-4).

The diffraction spacing of $\simeq$ $14A^o$ obtained from magnesium saturation, may be contributed by smectite, hydroxyl interlayered vermiculite or chlorite or by mixture of these species. On glycolation, a portion of $14A^o$ expanded to $17A^o$ or more, indicating the presence of smectite in clays of southern aspect and that are present at higher elevation with very gentle slope. Among $14A^o$ minerals, chlorite was one of the

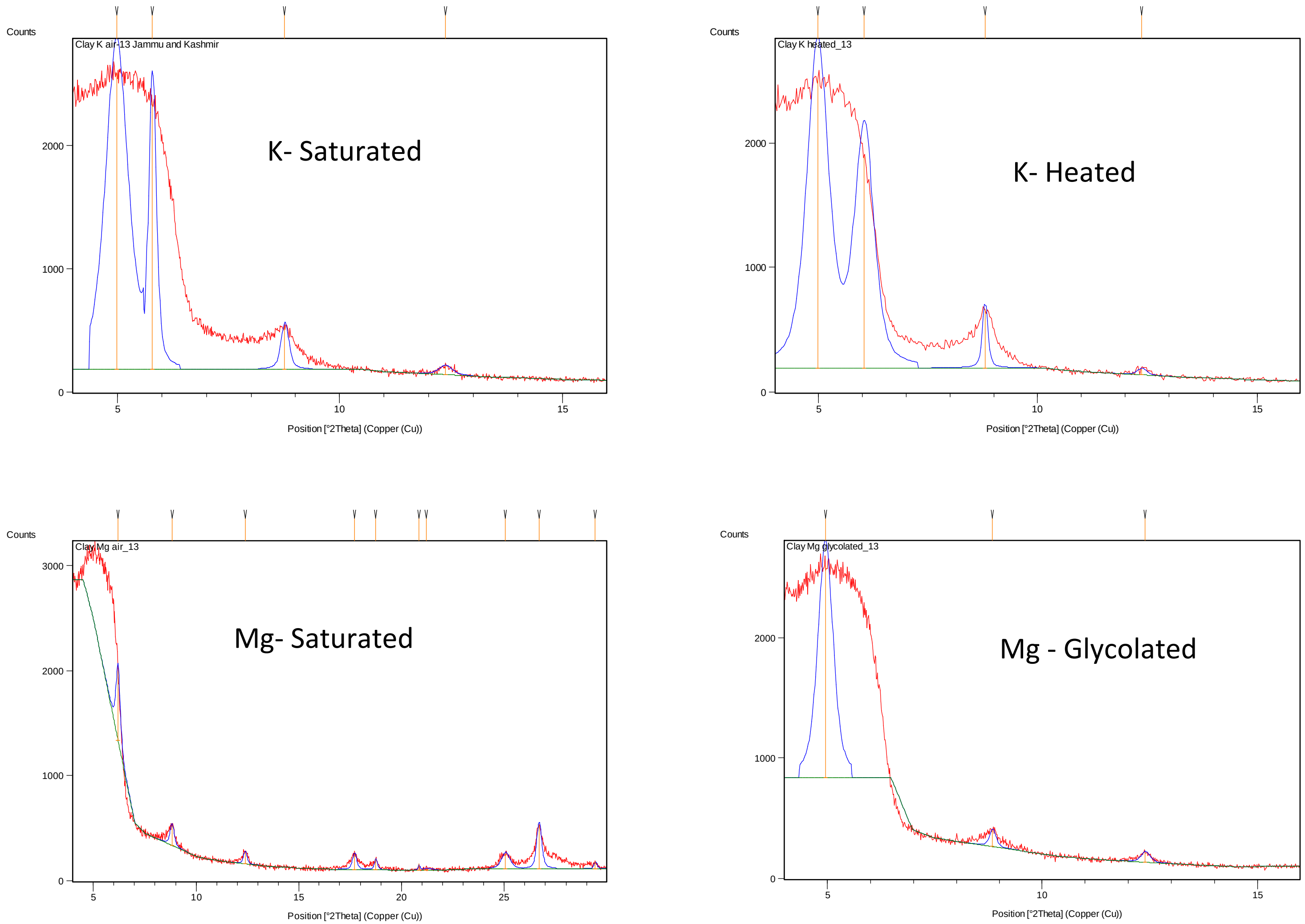

Fig. 3: XRD Patterns of Subsurface clay fractions of Khrew

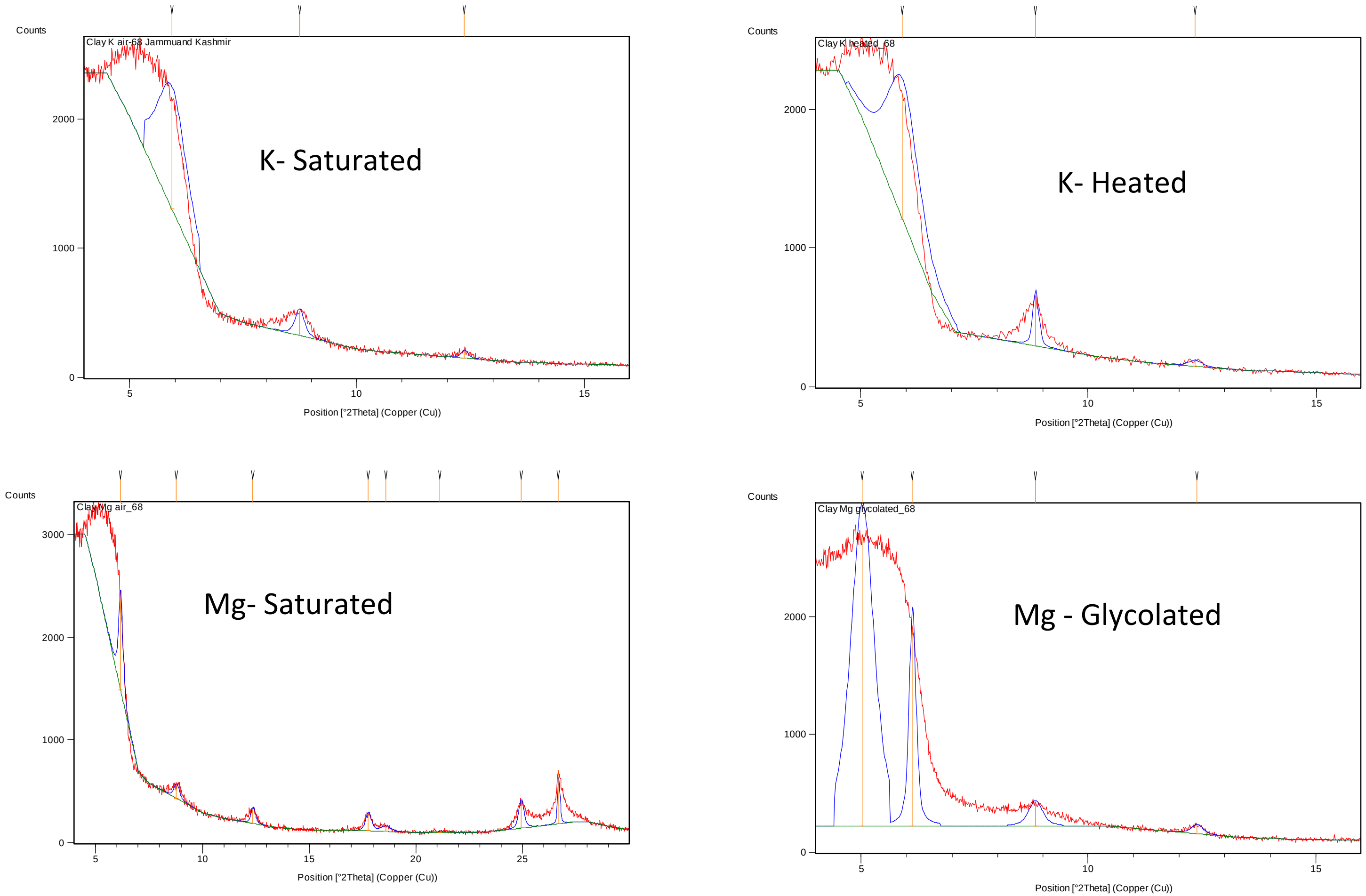

Fig. 4: XRD patterns of subsurface clay fractions of Sempur

components because of persistence of some portion of 14A^o reflection after heating potassium saturated clays at 550^{o}C in soils with very gentle slope. Heating of samples to 550 ^{o}C serves two important functions in collapsing hydroxyl interlayered vermiculite, which contains non-exchangeable interlayer hydroxyl complexes. The magnesium saturated and hydrated vermiculites yield 14A^o peak that doesn't expand to 11.0 A^o after heating at 550^{o}C.

Minerals of kaolinite group are characterized by strong reflection at 7.2 A^o and 2.6 A^o, which disappears and decreases in intensity on thermal treatment. The reflection observed in these samples at 7.14 to 7.17 A^o and 3.5 to 3.6 A^o are relatively weak and decreased in intensity after heating, thus presence of kaolinite is confirmed. Quartz and feldspar seems to be present due to the reflections at 4.20, 4.25, 4.26, 4.73 and 4.77 A^o. The intensity of 14.0 A^o reflection reduced due to heating with relative increase in 10.0 A^o reflection may suggest the presence of mica-vermiculite as mixed layer. The quantitative estimate for clay minerals is of the order of illite, mixed layer, hydroxyl interlayered vermiculite, smectite, chlorite = kaolinite and others (quartz and feldspar).

The most abundant clay minerals in soils under investigation was illite (Table-13). It ranged from 55 to 59.5 per cent in the soils of southern, northern-levelled and northern-very gentle sloping soils, respectively. Mixed layer mineral was the second most abundant mineral (14-17 %). Other constituting minerals in the clay fraction were hydroxyl inter-interlayed vermiculite (6-10 %), kaolinite (5-9%), chlorite (3-9%), smectite (3-6%) and quartz and feldspar (1-3 %). As evident from quantitative estimate of clay minerals (Table-14), contents of koalinite was maximum in the soils of levelled northern soils as compared with others, where no systematic distribution of chlorite was found in the clay minerals of the soils. Apart from variation in the content of different minerals of clay fraction, no systematic difference in potassium mineralogy was observed. All the soils contained illite in greater amount.

Table 5 : Relative abundance of clay minerals in saffron growing soils of District Pulwama

Pedon	Location	Sample	Aspect	Topography	Clay minerals						Others*
					Chlorite	Smectite	Hydrozyl inter layered vermiculite	Illite	Kaolinite	Mixed layers	
P_2	Samboora	Sub-surface	Southern	Near level	+	+	+	+++++	++	+++	Traces
P_{10}	Khrew	Sub-surface	Northern	Very gentle sloping	+	+	+	+++++	+	+++	Traces
P_{15}	Sempur	Sub-surface	Northern	Near level	+	+	++	+++++	++	++	Traces

* Quartz and fledspar

Table 6 : Relative abundance of clay minerals in saffron growing soils of District Pulwama

Pedon	Location	Sample	Aspect	Topography	Clay minerals						Others*
					Chlorite	Smectite	Hydrozyl inter layered vermiculite	Illite	Kaolinite	Mixed layers	
P_2	Samboora	Sub-surface	Southern	Near level	9.0	4.0	7.5	59.5	5.0	14.0	1.0
P_{10}	Khrew	Sub-surface	Northern	Very gentle sloping	8.5	6.0	6.0	56.5	8.0	15.5	1.5
P_{15}	Sempur	Sub-surface	Northern	Near level	3.0	3.0	10.0	55.0	9.0	17.0	3.0

* Quartz and fledspar

4.3 Physico-chemical and nutrient/fertility status of soils

4.3.1 Physico-chemical characteristics

4.3.1.1 Particle size distribution

Perusal of the data in Table-7 depicts the variation in the contents of coarse sand, fine sand, silt and clay in composite soil samples. The contents of coarse sand ranged from 1.24 to 2.4 and 1.5 to 4.1 per cent with mean values of 1.74 and 2.61 per cent in the southern and northern aspect composite samples, respectively. The coarse sand content also varied with the topography of the land. In near level lands, contents of coarse sand varied from 1.50 to 2.90 per cent with a mean value of 2.01 per cent, respectively. Whereas, on the gently sloping lands the coarse sand contents ranged from 2.10 to 4.10 per cent with a mean value of 2.94 per cent. It is also revealed from the table that coarse fractions of sand are predominant in sloping areas as compared to near level lands. The fine sand in the north facing and south facing composite soil samples varied from 21.60 to 48.50 and 9.50 to 32.60 per cent with mean values of 32.91 and 22.68 per cent, respectively. In gently sloping lands the fine sand fraction varied from 21.60 to 48.50 per cent with a mean value of 29.16 per cent, whereas in level lands it ranged from 9.50 to 36.40 per cent with a mean value of 15.50 per cent. The fine sand fraction of soil was found higher in northern and very gentle sloping soils as compared to southern and levelled lands.

Table- 7 : Particle size distribution in composite samples (0-15 cm depth) of Saffron growing areas of district Pulwama

Composite sample No.	Location	Elevation (amsl)	Topography	Slope (%)	Aspect	Latitude	Longitude	Soil separates (%)				Texture
								Coarse sand	Fine sand	Silt	Clay	
1	2	3	4	5	6	7	8	9	10	11	12	13
C_1	Alochibag	1637	Near level	0-1	Southern	33°58.228′N	74°56.494′E	1.2	9.5	68.6	20.7	sil
C_2	Samboora	1642	Near level	0-1	Southern	33°58.012′N	74°56.944′E	1.8	32.6	42.1	23.5	l
C_3	Borus	1644	Near level	0-1	Southern	33°57.503′N	74°58.930′E	2.4	31.7	44.2	21.7	l
C_4	Lethpora	1632	Near level	0-1	Southern	33°58.418′N	74°56.861′E	1.2	14.1	63.4	21.3	sil
C_5	Chandhore	1643	Near level	0-1	Southern	33°59.279′N	74°57.234′E	2.1	25.6	51.7	20.6	sil
C_6	Konibal	1661	Near level	0-1	Northern	34°00.097′N	74°57.098′E	2.7	32.5	44.8	20.0	l
C_7	Gundibal	1632	Near level	0-1	Northern	33°59.905′N	74°58.898′E	1.8	28.3	54.5	15.4	sil
C_8	Ladoo	1648	Very gentle sloping	1-3	Northern	34°00.085′N	75°00.356′E	2.8	24.2	45.8	27.2	l
C_9	Shar	1672	Very gentle sloping	1-3	Northern	34°00.027′N	75°01.434′E	2.3	21.7	51.6	24.4	l
C_{10}	Khrew	1652	Very gentle sloping	1-3	Northern	34°01.242′N	75°00.280′E	3.4	48.5	29.7	18.4	l
C_{11}	Balhama	1617	Very gentle sloping	1-3	Northern	34°02.176′N	74°55.727′E	2.1	29.6	48.1	20.2	l
C_{12}	Mueej	1616	Very gentle sloping	1-3	Northern	34°00.956′N	74°56.591′E	4.1	21.6	53.2	21.1	sil
C_{13}	Munipur	1634	Near level	0-1	Northern	34°00.701′N	74°57.999′E	2.9	31.2	47.4	18.5	l
C_{14}	Wuyan	1623	Near level	0-1	Northern	34°01.843′N	74°56.598′E	2.5	36.4	41.8	19.3	l
C_{15}	Sempur	1582	Near level	0-1	Northern	34°01.993′N	74°54.883′E	1.5	26.6	44.2	27.7	cl
Southern		**Mean**	-	-	-	-	-	**1.74**	**22.68**	**54.00**	**21.56**	
		Range	-	-	-	-	-	**1.2-2.4**	**9.5-32.6**	**42.1-68.6**	**20.60- 23.50**	
Northern		**Mean**	-	-	-	-	-	**2.61**	**32.91**	**46.11**	**21.22**	
		Range	-	-	-	-	-	**1.5-4.1**	**21.6-48.5**	**29.70 – 51.20**	**15.40 – 27.70**	

The silt content in the composite samples ranged from 29.70 to 54.50 and 42.10 to 68.60 per cent with mean values of 46.11 and 54.00 per cent in the northern and southern aspect, respectively. In levelled and very gentle sloping lands it varied from 41.80 to 68.60 and 29.70 to 53.20 per cent with mean values of 23.27 and 45.68 per cent, respectively. It is evident from the table that aspect and slope both affects the contents of silt in different soil samples. The contents of silt was found to be higher in southern and levelled land soil samples than the northern and sloping land soil samples. The contents of clay in southern and northern aspect drawn samples ranged from 20.60 to 23.50 and 15.40 to 27.70 per cent with mean value of 21.56 and 21.22 per cent, respectively. The contents of clay varied from 15.40 to 27.70 and 20.20 to 27.20 per cent with mean values of 20.87 and 22.26 per cent in level and gentle sloping areas, respectively. The contents of clay was higher in higher range in soils from northern aspect and particularly those that was on level lands/areas.

The texture in north facing soils was finer than south facing soils. It was also observed that soils on plains/near level lands was finer than those soil found on sloping lands/areas.

4.3.1.2 Soil reaction (pH)

Perusal of data in Table-8, revealed that the pH value of soils in northern and southern aspect ranged from 6.60 to 7.70 and 7.10 to 7.60 with mean values of 7.13 and 7.32, respectively. The values of pH in levelled and slopy areas varied from 6.60 to 7.60 and 7.40 to 7.70 with mean values of 7.03 and 7.52. The pH on southern aspect was slightly alkaline whereas, it was slightly acidic on the northern aspect. In level areas, the pH was slightly acidic to alkaline and on gentle sloping lands, it was near neutral to slightly alkaline.

4.3.1.3 Electrical conductivity (EC)

The electrical conductivity (Table-8), in northern, southern, level and slopy areas varied from 0.04 to 0.22, 0.11 to 0.17, 0.04 to 0.17 and 0.12 to 0.22 dsm^{-1} with mean values of 0.14, 0.136, 0.115 and 0.186 dsm^{-1}, respectively. Electrical conductivity showed little variation in southern aspect while as, it varied greatly in northern aspect. The electrical conductivity was found more on northern-sloping areas as compared to southern- near level areas.

4.3.1.4 Organic carbon

The data present as Table-8, depicts the trend observed in organic carbon contents in different aspects and topography. It varied from 14.80 to 17.40, 11.40 to 19.20, 14.20 to 19.20 and 11.40 to 12.50 g kg^{-1} soil with mean values of 16.16, 14.71, 16.87 and 11.90 g kg^{-1} soil in southern, northern, levelled and gentle sloping areas, respectively. The organic carbon content was found more in levelled areas in the northern aspect.

4.3.1.5 Cation exchange capacity

The cation exchange capacity varied from 11.35 to 15.32 [$cmol_c$ kg^{-1} soil] with mean value of 12.64 [$cmol_c$ kg^{-1} soil] in northern aspect (Table-8). Whereas, in southern aspect, it ranged from 12.31 to 14.87 [$cmol_c$ kg^{-1} soil] with mean value of 13.95 [$cmol_c$ kg^{-1} soil]. In gentle sloping and levelled areas, it varied from 11.40 to 12.50 [$cmol_c$ kg^{-1} soil] and 14.20 to 19.20 [$cmol_c$ kg^{-1} soil] with mean values of 12.54 and 13.35 [$cmol_c$ kg^{-1} soil], respectively. Cation exchange capacity was found more in soils from northern aspect as compared to southern aspect and in case of near level and sloping area, it was found more in near level lands.

4.3.1.6 Exchangeable cations and base saturation

Perusal of data in Table-8, revealed that the exchangeable calcium was the dominant cation in the studied area/soils followed by exchangeable magnesium and potassium, respectively. The exchangeable calcium varied from 6.17 to 8.64 and 6.94 to 8.61 $cmol_c$ kg^{-1} soil with mean values of 7.30 and 7.91 $cmol_c$ kg^{-1} soil in northern and southern aspect, respectively. In case of near level lands, it ranged from 6.17 to 8.64 $cmol_c$ kg^{-1} soil with mean value of 7.66 $cmol_c$ kg^{-1} soil where as, in gentle sloping area (1-3 %

slope) it varied from 6.72 to 7.82 $cmol_c$ kg^{-1} soil with mean value of 7.20 $cmol_c$ kg^{-1} soil, respectively. The exchangeable calcium was found more on northern aspect with near level/plain topography. The contents of exchangeable magnesium in soils of southern aspect with level/ plain topography ranged from 1.93 to 2.56 $cmol_c$ kg^{-1} soil with mean value of 2.31 $cmol_c$ kg^{-1} soil, whereas in soils of northern aspect with very gentle slope, it varied from 1.27 to 2.11 with mean value of 1.66 $cmol_c$ kg^{-1} soil, respectively. The exchangeable magnesium was found more on near level soils than soils from sloping areas. The exchangeable potassium varied from 0.74 to 0.92, 0.76 to 0.95, 0.74 to 0.95, 0.78 to 0.92 $cmol_c$ kg^{-1} soil with mean values of 0.81, 0.89, 0.83, 0.83 $cmol_c$ kg^{-1} soil in soils draw from northern, southern, near level and the sloping area, respectively. The exchangeable potassium didn't depict any relation with aspect/slope.

The base saturation ranged from 70.31 to 90.15 and 77.42 to 82.89 per cent in soils from northern and southern aspect, with mean values of 78.65 and 79.68 per cent respectively. In near level areas from both northern and southern aspect, it varied from 70.31 to 90.15 per cent with mean value of 79.84 per cent, respectively. Whereas, in north facing gentle sloping areas, the base saturation in soils ranged from 74.75 to 80.64 per cent with mean value of 77.29 per cent. Base saturation didn't show any

Table 8 : Physico-chemical properties of composite samples (0-15 cm depth) of saffron growing areas of district Pulwama

Composite sample No.	Location	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (g kg^{-1} soil)	$CaCO_3$ (%)	CEC ($cmol_c$ kg^{-1} soil)	Exchangeable cations ($cmol_c$ kg^{-1} soil)				Base saturation (%)
								Ca^{2+}	Mg^{2+}	K^+	Na^+	
1	2	3	4	5	6	7	8	9	10	11	12	13
C_1	Alochibag	0-15	7.4	0.16	16.4	Nil	13.56	7.84	2.51	0.89	Traces	82.89
C_2	Samboora	0-15	7.6	0.17	14.8	Nil	14.24	8.01	2.56	0.92	Traces	80.69
C_3	Borus	0-15	7.1	0.12	17.4	Nil	14.87	8.16	2.48	0.95	Traces	77.94
C_4	Lethpora	0-15	7.3	0.11	15.4	Nil	12.31	6.94	1.93	0.91	Traces	79.45
C_5	Chandhore	0-15	7.2	0.12	16.8	Nil	14.75	8.61	2.05	0.76	Traces	77.42
C_6	Konibal	0-15	6.7	0.10	19.2	Nil	15.32	8.07	2.17	0.78	Traces	71.93
C_7	Gundibal	0-15	6.8	0.06	18.2	Nil	12.59	8.64	1.97	0.74	Traces	90.15
C_8	Ladoo	0-15	7.4	0.22	11.8	Nil	12.28	7.18	1.52	0.83	Traces	77.60
C_9	Shar	0-15	7.5	0.18	12.2	Nil	12.44	6.84	1.72	0.92	Traces	76.21
C_{10}	Khrew	0-15	7.7	0.22	11.4	Nil	11.35	6.72	1.27	0.78	Traces	77.27
C_{11}	Balhama	0-15	7.6	0.12	11.6	Nil	12.86	7.45	2.11	0.81	Traces	80.64
C_{12}	Mueej	0-15	7.4	0.19	12.5	Nil	13.78	7.82	1.66	0.82	Traces	74.75
C_{13}	Munipur	0-15	6.7	0.15	18.5	Nil	12.16	6.17	1.64	0.74	Traces	70.31
C_{14}	Wuyan	0-15	6.9	0.04	17.8	Nil	11.77	6.83	2.11	0.81	Traces	82.84
C_{15}	Sempur	0-15	6.6	0.12	14.2	Nil	11.88	7.32	1.91	0.84	Traces	84.76
Southern	**Mean**	-	**7.32**	**0.136**	**16.16**	-	**13.95**	**7.91**	**2.31**	**0.89**	-	**79.68**
	Range	-	**7.10-7.60**	**0.11-0.17**	**14.80-17.40**	-	**12.31-14.87**	**6.94-8.61**	**1.93-2.56**	**0.76-0.95**	-	**77.42-82.89**
Northern	**Mean**	-	**7.13**	**0.14**	**14.71**	-	**12.64**	**7.30**	**1.81**	**0.81**	-	**78.65**
	Range	-	**6.6-7.7**	**0.04-0.22**	**11.40-19.20**	-	**11.35-15.32**	**6.17-8.64**	**1.27-2.17**	**0.74-0.92**	-	**70.31-90.15**
Levelled	**Mean**	-	**7.03**	**0.115**	**16.87**	-	**13.35**	**7.66**	**2.13**	**0.83**	-	**79.84**
	Range	-	**6.6-7.6**	**0.04-0.17**	**14.20-19.20**	-	**11.77-15.32**	**6.17-8.64**	**1.64-2.56**	**0.74-0.95**	-	**70.31-90.15**
Very gentle sloping	**Mean**	-	**7.52**	**0.186**	**11.90**	-	**12.54**	**7.20**	**1.66**	**0.83**	-	**77.29**
	Range	-	**7.40-7.70**	**0.12-0.22**	**11.40-12.50**	-	**11.35-13.78**	**6.72-7.82**	**1.27-2.11**	**0.78-0.92**	-	**74.75-80.64**

particular relation with the aspect, however, it was found higher in near level areas than in sloping lands (Table-7).

4.3.2 Nutrient status of soils

4.3.2.1 Available nitrogen, phosphorus (P_2O_5) and potassium (K_2O)

Perusal of data in Table-9, revealed that the available nitrogen and phosphorus ranged from 270.1 to 376.3 and 9.10 to 14.20 kg ha^{-1} with mean values of 304.12 and 11.66 kg ha^{-1} in soil from northern aspect, respectively. In soils from southern aspect, these varied from 290.50 to 367.20 and 11.60 to 13.80 kg ha^{-1} with mean value of 316.50 and 12.30 kg ha^{-1}.

The variation in nitrogen and phosphorus in soils from near level areas ranged from 285.80 to 376.30 and 11.30 to 14.20 kg ha^{-1} with mean values of 325.7 and 12.60 kg ha^{-1}, respectively. In case of gentle sloping lands, these varied from 270.20 to 276.80 and 9.10 to 11.20 kg ha^{-1} with mean values of 273.36 and 10.42 kg ha^{-1}, respectively. The data depicts that the values of nitrogen and phosphorus were in lower range in sloping areas. Whereas, in near level lands/ plains the nitrogen varied from lower to medium range and phosphorus was found in lower range irrespective of the topography and aspect.

Table 9 : Available nutrient content (NPK) in composite samples (0-15 cm depth) of saffron growing areas of district Pulwama

Composite sample No.	Location	Depth (cm)	Available nutrient (kg ha^{-1})		
			N	P	K
1	2	3	4	5	6
C_1	Alochibag	0-15	311.6	12.0	308.1
C_2	Samboora	0-15	290.5	11.6	280.5
C_3	Borus	0-15	313.6	12.2	324.8
C_4	Lethpora	0-15	299.6	11.9	268.8
C_5	Chandhore	0-15	367.2	13.8	255.6
C_6	Konibal	0-15	376.3	14.2	302.4
C_7	Gundibal	0-15	339.2	12.9	268.8
C_8	Ladoo	0-15	272.8	10.8	291.3
C_9	Shar	0-15	275.2	11.0	235.9
C_{10}	Khrew	0-15	270.2	9.1	229.6
C_{11}	Balhama	0-15	271.8	10.0	207.2
C_{12}	Mueej	0-15	276.8	11.2	162.4
C_{13}	Munipur	0-15	352.5	13.5	352.7
C_{14}	Wuyan	0-15	320.6	12.6	268.8
C_{15}	Sempur	0-15	285.8	11.3	240.8
Southern	**Mean**		**316.5**	**12.30**	**287.56**
	Range		**290.5-367.2**	**11.60-13.80**	**255.60-324.80**
Northern	**Mean**		**304.12**	**11.66**	**260.00**
	Range		**270.1-376.3**	**9.10-14.20**	**162.40-352.70**
Levelled	**Mean**		**325.7**	**12.60**	**287.13**
	Range		**285.8-376.3**	**11.30-14.20**	**240.80-352.70**
Very gentle sloping	**Mean**		**273-36**	**10.42**	**225.28**
	Range		**270.20-276.80**	**9.10-11.20**	**162.40-291.30**

The potassium in the southern and northern aspects varied from 255.60 to 324.80 and 162.40 to 352.70 kg ha^{-1} with mean values of 287.56 and 260.00 kg ha^{-1}, respectively. The data about potassium (Table-8) also revealed that potassium irrespective of topography and aspect, was always found in higher range.

4.3.2.2 Distribution of DTPA-extractable micro-nutrients

The data presented as Table-10, revealed that contents of zinc and copper varied from 1.04 to 2.63 and 0.81 to 2.92 ppm with mean values of 1.78 and 1.54 ppm in soils from northern aspect. Whereas, in southern aspect these ranged from 1.57 to 1.94 and 1.18 to 1.42 ppm with mean values of 1.79 and 1.31 ppm, respectively. In case of gently sloping areas, these varied from 1.04 to 1.31 and 0.81 to 1.77 ppm with mean values of 1.19 and 1.24 ppm, respectively. Whereas, in soil from near level areas irrespective of the aspect, these ranged from 1.57 to 2.63 and 1.18 to 2.92 ppm with mean values of 2.08 and 1.58 ppm. The contents of zinc and copper were found higher in soils facing northern aspect than soils found in southern aspect. In case of the topography, the near level areas/plains exhibited upper hand so for amount of DTPA-extractable Zn and Cu is concerned than the gentle sloping areas.

The DTPA-extractable iron (Fe) and manganese (Mn) showed variation in the ranges of 7.09 to 12.47 and 15.24 to 26.21 ppm with mean values of 10.01 and 21.30 ppm in the soils from northern aspect, whereas, in case of soils from southern aspect these ranged from 9.72 to 11.02 and 23.67 to 25.51 ppm with mean values of 10.49 and 24.64 ppm, respectively. On gentle slopping lands in northern aspect, these varied from 7.09 to 9.01 and 15.24 to 19.21 ppm with mean values of 8.22 and 17.63 ppm, whereas, in near level areas from both the aspect these ranged from 9.72 to 12.47 and 22.16 to 26.21 ppm with mean values of 11.15 and 24.80 ppm, respectively. It is evident from the data in Table-9, that the contents of micronutrient cations viz., Zn, Cu, Fe and Mn were found more in levelled areas as compared to the sloping areas/lands. The contents of these micronutrients were also found lower in southern aspect than the found/present in the soils from northern aspect.

4.4 Relationship between physico-chemical properties and available nutrients in composite samples

The correlation coefficient values of organic carbon, pH, cation exchange capacity and the clay content of saffron growing soils with available nutrients has been worked for composite samples and presented in Table-11. Perusal of the said data in Table-11, revealed that the contents of organic carbon in soil showed positive and significant correlation with N ($r = 0.891$), P ($r = 0.907$), K ($r = 0.682$), Zn ($r = 0.817$), Fe ($r = 0.842$) and

Table 10 : Distribution of micronutrient cations (Zn, Cu, Fe and Mn) in composite samples (0-15 cm depth) of saffron growing areas of district Pulwama

Composite sample No.	Location	Depth (cm)	Micronutrints cations (ppm)			
			Zinc (Zn)	Copper (Cu)	Iron (Fe)	Manganese (Mn)
1	**2**	**3**	**4**	**5**	**6**	**7**
C_1	Alochibag	0-15	1.92	1.31	10.44	24.71
C_2	Samboora	0-15	1.75	1.18	9.72	23.67
C_3	Borus	0-15	1.94	1.37	10.78	25.11
C_4	Lethpora	0-15	1.75	1.28	10.47	24.18
C_5	Chandhore	0-15	1.57	1.42	11.02	25.51
C_6	Konibal	0-15	2.17	1.28	11.12	25.34
C_7	Gundibal	0-15	2.42	1.63	12.34	25.93
C_8	Ladoo	0-15	1.23	1.77	8.16	19.01
C_9	Shar	0-15	1.25	1.75	8.71	19.13
C_{10}	Khrew	0-15	1.04	0.81	7.09	15.24
C_{11}	Balhama	0-15	1.12	0.83	8.11	15.67
C_{12}	Mueej	0-15	1.31	1.06	9.01	19.21
C_{13}	Munipur	0-15	2.17	1.25	10.95	25.19
C_{14}	Wuyan	0-15	2.63	2.92	12.47	26.21
C_{15}	Sempur	0-15	2.46	2.14	12.17	22.16
Southern	**Mean**		**1.79**	**1.31**	**10.49**	**24.64**
	Range		**1.57-1.94**	**1.18-1.42**	**9.72-11.02**	**23.67-25.51**
Northern	**Mean**		**1.78**	**1.54**	**10.01**	**21.30**
	Range		**1.04-2.63**	**0.81-2.92**	**7.09-12.47**	**15.24-26.21**
Levelled	**Mean**		**2.08**	**1.58**	**11.15**	**24.80**
	Range		**1.57-2.63**	**1.18-2.92**	**9.72-12.47**	**22.16-26.21**
Very gentle sloping	**Mean**		**1.19**	**1.24**	**8.22**	**17.63**
	Range		**1.04-1.31**	**0.81-1.77**	**7.09-9.01**	**15.24-19.21**

Table-11 : Relationship between available nutrients and physico-chemical properties of composite samples of saffron growing soils of district Pulwama

Nutrient	Composite samples physico-chemical properties			
	OC	**pH**	**CEC**	**Clay**
N	0.891**	-0.787**	0.356	-0.482
P	0.907**	-0.801**	0.514	-0.302
K	0.682**	-0.372	0.181	0.084
Zn	0.817**	-0.750**	0.015	-0.189
Cu	0.286	-0.451	-0.315	0.248
Fe	0.842**	-0.836**	0.149	-0.189
Mn	0.938**	-0.702**	0.382	-0.244

** Correlation is significant at 0.01 level.

Mn (r = 0.938). The correlation coefficient between soil organic carbon content and copper was although positive but was not upto the level of significance. A negatively significant correlation coefficients between pH with N (r = -0.787), P (r = -0.801), Zn (r = -0.750), Fe (r = -0.836) and Mn (r = -0.836) was noticed. The correlation coefficients between DTPA-extractable cations viz., Zn, Fe and Mn and cation exchange capacity (CEC) were found positively non-significant. The DTPA-extractable copper (Cu) contents in soils showed negative non-significant correlation coefficients with cation exchange capacity. The linear relationship between clay content and N, P, Zn, Fe and Mn was found negative but non-significant.

4.5 Nutrient indexing

For getting the nutrient index value (NIV) of the primary macronutrients N, P and K, 5-samples were taken from each location and were categorized after due laboratory analysis into low, medium and high soil fertility class by comparing the observed values of available nutrients with recommended level rating chart of available nutrients Muhr *et al.* (1965). Nutrient index value was then worked out for each nutrient using the formula proposed by Biswas and Mukherjee (1989). The formula is;

$$NIV = \frac{N_L 1 + 2\,N_M + 3\,N_H}{N_L + N_M + N_H}$$

Table 12 : Nutrient indexing (for available N, P&K) in saffron growing areas of district Pulwama

Location	Number of samples analyzed	Number of samples in each category									Nutrient index		
		Low			Medium			High			(NIV)		
		N	P	K	N	P	K	N	P	K	N	P	K
Alochibag	5	4	4	-	1	1	2	-	-	3	1.2	1.2	2.6
Samboora	5	-	4	-	4	1	3	1	-	2	2.2	1.2	2.4
Borus	5	1	4	-	4	1	1	-	-	4	1.8	1.2	2.8
Lethpora	5	1	3	1	4	2	1	-	-	3	1.8	1.4	2.4
Chandhore	5	-	4	-	4	1	2	-	-	3	1.8	1.2	2.6
Konibal	5	2	2	-	4	3	2	1	-	3	2.2	1.6	2.6
Gundibal	5	-	4	-	2	1	4	1	-	1	1.8	1.4	2.2
Ladoo	5	1	4	2	3	1	3	2	-	-	1.4	1.2	1.6
Shar	5	-	4	-	3	1	4	1	-	1	2.0	1.2	2.2
Khrew	5	-	4	-	2	1	2	3	-	3	2.6	1.2	2.6
Balhama	5	1	3	-	3	2	4	2	-	1	2.4	1.4	2.2
Mueej	5	2	4	-	4	1	4	-	-	1	1.8	1.2	2.2
Munipur	5	1	2	-	3	3	4	-	-	1	1.6	1.6	2.2
Wuyan	5	1	4	-	1	1	3	3	-	2	2.4	1.2	2.4
Sempur	5	2	2	1	3	1]	3	-	-	1	1.6	1.2	2.0
Over All Nutrients Index Value (NIV)											1.91	1.29	2.33

* Nutrient Index Value

Where;

N_L = number of samples in low class

N_M = number of samples in medium class

N_H = number of samples in high class

The subsequent evaluation showed that soils are low in phosphorus in majority of the locations, medium in nitrogen and medium to high in potassium, respectively. The over all NIV for the nitrogen, phosphorus and potassium was 1.91, 1.29 and 2.33, respectively (Table -12).

CHAPTER – 5

DISCUSSION

The experimental findings obtained during the course of present study are discussed in this chapter under the following heads :

5.1 Soil characterization

5.1.1 Morphological characteristics

5.1.2 Physico-chemical characteristics

5.2 Mineralogical characteristics

5.3 Physico-chemical characteristics and nutrients status of soils

5.3.1 Physico-chemical characteristics

5.3.2 Nutrient status of soils

5.3.2.1 Available nitrogen (N), phosphorus (P) and potassium (K)

5.3.2.2 Micro-nutrient cation distribution

5.4 Relationship between physico-chemical properties and available nutrients

5.5 Soil classification

5.6 Nutrient Indexing

5.1 Soil characterization

Fifteen soil profile were selected and exposed for detailed study at the representative sites, based on heterogeneity in apparent soil colour, topography and aspect. Their morphological, physico-chemical, mineralogical properties and nutrient status are discussed as under

5.1.1 Morphological characteristics/properties

The colour of the soil in the surface horizons of southern aspect varied from brown(10YR $^5/_3$)/dark brown (10YR $^4/_3$)/dark yellowish brown (10YR $^4/_4$) to pale brown (10YR $^4/_3$)/ yellowish brown (10YR $^5/_4$) while as profiles of northern aspect surface horizons varied from dark brown (10YR $^3/_4$)/very dark brown (10YR $^2/_2$) to dark yellowish brown (10YR $^4/_4$). In the subsurface horizons of the southern aspect the colour varied from brown (10YR $^5/_4$)/dark brown (10YR $^3/_4$)/dark yellowish brown (10YR $^4/_4$) to light yellowish brown (10YR $^6/_4$)/dark greyish brown (10YR $^4/_3$) and yellowish brown (10YR $^5/_4$). While as, the colour in the sub-surface horizons of the northern aspect varied from dark yellowish brown (10YR $^4/_4$) or yellowish brown (10YR $^5/_4$)/brown (10YR $^5/_4$) to dark greyish brown (10YR $^4/_2$)/very dark grey (10YR $^3/_2$). The dark colour in the surface horizon can be attributed to high soil carbon content and down the profile it can be attributed to clay alleviation. The various shades of grey colour in the studied profiles could be attributed to the presence of free calcium carbonate and/or coagulation of iron and/or calcium with humus components (Dhir, 1967 and Gupta, 1992). The dark brown, very dark brown, yellowish brown and the dark yellowish brown colour in the surface and sub-surface horizons of profiles indicates a good drainage condition of these soils.

The texture of surface horizons of southern aspect changed from loam to silty clay loam/clay loam and silt loam to silty clay loam/clay loam where as on the northern aspect, it changed from loam/silt loam to clay loam/sandy loam. However, in P15 it remained clay loam through out the depth. The textures become finer with the increase in depth in most of the profiles. In general, it was observed that as the elevation and slope gradient increased, the texture of the soils become coarser, which might be due to translocation or removal of finer fractions of soil by eluviations or surface erosion (soil) due to high rain fall in these zones. Similar observations have been reported by Mandal *et al.* (1990).

The diagnostic horizons were found to be Ap-AB/BA-B_1-B_2 type at Alochibagh (P_1) and Lethpora (P_4) and Ap-AB/BA-Bw_1-Bw_2 type at Borus (P_3) and Chandhore (P_5). At Samboora (P_2) it was found to be Ap-Bw_1-Bw_2-Bw_3 type. The soil pedons facing northern aspect on near level topography showed Ap-BA/AB/Bw-Bt_1-Bt_2 type profile development. Where as, profiles on very gentle sloping topography in northern aspect showed Ap-A/AC/C_1-C_2/C_1-C_2-C_3 type horizon development. The structure of north facing profiles was fine, weak/medium granular and medium/coarse moderate angular blocky to sub-angular blocky where as on southern aspect it was weak to moderate angular/sub-angular blocky. The development of weak to moderate granual structure in the sub-surface horizons of pedons facing north is attributed to high organic mater content as also reported by Sehgal *et al.* (1985) and Minhas *et al.* (1997) under such situation. Where as, the presence of angular/sub-angular blocky structure in both the aspects exhibit structural development (Najar, 2002)

The consistency of the soils of studied pedons varied widely. In surface horizons of northern aspect, it was hard/slightly hard when dry and friable/very friable to firm when moist. On the other hand in southern aspect the consistency of soils was slightly hard/hard when dry and friable when moist. In the sub-surface horizons of the northern aspect it was slightly hard to hard when dry and very friable/friable to very firm when moist. Whereas on southern aspect the consistency of the sub-surface horizons was hard when dry and friable to firm when moist. In general, the clay cutans (argillans) were found to be moderately thin and patchy in majority of the soil profiles. The effervescence with dilute hydrochloric acid (Hcl) was found to be slight to violet in sub-surface horizons. Variation is the consistency of the soils of various pedons could be due to differences in clay and organic matter content. (Najar, 2002)

The morphological patterns of well developed profiles facing north having slope 0-1%, were due to the illuviation of clay in B horizon, which resulted in the formation of Agrillic horizon and led to colour, textural, structural and consistency change. The leaching of calcium carbonate and its deposition in the lower horizons was quite evident from the effervescence with dilute Hcl, which also led some changes in morphological characters in these horizons. The calcareous nature of the parent material is manifested by the effervescence shown with dilute HCl.

The presence of the altered horizon (cambic) in profiles facing southern aspect, showed the intermediate process of development with the presence of calcium carbonate at the lower horizons and textural variation in the lower horizons. Similar results were obtained by Shinde *et al.* (1984); Mushki (1994); Wani (1994); Ganai *et al.* (2000); Mahapatra *et al.* (2000); Katoo (2001); Najar (2002); Ahmad (2003) and Kirmani (2004).

5.1.2 Physico-chemical characteristics

5.1.2.1 Particle size distribution/mechanical components

The soils varied widely in their make up. In general, the fine sand decreased with the depth of the soil profile in all the soil pedons except at Ladoo, Shar, Khrew, Balhama and Mueej, respectively. The silt fraction generally decreased with depth however, in profiles on very gentle sloping topography facing north viz., Ladoo (P_8), Khrew (P_{10}) and Balhama (P_{11}), it increased with the depth of the soil pedon. Clay content in general also increased with depth in the soil pedons. However, in soil profiles on very gentle sloping areas facing north, it decreased with depth of the soil pedons. The texture of surface horizons of south facing pedons changed from loam to silty clay loam/clay loam and silt loam to silty clay loam/ clay loam. Where as, on north aspect facing profiles, it varied from loam to clay loam on near level topography except in case of Sempur (P_{15}) were it remained clay loam through out the depth of soil pedon. The texture in case of profiles on very gentle topography changed from loam / silt loam to clay loam/ sandy loam, respectively.

This may be associated with the translocation and illluviation of clay in the B horizon during soil genesis. Similar observations were made by Handoo (1983), Farida (1997); Najar (2002) and Kirmani (2004).

5.1.2.2 Soil reaction

The soil studied exhibited slightly acidic to alkaline pH ranging between 6.7 to 8.1. In general, the soil pH increased with the depth of the soil pedon. Lower pH of the surface horizon might be due to the higher amount of organic carbon and rainfall distribution. Similar results were reported by Mandal *et al.* (1990); Verma *et al.* (1990) and Wani (1994). The increase in soil pH down the profile might be due to increased leaching of soluble salts from the surface and their subsequent deposition at the lower horizons besides higher contents of $CaCo_3$. Gupta *et al.* (1988); Najar (2002) and Kirmani (2004) reported similar results.

5.1.2.3 Electrical conductivity

The electrical conductivity of the soil was found with in the normal range in both surface and sub-surface horizons of profiles in both aspects. However, it exhibited an increasing trend with the depth of soil profile irrespective of aspect. This might be attributed to leaching of soluble salts from surface and their deposition at lower horizons. However, the increase was more pronounced in northern than profiles in southern aspect. The findings corroborates with the earlier results of Jalali *et al.* (1989); Kher and Singh (1993), Kirmani (2004) and Najar (2009).

5.1.2.4 Calcium carbonate

The mean average calcium carbonate content in sub-surface horizon of northern and southern aspect ranged from 0.00-7.00 per cent and 0.05 - 5.80 per cent, respectively. The higher content of calcium carbonate in the lower horizons might be due to the leaching of soluble salts and the calcareous nature of these soils. The results are in agreement with the finding of Talib (1984), Mushki (1994) and Kirmani (2004).

5.1.2.5 Organic carbon

The soils varied very conspicuously in the organic carbon content. The organic carbon content was found in higher range in surface horizon and lower to higher range in sub-surface horizon. In general, organic carbon content decreased with the increase in soil depth. The higher organic carbon content in surface soils (11.20 - 19.20 g kg^{-1} and 14.70 – 17.20 g kg^{-1} soil in north and south facing pedons, respectively) is due to lower rates of mineralization prevalent in temperate conditions. These results are in conformity with the findings of Mushki (1994); Xiubin *et al.* (2002) and Najar (2002).

5.1.2.6 Cation exchange capacity

The cation exchange capacity of north and south facing pedons showed slight variation and increased with the increase in the depth of the soil profile. The higher values of cation exchange capacity in lower horizons might be attributed to increase in clay content with the depth of the soil profile and might also be the reflection of the smectite/illitic mineralogy. The results are in agreement with the observations/findings of Farida (1997); Ahmad (2003) and Kirmani (2004).

5.1.2.7 Exchangeable cations and Base saturation

The exchangeable calcium was the dominant cation in all the soil profiles, followed by magnesium and potassium. The contents of exchangeable calcium showed increase with the depth of soil pedons in northern and southern aspect having slope 0-1%, where as, on north facing pedons having 1-3% slope, it did not depicted any trend with depth. The dominance of exchangeable calcium might be due to two reasons : (i) Leaching of the soluble salts and their illuviation at lower horizons and (ii) due to the calcareous nature of the parent material. Similar results were obtained by Verma *et al.* (1990); Mushki (1994); Najar (2002) and Kirmani (2004).

The contents of exchangeable magnesium in surface horizon of north and south facing pedons ranged from 1.23-2.13 and 1.90-2.48 $cmol_c\ kg^{-1}$ soil, respectively. In sub surface horizons on northern aspect, it was found higher than on southern aspect. The exchangeable magnesium showed increased trend with depth in north facing pedons, where as, on south facing pedons, it did not exhibit any trend with depth. The potassium was the third dominant cation in all the soil profiles irrespective of the aspect and topography. These could be attributed to the better distribution of rains and low temperature in the northern aspect and to the prevalence of potassium bearing minerals in these soil s. similar findings were reported by Talib (1984), Mandal *et al.* (1990) and Najar (2009)

In general, base saturation was found higher in the surface horizon than subsurface horizon. However, it did not show any trend in particular aspect. This might be due to the presence of higher amount of basic cations like calcium (Ca^{2+}) and magnesium (Mg^{2+}) and is one of the distinguishing characters of Alfisols. The results obtained are in conformity with the findings of Reddy and Prasad (1999); Katoo (2001) and Kirmani (2004).

5.2 Mineralogical characteristics

Three subsurface soil samples of three profiles P_2, P_8 and P_{15} were randomly selected for clay mineralogical studies from both aspect taking also into consideration altitude and slope gradient.

5.2.1 Clay mineralogy

The qualitative estimates of clay mineralogy as detected from x-ray diffractograms (XRD) revealed the presences of illite, mixed layers, hydroxyl interlayered vermiculite, kaolinite smectite and chlorite. Illite is a group name of non-expanding, clay sized, dioctahedral, micaceous minerals. Illite was invariably the dominant clay mineral in all the sample under investigation. The dominance of illite may be due to degradation or hydrolysis of feldspars. The invariable presences of illite as the dominant clay mineral in the soils of Kashmir was confirmed by Pal and Deshpanday (1987), Gupta *et al.* (1990) and Katoo (2001)

The presences of mixed layers in clay samples could be ascribed to the transformation of primary phyllosilicates (micas and chlorites) and was the second dominant clay mineral. The occurrence of mixed layer minerals in these soils are in agreement with the findings of Gupta and Awasthi (1982). On heating the samples at 550 ^{o}C, the 14.0 A^{o} reflections collapsed, indicating the presence of hydroxyl interlayered vermiculite, which was the third dominate clay mineral. Hydroxyl interlayered vermiculite was found to develop from the degradation of illite or mica under temperate weather conditions and from chlorite due to exchange of magnesium from brucite layer [Mg $(OH)_2$]. Similar findings where also reported by Dandroo (2001) and Kirmani (2004).

Expansion of 14.0 A^{o} reflection to 17.0 A^{o} or more on glycolation, indicated the presence of smectite. It commonly results from the weathering of basic rocks. Smectite formation is favoured by the near level to gentle sloping terranes that are poorly drained, mildly alkaline and have high silicon and magnesium potential (Borchardt, 1977). Other factors that favour formation of smectite includes availability of calcium and the paucity of potassium (Deer *et al.*, 1975)

The persistence of 14.0 A^o peak after K-saturation and heating at 550 ^oC indicates the presences of chlorite. It might be due to the degradation of illite and / or due to the transformation of primary minerals present in the parent material. Chlorites have peaks at 14.0 A^o-14.4 A^o, depending on the individual species. Peak positions are unchanged by ion saturation, salvation with ethylene glycol or heating. The other identified clay minerals were kaolinite, quartz and feldspars. The presence of kaolinite might be due to weather of feldspars or mica by chemical process. The identified minerals are in agreement with the findings of Gupta *et al.*(1986 and 1990). Kumar *et al.* (2000), Mall and Mishra (2000), Singh and Tomar (1993), Najar (2002), Srinivasa *et al.* (2004) and Gupta *et al.* (2009)

5.3 Physico-chemical characteristics and nutrient status of soils

5.3.1 Physio-chemical characteristics

5.3.1.1 Mechanical components/particle size distribution

The contents of coarse sand ranged from 1.24 - 2.40, 1.50 - 4.10, 1.50 - 2.90 and 2.10 - 4.10 per cent in the north, south, near level and very gentle sloping areas. The coarse fractions of sand were predominant in sloping areas as compared to near level level lands. The fine sand fractions varied from 21.60-48.50, 9.50-32.60, 21.60-48.50 and 9.50-36.40 in north, south, very gentle sloping and near level areas, respectively. The contents of fine sand fractions of soils were higher in northern aspect with very gentle sloping topography than southern areas with near level topography. The contents of silt in composite soil samples ranged from 29.70-54.50 and 42.10-68.60 in north and south facing pedons, respectively. The contents of silt were higher in southern aspect (0-1%) drawn soil samples than in northern aspect (1-3%). The contents of clay varied from 20.60-23.50, 15.40-27.70, 15.40-27.70 and 230.20-27.20 in souths, north, near level and very gentle sloping areas, respectively. The contents of clay were higher in soil samples drawn from northern aspect with near level topography.

In general, the textures were loam, silt loam and clay loam, respectively. The texture in north facing soils was finer than in soils facing south. Similarly, the texture on near level topography was also finer than on sloping areas. This might be attributed to presence of suitable conditions for weathering in northern aspect / near level topography than southern aspect/ sloping topography. Similar results were reported by Ganai *et al.* (2000), Kirmani (2004) and Najar *et al.* (2009).

5.3.1.2 Soil reaction

The pH of the soil was found to range from slightly acidic to moderately alkaline (6.7 to 7.7). The pH on southern aspect was moderately alkaline. Where as, it was slightly acidic to slightly alkaline in northern aspect. This could be attributed to higher amount of organic matter in northern aspect and its subsequent decomposition to release acids. The results are in agreement with the findings of Jalali *et al.* (1989) and Najar (2002).

5.3.1.3 Electrical conductivity

The electrical conductivity ranged from 0.04-0.22, 0.11-0.17, 0.04-0.17 and 0.12-0.22 dsm^{-1} in north, south, near level and very gentle sloping areas, respectively. Electrical conductivity showed little variation in southern aspect than north. However, irrespective of the aspect and topography, the concentration of soluble solutes was with in normal range. The results corroborate the findings of Kirmani (2004) and Bhat (2007).

5.3.1.4 Organic carbon

The organic carbon content was found in the higher range and varied from 14.80-17.40, 11.40-19.20, 14.20-19.20 and 11.40-12.50 in south, north, near level and the very gentle sloping areas, respectively. The higher contents of organic carbon were generally found in composite samples drawn from areas facing northern aspects than south facing locations. This might be due to the effect of the aspect on the plant growth and soil moisture and temperature conditions that in turn affect the organic carbon content in the soil. The results are in unison with the findings of Mushki (1994), Farida (1997) and Najar *et al.* (2009).

5.3.1.5 Calcium carbonate

The calcium carbonate was absent from the top plough layer that was taken for the nutrient indexing. The results confirm the findings of Kirmani (2004).

5.3.1.6 Cation exchange capacity

The cation exchange capacity varied in the range of 11.35-15.32, 12.31-14.87, 11.40-12.50 and 14.20-19.20 $cmol_c\ kg^{-1}$soil in north, south, very gentle sloping and near level topography, respectively. The cation exchange capacity was found to be influenced by the aspect, altitude and the slope of the location. The areas facing north with near level topography showed higher cation-exchange capacity than south facing areas with sloping topography. This is in consequence with the variation in the soil organic carbon and the mineralogical build up of the soil (Verma *et al.*, 2008 and Najar *et al.* 2009).

5.3.1.7 Exchangeable cations and Base saturation

The dominant cation in the exchange complex was Ca^{2+} followed by Mg^{2+} and K^{+} respectively. The exchangeable calcium in composite samples varied from 6.17-8.64, 6.94-8.61, 6.17-8.64 and 6.72-7.82 in north, south, near level and very gentle sloping areas, respectively. The exchangeable calcium was more on northern side with level topography than on southern aspect. Similar trend was observed with exchangeable Mg^{2+}. However, exchangeable K^{+} did not show any trend particular to any aspect or topography. The dominance of calcium (Ca^{2+}) in the exchangeable complex was due to the calcareous nature of the parent material (Verma *et al.*, 1990; Mushki, 1994; Katoo 2001 and Najar *et al.*, 2009).

The base saturation was found in higher range and varied from 70.31-90.15, 77.42-82.89, 70.31-90.15 and 74.75-80.64 per cent in composite soil samples drawn from north, south, near level and very gentle topography, respectively. It did not depict any relation with aspect but was more on level topography than sloping one. It might be in consequence to the presence of basic cations, clay and organic carbon content in the soil. The results are in corroboration with the findings of Kirmani (2004); Rao *et al.* (2008) and Najar (2009).

5.3.2 Nutrient status of soils

5.3.2.1 Available nitrogen (N), phosphorus (P) and Potassium (K)

5.3.2.1.1 Available nitrogen (N)

The available nitrogen content of the composite soil samples drawn from north, south, near level and very gentle sloping areas, varied in the range of 270.1-376.3, 290.5-367.2, 285.8-376.3 and 270.2-276.8, respectively. The available nitrogen in northern aspect was more than in southern aspect. The nitrogen availability was found to vary between lower to medium range in composite samples from areas on near level topography irrespective of the aspect. However, nitrogen was in lower range in samples drawn from locations on very gentle topography. These variations might be attributed to the climatic, topographical and altitudinal conditions favouring the accumulation of soil organic carbon, which is the index of fertility. Similar results were reported by Mushki (1994) and Najar (2002).

5.3.2.1.2 Available phosphorus (P_2O_5)

The available phosphorus was found in deficient range of availability with mean value of 11.8 kg ha^{-1} irrespective of aspect and topography. This might be attributed to calcareous nature of the soil and alkaline soil reaction that enjoys a negative relationship with phosphorus availability and retention. The results get supports in the findings of Wani (1994); Najar (2002) and Rao *et al.* (2008).

5.3.2.1.3 Available potassium (K_2O)

The available potassium doesn't exhibit any pattern or relationship with any aspect or topography. How ever, it depends largely on the dominant clay mineralogy of the area from which soil is taken. In present study available potassium ranged from 255.60-324.80 and 162.40-352.70 in composite soil samples from southern and northern aspect, respectively. The results are in conformity with the findings of Wani (1994); Farida (1997); Najar (2002) and Roa *et al.* (2008).

5.3.2.2 Micro-nutrient cation distribution

The DTPA-extractable micro-nutrients viz., zinc, copper, iron and manganese varied in their horizontal distribution with respect to aspect and the slope gradient. The contents of zinc in samples drawn from north, south, near level and very gentle sloping topographical units ranged from 1.04 - 2.63, 1.57-1.94, 1.57-2.63 and 1.04-1.31 ppm, respectively. The content of DTPA- extractable copper varied from 0.81-2.92, 1.18-1.42, 1.18-2.92 and 0.81-1.77 ppm, respectively. The contents of DTPA- extractable Zn and Cu were higher in northern aspect with near level slope drawn soil samples as compared to southern aspect/sloping topography.

The contents of DTPA-extractable iron (Fe) and manganese (Mn) ranged from 7.09-12.47 and 15.24-26.21, 9.72-11.02 and 23.67-25.51, 7.09-

9.01 and 15.24-19.21 and 9.72-12.47 and 22.16-26.21 ppm, respectively. In composite soil samples drawn from north, south, very gentle sloping and near level topographical areas. These micronutrients (Fe and Mn) contents were more in northern aspect with near level topography. The decrease in available zinc with the rise in soil pH be due to the conversion of Zn ions into negatively charged zincate ions and insoluble zinc hydroxide (Singh, 1987). The positive significant relationship of organic carbon with available zinc, copper, iron and manganese might be due to the release of these elements (ions) from organic complexes and also due to acidulating action of organic matter on minerals that contain these nutrients (Follet and Lindsay, 1970). Similar results were reported by Jalali *et al.* (1989); Ganai *et al.* (1999); Kirmani (2004); Sood *et al.* (2009) and Somasundaram (2009).

5.4 Relationship between physico-chemical properties and available nutrients

Nitrogen and phosphorus showed positive and significant correlation with organic carbon. Negative and significant correlation was observed between nitrogen and phosphorus with soil pH. Nitrogen and phosphorus were positively correlated with each other. Micronutrients viz. zinc, copper, iron and manganese showed significant positive correlation with organic carbon. However, these nutrients (Zn, Fe and Mn) exhibited negatively significant correlation with soil pH.

The distribution or availability of nitrogen and phosphorus is greatly affected by the soil organic matter and the presence or absence of basic cations in the soil. Similar results were reported by Sharma and Bhandari (1992) and Najar *et al.* (2005). Soil organic carbon through its chelating effect helps micro-nutrients to retain their availability in the soil by preventing their leaching losses. Soil pH having negative influence on micro-nutrient availability might be attributed to the formulation of complexes, which render them unavailable for plant uptake. The results obtained are in conformity with the findings of Singh *et al.* (1988); Mushki (1994); Wani (1994); Najar *et al.* (2005) and Sood *et al.* (2009).

5.5 Soil classification

Based on the morphological and physico-chemical characteristics, the soils have been classified according to the U.S. Comprehensive System of Soil Classification by following 'Keys to Soil Taxonomy' (Soil Survey Staff, 1998), Soil Taxonomy (Soil Survey Staff, 1999) and Soil Survey Manual (Soil Survey Staff, 2003) (Table 13).

The soil profiles in southern aspect with near level topography viz., P_1 to P_5 were classified as Inceptisols due to the presence of the cambic B (subsurface) horizon. The presence of Ochric epipedon (surface) horizon, qualify them to be placed under sub order Ochrepts and at great group level as Eutrochrepts. The soil profilesin the northern aspect with very gentle sloping topography (1-3 %) are classified as Entisols, as these donot show proper profile development. The occurance of Ochric epipedon in these soils and the texture in some of the horizons below Ap layer was sandy loam accompanied with decrease in organic carbon as depth increased reaching a value that key outs the pedon in suborder as Orthents and at great group level as Udorthents due to the presence of udic moisture regime. The soil profiles P_6 – P_7 and P_{13}-P_{15} in the northern aspect with near level topography were classified under Alfisols. Due to the presence of udic moisture regime, the soils qualified for suborder Udalfs. Owing to the

Table 13: Classification of saffron growing soils of District Pulwama

Profile No.	Aspect	Topography	Diagnostic horizon		Order	Sub-order	Great group
			Surface	Sub-surface			
P_1-P_5	Southern	Near level	Ochric	Cambic	Inceptisol	Ochrepts	Eutrochrepts
P_8-P_{12}	Northern	Very gentle sloping	Ochric	-	Entisol	Orthents	Udorthents
P_6-P_7 & P_{13}-P_{15}	Northern	Near level	Ochric	Argillic	Alfisol	Udalfs	Hapludalfs

presence of well developed argillic (Bt) subsurface horizon in exess to Ochric epipedon, qualifies these soils to be classified at great group level as Hapludalfs, respectively. Similar findings were reported by Walia and Rao. (1996), Rao *et al.*(1997), Mahapatra *et al* (2000), Najar (2002), Ahmad (2003) and Kirmani (2004) and Chaudhary *et al.* (2005).

5.6 Nutrient indexing

For getting the nutrient index value (NIV) of the primary macronutrients N, P and K, 5-samples were taken from each location and were categorized after due laboratory analysis into low, medium and high soil fertility class by comparing the observed values of available nutrients with recommended level rating chart of available nutrients (Muhr *et al.* 1965). Nutrient index value was then worked out for each nutrient using the formula proposed by Biswas and Mukherjee (1989). The formula is;

$$NIV = \frac{N_L 1 + 2\,N_M + 3\,N_H}{N_L + N_M + N_H}$$

Where;

N_L = number of samples in low class

N_M = number of samples in medium class

N_H = number of samples in high class

The subsequent evaluation showed that soils are low in phosphorus in majority of the locations, medium in nitrogen and medium to high in potassium, respectively. The over all NIV for the nitrogen, phosphorus and potassium was 1.91, 1.29 and 2.33, respectively. This is attributed to fixation of phosphorus in the soil and its subsequent retention. Similar results were reported by Wani (1994), Najar (2002) and Singh and Bansal (2009).

CHAPTER – 6

SUMMARY AND CONCLUSION

The investigation entitled, "Characterization, Classification and Nutrient indexing of Saffron growing soils of district pulwama" was undertaken to characterize and classify these soils and to evaluate their nutrient status. In order to achieve these objectives, 15 - profiles were studied based on the variation in apparent soil colour, aspect and topography. The morphological, physico-chemical, mineralogical and nutrient status of these selected profiles and composite samples are summed as follows;

6.1 Morphological properties

In general, the colour of soil varied from brown/dark brown/dark yellowish brown/pale brown to brown/dark brown/dark yellowish brown/light yellowish brown/dark greyish brown/yellowish brown from surface to the subsurface horizons in the southern aspect and from dark brown/very dark brown/dark yellowish brown to dark yellowish brown/yellowish brown/brown/dark greyish brown/very dark grey in the northern aspect. In general, profile colour in northern aspect was darker than in profiles from southern aspect. The texture in south facing pedons changed from loam/silt loam to silty clay loam/clay loam where as, in north facing pedons it changed from loam/silt loam to clay loam/sandy loam. In profile P_{15}, it remained clay loam through out the depth. The structure of north facing pedons changed from fine, weak/medium granular/ medium/coarse moderate angular blocky to subangular blocky. Where as, on south facing pedons it changed from weak to moderate angular/sub angular blocky. The consistency changed from hard/slightly hard (dry), friable/very friable (moist), sticky and plastic(wet) in Ap horizon to hard (dry), firm/very firm (moist) and very sticky and very plastic (wet) in B_t horizon in northern aspect. In southern aspect, it changed from hard hard/slightly hard (dry), friable/very friable, slight sticky and non –plastic (wet) in Ap horizon to hard (dry), firm (moist) and sticky and plastic(wet) in B-horizon. In profiles were C-horizon was observed, it changed from hard/slightly hard (dry), friable (moist), slightly sticky and non-plastic (wet) to hard (dry), firm (moist) and sticky and plastic (wet). Clay cutans were evident only on profiles facing northern aspect with near level topography. On southern as well as on northern aspect, only lower horizons showed effervescence, which was strong to violent, indicating the calcareous nature of parent material.

6.2 Physico-chemical properties

The physico-chemical characteristics confirmed the texture variations observed in the studied areas from both the aspects and the topography. The pH varied from being slightly acidic to alkaline in northern aspect and slightly alkaline to alkaline in southern aspect. Electrical conductivity was with in normal range from both the aspects. However, it was more in subsurface than surface horizons in both the aspects. Organic carbon content was found higher in the northern aspect facing soil pedons than the south facing pedons. It decreased with the increase in the depth of the soil profile in both the aspects.

Calcium carbonate was not found in the surface horizons of any of the studied soil profile irrespective of the aspect and topography. However, it was observed in lower horizons only to the extent of traces to 7 per cent and its content increased with depth in general. It was also found higher in profiles facing north than south facing pedons. Cation exchange capacity of north and south facing soil profiles varied from 11.28 to 15.61 and 12.16 to 14.81 $cmol_c$ kg^{-1} soil in the surface horizons and 9.40 to 18.50 and 14.21 to 18.29 $cmol_c$ kg^{-1} soil in the subsurface horizons. The cation exchange capacity of soil was higher in lower horizons than the epipedons. The soil exchange complex was dominated by exchangeable Ca^{2+} followed by Mg^{2+}

and K^+, respectively. The base saturation on average basis was higher in the surface than subsurface horizons in both the aspects irrespective of the topography.

6.3 **Clay mineralogy**

X-ray diffraction studies of the subsurface clay revealed dominance of illite followed by mixed layers, inter layered vermiculite, smectite, chlorite, kaolinite and some amount of quartz and feldspar.

6.4 Soil classification

On the basis of 'Keys to Soil Taxonomy' (Soil Survey Staff, 1998) and 'Soil Taxonomy' (Soil Survey Staff, 1999), the studied profiles were placed in the orders of Inceptisols, Entisols and the Alfisols, respectively. The Suborders and the great groups to which these soils were further classified are Ochrepts, Orthents and Udalfs and Eutrochrepts, Udorthents and Hapludalfs, respectively, on the basis of presence of diagnostic surface and subsurface horizons, profile development and the presence of particular moisture and temperature regime.

6.5 Physico-chemical properties and nutrient/fertility status of soils

6.5.1 Physico-chemical characteristics (Composite Samples)

Mechanical analysis of composite samples revealed that the texture in northern aspect facing soils was finer than southern aspect facing soils.

The texture varied from loam/silt loam to clay loam. The pH of composite soil samples drawn from southern locations was slightly to moderately alkaline. Where as, in case of soil samples drawn from northern aspect, it was slightly acidic to slightly alkaline in nature. The electrical conductivity was with in the normal range. Organic carbon content was found higher in northern aspect drawn composite soil samples than the southern aspect. Calcium carbonate was absent from the top plough layer that was taken for sampling. The cation exchange capacity was more in soil samples from northern aspect with near level topography. The exchangeable calcium dominated the exchange complex of all soils, followed by exchangeable magnesium and potassium, respectively. The base saturation was also found higher in samples from the northern aspect with near level topography than northern aspect with gentle sloping topography and the southern aspect.

6.5.2 Nutrient status/fertility class of soils

The available contents of nitrogen, phosphorus and potassium was found low to medium, low and medium to high, respectively. The amount of nitrogen, phosphorus and potassium was more in composite soil samples drawn from locations in northern aspect with near level topography than in southern aspect.

All the micronutrients were found in the sufficient range. However, higher amounts of these nutrients were present in the composite soil samples from northern aspect with near level topography than southern aspect irrespective of the topography.

The correlation between available primary macronutrients (N, P and K) and some micronutrient cations (Zn, Cu, Fe and Mn) with some physicochemical properties were also worked out. Nitrogen phosphorus and potassium showed positive significant correlation coefficients with organic carbon. However, the correlation coefficients of nitrogen and phosphorus with soil pH were negatively significant. Among the micronutrients Zn, Fe and Mn exhibited significant positive correlation coefficients with organic carbon content in soil. The correlation coefficients of Zn, Fe and Mn with soil pH were although significant but negative.

6.6 Nutrient indexing/Nutrient index value

Analysis and subsequent evaluation of the collected soil samples revealed that the soils are medium in nitrogen, low in phosphorus and medium to high in potassium with over all nutrient index value (NIV) of 1.91, 1.29 and 2.33, respectively.

CONCLUSION

The research is concluded with the following observations:-

- The texture of the soils changed from silt loam to silty clay loam/clay loam with respect to depth. $CaCO_3$ was observed only on deep subsurface horizons, thus confirming the calcareous nature of the parent material.
- Clay Mineralogy of the soil pedons were dominated by illites followed by mixed layers, hydroxyl interlayered vermiculite, smectite, chlorite, kaolinite, quartz and feldspar.

The soils are classified as Eutrochrepts, Udorthents and Hapludalfs on the basis of variation observed in the occurrence of diagnostic horizons, profile development, moisture and temperature regimes.

- Soils in the exchange complex are dominated by exchangeable calcium followed by magnesium and potassium.
- Nutrients showed positive correlation coefficients with organic matter and cation exchange capacity. Thus the management of organic inputs is essential.
- The soils are found low to medium in nitrogen, medium to high in potassium, but are low in phosphorus. Thus management of

phosphorus along with the management of nitrogen and potassium holds key for higher saffron productivity.

The present investigation is expected to deliver at the front of agro-technology transfer from one area to other, as part of it deals with the formation of requisite resource inventory. The study although through some light on mineralogy and the nutrient indexing but cannot be constructed as final word, there fore can be used as a base for developing critical limits of nutrients for saffron crop and study of mineralogy in relation to nutrient dynamics particularly potassium. There is also need to study other macro and micronutrients that were not part of present investigation, to get a better feel of the nutrient dynamics in saffron growing soils of Kashmir.

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*Original not seen

APPENDIX – I

Morphological Characteristics of Soil profiles

Profile No.	:	P_1
Location	:	Alochibag
Elevation	:	1637
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Southern
Vegetation	:	Willow, kikar, almond, rose, shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Eutrochrepts

Horizon	Depth	Description
Ap	0-20	Brown (10YR 5/3), silt loam, medium moderate, Subangular blocky, hard (dry), moderately-friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
AB	20-50	Brown (10YR 5/3), silt loam, medium moderate, Subangular blocky, hard (dry), moderately-friable, slight sticky and plastic (wet), clear and smooth boundary and effervescence nil.
B_1	52-75	Dark brown (10YR 4/3), silt loam, medium-moderate, sub angular blocky, hard (dry), moderately-fine, sticky and plastic (wet), clear and smooth boundary and effervescence nil.
B_2	75-120	Dark greyish brown (10YR 5/3), silty clay loam, medium moderate, angular blocky, moderately-friable, sticky and plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_2
Location	:	Samboora
Elevation	:	1642
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Southern
Vegetation	:	Poplar, willow, wild fig, grasses and shrubs
Parent material	:	Lacustrine deposits
Classification	:	Eutrochrepts

Horizon	Depth	Description
Ap	0-20	Yellowish brown (10YR 5/4), loam, medium weak, subangular blocky, slightly hard (dry), moderately-friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
BW_1	20-35	Light yellowish brown (10YR 6/4), clay loam, medium moderate, Subangular blocky, hard (dry), moderately-friable, slight sticky and plastic (wet), clear and smooth boundary and effervescence nil.
BW_2	35-87	Yellowish dark brown (10YR 5/4), clay loam, medium-moderate, sub angular blocky, hard (dry), moderately-fine, sticky and plastic (wet), clear and smooth boundary and effervescence strong.
B_2	87-120	Dark greyish brown (10YR 4/3), silty clay loam, medium moderate, angular blocky, moderately-fine, sticky and plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_3
Location	:	Borus
Elevation	:	1644
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Southern
Vegetation	:	Willow, poplar, fig, rose, bushes and shrubs
Parent material	:	Lacustrine deposits
Classification	:	Eutrochrepts

Horizon	Depth	Description
Ap	0-25	Yellowish brown (10YR 5/6), loam, medium weak, subangular blocky, slightly hard (dry), friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
AB	25-54	Yellowish brown (10YR 5/6), clay loam, medium weak, angular blocky, hard (dry), friable, slight non-sticky and non-plastic (wet), clear and smooth boundary and effervescence nil.
BW_1	54-85	Yellowish dark brown (10YR 4/3), clay loam, medium-moderate, angular blocky, hard (dry), fine, slightly sticky and plastic (wet), gradual and smooth boundary and effervescence slight.
BW_2	85-120	Dark brown (10YR 6/3), clay loam, medium moderate, angular blocky, fine, sticky and plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_4
Location	:	Lethpora
Elevation	:	1632
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Southern
Vegetation	:	Willow, poplar, fig, poppy rose, bushes and shrubs
Parent material	:	Lacustrine deposits
Classification	:	Eutrochrepts

Horizon	Depth	Description
Ap	0-20	Pale brown (10YR 6/3), silt loam, medium weak, Subangular blocky, hard (dry), moderately-friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
BA	20-54	Brown (10YR 5/3), silt loam, medium moderate, Subangular blocky, hard (dry), friable, slight sticky and plastic (wet), diffused and wavy boundary and effervescence slight.
B_1	54-89	Yellowish dark brown (10YR 5/4), silt clay loam, medium-moderate, sub angular blocky, fine, sticky and plastic (wet), clear and smooth boundary and effervescence strong.
B_2	89-120	Dark greyish brown (10YR 4/2), clay loam, medium moderate, angular blocky, very fine, sticky and plastic (wet) and violent effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_5
Location	:	Chandhore
Elevation	:	1643
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Southern
Vegetation	:	Willow, poplar, fig, poppy, rose, bushes and shrubs
Parent material	:	Lacustrine deposits
Classification	:	Eutrochrepts

Horizon	Depth	Description
Ap	0-22	Brown (10YR 5/3), silt loam, medium moderate, Subangular blocky, hard (dry), moderately-friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
AB	32-52	Brown (10YR 5/3), silt loam, medium moderate, Subangular blocky, friable, non-sticky and non-plastic (wet), clear and smooth boundary and effervescence nil.
B_1	52-88	Yellowish dark brown (10YR 5/4), clay loam, medium-moderate, sub angular blocky, slightly sticky and slight plastic (wet), gradual and smooth boundary and effervescence nil.
B_2	75-120	Dark greyish brown (10YR 4/2), clay loam, medium moderate, subangular blocky, fine, sticky and plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_6
Location	:	Konibal
Elevation	:	1661
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Northern
Vegetation	:	Willow, poplar, almond, rose, bushes and shrubs
Parent material	:	Lacustrine deposits
Classification	:	Hapludalfs

Horizon	Depth	Description
Ap	0-15	Dark brown (10YR 3/4), loam, medium moderate, granular, slightly hard (dry), friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
BW	15-35	Dark yellowish brown (10YR 3/4), silt loam, medium moderate, angular blocky, hard (dry), fine, non-sticky and non-plastic (wet), gradual and smooth boundary and effervescence nil.
Bt_1	35-87	Light yellowish dark brown (10YR 6/4), clay loam, medium-moderate, sub angular blocky, fine, sticky and plastic (wet), clear and wavy boundary and effervescence nil.
Bt_2	87-120	Very dark greyish (10YR 3/2), clay loam, medium weak, subangular blocky, very fine, very sticky and very plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_7
Location	:	Gundibal
Elevation	:	1632
Slope (%)	:	0-1
Topography	:	Nearly level
Aspect	:	Northern
Vegetation	:	Willow, kikar, fig, mulberry, rose and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Hapludafs

Horizon	Depth	Description
Ap	0-17	Dark brown (10YR 4/3), clay loam, medium weak, Subangular blocky, slightly hard (dry), friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
B	17-40	Dark yellowish brown (10YR 4/4), clay loam, medium moderate, subangular blocky, hard (dry), fine, slight sticky and less plastic (wet), gradual and wavy boundary and effervescence nil.
Bt_1	40-87	Dark yellowish brown (10YR 4/3), clay loam, coarse weak, angular blocky, fine, sticky and plastic (wet), gradual and wavy boundary and effervescence nil.
Bt_2	87-120	Dark greyish brown (10YR 4/2), clay loam, medium weak, subangular blocky, very fine, sticky and plastic (wet) and violent effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_8
Location	:	Ladoo
Elevation	:	1648
Slope (%)	:	1-3
Topography	:	Very gentle sloping
Aspect	:	Northern
Vegetation	:	Willow, kikar, almond, poplar, rose and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Udorthents

Horizon	Depth	Description
Ap	0-15	Brown (10YR 5/3), loam, coarse moderate, angular blocky, hard (dry), fine, slight sticky and less plastic (wet), clear and smooth boundary and effervescence nil.
A	15-37	Light grayish brown (10YR 6/2), clay loam, moderate, Subangular blocky, very fine, sticky and plastic (wet), gradual and smooth boundary and effervescence nil.
C_1	37-85	Light grayish brown (10YR 6/2), silt loam, fine weak, sub angular blocky, non-sticky and non-plastic (wet), gradual and smooth boundary and strong effervescence.
C_2	85-120	Pale brown (10YR 6/3), loam, coarse moderate, subangular blocky, friable, non-sticky and non-plastic (wet) and violent effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_9
Location	:	Shar
Elevation	:	1672
Slope (%)	:	1-3
Topography	:	Very gentle sloping
Aspect	:	Northern
Vegetation	:	Willow, kikar, poplar, almond, rose, maize, linseed and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Udorthents

Horizon	Depth	Description
Ap	0-20	Brown (10YR 5/3), silt loam, medium weak, angular blocky, hard (dry), friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
AC	20-55	Dark grayish brown (10YR 4/2), silt loam, medium moderate, Subangular blocky, hard (dry), friable, non-sticky and non-plastic (wet), clear and smooth boundary and effervescence nil.
C_1	55-90	Dark grayish (10YR 4/1), clay loam, medium-weak, angular blocky, hard (dry), fine slight, sticky and less plastic (wet), diffused and irregular boundary and effervescence slight.
C_2	90-120	Very dark greyish (10YR 3/1), sandy loam, medium moderate, angular blocky, friable, non-sticky and non-plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_{10}
Location	:	Khrew
Elevation	:	1652
Slope (%)	:	1-3
Topography	:	Very gentle sloping
Aspect	:	Northern
Vegetation	:	Willow, kikar, almond, rose and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	udorthents

Horizon	Depth	Description
Ap	0-20	Dark brown (10YR 4/3), silt loam, medium weak, granular, hard (dry), friable, non sticky and non plastic (wet), diffused and smooth boundary and effervescence nil.
C_1	20-47	Dark yellowish brown (10YR 4/4), sandy loam, medium moderate, subangular blocky, hard (dry), fine, slight sticky and less plastic (wet), diffused and smooth boundary and effervescence nil.
C_1	47-82	Dark yellowish brown (10YR 4/4), sandy loam, medium-moderate, sub angular blocky, hard (dry), fine, slight sticky and less plastic (wet), diffused and smooth boundary and effervescence slight.
C_3	82-120	Dark yellowish brown (10YR 5/3), sandy clay loam, medium moderate, angular blocky, friable, non-sticky and non-plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_{11}
Location	:	Balhama
Elevation	:	1617
Slope (%)	:	1-3
Topography	:	Very gentle sloping
Aspect	:	Northern
Vegetation	:	Willow, kikar, almond, rose and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Udorthents

Horizon	Depth	Description
Ap	0-15	Dark yellowish brown (10YR 4/4), clay loam, fine weak, subangular blocky, hard (dry), friable, slight sticky and less plastic (wet), gradual and smooth boundary and effervescence nil.
C_1	15-42	Grayish brown (10YR 5/2), loam, medium moderate, subangular blocky, slightly hard (dry), fine, non-sticky and non-plastic (wet), gradual and smooth boundary and effervescence slight.
C_2	42-90	Dark brown (10YR 4/3), silt loam, medium-moderate, subangular blocky, fine, slight sticky and less plastic (wet), gradual and smooth boundary and strong effervescence.
C_3	90-120	Yellowish brown (10YR 5/6), loam, medium moderate, sub-angular blocky, fine, slight sticky and plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_{12}
Location	:	Mueej
Elevation	:	1616
Slope (%)	:	1-3
Topography	:	Nearly level
Aspect	:	Northern
Vegetation	:	Willow, kikar, almond, rose and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Udorthents

Horizon	Depth	Description
Ap	0-15	Yellowish brown (10YR 5/4), silt loam, fine weak, subangular blocky, hard (dry), friable, non sticky and non plastic (wet), clear and smooth boundary and effervescence nil.
AC	15-35	Dark yellowish brown (10YR 3/4), clay loam, medium weak, subangular blocky, hard (dry), fine, slight sticky and plastic (wet), clear and smooth boundary and effervescence very slight.
C_1	35-87	Greyish dark brown (10YR 5/2), clay loam, medium-weak, subangular blocky, very fine, sticky and plastic (wet), gradual and irregular boundary and effervescence very slight.
C_2	87-120	Brownish grey (10YR 6/2), silt loam, medium weak, subangular blocky, fine, slight sticky and less plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_{13}
Location	:	Munipur
Elevation	:	1634
Slope (%)	:	0-1
Topography	:	Near level
Aspect	:	Northern
Vegetation	:	Willow, kikar, poplar, almond, rose, wild fig, mulberry and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Hapludalfs

Horizon	Depth	Description
Ap	0-28	Very dark brown (10YR 3/2), loam, fine weak moderate, granular, slightly hard (dry), friable, slight sticky and less plastic (wet), clear and smooth boundary and effervescence nil.
BW	28-72	Dark yellowish brown (10YR 4/4), clay loam, medium moderate, subangular blocky, hard (dry), friable, slight sticky and less plastic (wet), gradual and irregular boundary and effervescence nil.
Bt_1	72-95	Yellowish brown (10YR 5/4), silt loam, medium-moderate, sub angular blocky, gradual and irregular boundary and effervescence nil.
Bt_2	95-120	Brown (10YR 5/3), clay loam, medium moderate, subangular blocky, fine, sticky and plastic (wet) and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_{14}
Location	:	Alochibag
Elevation	:	1623
Slope (%)	:	0-1
Topography	:	Near level
Aspect	:	Northern
Vegetation	:	Willow, kikar, almond, poplar, pear, wild fid, mulberry, chest nut, rose and shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Hapludalfs

Horizon	Depth	Description
Ap	0-17	Dark yellowish brown (10YR 4/4), loam, fine weak, angular blocky, slightly hard (dry), very friable, non-sticky and non-plastic (wet), gradual and smooth boundary and effervescence nil.
BA	17-45	Dark yellowish brown (10YR 3/4), clay loam, medium moderate, angular blocky, hard (dry), friable, non-sticky and non-plastic (wet), gradual and irregular boundary and effervescence nil.
Bt_1	45-86	Yellowish dark brown (10YR 5/4), clay loam, coarse moderate, angular blocky, fine, slightl sticky and less plastic (wet), clear and wavy boundary and effervescence slight.
Bt_2	86-120	Pale brown (10YR 6/3), clay loam, coarse moderate, angular blocky, fine, sticky and plastic (wet), clear and wavy boundary and strong effervescence.

Morphological Characteristics of Soil profiles

Profile No.	:	P_{15}
Location	:	Sempur
Elevation	:	1582
Slope (%)	:	0-1
Topography	:	Near level
Aspect	:	Northern
Vegetation	:	Willow, kikar, almond, rose, poplar, pear, wild fig, mulberry, chest nut and other shrubs and grasses
Parent material	:	Lacustrine deposits
Classification	:	Hapludalfs

Horizon	Depth	Description
Ap	0-15	Very dark brown (10YR 3/2), clay loam, fine weak, subangular blocky, hard (dry), friable, non- sticky and non-plastic (wet), gradual and smooth boundary and effervescence nil.
AB	15-48	Brown (10YR 4/3), clay loam, medium moderate, Subangular blocky, hard (dry), fine, slight sticky and less plastic (wet), gradual and smooth boundary and effervescence nil.
Bt_1	48-85	Yellowish brown (10YR 5/3), clay loam, coarse moderate, angular blocky, hard (dry), very fine, sticky and plastic (wet), gradual and smooth boundary and effervescence nil.
Bt_2	85-120	Light yellowish brown (10YR 6/4), clay loam, coarse moderate, angular blocky, moderately-friable, sticky and plastic (wet) and strong effervescence.

APPENDIX – II

X-RAY DIFFRACTION 2 θ D SPACING – CONVERSION TABLE

2 θ d spacing values for Cu Ka Radiation with λ = 1.5404 A (0.1540 nm)

2θ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	-	882.630	441.320	294.210	220.660	176.530	147.110	126.090	110.330	98.080
1	88.263	80.245	73.555	67.897	63.047	58.845	55.167	51.922	49.038	46.457
2	44.135	42.033	40.122	38.378	36.779	35.308	33.950	32.693	31.526	30.440
3	29.425	28.476	27.587	26.751	25.964	25.223	24.522	23.859	23.232	22.636
4	22.071	21.532	21.020	20.531	20.065	19.619	19.193	18.785	18.394	18.018
5	17.659	17.312	16.979	16.660	16.352	16.054	15.768	15.491	15.225	14.967
6	14.717	14.476	14.243	14.017	13.798	13.586	13.381	13.181	12.988	12.800
7	12.617	12.440	12.267	12.099	11.936	11.777	11.622	11.471	11.325	11.182
8	11.042	10.906	10.773	10.644	10.517	10.394	10.273	10.155	10.040	9.927
9	9.817	9.710	9.604	9.501	9.400	9.302	9.205	9.111	9.017	8.926
10	8.838	8.750	8.665	8.551	8.499	8.418	8.339	8.261	8.185	8.110
11	8.036	7.964	7.894	7.823	7.755	7.688	7.622	7.557	7.493	7.431
12	7.369	7.308	7.248	7.190	7.132	7.075	7.019	6.964	6.910	6.857
13	6.804	6.752	6.702	6.651	6.602	6.553	6.505	6.455	6.411	6.336
14	6.320	6.276	6.232	6.188	6.146	6.104	6.062	6.021	5.983	5.941
15	5.901	5.862	5.824	5.786	5.749	5.712	5.676	5.640	5.604	5.569
16	5.35	5.500	5.467	5.433	5.400	3.368	6.336	5.304	5.273	5.242
17	5.211	5.181	5.151	5.121	5.092	3.063	5.035	5.006	4.979	4.951
18	4.924	4.897	4.870	4.844	4.817	4.792	4.766	4.741	4.716	4.691
19	4.667	4.643	4.619	4.595	4.572	4.548	4.525	4.503	4.480	4.458
20	4.436	4.414	4.392	4.371	4.349	4.329	4.308	4.287	4.267	4.247
21	4.227	4.207	4.187	4.168	4.149	4.130	4.111	4.092	4.073	4.055
22	4.037	4.019	4.000	3.983	3.966	3.948	3.931	3.914	3.897	3.880
23	3.864	3.847	3.831	3.814	3.798	3.782	3.767	3.751	3.735	3.720
24	3.705	3.689	3.675	3.659	3.645	3.630	3.616	3.601	3.587	3.573
25	3.559	3.545	3.531	3.517	3.504	3.490	3.477	3.463	3.450	3.437
26	3.424	3.411	3.398	3.386	3.373	3.361	3.348	3.336	3.324	3.312
27	3.299	3.288	3.276	3.264	3.252	3.241	3.229	3.218	3.206	3.195
28	3.184	3.173	3.162	3.151	3.139	3.129	3.118	3.108	3.098	3.087
29	3.076	3.066	3.056	3.046	3.035	3.025	3.015	3.005	2.996	2.986
30	2.976	2.966	2.957	2.947	2.938	2.928	2.919	2.910	2.901	2.891
31	2.882	2.873	2.864	2.855	2.847	2.838	2.829	2.820	2.812	2.803
32	2.795	2.786	2.778	2.769	2.761	2.753	2.744	2.736	2.728	2.720
33	2.712	2.704	2.696	2.688	2.680	2.673	2.665	2.657	2.650	2.642
34	2.635	2.627	2.620	2.612	2.604	2.597	2.590	2.583	2.576	2.569
35	2.562	2.554	2.547	2.540	2.533	2.530	2.520	2.513	2.506	2.499
36	2.493	2.486	2.479	2.473	2.466	2.460	2.453	2.447	2.440	2.434
37	2.427	2.421	2.415	2.409	2.402	2.396	2.390	2..384	2.378	2.372
38	2.366	2.360	2.354	2.348	2.342	2.336	2.331	2.325	2.318	2.313
39	2.307	2.302	2.296	2.291	2.285	2.279	2.274	2.268	2.263	2.257