<u>*Original Research Article*</u>

Characterization and Classification of High Density Apple Orchard Soils of North Kashmir

Abstract

Jammu & Kashmir presents a benefit for the economy of India, since is the rich producer of fruits and vegetables and is the most important temperate fruit producing state. Apple is the oldest and commercially the most important temperate fruit and is the fourth among the most widely produced fruit. Basic needs of life can be fulfilled by maintaining high productivity of soil and having the rational use of soil as per its potentiality in order to maintain sustainability. At the same time, the sustainable use of soil resource requires extensive knowledge regarding its genesis, morphology and other properties. Despite the importance of the area for producing quality apples, high density apple were planted in 2002. However no systematic study was undertaken so far with respect to soil characterization and classification of apple orchard soils under high density plantation. Keeping all this in view, the present investigation entitled, "Characterization and classification of High Density Apple Orchard Soils of North Kashmir" was undertaken . current paper aims to contribute to the existing challenge in soil research in India. To this end 45 soil profiles were observed in orchards,- Based on homogeneous properties, e.g., age, topography, rootstock, variety only 12 profiles were selected from 45 observed profiles (purposive method of sampling). These twelve profiles were categorized into high, mid and low altitudes for detailed investigation of the soil profile properties and to classify soils of the district as per Keys to Soil Taxonomy (2015). The excavated soil profiles were exposed to a depth of 120 cm and more for studying morphological and physico-chemical characteristics. As per the results, profiles of the study area were classified from ' moderately deep' to 'very deep. A slight strong effervescence with diluted HCl was observed both in surface and sub-surface horizons profile P_3, P_7 and P_{10} located especially in mid and low altitude. The pH were ranging between 6.60 to 8.10 in the surface horizons whereas in the sub surface horizons it ranged from 6.84 to 8.50 and showed an increasing trend with depth. The EC in general showed increasing trend with depth as compared to surface horizons and was found to be in normal range in both horizons. On the basis of the U.S. Comprehensive System of Soil Classification as per Keys to Soil Taxonomy (Soil Survey Staff, 2014) and Soil Survey Manual (Soil Survey Staff, 2003), studied profiles were placed in the orders of Mollisols, Alfisols, Inceptisols and Entisols and the suborders Udolls, Udalfs, Orchrepts and Orthents. The great groups to which these soils were further classified are Argiudolls, Hapludalfs,

Eutrochrepts and Udorthents respectively, on the basis of presence of the diagnostic surface and sub-surface horizons, profile development and the presence of particular moisture and temperature regime. However this study was first of its kind with an aim to evaluate the most probable path of plant nutrients added to soil. In this way, it can also support a better understanding of the soil genesis and the electro-chemical behavior. Besides, detailed study of clay mineralogy may provide a tool to classify the soils up to series level.

Keywords: HDP, Characterization, Kashmir, Temperate, Orchard, India

Introduction : The strategic geographical location of Jammu & Kashmir presents a benefit for the economy of India. Due to its geographical location, climate and soil type, Jammu and Kashmir is the producer of rich variety of fruits and vegetables and is the highest temperate fruit producing state of India (Farm-to-Fork, 2010). Apple is the oldest and commercially the most important temperate fruit and is the fourth among the most widely produced fruits in the world after orange, banana, and grape. China is the largest apple producer in the world. The total area under apple cultivation in J&K is 162971 ha with total production of 1726834 metric tons in an area of 18146 ha and production of 38421 metric tons in Jammu While as Kashmir is having an area of 144825 ha and 1688413 metric tons production (Anonymous, 2016-2017).From a historical perspective, a high density orchard is defined as any orchard with more than 150-180 trees per acre. Besides having an increased number of trees per acre, a high density orchard must come into bearing within 2-3 years after planting. With each tree yielding 18-19 kg high-quality apple, one hectare of land will produce 20-30 tons of fruit, which is a quantum jump over propagation of apples through traditional farming (10 tons per ha). This has allowed apple growers to achieve earlier and higher production and better fruit quality than previously.

The basic needs of life can be fulfilled by maintaining high productivity of soil and rational use of soil in order to maintain sustainability. The sustainable use of soil resources requires an extensive knowledge about its genesis, morphology and other properties. Studying of morphology and taxonomy of soils provides information on nature and type of soils, their constraints, potentials, capabilities and suitability for various needs (Sehgal, 1994). Besides also enables to make transfer from agro-technology easier among different locations belonging to the same agro ecological regions (Najar*et al.*, 2009). Several fruit orchards have been studied in Kashmir valley to characterize and evaluate the soils used for the cultivation of different fruit crops in order to identify the parameters that affect yield the most (Najar*et al.*, 2009). However there are some high density orchards and upland soils where the facts regarding soil genesis, origin and structure are still poorly understood. With this in mind, present paper aimed at filling existing gaps in soil studies of the north India.

Material and Methods

Keeping in view surface features, 45 soil profiles were observed (Fig. 1) in high density apple orchards at different locations of north Kashmir.

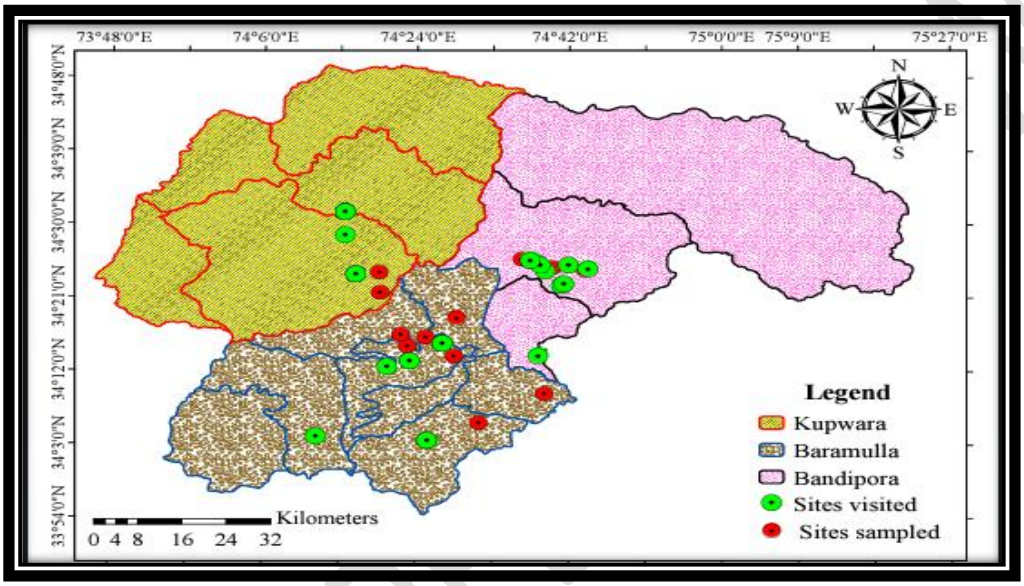

Fig. 1: Map showing observed sites under high density apple orchards of north Kashmir

Based on the uniformity like age, topography, rootstock and variety, only 12 profiles were selected from the total of 45 observed profiles following the principles of the purposive method of sampling. These twelve profiles were categorized into high, mid and low (High altitude (1800-2500m amsl), mid altitude (1665-1800m amsl), Low altitude (1500-1665 m amsl))altitudes for studying the soil profile in detail and to classify soils of these orchards located in the district as per Keys to Soil Taxonomy (2015). The locations selected for excavation of the profiles in high density apple orchards in three districts of north Kashmir district with their respective altitude, are shown below:

Chart 1 : Locations selected for excavation of the profiles in high density apple orchards of North Kashmir

S. No.	Orchard number	Location	Profile	Altitude (metre a.m.s.l)
	High altitude			
1.	H-1	SamblerBandipora	P_1	1864
	Mid altitude			
2.	M-1	KunzerBaramulla	P_2	1707
3.	M-2	ParihasporaBaramulla	P_3	1702
	Low altitude			
4.	L-1	UnagamBandipora	P_4	1592
5.	L-2	Upper KunanBandipora	P_5	1646
6.	L-3	LodderBaramulla	P_6	1583
7.	L-4	ChooruBaramulla	P_7	1598
8.	L-5	MazibugBaramulla	P_8	1586
9.	L-6	SoporeBaramulla	P_9	1624
10.	L-7	PandithporaKupwara	P_{10}	1597
11.	L-8	ChougulKupwara	P_{11}	1648
12.	L-9	Jalalabad Baramulla	P_{12}	1597

Site characteristics

The soil site description was observed following the standard proforma of soil site description of NBSS & LUP Soil Bulletin No. 23 (Sehgal, 1994). The site characteristics viz., latitude, longitude, slope, location, elevation, topography, slope, aspect, natural vegetation, etc. were recorded. The excavated soil profiles were exposed to a depth of 120 cm and more for studying the morphological and some physico-chemical characteristics described below.

Morphological characteristics

Soil horizon, boundary, depth, structure, texture, colour, consistency, cutans, roots, effervescence, concretions, mottling, plasticity etc. were recorded during the *in-situ* description for each horizon of the exposed profile, as per the procedure given in the Field Guide for Soil Survey (Natarajan and Sarkar, 2009).

Methods of laboratory analysis

The soil samples collected from different horizons of the studied soil profiles were processed in the laboratory:- air dried and grounded in a wooden pestle and mortar. Ambient soil was passed through 2 mm sieve to separate the coarse fragments and then subjected to the laboratory analysis.

1 Mechanical components (Particle Size Distribution)

The particle size analysis was worked out by the international pipette method as described by Piper (1966).

2 Physiochemical properties

2.1 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).

2.2 Electrical conductivity (EC)

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

2.3 Organic carbon (OC)

Organic carbon was determined by chromic acid wet digestion method as outlined by Wakley and Black (1934).

2.4 Calcium carbonate ($CaCO_3$)

Estimation of calcium carbonate was done by rapid titration method as described by Piper (1966).

2.5 Cation exchange capacity (CEC)

Cation exchange capacity was determined by Schollenberger and Simon (1945) method of leaching the soil with neutral normal ammonium acetate followed by determination of ammonical nitrogen.

2.6 Exchangeable cations

The exchangeable cations viz: calcium, magnesium, potassium, and sodium were extracted with neutral normal ammonium acetate. Potassium and sodium were determined by flame photometer, while calcium and magnesium were determined by versinate titration method suggested by Black (1965).

2.7 Base saturation percentage

$$\text{B S (\%)} = \frac{\text{Sum of exchangeable bases \{Cmol(p+) kg}^{-1}\text{\}}}{\text{CEC \{Cmol (p+) kg}^{-1}\text{\}}} \times 100$$

3. Soil taxonomical classification

Based on the morphological, physical and chemical properties the soils were classified up to sub group hierarchical level according to the U.S.

Comprehensive System of Soil Classification as per Keys to Soil Taxonomy (Soil Survey Staff, 2014) and Soil Survey Manual.

4. Statistical analysis

The data was statistically analysed following the standard procedures outlined by Gomez and Gomez (1984).the coefficient of correlation (r-values) between the different soil (physico-chemical properties, available nutrients) and plant (leaf and yield) parameters was estimated using statistical software 'SPSS'.

Chart 2 : Critical limits of the available nutrient elements in soils

Nutrient element	Unit	Soil fertility classes			Reference
		Low	Medium	High	
Organic carbon	%	<0.5	0.5-0.75	>0.75	Walkley and Black (1934)
Nitrogen	kg ha^{-1}	<125	125-544	>544	Subbiah and Asija (1956)
Phosphorus	kg ha^{-1}	<12	12-24	>24	Olsen *et al.* (1954)
Potassium	kg ha^{-1}	<125	125-280	>280	Hanway and Heidal (1952)
Calcium	ppm	<1000	>1000		
Magnesium	ppm				
Sulphur	ppm	<10	-	-	Kanwar and Mohan (1964)
Zinc	ppm	<0.6	0.6-1.2	>1.2	Takkar and Mann (1975)
Copper	ppm	<0.2	0.2-2.0	>2.0	Follet and Lindsay (1970)
Manganese	ppm	<1.0	1-2	>2	Follet and Lindsay (1970)
Iron	ppm	<4.5	-	-	Lindsay and Norvell (1978)
Boron	ppm	0.5-1.0	-	-	De-turk and Olsen (1941)

Results and Discussion

1 Morphological characteristics

The soil profiles of the study area were identified as 'moderately deep' to 'very deep'. The variation of the profile depths may be attributed to the variation in topography and slope gradient (Sitangang*et al.*, 2006). The degree and intensity of soil forming factors may be another reason for the development of such soils. The results are in agreement with the findings of Sitangang*et al.* (2006) and Naidu and Sireesha (2013).

The color of the soil in the surface horizons of low altitude profiles (P_4 to

P_{12}) varied from light yellow brown (10YR $^5/_3$)/ dark brown (10YR $^3/_3$) (10YR $^4/_3$) to dark yellowish brown (10YR $^3/_4$) (10YR $^4/_4$)/vary dark greyish brown (10YR $^3/_2$) (10YR $^3/_2$) while as in the profiles of mid altitude (P_2 and P_3) the colour of surface horizons varied from dark brown (10YR $^4/_3$) to dark greyish brown (10YR $^4/_2$) and high altitude soil profile (P_1) it was dark brown (10YR $^4/_3$). In the sub-surface horizons of low altitude soil profiles the colour varied from light yellowish brown (10YR $^5/_3$)/dark brown (10YR $^3/_3$) (10YR $^3/_4$) to dark yellowish brown (10YR $^4/_4$) (10YR $^4/_3$) (10YR $^4/_2$)/yellow brown (10YR $^5/_4$) and dark greyish brown (10YR 3/2) while in mid and high altitude soil profiles the colour of the sub surface horizon varied from dark yellowish brown (10YR $^4/_4$) (10YR $^4/_3$) to dark brown (10YR $^3/_3$) (10YR $^3/_4$). The dark color in the surface soil horizon may be due to presence of high soil organic carbon content and down the profile it can be attributed to clay illuviation. Various shades of grey color in the surface horizons (P_3, P_7, P_{10}) and subsurface horizons (P_{10}, P_{12}) of the studied profiles could be attributed to the presence of $CaCO_3$ or may be caused by the coagulation of iron or calcium with humus (Dhir, 1967 and Gupta, 1992). Various shades of brown, like dark brown, very dark brown, yellowish brown color in surface and sub-surface horizons of profiles indicate a good drainage condition of the soils (Mahajan*et al.*, 2007) and may be ascribed to the difference in soil organic matter, topographic position and geographical location (Sawhney*et al.*, 2005), Khanday (2013), Naidu and Sireesha (2013) and Wani*et al.* (2017).

The texture of the surface horizons of mid and low altitude varied from loam/ sandy loam to silt loam/clay loam whereas in sub-surface horizons it varied from silt loam/clay loam to loam/silty clay loam. Similarly, in the high altitude soil profile (P_1) texture was silty loam at the surface, while as silty loam to clay loam in sub-surface horizons (Table 1). However, in profiles P_4, P_7 and P_{12} it remained clay loam throughout the depth. In general, the soils were medium to moderately fine in texture. Transport of clay from surface to sub-surface and its deposition in the lower horizons was observed in all soil profiles except P_6. As the elevation increased, the texture of soil in general was course, which may be due to transport or removal of finer fraction of soil by illuvation process or surface erosion because of the high amount of rainfall in this area. Similar observations have been reported by Mandal*et al.* (1990) and Najar (2002). Besides, altitude and relief factors have significant bearing on the texture of soils. These results are in agreement with the findings of Mahapatra*et al.* (2000), Kai *et al.* (2015) and Wani*et al.* (2017).

Soil structure in low altitude soil profiles varied from medium weak sub angular blocky/medium moderate sub angular blocky to medium weak angular blocky/medium moderate angular blocky in surface horizons, while medium moderate angular blocky/medium moderate sub-angular blocky to medium week sub-angular blocky/medium week angular blocky in sub surface horizons. Similarly the structure in the surface horizon in the mid altitudes varied from the fine weak granular to medium weak angular blocky, where as in the sub-surface horizons it varied from the medium moderate sub angular blocky to medium moderate angular blocky. In surface horizons of higher altitudes it was medium week granular whereas in sub-surface horizons it varied from medium moderate angular blocky to medium moderate sub-angular blocky. The development of weak to moderate granular structure in surface in the profiles P_1 and P_2 can be attributed to the high organic matter content. Similar results were observed by Seghal *et al.* (1988) and Minhas *et al.* (1997), under such situation, where the development of angular blocky/sub angular blocky structure in sub surface horizons may be caused by the increase in clay content and soil compaction (Sharma *et al.*, 2004).

The consistency of soils in surface horizons of mid and lower altitudes was found to be slightly hard/hard and loose when dry, while slightly friable, friable, slightly firm and firm when moist. Whereas, in sub-surface horizons it was slightly hard, hard, very hard and loose when dry while as friable, loose to slightly firm, firm and very firm when moist. Surface horizons of higher altitude soils, consistency was slightly loose when dry and friable when moist whereas, in the sub-surface horizons it was loose when dry and firm to very firm when moist. Variations in the consistency of soils of various pedons may be due to the difference in content of clay and organic matter (Najar, 2002; Najar*et al.*, 2009). The increase in hardness, firmness with the depth may be attributed to the increase in compaction and clay content in the sub-surface horizons (Bhat, 2010). Similar results were earlier reported by Sarkar*et al.* (2001), Thangasamy*et al.* (2005) and Mahajan*et al.* (2007).

A slight strong effervescence with diluted HCl of the soils of studied profiles was observed both in surface and sub-surface horizons profile P_3, P_7 and P_{10} located especially in mid and low altitude of the study area while as rest profiles

Table 1: Morphological characteristics of High density apple orchard soils of north Kashmir

Profile No. Location	Horizon	Depth (cm)	Colour	Texture	Structure			Consistence			Boundary	Cutans/ Mottling	Roots	Concretions	Effervescence
			Moist		Size	Type	Grade	Dry	Moist	Wet					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P_1Sambler Bandipora (H-1)	Ap	0-15	10YR4/3	sil	m	gr	1	l	fr	wso wpo	cs	-	mf	-	-
	Bw	15-25	10YR4/4	sil	m	abk	2	-	fr	wso wpo	cs	-	ff	-	-
	Bt_1	25-58	10YR4/4	cl	m	abk	2	-	fi	wss wsp	cs	th-p	ff	-	-
	Bt_2	58-100	10YR4/3	cl	m	sbk	2	-	vfi	ws wp	-	-	-	-	-
P_2 Kunzer Baramulla (M-1)	Ap	0-15	10YR4/3	sil	f	gr	1	sh	vfr	wso wpo	as	-	fc	-	-
	Bw	15-25	10YR4/4	sil	m	sbk	1	-	fr	wso wpo	as	-	mf	-	-
	Bt_1	25-53	10YR4/3	cl	m	sbk	2	-	fi	wss wsp	cs	th-p	ff	-	-
	Bt_2	53-100	10YR4/4	cl	m	abk	2	-	vfi	ws wp	-	th-p	-	-	-
P_3Parihaspor	Ap	0-24	10YR4/2	sil	m	sbk	1	-	fr	Wso	cs	-	mf	-	es

a										Wpo					
Baramulla (M-2)	Bt_1	24-56	10YR3/4	cl	m	abk	2	-	fi	wss wsp	cs	th- p	ff	-	es
	Bt_2	56-80	10YR3/4	cl	m	sbk	2	-	vfi	ws wp	cs	th- p	-	-	es
	Bt_3	80-106	10YR3/4	cl	m	sbk	2	-	vfi	ws wp	-	th -p	-	-	es
P_4 Unagam Bandipora (L-1)	Ap	0-25	10YR5/3	cl	m	sbk	1	-	vfr	wss wsp	cs	-	pf	-	-
	AB	25-48	10YR5/3	cl	m	abk	2	-	fr	wss wsp	cs	-	cf	-	-
	B_1	48-76	10YR3/3	cl	m	abk	2	-	vfi	ws wp	cs	-	ff	-	-
	B_2	76-98	10YR3/3	cl	m	abk	2	-	fi	ws wp	cs	-	ff	-	-
P_5Upper kunanBandipora (L-2)	Ap	0-26	10YR3/3	sil	m	sbk	1	sh	fr	wso wpo	cs	-	mf	-	-
	Bw_1	26-45	10YR4/4	sil	m	abk	2	sh	fi	wss wsp	cs	-	ff	-	-
	Bw_2	45-80	10YR5/3	cl	m	sbk	2	h	vfi	ws wp	cs	-	ff	-	-
	Bw_3	80-104	10YR5/3	cl	m	sbk	2	vh	vfi	ws wp	-	-	-	-	-
P_6	Ap	0-25	10YR3/4	cl	m	sbk	2	h	vfi	wss	as	-	mf	-	-

LoduraBara mulla (L-3)										wsp					
	AC	25-51	10YR4/3	Sil	m	Sbk	1	-	fr	Wso Wpo	cs	-	ff	-	-
	C_1	51-76	10YR4/4	Sil	m	abk	1	-	l	wso wpo	-	-	ff	-	-
	C2	76-100	10YR3/4	Sil	m	abk	1	-	l	-	cs	-	-	-	-
P_7 Choora Baramulla (L-4)	Ap	0-12	10YR3/2	cl	m	abk	1	l	fr	wss wsp	cs	-	mc	-	e
	AB	12-25	10YR3/3	cl	m	abk	2	-	fr	wss wsp	cs	-	cc	-	e
	Bw_1	25-56	10YR4/3	cl	m	sbk	2	-	fi	ws wp	cs	-	ff	-	e
	Bw_2	56-92	10YR4/3	cl	m	sbk	2	-	vfi	ws wp	-	-	-	-	es
P_8 Mazbug Baramulla (L-5)	Ap	0-15	10YR4/4	sl	m	sbk	1	l	fr	wso wpo	cs	-	mc	-	-
	A_1	15-26	10YR3/4	sl	m	abk	2	-	fi	wso wpo	cs	-	ff	-	-
	B_1	26-58	10YR4/3	cl	m	sbk	2	-	fi	wss wsp	cs	-	ff	-	-
	B_2	58-106	10YR4/3	cl	m	sbk	2	-	vfi	ws wp	-	-	-	-	-
P_9Tragpora SoporeBaram	Ap	0-14	10YR4/3	l	m	sbk	1	l	fr	wso wpo	cs	-	mf	-	-

ulla (L-6)	BA	14-25	10YR4/4	l	m	sbk	2	-	vfr	wso wpo	as	-	ff	-	-
	B_1	25-52	10YR5/3	cl	m	sbk	2	-	fi	wss wsp	gs	-	ff	-	-
	B_2	52-101	10YR5/4	cl	m	abk	2	-	fi	ws wp	-	-	-	-	-
P_{10}Pandithpora Kupwara (L-7)	A_P	0-25	10YR3/2	cl	m	abk	1	sh	fi	wss wsp	sw	-	cf	-	e
	Bw	25-54	10YR3/2	cl	m	sbk	2	-	vfi	wss wsp	sc	-	ff	-	e
	B_1	54-92	10YR3/2	si cl	m	sbk	2	-	vfi	ws wp	-	-	-	-	e
P_{11} Chougul Kupwara (L-8)	A_P	0-24	10YR4/3	sl	m	abk	1	l	fr	wso wpo	cs	-	ff	-	-
	Bw_1	24-54	10YR4/4	cl	m	sbk	2	-	fi	wss wsp	-	-	ff	-	-
	Bw_2	54-90	10YR4/3	cl	m	sbk	2	-	vfi	ws wp	cs	-	mf	-	-
P_{12}Jalalabad Sopore Baramulla (L-9)	A_P	0-25	10YR4/3	cl	m	sbk	1	-	fi	wss wsp	cs	-	mf	-	-
	B_1	25-54	10YR4/2	cl	m	abk	2	-	vfi	ws wp	cs	-	ff	-	-
	B_2	54-90	10YR 4/2	cl	m	sbk	2	-	vfi	ws wp	-	-	-	-	-

showed negligible effervescence wit dil. HCl in both surface and sub-surface horizons. However, the effervescence may be due to calcareous nature of parent material/deposition of $CaCO_3$ leached from surface horizons. Similar results were obtained by Najar (2002) and Wani*et al.*, 2017

Chart 3 : Symbols used in Morphological characterization of soils as per soil survey manual by USDA department of agriculture

Boundary	**Structure**	**Consistency**
c= Clear	1=weak	d = dry
g=gradual	2=moderate,	l = loose
s=smooth	3= strong	h = hard
i=irregular	m=medium	sh = slightly hard
d=diffused	c=coarse	vh = very hard
w = wavey	f=fine	m = moist
Texture	sbk = sub-angular blocky	l= Loose
l = loam	abk = angular blocky	vfr =Slightly friable
cl= clay loam	gr = granular	fr = friable
sil = silt loam		fi = firm
sicl = silty clay loam	**Effervescence**	vfi = very firm
sl = sandy loam	e=slight	w = wet
	es=strong	wso = non sticky
Cutans	ev=voilent	wpo = non plastic
th = argillans		wss = slightly sticky
tn = thin		wsp =slightly plastic
P = prominant		ws = sticky
		wp = plastic

2 Particle size distribution

The most reactive fraction of various textural separates of soil is clay, which influences the most of the physical and chemical activities of soil, whereas, silt and sand fractions were considered as its skeleton. The data on mechanical composition of soils (Table-2) revealed that coarse sand in surface horizons of mid and low altitude profiles varied from 1.50 to 1.80 and 0.80 to 2.95 %, where as in high altitude it was 2.73%. In sub-surface soils it ranged from 1.20 to 2.71, 0.5 to 1.2 and 0.1 to 1.80 % in high, mid and low altitude respectively. The fine sand varied from 18.50 to 19.70, 18.00 to 36.10 and 26.55 % in surface soils of mid and low and high altitude profiles while as, it varied from 22.70 to 33.0, 16.50 to 36.20 and 27.20 to 29.00 % in sub-surface soils of mid, low and high altitude profiles, respectively. There was an erratic distribution of sand content with an increase in soil depth except P_1, P_4, P_5, P_9 and P_{11} which showed decreasing trend with depth and P_{10} and P_{12} showed a decreasing trend in fine sand. This may be attributed to the in-situ weathering of the parent material. These results are in line with the observations of Wani (2001) and Wani*et al.* (2016).

The silt content in the surface horizons of mid and low altitude profiles ranged from 59.30 to 61.50, 36.00 to 57.40 % and 52.92 % in high altitude. In the sub-surface soils it ranged from 36.40 to 56.80, 35.40 to 58.45 and 39.00-52.54 % in mid, low and high altitude profiles respectively. Sharma *et al.* (2005), Dar (2009), Najar (2009), Naik (2014) reported similar observations while working with the soils of Punjab and Kashmir respectively.

The clay content varied from 17.00 to 20.70, 18.40 to 29.20 and 17.80 % in surface soils of mid, low and high altitude profiles and it ranged from 20.00 to 30.80, 19.70 to 32.50 and 19.55 to 33.00 % in sub-surface soils of high, mid and low altitude profiles respectively. The distribution of clay content with depth showed an increasing trend within the profiles except in P_6 profile. The increasing trend may be attributed to the illuviation of clay to sub-surface horizons during soil development. These results corroborates with the findings of Bhat (2001), Farida (2005), Verma*et al.* (2012) and Naidu and Sireesha (2013).

Table 2: Particle size distribution of high density apple orchard soils of north Kashmir

Profile No. Location	Horizon	Depth (cm)	Soil separates (%)				Texture
			Coarse sand	Fine sand	Silt	Clay	
1	2	3	4	5	6	7	8
P_1	Ap	0-15	2.73	26.55	52.92	17.80	Silt Loam
	Bw	15-25	2.71	24.75	52.54	20.00	Silt Loam
	Bt_1	25-58	1.90	27.20	42.30	28.60	Clay Loam
	Bt_2	58-100	1.20	29.00	39.00	30.80	Clay Loam
P_2	Ap	0-15	1.80	19.70	61.50	17.00	Silt Loam
	AB	15-25	0.80	22.70	56.80	19.70	Silt Loam
	Bt_1	25-53	1.00	33.00	36.90	29.10	Clay Loam
	Bt_2	53-100	0.70	30.90	36.40	32.00	Clay Loam
P_3	Ap	0-24	1.50	18.50	59.30	20.70	Silt loam

	Bt_1	24-56	0.90	26.40	44.50	28.20	Clay Loam
	Bt_2	56-80	1.20	26.30	42.90	29.60	Clay Loam
	Bt_3	80-106	0.50	26.20	40.80	32.50	Clay Loam
P_4	Ap	0-25	1.40	33.50	39.60	25.50	Clay Loam
	AB	25-48	1.40	34.20	37.90	26.50	Loam
	B1	48-76	1.00	30.50	40.20	28.30	Clay Loam
	B2	76-98	0.70	30.60	37.40	31.30	Clay Loam
P_5	Ap	0-26	1.80	18.00	57.30	22.90	Silt Loam
	B_{W1}	26-45	1.50	17.70	53.80	27.00	Silt Loam
	B_{W2}	45-80	1.00	26.30	45.10	27.60	Clay Loam
	B_{W3}	80-104	0.40	27.50	43.80	28.30	Clay Loam
P_6	Ap	0-25	2.20	28.80	39.80	29.20	Clay Loam
	AC	25-51	1.50	25.00	58.45	25.05	Silt Loam
	C1	51-76	1.80	18.90	54.00	25.00	Silt Loam
	C2	76-100	1.40	25.75	53.30	19.55	Silt Loam
P_7	Ap	0-12	0.80	26.20	47.00	26.00	Clay Loam
	AB	12-25	0.80	27.00	45.60	27.60	Clay Loam
	B_{W1}	25-56	0.40	26.00	44.00	29.60	Clay Loam
	Bw2	56-92	0.60	25.87	43.82	29.71	Clay Loam
P_8	Ap	0-15	2.80	22.80	55.87	18.53	Silt Loam
	A1	15-26	1.00	20.40	57.40	21.20	Silt Loam
	B1	26-58	1.60	26.50	45.50	26.40	Loam
	B2	58-106	0.80	25.60	44.10	29.50	Clay Loam
P_9	Ap	0-14	1.40	30.20	50.00	18.40	Loam
	BA	14-25	1.40	28.70	51.00	18.90	Silty Loam
	B1	25-52	1.00	36.20	35.40	27.40	Clay Loam
	B2	52-101	0.90	35.80	35.50	27.80	Clay Loam
P_{10}	Ap	0-25	2.95	34.05	36.00	27.00	Clay Loam
	B_W	25-54	1.40	32.36	36.60	29.64	Clay Loam
	B1	54-92	1.50	16.50	49.00	33.00	Silty Clay loam
P_{11}	Ap	0-24	0.90	18.10	56.20	24.80	Silty clay Loam
	B_{W1}	24-54	0.70	28.10	43.10	28.10	Clay Loam
	B_{W2}	54-90	0.10	27.30	40.50	32.10	Clay Loam
P_{12}	Ap	0-25	1.20	36.10	40.40	22.30	Loam
	B1	25-54	0.70	28.94	39.40	30.96	Clay Loam
	B2	54-90	0.90	28.70	38.60	31.80	Clay Loam

3 Physico-chemical properties of profiles

3.1 Soil reaction

The studied soil samples exhibited a pH ranging between the 6.60 to 8.10 in the surface horizons whereas in the sub surface horizons it ranged from 6.84 to 8.50 (Table 3) and showed an increasing trend with depth. The soils were slightly acidic to slightly alkaline in reaction. The variation in the pH could be attributed to the variation in the content of organic matter and calcium carbonate as well as rainfall distribution in these physiographic zones. Similar reports were made by Naik (2017). The increase in the pH along with depth could be caused by leaching of bases from the surface and its deposition at lower horizons besides calcium carbonate content. The increase in the pH with depth had also been reported by Rajeshwar and Khan (2008), Bhat (2010) and Wani*et al*. (2017).

3.2 Electrical conductivity

Perusal of Table-3 indicated that electrical conductivity of surface horizons varied from 0.09 to 0.32., where as in sub surface horizons it varied from 0.10 to 0.46 dsm^{-1}. The EC in general showed increasing trend with depth as compared to surface horizons and was found to be in normal range in both horizons. The increase of the electrical conductivity with depth could be attributed to leaching of bases from the surface to sub surface horizons. The results are in agreement with the findings of Najar (2009) and Tuba and Kaleem (2016).

3.3 Organic carbon

The data presented in Table 3 revealed that organic carbon in surface horizons of mid and low altitude varied from 1.05 to 1.36 and 0.78 to 1.17 % respectively, where as in high altitude it was 1.70 %. Where as in sub surface horizons it varied from 0.50 to 0.86, 0.17 to 0.77 and 0.66 to 0.90 % in mid, low and high altitude profiles, respectively. The content of organic carbon revealed a decreasing trend with depth. The high content of organic carbon in the high altitude soils could be due to low rate of mineralization because of low temperature. The high content of organic carbon at the surface horizons as against sub surface horizons might be a result of the incorporation of crop residues and fallen leaves. These findings are in accordance with Sharma *et al.* (2005) and Najar*et al.* (2009), Wani*et al.* (2016).

3.4 Calcium carbonate ($CaCO_3$)

Calcium carbonate ($CaCO_3$) was present only in three profile i.e. P_3, P_7 and P_{10} which fall in mid and low altitudes, while the rest of the profiles were devoid of $CaCO_3$. The content of $CaCO_3$ in these profiles ranged from 0.45 to 1.05 % in the surface horizons, which showed an increasing trend with depth. The presence of $CaCO_3$ in these soils could be attributed to calcareous nature of these soils and increasing trend with depth suggested that these soils are formed under rainfall of less than 1200 mm with average mean temperature (Sahri*et al.*, 1987). The results are in agreement with the finding of Khanday (2013) and Naik (2014), Tuba and Kaleem (2016)

3.5 Cation exchange capacity (CEC)

Perusal of data (Table-3) indicated that the cation exchange capacity Varied in both surface and sub-surface soil horizons of all the profiles in three different altitudes. In general, the surface soils of studied profiles demonstrated lower values ranging from 13.08 to 17.61 Cmol (p+) kg^{-1} of CEC than sub-surface horizons. The low cation exchange capacity values of surface horizons may be attributed to the low active illitic and kaolinitic mineral dominance (Kirmani, 2004; Bhat, 2010). The cation exchange capacity showed an increasing trend with increase in depth in most of the profiles. The increase in cation exchange capacity with the increase in depth may be attributed to the gradual increase in clay content with depth besides increase in change on the xchange sites of the illuvated clay minerals. The results are in agreement with the observations/findings of Ayalew*et al.* (2015) and Wani*et al.* (2017).

3.6 Exchangeable calcium (Ca)

The data presented in Table 3 revealed that exchangeable calcium was the dominant cation among all the exchangeable cation and in surface soils of mid and low altitudes the exchangeable calcium varied from 10.70 to 12.05 and 8.50 to 12.00 Cmol (p+) kg^{-1} respectively and it was 9.50 Cmol (p+) kg^{-1} in high altitude, while as it ranged from 11.00 to 12.95, 8.90 to 12.50 and 10.00 to 10.90 Cmol (p+) kg^{-1} in sub-surface soils of mid, low and high altitude respectively (Table-3). The exchangeable calcium content showed increasing trend with soil depth in all soil profiles. This might be attributed to the increase in clay content with depth, thereby increasing cation exchange capacity and hence more and more exchangeable calcium was adsorbed on the exchange sites of the illuvated clay minerals. Similar results were obtained by Najar (2002), Kirmani (2004) and Verma*et al.* (2012). The highest values of exchangeable calciumin surface and sub-surface soils were found in the areas of mid altitude (Table-3). This could be ascribed to the higher pH which favours the release of calcium and higher $CaCO_3$ deposits. This is supported by the similar observations as reported by Maqbool*et.,al*(2017)

3.7 Exchangeable magnesium (Mg)

The analysis of data in Table-3 indicated that the exchangeable magnesium (Mg^{2+}) in surface soils of the mid and low altitude ranged from 2.23 to 2.38 and 1.81 to 2.38 Cmol (p+) kg^{-1} respectively and in high altitude profile it was 2.15 Cmol (p+) kg^{-1}.At the same time it ranged from 2.25 to 2.80, 1.81 to 2.80 and 2.16 to 2.24 Cmol (p+) kg^{-1} in the sub-surface soils of mid, low and high altitude respectively. The exchangeable magnesium showed an increasing trend with depth which may be due to leaching of magnesium from surface to lower horizons leading to high amounts of exchangeable magnesium in lower horizons. These results are in with the findings of Najar (2009), Naidu and Sireesha (2013) and Naik (2014).

Table 3: Physico-chemical properties of High density Apple orchard soils of north Kashmir

Location (Altitude)	Horizon	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC ($Cmolp^{+}kg^{-1}$)	Echangeable cations ($Cmol(p^{+})\ kg^{-1}$)				Base saturation (%)
								Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	
1	2	3	4	5	6	7	8	9	10	11	12	13
High altitude												
P_1	Ap	0-15	6.60	0.19	1.70	0	15.18	9.50	2.15	0.95	0.08	83.53
	B_W	15-25	6.90	0.20	0.90	0	15.54	10.00	2.16	0.91	0.09	84.68
	Bt_1	25-58	6.80	0.23	0.76	0	16.68	10.50	2.23	0.87	0.09	82.07
	Bt_2	58-100	6.84	0.20	0.66	0	16.57	10.90	2.24	0.87	0.11	85.21
Mid altitude												
P_2	Ap	0-15	7.1	0.26	1.36	0	16.55	10.70	2.23	0.80	0.10	83.56
	AB	15-25	7.2	0.27	0.88	0	16.21	11.00	2.25	0.77	0.12	87.23
	Bt_1	25-53	7.1	0.30	0.70	0	16.38	11.05	2.27	0.76	0.12	86.69
	Bt_2	53-100	7.3	0.32	0.50	0	16.57	11.30	2.27	0.71	0.13	86.96
P_3	Ap	0-24	8.1	0.32	1.05	1.05	17.61	12.05	2.38	0.91	0.11	87.73
	Bt_1	24-56	8.3	0.35	0.86	1.21	18.65	12.67	2.58	0.83	0.13	86.91
	Bt_2	56-80	8.4	0.36	0.73	1.25	18.99	12.80	2.68	0.64	0.14	85.62
	Bt_3	80-106	8.4	0.39	0.51	1.32	18.56	12.95	2.80	0.61	0.14	88.90
Low altitude												
P_4	Ap	0-25	7.1	0.20	1.15	0	13.08	8.50	1.81	0.65	0.08	84.40
	AB	25-48	7.3	0.23	0.75	0	13.89	8.90	1.81	0.64	0.09	82.36
	B1	48-76	7.2	0.29	0.52	0	16.92	11.48	2.29	0.54	0.11	85.22
	B2	76-98	7.5	0.33	0.41	0	16.99	11.49	2.29	0.52	0.12	84.87
P_5	Ap	0-26	7.2	0.19	1.17	0	13.67	9.00	2.04	0.76	0.09	86.97
	B_{W1}	26-45	7.4	0.21	0.77	0	15.11	10.05	2.17	0.68	0.09	85.96
	B_{W2}	45-80	7.3	0.22	0.61	0	15.54	10.90	2.24	0.68	0.10	89.57
	B_{W3}	80-104	7.4	0.24	0.45	0	15.76	11.00	2.25	0.67	0.11	89.02
P_6	Ap	0-25	7.2	0.10	0.78	0	15.65	10.97	2.23	0.71	0.09	89.45
	AC	25-51	7.5	0.15	0.58	0	16.95	11.50	2.30	0.69	0.12	86.19
	C1	51-76	7.5	0.19	0.40	0	17.08	11.75	2.34	0.67	0.12	87.11
	C2	76-100	7.8	0.18	0.17	0	17.56	12.00	2.35	0.65	0.12	86.10

P_7	**Ap**	**0-12**	**7.9**	**0.25**	**0.94**	**0.50**	**17.19**	**12.00**	**2.38**	**0.67**	**0.11**	**88.19**
	AB	**12-22**	**8.1**	**0.27**	**0.75**	**0.80**	**17.07**	**12.04**	**2.38**	**0.55**	**0.11**	**88.34**
	B_{W1}	**22-56**	**8.4**	**0.29**	**0.56**	**1.20**	**17.70**	**12.25**	**2.41**	**0.55**	**0.11**	**88.91**
	B_{W2}	**56-92**	**8.5**	**0.25**	**0.40**	**1.24**	**17.85**	**12.50**	**2.49**	**0.54**	**0.12**	**87.67**
P_8	**Ap**	**0-15**	**7.5**	**0.09**	**0.85**	**0**	**16.87**	**11.60**	**2.31**	**0.78**	**0.10**	**87.67**
	A1	**15-26**	**7.6**	**0.10**	**0.64**	**0**	**16.94**	**11.62**	**2.33**	**0.77**	**0.11**	**87.54**
	B1	**26-58**	**7.6**	**0.17**	**0.56**	**0**	**17.15**	**11.70**	**2.34**	**0.77**	**0.12**	**87.05**
	B2	**58-106**	**7.7**	**0.21**	**0.44**	**0**	**17.69**	**11.91**	**2.35**	**0.71**	**0.12**	**85.30**
P_9	**Ap**	**0-14**	**7.1**	**0.19**	**0.92**	**0**	**16.94**	**11.47**	**2.35**	**0.72**	**0.10**	**86.42**
	BA	**14-25**	**7.2**	**0.23**	**0.77**	**0**	**17.06**	**11.90**	**2.36**	**0.69**	**0.10**	**88.21**
	B1	**25-52**	**7.3**	**0.21**	**0.58**	**0**	**16.99**	**11.92**	**2.36**	**0.68**	**0.11**	**88.69**
	B2	**52-101**	**7.3**	**0.22**	**0.37**	**0**	**17.06**	**11.97**	**2.37**	**0.68**	**0.12**	**88.74**
P_{10}	**Ap**	**0-25**	**7.9**	**0.31**	**0.94**	**0.45**	**16.63**	**11.47**	**2.35**	**0.47**	**0.10**	**86.53**
	B_W	**25-54**	**8.2**	**0.40**	**0.60**	**0.60**	**16.89**	**11.91**	**2.36**	**0.48**	**0.11**	**87.98**
	B1	**54-92**	**8.4**	**0.43**	**0.45**	**0.90**	**16.95**	**11.95**	**2.37**	**0.48**	**0.12**	**88.02**
P_{11}	**Ap**	**0-24**	**7.2**	**0.17**	**0.95**	**0**	**13.27**	**9.00**	**1.87**	**0.70**	**0.09**	**87.86**
	B_{W1}	**24-54**	**7.1**	**0.19**	**0.73**	**0**	**16.68**	**11.00**	**2.25**	**0.69**	**0.10**	**84.17**
	B_{W2}	**54-90**	**7.3**	**0.24**	**0.50**	**0**	**16.98**	**11.50**	**2.33**	**0.68**	**0.11**	**86.10**
P_{12}	**Ap**	**0-25**	**7.3**	**0.30**	**0.81**	**0**	**16.11**	**11.40**	**2.27**	**0.67**	**0.10**	**89.63**
	B1	**25-54**	**7.5**	**0.46**	**0.55**	**0**	**16.68**	**11.40**	**2.35**	**0.65**	**0.11**	**86.99**
	B2	**54-90**	**7.4**	**0.46**	**0.42**	**0**	**16.79**	**11.94**	**2.38**	**0.62**	**0.12**	**89.69**

3.8 Exchangeable potassium (K)

The examination of data shown in Table 3 revealed that the exchangeable potassium of surface soils of mid and low altitude ranged from 0.80 to 0.91 and 0.47 to 0.78 Cmol (p+) kg^{-1} respectively and in high altitude profile it was 0.95 Cmol (p+) kg^{-1}, whereas, it ranged from 0.61 to 0.83, 0.48 to 0.77 and 0.87 to 0.91 Cmol (p+) kg^{-1} in sub-surface soils of mid, low and high altitudes, respectively. The exchangeable potassium demonstrated irregular distribution within depth column in these soils. The results are in agreement with the findings of Bhat (2010), Naidu and Sireesha (2013), Wani*et al.* (2017) In general, the surface soils of high density apple orchards of high, mid and low altitudes showed higher levels of exchangeable potassium as against their sub-surface soils. This could be attributed to the prevalence of potassium bearing clay minerals horizons and high organic matter which prevents its fixation with clay minerals. The results confirmred by previous findings of Naidu and Sireesha (2013), Naik*et al.* (2014) and Tuba *et al.* (2016)

3.9 Exchangeable sodium (Na)

The exchangeable sodiumin surface soils of mid and low altitude was found in the range 0.10 to 0.11, 0.08 to 0.11 and in high altitude it was 0.08 cmol (p^{+}) kg^{-1} while as, it ranged from 0.09 to 0.1, 0.12 to 0.14 and 0.09 to 0.12 cmol (p^{+}) kg^{-1} in sub-surface soils of high, mid and low altitude, respectively. Like exchangeable calcium,magnesium, exchangeable sodium reveal increasing trend in its vertical distribution with soil depth. This may be attributed to its leaching from surface horizons to lower horizons. Similar results were obtained by Najar*et al.* (2009), Verma*et al.* (2012), Naidu and Sireesha (2013) and Naik*et al.* (2014).

3.10 Base saturation

The base saturation in surface soils of mid and low altitude ranged from 83.56 to 87.73 and 84.46 to 89.45% and in high altitude it was 83.53 %. Whereas, it ranged from 85.62 to 88.92, 82.36 to 89.69 and 82.07 to 85.21 in sub-surface soils of mid, low and high altitude, respectively (Table-3). The base saturation was found to be maximum in the mid altitude, followed by the low and high altitude profiles in the surface and sub-surface horizons. It may be due to the high content of basic cations in mid altitude profiles, which is caused by the calcification process. Similar results are found by Wani*et al.* (2009) and Naik (2014).

4. Soil classification

Based on the morphological and physio-chemical properties these soils were classified according to the keys to soil taxonomy (Soil survey staff 2014) presented in Table-4.

The high altitude soil profiles (P_1) at Sambler is classified as Mollisol due to the presence of Mollicepipedons and a base saturation of more than 50 % in all horizons because of Udic moisture regime the soil qualifies for Udolls. The profile meets the requirements of Argillichorizons so is classified at the great group level as Argiudolls.

The profile P_2 (Kunzar) and P_3 (Parihaspora) at mid altitude possessed Orchricepipedons and Argillic horizon were placed under the Alfisols. Due to the presence of Udic moisture regime the soils qualified for sub orderUdalfs and at great group level as Hapludalfs. The low altitude soil profiles i.e. P_4, P_5, P_7, P_8, P_9, P_{10}, P_{11} and $P_{12,}$ except $P_{6,}$ were classified as the Inceptisols as they possessed Cambric B horizon due to the presence of Ochricepipedons. Therefore, they were placed under the sub order Ochrepts and at great group level as Eutrochrepts. The profile (P_6) that lacks development qualifies for Entisols. The texture in all horizons below Ap was silt loam accompanied with decrease in organic carbon with increase in depth reached a value of less than 0.2 per cent keyouts the profile in the sub order Orthents and at great group level Udorthents due to Udic moisture regime. Similar findings were reported by Mahapatra*et al.* (2000), Bhat (2010), Naik (2017) while working on the genesis and classification of soils in the Kashmir Valley

Table 4: Classification of different soil profiles of the high density apple orchards in the north Kashmir

Physiographic zone	**Profile No.**	**Diagnostic horizon**		**Order**	**Sub-order**	**Great-group**
		Surface	**Sub-surface**			
High Altitude (H)	P_1	Mollic	Argillic	Mollisols	Udolls	Argiudolls
Mid Altitude (M)	P_2 and P_3	Ochric	Argillic	Alfisols	Udalfs	Hapludalfs
Low Altitude (L)	P_4, P_5, P_7, P_8, P_9, P_{10}, P_{11} and P_{12}	Ochric	Cambic	Inceptisols	Ochrepts	Eutrochrepts
	P_6	Ochric	-	Entisols	Orthents	Udorthents

SUMMARY AND CONCLUSION

On the basis of the U.S. Comprehensive System of Soil Classification as per Keys to Soil Taxonomy (Soil Survey Staff, 2014) and Soil Survey Manual (Soil Survey Staff, 2003), the studied profiles were placed in the orders of Mollisols, Alfisols, Inceptisols and Entisols and the suborders Udolls, Udalfs, Orchrepts and Orthents. The great groups to which these soils were further classified are Argiudolls, Hapludalfs, Eutrochrepts and Udorthents respectively, the calsification was done on the basis of presence of the diagnostic surface and sub-surface horizons, profile development and presence of particular moisture and temperature regime.

The research is concluded by following observations.

- The soils of the high density apple orchards of north Kashmir are the result of interaction of climate and vegetation acting on the parent rock, as conditioned by relief and drainage, over a length of time. Due to this interaction several kinds of soils are developed which differ in morphological and physico-chemical properties.
- The soils are classified in the four orders (Mollisols, Alfisols, Inceptisols and Entisols) on the basis of variations observed in the occurrence of the diagnostic horizons, profile development, moisture and temperature regimes. Detailed study of clay mineralogy may provide a tool to classify soils up to series level and indicate the most probable path of plant nutrients added to soil. In such way can also support a better understanding of the soil genesis and the electro-chemical performance. The study of complete micro morphological characteristics and other pedological features are important aspects for understanding soil properties. It may serve to evaluate the influence of physical parameters on yield and confirm the data of chemical analysis and provide another relationship.

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