NUTRITIONAL SURVEY OF APPLE (*Malus domestica* Borkh) ORCHARDS IN KINNAUR DISTRICT OF HIMACHAL PRADESH

Thesis

by

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Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY SOLAN (NAUNI) HP - 173230 INDIA

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CERTIFICATE-I

This is to certify that the thesis titled**, "Nutritional survey of apple (*Malus domestica* Borkh) orchards in Kinnaur District of Himachal Pradesh**" submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE) SOIL SCIENCE** of Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)-173230 India is a bonafide research work carried out by **Ms Anjali kumari (F-2018-52-M)** daughter of Mr Ashok kumar under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni, Solan
Dated:

(Dr M.L. Verma)
Chairman
Advisory Committee

CERTIFICATE - II

This is to certify that the thesis entitled, **"Nutritional survey of apple (*Malus domestica* Borkh) orchards in Kinnaur district of Himachal Pradesh"** submitted by **Ms Anjali kumari (F-2018-52-M)** daughter of Mr Ashok kumar to the Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)-173230 India in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE) SOIL SCIENCE** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the internal examiner.

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"If we desire intensely and we act upon it, then everything stands within our reach"

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I own entire responsibility for all the errors and omissions.

Place: Nauni, Solan **(Anjali kumari)**

CONTENTS

ABBREVIATIONS USED

%	:	Per cent
Amsl	:	Above mean sea level
Cm	:	Centimeter
cmol (p^+) kg^{-1}	:	Centimole proton per kilogram
CV	:	Coefficient of variance
dSm^{-1}	:	Deci Siemens per meter
DTPA	:	Diethylene Triamine Penta Acetic Acid
E	:	East
EC	:	Electrical Conductivity
et al.	:	Co-workers
etc.	:	*et cetera*
FYM	:	Farm yard manure
g kg^{-1}	:	Gram per kilogram
H.P	:	Himachal Pradesh
i.e.	:	*That is*
kg ha^{-1}	:	Kilogram per hectare
L	:	Loam
M	:	Meter
mg kg^{-1}	:	Milligram per kilogram
Mg m^{-3}	:	Mega gram per meter cube
Mm	:	Mili meter
N	:	North
NS	:	Non significant
OC	:	Organic carbon
pH	:	*Puissance de Hydrogen*
ppm	:	Parts per Million
S.d.	:	Standard Deviation
Sl	:	Sandy loam
sq km	:	Square kilometer
Viz.	:	*Videlicet*

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Chapter-1

INTRODUCTION

Apple (*Malus domestica* Borkh) belongs to family rosaceae and sub family pomoideae. In India apple is the major fruit crop among the temperate fruits, and is grown mainly in the north-western Himalayan region of India comprising states of Himachal Pradesh, Jammu and Kashmir, Uttrakhand and to some extent in north-eastern states like Sikkim, Meghalaya, Mizoram, Nagaland, Manipur, and Arunachal Pradesh, but Jammu and Kashmir (J&K) and Himachal Pradesh are only principal apple growing states. India ranks 4^{th} in apple production in the world and occupies an area of 301 thousand hectares with production of 2327 thousand metric tonnes (Anonymous, 2018).

Himachal Pradesh on account of its production has been designated as Apple Bowl of India having production 446.57 metric tonnes from an area of about 112.63 thousand hectares and having productivity 3.96 metric tonnes per hectare (Anonymous, 2018). Horticulture plays an important role in the economic prosperity of the people of North-West Himalayan region, because of the suitable climate and topographic conditions. The varieties of apple cultivated in Himachal Pradesh are Stakrimson, Starking Delicious, Red Delicious, Red Spur, Red Chief, Top Red, Golden Spur and Golden Delicious. In Himachal Pradesh apple is grown in districts of Kinnaur, Shimla, Kullu, Mandi, Sirmour, Chamba, Lahul and Spiti. Apple can be grown at altitudes varying from 1500-2700 m. above m.s.l in the Himalayan range which experience, 1000-1500 chilling hours during winter season. Himachal Pradesh has its wide variety of climate and soil, which are well suited for growing large number of horticultural crops.

Kinnaur district of Himachal Pradesh is located on both sides of the river Satluj and shares its eastern boundary with Tibet. The commercial apple growing areas of Kinnaur region ($30^{0}22^{'}40^{''}$to $33^{0}12^{'}40^{''}$N latitude and $75^{0}47^{'}55^{''}$to $79^{0}04^{'}20^{''}$E longitude) namely Nichar (24 locations), Kalpa (31 locations) and Pooh (27 locations) representing the typical agro-microclimatic conditions. The climate of Kinnaur region provide congenial environment for growing high quality apple fruits due to topographical variations and altitudinal differences. Apple is an important fruit crop of Kinnaur with regards to average production and economic value .The economy of Kinnaur mainly depends on its fruits production. The apples of this region possess qualities at par with international standards for export purposes.

Horticulture is important to a sizable number of Kinnaur farmers as it improves their economic conditions.

For optimum growth and fruiting, apple trees need 100-125 cm. of annual rainfall, evenly distributed during the growing season. Excessive rains and fog near the fruit maturity period results in improper colour development with poor fruit quality and fungal spots on its surface. Exposed area with high velocity of wind is not desirable for apple cultivation. Most of the apple orchards in the states are rainfed, raised on poor and shallow soils with steep gradient. Heavy rains during July-August coupled with winter rains (January-February) causes severe losses of nutrients through leaching and erosion, thereby depleting the fertility status of hill soils.(Pant and Tiwari,1987). Introduction of high yielding varieties, intensive cultivation, use of high analysis fertilizes, monoculture and adoption of modern technologies have enhanced the rate of exhaustion of finite nutrient reserves of these soils. On the other hand, the consumption of fertilizers is low and there is scanty information on nutrient status of these soils. As a result the present management of the horticultural soils has brought out many nutritional problems related to macro nutrient elements (Dangarwala *et al.*,1994). Growth, vigour and fruit yield of apple trees are largely influenced by orchard management and environmental make up. Amongst other factors, the quantity of apple fruit is also influenced by nutritional status of soil, leaf- fruit ratio, fruit mineral composition and harvesting at the maturity stage (Hansein and Ryugo, 1979).Leaf is the principal site for the synthesis of photosynthetic compounds and other metabolic processors. Faust (1989) reported that 200 cm^2 of leaf area is needed to grow 100 g of apple fruit to full maturity.

Physico-chemical characteristics and nutrient status of soils are the major parameters, next to climate, that governs growth, productivity and yield of crops. It has been reported that soil characteristics markedly influenced nutrient availability and ultimately the growth, development and yield of apple trees. Soil reaction or pH is one of the outstanding chemical characteristics of soil which markedly influence the availability of nutrients, activity of microorganisms and physical characteristics of soil such as structure and permeability. Although apples can grow in fairly acidic to slightly alkaline soils, yet they grow best in slightly acidic soils with pH values between 6.0-6.5 (Bhandari and Raina, 2005).

Assessments of nutrient status render valuable information on the available nutrient status of soils and plants and helps in ameliorating their deficiencies through judicious and economic use of fertilizer. Such information is important not only for maintaining soil fertility but also for getting high crop yields of quality fruits. The key to mineral nutrition of the plants is the judicious application of the fertilizers bases on laboratory analysis values. Plant analysis is used to confirm the suspected deficiencies and toxicities of nutrient. Plants are the best indicators of soil nutrient supply under a given environment and leaf being the centre of nutrition of the plant, therefore, forms of basis of the foliar analysis. Hence both soil and leaf analysis should be taken into consideration for assessing the nutritional status.

Bhandari and Sharma (1981) studied the apple orchards of Shimla district and found half of the plant samples deficient in P, where as the deficiency of Ca, S, K, N, and Mg was in 38, 26, 25,6 and 1 percent samples, respectively. Raina *et al.* (1984) reported that some apple orchards in Himachal Pradesh an appreciable percentage of apple orchards to be low in N, P, K, Ca, Cu, and Zn supply. Sharma (1988) reported that apple orchards soils of Sirmour district were low to medium in available N, S and B, where as the leaf analysis data exhibited low to sufficient content of K, Zn, Cu, and B. Sharma (1994) surveyed some belts of Chamba district and concluded that the soils in the area were low to medium in available N and B, medium to high in P, Zn and Cu, adequate in K, Ca, Mg and S while they were high in available Fe and Mn. Talatam (2001) studied the nutritional status of apple orchards of Himachal Pradesh and found that apple orchards soils were low to medium in available N, medium to high in P, K and Cu and high in their Fe and Mn status, whereas, the leaf analysis revealed low to sufficient N, P, K, Cu and Mn status.

Literature revealed that for the last few decades the nutritional status of apple orchards of Kinnaur district has not been monitored and there is meagre information on current nutritional status of apple orchards of this district despite the fact that the old orchards have been gradually reconstituted by new plantation of developed varieties and the management of soils have also changed subsequently over the years. Keeping in view the importance of soil physico-chemical characteristics and nutrient status in plant nutrition as well as for growth, and quality of crop, present study entitled **"Nutritional survey of apple (*Malus domestica* Borkh) orchards in Kinnaur District of Himachal Pradesh"** was conducted with the following objectives.

OBJECTIVES

1. To study the soil physico- chemical properties and leaf nutrition status of apple in Kinnaur district
2. to study the relationship between soil properties and leaf nutrient contents.

Chapter-2

REVIEW OF LITERATURE

Testing of soil is well characterised as a sound scientific tool to assess inherent power of soil to supply plant nutrients. Soil fertility is affected by the natural (parent material, biosphere, climate topography and time) *Viz.*, management practices, crop rotation, green manuring and fertilization. The purpose of soil testing is to know the status of nutrient availability. The soil samples are analysed for physical conditions, nutrient status and chemical properties that affect their suitability as plant growing media. Therefore, the determination of nutrient status of surface and sub-surface soils is equally important to have a comprehensive picture of nutrient status of soils.

The soil and leaf analysis information is vital both for planning of research, extensive field demonstrations and making sound fertilizer recommendations for profitable production. The computation of relationships between soil characteristics, an available nutrient status of soil and plants are valuable information effective for soil and nutrient management. The germane literature has been reviewed under the following main headings;

2.1 Soil fertility status

- **2.1.1. Physico-chemical properties of the soils**
- **2.1.2. Macronutrients**
- **2.1.3. Micronutrients**

2.2 Macro and micronutrient concentration in plants

2.3 Relationship of soil properties with nutrient content in soils

2.4 Relationship of the available nutrient elements in soil with leaf nutrient composition

2.1 SOIL FERTILITY STATUS

2.1.1 Physico-chemical properties of soil

2.1.1.1 Soil texture

Mahajan *et al.* (2007) analysed the soil texture of Balh valley of district Mandi and they reported that dominating texture class was silty loam (25.7-49.2 %) followed by sandy texture (12.1-48.1%). Najar *et al.* (2009) examined characteristics of apple growing soils of

Kashmir region and found that soil of northern aspect contains 14.1 to 52.7 per cent sand, 27.4 to 63.0 per cent silt and 18.5 to 33.2 per cent clay, however, soils of southern aspect contain about 10.5 to 30 per cent sand, 37.8 to 50.6 per cent silt and 21.8 to 44.0 per cent clay.

Charan *et al.* (2013) studied the altitudinal variation in soil physico-chemical properties of high-altitude region of Leh-Ladakh, India. They observed that there was no variation in clay content, but sand percentage at higher altitude was significantly high. Tanveer *et al.* (2016) evaluated the soil texture in Kandi area of Kashmir and found that sand content ranged from 49.07- 75.64 per cent, silt 12-34 per cent and clay content ranged from 6-25 per cent. He also found that soils were sandy clay loam, loamy sand, sandy loam and loam.

Annepu *et al*. (2017) examined the soil fertility status of Mid Himalaya region of Himachal Pradesh and found that soil varied from loam to sandy loam in texture and dark grey to dark greyish brown in colour. Kumari *et al.* (2017) reported that sand, silt and clay contents in the soils of Himachal Pradesh varied from the 19.3 to 74.6, 14.6 to 43.6 and 5.8 to 36.2 per cent, respectively. They also concluded that the texture class varied from sandy loam to sandy clay.

2.1.1.2 Soil reaction (pH)

Dris and Niskanen (1998) studied the nutritional status of commercial apple orchards in the Finland They collected the samples of soil, leaf and fruit from nine apple orchards and studied early, intermediate and late cultivars. The study revealed that the mean soil pH was 7.0 in surface soils and 7.1 in sub-surface soil. Choudhary *et al.* (2005) observed that soils of Himachal Pradesh were slightly acidic (pH 6.0) to mildly alkaline (pH 8.3) and values increased with depth.

Farida (2005) examined the soils of apple orchards of Zaingier block of district Baramulla and found that the soil pH in surface layer varied from 6.7 to 7.3, however in the sub surface layers it varied from 6.9 to 7.6 giving a mean value of 6.9 in both the cases. The results concluded that soil pH increased with the soil depth. Verma and Tripathi (2007) categorised soils of mid Shivalik hills in Himachal Pradesh and found that soils were slightly acidic to slightly alkaline (6.5 to 7.7) in reaction.

Sharma and Kanwar (2010) studied soils of dry-temperate zones of Himachal Pradesh and found that soil pH varied from 6.2-8.3 with a mean value of 7.6. Soil pH of low land varied from 6.9-7.3, medium land varied from 7.3-7.4, while in high land it ranged from 5.8-7.2 with mean value of 7.15, 7.33, 6.13 respectively.

Kumar *et al.* (2012) studied the mango orchards at Malihabad region of Uttar Pradesh and found that the pH ranged from 6.1 to 7.4. Ahmed *et al.* (2017) found that soil pH varied from 6.35 to 8.25 with mean values of 7.51.

Rehman *et al.* (2017) examined various physico-chemical characteristics of soils in Kashmir Himalayas. In this study soils were classified as silty clay loam for Baranula, Ganderbal, Pulwama and Shapion regions, clay loam for Kupwara, Bandipora, Kulgam and Anantnag regions, clay soils were found in Budgam region. In this soil pH varied from 4.5 to 7.6 with the mean value of 6.3, indicated acidic to neutral soils.

2.1.1.3. Electrical conductivity (EC)

Hundal *et al*. (2005) evaluated the EC of mango orchards in sub-mountainous regions of Punjab and found that it ranged from 0.08 to 0.58 dSm^{-1}. Tripathi *et al.* (2005) examined the soils of four agro-climatic zones covering the districts of Kangra, Kinnaur, Sirmour, Chamba and Bilaspur of Himachal Pradesh. The mean EC of soils of different districts were; Kinnaur 0.37dSm^{-1}, Kangra 0.15 dSm^{-1}, Bilaspur 0.24 dSm^{-1}, Chamba 0.26 dSm^{-1} and Sirmour 0.20dSm^{-1} and the average of all soils was 0.24 dSm^{-1}.

Verma and Tripathi (2007) observed that in Shivalik hills of Himachal Pradesh soils has very low soluble salt concentration with values of electrical conductivity 0.01 - 0.15 dSm^{-1}. Dar *et al.* (2016) studied the electric conductivity under different climatic zone of Kashmir. They concluded that electrical conductivity was highest in temperate (0.23 dSm^{-1}) followed by sub temperate (0.14 dsm^{-1}) and least under cold arid (0.08 dSm^{-1}).

Rehman *et al.* (2017) studied the electrical conductivity of district Pulwama and found that it varied from 0.01-0.19 dSm^{-1}. The results indicated that electrical conductivity increases with depth and soils were non-saline in nature. Bangroo *et al.* (2018) examined the electric conductivity of apple orchards in Kashmir and found that electrical conductivity ranged from 0.43 to 0.77 dSm^{-1}.

2.1.1.4. Organic carbon

Sarkar and Sahoo (2000) observed that the organic carbon content of the soils varied from 0.08 to 0.86 per cent which decreased gradually with depth in Indo-Gangetic plains of Bihar. Dar *et al.* (2016) studied that soil nutrient status under different Agro-climatic zones of Kashmir and Ladakh region *viz*. temperate (Pattan) sub temperate (Gurez) and cold arid (kargil). The organic matter was highest in Pattan soil (1.0-1.14%) followed by Gurez soil (0.32%) and least under Kargil soil (0.27%).

Mogta and Sharma (2018) studied that nutrient status of polyhouse soils four districts (Sirmour, Shimla, Solan and Bilaspur) of Himachal Pradesh. Studies suggest that surface soils of these areas were found rich in organic carbon content which varied from 11.59 to 19.51 g kg^{-1}.

Sharma and Sood (2019) investigated organic carbon content of soils of Kinnaur district, and found it range from 0.84-5.55 per cent with mean value of 3.25 per cent. Thakur *et al*. (2018) studied the organic matter content of district Shimla and Kinnaur of Himachal Pradesh. Their study revealed that maximum organic carbon content was found in Kotkhai region of Shimla (0.75%) and minimum in Sangla valley of Kinnaur content (0.19%).

2.1.1 5. Cation exchange capacity

Subbian *et al.* (1986) observed that cation exchange capacity varied from 50 to 60 cmol (p+) kg^{-1} in soils of Andhra Pradesh. Mushki (1994) evaluated that the cation exchange capacity ranged from 12.00 to 27.40 cmol (p+) kg^{-1} in apple orchard soils of Kashmir valley.

Farida (1997) reported that the cation exchange capacity varied from 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 basin soils of Kashmir respectively. Kadao *et al.* (2003) examined the cation exchange capacity of banana growing soils of Wardha district of Maharashtra and reported that it varied from 9.81 to 73.30 cmol(p+) kg^{-1}.

Niranjana *et al*. (2011) observed that cation exchange capacity varied from 7.2 to 58.8 cmol (p+) kg^{-1}in soils of banana orchards in Kadapa district of Andra Pradesh. Bhanwaria *et al.* (2011) studied the cation exchange capacity in Mokla region of Rajasthan and found that it ranged from 8.84 to 12.54 cmol (p+) kg^{-1}.

2.1.1.6. Base Saturation percentage

Adejuwon and Ekanade (1987) reported that there was about 19-50 per cent losses of exchangeable $Ca^{2+,}$ Mg^{2+}, Na^{+} and K^{+} in a tropical region of Nigeria. Base saturation percentage was 5.4 to 8.7 per cent in tropical region and cation exchange capacity was reduced by 34-36 per cent. Ohta (1990) observed reduction in per cent base saturation as well as exchangeable Ca^{2+} in Philippines.

Saikh *et al.* (1998) studied the effects of deforestation and contents of exchangeable bases in Simlipal National Park Odisha, India. They observed that there was reduction in exchangeable bases and exchangeable Ca^{2+} and Mg^{2+} level compared to the adjoining unmanaged forest land.

Tripathi *et al.* (2005) studied the soil physico-chemical properties of soil and characteristics of Kiar-Nagali micro-watershed in north-west Himalayas and found that percent base saturation ranged from 56.6 to 74.8 per cent.

2.1.2 Macronutrients

2.1.2.1. Available nitrogen

Singh (1987) conducted a study on available nitrogen in soil in Kinnaur, Himachal Pradesh. The results revealed that, in surface soil the available nitrogen varied from 72-169 ppm with a mean value of 122 ppm, whereas, in sub-surface soil it varied from 45-123 ppm with an average of 90 ppm. Verma (1987) studied the available nitrogen content in surface soils of apple orchards located in Theog region of district Shimla, and found that it ranged from 274-322 ppm.

Sharma (1988) studied the nutritional status of apple orchards in Sirmour district. He found that available nitrogen content decreased with increase in the soil depth. Average nitrogen content in the 0-20, 20-40 and 40-60 cm soil depths were found to be 170.2, 147.1 and 182.2 ppm, respectively. Sharma (1990) observed that average nitrogen content in surface and sub surface soils of Mandi district was found to be 158 and 138 ppm, respectively

Attar and Joolka (2015) conducted nutritional survey in major apple growing belts viz., Jubbal-kotkhai, Karsog, Kalpa, Kotgarh, and Naggar of Himachal Pradesh. The available nitrogen content varied from 95.11-202.58 ppm. The maximum concentration of nitrogen was found in Karsog belt (164.78 ppm).

Karlidag *et al*. (2019) studied nutritional status of apple orchards in Dogansehir region of Turkey and found that available nitrogen content varied from 0.106 to 0.068 per cent at 0 -30 cm depth and 0.102 to 0.072 per cent at 30-60 cm depth.

2.1.2.2 Available phosphorus

Verma *et al.* (1985) observed that in soils of Kangra, Una and Shimla, the available phosphorus was low, whereas in soils of Kullu, Mandi, Hamirpur and Sirmour the available phosphorus was medium in status. The available phosphorus in surface and sub- surface soils in apple orchards of Kinnaur were 14-52 and 10-44 ppm, respectively.

Sharma (1988) examined the average values of available phosphorus in district Sirmour at three depths (0-20, 20-40 and 40-60 cm). The available phosphorus was in order; 0-20 (52.1ppm) > 20-40 (40.5ppm) > 40-60 (31.1ppm). They also found that all the samples were categorized high in their available phosphorus content.

Dar *et al.* (2016) studied the nutrient content of soil under different Agro-climatic zones of Kashmir and Ladakh. The available phosphorus content was highest in Pattan region (22.45 $kgha^{-1}$). Ganai (2018) conducted nutritional survey of apple orchards of south Kashmir (India). He reported that available phosphorus content was medium to high in Kashmir and varied from 20.16-38.52 $kgha^{-1}$ with mean value of 13.01 kg ha^{-1}.

2.1.2.3 Available Potassium

Singh (1987) studied that available K content in the apple orchards of Kinnaur district and it varied from 118-180 ppm with an average of 140.3 ppm. The distribution pattern revealed that available K decreased with increasing soil depth.

Sharma (1990) studied available potassium in surface and sub-surface soils of Mandi district and found that it ranged between 182-540 and 135-415 ppm, respectively. However, 5 per cent of sub-surface samples were under medium fertility category, while remaining samples were high in their available potassium content.

Attar and Joolka (2015) conducted a nutritional survey to evaluate soil fertility status in major apple growing belts of Himachal Pradesh. They reported that available K content varied from 53.11-278.07 ppm with mean value of 144.07 ppm.

Ganai *et al.* (2020) studied the available potassium content in apple orchards of south Kashmir. They found that available potassium content was higher in surface soil (468.27 kg ha^{-1}) as compared to sub-surface soil (419.85 kg ha^{-1}).

2.1.2.4. Exchangeable calcium

Bhandari and Randhawa (1985) observed that the available calcium content in soils of Himachal Pradesh ranged from 60.0 to 164.0 ppm. Awasthi *et al.* (1998) observed that calcium content in soils of apple orchards in Himachal Pradesh ranged from 1294.0 to 1630.0 ppm with an average value of 1389.0 ppm.

Siddique *et al.* (2009) investigated the calcium content in apple orchards in Punjab and found that orchards were deficient in calcium. However, the calcium content ranged from 0.045-0.16 mg kg^{-1} at the surface soil, while at sub-surface soil it ranged from 0.03-0.13 mg kg^{-1}.

Karlidag *et al.* (2019) evaluated nutritional status of apple orchards in Malatya region of Turkey. They observed that exchangeable calcium content varied from 978.60-2365.3 kg ha^{-1} at 0-30 cm and 858.20-2528.9 kg ha^{-1} at 30-60 cm soil depth. However, 8 per cent of total orchards were poor in calcium content and 12 per cent orchards were found moderate.

2.1.2.5. Exchangeable magnesium

Dris and Niskanen (1998) studied the nutritional status of apple orchards in the Aland Island. They found that the exchangeable magnesium content in the surface soils ranged from 105-288 mg kg^{-1} with the mean value is 185 mg kg^{-1} and in the deeper soils ranged from 100-330 mg kg^{-1} with the mean value is 181 mg kg^{-1} was recorded.

Farida (2005) evaluated the available magnesium content in apple orchards of Kashmir and observed that in surface layer exchangeable magnesium varied from 182.00 to 690.00 ppm with an average value of 443.20, however, in sub-surface layer it ranges from 186.00 to 920.00 ppm with an average value of 556.85 ppm.

Dar *et al.* (2016) studied the nutrient status of different agroclimatic zones of Kashmir and Ladakh. They found that exchangeable magnesium was highest at Patten valley whereas, it was lowest at Kargil site.

Karlidag *et al.* (2019) conducted a study on nutritional status of apple orchards in Malatya region of Turkey and found that the exchangeable magnesium content ranged from 54.40 to 176.40 kg ha^{-1} at 0-30 cm and 49.33 to 171.80 kg ha^{-1} at 30-60 cm depth .All of the orchards were found adequate in terms of exchangeable magnesium content at 0-30 cm depth.

2.1.2.6. Sulphur

Singh (1987) reported that SO4- S in the surface soils of apple orchards of Kinnaur district ranged from 11.0 to 45.0 ppm with a mean value of 25.8 ppm where as in the sub-surface soils it ranged from 14.0-39.1 ppm with mean value of 20 ppm. However, results revealed that all samples were high in sulphur content

Sharma (1990) studied the available sulphur of apple orchards in Mandi district. He found that available sulphur ranged from 7.2 -29.4 ppm in surface soil, whereas, in sub-surface soils it ranged from 6.2-30.7 ppm. It was also found that 15 per cent of the surface and 13 per cent of sub-surface samples were low in sulphur availability, whereas, remaining samples were having medium sulphur availability.

Sharma *et al.* (2008) studied the available sulphur content in soils of district Amritsar, Punjab and found that available sulphur content varied from 24.6-60.0 $kgha^{-1}$ with an average value of 37.6 $Kgha^{-1}$. However, 47 per cent samples were medium, 45 per cent were high and remaining 8 per cent samples were very high in sulphur content.

Dar *et al.* (2016) studied the nutrient status of Agro-climatic zones of Kashmir and Ladakh and they reported that the available sulphur in soil was maximum (53.4 kg ha^{-1}) at Kargil followed by Gurez (41.9 kg ha^{-1}) and least under Pattan (40.2 kg ha^{-1}).

2.1.3. Micronutrients

2.1.3.1. DTPA- extractable zinc

Bhandari and Randhawa (1985) observed the DTPA extractable Zn in apple orchards of Shimla hills, and reported that it ranged from 0.2 -3.5 ppm in the surface soils and 1.7 ppm in sub-surface soils. Singh (1987) studied the DTPA extractable zinc in surface and sub-surface soils in apple orchards of Kinnaur district and found that it varied from 1.5 - 5.0 ppm in surface soil and 1.4- 4.8 ppm in sub-surface soil.

Sharma (1994) studied the zinc content in apple orchards of Chamba district and found that it varied from 0.40 – 8.40 and 0.29 – 5.98 mgkg $^{-1}$with the mean values of 2.91 and 2.39 mgkg $^{-1}$ in the 0-20 and 20-40 cm soil depths, respectively.

Raina *et al.* (2003) studied 144 apple orchards located in different districts in Himachal Pradesh for Zn status. They found that the DTPA extractable Zn was in optimum range in surface soils whereas in sub- surface soils there was zinc deficiency to the extent of 34-100 per cent.

Sharma and Chaudhary (2007) reported that zinc content in soils of district Solan ranged from 0.31-4.7 mg kg^{-1}. However, 61.1 per cent soil samples were sufficient in zinc content, while 23.7 per cent were marginal and rest 15.2 per cent soil samples were found low in zinc content.

2.1.3.2. DTPA –extractable copper

Bhandari and Randhawa (1985) studied the extractable copper content in the surface and sub-surface soils of apple orchards in Shimla district and found that it ranged from 0.8-7.6 ppm with average of 2.3 ppm in surface soil and 0.1-5.3 ppm with average of 1.4 ppm in sub-surface soil. However, 2 per cent of the sub-surface samples were deficient in copper, while others were adequate in copper availability.

Raina (1988) observed the nutritional status of soil of apple orchard in Sirmour. He found that the extractable copper content in Ponta valley ranged from 0.4-8.0 ppm with an average of 2.2 ppm. Sharma (1990) observed the soils of apple orchards in Mandi district and reported that extractable copper ranged from 1.4-4.2 ppm with mean values of 4.4 ppm. It is also observed that 20 per cent of surface and 43 per cent sub-surface samples were medium in copper availability; however, remaining samples were rated high in their copper availability

Tripathi *et al.* (1994) observed that the copper content in soils of Himachal Pradesh varied from 0.4 to 4.8 mgkg^{-1} with an average value 1.7 mgkg^{-1}. Karlidug *et al.* (2019) studied the nutritional status of apple orchards in Malatya region of Turkey and noticed that the extractable copper content decreased with depth. The extractable copper content ranged from 0.89 to 19.08 ppm for 0-30 cm and 0.73 to 24.74 ppm for 30-60 cm depth.

2.1.3.3. DTPA- extractable iron

Sharma (1988) studied the extractable iron in surface and sub-surface layer in apple orchard in Sirmour. It ranged from 30.6-78.3 and 20.4-68.1 ppm with a mean of 51.6 and 39.2 ppm in surface and sub-surface soils, respectively. He also reported that there was high iron availability in the soils of Sirmour district.

Sharma and Bhandari (1992) reported that in soils of apple orchard in Mandi district, DTPA extractable iron ranged from 22.6-11.8 and 12.8-84.5 ppm with an average of 52.9 and 37.4 ppm for surface and sub-surface layers, respectively.

Sharma *et al.* (1999) analysed the DTPA-iron content in soils of different physiographic units of Punjab and concluded that the DTPA-iron content ranged from 0.50 to 8.58 mg kg^{-1}. Highest content of iron (4.45 mg kg^{-1}) was recorded in foot slopes and least (0.67 mg kg^{-1}) was recorded in shoulder soils.

Zia *et al.* (2006) studied the micronutrients status and management in orchards soils of Pakistan. The 329 soil samples of various depths collected throughout the Pakistan from citrus, mango, guava, banana and apple. They reported that the available iron content was found 19 per cent deficient in apple orchards.

Ganai *et al.* (2020) observed that iron content in apple orchards of Kashmir varied from 45.2 to 70.0 ppm in surface soils, while in sub-surface soil it ranged from 32.50-60.12 ppm, with mean values of 56.77 and 51.30 ppm, respectively. They revealed that all samples were high in iron content.

2.1.3.4. DTPA- extractable manganese

Sharma (1990) studied the soils of apple orchard in district Mandi and found that level of DTPA extractable manganese varied from 8.0-68.0 and 6.0-28.0 ppm with an average value of 22.5 and 14.9 ppm for surface and sub-surface soil, respectively.

Khattak and Hussain (2007) evaluated the soil fertility status and nutrition of orchards (apple, peach, pear, citrus and plump) in Galliyat area of Abbottabad district and found that

70 per cent of total samples contained moderate manganese concentration. The available manganese content varied from 0.76-22.5 mg kg^{-1}.

Ganai *et al*. (2020) reported that manganese content was higher in surface soil than in sub surface soils. The results also revealed that manganese content of surface soil varied from 30.12-54.79 ppm with an average value of 42.43 ppm, while in sub-surface soil it varied from 21.50-42.17 ppm with mean value of 33.34 ppm.

Karlidag *et al.* (2019) studied the nutritional status of apple orchards in Malatya region of Turkey. The available manganese content ranged from 2.51 to 25.86 ppm in 0-30 cm and 2.28 to 69.09 ppm in 30-60 cm soil depth.

2.1.3.5. Available boron

Verma (1987) reported that available boron content ranged from 19.7-33.1 ppm with a mean 27.9 ppm in royal delicious apple orchards of Shimla district. Sharma (1988) revealed that in the orchards of Sirmour district the boron content was in the range of 21.0-41.8 ppm with a mean value of 31.0 ppm.

Raina *et al.* (2003) studied the status and transformation of boron in apple orchard of Himachal Pradesh. About 144 samples were collected in different areas of all the apple growing districts of Himachal Pradesh. They found that the surface soils were deficient in boron concentration (21-65%) in Shimla, Kullu, Mandi, Chamba, Sirmour and Kinnaur district of Himachal Pradesh.

Kumar and Babel (2011) observed that available boron content ranged from 0.2 to 2.0 ppm with a mean value of 0.68 ppm. Kumar *et al.* (2012) reported that in mango orchards of Uttar Pradesh, the soils were deficient in available boron content which varied from 0.03-0.55 ppm with a mean of 0.13 ppm.

2.1.3.6. Available molybdenum

Bhandari and Randhawa (1985) carried out a study on distribution of micronutrients in soils of apple orchards in Himachal Pradesh and found that in surface soils the available molybdenum was 0.16 ppm while in sub-surface it was 0.15 ppm. They also reported that in surface soils about 30 per cent and in sub-surface soils about 35 per cent samples were deficient in molybdenum content.

Patel *et al.* (2015) observed the micronutrient status in soils of central India and reported that the available molybdenum in surface and sub-surface soils varied from 0.1 to 8.9 and 3.4 to 9.2 ppm, respectively.

2.2 MACRO AND MICRONUTRIENT CONCENTRATION IN PLANTS

2.2.1. Macronutrients

2.2.1.1 Nitrogen

Sharma (1988) conducted nutritional survey in Sirmour district of Himachal Pradesh and found that the leaf nitrogen content in Red, Royal and Golden Delicious cultivars ranged from 1.99 to 2.62, 1.73 to 2.52 and 1.68 to 2.58 per cent with the mean value of 2.29, 2.25 and 2.18 per cent, respectively.

Sharma and Bhandari (1992) studied the nutritional status of the apple orchards in Mandi district and found that 50 per cent of the apple orchards were deficient their nitrogen status. Sharma (1994) studied the leaf nitrogen content in apple orchards of Chamba district and reported that it ranged from 1.48-2.48 per cent with an average value 1.98 per cent.

Qayum *et al.* (2013) studied the nitrogen content in leaves of apple orchards in Kashmir valley and observed that it varied from 1.87-2.38 per cent having mean value of 2.18 per cent. Sharma *et al.* (2018) studied that soil fertility and leaf nutrient status of micro nutrients in mango orchards in Kangra district of Himachal Pradesh. The nitrogen content in mango leaves indicate variation from 1.12 to 2.24 per cent with the mean value of 1.61 percent.

2.2.1.2 Phosphorus

Dris and Niskanen (1998) studied nutritional status of commercial apple orchards in the Aland Islands and reported that the phosphorus (P) content in the leaves of apple varied from 0.2-0.3 per cent.

Sharma (1988) examined the apple orchards of Sirmour district in Himachal Pradesh and found that the average leaf phosphorus content in Red, Royal, and Golden Delicious cultivars was 0.25, 0.23, and 0.26 per cent respectively. Result showed that only 3 per cent of the orchards were low in phosphorus, while remaining 97 per cent orchards were sufficient to high in phosphorus content.

Sharma *et al*. (2018) conducted a survey on leaf nutrients in apple plantations in Nichar, Kalpa and Pooh region of Kinnaur district in Himachal Pradesh and found that the P content in the leaves of apple ranged from 0.20 to 0.32.

2.2.1.3. Potassium

Singh (1987) reported that potassium (K) content of Red, Royal, Golden Delicious cultivars of apple in Kinnaur district varied from 0.67-1.85, 0.68-1.87 and 0.70-1.91 per cent with mean of 1.24, 1.27 and 1.35 per cent, respectively. About 43 percent of the analysed samples were found low to deficient in their K contents.

Verma (1987) observed the nutritional status of the apple orchard in Shimla district and found that K content in apple orchards of Theog area varied from 1.04-1.25 per cent with mean 1.14 per cent. However, results showed that 43 per cent of samples were low to deficient in their potassium contents.

Dar *et al.* (2014) studied the potassium content in leaves of pear orchards in Kashmir and found that K content varied from 1.62-1.97 per cent having average value of 1.84 per cent. Results also showed that concentration of potassium was optimum to high in range. Sharma *et al.* (2018) evaluated the leaf nutrient status of apple plantations of Kinnaur district of Himachal Pradesh. In apple K content varied from 0.90-1.70 per cent.

2.2.1.5. Calcium.

Awasthi *et al*. (1998) studied the apple orchards of district Shimla of Himachal Pradesh and found that calcium content ranged from 1.50 to 2.20 with an average value of 1.9 per cent. Malik *et al*. (2018) examined the calcium content in leaves of apple cultivars of Red delicious and Benoni at Srinagar and reported that calcium content in Red Delicious varied from 0.63 per cent in May to 2.362 per cent in October and in Benoni leaves it varied from 0.587 per cent in May to 2.112 per cent in October.

Shunfeng *et al*. (2018) evaluated the calcium content in leaves of apple orchards of Bohai Bay and Loess plateau and found that in Bohai Bay region the average content of calcium was 9.63 g kg^{-1}, on the other hand in Loess Plateau calcium content was 10.23 g kg^{-1}. However, the average calcium content in leaves of apple orchards of Loess plateau was more than Bohai Bay region.

Karlidag *et al*. (2019) studied the available calcium content in leaves of apple orchards of Malatya province and concluded that it ranged from 0.58 to 1.38 ppm with an average value of 0.80 ppm. The study also suggested that the calcium content was not adequate in leaf samples.

2.2.1.6. Magnesium

Srivastva *et al.* (1994) studied the seasonal trend of leaf Mg content in Nagpur mandarin and observed that more or less irregular increasing trend of leaf Mg content till August nearly constant from September to October and again irregular fluctuations thereafter were recorded.

Shunfeng *et al.* (2018) reported that average magnesium content in leaf of apple orchards in Bohai Bay was 2.86 g kg^{-1} and in Loess plateau was 2.99 g kg^{-1}. The average value of magnesium content was found higher in Loess plateau.

Karlidag *et al*. (2019) studied the magnesium content in leaves of apple orchards in Malatya province and found that it varied from 0.18 to 0.29 ppm with an average value of 0.22 ppm.

2.2.1.4. Sulphur

Sharma (1988) examined the sulphur content in Red, Royal and Golden Delicious cultivars in Sirmour district of Himachal Pradesh and reported that it ranged from 0.13 -0.26, 0.12-0.22 and 0.12-0.23 per cent, respectively. Results also showed that orchards were sufficiently enriched with sulphur content.

Sharma and Bhandari (1992) revealed that the sulphur content varied from 0.11-0.35 per cent with an average value of 0.19 per cent in Royal Delicious cultivars of Mandi district. Results also indicated that 100 per cent orchards were sufficient in sulphur content. Sharma (1994) observed the sulphur content in the apple leaves of Chamba district and found that it ranged from 0.14-0.41 per cent with an average value of 0.26 per cent.

Dar *et al.* (2015) reported that the available sulphur concentration in foliage of Bartlett cultivar of pear was found in the range of 0.22 to 0.27 per cent with mean values of 0.24 per cent

2.2.2 Micronutrient

2.2.2.1. Zinc

Singh (1987) reported that Zn status in delicious group of apples in Kinnaur district ranges from 12.5–53.1 ppm with mean value of 27.1 ppm. He noted that only 50 per cent orchards have optimum Zn supply.

Sharma and Bhandari (1992) reported that the Zn content in Royal Delicious orchards of Mandi district ranged 17.0 - 38.0 ppm with an average value of 23.8 ppm. They also found that 70 per cent of the orchards were sufficient in leaf Zn status and whereas 30 per cent falls in the low category.

Wani *et al.* (2017) studied the zinc content of pear orchards at Kashmir and results revealed that zinc content in leaves of Bartlett cultivar varied from 44.7-58.3, 39.0-48.0 and 24.0-44.0 ppm with mean value 52.19, 44.30 and 32.10 ppm in high, mid and low altitude orchards, respectively.

Maqbool *et al.* (2018) observed the zinc content in leaves of high-density apple orchards of Kashmir and found that it varied from the 14.72-59.90 per cent in high altitude, in mid altitude it varied from 11.31 to 73.58 per cent, in low altitude it varied from the 36.56 to 38.79 per cent.

2.2.2.2 Manganese

Singh (1987) studied the manganese content in delicious group of apple orchards in Kinnaur district and found that it varied from 19.0 – 81.5 ppm with a mean value of 42.0 ppm. Verma (1987) observed the manganese content in Royal Delicious apple cultivar in Theog was in the range of 56.1-86.2 ppm with an average value of 41.2 ppm.

Sharma and Bhandari (1992) reported that the manganese content was in range of 25.0 -138.0 ppm with an average value of 74.4 ppm in delicious group of apple orchards of Mandi district. About15 per cent apple orchards fall in low manganese content category whereas, rest 85 per cent apple orchards fall in sufficient category.

Sharma (1994) studied the nutritional status of apple orchards of Chamba district of Himachal Pradesh and depicted manganese deficiency in 3 per cent of selected orchards, whereas remaining orchards were sufficient to high in their manganese status.

Sharma *et al*. (2018) conducted a survey of apple plantation in Kinnaur district of Himachal Pradesh. He found that in leaves, manganese content varied from 71.0 mg kg^{-1} to 23.0 mg kg^{-1}.

2.2.2.3 Copper

Verma (1987) observed that copper content in leaves of Royal Delicious in Theog area ranged from 14.0 -26.0 ppm with an average of 19.5 ppm .Sharma (1988) studied the

Red, Royal and Golden Delicious verities of apple in district Sirmour and found leaf copper content of 10.0 -22.0, 10.0 -24.0 and 10.0 -21.0 ppm with mean values of 14 .7, 17.5 and 15.9 ppm, respectively.

Sharma and Bhandari (1992) reported that the copper content in leaves of apples varied from 10-27 ppm in Mandi district of Himachal Pradesh. Karlıdag *et al.* (2019) studied the nutritional status of apple orchards of Malatya province and found that copper content in leaves of apple orchards varied from 4.70 to 61.20 ppm with an average value of 10.72 ppm.

2.2.2.4 Iron

Rana *et al.* (1984) found that apple orchards in Himachal Pradesh are well supplied with iron as its content in leaves varied from 40.0-380.0 ppm. Singh (1987) observed that iron concentration in delicious group of apple orchards of Kinnaur district ranged from 144.2-387.6 ppm with a mean of 256.1 ppm. Qayum *et al.* (2013) examined the leaf iron content in apple orchards in Kashmir valley and found that it ranged from 88.47-143.97 ppm having a mean value of 117.55 ppm.

Sharma *et al.* (2018) observed the leaf iron status of apple plantation in Kinnaur, Himachal Pradesh. He studied leaf iron of apple in Nichar, Kalpa, and Pooh region. The iron content in the leaves of apple orchards varied from 98 to 398 mg kg^{-1}.

2.2.2.5 Boron

Sharma and Bhandari (1992) conducted a nutritional survey of apple orchards in Mandi district of Himachal Pradesh and observed that leaf boron content was deficient in this area. Sharma *et al.* (2018) examined spatial variability of leaf nutrients in apple orchards of Nichar, Kalpa and Pooh region of Himachal Pradesh. Boron concentration was lower in Nichar than Kalpa and Pooh region of Kinnaur. The boron content in the leaves of apple orchards ranges from minimum (17.7 mg kg^{-1}) to maximum (17.7 mg kg^{-1}).

2.2.2.6 Molybdenum

Bhat *et al.* (2017) studied the nutrient status of grape orchards of Jammu and Kashmir and found that the molybdenum content varied from 0.33 to 0.42 ppm. Sharma *et al.* (2018) studied the leaf molybdenum concentration in apple orchards of Kinnaur district of Himachal Pradesh. The concentration of molybdenum ranged from 0.44 mg kg^{-1} to 0.85 mg kg^{-1}.

2.3. RELATIONSHIP OF SOIL PROPERTIES WITH NUTRIENT CONTENT IN SOILS

Raina (1988) studied soils of Paonta valley in district Sirmour and observed that soil pH was negatively and significantly correlated with available P, K, Cu, Fe and Mn content. However, organic carbon was significantly and positively correlated with available K and micronutrient contents.

Tripathi *et al.* (1992) studied the apple orchards of district Mandi and found that there was positive and significant correlation of available potassium with electrical conductivity (r = 0.45**) and organic matter content (r =0.49**). They indicated that the electrical conductivity and organic matter content of apple orchards soils had noticeable influence on the availability of potassium.

Kumar (1996) reported correlation coefficient of some soil characteristics with available nutrient elements in soils of forest nursery in Nahan division in district Sirmour. Parmar *et al*. (1999) observed the significant and negative correlation of Fe, Mn and Cu with soil pH. However, with organic carbon a significant and positive correlation was obtained for Fe and Mn content.

Trivedi *et al.* (2010) reported negative and highly significant relation of EC with available phosphorus in the soils of Madhya Pradesh. Bhanwaria *et al.* (2011) found a negative and non- significant correlation between available micronutrients and EC in soils of Rajasthan.

Chander *et al.* (2014) observed that DTPA-Fe and Mn reported a negative correlation with soil pH and their availability is largely influenced by acidic nature of the soil. But a significant relationship was observed between DTPA-Fe and pH (r= - 0.66*) only. Reduction in availability of Fe with an increase in pH may be attributed to precipitation as insoluble $Fe(OH)_2$.

2.4 RELATIONSHIP OF AVAILABLE NUTRIENT ELEMENTS IN SOIL WITH LEAF NUTREINT COMPOSITION

Bhandari (1973) studied soils of apple orchard in Shimla and found non-significant but positive correlation of available Cu and Fe in both surface and sub-surface soils with their contents in leaves.

Singh (1987) studied the apple orchards of district Kinnaur and found a significant and positive correlation between soil copper and leaf copper contents for all depths, while soil and leaf phosphorus were positively and significantly correlated only in 0-20 cm soil.

Sharma (1988) reported positive and significant correlations between soil and leaf concentrations of nitrogen, phosphorus, potassium and copper in apple orchards of Sirmour district.

Sharma and Bhandari (1992) observed a significant and positive relationship between the contents of copper and iron in leaves and soils, while for manganese, such relationship was significant only for surface soils. On the other hand, relationship between soil and leaf potassium was not found statistically significant.

Sharma (1994) found that available nitrogen and manganese in both the surface and sub-surface soils have positive and highly significant relationship with their respective contents in leaves, whereas; for phosphorus and potassium, the relationship was found to be positive, but statistically non-significant.

Awasthi *et al*. (1998) reported that available N, P, K, Ca and Mg showed significant and positive correlation with the respective leaf nutrient contents. The soil N reflected significant and negative relationship with leaf P, K and Ca and positive with Mg.
Trivedi *et al*. (2010) found a negative and highly significant relation to EC with available P in the soils of Madhya Pradesh.

Chapter-3

MATERIALS AND METHODS

The experimentation and its scientific validation depend upon the methodology adopted. The importance of soil quality attributes varies among different soils in various Agro-ecological conditions and therefore, site specific information is needed for evaluation of soil fertility. This chapter presents the analytical tools and methods employed to achieve the specific objectives under different sections and sub-sections under the following heads;

3.1 General description of the study area

3.2 Selection of apple orchards

3.3 Collection and preparation of soil and leaf samples

3.4 Soil and plant analysis methods

3.5 Interpretation of data

3.6 Statistical analysis

3.1 GENERAL DESCRIPTION OF STUDY AREA

Kinnaur district of Himachal Pradesh is located on both sides of the river Sutlej and shares its eastern boundary with Tibet. Kinnaur is one of twelve administrative districts of Himachal Pradesh, India. The district is itself divided into three developmental blocks namely Pooh, Kalpa, and Nichar. The commercial apple growing areas of Kinnaur region ($30^{0}22^{'}40^{''}$to $33^{0}12^{'}40^{''}$N latitude and $75^{0}47^{'}55^{''}$to $79^{0}04^{'}20^{''}$E longitude) namely Nichar (24 locations), Kalpa (31 locations) and Pooh (27 locations) representing the typical Agro-microclimatic conditions. The district has a total geographical area of 6401 sq. km, covers 11.5% area of the state and ranks 3^{rd} in the state.

In Kinnaur the summer is relatively humid and the winter is extremely cold at the elevation of from 8000 to 10000 feet. In favourable situation, Chango, Leo and Moorang areas the temperature of July and August is 20^{o} to 22^{o} C and in October temperature is about 10^{o} C. The winter is often rigorous, and in some parts people do not venture out of their homes because of heavy snow. The average annual rainfall in the district is 816 mm. The major source of irrigation are small water channels or the kuhls, in the district and an area of 77.86 sq km is brought under irrigation by surface water source like, major khads and nallahs.

The district receives heavy snowfall from November end or early December till March or sometimes April. During this period, the area remains totally cut off from rest of the area. The higher peaks of Kinnaur district are completely covered with snow throughout the year.

3.2 SELECTION OF APPLE ORCHARDS

Based on uniformity in respect of age and tree vigour, 30 representative orchards from Nichar, Kalpa and Pooh blocks of Kinnaur district, during 2019, were selected. Starking Delicious variety of apple was selected for study because most of the well-established orchards in these blocks are under this variety.

3.3. COLLECTION AND PREPARATION OF SOIL AND LEAF SAMPLES

3.3.1 SOIL SAMPLING

Soil samples were collected from the basins of trees from two depths i.e. 0-15 (cm) and 15-30 (cm) in each selected orchard during the months of October before application of fertilizers. The soil samples were air dried and grinded with help of wooden pestle and mortar and passed through a 2mm sieve. The processed samples were stored in plastic container with appropriate labels for further analysis.

3.3.2 LEAF SAMPLING

Representative leaf samples comprising of 60-100 leaves were taken from the same orchard where the soil samples were collected. Fully expanded leaves were drawn from 8-10 randomly selected trees in each selected orchard between 15June -5 August. The leaf samples were washed with ordinary water and then with 0.1N HCl followed by washing with distilled water. They were dried in an oven at 60_+5^{0}C for 72 hours. The dried samples were ground in stainless steel grinder for proper mixing of plant material and stored in paper bags for subsequent analysis (Chapman, 1964).

3.4 SOIL AND PLANT ANALYSIS METHODS

The soil and plant samples were further analyzed for different parameter like texture, pH, electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC) , available macro and micro-nutrients (N,P,K Ca, Mg, S, Fe, Cu, Zn, Mn, B, Mo) using standard methods given below.

3.4.1 Soil texture:

Soil texture was determined by relative distribution of sand, silt and clay in the sample by Hydrometer method (Bouyoucos,1972).

3.4.2 Soil pH and electrical conductivity

Soil pH was determined in 1:2:5 soil water suspension and electrical conductivity (EC) of the supernatant liquid was recorded as per the procedure outlined by Jackson (1973).

3.4.3 Organic carbon

It was determined by wet digestion method (Walkley and Black, 1934).

3.4.4 Cation exchange capacity

Cation exchange capacity (CEC) was determined by the Sodium and ammonium acetate Centrifuge method Bower *et al.* (1952).

3.4.5 Base saturation percentage

Percent base saturation is the percentage of the CEC occupied by the basic cations Ca^{2+},Mg^{2+} , Na^{+} and K^{+}. The percentage base saturation was calculated as follows:

BSP (%) = Exchangeable bases[(Ca^{2+} + Mg^{2+}+ K^{+} + Na^{+})/ CEC]×100

Where BSP = Base saturation percentage

3.5 AVAILABLE MACRO AND MICRO-NUTRIENTS

Surface and sub-surface soil samples were analysed for the following nutrient elements.

3.5.1 Available nitrogen

It was determined by alkaline permanganate method of Subbiah and Asija (1956).

3.5.2 Available phosphorous

Available phosphorous was estimated by extraction with 0.5M sodium bicarbonate at pH 8.5 described by Olsen *et al*. (1954).

3.5.3 Available potassium

It was estimated by the method of Merwin and Peech (1951), where soil was extracted with neutral normal ammonium acetate and determined by flame photometer.

3.5.4 Exchangeable Ca and Mg

Exchangeable Ca and Mg in the ammonium acetate extract were determined by atomic adsorption spectrophotometer (Sarma *et al*., 1987).

3.5.5 SO_4^{2-} Sulphur

SO_4-S was extracted by Morgan's reagent (Morgan 1937) and determined by turbidity method by (Chesnin and Yien 1950).

3.5.6 DTPA extractable micronutrients

Available Fe, Mn, Cu and Zn contents in soil were extracted by using DTPA-extractant at pH 7.3 (Lindsay and Norvell, 1978) and determined by Atomic Absorption Spectrophotometer.

3.5.7 Available Boron

Boron was extracted by the method given by Tondon (1993). Twenty grams of soil was taken in a 250 ml boron free conical flask. To this 40 ml of double distilled water and 0.5 g activated charcoal were added. The flask was heated on hot plate to first sign of boiling, exactly for the 5 minutes. Then contents were allowed to cool and then filtered by using Whatman No. 42 filter paper. Then B in extract was determined by using Azomethine –H method (Gupta, 1979).

3.5.8 Available Molybdenum.

Molybdenum was extracted with ammonium bicarbonate-DTPA and was determined on ICPS as per the method suggested by Soltanpour *et al*. (1982).

Soil Nutrient Indices

Soil Nutrient Indices (SNI) were also worked out to depict the available status of each macro and micro nutrient at the district level by using the formula proposed by Parker *et al.* (1951) as given below;

$$SNI = \frac{(NL \times 1) + (NM \times 2) + (NH \times 3)}{NT}$$

Where

NL	=	number of samples falling in low category of nutrient status
NM	=	number of samples falling in medium category of nutrient status
NH	=	number of samples falling in high category of nutrient status
NT	=	total number of samples analyses for a given nutrient

3.6 PLANT ANALYSIS

Leaf samples were digested in a diacid of HCl: $HClO_4$ (4:1) for P, K, Ca, Mg S, Fe, Cu, Zn, Mn and Mo estimation and final volume was made to 100 ml (Jackson, 1973).

3.6.1 Nitrogen

The total leaf nitrogen was determined by micro-kjeldhal's method as outline in A.O.A.C (1970).

3.6.2 Phosphorous and Potassium

Phosphorus in the digest was determined by vandomolybdate yellow color method (Jackson,1973) and potassium was determined by Flame photometer. (Jackson, 1967).

3.6.3 Calcium and Magnesium: Leaf calcium and magnesium were determined by Flame photometer and Atomic Absorption Spectrophotometer respectively.

3.6.4 Sulphur

Leaf Sulphur was estimated by turbidimetric method (Chesnin and Yien, 1950).

3.6.5 Micronutrients

Leaf Zn, Cu, Fe and Mn were determined on Atomic Absorption Spectrophotometer (Vogel, 1978).

3.6.6 Boron

Boron content of the leaves was determined by dry ashing method 0.5g of dried plant sample was placed in a silica crucible and ashed at 150^o C in a muffle furnace. The grey white ash was dissolved in 10 ml of 6N HCL and heated to 80^o C on a hot plate to evaporate to dryness. The residue was dissolved in deionised water and transferred to 25 ml volumetric flask and volume was made up to the mark with deionised water. The solution was then filtered through Whatman No - 42 filter paper. The B in the extract was determined by using Azomethine-H method (Gupta, 1979).

3.6.7 Molybdenum

Molybdenum was estimated on ICPS as per the procedure given by Soltanpour *et al*. (1982).

3.7 INTERPRETATION OF DATA

Results of soil analysis were interpreted using the critical limits given in Table 3.1 and Table 3.2 and plant analysis results were interpreted using Table 3.3.

A SNI (Soil nutrient indices) value <1.67, 1.67 to 2.33 and > 2.33 indicate low, medium and high nutrient status of soils, respectively (Ramamoorthy and Bajaj, 1969).

Table 3.1 Critical limits used for available macronutrient of the soil

Sr. No.	Nutrient elements	Soil fertility class			References
		Low	Medium	High	
1	Organic carbon (g/kg)	< 0.5	0.5-1.0	> 1.5	Bhandari and Tripathi (1979)
2	Nitrogen (kg/ha)	< 280.0	280.0-560.0	> 560.0	Anonymous (2015)
3	Phosphorous (kg/ha)	< 10.0	10.0-25.00	> 25.00	
4	Potassium (kg/ha)	< 118.0	118-260.0	>260.0	
Secondary micronutrients					
		Deficient	**Sufficient**		
1	Available Ca [cmol(p)/kg^{-1}]	<1.5	1.5		Anonymous (2015)
2	Available Mg[cmol(p)/kg^{-1}]	<1.0	1.0		
3	Sulphate S (kg/ ha^{-1})	<22.5	22.5		

Table 3.2 Critical limits for available micronutrients

Micronutrients (mg/kg)	Availability			References
	Low	Medium	High	
Zn	<1.0	1.0-3.0	>3.0	Lindsay and Norvell, (1978)
Cu	<0.3	0.3-0.8	>0.8	
Fe	<4.0	4.0-6.0	>6.0	
Mn	<1.2	1.2-3.5	>3.5	
B	<0.5	0.5-1.0	>1.0	Tandon, (1989)
Mo	<0.05	0.05-0.1	>0.1	Soltanpour *et al.* (1982)

Table 3.3 Critical limits of nutrients for plant samples

Sr. No. A. Macronutrients (per cent)	Nutrient Element	Concentration			
		Low	Medium	High	References
1	N	1.50-1.80	1.80-2.40	>2.50	Plant analysis laboratory of Ohio State Universitys, USA
2	P	0.15-0.18	0.18-0.28	>0.30	
3	K	1.00-1.20	1.30-1.80	>1.90	
4	Ca	1.00-1.20	1.30-1.70	>1.80	
5	Mg	0.20-0.24	0.24-0.36	>0.37	
6	S	<0.1	>0.1	-	
B. Micronutrients (ppm)					
7	Zn	15.0-20.0	20.0-50.0	>50	
8	Cu	5.0-10.0	10.0-20.0	>20	
9	Fe	30.0-35.0	35.0-150.0	>150	
10	Mn	25.0-30.0	31.0-150.0	>150	
11	B	20.0-28.0	28.0-50.0	>50	
12	Mo	<0.1	0.1-0.5	>0.5	Soltanpour *et al.* (1982)

STASTICAL ANALYSIS:

The descriptive statistics viz., range, mean, standard deviation and coefficient of variation were derived for each soil (0 to 15 and 15-30 cm) and leaf parameter. Also, the data was subjected to statistical analysis by adopting simple correlations to find out the extent of relationship between the soil nutrient characteristics and leaf nutrient status. The descriptive analysis was done by data analysis function of MS Excel 2007 and correlation analysis was done by using SPSS V16.0 (IBM corp. Released 2007).

Chapter-4

RESULTS AND DISCUSSION

The results emerging from the present investigation entitled ‘‘**Nutritional survey of apple(*Malus domestica* Borkh) orchards in Kinnaur district of Himachal Pradesh”** have been described under the following heads:

4.1 Soil properties

- **4.1.1 Soil texture**
- **4.1.2. Soil pH, electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC) and base saturation percentage (BSP).**
- **4.1.3. Macronutrient status of soil**
- **4.1.4 Micronutrient status of soils**

4.2 Nutrient indices of soil

4.3 Leaf nutrient status

4.4 Relationship of soil properties with nutrient contents in soil

4.5 Relationship of soil properties with plant nutrients

4.1 SOIL PROPERTIES

4.1.1 Soil texture

The data given in Table 4.1 revealed that soil of apple orchards of Kinnaur district varied in texture. Sand content in surface layer (0-15 cm) and sub surface layer (15-30 cm) varied from 54 to 66 and 47to 60 per cent with mean values of 59.33 and 53.53 per cent, respectively. The CV of 6.10 per cent and 6.39 per cent for sand content in both surface and subsurface depths respectively indicated that it varied spatially. The silt content in surface soil (0-15cm) and subsurface (15-30cm) depths varied from 18 to 28 and 20 to 32 per cent with mean values 21.40 and 25.03 per cent respectively. The CV of 14.49 and 13.49 per cent for silt content in surface and subsurface depths showed that these varied spatially in both the depths. The clay content in the surface layer (0-15cm) varied from 15 to24 percent with mean values of 19.06 per cent in sub surface layer (15-30cm) it varied from 17 to 26 percent with the mean values of 21.60 per cent.

Table 4.1 Soil texture of apple orchards in Kinnaur district

Orchards No.	% Sand		%Silt		%Clay		Textural class	
	Soil depth (cm)							
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	56	53	23	22	17	25	Sandy loam	Sandy clay loam
2	63	53	19	23	18	24	Sandy loam	Sandy clay loam
3	57	48	20	28	23	24	Sandy loam	Sandy clay loam
4	62	49	19	26	19	25	Sandy loam	Sandy clay loam
5	57	51	26	30	17	19	Sandy loam	Sandy clay loam
6	61	53	20	28	19	19	Sandy loam	Sandy clay loam
7	60	57	22	23	18	20	Sandy Clay loam	Sandy clay loam
8	62	60	21	22	17	18	Sandy loam	Sandy clay loam
9	64	58	20	23	16	19	Sandy loam	Sandy clay loam
10	56	51	25	28	19	20	Sandy Clay loam	Sandy clay loam
11	60	57	20	22	20	21	Sandy loam	Sandy clay loam
12	58	53	20	24	22	23	Sandy loam	Sandy clay loam
13	54	52	28	29	18	19	Sandy clay loam	Sandy loam
14	66	60	18	20	16	20	Sandy loam	Sandy clay loam
15	64	49	19	25	17	26	Sandy loam	Sandy loam
16	61	50	18	24	21	26	Sandy loam	Sandy clay loam
17	63	47	18	32	19	21	Sandy loam	Sandy clay loam
18	65	52	20	31	15	17	Sandy loam	Sandy clay loam
19	63	54	19	24	16	22	Sandy loam	Sandy clay loam
20	57	55	27	28	16	17	Sandy loam	Sandy clay loam
21	54	52	26	27	20	21	Sandy Clay loam	Sandy clay loam
22	55	51	27	29	18	20	Sandy loam	Sandy clay loam
23	59	57	24	25	17	18	Sandy loam	Sandy clay loam
24	64	59	19	22	17	19	Sandy loam	Sandy clay loam
25	58	56	19	20	23	24	Sandy Clay loam	Sandy loam
26	54	52	22	23	24	25	Sandy loam	Sandy clay loam
27	58	55	19	26	23	25	Sandy Clay loam	Sandy clay loam
28	57	54	20	21	23	25	Sandy loam	Sandy clay loam
29	55	53	25	26	20	21	Sandy loam	Sandy clay loam
30	57	55	19	20	24	25	Sandy loam	Sandy clay loam
Range	**54-66**	**47-60**	**18-28**	**20-32**	**15-24**	**17-26**		
Mean	**59.33**	**53.53**	**21.40**	**25.03**	**19.06**	**21.60**		
SD	**3.62**	**3.42**	**3.10**	**3.37**	**2.69**	**2.88**		
CV	**6.10**	**6.39**	**14.49**	**13.49**	**14.10**	**13.35**		

The CV of 14.10 per cent and 13.35 per cent for clay content indicated that these varied spatially in both surface and sub surface depths, respectively.

The cumulative range data showed that there was a decrease in the percentage of sand and increase in percentage of silt and clay with increase in soil depth, indicating translocation of finer soil fractions to lower depths. The higher clay content in the subsurface layers was also reported by Gupta and Verma (1992) which may be attributed to the downward translocation of clay under higher rain fall conditions and due to development of textural horizons. The results were in line with the findings of Singh (1987), Sharma and Bhandari (1992) and Sharma *et al.* (2018). They also reported higher clay content in the subsurface layers of district Kinnaur, Mandi and Kangra, respectively.

The analysis of sand, silt and clay (Table 4.1) revealed that apple orchards soils of Kinnaur district varied in texture from sandy loam to sandy clay loam with surface layer being predominately sandy loam and sub surface layer showing dominance of sandy clay loam soil.

4.1.2 SOIL pH, ELECTRICAL CONDUCTIVITY (EC), ORGANIC CARBON (OC), CATION EXHANGE CAPACITY (CEC) AND BASE SATURATION PERCENTAGE (BSP).

4.1.2.1 Soil pH

The data presented (Table 4.2) revealed that soil pH ranged between 5.79 to 7.31 and 5.98 to 7.51 in surface and sub surface depths, respectively. The CV in surface (7.82%) and sub surface (7.01%) depths for soil pH indicated that, it varied spatially in both the depths. The data indicates lower pH in surface depths compared to sub-surface depth. This might be due to leaching of bases from surface to sub surface layer (Kaistha *et al.,* 1990, Sahu and Patnaik, 1990).

Considering the overall pH values of the district, it was slightly acidic to slightly alkaline in range. These observations indicated that soil reaction was favourable for availability of most of the mineral nutrients.

4.1.2.2 Electrical conductivity (EC)

The data depicted (Table 4.2) revealed that electrical conductivity in the surface layer ranged from 0.12 to 0.66 dSm^{-1} with the mean value of 0.38 dSm^{-1}. The subsurface depth recorded lower value ranging from 0.11 to 0.62 $dSm^{-1}$with the mean value of 0.29 dSm^{-1}. The CV of 42.20 per cent and 44.97 per cent for EC in both surface and sub surface depths, respectively indicated that these varied spatially. High values of EC were obtained for surface layer as compared to subsurface layer. The decrease in EC with increase in depth has also been reported by Raina (1998) and Sharma (1994).

4.1.2.3 Organic carbon (OC)

The perusal of the data in the Table 4.2 revealed that organic carbon content in surface and sub surface layer of apple orchards ranged from 12.21 to 22.56 g kg^{-1} and 10.72 to 21.45 g kg^{-1} with a mean value of 17.00 g kg^{-1} and 15.23 g kg^{-1}, respectively. The CV for OC indicated that it varied spatially in both surface and sub surface depths. The results obtained are in accordance with the findings of Singh (1987) and Sharma (1988). They reported that the average organic carbon content was found 21.0 to 22.0 g kg^{-1} in the districts Kinnaur and Sirmour, respectively.

The data given in Table 4.2 further revealed that the organic carbon content decreased in sub-surface layer which may be due to the addition of organic manures and litter fall to the surface soils. These findings are in line with those of Singh and Datta (1988), Triphati *et al* (1994), and Pal *et al* (2013).

4.1.2.4 Cation exchange capacity (CEC)

The examination of the data presented in Table 4.3 revealed that the cation exchange capacity of the surface soils of the district Kinnaur ranged from 9.49 to 38.97 cmol(p^+) kg^{-1} with the mean value of 24.10 cmol(p^+) kg^{-1}. The lowest cation exchange capacity of 9.49 cmol (p^+) kg^{-1} was reported in Nichar block whereas the highest cation exchange capacity of 38.97 cmol(p^+) kg^{-1} was reported in Pooh block of district Kinnaur. This high cation exchange capacity may be attributed to high organic matter and clay content in the soils.

High organic matter and more addition of FYM results in higher CEC, as organic matter act as a chelating agent in the soils. Similar findings are reported by Verma and Tripathi (2007), Kumar *et al* (2011) and Chandel (2013).

Table 4.2 Soil pH, electrical conductivity (dSm^{-1}) and organic carbon (g/kg^{-1}) in apple orchards of Kinnaur district

Orchard No.	pH		EC		OC	
	Soil depth(cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	5.89	6.15	0.21	0.19	12.21	10.72
2	6.03	6.25	0.26	0.21	14.15	12.05
3	5.92	6.29	0.14	0.12	15.46	14.56
4	6.35	6.61	0.23	0.21	21.75	20.55
5	6.52	6.63	0.33	0.26	16.25	15.11
6	5.79	5.92	0.17	0.12	17.25	16.34
7	6.67	6.78	0.51	0.41	13.42	11.65
8	7.19	7.31	0.42	0.39	12.46	10.55
9	6.51	6.78	0.36	0.32	13.85	12.14
10	6.89	7.10	0.67	0.62	14.35	12.15
11	6.03	6.31	0.66	0.32	20.85	19.5
12	5.86	6.25	0.53	0.46	22.31	21.45
13	5.78	5.98	0.36	0.27	15.95	14.85
14	6.21	6.38	0.31	0.29	14.22	13.15
15	6.02	6.41	0.29	0.19	19.25	18.16
16	6.31	6.31	0.61	0.21	18.41	15.72
17	6.61	6.88	0.42	0.38	19.51	16.81
18	6.86	7.12	0.62	0.51	16.72	14.71
19	6.56	6.89	0.41	0.32	16.31	14.16
20	6.46	6.57	0.27	0.19	17.72	15.91
21	7.42	7.52	0.12	0.11	19.12	17.61
22	6.56	6.71	0.19	0.14	16.43	14.21
23	7.16	7.23	0.31	0.21	16.81	15.52
24	6.72	6.89	0.27	0.22	14.61	12.81
25	6.86	6.9	0.32	0.29	17.83	14.46
26	7.36	7.51	0.41	0.31	15.82	13.36
27	6.98	7.23	0.27	0.17	18.92	15.72
28	7.24	7.39	0.61	0.52	22.56	21.12
29	7.15	7.19	0.51	0.48	16.31	14.26
30	7.31	7.51	0.48	0.37	19.26	17.68
Range	**5.79-7.31**	**5.98-7.51**	**0.12-0.66**	**0.11-0.62**	**12.21-22.56**	**10.72-21.45**
mean	**6.57**	**6.77**	**0.38**	**0.29**	**17.00**	**15.23**
SD	**0.51**	**0.47**	**0.16**	**0.13**	**2.79**	**2.92**
CV	**7.82**	**7.01**	**42.20**	**44.97**	**16.42**	**19.17**

4.1.2.5 Base saturation percentage (BSP)

The data given in Table 4.3 revealed that the base saturation percentage in surface soil of district Kinnaur varied from 23.53-98.62 % with the mean value of 62.01 %, whereas the CV of BSP is 34.35 %. The minimum (23.53) and maximum (98.62) BSP was reported in Nichar and Pooh block, respectively. Higher the cation exchange capacity of soil, higher will be the base saturation percentage in soil.

Table 4.3 Cation exchange capacity cmol $(p^+)kg^{-1}$ and base saturation percentage (%) of soil in Kinnaur district.

Orchard No.	CEC	BSP
1	19.27	74.33
2	28.45	48.66
3	33.56	48.28
4	18.24	60.42
5	16.51	85.31
6	14.21	88.11
7	17.01	97.84
8	23.12	85.59
9	28.45	48.37
10	20.08	72.86
11	19.11	77.31
12	17.19	80.23
13	34.07	36.49
14	37.56	38.32
15	30.41	46.24
16	38.97	48.09
17	14.48	98.62
18	35.47	32.18
19	23.49	53.65
20	33.38	23.53
21	20.63	80.08
22	24.01	26.43
23	28.45	44.36
24	9.49	76.43
25	32.31	56.34
26	18.67	79.04
27	17.48	86.17
28	16.42	61.95
29	21.28	58.74
30	31.26	46.46
Range	**9.49-38.97**	**23.53-98.62**
Mean	**24.10**	**62.01**
SD	**7.95**	**21.30**
CV	**32.99**	**34.35**

As regards the base saturation status, relatively higher values of this parameter were observed in soils of Kinnaur district which might be due to higher amount of Ca^{2+} occupying the exchange sites on the colloidal complex. Further, this may be safely ascribed to the nature of parent material of these soils having predominance of dolomite. Similar results regarding the base saturation status of the soils of the mountains have earlier been reported by Singh *et al.* (1991) and Kumar (1996)

4.1.3 MACRO NUTRIENT STATUS OF SOIL

4.1.3.1 Available nitrogen

The available nitrogen in the surface 0-15 cm layer ranged from 266.56-623.51 kg ha^{1} with the mean value of 441.39 kg ha^{-1} (Table 4.4). In the sub-surface 15-30 cm layers values ranged from 259.15-619.61 kg ha^{-1} with the mean value of 427.96 kg ha^{-1}. The CV of 26.79 % and 26.75 % for available N indicated that it varied spatially in the surface and sub-surface depths, respectively. The fertility categorization given in Table 4.8 and 4.9 showed that the N content in the apple growing areas of Kinnaur district ranged from medium to high and also the available N was found to decrease with increase in soil depth (Table 4.4).

The results are in line with the findings of Sharma *et al* (2018) who reported that the cultivated soil of Kinnaur region of Himachal Pradesh were medium to high in available nitrogen. The surface layer registered higher N content as compared to sub-surface layer which obviously is result of addition of organic manures, fertilizers and litter decomposition in surface layer itself. A decrease in available nitrogen content in sub-surface layer has also been reported by Sharma (1988), Sharma (1990) and Talatam (2001).

4.1.3.2 Available phosphorus

The data regarding the status of available phosphorus is portrayed in Table 4.4. The data revealed that the available phosphorus content ranged from 19.97 to 118.62 kg ha^{-1} in surface depth with mean value of 60.29 kg ha^{-1} , whereas, in sub-surface depth it ranged from 18.41- 111.31 kg ha^{-1} with the mean value of 54.55 kg ha^{-1} . The CV of 50.98 per cent in surface depth and 51.83 per cent in sub-surface depth for available P distribution indicated that it varied spatially in both the depths. The phosphorus content in apple growing areas of Kinnaur district ranged from medium to high and also the available P found to decrease with an increase in soil depth (Table 4.8 and 4.9). A decrease in available P with increase in soil depth has been reported by Sood *et al.* (1991). The results are in agreement with the findings of Raina (1988) and Sharma *et al*. (2018). They also reported medium to high available phosphorus content in sub-surface layers of district Sirmour and Kinnaur respectively.

4.1.3.3 Available potassium

The data on the available potassium content is enumerated in Table 4.4. The data showed that the available potassium in surface depth varied from 247.17 to 792 kg ha^{-1} with mean value of 563.58 kg ha^{-1}. For the sub-surface depth, the values varied from 245.21 to 789.33 kg ha^{-1} with the mean value of 550.52 kg ha^{-1}. The CV of 28.73 per cent in surface depth and 29.37 per cent in sub-surface depth for available potassium indicated that, it varied spatially in both the depths. The available potassium was found to decrease with increase in soil depth. A decrease in potassium content in subsurface layers has also been reported by Singh (1987).

The data depicted in Table 4.3 further revealed that the available potassium was found in high range in apple growing soils of Kinnaur district (Table 4.8 and 4.9). The finding of Sharma *et al* (2018) revealed that apple growing areas of Kinnaur district were medium to high in available potassium.

4.1.3.4 Exchangeable calcium

The data in Table 4.5 shows that neutral normal ammonium acetate extractable calcium content in surface depth ranged from 2.55 to 10.23 cmol (p^{+}) kg^{-1} with a mean value of 6.99 cmol (p^{+}) kg^{-1}. In sub-surface depth, it ranged from 2.13 to 9.96 cmol (p^{+}) kg^{-1} with mean value of 6.59 cmol (p^{+}) kg^{-1}. The CV of 34.90 per cent in surface depth and 38.32 per cent in sub-surface depth indicated that, exchangeable calcium varied spatially in both the depths. The exchangeable calcium content decreased with an increase in soil depth. Similar trend of distribution has also been reported by Sharma and Bhandari (1992) and Kumari (2015).

Soils of both the surface and sub-surface depths were reported higher in exchangeable calcium. This may be attributed to use of single super phosphate as well as to the nature of parent material of hill soils in the orchards of Kinnaur district.

Nair and Chamuah (1988) and Bala and Sahu (1993) have also reported calcium as dominant cation in the soils of pine forest of Himachal Pradesh.

Table 4.4 Available nitrogen, phosphorus and potassium contents (kg ha^{-1}) in apple orchards soils of Kinnaur district.

Orchard No.	Nitrogen		Phosphorus		Potassium	
	Soil depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	275.96	272.83	19.97	18.41	520.21	512.43
2	268.56	266.24	43.16	42.11	357.32	342.28
3	282.24	272.56	22.61	19.32	534.62	526.21
4	363.11	347.56	32.82	30.12	247.16	245.21
5	366.23	362.42	26.76	24.81	497.23	495.36
6	398.32	378.91	42.09	40.23	470.22	462.13
7	449.11	422.84	88.02	86.21	534.62	478.08
8	488.39	446.56	79.32	69.43	608.49	559.56
9	428.87	424.31	86.24	72.32	693.24	652.62
10	542.34	487.32	83.68	68.22	761.93	767.41
11	266.56	259.15	20.69	19.12	427.21	424.11
12	277.57	274.92	21.22	19.64	398.12	394.21
13	321.61	315.12	49.12	46.71	524.92	496.23
14	427.87	422.98	38.41	36.22	650.11	648.16
15	286.29	285.71	92.36	90.12	761.93	758.02
16	479.98	474.98	109.26	98.67	672.37	648.96
17	586.28	583.54	84.92	65.98	777.12	775.18
18	542.32	531.29	21.92	20.12	478.19	476.12
19	615.52	598.16	81.23	70.11	601.06	596.12
20	625.26	613.39	85.21	78.26	650.11	648.19
21	311.28	298.64	61.63	50.28	578.82	552.41
22	431.56	421.61	37.52	35.61	447.67	443.58
23	482.62	481.11	39.62	36.41	297.06	278.12
24	442.36	438.24	23.58	20.23	397.03	394.25
25	587.58	582.84	72.56	69.58	288.58	278.92
26	623.51	619.61	118.62	111.31	792.02	788.14
27	578.62	542.35	72.04	70.13	731.22	672.98
28	528.36	523.89	62.28	51.58	788.01	785.15
29	457.28	451.31	77.28	64.26	629.07	626.19
30	506.27	438.56	114.71	111.02	792.02	789.33
Range	**266.56-623.51**	**259.15-619.61**	**19.97-118.62**	**18.41-111.31**	**247.17- 792.02**	**245.21-789.33**
mean	**441.39**	**427.96**	**60.29**	**54.55**	**563.58**	**550.52**
SD	**118.28**	**114.49**	**30.74**	**28.27**	**161.95**	**161.74**
CV	**26.78**	**26.75**	**50.98**	**51.83**	**28.73**	**29.38**

4.1.3.5 Exchangeable magnesium

A perusal of the data presented in Table 4.5 revealed that the exchangeable magnesium in the surface 0 to15 cm layers ranged from 3.26 to 8.91 cmol (p^+) kg^{-1} with the mean value of 5.93 cmol (p^+) kg^{-1}. For the sub-surface 15 to 30 cm layers it ranged from 2.92 to 8.72 cmol (p^+) kg^{-1} with the mean value of 5.50 cmol (p^+) kg^{-1} (Table 4.4). The CV of 31.75 per cent and 34.50 per cent for exchangeable magnesium in surface and sub-surface depths, respectively, indicated that exchangeable magnesium varied spatially in both the depths (Table 4.8 and 4.9).

The exchangeable magnesium content decreased with an increase in soil depth. Singh and Raman (1982) also observed a decreasing trend of soil magnesium with increase in soil depth in the North-Eastern Himalayan soils. Higher exchangeable magnesium in surface depth may be attributed to the nutrient management practices followed by the orchardist of the area and also due to the parent material. Similar findings were reported by Sharma *et al* (2002). They reported that the soils of Fatehpur block of Himachal Pradesh were sufficient in magnesium.

4.1.3.6 Sulphate sulphur

The insight of the data in Table 4.5 showed that the SO_4^{2-}-S ranged from 55.60 to 75.60 kg ha^{-1} and 52.18 to 73.50 kg ha^{-1} with mean values of 65.75 kg ha^{-1} and 63.09 kg ha^{-1} in surface and sub-surface depths, respectively. The CV indicated that spatial variation in both the depths. Both surface and sub-surface soils were found high in SO_4^{2-} sulphur content (Table 4.8 and 4.9).

The higher content of SO_4^{2-}-S in the soils may be due to the presence of gypsiferrous minerals and ferruginous nature of parent material (Wadia,1996). Similar trend has also been observed by Jamio (2014) and Sharma *et al.* (2018) for Himachal Pradesh soils. The data depicted in Table 4.5 further revealed that sulphur decreased with increase in soil depth. Higher organic matter and use of fertilizers like SSP may be contributing to higher sulphur supplies in the surface soils. Similar trend of distribution has also been reported by Sharma (1994).

Table 4.5 Exchangeable calcium, magnesium (cmol (p^+) kg^{-1}) and sulphate sulphur ($kg\ ha^{-1}$) contents in apple orchards of Kinnaur district.

Orchard No.	Calcium		Magnesium		Sulphur	
	Soil depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	4.86	4.32	8.86	8.31	58.10	55.23
2	8.43	7.98	4.98	4.32	61.90	58.18
3	9.87	9.43	5.71	5.24	57.60	53.82
4	3.52	2.98	6.97	6.43	62.20	59.61
5	6.26	5.99	7.23	6.85	55.60	52.18
6	8.35	7.98	3.45	2.99	56.90	52.26
7	8.54	8.11	7.25	6.95	65.20	63.10
8	10.12	9.87	8.91	8.72	63.60	61.20
9	9.18	8.95	3.61	3.12	64.30	61.50
10	9.32	8.98	4.42	4.10	71.20	69.20
11	8.36	8.91	5.89	5.45	73.90	71.50
12	5.89	5.23	7.41	7.10	75.60	73.50
13	6.98	6.75	5.23	4.92	66.90	63.50
14	7.85	7.21	5.78	5.32	71.10	68.40
15	9.28	8.76	3.89	3.46	75.20	73.20
16	9.10	8.79	8.41	8.11	67.20	65.30
17	8.91	8.37	4.47	3.99	68.90	65.80
18	4.52	3.93	6.33	5.89	59.70	56.70
19	3.47	2.96	8.43	7.94	67.60	65.40
20	2.87	2.24	4.22	3.91	58.60	55.30
21	8.58	8.12	7.26	6.89	61.10	59.20
22	2.55	2.13	3.26	2.92	67.30	65.20
23	3.91	3.32	8.34	7.92	69.20	65.30
24	2.85	2.42	4.20	3.87	59.30	57.30
25	9.45	9.10	7.80	7.23	58.20	56.20
26	10.23	9.96	3.56	2.92	74.20	72.80
27	5.72	5.31	8.41	7.94	71.30	68.50
28	6.16	5.94	3.25	2.88	64.90	62.80
29	6.89	6.32	4.66	4.12	75.80	73.20
30	7.81	7.35	5.87	5.42	69.90	67.40
Range	**2.55-10.23**	**2.13-9.96**	**3.26-8.91**	**2.92-8.72**	**55.6-75.6**	**52.18-73.5**
mean	**6.99**	**6.59**	**5.94**	**5.51**	**65.75**	**63.09**
SD	**2.44**	**2.53**	**1.88**	**1.90**	**6.19**	**6.55**
CV	**34.90**	**38.33**	**31.75**	**34.50**	**9.42**	**10.37**

4.1.4 MICRONUTRIENT STATUS OF SOIL

4.1.4.1 DTPA extractable iron

The DTPA extractable iron in the surface 0-15 cm layers ranged from 18.91 to 69.52 mg kg^{-1} with the mean value ranged from 34.43 mg kg^{-1}. In sub-surface soils it ranged from 17.56 to 65.58 mg kg^{-1} with the mean value of 31.88 mg kg^{-1}(Table 4.6). The CV of 44.08 per cent and 47.87 per cent for DTPA iron indicated that, it varied spatially in the surface and sub-surface depths, respectively. The surface soils registered higher available Fe contents as compared to the sub-surface soils probably due to the higher organic matter in the surface soils. Similar findings has also been reported by Talatam (2001), Singh and Rathore (2013) and Mogta (2015). The iron content was found high in range in apple growing areas of Kinnaur district of Himachal Pradesh (Table 4.8 and 4.9). Verma (1987) and Sharma and Bhandari (1992) have also observed high iron content in the orchard soils of Shimla and Mandi, respectively.

4.1.4.2 DTPA extractable manganese

The perusal of the data in Table 4.6 revealed that the status of DTPA extractable manganese in the orchards soil ranged from 11.20 to 41.91 mg kg^{-1} with the mean value of 26.38 mg kg^{-1} in surface depth. However, in sub-surface depth it ranged from 10.12 to 40.12 mg kg^{-1} with a mean value of 25.05 mg kg^{-1}. The CV in surface (35.68 %) and sub-surface (36.13%) depths indicated that, DTPA Mn varied spatially in both surface and sub-surface depths. The DTPA extractable Mn decrease with increase in soil depth (Table 4.6). The results are in accordance with that of Kaul (1968) who observed a decrease in Mn content with the increasing depth of soils.

All orchards were high in Mn status (Table 4.8 and 4.9). Sharma *et al.* (2018) reported the occurrence of adequate levels of Mn in orchards soils of Kinnaur district of Himachal Pradesh

4.1.4.3 DTPA extractable zinc

The data depicted in Table 4.6 revealed that the DTPA extractable zinc content in the surface and sub-surface soil ranged from 1.10 to 4.58 mg kg^{-1} and 0.58 to 4.10 with the mean value of 2.89 mg kg^{-1} and 2.44 mg kg^{-1}, respectively.

4.6 DTPA extractable iron, manganese and zinc contents (mg kg^{-1}) in apple orchards of Kinnaur district.

Orchard No.	Iron		Manganese		Zinc	
	Soil depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	18.91	17.56	11.21	10.12	1.61	1.1
2	21.27	18.67	14.56	13.23	1.81	1.24
3	23.67	11.94	17.34	16.22	2.12	1.98
4	18.98	17.64	16.47	15.98	2.56	2.26
5	25.64	24.12	28.21	26.1	1.78	1.29
6	32.96	31.69	36.61	34.31	2.78	2.23
7	39.74	38.12	31.26	29.52	1.91	0.71
8	41.98	40.12	35.12	33.18	2.11	1.24
9	19.72	17.86	34.27	32.21	4.27	4.23
10	44.64	43.12	31.06	30.12	3.19	2.98
11	22.16	19.98	14.08	13.68	1.1	0.64
12	23.29	20.89	11.34	10.12	1.51	0.58
13	57.98	56.64	19.56	18.54	2.47	2.31
14	25.61	24.16	23.12	22.21	3.31	3.12
15	28.98	27.81	28.17	27.98	3.12	2.88
16	34.69	33.16	33.18	32.13	2.87	2.34
17	69.52	65.58	34.56	32.16	2.67	2.24
18	48.91	47.19	29.13	27.32	3.98	3.15
19	63.41	61.28	32.16	30.63	4.28	3.96
20	58.98	57.61	36.12	34.14	4.58	4.16
21	26.21	25.16	15.66	14.62	2.16	1.79
22	29.11	26.27	13.17	12.64	3.45	2.93
23	34.21	28.91	17.98	16.98	2.78	2.07
24	18.12	17.64	19.12	18.12	3.56	3.09
25	25.71	22.38	34.74	33.94	3.18	3.12
26	38.91	27.62	29.18	28.71	4.21	3.76
27	23.74	22.32	38.59	36.28	4.31	3.94
28	25.61	24.91	41.91	40.12	3.27	2.86
29	64.28	61.16	24.64	23.14	2.48	2.16
30	26.12	25.13	38.91	37.22	3.44	2.96
Range	**18.91-69.52**	**17.56-65.58**	**11.2-41.91**	**10.12-40.12**	**1.1-4.58**	**0.58-4.1**
Mean	**34.43**	**31.88**	**26.38**	**25.05**	**2.89**	**2.44**
SD	**15.18**	**15.26**	**9.41**	**9.05**	**0.94**	**1.05**
CV	**44.08**	**47.87**	**35.68**	**36.13**	**32.45**	**43.09**

The CV of 32.45 per cent and 43.09 per cent for DTPA Zn indicated that it varied spatially in surface and sub-surface depths, respectively. The DTPA extractable Zn was found to decrease with increase in soil depth. The DTPA extractable Zn was found medium to high in range in apple growing areas of Kinnaur district (Table 4.8 and 4.9).

. The results get strength from the findings of Sharma *et al* (2018) who also found decrease in Zn content with increase in depth in Mango orchards of Kangra district. Higher content of DTPA extractable Zn in surface layers may be due to higher organic carbon content and more favourable soil reaction

4.1.4.4 DTPA extractable copper

The data in Table 4.7 indicated that the DTPA extractable copper contents ranged from 1.38 to 5.12 mg kg^{-1} in the surface depth and 1.19 to 4.75 mg kg^{-1} in the sub-surface depth with the mean values 2.91 mg kg^{-1} and 2.22 mg kg^{-1}, respectively. The CV of 39.09 per cent in surface and 45.11 per cent in sub-surface depth showed spatial variation in both the depths. The DTPA extractable copper content decreased with increase in depth, however, followed similar trend for all the blocks as by the surface layer. The overall status of DTPA extractable copper was found high in apple growing areas of Kinnaur district. the soils (Table 4.8 and 4.9)

These results are in conformity with the findings of Tripathi *et al.*(1994) and Mahajan (2001) who also found high levels of DTPA extractable copper in soils of Himachal Pradesh

4.1.4.5 Available boron

The available boron content in the surface depth 0-15 cm layers ranged from 0.24 to 1.78 mg kg^{-1} with the mean value of 0.89 mg kg^{-1} . In the sub-surface 15-30 cm layers it ranged from 0.19 to 1.61 mg kg^{-1} with the mean value of 0.69 mg kg^{-1},respectively. (Table 4.7). The CV indicated that, available boron varied spatially in both the depths. The availability of boron decrease with increasing soil depth.

The results are in accordance with that of Sharma *et al*. (2018) who reported the range of available boron from 0.36 to 1.70 mg kg^{-1} with the mean value of 0.68 mg kg^{-1} in apple growing areas of Kinnaur district. A sharp decrease in available micronutrient contents except molybdenum in the sub-surface depths indicated hardly any leaching of lower layers, however these elements were being mined by vegetation and redeposited in the surface layer having higher contents of compexing organic materials (Follet and Lindsay, 1970).

4.2.3.6 Available molybdenum

The perusal of the data in Table 4.7 revealed that the available Mo ranged from 0.03 to 0.25 mg kg^{-1} in the surface depth and 0.07 to 0.32 mg kg^{-1} in the sub-surface depth with mean values of 0.12 mg kg^{-1} and 0.16 mg kg^{-1} , respectively. The CV indicated that, available Mo varied spatially in both surface (53.88 %) and sub-surface (45.47%) depth. Available Mo was medium in surface (70%) and sub-surface soils (80%) (Table 4.8 and 4.9).

The data further revealed that the availability of Mo increased with depth which may be attributed to the higher pH in sub-surface depth as compared to surface depth (Table 4.2) Similar trend has also been observed by Bhandari and Randhawa (1985) and Bhat *et al.*(2017).

4.2. NUTRIENT INDICES OF SOIL

The data in Table 4.8 of surface layer revealed that 13.33 and 30 per cent samples of Kinnaur district fall under low category with respect to N and Mo respectively. All the soil samples of Kinnaur district were high in P, K, Ca, Mg, S, Cu, Fe and Mn.

Nutrient indices (Table 4.8) indicated that soils of the district, as regards the nutrients status were high in available potassium (3.00) available sulphur (3.00), exchangeable calcium (3.00) and exchangeable magnesium (3.00), DTPA extractable copper (3.00), iron (3.00) and manganese (3.00). However, with respect to boron (1.33) , DTPA extractable zinc (2.08) and molybdenum (1.70) medium in nutrient status.

4.7 DTPA extractable copper, available boron and molybdenum content (mg kg^{-1}) in apple orchards of Kinnaur district.

Orchard No.	Copper		Boron		Molybdenum	
	Soil depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	1.38	1.19	0.31	0.22	0.07	0.09
2	1.91	1.42	0.64	0.53	0.16	0.22
3	2.43	1.42	0.24	0.19	0.25	0.32
4	1.98	1.01	0.56	0.44	0.08	0.16
5	2.64	1.98	0.69	0.53	0.04	0.11
6	1.59	1.13	0.78	0.65	0.18	0.22
7	2.91	1.64	0.82	0.71	0.06	0.08
8	3.19	2.94	0.48	0.32	0.12	0.17
9	4.41	3.99	0.91	0.79	0.14	0.19
10	2.18	1.64	0.36	0.24	0.22	0.25
11	1.51	1.41	0.19	0.21	0.09	0.15
12	1.78	1.14	0.43	0.34	0.06	0.08
13	2.61	1.98	0.48	0.37	0.21	0.28
14	3.91	2.68	0.52	0.48	0.24	0.31
15	2.69	1.98	0.68	0.61	0.21	0.26
16	1.64	1.23	0.72	0.68	0.05	0.08
17	4.46	3.52	0.86	0.72	0.07	0.09
18	3.79	2.98	0.99	0.81	0.05	0.08
19	5.12	4.75	1.12	1.1	0.04	0.07
20	4.71	3.69	1.18	1.02	0.03	0.07
21	2.21	1.82	0.29	0.18	0.16	0.22
22	3.82	2.71	0.38	0.26	0.17	0.18
23	5.11	3.51	2.52	0.34	0.22	0.24
24	1.86	1.32	1.52	1.42	0.18	0.23
25	1.89	1.32	1.26	1.52	0.15	0.21
26	2.61	1.91	1.23	1.12	0.08	0.12
27	3.91	2.64	2.27	0.74	0.05	0.07
28	2.68	2.14	1.37	1.23	0.13	0.17
29	4.11	3.54	1.78	1.61	0.12	0.14
30	2.34	1.98	1.34	1.21	0.18	0.22
Range	**1.38-5.12**	**1.19-4.75**	**0.24-1.78**	**0.19-1.61**	**0.03-0.25**	**0.07-0.32**
Mean	**2.91**	**2.22**	**0.89**	**0.69**	**0.12**	**0.16**
SD	**1.13**	**1.00**	**0.57**	**0.42**	**0.06**	**0.07**
CV	**39.09**	**45.11**	**64.51**	**61.21**	**53.88**	**45.47**

Table 4.8. Nutrient indices of surface soils of Kinnaur district

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
	Surface soil depth 0-15				
N	13.33	66.67	20	2.06	Medium
P	-	20	80	2.8	High
K	-	-	100	3.00	High
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High
S	-	-	100	3.00	High
Cu	-	-	100	3.00	High
Zn	-	56	44	2.08	Medium
Fe	-	-	100	3.00	High
Mn	-	-	100	3.00	High
B		65	35	1.33	Medium
Mo	10	90	-	1.70	Medium

Table 4.9 Nutrient indices of sub-surface soils of Kinnaur district.

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
	Surface soil depth 15-30				
N	16.66	66.66	16.68	2.20	Medium
P	-	23.31	76.8	2.76	High
K	-	-	100	3.00	High
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High
S			100	3.00	High
Cu	-	-	100	3.00	High
Zn		57	43	2.00	Medium
Fe	-	-	100	3.00	High
Mn	-	-	100	3.00	High
B		60	40	1.40	Medium
Mo	20	80		1.80	Medium

Nutrient indices of sub-surface layers (Table 4.9) indicated that soils, as regards the nutrient status are high in phosphorus (2.76) and potassium (3.00) and exchangeable calcium (3.00) and magnesium (3.00). DTPA extreactable copper (3.00), manganese (3.00) and DTPA iron (3.00). However, with respect to available nitrogen (2.20), available molybdenum (1.80) and boron (1.40) soils are medium in nutrient status.

4.3.1 Leaf Nutrient Status

4.3.1 Macronutrients

The insight of the data depicted in Table 4.10 revealed that leaf nitrogen content in the apple orchards of Kinnaur district of Himachal Pradesh varied from 1.39 to 2.94 per cent with the mean value of 2.20 per cent. The CV of 22.32 per cent for leaf nitrogen indicates that it varied spatially. The concentration of leaf nitrogen was found sufficient in all the apple orchards of Kinnaur district (Table 4.14)

Table 4.10 showed that the leaf phosphorus content in the apple orchards of Kinnaur district ranged from 0.14 to 0.35 per cent with a mean value of 0.24 per cent . The CV of 27.20 per cent for leaf phosphorus indicated that it varied spatially. In all the orchards, leaf phosphorus content was found sufficient. The overall status of leaf phosphorus in the apple orchards was medium to high in range (Table 4.14)

Leaf potassium content in apple orchards of Kinnaur district ranged from 1.12 to 2.40 per cent with the mean value of 1.74 per cent. The CV of leaf potassium was 18.08 per cent which indicated that it varied spatially. Like nitrogen and phosphorus, leaf potassium content was also found sufficient in all the apple orchards of Kinnaur district (Table 4.14)

The sufficient concentration of leaf nitrogen, phosphorus and potassium in the apple orchards of Kinnaur district may be ascribed to the medium availability of nitrogen and high availability of phosphorus and potassium in these soils to the plants. Similar findings has also been reported by Kumar and Rehalia (2007) who recorded an average of 2.23 per cent leaf nitrogen, 0.12 per cent phosphorus and 0.64 per cent potassium in mango under suitable conditions.

4.10 Leaf nitrogen, phosphorus and potassium contents (%) in the apple orchards of Kinnaur district

Orchard No.	Nitrogen	Phosphorus	Potassium
1	1.48	0.26	1.31
2	1.56	0.35	1.42
3	1.78	0.22	1.51
4	2.81	0.24	1.38
5	1.98	0.28	1.78
6	2.78	0.18	1.61
7	2.56	0.14	1.68
8	2.48	0.31	1.71
9	2.34	0.17	1.76
10	1.43	0.19	1.43
11	2.01	0.15	1.12
12	2.94	0.18	1.36
13	2.13	0.35	1.46
14	2.09	0.28	1.97
15	2.19	0.34	1.56
16	2.34	0.21	1.78
17	2.48	0.17	1.93
18	2.74	0.31	1.79
19	2.66	0.33	1.81
20	2.56	0.25	1.65
21	1.82	0.14	1.66
22	1.76	0.29	2.34
23	2.81	0.16	1.98
24	1.56	0.32	2.40
25	1.48	0.23	2.30
26	1.39	0.22	1.65
27	2.56	0.19	1.72
28	2.64	0.26	2.12
29	2.78	0.24	1.89
30	1.98	0.28	2.18
Range	**1.39-2.94**	**0.14-0.35**	**1.12-2.40**
Mean	**2.20**	**0.24**	**1.74**
SD	**0.49**	**0.07**	**0.31**
CV	**22.32**	**27.20**	**18.08**

4.11 Leaf calcium, magnesium and sulphur contents (%) in the apple orchards of Kinnaur district

Orchard No.	Calcium	Magnesium	Sulphur
1	1.19	0.31	0.11
2	1.12	0.42	0.14
3	1.24	0.23	0.13
4	1.36	0.21	0.09
5	1.44	0.29	0.16
6	1.59	0.22	0.21
7	1.62	0.33	0.19
8	1.78	0.39	0.23
9	1.98	0.25	0.18
10	2.11	0.32	0.24
11	0.81	0.29	0.17
12	2.18	0.38	0.26
13	2.12	0.41	0.19
14	2.41	0.43	0.29
15	2.31	0.42	0.31
16	2.23	0.49	0.28
17	2.29	0.14	0.26
18	1.88	0.46	0.32
19	1.72	0.36	0.29
20	1.69	0.47	0.31
21	1.55	0.31	0.11
22	2.28	0.26	0.23
23	2.13	0.42	0.3
24	0.82	0.22	0.28
25	1.27	0.36	0.27
26	1.98	0.38	0.31
27	2.46	0.33	0.29
28	1.99	0.29	0.24
29	2.43	0.44	0.18
30	2.47	0.26	0.28
Range	**0.81-2.47**	**0.21-0.49**	**0.09-0.32**
Mean	**1.82**	**0.34**	**0.23**
SD	**049**	**0.09**	**0.07**
CV	**27.01**	**26.52**	**30.48**

The leaf Ca, Mg and S contents Table 4.11 ranged from 0.81 to 2.47 per cent, 0.21 to 0.49 per cent and 0.09 to 0.32 per cent with the mean values fom 1.82 , 0.34 and 0.23 per cent, respectively. The CV of 27.01%, 26.52 % and 30.48 % for leaf Ca, Mg and S, respectively indicated that, these varied spatially with respect to the orchards.

These results are in accordance with the findings of Kumar and Rehalia (2007) and Sharma *et al* (2018) They reported the medium concentration of sulphur, calcium and magnesium in leaves of mango orchards of Kangra district of Himachal Pradesh.

4.3.2 Micronutrient

The data presented in Table 4.12 revealed that the leaf iron content ranged from 84.00 to 349.00ppm in the apple orchards of Kinnaur district of Himachal Pradesh with the mean value of 221.17 ppm. The CV of 41.67 per cent for leaf iron indicated its spatial variation. The ovearall status of leaf iron was medium to high in range in all the apple orchards of Kinnaur district of Himachal Pradesh (Table 4.14)

The leaf zinc content in the apple orchard of Kinnaur district ranged from 12.51 to 82.12 ppm with the mean value of 36.40 ppm (Table 4.12) The leaf zinc content varied spatially as indicated by CV of 47.51 per cent. The concentration of leaf Zn was observed low to medium in range in apple orchards of Kinnaur district of Himachal Pradesh (Table 4.14)

The leaf copper content in the apple orchards of Kinnaur district of Himachal Pradesh in Table 4.12 ranged from 17.41 to 59.42 ppm with a mean value of 30.07 ppm. The CV of 42.73 per cent of leaf copper showed that it varied spatially. The concentration of leaf copper in the apple orchards of Kinnaur district was sufficient in range (Table 4.14)

The data depicted in Table 4.13 revealed that the manganese content ranged from 30.48 to 85.62 ppm in the apple orchards of Kinnaur district of Himachal Pradesh with the mean value of 59.29 ppm. The CV of 26.41 per cent for leaf manganese indicated that it varied spatially. The concentration of leaf manganese in all the apple growing areas of Kinnaur district was in sufficient range (Table 4.14)

These results are in accordance with the findings of Kumar *et al.* (2012) who reported Cu, Zn, Fe and Mn with mean value of 26.50 ppm, 33.60 ppm, 396.00ppm and 146.50ppm, respectively in mango leaf samples at Malihabad region.

The leaf boron and molybdenum ranged from 17.56 to 42.46 ppm and 0.46 to 0.86 ppm with a mean value of 29.75ppm and 0.63 ppm, respectively. The CV of 23.67 % and 19.01 % for leaf B and Mo respectively indicated that, these varied spatially with respect to the orchards. The concentration of boron was observed medium in range and molybdenum was found high in range in apple orchards of Kinnaur district (Table 4.14)

Table 4.12 Leaf iron, zinc and copper contents (ppm) in the apple orchards of Kinnaur district.

Orchard No.	Iron	Zinc	Copper
1	212.00	12.51	17.54
2	154.00	14.61	19.56
3	246.00	25.41	22.41
4	178.00	39.17	26.31
5	226.00	20.14	26.81
6	358.00	19.42	31.41
7	163.00	18.11	25.46
8	318.00	39.19	17.29
9	118.00	32.21	20.42
10	143.00	47.51	22.26
11	96.00	59.73	24.22
12	102.00	31.63	27.71
13	84.00	39.62	19.57
14	156.00	28.41	32.43
15	248.00	26.52	18.41
16	312.00	39.67	31.62
17	296.00	25.78	32.61
18	354.00	67.21	32.67
19	289.00	71.62	52.53
20	332.00	82.12	58.41
21	98.00	58.41	23.67
22	126.00	47.81	28.23
23	91.00	29.61	59.42
24	178.00	38.61	51.42
25	248.00	42.42	56.43
26	315.00	31.52	17.41
27	294.00	17.96	38.41
28	349.00	33.76	23.51
29	342.00	22.51	18.72
30	209.00	28.83	25.19
Range	**84.00-349.00**	**12.51-82.12**	**17.41-59.42**
Mean	**221.17**	**36.40**	**30.07**
SD	**92.16**	**17.30**	**12.85**
CV	**41.67**	**47.51**	**42.73**

4.13 leaf manganese, boron and molybdenum contents (ppm) in the apple orchards of Kinnaur district.

Orchard No.	Manganese	Boron	Molybdenum
1	52.61	17.56	0.46
2	62.31	22.41	0.48
3	56.91	19.27	0.52
4	33.36	24.74	0.63
5	37.62	35.66	0.56
6	47.37	42.46	0.71
7	31.51	33.29	0.73
8	67.32	38.77	0.69
9	56.41	26.49	0.76
10	60.27	41.23	0.79
11	84.36	31.12	0.47
12	37.48	22.21	0.52
13	47.62	24.31	0.66
14	57.38	27.11	0.73
15	30.48	26.21	0.59
16	77.18	40.21	0.72
17	85.62	24.71	0.63
18	68.42	33.61	0.81
19	75.32	29.41	0.84
20	69.82	19.51	0.86
21	77.13	25.31	0.47
22	52.62	21.12	0.56
23	63.43	28.63	0.64
24	62.71	38.12	0.71
25	42.56	35.16	0.49
26	67.13	32.81	0.56
27	57.16	30.42	0.65
28	77.16	31.12	0.71
29	77.1	39.71	0.49
30	62.19	29.81	0.52
Range	**30.48-85.62**	**17.56-42.46**	**0.46-0.86**
Mean	**59.29**	**29.75**	**0.63**
SD	**15.66**	**7.04**	**0.12**
CV	**26.41**	**23.67**	**19.01**

These results are in accordance with the finding of Sharma *et al.*(2018) who reported that boron and molybdenum contents ranged from 17.70 to 45.00 and 0.45 to 0.85 ppm, in apple leaf samples, respectively.

Table 4.14 Plant nutrient status of apple orchards of Kinnaur district.

Nutrient	Percent samples		
	Low	Medium	High
N	-	15	85
P	-	53	47
K	-	-	100
Ca	60	40	-
Mg	-	100	-
S	40	60	-
Cu	-	80	20
Zn	5	95	-
Fe	-	60	40
Mn	-	73.3	26.7
B	-	100	-
Mo	-		100

4.4 REALATIONSHIP OF SOIL PROPERTIES WITH NUTRIENT CONTENTS IN SOIL

The data presented in Table 4.15 showed the relationship of nutrient elements with soil pH, EC and organic carbon contents. The data revealed that the soil pH of the surface layers was significantly and positively co-related with available N (r=0.62*), P (r=0.47**) and B (r=0.54**), but was found to be significantly and negatively correlated with available Zn (r= -0.37*) and Cu (r= -0.15*). For the sub-surface layer, the soil pH was significantly and positively correlated with available N (r=0.56**), P (r= 0.41*) and B (r=0.39*) but, significantly negatively correlated with available Zn (r=-0.31*) and Cu (r=-0.12*).

Soil pH is considered as the driver of soil fertility because of its direct impact on plant growth and nutrient availability. Negative relationship of pH with available micro nutrients cations has been reported by Bhandari and Randhawa (1985). Mishra *et al.* (1990) observed a positive relationship of soil pH with available P in foot hills of Himalayas.

The electrical conductivity of the surface layers was found to be significantly and positively correlated with Ca (r=0.47**) and also the sub-surface layers, a significantly positive correlated (r=0.38*). The organic carbon content in the surface soils was significantly and positively correlated with available N(r=0.54**) and Ca (r=0.28**). For the sub-surface layers the organic carbon was positively correlated with soil N (r- 0.47**) and Ca (0.23**) and significant and positively correlated with Zn (0.02**) (Table 4.15) The significant and positive relationship of organic carbon with nitrogen content of soil is obvious since the bulk of total nitrogen in soils is present in organic combinations.

The significant and positive correlation of EC with exchangeable Ca was also reported by Kakar (2014) and Kumari (2015).Raina and Goswami (1988) reported that the organic matter besides being a major source of nutrient ions such as N and P, promotes the availability of micronutrient through its chelating effects. Similar results have also been observed by Singh (1987) and Raina (1988) in orchards soils of district Kinnaur and Sirmour, respectively. The studies of Bhandari and Randhawa (1985) reported that the positive correlation of organic carbon with available micro nutrient elements in soils of Himachal Pradesh.

Table 4.15 Relationship (r –values) of soils chemical properties with available nutrient elements in apple orchards of Kinnaur district

Property / Nutrient Element	Soil pH		Electrical conductivity		Organic carbon	
	Soil depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
N	0.62*	0.56**	0.28	0.30	0.54**	0.47**
P	0.47**	0.41*	0.27	0.15	0.006	0.11
K	0.32	0.34	0.30	0.31	0.001	-0.08
Ca	0.13	0.22	0.47**	0.38*	0.28	0.23**
Mg	0.02	0.08	0.18	0.14	-0.13	-0.13
S	0.05	0.04	0.01	-0.07	-0.06	-0.19
Cu	-0.15*	-0.12*	0.29	0.38*	-0.08	-0.11
Zn	-0.37**	-0.31*	-0.02	0.03	0.02**	-0.09
Fe	0.32	0.36*	-0.01	0.17	-0.13	-0.19
Mn	0.41	0.39	0.30	0.31	0.06	-0.02
B	0.54**	0.39*	0.04	0.26	0.10	-0.008
Mo	-0.07	-0.13	-0.29	-0.21	-0.20	-0.08

4.5 RELATIONSHIP OF SOIL PROPERTIES WITH PLANT NUTRIENTS

The data presented in Table 4.16 showed that the surface soil pH was a significantly positive relationship with leaf K (r=0.522**), Mn (r =0.393*) and B (r=0.370*). The electrical conductivity of the soil was found to be significantly and positive correlated with leaf B (r=0.548*). The organic carbon content of the soil was significant and positively correlated with leaf N (r=0.398*). The available N in the soil was significant and positively correalated with leaf K (r =0.519**), S (r = 0.668*), Fe (r=0.548**) Cu (r=0.505**) Mn (r=0.359*) and Mo (r=0.554*).

The P content in the soil was significant and positive correlated with leaf S (0.399*) and Ca (r=0.500**). The available K was significant and positively correlated with leaf Ca (r=0.587**), Fe (r=0.395*) and Mn (r=0.316*) whereas signicantly and negatively correlated with leaf Cu (r-0.316*). The S content in soil was significant and positively correlated with leaf S (r=0.364*) and Ca (r=0.618). The Cu content in the soils was significant and positively correlated with leaf N (r=0.443*), S (r =0.416*) and Ca (r=0.483**). The Zn content in soils was significantly and positively with leaf Cu (r=0.433*) , while it was significant and negatively correlated with leaf Fe (r=-0.381*) and B (r=-0.086*). The Fe content in soil was significantly and positively correlated with leaf Ca (r=0.372*) and significantl and negatively correlated with leaf Mn (r=-0.387*).

The B content in soils was significant and positively correlated with Leaf Cu (r=0.547**), while it was significant and negatively correlated with the leaf K (r=-0.502**). The Mn content in soil was significant and positively correlated with leaf Mn (r=0.161**), Mo (r=0.530**) and B (r=0.485**). The Mo content in soils was significant and positively correlated with leaf Mo (r=0.150**) and significant and negatively correlated with the leaf Zn (r=-0.384**).

The data given in the Table 4.17 showed that the sub-surface soil pH was found to be significant and positively correlated with the leaf K (r=0.468**) and Mn (r=0.384*). The EC content in soil was significant and positively correlated with leaf B (r=0.380**). The OC content in the soils was significant and positively correlated with the leaf N (r=0.428*). The available soil N was significant and positively correlated with the leaf K (r=0.532**), S (r=0.676**), Fe (r=0.557), Cu (r=0.537**) Mn (r=0.371*) and Mo (r=0.548**).

Table 4.16 Relationship (r -values) of surface soil characteristics (0-15cm depth) with leaf nutrient contents of apple orchards of Kinnaur district

Leaf / Soil	N	P	K	S	Ca	Mg	Fe	Zn	Cu	Mn	B	Mo
pH	-0.005	-0.156	0.522**	0.272	0.276	0.035	0.226	0.159	0.137	0.393*	0.370*	0.064
EC	0.216	-0.121	-0.071	0.327	0.248	0.266	0.131	0.201	-0.141	0.325	0.548*	0.249
OC	0.398*	-0.242	-0.027	0.109	0.165	-0.148	0.064	0.200	0.108	0.082	-0.106	-0.172
N	0.151	-0.044	0.519**	0.668**	0.361*	0.112	0.548**	0.334	0.505**	0.359	0.360	0.554**
P	-0.006	-0.095	0.195	0.399*	0.500**	0.192	0.344	0.042	-0.049	0.205	0.276	0.228
K	-0.030	-0.025	0.072	0.343	0.587**	0.032	0.395*	-0.038	-0.316*	0.351	0.115	0.262
S	0.166	-0.141	-0.104	0.364*	0.618**	0.247	-0.162	-0.069	-0.221	0.157	0.053	0.108
Ca	-0.286	-0.271	-0.240	-0.120	0.074	-0.004	0.056	-0.338	-0.565	0.036	0.271	0.247
Mg	0.161	-0.107	-0.162	-0.098*	-0.121	0.249	-0.076	-0.009	0.217	-0.081	0.016	0.115
Fe	0.337	0.099	0.038	0.318	0.372*	0.270	0.391	0.355	0.159	-0.387*	0.145	0.142
Zn	0.071	0.184	0.477	0.653	0.337	0.123	-0.381*	0.375	0.433*	0.172	-0.086*	0.611*
Cu	0.443*	0.032	0.334	0.416*	0.483**	0.187	0.165	0.262	0.397	0.279	-0.147	0.476
Mn	0.216	-0.040	0.349	0.192	0.371	0.013	0.656	0.050	0.174	0.161**	0.485**	0.530**
B	0.318	-0.867	-0.502**	0.506	0.299	0.165	0.296	-0.110	0.547**	0.174	0.261	0.175
Mo	-0.349	0.137	0.178	-0.62	0.081	-0.106	-0.384*	-0.218	-0.115	-0.134	-0.029	0.150**

Table 4.17 Relationship (r-values) of sub – surface soil characteristics (15-30cm depth) with leaf nutrient contents of apple orchards of Kinnaur district.

Leaf / Soil	N	P	K	S	Ca	Mg	Fe	Zn	Cu	Mn	B	Mo
pH	0.006	-0.137	0.468**	0.282	0.287	-0.022	0.207	0.168	0.096	0.384*	0.291	0.058
EC	0.198	-0.037	0.027	0.241	0.290	0.131	0.130	0.100	-0.194	0.186	0.380*	0.257
OC	0.428*	-0.217	-0.108	0.024	0.123	-0.167	-0.016	0.164	0.039	0.005	0.162	-0.182
N	0.159	0.038	0.532**	0.676**	0.339	0.137	0.557**	0.338	0.537**	0.371*	0.328	0.548**
P	0.023	0.058	0.190	0.423	0.487	0.230	0.329	0.009	-0.039	0.116	0.258	0.167
K	-0.051	0.001	0.080	0.356	0.577	0.022	0.406	-0.014	-0.0306	0.365	0.108	0.250
S	0.126	-0.133	-0.080	0.361*	0.596**	0.248	-0.170	-0.044	-0.222	0.141	0.070	-0.115
Ca	-0.298	-0.278	-0.254	-0.135	0.039	0.020	0.039	-0.316	0.521**	0.056	0.286	-0.254
Mg	0.174	-0.108	-0.156	-0.088	-0.111	0.253	-0.083	0.009	0.219	-0.032	0.207	-0.091
Fe	0.379*	0.130	0.051	0.314	0.378*	0.278	0.371	0.375	0.172	0.367*	0.174	0.456*
Zn	-0.025	0.198	0.443*	0.557**	0.353	0.069	0.329	0.357	0.391*	0.173	0.043	-0.536**
Cu	0.402*	0.099	0.297	0.375	0.426*	0.168	0.218	-0.346*	0.318*	-0.415*	-0.079	0.462**
Mn	0.240	-0.033	0.353	0.508**	0.374*	0.025	0.651	0.061	0.124	0.155	0.408**	0.062
B	0.072	0.193	0.595**	0.432*	0.092	0.086	0.527**	0.509	0.358	0.188	0.381	0.162
Mo	0.379*	0.186	0.107	-0.156	-0.044	-0.120	-0.396*	-0.182	-0.140	-0.170	-0.047	0.171

The S content in the soils was significant and positively correlated with the leaf S (r=0.361*) and Ca (r=0.596**). The Ca content in soil was significant and positively correlated with the leaf Cu (0.521**). The Zn content in soil was significant and negatively correlated with the leaf Mo (r=-0.536**). The Cu content in soil was significant and positively correlated with the leaf Cu (r=0.318*) and N (r=0.402**), while it was significant and negatively correlated with the leaf Mn (r=-0.415*) and Zn (r=-0.346*). The Mn content in soil was significant and positively correlated with the leaf S (r=0.508**), Ca (r=0.374*) and B (r=0.408**). The Mo content in soil was significant and positively correlated with leaf N (r=0.379*) and significant and negatively correlated with leaf Fe (-0.396*).

These results are in accordance with the findings of Sharma and Bhandari (1992) and Awasthi *et al.* (1998) who reported the significant and positive correlation among leaf and soil samples. Awasthi *et al.* (1999) found negative and significant correlation between leaf N and K of peach orchards in Sirmour district. Sharma *et al.* (2018) observed the significant and positively correlation with leaf and soil samples of Kinnaur district of Himachal Pradesh.

Chapter-5

SUMMARY AND CONCLUSION

Present investigation entiled "**Nutritional survey of apple (*Malus domestica* Borkh orchards in Kinnaur district of Himachal Pradesh"** was carried out during 2019 in the Nichar, Kalpa and Pooh blocks of Kinnaur district of Himachal Pradesh with the objective to study the nutritional and fertility status of apple orchards and the relationship between soil properties and leaf nutrient content. Soil and plant samples from 30 representative apple orchards of Kinnaur district were collected. Soil samples were collected from two depths of 0-15 and 15-30 cm at each place and analysed for mechanical separates, organic carbon, pH, EC, available macro and micronutrient elements.

- Leaf samples were collected from commercially important cultivar of apple namely, Royal as per sampling time recommended by Tandon (1989). Leaf samples were collected from the orchards from which soil samples were also collected and analysed for all macro and micronutrient elements. The results obtained are summarized as below:

- The sand, silt and clay percentage in the surface depth ranged from 54 to 66, 18 to 28 and 15 to 24 per cent with the mean value of 59.33, 21.40 and 19.06 per cent, respectively. The contents of the respective fractions in the sub-surface depth varied from 47 to 60, 20 to 32 and 17 to 26 per cent with the mean values of 53.53, 25.03 and 21.60 per cent. The decrease in percentage of sand and increase in percentage of silt and clay was observed from surface to sub-surface depths.

- In the surface and sub-surface depths, pH ranged from 5.79 to 7.31 and 5.98 to 7.51 with the mean values of 6.57 and 6.77. The EC varied from 0.12 to 0.66 and 0.11 to 0.62 dSm^{-1} with the mean values of 0.38 and 0.29 dSm^{-1} in the surface and sub-surface depths, respectively. The organic carbon content in surface and sub-surface depths varied from 12.21to 22.56 and 10.72 to 21.45 g kg^{-1} with the mean values of 17.00 g kg^{-1} and 15.23 g kg^{-1} The soil pH was acidic to alkaline in reaction and showed an increasing trend with depth, while EC and organic carbon contents decreased with the increase in soil depth.

- The cation exchange capacity of the surface soil ranged from 9.49 to 38.97 cmol (p^+) kg^{-1} with the mean value of 24.10cmol (p^+) kg^{-1}. The lowest cation exchange capacity of 9.49 cmol (p^+) kg^{-1} was reported in Nichar block whereas the highest cation exchange capacity of 38.97 cmol (p^+) kg^{-1} was reported in Pooh block of district Kinnaur.
- The base saturation percentage in soil of distrct Kinnaur varied from 23.53 to 98.62 % with the mean value of 62.01%, whereas the CV of BSP is 34.35%. The minimum (23.53) and maximum (98.62) BSP was reported in Nichar and Pooh block, respectively.
- Available nitrogen content varied from 266.56 to 623.51 and 259.15 to 619.61 kg ha^{-1} with mean value of 441.39 and 427.96 kg ha^{-1} in surface and sub-surface depths, respectively. The soils of the district were medium to high in available nitrogen contents and its availability decreased with soil depth. In surface depth, available phosphorus contents ranged from 19.97 to 118.62 kg ha^{-1} with the mean value of 60.29 kg ha^{-1}, whereas in sub-surface soils, it varied from 18.41 to 111.31 kg ha^{-1} with the mean value of 54.55 kg ha^{-1}. It can be inferred that soils of apple orchards of Kinnaur district were medium to high in available phosphorus contents.. Surface soils have higher available phosphorus content as compared to sub-surface depth. In surface soils, available potassium content varied from the 247.17 to 792.00 kg ha^{-1} with the mean values of 563.58 kg ha^{-1} and in sub-surface soils it varied from 245.21 to 789.33 kg ha^{-1} with the mean value of 550.52 kg ha^{-1}.The soils were high in available potassium contents.
- The exchangeable Ca content varied from 2.55 to 10.23 and 2.13 to 9.96 cmol (p^+) kg^{-1} with the mean value of 6.69 and 6.59 cmol (p^+) kg^{-1} in surface and sub-surface depths, respectively. The exchangeable Mg content ranged from 3.26 to 8.91 and 2.92 to 8.72 cmol (p^+) kg^{-1} with the mean values of 5.93 and 5.50 cmol (p^+) kg^{-1} in surface and sub-surface depth, respectively. The sulphur contents in the surface and sub-surface depths varied from 55.60 to 75.60 and 52.18 to 73.5 kg ha^{-1} with the mean values of 65.75 and 63.09 kg ha^{-1}, respectively. The sulphur content decreased with the increase in soil depth. The soils of Kinnaur district were high in availability status with respect to available Ca, Mg and S. All the soils were (100%) found high in available Ca Mg and S contents.

- The availability of DTPA extractable Fe contents of the soil varied from 18.91 to 69.52 and 17.56 to 65.58 mg kg^{-1} with the mean values of 34.43 and 31.88 mg kg^{-1} in the surface and sub-surface depts, respectively. The Fe content was found high in range in apple orchards of Kinnaur district. The availability of DTPA extractable Mn contents in soil ranged between 11.20 to 41.91 mg kg^{-1} with the mean values of 26.38 mg kg^{-1} in surface soils whereas in sub-surface soil it ranged from 10.12 to 40.12 mg kg^{-1} with mean value of 25.05 mg kg^{-1}.The concentration of Mn was sufficient to apple orchards of Kinnaur district.
- The DTPA extractable Zn ranged from 1.10 to 4.58 and 0.58 to 4.10 mg kg^{-1} with the mean values of 2.89 and 2.44 mg kg^{-1} in surface and sub-surface depth. The Zn content was found medium to high in range.
- DTPA extractable Cu contents of the soil varied from 1.38 to 5.12 mg kg^{-1} with the mean values of 2.91 mg kg^{-1} in surface depths. For sub-surface depth it ranged from 1.19 to 4.75 mg kg^{-1} with the mean values of 2.22 mg kg^{-1}. The copper content was also high in range.
- Available B content ranged from 0.24 to 1.78 mg kg^{-1} with the mean value of 0.89 mg kg^{-1} in surface depth. In sub-surface depth it varied from 0.19 to 1.61 mg kg^{-1} with the mean value of 0.69 mg kg^{-1}. The B content was found medium in range. Available Mo content in soil ranged from 0.03 to 0.25 and 0.07 to 0.32 mg kg^{-1} with the mean values of 0.12 and 0.16 mg kg^{-1} in both surface and sub-surface depths, respectively The concentration of Mo was found high in range.
- The coefficient of variation for available macronutrients varied from 9.41 to 51.83 % and micronutrients from 32.45 to 64.51 %. Therefore, to delineate the deficiency and sufficiency areas for both macro and micronutrients, there is a need for more detailed survey as it is difficult to give a generalized picture of micronutrient status beside their limits of deficiency and sufficiency being very narrow. The high per cent of coefficient of variation may be due to variation in parent material and orchard management practices.
- The Nutrient indices indicated that the surface and sub-surface depths of the orchards, observed high status of available K (3.00), Ca (3.00),Mg (3.00), and S (3.00), DTPA Cu (3.00), Mn (3.00) and Fe (3.00). However with respect with N, Zn, B and Mo soils were medium in both surface and sub surface depths.

- Leaf N,P and K contents ranged from 1.39 to 2.94, 0.14 to 0.35 and 1.12 to 2.40 per cent, with the mean values of 2.20 ,0.24 and 1.74 per cent, respectively. The leaf N,P and K was found sufficient in range.
- The concentration of Ca, Mg and S in apple leaf samples varied from 0.81 to 2.47, 0.21 to 0.49 and 0.09 to 0.32 per cent with the mean values of 1.82, 0.34 and 0.23 per cent respectively. The Ca and S content in leaf were were found low to medium in range. The Mg was found medium in range.
- Leaf Fe, Zn, Cu and Mn contents ranged from 84.00 to 349.00 ,12.51 to 82.12, 17.41 to 59.42 and 30.48 to 85.62 ppm with the mean value of 221.17, 36.40, 30.07 and 59.29 ppm respectively. The leaf B and Mo contents ranged from 17.56 to 42.46 and 0.46 to 0.86 ppm with mean value of 29.75 and 0.63 ppm, respectively. Fe, Cu and Mn contents in leaf were medium to high in range where as Mo was high in range in apple growing areas of Kinnaur district. Zn and B contents in leaf were medium in range.
- The coefficient of variation for the different nutrient elements was high and ranged from 18.08 to 47.51 per cent. The high coefficient of variation in plants may be due to high variation in soils.
- Soil pH of the surface layer was found significantly and positively correlated with the available N, P and B but was found to be significantly and negatively correlated with available Zn and Cu. In sub-surface soil pH was also significantly and positively correlated with available N and P and B but significantly and negatively correlated with available Zn and Cu. The Electrical conductivity in the surface soil a positive and significant correlation with exchangeable Ca content. Organic carbon content was highly positive and significant corealtion with the N,Ca and Zn.
- Surface soil pH was a significant positive relationship with leaf K, Mn and B. The electrical conductivity of the soil was found to be significantly and positive correlated with leaf B. The organic carbon content of the soil was significant and positively correlated with leaf N. The available N in the soil was significant and positively correalated with leaf K, S, Fe, Cu Mn and Mo. Available nutrients in both the surface and sub-surface depths had positive correlation with their respective leaf nutrient contents.
- The Zn content in soil was significantly and negatively correlated with leaf Fe and B. Available B content in soil was significantly and negatively correlated with the leaf K.

The Mo content in soil was significant and psositively correlated with leaf Mo whereas, significantly and negatively correlated with the leaf Zn. A highly positive and significant correlation of available nutrients in the surface depth with their respective leaf nutrient contents indicated that, surface depth was contributing more towards nutrient uptake by the apple trees.

CONCLUSION

On the basis of overall results, it was be concluded that in orchard soils of Kinnaur district, soil texture was found to vary from sandy loam to sandy clay loam, which exhibited to addition of organic matter to improve the water and nutrient retentivity of soils. Soil reaction was slightly acidic to slightly alkaline in nature, which suits for apple cultivation in Kinnaur district. The soil was in safe limits of electrical conductivity indicating that no accumulation of soluble salts. The apple orchards of Kinnaur district was rich in organic carbon contents due to the addition of the FYM in orchards by the farmers. All macro and micro-nutrients indicated decreasing trend, except Mo, which was showed increasing trend with increase in soil depth. On the basis of nutrient index, it is concluded that the soil samples were high in K, Ca, Mg and S, Fe, Cu and Mn and medium in N, Zn, B and Mo.

The leaf nutrient status showed that N,K and Mo was found high in range and Ca, S and Zn was low to medium in range. The Mg and B was found medium in range. All the nutrient elements in the surface and sub- surface depths have a positive correlation with their respective leaf nutrient contents. The coefficient of variation in soil and leaf samples were high.This shows a wide variation in the soil management of the apple orchards in Kinnaur district which is clearly visible in the wide variation in the physico-chemical properties.

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APPENDIX-1

List of Farmers and villagers from where the soil and leaf samples were collected

Orchards No.	Tehsil	Village	Farmer Name	Telephone number
1	Nichar	Chagaon	Ashok Kumar	7018926354
2	Nichar	Jani	Sanjog Devi	8628072812
3	Nichar	Ramni	Manisha Negi	8894043309
4	Nichar	Punang	Pradeep	7807845007
5	Nichar	Nichar	Nilam	9805680185
6	Nichar	Urni	Sushila	9805882009
7	Nichar	Meeru	Pinky	9854393235
8	Nichar	Kilba	Budhratan	8894034136
9	Nichar	Katgaon	Jashwant	8894314342
10	Nichar	Sungra	Karjang	9854318903
11	Kalpa	Rali	Dalveer	8580421173
12	Kalpa	Rogi	Sanjana Devi	8091779243
13	Kalpa	Duni	Ram Kumar	9418759469
14	Kalpa	Telangi	Chander Prakash	8219208036
15	Kalpa	Kothi	Snoki Devi	7018280570
16	Kalpa	Rarang	Namrata Negi	9805206803
17	Kalpa	Yorangi	Kulwant Negi	8219079624
18	Kalpa	Khaungi	Kanta Devi	7876594206
19	Kalpa	Sangla	Suryaprakash	8894313831
20	Kalpa	Kalpa	Ajay Negi	8894359503
21	Pooh	Ribba	Gopal	962509887
22	Pooh	Pangi	Naveen	9816775456
23	Pooh	Aakpa	Kashish Negi	8894558044
24	Pooh	Pooh	Krishna	9805128718
25	Pooh	Gyabung	Laxminand	9805227812
26	Pooh	Jangi	Hemant	8580565976
27	Pooh	Lippa	Srojini Negi	9418578336
28	Pooh	Moorang	Vikram Negi	8894875823
29	Pooh	Thangi	Jay Prakash	8679111187
30	Pooh	Cinne	Manoj Negi	9805128718

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Title of Thesis	**:**	**“Nutritional survey of apple (*Malus domestica* Borkh) orchards in Kinnaur district of Himachal Pradesh**
Name of student	**:**	Anjali Kumari
Admission number	**:**	F-2018-52-M
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Minor Discipline (s)	**:**	Department of Fruit Science
Degree Awarded	:	M.Sc. (Agri.) Soil Science
Year of Award of Degree	:	2020
No. of pages in thesis	**:**	73+i
No. of words in abstract	**:**	293
Major Advisor	**:**	Dr M.L. Verma

ABSTRACT

Investigation entitled “**Nutritional survey of apple (*Malus domestica* Borkh) orchards in Kinnaur district of Himachal Pradesh**” was undertaken to ascertain the nutritional status of apple orchards, located in Nichar, Kalpa and Pooh blocks of Kinnaur district and to establish the relationships among soil characteristics and nutrient contents of soils and plants. Based on uniformity in respect of age and tree vigour, 30 representative orchards were selected. Starking Delicious variety of apple was selected for study as most of the well established orchards in these blocks were under this variety. Soil (0-15 and 15-30 cm depths) and plant samples collected from apple orchards were analyzed for soil properties *viz*., soil texture, pH ,EC OC, N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B and Mo status. The soils were found sandy loam to sandy clay loam in texture and slightly acidic to slightly alkaline in reaction. The electrical conductivity values were in safe limits (less than 0.8 dSm^{-1}). The organic carbon contents were found high in range. Nutrient index value indicated that the soils were high in available K, Ca, Mg, S, Cu, Fe and Mn except N, Zn, B and Mo and they were medium in both surface and sub-surface depths. The leaf nutrient status showed that the N,K and Mo were found high in range and Ca, S and Zn was low to medium in range. The Mg and B were found medium in range. The per cent coefficient of variation found high in soil and plants could be due to variations in parent material and orchard management practices. Organic carbon was significantly and positively correlated with N, Ca and Zn. Available N, K Ca, Mg, S and Cu exhibited positively and significant relationship with their respective leaf nutrient contents.

Signature of the Student	**Signature of Major Advisor**
Anjali kumari	**Dr M.L. Verma**

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BIO-DATA

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ACADEMIC QUALIFICATION:

Examination Passed	Month and Year	University/Board	Marks obtained (%)	Division
Matriculation	March, 2011	HPBSE, Dharamshala (H.P.)	64.29	FIRST
10+2	March, 2013	HPBSE, Dharamshala (H.P.)	51.80	SECOND
Graduation	June, 2018	Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, (H.P.)	68.70	FIRST

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