

**STUDIES ON ORGANIC NUTRITION  
IN APPLE (*Malus × domestica* Borkh.)**

***Thesis***

by

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*Submitted in partial fulfilment of the requirements for the  
degree of*

**DOCTOR OF PHILOSOPHY**

in

**HORTICULTURE  
(FRUIT SCIENCE)**



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## **CERTIFICATE - I**

This is to certify that the thesis entitled, “**Studies on organic nutrition in apple (*Malus × domestica* Borkh.)**” submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **HORTICULTURE (Fruit Science)** to Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Mr. Ghumare Vikas Shivajirao (H-2009-11-D)** under my guidance and supervision. 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.

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This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled **“Studies on organic nutrition in apple (*Malus × domestica* Borkh.)”** submitted to Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) by **Mr. Ghumare Vikas Shivajirao (H-2009-11-D)** in partial fulfillment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY in HORTICULTURE (FRUIT SCIENCE)**.

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**Place : Nauni, Solan**

**Date:**

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# **C O N T E N T S**

<b>Chapter No.</b>	<b>Chapter Title</b>	<b>Page(s)</b>
<b>1.</b>	<b>INTRODUCTION</b>	<b>1</b>
<b>2.</b>	<b>REVIEW OF LITERATURE</b>	<b>6</b>
<b>3.</b>	<b>MATERIAL AND METHODS</b>	<b>24</b>
<b>4.</b>	<b>EXPERIMENTAL RESULTS</b>	<b>38</b>
<b>5.</b>	<b>DISCUSSION</b>	<b>112</b>
<b>6.</b>	<b>SUMMARY AND CONCLUSION</b>	<b>129</b>
<b>7.</b>	<b>REFERENCES</b>	<b>138</b>
	<b>ABSTRACT</b>	<b>161</b>
	<b>APPENDICES</b>	<b>I-XII</b>

## LIST OF TABLES

### Experiment no. I

Table No.	Title	Page No.
4.1.1	Fruit yield (kg/plant) of apple in organic and inorganic orchards at different locations	39
4.1.2	Fruit weight (g) of apple fruits in organic and inorganic orchards at different locations	39
4.1.3	Fruit firmness (kg/ sq. inch) of apple fruits in organic and inorganic orchards at different locations	40
4.1.4	Total soluble solids (TSS) content ( <sup>0</sup> B) of apple fruits in organic and inorganic orchards at different locations	40
4.1.5	Titration acidity (%) of apple fruits in organic and inorganic orchards at different locations	43
4.1.6	Reducing sugars (%) content of apple fruits in organic and inorganic orchards at different locations	43
4.1.7	Total Sugars (%) content of apple fruits in organic and inorganic orchards at different locations	45
4.1.8	Anthocyanins (mg/100 g) content of apple fruits in organic and inorganic orchards at different locations	45
4.1.9	Total phenols (mg/100 g) content of apple fruits in organic and inorganic orchards at different locations	48
4.1.10	Antioxidants (mg/100 g) of apple fruits in organic and inorganic orchards at different locations	48
4.1.11	Physiological loss in weight (%) of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations A], B], C]	49, 50, 51
4.1.12	Rotting (%) of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations A], B], C]	54, 55, 56
4.1.13	Fruit firmness (kg/sq. inch) of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations A], B] C]	56, 57, 58
4.1.14	Total soluble solids ( <sup>0</sup> Brix) content of apple fruits On different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations A], B], C]	60, 61, 62

4.1.15	Leaf N (%) content in organic and inorganic apple orchards at different locations	64
4.1.16	Leaf P (%) content in organic and inorganic apple orchards at different locations	64
4.1.17	Leaf K (%) content in organic and inorganic apple orchards at different locations	66
4.1.18	Leaf Zn (ppm) content in organic and inorganic apple orchards at different locations	66
4.1.19	Leaf Fe (ppm) content in organic and inorganic apple orchards at different locations	69
4.1.20	Leaf Cu (ppm) content in organic and inorganic apple orchards at different locations	69
4.1.21	Leaf Mn (ppm) content in organic and inorganic apple orchards at different locations	70
4.1.22	Water holding capacity of the soil in organic and inorganic apple orchards at different locations	70
4.1.23	Soil bulk density (g/cc) in organic and inorganic apple orchards at different locations	72
4.1.24	Soil pH in organic and inorganic apple orchards at different locations	72
4.1.25	Soil electric conductivity (EC) (dSm/m <sup>2</sup> ) in organic and inorganic apple orchards at different locations	74
4.1.26	Organic carbon (%) in organic and inorganic apple orchards at different location	74
4.1.27	Available N (kg/ha) content in organic and inorganic apple orchards at different locations	75
4.1.28	Available P (kg/ha) content in organic and inorganic apple orchards at different locations	75
4.1.29	Available K (kg/ha) content in organic and inorganic apple orchards at different locations	78
4.1.30	Available Zn (mg kg <sup>-1</sup> ) content in organic and apple inorganic orchards at different locations	78
4.1.31	Available Fe (mg kg <sup>-1</sup> ) content in organic and inorganic apple orchards at different locations	80
4.1.32	Available Cu (mg kg <sup>-1</sup> ) content in organic and inorganic apple orchards at different locations	80
4.1.33	Available soil Mn (mg kg <sup>-1</sup> ) content in organic and inorganic apple orchards at different locations	81
4.1.34	Total soil microbial counts (cfu/g) in organic and inorganic orchards at different locations	81

## Experiment no. II

Table No.	Title	Page No.
4.2.1	Effect of organic nutrition on trunk girth, duration of flowering and per cent fruit set	85
4.2.2	Effect of organic nutrition on leaf N, P and K content	87
4.2.3	Effect of organic nutrition on leaf micronutrients content	89
4.2.4	Effect of organic nutrition on fruit yield and fruit weight	90
4.2.5	Effect of organic nutrition on fruit firmness and TSS content	91
4.2.6	Effect of organic nutrition on titratable acidity, reducing and total sugars content	93
4.2.7	Effect of organic nutrition on anthocyanins, total phenols and antioxidants content	95
4.2.8	Effect of organic nutrition on physiological loss in weight (PLW) of apple fruits at different storage intervals (days) and ambient storage temperature	97
4.2.9	Effect of organic nutrition on rotting percentage of apple fruits at different storage intervals (days) and ambient storage temperature	98
4.2.10	Effect of organic nutrition on apple fruit firmness at different storage intervals (days) and ambient storage temperature	101
4.2.11	Effect of organic nutrition on total soluble solids of apple fruits at different storage intervals (days) and ambient storage temperature	102
4.2.12	Effect of organic nutrition on maximum water holding capacity (MWHC) and bulk density (BD) of soil	103
4.2.13	Effect of organic nutrition on soil pH and electrical conductivity (EC)	105
4.2.14	Effect of organic nutrition on soil organic carbon (OC) content and total microbial counts (TMC)	106
4.2.15	Effect of organic nutrition on available N, P and K status in the soil	108
4.2.16	Effect of organic nutrition on available micronutrients status in the soil	109

### LIST OF PLATES

Plate no.	Title	After page No.
1	Application of organic manure in tree basins	27
2	Fruit quality among different treatments	91

## LIST OF ABBREVIATIONS

%	Per cent
cm	Centimeter
dSm <sup>-1</sup>	deci Siemens per meter
EC	Electrical conductivity
<i>et al</i>	Co-workers
g	gram
g kg <sup>-1</sup>	Gram per kilogram
ha	Hectare (10,000 m <sup>2</sup> )
ha <sup>-1</sup>	Per hectare
N	Nitrogen
P	Phosphorus
K	Potassium
Zn	Zinc
B	Boron
Fe	Iron
Cu	Copper
Mn	Manganese
mg kg <sup>-1</sup>	Milli gram per kilogram
OC	Organic carbon
pH	<i>Puissance de Hydrogen</i>
ppm	Parts per million

# Chapter-1

## INTRODUCTION

---

Apple (*Malus × domestica* Borkh.) belongs to the family Rosaceae and is most important fruit crop of temperate region. In the world it occupies an area of 48,32,419 hectares with a production of 7,60,90,713 MT having a productivity of 15.7 MT per hectare (NHB, 2013). However, India ranks 5<sup>th</sup> in the world with a production of 19, 15, 375 MT from an area of about 3, 11, 497 hectares with 6.1 MT productivity (NHB, 2013). In India, apple is produced predominantly in North-Western Himalayan region comprising of Jammu and Kashmir, Himachal Pradesh and Uttarakhand contributing 90% of the total production in the country. In addition, its cultivation has been extended to Arunachal Pradesh, Sikkim, Nagaland, Meghalaya and Nilgiri hills of Tamil Nadu, where mild temperate climatic conditions prevail. In Himachal Pradesh, apple industry has made tremendous strides on account of extensive cultivation and quality. At present, the area under its cultivation has reached 1,06,230 hectares, with 4,12,400 MT of annual production and with a productivity of 3.9 MT per hectare (NHB, 2013). Nearly 45% area is exclusively under apple cultivation. So, the state has been named as “Apple Bowl of India”.

In the past two decades, sustainable and environmentally benign productions have become major concerns in the whole fruit-growing sector because of the increasing consumer demand for healthier and more environmentally sustainable products. Therefore, there has been a great increase in the number of growers and the total land area utilizing organic and integrated farm management systems in apple orchards around the world (Willer and Yussefi 2007). In the last few years, organic cultivation has attracted many farmers across the country and many farmers have experimented it

successfully. To achieve the larger goal of sustainable production and minimize the use of chemicals, use of biological agents, recycling of nutrients, harnessing solar radiation, utilization of horticultural waste etc., has to be restored in ecofriendly manner. Conventional management system evolved globally in response to the availability of high yielding crop cultivars, chemical fertilizers and pesticides, progressing irrigation and mechanization. Additionally, farmland used to grow organic crops is prohibited from treatment with synthetic pesticides and herbicides for at least three years prior to harvest.

Organic farming system in India is not new and is being followed from ancient time. It is a method which primarily aimed at cultivating the land and raising crops in such a way to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes) and other biological materials along with beneficial microorganisms (biofertilizers) to release nutrients to crops for increased sustainable production. Organic management practices exclude the use of synthetic pesticides and fertilizers, allowing the use of animal and green manures, compost, soluble rock powders, sulfur and copper compounds, fungicidal and insecticidal soaps, botanical insecticides, traps and other biological control methods and incorporating legumes to maintain soil productivity (Palaniappan and Annadurai 1999). Miller and Miller (2000) highlighted that organic material application to cropland could improve soil properties, but the effects generally may not be apparent over a short time period. The slow release of these nutrients is responsible for the increase in crop yields in the subsequent years, thus determining the difficulty of quickly evaluating the true value of these organic materials as amendments. However, there is a considerable variability between experimental techniques, climate, soil type and organic material characteristics,

and therefore attention must be paid to generalizing the effects of composts and raw waste application on the soil-plant system.

A considerable number of studies, concerning long-term fertility trials, pointed out that soil organic material applications increased the organic carbon stock and, therefore, increased the cation exchange capacity. This effect was due to the high negative charge of organic matter. This is important for retaining nutrients and making them available to plants (Weber *et al.*, 2007). Furthermore, the presence of weak acidic chemical functional groups on organic molecules makes organic matter an effective buffer, as supported by the findings of Garcia *et al.*, (2004). These authors observed a long-term (9 years) and short-term improvement in the soil humic acid buffering capacity in municipal solid waste compost-amended soils, derived from a residual effect of a single application and cumulative effects from repeated ones. These distributions will favor the general soil fertility status and crop production.

Maintaining and improving soil quality is crucial, if productivity and environmental quality are to be sustained for future generations. Increased inputs and technologies in modern farming systems can often compensate and mask losses in productivity associated with reductions in soil quality. However, increased agricultural inputs not only reduce economic sustainability but also increase the potential for negatively impacting environmental quality. Conventional management puts its focus on achieving maximum yields of a specific crop. It is based on a rather simple understanding; crop yields are increased by nutrient inputs and are reduced through pests, diseases and weeds elements that must be combated. Sources of organic nutrition are a holistic way of farming besides production of goods of high quality; an important aim is the conservation of the natural resources, fertile soil, clean water and

rich biodiversity. The art of organic farming is to make the best use of ecological principles and processes.

Organic nutrient management is based on biodegradable material, i.e. plant and animal residues. Nutrient cycles are closed with the help of composting, mulching, green manuring, crop rotation, oil cakes etc. Farm animals can play an important role in the nutrient cycle, their dung is of high value and its use enables nutrients provided with the fodder to be recycled. If carefully managed, losses of nutrients due to leaching, soil erosion and gasification can be reduced to the minimum. This reduces the dependency on external inputs and helps to save costs. However, nutrients exported from the farm with the sold produce need to be replaced. Soil and its fertility constitute the center of the natural ecosystem. The continuous supply of organic material feeds a huge number of soil organisms and provides an ideal environment for them. As a result the soil becomes soft and capable of taking up and storing large quantities of nutrients and water.

Clearly, with the large growth of organic consumption over the past decade and with produce comprising a substantial share, the area of organic fruit production has had to expand. For many organically managed fruit crops, soil nutrient availability plays a critical role in the potential success of fruit production. However, the sustainability of conventional apple production systems have been brought into question by consumers increasing in demand for apples free of chemical residues, escalating production costs, water contamination from orchard practices, and soil degradation (Peck *et al.*, 2006 and Jonsson 2007).

The present investigations is therefore proposed with the following objectives:

**Objectives:**

1. To study the effect of organic sources of nutrients on growth, yield and quality of apple.
2. To study the effect of organic sources of nutrients on nutritional status of plant and soil.
3. Comparison of organic and inorganic apple orchards in relation to growth, yield, quality, plant and soil nutritional status.

## Chapter-2

### REVIEW OF LITERATURE

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The information on organically grown apple is scarce, however, efforts have been made to review the work done on organic cultivation of apple and other fruit crops to support the present investigation. The available literature is divided into following headings:

**2.1 Effect of different sources of organic nutrition on plant growth and flowering parameters**

**2.2 Effect of different sources of organic nutrition on fruit yield and quality parameters**

**2.3 Effect of different sources of organic nutrition on soil physical and chemical properties**

**2.4 Effect of different sources of organic nutrition on soil microbial population**

**2.1 Effect of different sources of organic nutrition on plant growth and flowering parameters**

Roussos and Gasparatos (2009) compared the conventional and organic apple orchards in terms of plant growth, marketable fruit quality and yield. They observed that apple trees grown under organic management exhibited greater cross sectional area than those under conventional management system. Verma *et al.*, (2009) found effect of different organic manures on overall apple tree growth, out of which farm yard manure @ 100 kg per tree recorded maximum growth, fruit size and yield under organic cultivation. Srivastava (2002) conducted an experiment on papaya using organics like mahua cake, castor cake, biogas sludge, neemcake, karanj cake @ 2.5 tonnes ha<sup>-1</sup>. He found that biogas sludge gave the maximum

plant height (130.8 cm), while girth of stem was higher in neemcake-applied treatment.

Patil *et al.*, (1997) found that papaya cv. Washington seedlings were supplied with groundnut cake, neemcake, FYM and NPK (as urea, single super phosphate and muriate of potash, respectively) and no fertilizers. Under vegetative growth parameters trunk circumference was highest (31.5 cm) with 30 g N as neemcake. Saha *et al.*, (2010) reported that farmyard manure at 10 kg plant<sup>-1</sup> significantly influenced the growth parameters of five years old mango trees. There was a positive relationship between increasing rates of application of FYM and trunk cross sectional area.

Ram *et al.*, (2007) reported that the stem diameter of guava was significantly increased with the application of vermicompost @ 5 kg tree<sup>-1</sup>. Archana (2008) reported that maximum shoot extension growth (31.47 cm) was obtained when plum trees were treated with vermicompost @ 20 kg tree<sup>-1</sup>. Maximum leaf area and pseudostem height in banana was recorded with the application of vermicompost (Geetha and Nair, 2000).

Arancon *et al.*, (2002) found that number of runners, number of flowers, shoot weight, and total marketable strawberry yield increased significantly in plots treated with vermicompost compared to those that received inorganic fertilizers only. The influence of organic amendments such as cocopeat, vermicompost, farmyard manure and neemcake in growing media on plant growth and buddability of rough lemon seedlings was studied by Bhagat *et al.*, (2013). Cocopeat and vermicompost improved seed germination and growing media having cocopeat or vermicompost and FYM were more effective on plant growth.

Naik and Babu (2007) reported that application of vermicompost resulted in maximum leaf area in guava. Leaf area was significantly increased in citrus, when fertilized with sole

application of vermicompost (Battisa *et al.*, 2008). In situ vermiculture produced higher leaf area in banana (Sabarad *et al.*, 2004). Patel (2008) found that combination of 3.0 kg vermicompost and 3.0 kg castor cake per plant resulted in maximum plant height (174.25 cm), pseudostem girth (63.00 cm), number of functional leaves (21.27) and maximum total leaf area (23.43 m<sup>2</sup>) during the study of effect of different organic manures on growth, yield and quality of banana. Arancon *et al.*, (2006) also reported maximum leaf area (507.6 cm<sup>2</sup>) with the application of vermicompost @ 10 tons ha<sup>-1</sup>.

### **2.1.1 Effect on leaf nutrient contents**

Dong and Shu (2004) reported that application of sheep manure in apple orchard improved plant nutrient status. The Leaf N concentration was significantly increased by the application of sheep manure. They suggested that a dose of 15 t/ha supply enough available N for the growth of plant. Nagy *et al.*, (2013) reported three-year's data of leaf phosphorus, sulphur and zinc and found no significant differences between production systems. Nevertheless, manganese and copper contents of leaves were higher in the organic orchard compared to the integrated one. Similarly, compost application increased N in leaves of orange (Parsons and Wheaton, 1994).

Regarding the basic cations Ca and K contents of plants increase noticeably with the application of wood ash. Since these elements are more available for plants, they are preferentially absorbed (Ohno and Erich, 1990). Erich (1991) suggested that the availability of wood ash K is similar to fertilizer K. Vermicompost had relatively higher concentration of different nutrients, which affected in meeting the nutrient requirement of crop in a reasonably better and suitably modified way (Ramamurthy, 2006).

Shivaputra *et al.*, (2004) noticed that leaf N, P and K contents were increased over control when papaya plants were treated with vermicompost. Chamani *et al.*, (2008) revealed that N and P concentration in Petunia shoot tissues increased significantly with increasing the vermicompost volumes in the base media as compared to the control. Preetha *et al.*, (2005) inferred that addition of vermicompost resulted in significant increase in nutrient uptake of amaranth. Vermicompost application enhanced the N, P, Ca and Mg contents and higher Zn contents in lettuce leaves (Morselli *et al.*, 2004).

## **2.2 Effect of different sources of organic nutrition on fruit yield and quality parameters**

Peck *et al.*, (2006) reported that organic crop yields were lower compared to conventional and integrated in 2002, but it was higher than both the systems in 2003. However, the organic apples in this study showed improvement in fruit quality attributes. It was also observed that Consumers rated apples produced by organic and integrated management were better in firmness, texture and overall acceptability than conventionally produced apples. Laboratory measurements coincided with consumer ratings, with organic apples being firmest, integrated management second, and the conventional least firm. After six months of controlled atmosphere (CA) storage, 90% of the organic apples were still considered to be of acceptable firmness compared with only 64% of conventional apples and 42% of integrated apples. Results from long-term studies comparing the effects of organic, integrated, and conventional farm management show that organic systems have equal to slightly lower yields in a range of crops than conventional systems, but that organic and integrated systems generally have greater economic and environmental sustainability and energy efficiency (Smolik *et al.*,

1995; Drinkwater et al., 1998; Reganold et al., 2001; Mäder et al., 2002; Porter et al., 2003).

Patil *et al.*, (1997) studied the manurial requirement of papaya. They reported that application of farm yard manure @ 15 g N plant<sup>-1</sup> month<sup>-1</sup> can be effectively used for getting higher yield (70.2 kg plant<sup>-1</sup>) with maximum number of fruits per plant (120). They also reported maximum pulp (80%), total sugar (14.2%), reducing sugar (12.6%) and non-reducing sugar (1.6%) from the treatment of 30 g N through neemcake, while TSS was maximum in 15 g N of groundnut cake treatment. Rey et al., (2008) observed maximum number of fruits per plant (36.5) and yield (43.80 kg plant<sup>-1</sup>) in papaya from inorganic fertilizer followed by FYM, while average fruit weight (1.3 kg), fruit length and breadth were higher in FYM. Hossain *et al.*, (1990) studied yield response of papaya from different sources of nitrogen. They used urea, cow dung and oil cake as sources of nitrogen and obtained significantly highest yield in the treatment combination of cow dung and oil cake.

Reig *et al.*, (2007) reported that organically grown apple fruits were firmer, sweeter with improved fruiting quality. Jonsson (2007) and Roth *et al.*, (2007) reported no significant differences in fruit quality between apples from organic and integrated nutrition applied orchards, neither at harvest nor after storage. DeEll and Prange (1992) observed higher soluble solids concentrations in organically grown apples than in conventionally grown apples. No differences in firmness or titratable acids due to production method were observed.

Plant nutrition also influences the fruit quality. Fruit size depends on plant nutrition, which also remarkably influences postharvest quality. Cassandro *et al.*, (2008) studied two cultivars viz., Royal Gala and Fuji from organic and conventional apple orchards. In both cultivars, fruits from the organic orchard harvested

at commercial maturity had higher soluble solids and flesh firmness than fruits from the conventional orchard. However, fruits from the organic orchards had lower titratable acidity in 'Royal Gala'. Studies have partly confirmed this opinion. However, the plants cultivated in organic systems generally have 20% lower yields than conventionally produced crops (Ewa, 2007). In organically cultured fruit, the average values for the ORAC, total anthocyanins, and total phenolic contents were 46.14  $\mu\text{mol}$  of Trolox (TE)/g of fresh weight (fwt), 131.2 mg/100 g of fwt, and 319.3 mg/100 g of fwt, respectively.

The effect of cultivation practices on fruit quality and antioxidant capacity in high bush blueberries var. Blue berry (*Vaccinium corymbosum* L.) was evaluated from random samples of commercial late harvest fields. Results from this study showed that blueberry fruits grown from organic culture yielded significantly higher sugars (fructose and glucose), malic acid, total phenols, total anthocyanins, and antioxidant activity than fruit from the conventional culture (Wang *et al.*, 2008). Many review articles published made comparisons of the nutritional quality of organic and conventional foods. Woese *et al.*, (1997) concluded that no major differences in nutrient levels were observed between the different production methods in some cases while in other cases contradictory findings did not permit definite conclusions to be drawn from the influence of production methods on nutrient levels.

Ram *et al.*, (2007) studied the organic nutrition in guava and found that fruit quality parameters like TSS and vitamin C were improved with application of different organic treatments. Eman *et al.*, (2008) studied organic fertilization by using banana compost and farm yard manure and reported improvement in fruit quality in terms of increasing finger weight, per cent total soluble solids, per cent total sugars and in decreasing starch and total acidity. Johannes (2003) studied two storage experiments on different aspects of post

harvest behavior of organic and integrated grown pears. They concluded that fruits from organic nutrition applied system had better quality standards for fruits and performed well compared to integrated grown pears.

Patel (2008) concluded that 3.0 kg vermicompost + 3.0 kg castor cake gave maximum TSS, total sugars, highest fruit yield (22.40 kg plant<sup>-1</sup>), number of fingers bunch<sup>-1</sup> (144.33). Higher sugar/acid ratio was recorded in banana cv. Njali poovam when vermicompost was used as a sole source of nutrients (Ushakumari *et al.*, 1997). Highest ascorbic acid contents with the vermicompost application were recorded in aonla (Korwar *et al.*, 2006).

Reddy *et al.*, (2010) studied the effect of six organic nutrition treatments along with recommended dose of fertilizers and no manure/fertilizer application on papaya cv. Surya. Results revealed that there was no significant variation in average fruit weight and TSS, but shelf life of the fruit was significantly higher in organic treatments (6.2 to 7.9 days) as compared to inorganic fertilizer treatment (5.1days). Various physical properties like polar diameter, fruit weight, fruit volume, pulp thickness and pulp weight were significantly increased when guava trees were applied with vermicompost at the rate of 10 kg per plant (Athani *et al.*, 2007).

Venkatesh *et al.*, (2000) reported that highest amount of TSS and ascorbic acid contents recorded from vermicompost treated plants. Same author in 2002 studied the effect of in situ vermiculture and vermicompost on the composition of grape berries. The vermicompost treated fruits had highest amount of total soluble solids (23.0°B) and ascorbic acid (2.61 mg/100 ml). In situ vermiculture increased the ascorbic acid contents when compared with 100 per cent recommended fertilizer rate (RFR) and vermicompost alone. Athani *et al.*, (1999) reported that vermicompost and in situ vermiculture resulted in longest shelf life,

highest total soluble solids, TSS:Acidity, non-reducing and total sugars in banana cv. Rajapuri.

Several reviews of studies comparing the nutritional quality of organic and conventional produce were inconclusive (Woese *et al.*, 1997; Bourn and Prescott, 2002), although some authors have suggested a slight nutritional gain in organically produced fruits and vegetables (Brandt and Mølgaard, 2001; Heaton, 2001; Worthington, 2001). Some recent studies looking more in depth at perennial horticultural crops found higher concentrations of polyphenolic compounds and other antioxidants in pears (*Pyrus communis* L.) and peaches (*Prunus persica* L.) (Carbonaro and Mattera, 2001; Carbonaro *et al.*, 2002) for yellow plums (*Prunus domestica* L.), conventional fruit had higher concentrations of polyphenols and quercetin, while other flavonoids and several vitamins were higher in organic plums (Lombardi-Boccia *et al.*, 2004).

### **2.3 Effect of different sources of organic nutrition on soil physical and chemical properties**

A healthy soil is defined as a stable system with resilience to stress, high biological diversity, and high levels of internal nutrient cycling (Van Bruggen and Semenov, 2000). Several studies have shown that application of organic manures leads to better soil quality with higher microbiological activity than conventional farming, due to reduced application of synthetic nutrients, and the absence of pesticides (Hansen *et al.*, 2001; Shannon *et al.*, 2002). Drinkwater *et al.*, (1995) reported higher soil pH, organic C and N, N mineralization potential, and diversity in organic fields than conventional ones. In organic systems, plant production depends almost exclusively on nutrient transformations in soils, since only limited amounts of permitted fertilizers are used. Because microbes primarily control nutrient transformations, as an active soil microflora and a considerable pool of accessible nutrients are very

important for the smooth functioning of organic systems (Monokrousos *et al.*, 2006).

Chang (2007) studied the effects of different application rates of compost and compared them with the effects of chemical fertilizer (CF) and no application of fertilizer treatments for some selected soil chemical properties and microbial populations. The results showed that pH, electrical conductivity, concentration of total nitrogen (N) and the organic matter received from compost were higher than those received through CF treatment. Bulluck *et al.*, (2002) found that SOM and total C were higher in plots with organic amendment compared with synthetic fertilizer. Andrews *et al.*, (2001) reported that the application of 11.2 to 22.5 Mg ha<sup>-1</sup> of different composts increased OC by 8% compared with conventional fertilized sites in the first 2 years. In the third year there was a 16% increase in OC in the organic sites compared with conventional fertilized sites.

Werner (1997) reported no differences in organic and conventional soils in the respiratory ratio of biomass C to total organic carbon. Glover *et al.*, (2000) also recorded reduced soil bulk density in organic orchards. Albiach *et al.*, (2001) observed the effect of fine organic amendments on the soil contents of organic matter and microbial gums. Refuse compost yielded the highest organic matter and carbohydrates appeared to be closely related to soil aggregate stability. Lanjewar *et al.*, (1992) observed an improvement in soil structure and a decrease in bulk density due to crop residue incorporation. Ademir *et al.*, (2009) studied the conventional and organic management systems and found decrease in soil bulk density after adoption of organic system. Soil organic carbon (SOC) was higher in the organic than in the conventional management system. Maheswarappa *et al.*, (1999) showed that

application of organic manures (FYM and vermicompost) alone decreased the soil bulk density and improved soil porosity.

Amiri and Fallahi (2009) reported that incorporating deep litter cow and deep litter poultry manures with top 30 cm soil improved orchard soil properties, such as nutrient availability, soil organic matter, electrical conductivity (EC), pH, cation exchange capacity (CEC) and biological activity in a 'Golden Delicious' apple orchard.

Bhriguvanshi (1988) studied long-term effect of FYM and reported that pH remained unchanged but electrical conductivity was increased with increasing levels of organic manuring. Organic carbon was also increased significantly due to application of FYM. Carey *et al.*, (2009) compared the soil properties between organic and conventional kiwifruit orchards. Soil chemical properties such as organic C, Total N, CEC, pH, extractable Ca and Mg were higher in organic orchards compared to conventional orchards. Similarly, lower soil bulk density with greater porosity scores were recorded in organic kiwi cultivation compared to conventional orchards.

Celik *et al.*, (2010) undertook a long-term field experiment to investigate the role of mycorrhizal inoculation and organic fertilizers on soil properties. The highest organic matter contents both at 0–15 cm and 15–30 cm soil depths were obtained with manure application. Manure, compost and mycorrhizal inoculation + compost application had 69%, 32% and 24% higher organic matter contents at 0–30 cm depth as compared to the control. The compost application resulted in the lowest bulk densities, whereas the highest bulk density values were obtained with mineral fertilizer application. Chaudhary *et al.*, (1981) studied the effect of long-term application of FYM on soil chemical properties and reported that addition of FYM maintained soil pH and EC, while significantly increased the organic carbon, available N, P and K contents.

Marinari *et al.*, (2006) observed that field under organic management showed significantly better soil nutritional conditions, with increased level of total nitrogen, nitrate and available phosphorus. Results of the study suggest that, over the period of 7 years, organic management method strongly affects soil quality indicators.

Ghosh *et al.*, (1981) revealed that application of organic manures significantly reduced the fixation of added as well as nutritive P, making P more available to plants. The additions of organic manures resulted in increased soil organic matter contents. Many reports have shown that organic manures result in increased water holding capacity; porosity, infiltration capacity, hydraulic conductivity and water stable aggregation and decreased bulk density. Problems associated with large applications of manure include dispersion caused by accumulated K, Na substances by decomposer fungi (Haynes and Naidu, 1998). Ikemura and Shukla (2009) studied the sustainability of organic cropping systems and found that a three year organically managed field was more sustainable compared to conventional system.

Lee and Chung (2007) studied the soil chemical properties in conventional and organic apple orchards. Soil pH in organic nutrition applied orchard was around 7.5, whereas below 6.0 in conventional farming. Organic nutrition resulted in significant increase in organic matter and Kjeldahl-N contents as compared to conventional management. Reddy *et al.*, (2010) studied the effect of six organic treatments along with recommended dose of fertilizers and no manure/fertilizer application on papaya cv. Surya. Results indicated that application of 7 kg urban compost plant<sup>-1</sup> or 10 kg FYM plant<sup>-1</sup> improved soil health in terms of microbial population, and biochemical reaction compared to other treatments. Douglas (2003) found that manured soils had higher contents of organic matter and microfauna than fertilized soils. These were more

enriched in P, K, Ca and Mg in top soils and nitrate N, Ca and Mg in subsoils. Manured soils also had lower bulk density and higher porosity, hydraulic conductivity and aggregate stability, relative to fertilized soils.

Mukherjee *et al.*, (1991) studied the effect of oilcakes on changes in carbon and nitrogen in soil through laboratory incubation studies. They reported that oilcakes, in general increased the organic carbon, total and inorganic nitrogen and available phosphorus contents of the soil. Edible oilcakes released more nitrogen from soil than non-edible oil cakes. On the other hand, non-edible oil cakes liberated available phosphorus from soil in greater proportions than the edible oil cakes.

Peshanasi *et al.*, (1992) observed a long-term effect of different production systems including organic, conventional and integrated. It was observed that organic and integrated system resulted in an increase in total sub soil N as compared to conventional system. More (1994) reported that the addition of farm wastes and organic manures increased the availability of N, P and K. In terms of sustainability, farmyard manure fertilization maintained the total organic carbon level of 40 t C ha<sup>-1</sup>, measured in the top soil layers at the start of a 40-year experiment, while the average total organic C depletion was 23% with liquid manures and mixed fertilization treatments and 43% with mineral fertilizers (Nardi *et al.*, 2004). Laxminarayana and Patiram (2006) reported that water-holding capacity of soil was progressively improved with the application of organic manures as compared to inorganic fertilizers. The moisture retention and field capacity was highest with the addition of FYM.

Prakash *et al.*, (2002) reported that availability of all major nutrient elements, except P and micronutrients was higher in the treatments with organic sources compared to chemical fertilizers and

untreated control. The organic manured plot had a relatively higher CEC as compared to inorganic fertilizer plots. Bulk density decreased in the treatments with organic sources as compared to treatments of chemical fertilizer. They also observed higher Fe, Cu and Zn availability in the soil profile when supplemented with organic manures. Raju *et al.*, (1991) reported that the available N and P of soil after harvest of the crop were increased considerably over initial level due to incorporation of FYM. Asmus (1993) showed beneficial results on effective application of FYM in crop production. It was observed that FYM decreased NH<sub>3</sub> emission immediately after application. Ramchandra *et al.*, (1993) revealed that one-ton of cow dung supplied 5 kg K<sub>2</sub>O to soil. Muthuvel *et al.*, (1982) observed higher available N contents of soil with FYM addition, which could be attributed to the favourable microbial activity, and an enhanced biomass addition to the soil. Saha *et al.*, (2010) studied the effect of farmyard manure on soil organic carbon (SOC) in five years old mango cultivar Mallika. The highest SOC density (554 g m<sup>-2</sup>) was recorded in the treatment with FYM at 10 kg plant<sup>-1</sup>. Selvakumari (1981) observed that exchangeable K was found to increase with continuous application of manures, which could be due to the increased contents of K released from FYM.

Sharma (2002) reported that vermicompost releases nutrients slowly and steadily into the soil that enhances the capability of plants to absorb these nutrients. The soil enriched with vermicompost provided additional substances that are not found in the chemical fertilizers. Hidalgo (1999) reported that application of vermicompost increased percentage of pore space and water-holding capacity, while decreased the bulk density and percentage of air space.

The effects of coal ash addition on physical properties of soil were studied by Chang *et al.*, (2007). They found an increase in water holding capacity, but without subsequent increase in plant-

available water. At normal agronomic rates (<2.5% by volume) the impact on water release was very small. Etiegni and Campbell (1991) showed that wood ash particles swell in contact with water and can obstruct soil pores. Consequently, this may reduce the aeration and increase the water holding capacity. According to Clapham and Zibilske (1992), the electrical conductivity of the soil solution increased linearly with wood ash dose and may cause salinity problems. The application of wood ash to soil undoubtedly increased the concentration of major cations and anions in the soil solution, with risk of losses by leaching (Williams *et al.*, 1996).

There was an improvement in soil health with the application of Vermicompost. The bulk density (BD) decreased from initial value of 1.38 mg/m<sup>3</sup> to 1.19 mg/m<sup>3</sup>. This may be due to better soil aggregation and aeration brought about by organic amendments by adding various humic fractions (Kadalli *et al.*, 2000) and increased microbial and enzymatic activity which was reported to be accelerated by vermicompost (Mukherjee *et al.*, 1991). Srikanth *et al.*, (2002) studied the residual effect of enriched composts i.e. FYM, vermicompost and fertilizers on different soil properties. They reported slight decrease in the bulk density of the soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer application. They also observed slight decrease in soil pH and electrical conductivity with the application of vermicompost. Vasanthi and Kumaraswamy (1999) reported that available N, P, K, Fe and Cu status of soil was significantly higher in the treatments receiving vermicompost from any one source of organic material. All the treatments having compost invariably showed build up of available N, P and K, which might be due to mineralization of P and K present in organic manure and were released from the native source (Sing *et al.*, 2001).

Ghuman and Gur (2006) reported that increase in organic carbon in manured plots caused reduction in bulk density. Tomar *et*

*al.*, (1987) stated that organic matter is known to reduce phosphorus fixation and improves phosphorus use efficiency particularly in calcareous soils. Under organic cultivation of apple Verma *et al.*, (2009) observed significant increase in soil moisture availability, pH, organic carbon and nutrient status due to incorporation of organic manure @ 20 kg tree<sup>-1</sup> and FYM @ 100 kg tree<sup>-1</sup>. Werner (1997) reported that during third year of conversion to organic orchard management, earthworm abundance and biomass increased in organic soils as compared to conventional soil. Bertschinger *et al.*, (2004) compared the integrated and organic apple orchards and found higher soil nutrients level in organic compared to integrated orchards.

#### **2.4 Effect of different sources of organic nutrition on soil microbial population**

In a biological sense, healthy, thriving ecosystems are generally considered to be highly diverse with numerous taxa, which form a complex food web with many trophic levels (Metting and Blaine, 1993). Therefore, taxonomic and functional diversity indices are often used as an index for the health status of soil (Van Bruggen and Semenov, 2000). Cultivated soils often have lower microbial diversities than they had as a natural habitat (Buckley and Schmidt, 2001). But, organically managed soils had a higher diversity of bacteria (Drinkwater *et al.*, 1995), arbuscular mycorrhizal fungi (Oehl *et al.*, 2003), nematodes (Mulder *et al.*, 2003), earthworms (Mader *et al.*, 2002) and insects and arthropods (Asteraki *et al.*, 2004; Drinkwater *et al.*, 1995; Mader *et al.*, 2002) than conventionally managed soils. Also a higher microbial activity (Workneh *et al.*, 1993) and microbial biomass (Mulder *et al.*, 2003) were found in organic soils. However, some authors found no differences in bacterial biodiversity (Lawlor *et al.*, 2000) or in fungal communities (Franke-Snyder *et al.*, 2001) between organically or conventionally managed soils.

Soil contains enormous numbers of diverse living organisms assembled in complex and varied communities. Soil microorganisms constitute an active component of the soil organic pool, controlling the breakdown of organic matter and, hence, the release of nutrients and their availability to other organisms. The microbial biomass also acts as a small but labile reservoir of nutrients that contributes to maintaining long-term sustainability (Melero *et al.*, 2006). These microorganisms play an essential role in the sustainable function of all ecosystems, including recycling of nutrients, regulation of the soil organic matter and soil carbon sequestration, modification of soil physical structure and water regimes, enhancement of the efficiency of nutrient acquisition and plant health, suppression of undesirable organisms and detoxification of noxious chemicals. Marinari *et al.*, (2006) found that field under organic management system showed significantly better soil microbiological conditions with increased level of microbial biomass contents, and enzymatic activities (acid phosphatase, protease and dehydrogenase). Results of the study suggest that, over the period of 7 years, organic management method strongly affects soil quality indicators. Large differences between the two soils were found in terms of microbiological properties, which were the sensitive soil indicators of changes occurred under different farming systems.

A field study carried out by Melero *et al.*, (2006) evaluated the microbial biomass in soil under organic and conventional farming. The results showed that the microbial biomass was significantly higher under organic than conventional management system. The affirmation that the organic input increases the soil microbial biomass was confirmed by Araujo (2008) who evaluated the soil organic C and microbial biomass in different plots of *Malphigia glabra* orchard under six, twelve, eighteen and twenty-four months of soil organic management. From the twelve month of organic management, the highest microbial biomass C values were

recorded and significant differences between conventional and organic management were observed, while the highest organic C values were observed after twenty-four months.

Ademir *et al.*, (2009) evaluated the microbial activities in soils under conventional and organic agricultural system management regimes. Soil microbial activity and biomass was significantly greater in organic nutrition applied plots as compared to conventional plots. Chowdhury *et al.*, (2000) observed that manure compost with high decomposable C was more effective than sawdust and rice husk composts in enhancing soil microbial biomass C.

Kumar *et al.*, (2010) studied the influence of three types of soil amendments and fertilizers viz., urea, FYM, and Vermicompost on soil fungi. The maximum number of fungi were recorded when soil was amended with FYM. A total of 25 fungi were recorded during the experimental period. Lee and Chung (2007) studied the soil microbiological qualities in conventional and organic nutrition apple orchards. Microbial populations and biomass in soils of organically managed orchards were higher than those found in conventional farming. Biological soil quality indicators showed significant positive correlations with soil organic matter contents. The improvements in plant growth and fruit yields could be partially due to large increase in soil microbial biomass after vermicompost applications, leading to production of hormones or humates in the vermicompost acting as plant growth regulators independent of nutrient supply (Arancon *et al.*, 2006).

Margarita (2003) observed that amendment done with organic manures in the soil initially increased the levels of microbial biomass and basal respiration and some enzyme activities related to the C and N cycles. These values decreased but always remained higher than those of the unamended soil. The results indicate that

the addition of urban organic waste is beneficial for recovering degraded soils, the microbial activity of which clearly increases with amendment. Sharma (2002) reported that some of the secretions of worms and the associated microbes act as growth promoter along with other nutrients.

The vermicompost when applied at the rate of 20 tonnes ha<sup>-1</sup> significantly increased microbial population in grapes (Gomez *et al.*, 2006). Naidu *et al.*, (2002) also reported that application of vermicompost @ 14 tons ha<sup>-1</sup> resulted in higher microbial population in soil as compared to control. Tejada and Gonzalez (2008) reported that soil respiration and soil microbial biomass were significantly improved under vermicompost-received plots over control. Vermicompost produced from sheep and cattle manure significantly increased population of phosphate solubilizing bacteria (PSB) and free-living microorganisms (Kumari and Kumari, 2002). Nahar *et al.*, (2006) found that application of raw manure increased total organic matter, microbial biomass-N, potentially mineralizable-N and C over composted manure in 2001, while both raw and composted manure increased organic matter in both years. The organic management affects soil microbial properties with a large input of organic matter derived from green manure and organic fertilizers (Chander *et al.*, 1997).

## Chapter-3

### MATERIAL AND METHODS

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The present investigations entitled “Studies on organic nutrition in apple (*Malus × domestica* Borkh.)” were carried out at Theog and Rohru in the district Shimla during the years 2011 and 2012. The details about experiments and methodology adopted are given as under:

#### 3.1 EXPERIMENTAL DETAILS

The experiments were laid out on approx. 15-years old apple cv. Starking Delicious grown on seedling rootstock planted at a spacing of 6 x 6 meters and trained on modified central leader system. All the recommended cultural practices were followed and were kept uniform during entire course of the study for both the years. The details of experiments are given as under:

##### 3.1.1 Location

For the second experiment, selected orchard site of farmer is located at 31° 10' 18.63" latitude and 77° 44' 54.46" longitude at an elevation of 1920 m above msl, representing high hill zone of the state.

##### 3.1.2 Climate

The climate of the area is typically temperate. The annual rainfall ranges between 800-1300 mm, of which 75 per cent is received during June to September.

#### 3.2. Experiment I- Survey of organic and inorganic apple orchards.

The survey work was carried out on apple cultivar Starking Delicious at two different locations in Shimla district i.e. Theog and

Rohru for comparing the organic and inorganic management practices. The comparison of nutrition effect was done on the basis of plant health, soil health and fruit quality. Therefore, six orchards were selected randomly at each location, of which three were of certified organic orchards and three of inorganic management practices. Orchards were of similar age in each pair (one organically and one inorganically managed) were located at a close distance from one another so as to limit microclimatic and site effects.

**Experimental details:**

<b>Locations</b>	:	4 (Rohru 1, 2 and Theog 1, 2)
<b>Orchards within location</b>	:	12 (6 organic and 6 inorganic)
<b>Total no. of orchards selected</b>	:	24
<b>Number of plants from each orchards</b>	:	15
<b>Sources of nutrition</b>	:	Organic and Inorganic
<b>Cultivar</b>	:	Starking Delicious
<b>Age of plants</b>	:	15 years approximately

**3.3 Experiment II - Effect of organic sources of nutrients on apple production.**

The experiment was conducted in farmer's orchard at Lower kotti, Village Dhara, Rohru approximately on 15 years old apple plants of cultivar Starking Delicious at spacing of 6 x 6 m trained on modified central leader training system. All other cultural practices including nutrient applications were carried out as per recommendations. For the present study 20 uniform healthy trees were selected randomly from the certified organic orchard and five

inorganically managed which was adjacent to same organically managed orchard. The organic orchard was certified for organic farming by One Cert Asia agency from 2010-2012.

<b>Number of treatments</b>	<b>:</b>	<b>5</b>
<b>Experimental Design</b>	<b>:</b>	<b>RBD</b>
<b>Number of replications</b>	<b>:</b>	<b>5</b>
<b>Cultivar</b>	<b>:</b>	<b>Starking Delicious</b>
<b>Location</b>	<b>:</b>	<b>Rohru</b>

### **3.3.1 Treatments:**

- T<sub>1</sub> - FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)**
- T<sub>2</sub> - FYM (60 kg/tree) +Vermicompost (15 kg/tree) + Wood ash (4 kg/tree) + Neem cake (4 kg/tree)**
- T<sub>3</sub> - FYM (80 kg/tree) +Vermicompost (20 kg/tree) + Wood ash (6 kg/tree) + Neem cake (4 kg/tree)**
- T<sub>4</sub> - FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)**
- T<sub>5</sub> - Recommended dose of fertilizers [700-350-700 g/tree]**

### **3.3.2 Time and method of application**

FYM, Vermicompost, Neem cake and ash were applied at various concentrations in the first fortnight of February in the tree basin, while full dose of recommended fertilizers was applied only in control treatment which was allocated in adjacent inorganic orchard.

**Table 3.2 The physico-chemical characteristics of the experimental soil and the method used for estimation**

<b>Sr. No.</b>	<b>Soil properties</b>	<b>Method Used</b>	<b>Values</b>
1.	Bulk density (Mg/m <sup>3</sup> )	Pycnometer method	1.22
2.	MWHC (%)	K R Box method (Piper, 1966)	47.87
3.	pH	soil: water suspension 1: 2.5 (Jackson, 2005)	5.81
4.	EC (dSm <sup>-1</sup> )	soil: water suspension 1: 2.5 (Jackson, 2005)	0.29
5.	Organic carbon (%)	Walkley and Black wet digestion method (Jackson 1973)	1.83
6.	N (kg/ha)	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	251.45
7.	P (kg/ha)	Olsen's method (Olsen <i>et al.</i> , 1954)	11.58
8.	K (kg/ha)	Neutral normal ammonium acetate method (Merwin and Peech, 1951)	186.31
9.	Fe (ppm)	DTPA extraction at pH 7.3 (Lindsay and Norvell, 1978)	55.68
10.	Zn (ppm)		3.53
11.	Cu (ppm)		6.38
12.	Mn (ppm)		16.21

**3.3.3 Observations recorded:**

The observations given as under were same for both the experiments.

**3.3.3.1 Fruit yield and quality Parameters:****3.3.3.1.1 Fruit yield (kg/tree)**

After harvest fruit weight was taken on electrical balance and expressed in kilograms per tree.



**FYM and Vermicompost**



**Neem cake application**



**Wood ash applied basin**



**Mixing with soil**

**Plate-1 Application of organic manures in tree basins**

#### **3.3.3.1.2 Fruit weight (g)**

The weight of eight randomly selected fruits were measured with the help of electronic weighing pan and average fruit weight was calculated and expressed as weight per fruit in grams.

#### **3.3.3.1.3 Fruit firmness (kg/cm<sup>2</sup>)**

The fruit firmness was measured with a portable Effigi penetrometer (FT-327) that recorded the pressure required to force a plunger of 11 mm diameter into the flesh of pared fruit samples. The readings were taken on diagonally opposite sides of each fruit and results expressed in kg/cm<sup>2</sup>.

#### **3.3.3.1.4 Total soluble solids (TSS) (°B)**

The total soluble solids contents in fruits were determined by Erma hand refractometer (0-32°B). Temperature corrections were applied before recording the readings at 20°C (A O A C, 1980). The refractometer was calibrated with distilled water before use and then a few drops of fruit juice from each fruit were placed on the refractometer. The average of five fruits comprising one sample was taken and reading was recorded. The total soluble solids were expressed in degree brix (°B).

#### **3.3.3.1.5 Titratable acidity (%)**

A known weight of the fruit sample was crushed and taken in a 100 ml volumetric flask by adding distilled water to make up the volume. After filtration, 10 ml of the filtrate was taken in a separate conical flask and titrated against 0.1 N sodium hydroxide using phenolphthalein as an indicator. The end point was determined by the appearance of a faint pink colour. Titratable acidity was calculated and expressed as per cent malic acid (Ranganna, 1979).

$$\text{Percent acidity} = \frac{\text{Titre value x normality of NaOH} \times \text{volume made x equivalent weight of acid acidity}}{\text{Weight of sample x Aliquot taken x 1000}} \times 100$$

### 3.3.3.1.6 Reducing sugars (%)

The de-leaded and clarified solution of juice was titrated against 10 ml of boiling Fehling solutions (5 ml each of Fehling A and B) using methylene blue as an indicator, as per the method ascribed in A.O.A.C. (1980). The reducing sugars content were expressed in per cent.

$$\text{Reducing sugar (\%)} = \frac{\text{Fehling Factor x Dilution}}{\text{Titre value x weight of sample taken}} \times 100$$

### 3.3.3.1.7 Total sugars (%)

Total sugars were estimated by taking 25 grams of fruit pulp, which was thoroughly homogenized with distilled water in warring blender and the volume was made to 250 ml. To this 250 ml solution, 2 ml of saturated lead acetate was added and kept as such for ten minutes. Thereafter, 2 ml of potassium oxalate was added to remove the excess of lead. The solution was kept as such for another ten minutes and then filtered. Hundred ml of this filtered solution was hydrolyzed by adding two ml of concentrated HCl, allowing it to stand overnight for completing the inversion of sucrose. The excess of HCl was neutralized with saturated NaOH after the completion of hydrolysis in the next morning. The solution so obtained was titrated against 10 ml of the boiling Fehling's solution (5 ml each of Fehlings solution A and B) in a conical flask, using methylene blue as an indicator. The end point was indicated by the appearance of brick red colour. The total sugars content was expressed as percentage of juice weight as per the method of A O A C (1980), using formula as:

$$\text{Total sugars (\%)} = \frac{\text{Fehling Factor} \times \text{Dilution}}{\text{Titre value} \times \text{weight of sample taken}} \times 100$$

### 3.3.3.1.8 Anthocyanins (mg/100g)

Ten grams of fruit skin was taken randomly from four sides of fruit samples and crushed. To it 10 ml of ethanolic HCl was added and the mixture was allowed to stay overnight in a test tube at room temperature in dark. Absorbance was recorded on spectronic-20 at 540 nm and results were expressed in mg/100g as given below:

$$\text{Total absorbance per 100 g} = \frac{\text{Absorbance at 540 nm} \times \text{Vol. made up of the extract used for colour measurement} \times \text{Total vol.}}{\text{ml of the extract used} \times \text{Weight of the sample taken}} \times 100$$

$$\text{Total anthocyanin contents (mg/100g)} = \frac{\text{Total absorbance at 540 nm}}{\text{E value for 1\% solution}}$$

### 3.3.3.1.9 Total Phenols (mg/100g)

The total phenols content were determined by the method of Bray and Thorpe (1955) as described below:

One gram of fresh fruit pulp was macerated with 10 ml of 80 per cent ethanol and filtered through cheesecloth. The residue was washed with 1 to 5 ml of 80 per cent of ethanol. 0.2 ml of filtrate was taken in a graduated 25 ml test tube and to it 1 ml of Folin phenol reagent (1 N) was added followed by 2 ml of 20 per cent sodium carbonate. The contents were thoroughly shaken and heated on boiling water bath for one minute and then cooled under running tap water. The blue solution so obtained was diluted to 25 ml with distilled water. After 20 minutes, the optical density of the solution was recorded using spectronic-20 colorimeter at 650 nm. A blank was run simultaneously to adjust zero absorbance. Total phenols

were calculated against a standard curve prepared from different concentrations of Caffeic acid as reference. Results were expressed as mg/100g fresh weight.

### 3.3.3.1.10 Antioxidant activity (%)

Free radical scavenging was measured as per the method of Brand Williams *et al.*, (1995). DPPH (2, 2-diphenyl-1-picrylhydrazyl) was used as a source of free radical. A quantity of 3.9 ml of  $6 \times 10^{-5}$  mol/L DPPH in methanol was put into a cuvette with 0.1 ml of sample extract and the decrease in absorbance was measured at 515 nm for 30 min or until the absorbance become steady. The remaining DPPH concentration was calculated using the following equation:

$$\text{Free radical scavenging activity (\%)} = \frac{\text{Ab}_{(B)} - \text{Ab}_{(s)}}{\text{Ab}_{(B)}} \times 100$$

Where,

$\text{Ab}_{(B)}$  = Absorbance of blank

$\text{Ab}_{(s)}$  = Absorbance of sample

### 3.3.3.2 Storage studies at ambient temperature

#### 3.3.3.2.1 Physiological loss in weight (PLW) (%)

At the start of the experiment marked fruits were weighed using a digital balance and the same fruits were weighed at an interval of 15 days expressed as per cent of initial weight for every sample.

#### 3.3.3.2.2 Rotting percentage

Fruits spoiled due to fungal rots were counted at every storage interval and the total number was calculated by adding up all the diseased fruits from successive storage intervals. Dividing the

number of fruits spoiled by the total number of fruits stored and multiplying the result by 100 calculated the spoilage per cent.

#### **3.3.3.2.3 Fruit Firmness (kg/cm<sup>2</sup>)**

The procedure was followed as detailed in 3.3.3.1.3

#### **3.3.3.2.4 Total soluble solids (TSS)(<sup>0</sup>B)**

The procedure was followed as detailed in 3.3.3.1.4

### **3.3.3.3 Leaf nutrient status**

#### **3.3.3.3.1 Collection and preparation of samples**

Leaf samples from the experimental plants were collected during each year of the study in the last week of July from mid terminal shoots of current season's growth. Collected leaf samples were washed under tap water followed by 0.1 N HCl, distilled water and finally with double distilled water. The drying, grinding and storing of samples were carried out in accordance with the procedure described by Kenworthy (1964). Further, the samples were analyzed for their estimation of macro and micronutrients content.

#### **3.3.3.3.2 Digestion of leaf samples for estimation of Nitrogen (%)**

Leaf nitrogen (N) was determined by micro-Kjeldahl method as described by Jackson (1973).

#### **3.3.3.3.3 Digestion of leaf samples for estimation of P, K, Cu, Zn, Fe and Mn (ppm)**

a) The leaf samples were digested in  $\text{HN0}_3:\text{HC1O}_4$  mixture (4:1). Phosphorus was determined by Vanadomolybdate yellow colour method (Jackson, 1973) and potassium was estimated on flame photometer.

**b) Micronutrients:** Leaf Zn, Cu, Fe and Mn were digested in the di-acid extract (HNO<sub>3</sub> and HClO<sub>4</sub>) and determined on Atomic Absorption Spectrophotometer.

**Table 3.1 Methods used for estimating nutrient content from leaves**

Particular	Method employed	Reference(s)
1. Nitrogen	Microkjeldhal distillation	A O A C. (1980)
2. Phosphorus	Vando-molybdophosphoric yellow colour method	Jackson (1973)
3. Zinc, Manganese, Copper, Iron	Atomic absorption spectrophotometer (AAS)	Vogel (1978)

#### 3.3.3.4 Physico-Chemical properties of soil

The soil was analyzed for important physico-chemical properties and available nutrient status by adopting the following procedures.

##### 3.3.3.4.1 Physical properties

###### 3.3.3.4.1.1 Water holding capacity (%)

The maximum water holding capacity was analyzed with the procedure described by K R Box method (Piper, 1966)

###### 3.3.3.4.1.2 Bulk density (g/cc)

Bulk density of soil was determined in the field by core tube method and calculated by using the formula:

$$\text{BD (Mg m}^{-3}\text{)} = \frac{\text{weight of oven dry soil in the core (Mg)}}{\text{volume of the soil (m}^3\text{)}}$$

### **3.3.3.4.2 Chemical Properties**

#### **3.3.3.4.2.1 pH**

The soil pH was determined in 1:2.5 soil : water suspension.

#### **3.3.3.4.2.2 Electrical conductivity (dSm/m<sup>2</sup>)**

The soil electrical conductivity was determined in 1:2.5 soil : water suspension and the supernatant liquid was recorded and expressed in dSm<sup>-1</sup> (Jackson 1973).

#### **3.3.3.4.2.3 Organic carbon (%)**

Organic carbon was determined by Chromic acid titration method of Walkley and Black (1934).

#### **3.3.3.4.2.4 Available Nitrogen (kg/ha)**

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

#### **3.3.3.4.2.5 Available Phosphorous (kg/ha)**

0.5 N NaHCO<sub>3</sub> at 8.5 pH was used to extract available phosphorus (Olsen's *et al.*, 1954) and determined by spectrophotometrically.

#### **3.3.3.4.2.6 Available Potassium (kg/ha)**

Available potassium was extracted by normal neutral ammonium acetate (Merwin and Peech, 1951) and determined on flame photometer.

#### **3.3.3.4.2.7 Available micronutrients (mg/kg<sup>-1</sup>)**

These were determined by following the procedures as outlined by Lindsay and Norvell (1978). Ten gram of soil was shaken with 20 ml of DTPA extractant of pH 7.3 for two hours and

filtered. Available Zn, Cu, Fe and Mn in the extract were determined on Atomic Absorption Spectrophotometer.

### **3.3.3.4.3 Biological Properties of soil**

#### **3.3.3.4.3.1 Total Microbial Count (cfu/g soil)**

The soil was analyzed for total microbial count. 1g of soil mixture was taken in 9 ml of sterilized water blank and the soil suspension was diluted in 10 folds series, then microbial count was determined by standard pour plate technique on soil extract medium as described by (Subba Rao 1999). The population was expressed as colony forming units (cfu/g soil).

### **3.3.4 Observations recorded for second experiment:**

#### **3.3.4 Plant growth and flowering parameters**

##### **3.3.4.1 Trunk girth (cm)**

The trunk girth of each experimental plant was recorded by marking the trunk 30 cm above the ground level with the help of measuring tape.

##### **3.3.4.2 Duration of flowering (Days)**

The observations on flowering were taken by recording the dates of starting of flowering, full bloom (75 % flowers opened) and end of flowering. From these dates, the duration of flowering was worked and expressed in days.

##### **3.3.4.3 Fruit set (%)**

Four branches of one-meter length were selected on each tree in all the directions. The numbers of flowers present on these branches were counted 15 days after full bloom. The numbers of fruits were also counted at fruit set. The per cent fruit set was calculated as under:

$$\text{Per cent fruit set} = \frac{\text{Total number of fruit set}}{\text{Total number of flower clusters}} \times 100$$

### 3.3.5 Statistical analysis

a) For first experiment the data was analyzed in two-way analysis (Two-way ANOVA) for locations and nutrition sources to elucidate the variations in fruit parameters, leaf and soil nutrient status.

b) The data generated from experiment second investigation were subjected to Randomized Block Design statistical analysis using the statistical package SPSS (14.0) and Microsoft Excel.

**Table 3.3 Critical limits (kg ha<sup>-1</sup>) of available nutrients in soil**

Sr. No.	Nutrient Element	Soil fertility class			References
		Low	Medium	High	
1	Organic carbon (%)	<0.5	0.5-1.0	>1.0	<b>Bhandari and Tripathi, (1979)</b>
2	Available N (kg ha <sup>-1</sup> )	< 280.0	280.0-560	> 560.0	<b>FAI (1977)</b>
3	Available P (kg ha <sup>-1</sup> )	< 10.0	10.0-24.6	>24.6	<b>FAI (1977)</b>
4	Available K (kg ha <sup>-1</sup> )	< 98.6	98.6-280.0	> 280.0	<b>FAI (1977)</b>
<b>Secondary macronutrients</b>					
		Deficient	Sufficient		
5	Available S (kg ha <sup>-1</sup> )	<22.4	>22.4		Tandon (1991)
<b>Micronutrients (mg kg<sup>-1</sup>)</b>					
6	Zn	<1.0	1.0-3.0	>3.0	<b>Lindsay and Norvell (1978)</b>
7	Cu	< 0.2	0.2-2.0	> 2.0	<b>Follet and Lindsay (1978)</b>
8	Fe	< 4.0	4.0-6.0	>6.0	<b>Lindsay and Norvell (1978)</b>
9	Mn	< 1.2	1.2-3.5	> 3.5	<b>Lindsay and Norvell (1978)</b>

**Table 3.4. Rating limits of nutrients used for apple (leaves)**

Sr. No.	Nutrient element	Nutrient level			
		Macronutrients (%)			
		Deficient	Low	Medium	High
1	N	1.50	1.50-1.80	1.80-2.40	2.50+
2	P	0.14	0.15-0.18	0.18-0.28	0.30+
3	K	1.00	1.00-1.20	1.30-1.70	1.80+
4	S	<0.10	-	-	>0.10
Micronutrient (ppm)					
5	Zn	15.0	15.0-20.0	20.0-50.0	50.0+
6	Cu	5.0	5.0-10.0	10.0-20.0	20.0+
7	Fe	30.0	30.0-35.0	35.0-150.0	150.0+
8	Mn	25.0	25.0-30.0	31.0-150.0	150.0+

\* Plant analysis laboratory of Ohio State University, USA

## **Chapter-4**

# **EXPERIMENTAL RESULTS**

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The results emanating from the experiments carried out on farmer's field at Theog and Rohru sites of Shimla district during the years 2011 and 2012 with their pooled analysis have been described under following heads:

### **4.1 EXPERIMENT I- SURVEY OF ORGANIC AND INORGANIC APPLE ORCHARDS**

The survey work was carried out on apple cultivar Starking Delicious at two different locations in Shimla district i.e. Theog and Rohru for comparing the organic and inorganic farming practices of apple orchards. The plant health, soil health and fruit quality parameters were used as basis for the study and explained on the basis of pooled data under different headings:

#### **4.1. A Fruit Quality Parameters:**

##### **4.1.1.1 Fruit Yield:**

The data pertaining to fruit yield from survey of organic and inorganic apple orchards at Theog and Rohru are presented in Table 4.1.1.

Perusal of data on fruit yield revealed that there was significant variation between nutrition sources. However, there was no significant difference among locations and interactions. Between nutrition sources significantly higher fruit yield (59.79 kg/tree) was recorded from inorganic as compared to organic (37.76 kg/tree) apple orchards. However, among different locations, maximum fruit yield (52.22 kg/tree) was recorded at Theog-1 and minimum (45.31 kg/tree) in Rohru-2 apple orchards. Among interactions, maximum fruit yield (63.70 kg/tree) was recorded from inorganic apple

**Table 4.1.1. Fruit yield (kg/plant) of apple in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	45.62	68.64	<b>57.13</b>	35.84	58.75	<b>47.30</b>	40.73	63.70	<b>52.22</b>
<b>Theog-2</b>	47.44	64.89	<b>56.17</b>	33.31	50.72	<b>42.02</b>	40.38	57.81	<b>49.09</b>
<b>Rohru-1</b>	39.67	65.66	<b>52.67</b>	29.66	55.78	<b>42.72</b>	34.66	60.72	<b>47.69</b>
<b>Rohru-2</b>	38.58	61.97	<b>50.28</b>	28.73	51.94	<b>40.34</b>	33.66	56.96	<b>45.31</b>
<b>Mean</b>	<b>42.83</b>	<b>65.29</b>		<b>31.89</b>	<b>54.30</b>		<b>37.36</b>	<b>59.79</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	NS			NS			NS		
<b>Sources</b>	<b>4.41</b>			<b>4.15</b>			<b>3.94</b>		
<b>LxS</b>	NS			NS			NS		

**Table 4.1.2. Fruit weight (g) of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	135.33	162.69	<b>149.01</b>	142.24	159.93	<b>151.09</b>	138.79	161.31	<b>150.05</b>
<b>Theog-2</b>	141.42	154.67	<b>148.04</b>	142.11	154.73	<b>148.42</b>	141.77	154.70	<b>148.23</b>
<b>Rohru-1</b>	132.11	153.05	<b>142.58</b>	138.22	153.01	<b>145.62</b>	135.17	153.03	<b>144.10</b>
<b>Rohru-2</b>	138.89	148.17	<b>143.53</b>	140.72	152.22	<b>146.47</b>	139.80	150.20	<b>145.00</b>
<b>Mean</b>	<b>136.94</b>	<b>154.64</b>		<b>140.82</b>	<b>154.97</b>		<b>138.88</b>	<b>154.81</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	NS			NS			NS		
<b>Sources</b>	<b>5.36</b>			<b>5.82</b>			<b>5.31</b>		
<b>LxS</b>	NS			NS			NS		

**Table 4.1.3. Firmness (kg/ sq. inch) of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	6.34	6.23	<b>6.28</b>	6.40	6.23	<b>6.32</b>	6.37	6.23	<b>6.30</b>
<b>Theog-2</b>	6.25	6.19	<b>6.22</b>	6.30	6.19	<b>6.25</b>	6.28	6.19	<b>6.24</b>
<b>Rohru-1</b>	6.27	6.19	<b>6.23</b>	6.30	6.25	<b>6.27</b>	6.29	6.22	<b>6.25</b>
<b>Rohru-2</b>	6.32	6.17	<b>6.25</b>	6.35	6.21	<b>6.28</b>	6.34	6.19	<b>6.27</b>
<b>Mean</b>	<b>6.30</b>	<b>6.20</b>		<b>6.34</b>	<b>6.22</b>		<b>6.32</b>	<b>6.21</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	NS			NS			NS		
<b>Sources</b>	<b>0.04</b>			<b>0.05</b>			<b>0.04</b>		
<b>LxS</b>	NS			NS			NS		

**Table 4.1.4. Total soluble solids (TSS) contents (<sup>0</sup>B) of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	12.44	12.31	<b>12.38</b>	12.47	12.33	<b>12.40</b>	12.47	12.32	<b>12.39</b>
<b>Theog-2</b>	12.38	12.28	<b>12.33</b>	12.42	12.31	<b>12.37</b>	12.40	12.28	<b>12.34</b>
<b>Rohru-1</b>	12.34	12.29	<b>12.32</b>	12.41	12.32	<b>12.37</b>	12.38	12.32	<b>12.35</b>
<b>Rohru-2</b>	12.33	12.27	<b>12.30</b>	12.36	12.29	<b>12.33</b>	12.35	12.24	<b>12.29</b>
<b>Mean</b>	<b>12.37</b>	<b>12.29</b>		<b>12.42</b>	<b>12.31</b>		<b>12.40</b>	<b>12.29</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	NS			NS			NS		
<b>Sources</b>	<b>0.10</b>			<b>0.09</b>			<b>0.08</b>		
<b>LxS</b>	NS			NS			NS		

orchards of Theog-1 and minimum (33.66 kg /tree) from organic apple orchards in Rohru-2.

#### **4.1.1.2 Fruit weight**

The data pertaining to fruit weight as influenced by different locations, nutrient sources and their interactions are presented in Tables 4.1.2. Pooled data revealed significantly higher average fruit weight (154.81 g) from inorganic as compared to organic (138.88 g) apple orchards. In different locations no significant variations were observed, however, maximum fruit weight (150.05 g) was recorded in Theog-1 and minimum (144.10 g) in Rohru-1 apple orchard fruits.

There was no significant difference found among interactions. However, maximum (161.31 g) and minimum (135.17 g) fruit weight was recorded in Theog-1 inorganic and Rohru-1 organic apple orchards, respectively.

#### **4.1.1.3 Fruit Firmness**

The effect of nutrient sources and locations of apple orchards on fruit firmness are indicated in Table 4.1.3.

Mean pooled values of fruit firmness displayed significant variations under different nutrient sources. Significantly better fruit firmness (6.32 kg/sq. inch) was recorded from organic as compared to inorganic (6.21 kg/sq. inch) apple orchards. There were no significant differences observed among different locations and interactions. Maximum fruit firmness (6.30 kg/sq. inch) was recorded in Theog-1 and minimum (6.24 kg/sq. inch) in Theog-2 apple orchard fruits. Among interactions, maximum fruit firmness (6.37 kg/sq. inch) was recorded in organic orchards of Theog-1 and minimum (6.19 kg/ sq. inch) in Theog-1 and Rohru-2 inorganic apple orchards.

#### **4.1.1.4 Total soluble solids**

Total soluble solids contents of apple fruits recorded from organic and inorganic apple orchards in Theog and Rohru are presented in Table 4.1.4.

It is evident from the data that nutrient sources showed significant effect on total soluble solids of apple fruits. Significantly higher TSS ( $12.40^0\text{B}$ ) contents were recorded from organic as compared to inorganic ( $12.29^0\text{B}$ ) apple orchard fruits. Simultaneously, in different locations there was no significant variation. Maximum TSS ( $12.39^0\text{B}$ ) contents were registered in the fruits of Theog-1 and minimum ( $12.29^0\text{B}$ ) in Rohru-2 apple orchards.

There were no significant differences observed among interactions. However, maximum TSS ( $12.47^0\text{B}$ ) contents were observed in fruits of organic orchards from Theog-1 and minimum ( $12.24^0\text{B}$ ) from inorganic apple orchards of Rohru-2.

#### **4.1.1.5 Titratable acidity**

The data in relation to titratable acidity of apple fruits from organic and inorganic apple orchards in Theog and Rohru are presented in Table 4.1.5.

The pooled data on titratable acidity showed significant changes from different sources of nutrition, but no significant variations were observed in locations and among interactions. Between nutrition sources significantly higher titratable acidity (0.29 %) contents of apple fruits was recorded from organic as compared to inorganic (0.25 %) apple orchard. In different locations maximum titratable acidity (0.29 %) contents of apple fruits was recorded in Theog-1 organic and minimum (0.24 %) at Rohru-1 and Rohru-2 inorganic apple orchards, respectively.

**Table 4.1.5. Titrable acidity (%) of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	0.32	0.26	<b>0.29</b>	0.31	0.27	<b>0.29</b>	0.31	0.27	<b>0.29</b>
<b>Theog-2</b>	0.29	0.24	<b>0.26</b>	0.30	0.27	<b>0.29</b>	0.29	0.26	<b>0.28</b>
<b>Rohru-1</b>	0.28	0.23	<b>0.25</b>	0.30	0.25	<b>0.28</b>	0.29	0.24	<b>0.27</b>
<b>Rohru-2</b>	0.27	0.24	<b>0.26</b>	0.29	0.26	<b>0.28</b>	0.28	0.25	<b>0.27</b>
<b>Mean</b>	<b>0.29</b>	<b>0.24</b>		<b>0.30</b>	<b>0.26</b>		<b>0.29</b>	<b>0.25</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	NS			NS			NS		
<b>Sources</b>	<b>0.03</b>			<b>0.02</b>			<b>0.02</b>		
<b>LxS</b>	NS			NS			NS		

**Table 4.1.6. Reducing sugars (%) content of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	6.57	6.32	<b>6.44</b>	6.60	6.35	<b>6.47</b>	6.58	6.33	<b>6.46</b>
<b>Theog-2</b>	6.42	6.25	<b>6.33</b>	6.50	6.33	<b>6.41</b>	6.46	6.29	<b>6.37</b>
<b>Rohru-1</b>	6.46	6.25	<b>6.36</b>	6.47	6.39	<b>6.43</b>	6.46	6.32	<b>6.39</b>
<b>Rohru-2</b>	6.35	6.21	<b>6.28</b>	6.46	6.28	<b>6.37</b>	6.40	6.24	<b>6.32</b>
<b>Mean</b>	<b>6.45</b>	<b>6.26</b>		<b>6.51</b>	<b>6.34</b>		<b>6.48</b>	<b>6.30</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	NS			NS			NS		
<b>Sources</b>	<b>0.19</b>			<b>0.14</b>			<b>0.14</b>		
<b>LxS</b>	NS			NS			NS		

#### **4.1.1.6 Reducing sugars**

The effects of nutrition sources and locations on reducing sugars contents of apple fruits are depicted in Table 4.1.6.

There were significant variations observed in reducing sugars content between different nutrition sources. Significantly higher reducing sugars (6.48 %) content was recorded in fruits of organic as compared to inorganic (6.30 %) apple orchards. In different locations no significant variations were found. However, maximum reducing sugars (6.46 %) content was registered in fruits from Theog-1 and minimum (6.32 %) in Rohru-1 apple orchards. However, there were no significant variations observed in interactions.

#### **4.1.1.7 Total Sugars**

The data on total sugars contents of apple fruits from organic and inorganic apple orchards in Theog and Rohru are shown in Table 4.1.7.

The values of pooled data for total sugars differed significantly for nutrition sources. The fruits from organic orchards recorded significantly higher total sugars (8.45 %) as compared to inorganic (8.22 %) apple orchards. There were no significant variations in different locations. While, maximum fruit total sugars (8.42 %) contents was shown in Theog-1 and minimum (8.24 %) in Rohru-2 apple orchards. There were no significant differences among interactions also. Higher total sugars contents (8.58 %) were recorded in Theog-1 organic and lower in Rohru-2 (8.08 %) inorganic apple orchard fruits.

**Table 4.1.7. Total Sugars (%) contents of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	8.55	8.18	<b>8.37</b>	8.60	8.37	<b>8.48</b>	8.58	8.27	<b>8.42</b>
<b>Theog-2</b>	8.35	8.21	<b>8.28</b>	8.41	8.33	<b>8.37</b>	8.38	8.27	<b>8.32</b>
<b>Rohru-1</b>	8.43	8.26	<b>8.35</b>	8.45	8.30	<b>8.37</b>	8.44	8.28	<b>8.36</b>
<b>Rohru-2</b>	8.40	8.07	<b>8.23</b>	8.42	8.08	<b>8.25</b>	8.41	8.08	<b>8.24</b>
<b>Mean</b>	<b>8.43</b>	<b>8.18</b>		<b>8.47</b>	<b>8.27</b>		<b>8.45</b>	<b>8.22</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		
<b>Sources</b>	<b>0.23</b>			<b>0.20</b>			<b>0.18</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.8. Anthocyanins (mg/100g) contents of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	28.57	25.12	<b>26.84</b>	30.40	25.26	<b>27.83</b>	29.49	25.19	<b>27.34</b>
<b>Theog-2</b>	25.62	24.90	<b>25.26</b>	26.53	24.62	<b>25.58</b>	26.08	24.76	<b>25.42</b>
<b>Rohru-1</b>	32.40	26.80	<b>29.60</b>	33.89	26.21	<b>30.05</b>	33.15	26.50	<b>29.82</b>
<b>Rohru-2</b>	27.60	26.76	<b>27.18</b>	28.15	25.64	<b>26.89</b>	27.87	26.20	<b>27.04</b>
<b>Mean</b>	<b>28.55</b>	<b>25.89</b>		<b>29.74</b>	<b>25.43</b>		<b>29.14</b>	<b>25.66</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>1.74</b>			<b>1.78</b>			<b>1.32</b>		
<b>Sources</b>	<b>1.23</b>			<b>1.26</b>			<b>0.93</b>		
<b>LxS</b>	<b>2.46</b>			<b>2.51</b>			<b>1.86</b>		

#### **4.1.1.8 Anthocyanins**

The data pertaining to anthocyanins contents of apple fruits from organic and inorganic apple orchards in Theog and Rohru are presented in Table 4.1.8.

There were significant differences observed among different locations, nutrient sources and their interactions. Maximum anthocyanins (29.82 mg/100g) contents were recorded in the fruits from Rohru-1. However, lowest contents were observed in the fruits from Theog-2 (25.42 mg/100g) apple orchards. Between nutrition sources, significantly higher anthocyanins (29.14 mg/100g) contents were recorded from organic as compared to inorganic (25.66 mg/100g) apple orchard fruits. Among interactions, significantly higher (29.49 mg/100g) anthocyanins contents were recorded in the fruits of Theog-1 organic compared to Theog-2 (24.76 mg/100g) inorganic apple orchards.

#### **4.1.1.9 Total Phenols**

The pooled data pertaining to total phenols contents of apple fruits from organic and inorganic orchards at Theog and Rohru are presented in Table 4.1.9.

Maximum total phenols contents (56.67 mg/100g) were recorded in the fruits from Theog-1, which was significantly higher than all other locations. However, lowest total phenols contents were found in the fruits from Theog-2 (50.67 mg/100g) orchards. Between nutrient sources, significantly higher total phenols contents (56.34 mg/100g) were observed in fruits from organic compared to inorganic (50.21 mg/100g) apple orchards. There were no significant differences observed among interactions.

#### **4.1.1.10 Antioxidants**

Pooled data from Table 4.1.10 revealed antioxidants contents of apple fruits, which were significantly influenced at different locations with organic and inorganic nutrient management practices and their interactions.

Maximum antioxidant contents (62.25 %) were recorded in the fruits from Theog-1, which was statistically at par (60.01 mg/100g) with Rohru-1 and lowest from Rohru-2 (57.07 %) apple orchards. At the same time, between nutrient sources antioxidants contents (62.99 %) were significantly higher in fruits from organic as compared to inorganic (56.04 %) apple orchards.

Interactions were also found to be significantly different for both locations and nutrient sources. Maximum antioxidant activity (66.47 %) was recorded in the fruits from Theog-1 organic apple orchards, which was statistically at par with Rohru-1 organic apple orchard recording 65.44 per cent. However, the lowest antioxidant activity (54.59 %) was recorded from Rohru-1 inorganic apple orchard fruits.

**Table 4.1.9.Total Phenols (mg/100g) content of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	61.20	50.20	<b>55.70</b>	62.53	52.73	<b>57.63</b>	61.87	51.47	<b>56.67</b>
<b>Theog-2</b>	53.29	46.40	<b>49.84</b>	54.07	48.94	<b>51.51</b>	53.68	47.67	<b>50.67</b>
<b>Rohru-1</b>	56.28	49.69	<b>52.99</b>	56.89	52.73	<b>54.81</b>	56.59	51.21	<b>53.90</b>
<b>Rohru-2</b>	51.86	49.20	<b>50.53</b>	54.58	51.80	<b>53.19</b>	53.22	50.50	<b>51.86</b>
<b>Mean</b>	<b>55.66</b>	<b>48.87</b>		<b>57.02</b>	<b>51.55</b>		<b>56.34</b>	<b>50.21</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>4.05</b>			<b>3.72</b>			<b>2.40</b>		
<b>Sources</b>	<b>2.86</b>			<b>2.63</b>			<b>1.69</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.10.Antioxidants (%) of apple fruits in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	66.62	57.86	<b>62.24</b>	66.31	58.20	<b>62.25</b>	66.47	58.03	<b>62.25</b>
<b>Theog-2</b>	60.29	56.55	<b>58.42</b>	61.12	56.91	<b>59.01</b>	60.71	56.73	<b>58.72</b>
<b>Rohru-1</b>	64.57	53.73	<b>59.15</b>	66.31	55.44	<b>60.88</b>	65.44	54.59	<b>60.01</b>
<b>Rohru-2</b>	58.62	53.77	<b>56.19</b>	60.05	55.86	<b>57.95</b>	59.33	54.82	<b>57.07</b>
<b>Mean</b>	<b>62.53</b>	<b>55.48</b>		<b>63.45</b>	<b>56.60</b>		<b>62.99</b>	<b>56.04</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>2.74</b>			<b>2.46</b>			<b>2.40</b>		
<b>Sources</b>	<b>1.94</b>			<b>1.74</b>			<b>1.70</b>		
<b>LxS</b>	<b>3.88</b>			<b>3.47</b>			<b>3.40</b>		

**Table 4.1.11. Physiological loss in weight (%) of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations**

A]

		2011											Mean
Sources	Organic					Mean	Inorganic						
Intervals Locations	0	15	30	45	60		0	15	30	45	60		
Theog-1	0.00	4.80	5.49	5.98	6.48	<b>4.55</b>	0.00	4.87	5.59	5.89	6.99	<b>4.67</b>	
Theog-2	0.00	4.77	5.46	6.06	6.52	<b>4.56</b>	0.00	5.01	5.70	6.47	7.21	<b>4.88</b>	
Rohru-1	0.00	5.16	6.19	6.74	7.18	<b>5.05</b>	0.00	5.77	6.22	6.53	7.79	<b>5.26</b>	
Rohru-2	0.00	5.31	5.80	6.65	7.10	<b>4.97</b>	0.00	5.71	6.40	7.17	7.81	<b>5.42</b>	
Mean	<b>0.00</b>	<b>5.01</b>	<b>5.73</b>	<b>6.36</b>	<b>6.82</b>		<b>0.00</b>	<b>5.34</b>	<b>5.98</b>	<b>6.51</b>	<b>7.45</b>		
Mean (S)	<b>4.78</b>						<b>5.06</b>						
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>						
Sources	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>					<b>0.17</b>	
Theog-1	0.00	4.83	5.54	5.93	6.74	<b>4.61</b>	<b>Sources (S)</b>					<b>0.12</b>	
Theog-2	0.00	4.89	5.58	6.26	6.86	<b>4.72</b>	<b>Intervals (I)</b>					<b>0.20</b>	
Rohru-1	0.00	5.46	6.20	6.63	7.48	<b>5.16</b>	<b>L×S</b>					<b>NS</b>	
Rohru-2	0.00	5.51	6.10	6.91	7.45	<b>5.19</b>	<b>L×I</b>					<b>0.28</b>	
Mean (I)	<b>0.00</b>	<b>5.17</b>	<b>5.86</b>	<b>6.44</b>	<b>7.13</b>		<b>S×I</b>					<b>NS</b>	
							<b>L×S×I</b>					<b>NS</b>	

B]

	2012											
Sources	Organic					Mean	Inorganic					Mean
Intervals Locations	0	15	30	45	60		0	15	30	45	60	
<b>Theog-1</b>	0.00	3.62	5.38	5.82	6.35	<b>4.24</b>	0.00	4.77	5.41	5.77	6.70	<b>4.53</b>
<b>Theog-2</b>	0.00	4.78	5.42	5.84	6.59	<b>4.52</b>	0.00	4.83	5.50	6.76	7.35	<b>4.89</b>
<b>Rohru-1</b>	0.00	4.32	6.08	6.52	7.05	<b>4.80</b>	0.00	5.60	6.11	6.51	7.40	<b>5.12</b>
<b>Rohru-2</b>	0.00	5.26	5.78	6.66	7.03	<b>4.95</b>	0.00	5.53	6.20	7.15	7.29	<b>5.23</b>
<b>Mean</b>	<b>0.00</b>	<b>4.49</b>	<b>5.67</b>	<b>6.21</b>	<b>6.75</b>		<b>0.00</b>	<b>5.18</b>	<b>5.80</b>	<b>6.55</b>	<b>7.19</b>	
<b>Mean (S)</b>	<b>4.63</b>						<b>4.94</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
<b>Sources</b>	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>					<b>0.21</b>
<b>Theog-1</b>	0.00	4.20	5.40	5.80	6.53	<b>4.38</b>	<b>Sources (S)</b>					<b>0.15</b>
<b>Theog-2</b>	0.00	4.80	5.46	6.30	6.97	<b>4.71</b>	<b>Intervals (I)</b>					<b>0.24</b>
<b>Rohru-1</b>	0.00	4.96	6.10	6.52	7.23	<b>4.96</b>	<b>L×S</b>					<b>NS</b>
<b>Rohru-2</b>	0.00	5.39	5.99	6.91	7.16	<b>5.09</b>	<b>L×I</b>					<b>0.33</b>
<b>Mean (I)</b>	<b>0.00</b>	<b>4.84</b>	<b>5.74</b>	<b>6.38</b>	<b>6.97</b>		<b>S×I</b>					<b>NS</b>
							<b>L×S×I</b>					<b>NS</b>

C]

Sources Intervals Locations	Pooled											Mean
	Organic					Mean	Inorganic					
	0	15	30	45	60		0	15	30	45	60	
<b>Theog-1</b>	0.00	4.21	5.44	5.90	6.41	<b>4.39</b>	0.00	4.82	5.50	5.83	6.85	<b>4.60</b>
<b>Theog-2</b>	0.00	4.77	5.44	5.95	6.55	<b>4.54</b>	0.00	4.92	5.60	6.62	7.28	<b>4.88</b>
<b>Rohru-1</b>	0.00	4.74	6.14	6.63	7.11	<b>4.92</b>	0.00	5.68	6.17	6.52	7.60	<b>5.19</b>
<b>Rohru-2</b>	0.00	5.28	5.79	6.66	7.06	<b>4.96</b>	0.00	5.62	6.30	7.16	7.55	<b>5.32</b>
<b>Mean</b>	<b>0.00</b>	<b>4.75</b>	<b>5.70</b>	<b>6.29</b>	<b>6.78</b>		<b>0.00</b>	<b>5.26</b>	<b>5.89</b>	<b>6.53</b>	<b>7.32</b>	
<b>Mean (S)</b>	<b>4.70</b>						<b>5.00</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
<b>Sources</b>	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>					<b>0.16</b>
<b>Theog-1</b>	0.00	4.52	5.47	5.87	6.63	<b>4.50</b>	<b>Sources (S)</b>					<b>0.11</b>
<b>Theog-2</b>	0.00	4.84	5.52	6.28	6.91	<b>4.71</b>	<b>Intervals (I)</b>					<b>0.18</b>
<b>Rohru-1</b>	0.00	5.21	6.15	6.58	7.35	<b>5.06</b>	<b>L×S</b>					<b>NS</b>
<b>Rohru-2</b>	0.00	5.45	6.04	6.91	7.31	<b>5.14</b>	<b>L×I</b>					<b>0.25</b>
<b>Mean (I)</b>	<b>0.00</b>	<b>5.00</b>	<b>5.80</b>	<b>6.41</b>	<b>7.05</b>		<b>S×I</b>					<b>0.36</b>
							<b>L×S×I</b>					<b>NS</b>

#### **4.1.B Effect on storage studies of apple fruits at room temperature**

##### **4.1.2.1 Physiological loss in weight (PLW)**

The mean of pooled Table 4.1.11 C revealed that there was an overall increase in PLW of apple fruits during storage period. The overall effect of locations (L), nutrient sources (S), and storage interval (I) on PLW of apple fruits increased from 5.00 to 7.05 % and retained significantly higher (5.00 %) from inorganic compared to organic 4.70 % apple orchard fruits. However, at different locations significantly higher (5.14 %) PLW was recorded at Rohru-2 compared to other locations and lowest was recorded in Theog-1 (4.50 %) apple orchard fruits.

The combined effect of locations, nutrient sources, storage intervals (L×S×I), locations and storage intervals (L×I) and nutrient sources and storage interval (S×I) differed significantly. However, combined effect of locations and nutrient sources (L×S) and locations, nutrient sources and storage intervals (L×S×I) were found to be non-significant.

##### **4.1.2.2 Rotting percentage**

An appraisal of pooled data (Table 4.1.12 C) reveals that there was an overall increase in rotting percentage of apple fruits during storage interval. The overall effect of locations (L), nutrient sources (S), and storage interval (I) on rotting of apple fruits increased from 7.73 to 33.34 per cent during storage period. Further, while comparing the overall effect of nutrient sources (S) it was found that significantly more (16.53 %) rotting was observed from organic orchard fruits as compared to inorganic (14.23 %) apple orchard fruits. The overall effect of locations (L) indicated that

**Table 4.1.12. Rotting (%) of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations**

A]

		2011										Mean
Sources	Organic					Mean	Inorganic					
Intervals	0	15	30	45	60		0	15	30	45	60	
Locations												
Theog-1	0.00	6.64	14.00	21.00	36.00	<b>15.53</b>	0.00	7.20	12.60	18.40	33.00	<b>14.24</b>
Theog-2	0.00	4.20	14.60	23.40	41.00	<b>16.64</b>	0.00	5.80	12.20	19.00	31.00	<b>13.60</b>
Rohru-1	0.00	11.24	19.00	26.00	42.20	<b>19.69</b>	0.00	9.80	14.60	24.20	33.40	<b>16.40</b>
Rohru-2	0.00	10.00	19.60	28.40	39.60	<b>19.52</b>	0.00	10.80	17.20	24.00	31.20	<b>16.64</b>
Mean	<b>0.00</b>	<b>8.02</b>	<b>16.80</b>	<b>24.70</b>	<b>39.70</b>		<b>0.00</b>	<b>8.40</b>	<b>14.15</b>	<b>21.40</b>	<b>32.15</b>	
Mean (S)	<b>17.84</b>						<b>15.22</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
Sources	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>		<b>1.63</b>			
Theog-1	0.00	6.92	13.30	19.70	34.50	<b>14.88</b>	<b>Sources (S)</b>		<b>1.15</b>			
Theog-2	0.00	5.00	13.40	21.20	36.00	<b>15.12</b>	<b>Intervals (I)</b>		<b>1.82</b>			
Rohru-1	0.00	10.52	16.80	25.10	37.80	<b>18.04</b>	<b>L×S</b>		<b>NS</b>			
Rohru-2	0.00	10.40	18.40	26.20	35.40	<b>18.08</b>	<b>L×I</b>		<b>2.57</b>			
Mean (I)	<b>0.00</b>	<b>8.21</b>	<b>15.48</b>	<b>23.05</b>	<b>35.93</b>		<b>S×I</b>		<b>NS</b>			
							<b>L×S×I</b>		<b>NS</b>			

B]

	2012											
Sources	Organic					Mean	Inorganic					Mean
Intervals Locations	0	15	30	45	60		0	15	30	45	60	
<b>Theog-1</b>	0.00	6.00	12.40	19.80	31.20	<b>13.88</b>	0.00	6.60	11.00	18.80	27.20	<b>12.72</b>
<b>Theog-2</b>	0.00	4.40	12.40	18.20	31.60	<b>13.32</b>	0.00	5.21	8.20	16.60	23.40	<b>10.68</b>
<b>Rohru-1</b>	0.00	9.00	15.00	22.80	38.20	<b>17.00</b>	0.00	9.20	15.00	22.80	16.32	<b>12.66</b>
<b>Rohru-2</b>	0.00	8.40	16.80	22.20	35.80	<b>16.64</b>	0.00	9.21	12.20	20.60	15.26	<b>11.45</b>
<b>Mean</b>	<b>0.00</b>	<b>6.95</b>	<b>14.15</b>	<b>20.75</b>	<b>34.20</b>		<b>0.00</b>	<b>7.56</b>	<b>11.60</b>	<b>19.70</b>	<b>20.55</b>	
<b>Mean (S)</b>	<b>15.21</b>						<b>11.88</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
<b>Sources</b>	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>		<b>1.14</b>			
<b>Theog-1</b>	0.00	6.30	11.70	19.30	29.20	<b>13.30</b>	<b>Sources (S)</b>		<b>0.81</b>			
<b>Theog-2</b>	0.00	4.81	10.30	17.40	27.50	<b>12.00</b>	<b>Intervals (I)</b>		<b>1.28</b>			
<b>Rohru-1</b>	0.00	9.10	15.00	22.80	27.26	<b>14.83</b>	<b>L×S</b>		<b>NS</b>			
<b>Rohru-2</b>	0.00	8.81	14.50	21.40	25.53	<b>14.05</b>	<b>L×I</b>		<b>1.81</b>			
<b>Mean (I)</b>	<b>0.00</b>	<b>7.25</b>	<b>12.88</b>	<b>20.23</b>	<b>27.37</b>		<b>S×I</b>		<b>NS</b>			
							<b>L×S×I</b>		<b>NS</b>			

C]

	Pooled											
Sources	Organic					Mean	Inorganic					Mean
Intervals Locations	0	15	30	45	60		0	15	30	45	60	
Theog-1	0.00	6.32	13.20	20.40	33.60	<b>14.70</b>	0.00	6.90	11.80	18.60	30.10	<b>13.48</b>
Theog-2	0.00	4.30	13.50	20.80	36.30	<b>14.98</b>	0.00	5.51	10.20	17.80	27.20	<b>12.14</b>
Rohru-1	0.00	10.12	17.00	24.40	40.20	<b>18.34</b>	0.00	9.50	14.80	23.50	32.30	<b>16.02</b>
Rohru-2	0.00	9.20	18.20	25.30	37.70	<b>18.08</b>	0.00	10.01	14.70	22.30	29.30	<b>15.26</b>
Mean	<b>0.00</b>	<b>7.49</b>	<b>15.48</b>	<b>22.73</b>	<b>36.95</b>		<b>0.00</b>	<b>7.98</b>	<b>12.88</b>	<b>20.55</b>	<b>29.73</b>	
Mean (S)	<b>16.53</b>						<b>14.23</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
Sources	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>		<b>0.95</b>			
Theog-1	0.00	6.61	12.50	19.50	31.85	<b>14.09</b>	<b>Sources (S)</b>		<b>0.67</b>			
Theog-2	0.00	4.90	11.85	19.30	31.75	<b>13.56</b>	<b>Intervals (I)</b>		<b>1.06</b>			
Rohru-1	0.00	9.81	15.90	23.95	36.25	<b>17.18</b>	<b>L×S</b>		<b>NS</b>			
Rohru-2	0.00	9.60	16.45	23.80	33.50	<b>16.67</b>	<b>L×I</b>		<b>1.51</b>			
Mean (I)	<b>0.00</b>	<b>7.73</b>	<b>14.18</b>	<b>21.64</b>	<b>33.34</b>		<b>S×I</b>		<b>2.13</b>			
							<b>L×S×I</b>		<b>NS</b>			

**Table 4.1.13. Firmness (kg/cm<sup>2</sup>) of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations**

A]

		2011										Mean
Sources	Organic					Mean	Inorganic					
Intervals Locations	0	15	30	45	60		0	15	30	45	60	
Theog-1	6.37	6.03	5.43	4.98	4.27	<b>5.42</b>	6.23	5.75	5.24	4.62	4.19	<b>5.20</b>
Theog-2	6.30	5.74	5.24	4.57	4.20	<b>5.21</b>	6.25	5.77	5.39	4.60	4.14	<b>5.23</b>
Rohru-1	6.28	5.83	5.31	4.91	4.14	<b>5.30</b>	6.35	5.69	5.10	4.74	4.22	<b>5.22</b>
Rohru-2	6.31	5.64	5.25	4.63	4.24	<b>5.21</b>	6.18	5.70	5.29	4.55	4.12	<b>5.17</b>
Mean	<b>6.32</b>	<b>5.81</b>	<b>5.31</b>	<b>4.77</b>	<b>4.21</b>		<b>6.25</b>	<b>5.73</b>	<b>5.26</b>	<b>4.63</b>	<b>4.17</b>	
Mean (S)	<b>5.28</b>						<b>5.21</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
Sources	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	Mean (L)	Locations (L)	<b>0.10</b>				
Theog-1	6.30	5.89	5.34	4.80	4.23	<b>5.31</b>	Sources (S)	<b>0.07</b>				
Theog-2	6.28	5.76	5.32	4.59	4.17	<b>5.22</b>	Intervals (I)	<b>0.11</b>				
Rohru-1	6.32	5.76	5.21	4.83	4.18	<b>5.26</b>	L×S	NS				
Rohru-2	6.25	5.67	5.27	4.59	4.18	<b>5.19</b>	L×I	NS				
Mean (I)	<b>6.28</b>	<b>5.77</b>	<b>5.28</b>	<b>4.70</b>	<b>4.19</b>		S×I	NS				
							L×S×I	NS				

B]

		2012											
Sources		Organic					Mean	Inorganic					Mean
Intervals	Locations	0	15	30	45	60		0	15	30	45	60	
Theog-1		6.39	6.05	5.49	5.05	4.33	<b>5.46</b>	6.25	5.72	5.30	4.78	4.23	<b>5.26</b>
Theog-2		6.35	6.00	5.56	4.68	4.35	<b>5.38</b>	6.32	5.64	5.17	4.59	4.04	<b>5.15</b>
Rohru-1		6.39	6.09	5.83	5.49	4.73	<b>5.71</b>	6.38	5.87	5.40	4.89	4.30	<b>5.37</b>
Rohru-2		6.36	6.00	5.56	4.85	4.52	<b>5.46</b>	6.22	5.86	5.53	4.59	4.14	<b>5.27</b>
Mean		<b>6.37</b>	<b>6.03</b>	<b>5.61</b>	<b>5.02</b>	<b>4.48</b>		<b>6.29</b>	<b>5.77</b>	<b>5.35</b>	<b>4.71</b>	<b>4.18</b>	
Mean (S)		<b>5.50</b>						<b>5.26</b>					
L×S×I interaction Table							CD <sub>(0.05)</sub>						
Sources	0	15	30	45	60	Mean (L)	Locations (L)						0.08
Theog-1	6.32	5.89	5.39	4.92	4.28	<b>5.36</b>	Sources (S)						0.06
Theog-2	6.33	5.82	5.36	4.63	4.19	<b>5.27</b>	Intervals (I)						0.09
Rohru-1	6.38	5.98	5.62	5.19	4.52	<b>5.54</b>	L×S						NS
Rohru-2	6.29	5.93	5.54	4.72	4.33	<b>5.36</b>	L×I						NS
Mean (I)	<b>6.33</b>	<b>5.90</b>	<b>5.48</b>	<b>4.86</b>	<b>4.33</b>		S×I						0.18
							L×S×I						NS

C]

	Pooled											
Sources	Organic					Mean	Inorganic					Mean
Intervals Locations	0	15	30	45	60		0	15	30	45	60	
Theog-1	6.38	6.04	5.46	5.01	4.30	<b>5.44</b>	6.24	5.73	5.27	4.70	4.21	<b>5.23</b>
Theog-2	6.32	5.87	5.40	4.63	4.27	<b>5.30</b>	6.28	5.71	5.28	4.60	4.09	<b>5.19</b>
Rohru-1	6.34	5.96	5.57	5.20	4.43	<b>5.50</b>	6.36	5.78	5.25	4.81	4.26	<b>5.29</b>
Rohru-2	6.33	5.82	5.40	4.74	4.38	<b>5.33</b>	6.20	5.78	5.41	4.57	4.13	<b>5.22</b>
Mean	<b>6.34</b>	<b>5.92</b>	<b>5.46</b>	<b>4.90</b>	<b>4.35</b>		<b>6.27</b>	<b>5.75</b>	<b>5.30</b>	<b>4.67</b>	<b>4.17</b>	
Mean (S)	<b>5.39</b>						<b>5.23</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
Sources	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>		<b>0.06</b>			
Theog-1	6.31	5.89	5.37	4.86	4.26	<b>5.34</b>	<b>Sources (S)</b>		<b>0.04</b>			
Theog-2	6.30	5.79	5.34	4.61	4.18	<b>5.24</b>	<b>Intervals (I)</b>		<b>0.07</b>			
Rohru-1	6.35	5.87	5.41	5.01	4.35	<b>5.40</b>	<b>L×S</b>		<b>NS</b>			
Rohru-2	6.27	5.80	5.41	4.66	4.26	<b>5.28</b>	<b>L×I</b>		<b>NS</b>			
Mean (I)	<b>6.31</b>	<b>5.84</b>	<b>5.38</b>	<b>4.78</b>	<b>4.26</b>		<b>S×I</b>		<b>0.13</b>			
							<b>L x S x I</b>		<b>NS</b>			

maximum (17.18 %) rotting was rerecorded in Rohru-1 and minimum in Theog-2 (13.56 %) apple orchards.

The combined effect of locations and storage intervals (L×I); nutrient sources and storage interval (S×I) were found to be significant. However, the combined effect of locations and nutrient sources (L×S); locations, nutrient sources and storage intervals (L×S×I) were found to be non-significant.

#### **4.1.2.3 Fruit firmness**

Evaluation of pooled data (Table 4.1.13 C) reveals that there was a general decreasing trend in fruit firmness of apple fruits during entire storage period of two months. The overall effect of storage period (I) reveals that there was a significant decrease in firmness of fruits (6.31 to 4.26 kg/cm<sup>2</sup>). While, comparing the overall effect of nutrition sources (S) on fruit firmness, it was retained more (5.39 kg/cm<sup>2</sup>) from organic orchard fruits as compared to inorganic orchard fruits (5.23 kg/cm<sup>2</sup>). The overall effect of locations (L) indicates that significantly higher fruit firmness (5.40 kg/cm<sup>2</sup>) was recorded in Rohru-1, which was statistically at par with Theog-1 (5.34 kg/cm<sup>2</sup>) and lower (5.24 kg/cm<sup>2</sup>) fruit firmness was recorded from Theog-2 apple orchards.

The combined effect of nutrient sources and storage interval (S×I) differed significantly. However, the combined effect of locations and nutrient sources (L×S); locations and storage intervals (L×I) and locations, nutrient sources and storage intervals (L×S×I) were found to be non-significant.

**Table 4.1.14. Total soluble solids (<sup>0</sup>B) contents of apple fruits on different intervals under ambient storage temperature in organic and inorganic apple orchards at different locations**

A]

		2011											
Sources		Organic					Mean	Inorganic					Mean
Intervals	Locations	0	15	30	45	60	Mean	0	15	30	45	60	Mean
		<b>Theog-1</b>	12.64	13.35	12.31	11.38		9.77	<b>11.89</b>	12.50	13.22	12.26	
<b>Theog-2</b>	12.52	13.24	12.26	11.26	9.84	<b>11.82</b>	12.46	13.13	12.31	11.22	9.81	<b>11.78</b>	
<b>Rohru-1</b>	12.39	13.37	12.23	11.21	9.86	<b>11.81</b>	12.28	13.08	12.22	11.07	9.72	<b>11.67</b>	
<b>Rohru-2</b>	12.49	13.14	12.12	11.16	9.74	<b>11.73</b>	12.40	13.13	12.21	11.12	9.66	<b>11.71</b>	
<b>Mean</b>	<b>12.51</b>	<b>13.27</b>	<b>12.23</b>	<b>11.25</b>	<b>9.80</b>		<b>12.41</b>	<b>13.14</b>	<b>12.25</b>	<b>11.18</b>	<b>9.75</b>		
<b>Mean (S)</b>	<b>11.81</b>						<b>11.75</b>						
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>						
<b>Sources</b>	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>					<b>0.05</b>	
<b>Theog-1</b>	12.57	13.28	12.29	11.35	9.80	<b>11.86</b>	<b>Sources (S)</b>					<b>0.04</b>	
<b>Theog-2</b>	12.49	13.18	12.29	11.24	9.82	<b>11.80</b>	<b>Intervals (I)</b>					<b>0.06</b>	
<b>Rohru-1</b>	12.33	13.22	12.22	11.14	9.79	<b>11.74</b>	<b>L×S</b>					<b>NS</b>	
<b>Rohru-2</b>	12.45	13.14	12.17	11.14	9.70	<b>11.72</b>	<b>L×I</b>					<b>NS</b>	
<b>Mean (I)</b>	<b>12.46</b>	<b>13.21</b>	<b>12.24</b>	<b>11.22</b>	<b>9.78</b>		<b>S×I</b>					<b>NS</b>	
							<b>L×S×I</b>					<b>NS</b>	

B]

	2012											
Sources	Organic					Mean	Inorganic					Mean
Intervals Locations	0	15	30	45	60		0	15	30	45	60	
<b>Theog-1</b>	12.69	13.38	12.45	11.38	9.94	<b>11.97</b>	12.59	13.32	12.33	11.37	9.85	<b>11.89</b>
<b>Theog-2</b>	12.66	13.18	12.32	11.34	9.89	<b>11.88</b>	12.51	13.18	12.28	11.26	9.86	<b>11.82</b>
<b>Rohru-1</b>	12.56	13.54	12.35	11.38	10.05	<b>11.98</b>	12.49	13.24	12.39	11.37	9.76	<b>11.85</b>
<b>Rohru-2</b>	12.58	13.29	12.32	11.28	9.91	<b>11.88</b>	12.56	13.26	12.37	11.34	9.77	<b>11.86</b>
<b>Mean</b>	<b>12.63</b>	<b>13.35</b>	<b>12.36</b>	<b>11.34</b>	<b>9.95</b>		<b>12.54</b>	<b>13.25</b>	<b>12.34</b>	<b>11.34</b>	<b>9.81</b>	
<b>Mean (S)</b>	<b>11.92</b>						<b>11.86</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
<b>Sources</b>	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>					<b>0.06</b>
<b>Theog-1</b>	12.64	13.35	12.39	11.38	9.89	<b>11.93</b>	<b>Sources (S)</b>					<b>0.04</b>
<b>Theog-2</b>	12.59	13.18	12.30	11.30	9.88	<b>11.85</b>	<b>Intervals (I)</b>					<b>0.06</b>
<b>Rohru-1</b>	12.53	13.39	12.37	11.38	9.91	<b>11.91</b>	<b>L×S</b>					<b>NS</b>
<b>Rohru-2</b>	12.57	13.27	12.35	11.31	9.84	<b>11.87</b>	<b>L×I</b>					<b>NS</b>
<b>Mean (I)</b>	<b>12.58</b>	<b>13.30</b>	<b>12.35</b>	<b>11.34</b>	<b>9.88</b>		<b>S×I</b>					<b>NS</b>
							<b>L×S×I</b>					<b>NS</b>

C]

Sources Intervals Locations	Pooled											Mean
	Organic					Mean	Inorganic					
	0	15	30	45	60		0	15	30	45	60	
<b>Theog-1</b>	12.67	13.36	12.38	11.38	9.85	<b>11.93</b>	12.54	13.27	12.30	11.34	9.84	<b>11.86</b>
<b>Theog-2</b>	12.59	13.21	12.29	11.30	9.87	<b>11.85</b>	12.48	13.16	12.29	11.24	9.83	<b>11.80</b>
<b>Rohru-1</b>	12.48	13.45	12.29	11.29	9.96	<b>11.89</b>	12.38	13.16	12.30	11.22	9.74	<b>11.76</b>
<b>Rohru-2</b>	12.54	13.21	12.22	11.22	9.83	<b>11.80</b>	12.48	13.20	12.29	11.23	9.72	<b>11.78</b>
<b>Mean</b>	<b>12.57</b>	<b>13.31</b>	<b>12.29</b>	<b>11.30</b>	<b>9.88</b>		<b>12.47</b>	<b>13.20</b>	<b>12.30</b>	<b>11.26</b>	<b>9.78</b>	
<b>Mean (S)</b>	<b>11.87</b>						<b>11.80</b>					
<b>L×S×I interaction Table</b>							<b>CD<sub>(0.05)</sub></b>					
<b>Sources</b>	<b>0</b>	<b>15</b>	<b>30</b>	<b>45</b>	<b>60</b>	<b>Mean (L)</b>	<b>Locations (L)</b>					<b>0.04</b>
<b>Theog-1</b>	12.60	13.32	12.34	11.36	9.85	<b>11.89</b>	<b>Sources (S)</b>					<b>0.03</b>
<b>Theog-2</b>	12.54	13.18	12.29	11.27	9.85	<b>11.83</b>	<b>Intervals (I)</b>					<b>0.04</b>
<b>Rohru-1</b>	12.43	13.31	12.30	11.26	9.85	<b>11.83</b>	<b>L×S</b>					<b>0.06</b>
<b>Rohru-2</b>	12.51	13.21	12.26	11.22	9.77	<b>11.79</b>	<b>L×I</b>					<b>NS</b>
<b>Mean (I)</b>	<b>12.52</b>	<b>13.25</b>	<b>12.30</b>	<b>11.28</b>	<b>9.83</b>		<b>S×I</b>					<b>NS</b>
							<b>L x S x I</b>					<b>NS</b>

#### **4.1.2.4 Total Soluble solids**

Scrutiny of pooled data presented in Table 4.1.14 C revealed general increasing trend in the TSS contents of apple fruits for first 15 days of storage. The overall effect of storage interval (I) on TSS contents of fruits showed that there was a significant decrease from 12.52 to 9.83<sup>0</sup>B, significantly higher (11.87<sup>0</sup>B) and lower (11.80<sup>0</sup>B) TSS contents were recorded in organic and inorganic orchard fruits (S), respectively. The overall effect of locations (L) revealed that maximum (11.89<sup>0</sup>B) TSS contents were found at Theog-1 and minimum in Rohru-2 (11.79<sup>0</sup>B) apple orchard fruits.

The combined effect of locations and nutrient sources (L×S) differed significantly. However, the combined effect of locations and storage intervals (L×I); nutrient sources and storage interval (S×I) and locations, nutrient sources and storage intervals (L×S×I) on TSS contents of fruits were observed to be non-significant.

#### **4.1.C Leaf nutrient status**

##### **4.1.3.1 Leaf N**

The effect of nutrient sources at different locations of apple orchards on per cent leaf N contents are depicted in Table 4.1.15.

There were significant variations in leaf N contents observed in all factors of study. Maximum leaf N contents (2.44 %) were recorded in Theog-1, which were significantly higher than all other locations. However, lowest contents (2.23 %) were recorded in Rohru-2 apple orchards. Between sources, significantly higher leaf N contents (2.52 %) were recorded in inorganic as compared to organic (2.13 %) apple orchards.

**Table 4.1.15. Leaf N (%) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	2.19	2.67	<b>2.43</b>	2.20	2.71	<b>2.46</b>	2.20	2.69	<b>2.44</b>
<b>Theog-2</b>	2.11	2.46	<b>2.29</b>	2.14	2.48	<b>2.31</b>	2.13	2.47	<b>2.30</b>
<b>Rohru-1</b>	2.09	2.55	<b>2.32</b>	2.10	2.58	<b>2.34</b>	2.10	2.56	<b>2.33</b>
<b>Rohru-2</b>	2.06	2.34	<b>2.20</b>	2.12	2.39	<b>2.25</b>	2.09	2.37	<b>2.23</b>
<b>Mean</b>	<b>2.11</b>	<b>2.51</b>		<b>2.14</b>	<b>2.54</b>		<b>2.13</b>	<b>2.52</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.07</b>			<b>0.08</b>			<b>0.05</b>		
<b>Sources</b>	<b>0.05</b>			<b>0.06</b>			<b>0.04</b>		
<b>LxS</b>	<b>0.11</b>			<b>0.12</b>			<b>0.08</b>		

**Table 4.1.16. Leaf P (%) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	0.19	0.29	<b>0.24</b>	0.21	0.30	<b>0.26</b>	0.20	0.30	<b>0.25</b>
<b>Theog-2</b>	0.18	0.25	<b>0.21</b>	0.21	0.27	<b>0.24</b>	0.19	0.26	<b>0.23</b>
<b>Rohru-1</b>	0.20	0.26	<b>0.23</b>	0.21	0.29	<b>0.25</b>	0.21	0.28	<b>0.24</b>
<b>Rohru-2</b>	0.16	0.23	<b>0.20</b>	0.21	0.25	<b>0.23</b>	0.19	0.24	<b>0.21</b>
<b>Mean</b>	<b>0.18</b>	<b>0.26</b>		<b>0.21</b>	<b>0.28</b>		<b>0.20</b>	<b>0.27</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.03</b>			<b>0.02</b>			<b>0.02</b>		
<b>Sources</b>	<b>0.02</b>			<b>0.01</b>			<b>0.01</b>		
<b>LxS</b>	<b>0.04</b>			<b>0.02</b>			<b>0.03</b>		

There was significant difference observed among interactions. Maximum leaf N (2.69 %) contents were recorded in Theog-1 inorganic apple orchards, which were significantly higher than all other interactions. However, minimum (2.09 %) was recorded in Rohru-2 organic apple orchards.

#### **4.1.3.2 Leaf P**

The effect of various nutrient sources at different locations of apple orchards on per cent leaf P contents are given in Table 4.1.16.

It was evident from the pooled data that locations, sources of nutrition and their interactions differed significantly for both the years of study. Maximum leaf P (0.25 %) contents were recorded in Theog-1, which were statistically at par with Rohru-1 and Theog-2 recording 0.24 and 0.23 per cent, respectively and was significantly higher than Rohru-2 (0.21 %) apple orchards. Between nutrition sources, significantly higher leaf P contents (0.27 %) were registered from inorganic apple orchards as compared to organic (0.20 %) apple orchards.

Significant differences were observed among all interactions effect. Maximum leaf P contents (0.30 %) were recorded at Theog-1 inorganic orchards, which were statistically at par with Rohru-1 inorganic orchards recording 0.28 per cent and significantly higher than all other interactions. However, lowest (0.19%) contents were recorded at Rohru-2 and Theog-2 organic apple orchards.

#### **4.1.3.3 Leaf K**

The data on leaf K contents as affected by locations and different nutrient sources are presented in Table 4.1.17.

The pooled data revealed significant variation in per cent leaf K contents among locations, nutrition sources and with their interactions. Maximum leaf K contents (1.62 %) were recorded at

**Table 4.1.17. Leaf K (%) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	1.41	1.65	<b>1.53</b>	1.43	1.67	<b>1.55</b>	1.42	1.66	<b>1.54</b>
<b>Theog-2</b>	1.42	1.60	<b>1.51</b>	1.46	1.63	<b>1.54</b>	1.44	1.62	<b>1.53</b>
<b>Rohru-1</b>	1.45	1.51	<b>1.48</b>	1.49	1.57	<b>1.53</b>	1.47	1.54	<b>1.50</b>
<b>Rohru-2</b>	1.48	1.74	<b>1.61</b>	1.49	1.76	<b>1.62</b>	1.48	1.75	<b>1.62</b>
<b>Mean</b>	<b>1.44</b>	<b>1.63</b>		<b>1.47</b>	<b>1.66</b>		<b>1.45</b>	<b>1.64</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.08</b>			<b>0.07</b>			<b>0.06</b>		
<b>Sources</b>	<b>0.05</b>			<b>0.05</b>			<b>0.04</b>		
<b>LxS</b>	<b>0.11</b>			<b>0.09</b>			<b>0.08</b>		

**Table 4.1.18. Leaf Zn (ppm) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	40.77	48.05	<b>44.41</b>	42.62	50.60	<b>46.61</b>	41.70	49.32	<b>45.51</b>
<b>Theog-2</b>	37.05	38.84	<b>37.95</b>	39.99	41.59	<b>40.79</b>	38.52	40.22	<b>39.37</b>
<b>Rohru-1</b>	23.60	29.65	<b>26.62</b>	29.22	32.80	<b>31.01</b>	26.41	31.22	<b>28.82</b>
<b>Rohru-2</b>	23.23	30.80	<b>27.01</b>	24.41	31.40	<b>27.90</b>	23.82	31.10	<b>27.46</b>
<b>Mean</b>	<b>31.16</b>	<b>36.83</b>		<b>34.06</b>	<b>39.10</b>		<b>32.61</b>	<b>37.97</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>3.29</b>			<b>3.11</b>			<b>2.15</b>		
<b>Sources</b>	<b>2.33</b>			<b>2.20</b>			<b>1.52</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

Rohru-2, which was significantly higher than all other locations, however, lowest contents were recorded at Rohru-1 (1.50 %) apple orchards. Between nutrient sources significantly higher leaf K contents (1.64 %) were observed from inorganic compared to organic (1.45 %) apple orchards.

The interactions effect between locations and plant nutrient sources revealed significant variation. Maximum leaf K contents (1.75 %) were recorded from Rohru-2 inorganic apple orchard, which were significantly higher than all other interactions. The lowest (1.42 %) contents were recorded in Theog-1 organic apple orchards.

#### **4.1.3.4 Leaf Zn**

The effect of nutrient sources at different locations of apple orchards on leaf Zn contents are indicated in Table 4.1.18.

A scrutiny of pooled data revealed that there was significant difference between locations and nutrient sources. Maximum leaf Zn (45.51 ppm) contents were recorded in Theog-1 orchards, which were significantly higher than all other locations. However, lowest contents were recorded in Rohru-2 (27.46 ppm) apple orchards. The data in relation to nutrient sources exhibited significantly higher leaf Zn contents (37.97 ppm) from inorganic as compared to organic (32.61 ppm) apple orchards. However, there were no significant differences among interactions.

#### **4.1.3.5 Leaf Fe**

The data on effect of nutrient sources at different locations of apple orchards on leaf Fe contents are expressed in Table 4.1.19.

The pooled data showed significant variations in locations and between nutrient sources. Maximum leaf Fe (119.70 ppm) contents

were recorded in Theog-1 orchards that were statistically at par with Rohru-2 recording 118.21 ppm and significantly higher than all other locations. The lowest contents were recorded in Theog-2 (187.97 ppm) apple orchards. Between nutrient sources, significantly higher leaf Fe contents (120.11 ppm) were observed from inorganic compared to organic (109.70 ppm) apple orchards. There were no significant differences observed among interactions.

#### **4.1.3.6 Leaf Cu**

The leaf copper contents from organic and inorganic apple orchards under survey study are denoted in Table 4.1.20.

The mean of pooled values revealed that maximum leaf Cu (15.02 ppm) contents were recorded at Theog-1 which were statistically at par with Rohru-1 recording 14.73 ppm and significantly higher than all other locations. The lowest (12.97 ppm) contents were recorded in Rohru-2 apple orchards. The nutrient sources varied significantly with recording of higher leaf Cu (15.26 ppm) contents from inorganic as compared to organic (12.62 ppm) apple orchards. Interactions were found to be non-significant.

#### **4.1.3.7 Leaf Mn**

The survey study of plant nutrient sources on application in different locations of apple orchards on leaf Mn contents are expressed in Table 4.1.21.

A scrutiny of pooled data revealed that there was significant difference among locations, between nutrient sources and in their interactions. Maximum leaf Mn contents (95.97 ppm) were registered in Theog-1, which were significantly higher than all other locations. The lowest contents were recorded in Rohru-2 (59.25 ppm) apple orchards. Between nutrient sources, significantly higher

**Table 4.1.19. Leaf Fe (ppm) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	114.94	124.60	<b>119.77</b>	116.27	123.00	<b>119.63</b>	115.60	123.80	<b>119.70</b>
<b>Theog-2</b>	102.33	114.00	<b>108.17</b>	107.88	115.40	<b>111.64</b>	105.11	114.70	<b>109.90</b>
<b>Rohru-1</b>	103.60	117.03	<b>110.31</b>	107.80	118.80	<b>113.30</b>	105.70	117.91	<b>111.81</b>
<b>Rohru-2</b>	110.51	121.63	<b>116.07</b>	114.30	126.40	<b>120.35</b>	112.40	124.01	<b>118.21</b>
<b>Mean</b>	<b>107.85</b>	<b>119.31</b>		<b>111.56</b>	<b>120.90</b>		<b>109.70</b>	<b>120.11</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>7.34</b>			<b>7.29</b>			<b>5.18</b>		
<b>Sources</b>	<b>5.19</b>			<b>5.15</b>			<b>3.66</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.20. Leaf Cu (ppm) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	12.86	16.30	<b>14.58</b>	13.90	17.04	<b>15.47</b>	13.38	16.67	<b>15.02</b>
<b>Theog-2</b>	11.30	13.43	<b>12.37</b>	12.45	14.94	<b>13.70</b>	11.87	14.19	<b>13.03</b>
<b>Rohru-1</b>	13.04	15.16	<b>14.10</b>	13.90	16.84	<b>15.37</b>	13.47	16.00	<b>14.73</b>
<b>Rohru-2</b>	11.05	13.62	<b>12.34</b>	12.45	14.74	<b>13.60</b>	11.75	14.18	<b>12.97</b>
<b>Mean</b>	<b>12.06</b>	<b>14.63</b>		<b>13.18</b>	<b>15.89</b>		<b>12.62</b>	<b>15.26</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>1.62</b>			<b>1.68</b>			<b>1.07</b>		
<b>Sources</b>	<b>1.14</b>			<b>1.19</b>			<b>0.75</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.21. Leaf Mn (ppm) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	102.45	87.33	<b>94.89</b>	104.86	89.22	<b>97.04</b>	103.66	88.28	<b>95.97</b>
<b>Theog-2</b>	96.40	81.95	<b>89.18</b>	95.40	84.60	<b>90.00</b>	95.90	83.28	<b>89.59</b>
<b>Rohru-1</b>	59.80	56.40	<b>58.10</b>	67.07	58.00	<b>62.53</b>	63.43	57.20	<b>60.32</b>
<b>Rohru-2</b>	53.60	58.00	<b>55.80</b>	60.60	64.80	<b>62.70</b>	57.10	61.40	<b>59.25</b>
<b>Mean</b>	<b>78.06</b>	<b>70.92</b>		<b>81.98</b>	<b>74.16</b>		<b>80.02</b>	<b>72.54</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>4.73</b>			<b>5.15</b>			<b>3.99</b>		
<b>Sources</b>	<b>3.34</b>			<b>3.64</b>			<b>2.82</b>		
<b>LxS</b>	<b>6.69</b>			<b>7.29</b>			<b>5.65</b>		

**Table 4.1.22. Water holding capacity of the soil in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	52.31	48.00	<b>50.16</b>	52.40	48.80	<b>50.60</b>	52.36	48.40	<b>50.38</b>
<b>Theog-2</b>	49.80	46.18	<b>47.99</b>	50.60	46.60	<b>48.60</b>	50.20	46.39	<b>48.29</b>
<b>Rohru-1</b>	48.60	44.62	<b>46.61</b>	49.30	45.40	<b>47.35</b>	48.95	45.01	<b>46.98</b>
<b>Rohru-2</b>	48.20	43.40	<b>45.80</b>	49.18	44.20	<b>46.69</b>	48.69	43.80	<b>46.24</b>
<b>Mean</b>	<b>49.73</b>	<b>45.55</b>		<b>50.37</b>	<b>46.25</b>		<b>50.05</b>	<b>45.90</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>2.66</b>			<b>2.27</b>			<b>1.92</b>		
<b>Sources</b>	<b>1.88</b>			<b>1.61</b>			<b>1.36</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

leaf Mn contents (80.02 ppm) were recorded from organic as compared to inorganic (72.54 ppm) apple orchards. Simultaneously, among interactions maximum leaf Mn (103.66 ppm) contents were recorded in Theog-1 organic apple orchards, which was significantly higher than all other interactions. However, lowest leaf Mn (57.10 ppm) contents were recorded in Rohru-2 organic apple orchards.

#### **4.1.D Physico-Chemical properties of soil**

##### **4.1.4.a Physical Properties**

##### **4.1.4.1.1 Maximum Water holding capacity (MWHC) (%)**

The effect of nutrient sources on maximum water holding capacity of soil at different locations of apple orchards is given in Table 4.1.22.

There were significant differences observed in MWHC of soil at different locations and nutrient sources. Maximum increase in water holding capacity (50.38 %) of soil was recorded at Theog-1, which was significantly higher than all other locations. The lowest were recorded in Rohru-2 (46.24 %) apple orchards. Simultaneously, between nutrition sources significantly higher (50.05 %) MWHC of soil was registered in organic as compared to inorganic (45.90 %) apple orchards. There were non-significant differences among interactions. However, maximum (52.36 %) increase in WHC of soil was recorded at Theog-1 organic and minimum in Rohru-2 (43.80 %) inorganic apple orchards.

##### **4.1.4.1.2 Bulk density (g/cc)**

The data in the Table 4.1.23 revealed that soil bulk density recorded in survey study was significantly influenced by the organic and inorganic management practices and in different locations but were found to be non-significant under interactions.

**Table 4.1.23. Soil bulk density (g/cc) in organic and inorganic orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	1.28	1.31	<b>1.29</b>	1.26	1.29	<b>1.28</b>	1.27	1.30	<b>1.29</b>
<b>Theog-2</b>	1.29	1.34	<b>1.32</b>	1.27	1.33	<b>1.30</b>	1.28	1.33	<b>1.31</b>
<b>Rohru-1</b>	1.32	1.36	<b>1.34</b>	1.30	1.35	<b>1.32</b>	1.31	1.36	<b>1.33</b>
<b>Rohru-2</b>	1.33	1.42	<b>1.38</b>	1.32	1.39	<b>1.36</b>	1.33	1.40	<b>1.37</b>
<b>Mean</b>	<b>1.31</b>	<b>1.36</b>		<b>1.29</b>	<b>1.34</b>		<b>1.30</b>	<b>1.35</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.047</b>			<b>0.050</b>			<b>0.037</b>		
<b>Sources</b>	<b>0.042</b>			<b>0.035</b>			<b>0.031</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.24. Soil pH in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	5.92	5.64	<b>5.78</b>	5.87	5.49	<b>5.68</b>	5.89	5.56	<b>5.73</b>
<b>Theog-2</b>	5.91	5.80	<b>5.86</b>	5.90	5.81	<b>5.86</b>	5.91	5.80	<b>5.86</b>
<b>Rohru-1</b>	5.44	5.42	<b>5.43</b>	5.51	5.45	<b>5.48</b>	5.47	5.44	<b>5.45</b>
<b>Rohru-2</b>	5.68	5.50	<b>5.59</b>	5.70	5.52	<b>5.61</b>	5.69	5.51	<b>5.60</b>
<b>Mean</b>	<b>5.74</b>	<b>5.59</b>		<b>5.74</b>	<b>5.56</b>		<b>5.74</b>	<b>5.58</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.09</b>			<b>0.11</b>			<b>0.08</b>		
<b>Sources</b>	<b>0.07</b>			<b>0.08</b>			<b>0.06</b>		
<b>LxS</b>	<b>0.13</b>			<b>0.16</b>			<b>0.11</b>		

Significantly lower soil bulk density (1.29 g/cc) was registered in Theog-1, which was statistically at par with Rohru-1 and Theog-2 recording 1.33 and 1.31 g/cc, respectively, and higher (1.36 g/cc) at Rohru-2 apple orchards. Between the nutrient sources, significantly lower soil bulk density (1.30 g/cc) was recorded from organic as compared to inorganic (1.35 g/cc) apple orchard.

#### **4.1.4.b Chemical Properties**

##### **4.1.4.2.1 Soil pH**

From the mean of pooled data shown in the Table 4.1.24 revealed significant differences in soil pH at different locations, nutrient sources and in their interaction effects.

Maximum soil pH (5.86) was recorded at Theog-2 orchards, which was significantly higher than all other locations. However, lowest pH (5.45) was recorded in Rohru-1 apple orchards. Between nutrient sources, significantly higher soil pH (5.74) was recorded from organic as compared to inorganic (5.58) apple orchards. In interactions maximum soil pH (5.91) was recorded in Theog-2 organic orchards, which was statistically at par with Theog-1 organic orchards recording 5.89 and significantly higher than all other interactions. The lowest (5.44) was recorded in Rohru-1 inorganic apple orchards.

##### **4.1.4.2.2 Soil Electrical Conductivity (EC)**

The effect of nutrient sources at different locations of apple orchards on status of soil electrical conductivity is depicted in Table 4.1.25.

Soil EC differed significantly among locations, in nutrition sources and their interactions. In locations maximum soil EC (0.47 dS/m<sup>2</sup>) was recorded at Rohru-1, which was significantly higher than all other locations. The lowest (0.38 dS/m<sup>2</sup>) was recorded in Theog-2

**Table 4.1.25. Soil electric conductivity (EC) (dSm/m<sup>2</sup>) in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
Theog-1	0.36	0.46	<b>0.41</b>	0.37	0.47	<b>0.42</b>	0.37	0.47	<b>0.42</b>
Theog-2	0.33	0.42	<b>0.37</b>	0.32	0.44	<b>0.38</b>	0.32	0.43	<b>0.38</b>
Rohru-1	0.45	0.52	<b>0.48</b>	0.42	0.48	<b>0.45</b>	0.44	0.50	<b>0.47</b>
Rohru-2	0.39	0.44	<b>0.41</b>	0.37	0.44	<b>0.41</b>	0.38	0.44	<b>0.41</b>
Mean	<b>0.38</b>	<b>0.46</b>		<b>0.37</b>	<b>0.46</b>		<b>0.38</b>	<b>0.46</b>	
CD <sub>0.05</sub>									
Locations	<b>0.04</b>			<b>0.03</b>			<b>0.03</b>		
Sources	<b>0.03</b>			<b>0.02</b>			<b>0.02</b>		
LxS	NS			NS			NS		

**Table 4.1.26. Organic carbon (%) in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
Theog-1	2.04	1.82	<b>1.93</b>	2.12	1.83	<b>1.97</b>	2.08	1.83	<b>1.95</b>
Theog-2	2.15	1.91	<b>2.03</b>	2.16	1.94	<b>2.05</b>	2.15	1.93	<b>2.04</b>
Rohru-1	1.99	1.68	<b>1.84</b>	2.01	1.69	<b>1.85</b>	2.00	1.69	<b>1.84</b>
Rohru-2	1.84	1.54	<b>1.69</b>	1.86	1.59	<b>1.72</b>	1.85	1.56	<b>1.70</b>
Mean	<b>2.00</b>	<b>1.74</b>		<b>2.03</b>	<b>1.76</b>		<b>2.02</b>	<b>1.75</b>	
CD <sub>0.05</sub>									
Locations	<b>0.08</b>			<b>0.11</b>			<b>0.06</b>		
Sources	<b>0.06</b>			<b>0.08</b>			<b>0.04</b>		
LxS	NS			NS			NS		

**Table 4.1.27. Available N (kg/ha) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	294.89	394.05	<b>344.47</b>	299.26	400.11	<b>349.69</b>	297.07	397.08	<b>347.08</b>
<b>Theog-2</b>	270.02	390.75	<b>330.39</b>	279.42	398.95	<b>339.19</b>	274.72	394.85	<b>334.79</b>
<b>Rohru-1</b>	259.37	342.27	<b>300.82</b>	269.37	357.35	<b>313.36</b>	264.37	349.81	<b>307.09</b>
<b>Rohru-2</b>	288.79	373.98	<b>331.38</b>	293.62	394.17	<b>343.90</b>	291.21	384.15	<b>337.94</b>
<b>Mean</b>	<b>278.27</b>	<b>375.26</b>		<b>285.42</b>	<b>387.65</b>		<b>281.84</b>	<b>381.45</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>13.64</b>			<b>10.76</b>			<b>9.15</b>		
<b>Sources</b>	<b>9.65</b>			<b>7.61</b>			<b>6.47</b>		
<b>LxS</b>	<b>19.29</b>			<b>15.22</b>			<b>12.94</b>		

**Table 4.1.28. Available P (kg/ha) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	26.02	41.29	<b>33.66</b>	27.40	42.73	<b>35.06</b>	26.71	42.01	<b>34.36</b>
<b>Theog-2</b>	23.76	30.02	<b>26.89</b>	27.73	31.29	<b>29.51</b>	25.74	30.66	<b>28.20</b>
<b>Rohru-1</b>	27.97	31.80	<b>29.89</b>	29.00	32.00	<b>30.50</b>	28.49	31.90	<b>30.19</b>
<b>Rohru-2</b>	24.36	30.00	<b>27.18</b>	25.40	30.72	<b>28.06</b>	24.88	30.36	<b>27.62</b>
<b>Mean</b>	<b>25.53</b>	<b>33.28</b>		<b>27.38</b>	<b>34.18</b>		<b>26.46</b>	<b>33.73</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>2.22</b>			<b>2.83</b>			<b>1.54</b>		
<b>Sources</b>	<b>1.57</b>			<b>2.00</b>			<b>1.09</b>		
<b>LxS</b>	<b>3.14</b>			<b>4.00</b>			<b>2.18</b>		

apple orchards. Between nutrition sources significantly higher soil EC ( $0.46 \text{ dS/m}^2$ ) was recorded from inorganic as compared to organic ( $0.38 \text{ dS/m}^2$ ) apple orchards. There were no significant variations among interactions.

#### **4.1.4.2.3 Soil OC**

The effect of nutrient sources at different locations of apple orchards on per cent soil organic carbon contents is shown in Table 4.1.26.

From the pooled data it is clear that maximum soil organic carbon (2.04 %) contents were recorded in Theog-2, which were significantly higher than all other locations. However, lowest contents were recorded in Rohru-2 (1.70 %) apple orchards. Simultaneously, in between nutrient sources significantly higher soil organic carbon (2.02 %) contents were recorded from organic as compared to inorganic (1.75 %) apple orchards. There were no significant differences found among interactions. However, maximum soil organic carbon contents (2.15 %) were recorded at Theog-2 organic orchards and minimum (1.56 %) at Rohru-2 inorganic apple orchards.

#### **4.1.4.2.4 Available N**

The survey on effect of nutrition sources at different locations of apple orchards on available nitrogen (N) contents are presented in Table 4.1.27.

The pooled revealed significant variations in locations, nutrition sources and in their interactions. Maximum available N contents (347.08 kg/ha) were recorded in Theog-1, which were statistically at par with Rohru-2 recording 337.94 kg/ha and significantly higher than other locations. However, lowest contents were recorded at Rohru-1 (307.09 kg/ha) apple orchards. Simultaneously, between nutrient sources significantly higher

available N (381.45 kg/ha) contents were registered from inorganic as compared to organic (281.84 kg/ha) apple orchards.

Among interactions maximum available N (397.08 kg/ha) contents were recorded at Theog-1 inorganic orchards, which were statistically at par with Theog-2 and Rohru-2 inorganic orchards recording 394.85 and 384.15 kg/ha, respectively. While, lowest available N contents were recorded in Rohru-1 (264.37 kg/ha) organic apple orchards.

#### **4.1.4.2.5 Available P**

The survey on nutrient sources at different locations of apple orchards on available phosphorus (P) contents are indicated in Table 4.1.28.

From the mean of pooled data it was observed that there were significant variations among locations, nutrient sources and in their interactions. Maximum available P (34.36 kg/ha) contents were observed at Theog-1, which were significantly higher than other locations. The lowest contents were recorded in Rohru-2 (27.62 kg/ha) apple orchards. Likewise, in nutrient sources significantly higher available P contents (33.73 kg/ha) were recorded from inorganic as compared to organic (26.46 kg/ha) apple orchards.

Simultaneously, among interactions maximum available P (42.01 kg/ha) contents were recorded at Theog-1 inorganic orchards, which was significantly higher than other interactions. However, lowest contents were recorded in Rohru-2 (24.88 kg/ha) organic apple orchards.

#### **4.1.4.2.6 Available K**

The data on available potassium (K) contents from organic and inorganic apple orchards in Theog and Rohru are shown in Table

**Table 4.1.29. Available K (kg/ha) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	237.43	267.44	<b>252.44</b>	238.03	273.33	<b>255.68</b>	237.73	270.39	<b>254.06</b>
<b>Theog-2</b>	239.33	289.86	<b>264.60</b>	241.91	293.09	<b>267.50</b>	240.62	291.48	<b>266.05</b>
<b>Rohru-1</b>	301.19	330.27	<b>315.73</b>	307.75	334.64	<b>321.20</b>	304.47	332.46	<b>318.46</b>
<b>Rohru-2</b>	291.27	312.51	<b>301.89</b>	302.93	315.40	<b>309.16</b>	297.10	313.96	<b>305.53</b>
<b>Mean</b>	<b>267.31</b>	<b>300.02</b>		<b>272.65</b>	<b>304.12</b>		<b>269.98</b>	<b>302.07</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>10.20</b>			<b>12.43</b>			<b>8.21</b>		
<b>Sources</b>	<b>7.21</b>			<b>8.79</b>			<b>5.81</b>		
<b>LxS</b>	<b>14.42</b>			<b>17.58</b>			<b>11.61</b>		

**Table 4.1.30. Available Zn (mg kg<sup>-1</sup>) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	3.79	3.99	<b>3.89</b>	3.82	4.00	<b>3.91</b>	3.80	3.99	<b>3.90</b>
<b>Theog-2</b>	3.83	3.89	<b>3.86</b>	3.85	3.91	<b>3.88</b>	3.84	3.90	<b>3.87</b>
<b>Rohru-1</b>	3.63	3.64	<b>3.64</b>	3.65	3.68	<b>3.67</b>	3.64	3.66	<b>3.65</b>
<b>Rohru-2</b>	3.59	3.69	<b>3.64</b>	3.64	3.72	<b>3.68</b>	3.62	3.70	<b>3.66</b>
<b>Mean</b>	<b>3.71</b>	<b>3.80</b>		<b>3.74</b>	<b>3.83</b>		<b>3.72</b>	<b>3.82</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.13</b>			<b>0.11</b>			<b>0.07</b>		
<b>Sources</b>	<b>0.09</b>			<b>0.08</b>			<b>0.05</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

## 4.1.7.

There were significant differences observed in locations, nutrient sources and their interactions. Maximum available K (318.46 kg/ha) contents were recorded in Rohru-1, which were significantly higher than all other locations, however, lowest contents were recorded in Theog-1 (254.06 kg/ha) apple orchards. Simultaneously, between nutrient sources significantly higher available K (302.07 kg/ha) contents were registered from inorganic compared to organic (269.98 kg/ha) apple orchards.

Among interactions, maximum available potassium (332.46 kg/ha) contents were recorded in Rohru-1 inorganic orchards, which was significantly higher than all other interactions and lowest contents was recorded in Theog-1 (237.73 kg/ha) organic apple orchards.

**4.1.4.2.7 Available Zn**

The data pertaining to available zinc (Zn) contents from organic and inorganic apple orchards of Theog and Rohru are depicted in Table 4.1.30.

The pooled data was significantly different at locations and in sources of nutrition. Significantly higher available Zn ( $3.90 \text{ mg/kg}^{-1}$ ) contents were recorded in Theog-1, which was statistically at par with Theog-2. The lowest contents ( $3.65 \text{ mg/kg}^{-1}$ ) were recorded in Rohru-1 apple orchards. Between nutrient sources significantly higher available Zn contents ( $3.82 \text{ mg/kg}^{-1}$ ) was recorded from inorganic as compared to organic ( $3.72 \text{ mg/kg}^{-1}$ ) apple orchards. There were no significant differences recorded among interactions.

**Table 4.1.31. Available Fe (mg kg<sup>-1</sup>) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	35.65	43.89	<b>39.77</b>	37.89	46.05	<b>41.97</b>	36.77	44.97	<b>40.87</b>
<b>Theog-2</b>	55.20	58.60	<b>56.90</b>	57.80	59.20	<b>58.50</b>	56.50	58.90	<b>57.70</b>
<b>Rohru-1</b>	35.65	43.89	<b>39.77</b>	37.89	45.05	<b>41.47</b>	36.77	44.47	<b>40.62</b>
<b>Rohru-2</b>	25.26	26.90	<b>26.08</b>	26.22	28.03	<b>27.12</b>	25.74	27.46	<b>26.60</b>
<b>Mean</b>	<b>37.94</b>	<b>43.32</b>		<b>39.95</b>	<b>44.58</b>		<b>38.94</b>	<b>43.95</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>3.09</b>			<b>3.76</b>			<b>2.43</b>		
<b>Sources</b>	<b>2.19</b>			<b>2.66</b>			<b>1.71</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.32. Available Cu (mg kg<sup>-1</sup>) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	4.26	4.57	<b>4.42</b>	4.40	4.67	<b>4.54</b>	4.33	4.62	<b>4.48</b>
<b>Theog-2</b>	4.35	4.49	<b>4.42</b>	4.27	4.53	<b>4.40</b>	4.31	4.51	<b>4.41</b>
<b>Rohru-1</b>	4.03	4.13	<b>4.08</b>	4.08	4.39	<b>4.23</b>	4.05	4.26	<b>4.16</b>
<b>Rohru-2</b>	3.81	4.34	<b>4.08</b>	3.90	4.41	<b>4.16</b>	3.86	4.38	<b>4.12</b>
<b>Mean</b>	<b>4.11</b>	<b>4.39</b>		<b>4.16</b>	<b>4.50</b>		<b>4.14</b>	<b>4.44</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>0.18</b>			<b>0.21</b>			<b>0.14</b>		
<b>Sources</b>	<b>0.13</b>			<b>0.15</b>			<b>0.10</b>		
<b>LxS</b>	<b>NS</b>			<b>NS</b>			<b>NS</b>		

**Table 4.1.33. Available soil Mn (mg kg<sup>-1</sup>) contents in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	23.40	15.60	<b>19.50</b>	24.40	17.00	<b>20.70</b>	23.90	16.30	<b>20.10</b>
<b>Theog-2</b>	13.20	14.80	<b>14.00</b>	15.00	16.80	<b>15.90</b>	14.10	15.80	<b>14.95</b>
<b>Rohru-1</b>	17.40	15.82	<b>16.61</b>	18.08	17.78	<b>17.93</b>	17.74	16.80	<b>17.27</b>
<b>Rohru-2</b>	15.42	13.99	<b>14.71</b>	16.55	14.85	<b>15.70</b>	15.98	14.42	<b>15.20</b>
<b>Mean</b>	<b>17.35</b>	<b>15.05</b>		<b>18.51</b>	<b>16.61</b>		<b>17.93</b>	<b>15.83</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>3.05</b>			<b>2.41</b>			<b>1.88</b>		
<b>Sources</b>	<b>2.16</b>			<b>1.70</b>			<b>1.33</b>		
<b>LxS</b>	<b>4.31</b>			<b>3.41</b>			<b>2.67</b>		

**Table 4.1.34. Total soil microbial counts (cfu/g) in organic and inorganic apple orchards at different locations**

S L	2011			2012			Pooled		
	Organic	Inorganic	Mean	Organic	Inorganic	Mean	Organic	Inorganic	Mean
<b>Theog-1</b>	148.07	118.80	<b>133.43</b>	151.80	119.60	<b>135.70</b>	149.93	119.20	<b>134.57</b>
<b>Theog-2</b>	132.60	91.60	<b>112.10</b>	148.80	93.60	<b>121.20</b>	140.70	92.60	<b>116.65</b>
<b>Rohru-1</b>	119.00	102.80	<b>110.90</b>	121.80	114.40	<b>118.10</b>	120.40	108.60	<b>114.50</b>
<b>Rohru-2</b>	113.80	94.60	<b>104.20</b>	115.40	98.20	<b>106.80</b>	114.60	96.40	<b>105.50</b>
<b>Mean</b>	<b>128.37</b>	<b>101.95</b>		<b>134.45</b>	<b>106.45</b>		<b>131.41</b>	<b>104.20</b>	
<b>CD<sub>0.05</sub></b>									
<b>Locations</b>	<b>9.45</b>			<b>10.00</b>			<b>7.57</b>		
<b>Sources</b>	<b>6.69</b>			<b>7.07</b>			<b>5.35</b>		
<b>LxS</b>	<b>13.37</b>			<b>14.14</b>			<b>10.70</b>		

#### **4.1.4.2.8 Available Fe**

The data pertaining to available iron (Fe) contents from organic and inorganic apple orchards of Theog and Rohru are shown in Table 4.1.31.

A perusal of pooled data revealed that available iron contents was significantly influenced by different locations and nutrient sources. Maximum available Fe ( $57.70 \text{ mg/kg}^{-1}$ ) contents were registered in Theog-2 orchards, which were significantly higher than all other locations. The lowest contents were recorded in Rohru-2 ( $26.60 \text{ mg/kg}^{-1}$ ) apple orchards. Between nutrient sources, significantly higher available Fe ( $43.95 \text{ mg/kg}^{-1}$ ) contents were recorded from inorganic as compared to organic ( $38.94 \text{ mg/kg}^{-1}$ ) apple orchards. There were no significant differences observed among interactions.

#### **4.1.4.2.9 Available Cu**

The data on available copper (Cu) contents in organic and inorganic apple orchards at Theog and Rohru are shown in Table 4.1.32.

From the mean of pooled data maximum available Cu ( $4.48 \text{ mg/kg}^{-1}$ ) contents was recorded in Theog-1, which was statistically at par with Theog-2 recording  $4.41 \text{ mg/kg}^{-1}$  and significantly higher than other locations. The lowest contents were registered in Rohru-2 ( $4.12 \text{ mg/kg}^{-1}$ ) apple orchards. Between nutrient sources, significantly higher available Cu ( $4.43 \text{ mg/kg}^{-1}$ ) contents were recorded from inorganic as compared to organic ( $4.37 \text{ mg/kg}^{-1}$ ) apple orchards. The interactions between locations and nutrient sources revealed no significant variation.

#### **4.1.4.2.10 Available Mn**

The available Mn contents from organic and inorganic apple orchards of Theog and Rohru are depicted in Table 4.1.33.

It was observed from pooled data that maximum available Mn contents (20.10 mg/kg<sup>-1</sup>) were observed in Theog-1, which was significantly higher than other locations. However, lowest contents were recorded in Theog-2 (14.95 mg/kg<sup>-1</sup>) apple orchards. Between nutrient sources, significantly higher available Mn (17.93 mg/kg<sup>-1</sup>) contents were recorded from organic as compared to inorganic (15.83 mg/kg<sup>-1</sup>) apple orchards. There were significant variations observed among interactions. Maximum available Mn (23.90 mg/kg<sup>-1</sup>) contents were recorded in Theog-1 organic orchards, which were significantly higher than other interactions. However, lowest leaf Mn contents (14.10 mg/kg<sup>-1</sup>) were registered in Theog-2 organic apple orchards.

#### **4.1.4.c Biological properties**

##### **4.1.4.3.1 TMC**

The pooled data depicted in Table 4.1.34 revealed that total microbial counts were significantly different in locations, nutrient sources and among their interactions. Maximum total microbial counts ( $134.57 \times 10^5$  cfu/g soil) were recorded at Theog-1, which was significantly higher than all other locations. However, lowest counts were recorded in Rohru-2 ( $105.50 \times 10^5$  cfu/g soil) apple orchards. Likewise, between nutrient sources higher total microbial counts ( $131.41 \times 10^5$  cfu/g soil) were recorded under organic as compared to inorganic ( $104.20 \times 10^5$  cfu/g soil) apple orchards.

Among interactions maximum total microbial counts ( $149.9 \times 10^5$  cfu/g soil) were recorded in Theog-1 organic, which were statistically at par with Theog-2 organic orchards recording 140.70 cfu/g soil and was significantly higher than all other interactions.

However, lowest counts were recorded in Theog-2 inorganic ( $92.60 \times 10^5$  cfu/g soil) apple orchards.

## **4.2 EXPERIMENT II - EFFECT OF ORGANIC SOURCES OF NUTRIENTS ON APPLE PRODUCTION.**

### **4.2.A EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON PLANT GROWTH AND FLOWERING PARAMETERS**

#### **4.2.1.1 Trunk girth**

The data on trunk girth (cm) as influenced by different sources of organic nutrition during 2011, 2012 and pooled are presented in Table 4.2.1.

There was non-significant difference with application of various sources of organic nutrition in trunk girth over conventional soil fertilization. The pooled data of both the years revealed that among different treatments, T<sub>5</sub> [Recommended dose of fertilizers] was found most effective in increasing (57.77cm) the plant trunk girth whereas, minimum (56.27 cm) increase was recorded in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.1.2 Duration of flowering**

The pooled data indicated that the duration of flowering (days) as influenced by different sources of organic nutrition were non-significant during 2011, 2012 and in their pooled analysis (Table 4.2.1). However, maximum (13.40 days) duration of flowering in days was noticed in T<sub>5</sub> [Recommended dose of fertilizers] and minimum (11.80 days) was observed in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

**Table 4.2.1. Effect of organic nutrition on trunk girth, duration of flowering and per cent fruit set**

Treatments	Trunk Girth (cm)			Duration of flowering (Days)			Fruit Set (%)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
<b>T<sub>1</sub></b>	56.06	56.49	<b>56.27</b>	11.60	12.00	<b>11.80</b>	13.60	14.00	<b>13.80</b>
<b>T<sub>2</sub></b>	56.09	56.75	<b>56.42</b>	12.20	12.60	<b>12.40</b>	14.20	14.60	<b>14.40</b>
<b>T<sub>3</sub></b>	56.19	56.84	<b>56.52</b>	12.60	13.00	<b>12.80</b>	14.40	15.00	<b>14.70</b>
<b>T<sub>4</sub></b>	56.92	57.71	<b>57.32</b>	12.80	13.00	<b>12.90</b>	15.40	16.00	<b>15.70</b>
<b>T<sub>5</sub></b>	57.20	58.33	<b>57.77</b>	13.00	13.80	<b>13.40</b>	16.20	17.00	<b>16.60</b>
<b>CD<sub>0.05</sub></b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>

#### **4.2.1.3 Per cent fruit set**

The data pertaining to the effect of different sources of organic nutrition on per cent fruit set (Table 4.2.1) revealed that different treatment had a non-significant influence on per cent fruit set during 2011, 2012 and in their pooled analysis. However, T<sub>5</sub>

[Recommended dose of fertilizers] gave maximum (16.60 %) per cent of fruit set, whereas minimum (13.80 %) was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

### **4.2.B EFFECT ON DIFFERENT SOURCES OF ORGANIC NUTRITION ON LEAF NUTRIENT STATUS**

#### **4.2.1.5 Leaf Nitrogen**

The combination of different sources of organic nutrition and recommended dose of fertilizer held as control significantly influenced the total nitrogen (N) contents in leaf (%) of apple during 2011, 2012 and in pooled data denoted in Table 4.2.2.

The pooled data revealed significantly higher (2.25 %) leaf N contents in T<sub>5</sub> [Recommended dose of fertilizers] which was statistically at par with T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] recording 2.16 per cent whereas, lowest (2.08 %) was recorded in T<sub>1</sub> treatment.

#### **4.2.1.6 Leaf Phosphorus**

The data on the effect of various sources of organic nutrition and their combination with different proportion against recommended dose of fertilizer as control on the total phosphorus (P) contents in leaf (%) and the pooled data are presented in Table 4.2.2.

**Table 4.2.2. Effect of organic nutrition on leaf N, P and K contents**

<b>Treatments</b>	<b>N (%)</b>			<b>P (%)</b>			<b>K (%)</b>		
	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>
<b>T<sub>1</sub></b>	2.05	2.10	<b>2.08</b>	0.19	0.22	<b>0.21</b>	1.35	1.36	<b>1.36</b>
<b>T<sub>2</sub></b>	2.07	2.11	<b>2.09</b>	0.21	0.23	<b>0.22</b>	1.46	1.47	<b>1.47</b>
<b>T<sub>3</sub></b>	2.11	2.15	<b>2.13</b>	0.22	0.24	<b>0.23</b>	1.50	1.56	<b>1.53</b>
<b>T<sub>4</sub></b>	2.13	2.18	<b>2.16</b>	0.24	0.27	<b>0.26</b>	1.55	1.59	<b>1.57</b>
<b>T<sub>5</sub></b>	2.24	2.26	<b>2.25</b>	0.25	0.29	<b>0.27</b>	1.71	1.73	<b>1.72</b>
<b>CD<sub>0.05</sub></b>	<b>0.02</b>	<b>0.04</b>	<b>0.02</b>	<b>0.01</b>	<b>0.02</b>	<b>0.01</b>	<b>0.10</b>	<b>0.15</b>	<b>0.10</b>

It was revealed from pooled data that significantly higher (0.27 %) leaf P contents was observed in T<sub>5</sub> [Recommended dose of fertilizers], which was statistically at par with T<sub>4</sub> (0.26 %) [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], however, minimum 0.21 per cent was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.1.7 Leaf Potassium**

The combination of different sources of organic nutrition and recommended dose of fertilizer observed as control significantly influenced the total potassium (K) contents in leaves of apple during 2011, 2012 and in pooled analysis are depicted in Table 4.2.2.

Among different treatments, T<sub>5</sub> [Recommended dose of fertilizers] was found significantly higher in increasing (1.72 %) leaf K contents, whereas lowest (1.36 %) leaf potassium contents was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.1.8 Leaf micronutrients**

The effect of combination of various sources of organic nutrition and recommended dose of fertilizer as control on micronutrients such as Zn, Fe, Cu, and Mn contents of leaves of apple during 2011, 2012 and their pooled data are presented in Table 4.2.3.

There was no significant difference observed in leaf micronutrients contents. However, maximum leaf Zn, Fe and Cu contents were recorded in T<sub>5</sub> [Recommended dose of fertilizers] and minimum in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)]. Whereas, leaf Mn contents was recorded maximum in T<sub>4</sub> [FYM (100 kg/tree) +

**Table 4.2.3. Effect of organic nutrition on leaf micronutrients contents**

Treatments	Zn (ppm)			Fe (ppm)			Cu (ppm)			Mn (ppm)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
<b>T<sub>1</sub></b>	22.73	22.97	<b>22.85</b>	130.20	130.40	<b>130.30</b>	13.85	13.89	<b>13.87</b>	57.71	57.78	<b>57.74</b>
<b>T<sub>2</sub></b>	23.31	23.52	<b>23.42</b>	130.80	131.10	<b>130.95</b>	14.24	14.83	<b>14.53</b>	59.00	59.60	<b>59.30</b>
<b>T<sub>3</sub></b>	23.80	24.22	<b>24.01</b>	131.00	132.40	<b>131.70</b>	14.86	15.12	<b>14.99</b>	59.40	60.20	<b>59.80</b>
<b>T<sub>4</sub></b>	24.05	25.71	<b>24.88</b>	133.80	135.20	<b>133.70</b>	15.17	16.41	<b>15.79</b>	59.63	60.48	<b>60.06</b>
<b>T<sub>5</sub></b>	25.05	25.82	<b>25.43</b>	134.87	135.85	<b>135.36</b>	15.35	16.88	<b>16.11</b>	58.63	59.87	<b>59.25</b>
<b>CD<sub>0.05</sub></b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>

Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] and minimum in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.C EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON FRUIT YIELD AND QUALITY PARAMETERS**

##### **4.2.2.1 Fruit yield**

The data related to effect on application of treatments on fruit yield per tree are presented in Table 4.2.4. Significantly highest fruit yield (48.53 kg/tree) was registered in plants applied with T<sub>5</sub> [Recommended dose of fertilizers] whereas, lowest (30.02 kg/tree) was recorded in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

**Table 4.2.4. Effect of organic nutrition on fruit yield and fruit weight**

<b>Treatments</b>	<b>Fruit yield (kg/tree)</b>			<b>Fruit weight (g)</b>		
	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>
<b>T<sub>1</sub></b>	34.78	25.27	<b>30.02</b>	139.35	142.06	<b>140.71</b>
<b>T<sub>2</sub></b>	39.13	27.66	<b>33.40</b>	141.55	144.66	<b>143.11</b>
<b>T<sub>3</sub></b>	44.82	29.03	<b>36.92</b>	143.13	147.06	<b>145.10</b>
<b>T<sub>4</sub></b>	47.66	34.03	<b>40.84</b>	144.43	148.43	<b>146.43</b>
<b>T<sub>5</sub></b>	60.19	36.88	<b>48.53</b>	157.49	160.62	<b>159.05</b>
<b>CD<sub>0.05</sub></b>	<b>4.55</b>	<b>3.36</b>	<b>3.17</b>	<b>9.05</b>	<b>9.78</b>	<b>9.03</b>

##### **4.2.2.2 Fruit weight**

The data on the effect of various sources of organic nutrition and recommended dose of fertilizer as control on the fruit weight during 2011, 2012 and the pooled data presented in Table 4.2.4.

Significantly higher (159.05 g) fruit weight were recorded in T<sub>5</sub> [Recommended dose of fertilizers and lower (140.71 g) in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### 4.2.2.3 Fruit firmness

Effect on apple fruit firmness of organic nutrition sources and recommended dose of fertilizer as control during 2011, 2012 and pooled data presented in Table 4.2.5.

Significantly higher (6.40 kg/cm<sup>2</sup>) fruit firmness was recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], whereas lowest (6.13 kg/cm<sup>2</sup>) was recorded with T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

**Table 4.2.5. Effect of organic nutrition on fruit firmness and TSS contents**

Treatments	Fruit firmness (kg/cm <sup>2</sup> )			TSS ( <sup>0</sup> Brix)		
	2011	2012	2011	2012	2011	2012
T <sub>1</sub>	6.12	6.14	<b>6.13</b>	12.13	12.18	<b>12.16</b>
T <sub>2</sub>	6.16	6.22	<b>6.19</b>	12.21	12.25	<b>12.23</b>
T <sub>3</sub>	6.20	6.26	<b>6.23</b>	12.28	12.35	<b>12.32</b>
T <sub>4</sub>	6.35	6.45	<b>6.40</b>	12.54	12.59	<b>12.56</b>
T <sub>5</sub>	6.25	6.27	<b>6.26</b>	12.41	12.47	<b>12.44</b>
CD <sub>0.05</sub>	<b>0.15</b>	<b>0.19</b>	<b>0.13</b>	<b>0.23</b>	<b>0.23</b>	<b>0.22</b>

#### 4.2.2.4 Total soluble solids (TSS)

Total soluble solids contents of apple fruits represented in Table 4.2.5 significantly influenced by various treatments of organic nutrition and recommended dose of fertilizer regarded as control.



**Plate-2 Fruit quality among different treatments**

Significantly higher TSS (12.56<sup>0</sup>B) contents of apple fruits were recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which was statistically at par with T<sub>5</sub> recording 12.44<sup>0</sup>B, while, T<sub>1</sub> was found to be inferior recording 12.16<sup>0</sup>B.

#### **4.2.2.5 Titratable acidity**

The effect of various sources of organic nutrition and recommended dose of fertilizer as control on titratable acidity contents of apple fruit during 2011, 2012 and their pooled data are presented in Table 4.2.6.

The pooled data revealed that significantly higher titratable acidity contents (0.25 %) were recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], while lower (0.19 %) were recorded in treatment T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.2.6 Reducing sugars**

The influence of different sources of organic nutrition and recommended dose of fertilizer as control on reducing sugars contents of apple fruit during 2011, 2012 and in pooled analysis are given in Table 4.2.6.

It is evident from pooled data that reducing sugars contents was significantly higher (6.45 %) in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], and least (6.25 %) were noticed in T<sub>1</sub> treatment.

**Table 4.2.6. Effect of organic nutrition on titratable acidity, reducing and total sugars contents**

<b>Treatments</b>	<b>Titratable acidity (%)</b>			<b>Reducing sugars (%)</b>			<b>Total sugars (%)</b>		
	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>
<b>T<sub>1</sub></b>	0.20	0.18	0.19	6.24	6.27	<b>6.25</b>	8.28	8.30	<b>8.29</b>
<b>T<sub>2</sub></b>	0.22	0.21	0.22	6.28	6.29	<b>6.29</b>	8.34	8.37	<b>8.35</b>
<b>T<sub>3</sub></b>	0.24	0.23	0.23	6.32	6.34	<b>6.33</b>	8.45	8.49	<b>8.47</b>
<b>T<sub>4</sub></b>	0.26	0.25	0.25	6.42	6.47	<b>6.45</b>	8.56	8.66	<b>8.61</b>
<b>T<sub>5</sub></b>	0.24	0.23	0.23	6.36	6.42	<b>6.39</b>	8.49	8.56	<b>8.53</b>
<b>CD<sub>0.05</sub></b>	<b>0.03</b>	<b>0.04</b>	<b>0.02</b>	<b>0.07</b>	<b>0.08</b>	<b>0.05</b>	<b>0.17</b>	<b>0.18</b>	<b>0.10</b>

#### **4.2.2.7 Total sugars**

The effect of different sources of organic nutrition on total sugars contents of apple fruits estimated during 2011, 2012 and their pooled are given in Table 4.2.6.

Treatment T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] recorded significantly higher (8.61%) total sugars contents, which was at par with T<sub>5</sub> (8.53%) and least (8.29 %) were observed in T<sub>1</sub> treatment.

#### **4.2.2.8 Anthocyanins**

Data shown in Table 4.2.7 revealed that anthocyanins contents of apple fruits were significantly affected by application of different sources of organic nutrition and recommended dose as control during both years of study and in their pooled.

It was evident from pooled data that highest anthocyanins contents (24.50 mg/100g) were recorded in the treatment T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which was followed by T<sub>5</sub> (23.90 mg/100g) whereas, minimum (20.65 mg/100g) was recorded with the application of T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.2.9 Total Phenols**

The data on the effect of various sources of organic nutrition and RDF as control on the total phenols contents in apple fruits are presented in Table 4.2.7. The total phenols contents in fruits were significantly affected by the application of different sources of organic nutrition during both the years as well as in pooled.

**4.2.7. Effect of organic nutrition on anthocyanins, total phenols and antioxidants contents**

<b>Treatments</b>	<b>Anthocyanins (mg/100g)</b>			<b>Total Phenols (mg/100 g)</b>			<b>Antioxidants (%)</b>		
	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2012</b>	<b>Pooled</b>
<b>T<sub>1</sub></b>	20.30	21.00	<b>20.65</b>	49.00	49.40	<b>49.20</b>	49.80	50.20	<b>50.00</b>
<b>T<sub>2</sub></b>	21.80	22.03	<b>21.91</b>	50.90	51.00	<b>50.95</b>	51.60	52.60	<b>52.10</b>
<b>T<sub>3</sub></b>	21.87	22.07	<b>21.97</b>	51.43	52.00	<b>51.71</b>	51.80	53.00	<b>52.40</b>
<b>T<sub>4</sub></b>	23.80	25.20	<b>24.50</b>	55.62	56.02	<b>55.82</b>	55.00	57.00	<b>56.00</b>
<b>T<sub>5</sub></b>	23.30	24.50	<b>23.90</b>	53.80	54.03	<b>53.92</b>	54.40	54.60	<b>54.50</b>
<b>CD<sub>0.05</sub></b>	<b>1.62</b>	<b>1.85</b>	<b>1.52</b>	<b>4.13</b>	<b>4.25</b>	<b>3.16</b>	<b>3.86</b>	<b>3.10</b>	<b>2.84</b>

The pooled data revealed that highest (55.82 mg/100g) phenols contents were recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which were at par with T<sub>5</sub> [RDF] recording 53.92 mg/100g. However, minimum (49.20 mg/100g) was recorded with the application of T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)], which was on par with T<sub>2</sub> [FYM (60 kg/tree) + Vermicompost (15 kg/tree) + Wood ash (4 kg/tree) + Neem cake (4 kg/tree)] recording 50.95 mg/100g.

#### **4.2.2.10 Antioxidants**

The effect of different sources of organic nutrition and control as recommended dose of fertilizer on antioxidants contents of apple fruit estimated during 2011, 2012 and pooled analysis are presented in Table 4.2.7. The pooled data revealed significantly higher (56.00 %) antioxidants in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which was followed by T<sub>5</sub> (54.50 %) whereas minimum (50.00 %) was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

### **4.2.D EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON STORAGE STUDIES OF APPLE FRIUTS AT ROOM TEMPERATURE**

#### **4.2.3.1 Physiological loss in weight**

The data on effect of organic nutrition and recommended dose of fertilizer as control on physiological loss in weight of apple fruits at different storage intervals (days) and on ambient storage temperature during the year 2011, 2012 and their pooled analysis are depicted in Table 4.2.8. There was a gradual increase in percent physiological loss in weight of apple fruits during storage period of 60 days irrespective of treatments. The data also indicated that the

**Table 4.2.8. Effect of organic nutrition on physiological loss in weight (PLW) of apple fruits at different storage intervals (days) and ambient storage temperature**

Treatments	PLW (%)																	
	2011						2012						Pooled					
	0	15	30	45	60	Mean	0	15	30	45	60	Mean	0	15	30	45	60	Mean
<b>T<sub>1</sub></b>	0.00	6.11	7.12	8.63	9.11	<b>6.19</b>	0.00	6.10	7.16	8.51	9.02	<b>6.16</b>	0.00	6.11	7.14	8.57	9.07	<b>6.18</b>
<b>T<sub>2</sub></b>	0.00	6.16	7.09	8.43	9.13	<b>6.16</b>	0.00	6.25	7.12	8.38	8.95	<b>6.14</b>	0.00	6.20	7.11	8.40	9.04	<b>6.15</b>
<b>T<sub>3</sub></b>	0.00	6.10	7.07	7.94	8.64	<b>5.95</b>	0.00	6.02	7.06	7.91	8.64	<b>5.93</b>	0.00	6.06	7.07	7.93	8.64	<b>5.94</b>
<b>T<sub>4</sub></b>	0.00	6.09	6.90	7.52	8.46	<b>5.79</b>	0.00	6.04	6.88	7.49	8.21	<b>5.72</b>	0.00	6.07	6.89	7.51	8.34	<b>5.76</b>
<b>T<sub>5</sub></b>	0.00	6.27	7.28	8.77	9.35	<b>6.33</b>	0.00	6.24	7.27	8.75	9.41	<b>6.30</b>	0.00	6.25	7.27	8.76	9.31	<b>6.32</b>
<b>Mean</b>	<b>0.00</b>	<b>6.14</b>	<b>7.09</b>	<b>8.26</b>	<b>8.94</b>	<b>6.09</b>	<b>0.00</b>	<b>6.13</b>	<b>7.10</b>	<b>8.21</b>	<b>8.85</b>	<b>6.05</b>	<b>0.00</b>	<b>6.14</b>	<b>7.10</b>	<b>8.23</b>	<b>8.88</b>	<b>6.07</b>
<b>CD<sub>0.05</sub></b>																		
<b>T</b>	<b>0.12</b>						<b>0.14</b>						<b>0.11</b>					
<b>I</b>	<b>0.12</b>						<b>0.14</b>						<b>0.11</b>					
<b>TxI</b>	<b>0.28</b>						<b>0.31</b>						<b>0.24</b>					

**Table 4.2.9. Effect of organic nutrition on rotting percentage of apple fruits at different storage intervals (days) and ambient storage temperature**

Treatments	Rotting (%)																	
	2011						2012						Pooled					
	0	15	30	45	60	Mean	0	15	30	45	60	Mean	0	15	30	45	60	Mean
<b>T<sub>1</sub></b>	0.00	12.60	25.20	36.80	54.40	<b>25.80</b>	0.00	12.00	25.00	36.20	52.60	<b>25.16</b>	0.00	12.30	25.10	36.50	53.50	<b>25.48</b>
<b>T<sub>2</sub></b>	0.00	10.80	23.20	33.80	54.20	<b>24.40</b>	0.00	10.20	22.80	33.00	53.20	<b>23.84</b>	0.00	10.50	23.00	33.40	53.70	<b>24.12</b>
<b>T<sub>3</sub></b>	0.00	9.60	21.60	32.20	53.00	<b>23.28</b>	0.00	9.00	20.60	28.00	51.80	<b>21.88</b>	0.00	9.30	21.10	30.10	52.40	<b>22.58</b>
<b>T<sub>4</sub></b>	0.00	8.00	14.70	28.60	51.40	<b>20.54</b>	0.00	7.80	14.40	27.40	47.20	<b>19.36</b>	0.00	7.90	14.55	28.00	49.30	<b>19.95</b>
<b>T<sub>5</sub></b>	0.00	5.80	13.20	26.80	55.00	<b>20.16</b>	0.00	5.60	12.80	26.20	53.80	<b>19.68</b>	0.00	5.70	13.00	26.50	54.40	<b>19.92</b>
<b>Mean</b>	<b>0.00</b>	<b>9.36</b>	<b>19.58</b>	<b>31.64</b>	<b>53.60</b>	<b>22.84</b>	<b>0.00</b>	<b>8.92</b>	<b>19.12</b>	<b>30.16</b>	<b>51.72</b>	<b>21.98</b>	<b>0.00</b>	<b>9.14</b>	<b>19.35</b>	<b>30.90</b>	<b>52.66</b>	<b>22.41</b>
<b>CD<sub>0.05</sub></b>																		
<b>T</b>	<b>1.75</b>						<b>2.04</b>						<b>1.38</b>					
<b>I</b>	<b>1.75</b>						<b>2.04</b>						<b>1.38</b>					
<b>TxI</b>	<b>3.92</b>						<b>4.56</b>						<b>3.08</b>					

difference in PLW due to treatments were statistically significant throughout the storage period. From the mean value denoted in Table minimum (5.76 %) PLW was obtained under T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] and maximum (6.32 %) in T<sub>5</sub> [RDF]. In different storage intervals minimum (6.14 %) PLW was recorded at 15<sup>th</sup> day of storage interval and simultaneously there was increment for the rest of period till disposing of fruits. Among interaction minimum (8.34 %) PLW was noted at 60<sup>th</sup> day of storage interval under T<sub>4</sub> and maximum (9.31 %) with T<sub>5</sub> treatment.

#### **4.2.3.2 Rotting percentage**

The effect of different organic nutrition sources and RDF as control on rotting percentage of apple fruits at different storage intervals (days) and on ambient storage temperature during the years 2011, 2012 and their pooled data are furnished in Table 4.2.9.

It is evident from the data that different sources of organic nutrition had significant influence on rotting percentage of apple fruits at different storage intervals (days) and at ambient storage temperature. The pooled data of both the years exhibited that rotting percentage was higher during the year 2011 as compared to the year 2012. Rotting percentage increased with the time, minimum (19.92 %) was recorded under T<sub>5</sub> [RDF] and maximum (25.48) under T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)]. On different interval days it was found that minimum (9.14 %) rotting was recorded at 15<sup>th</sup> day storage interval and maximum (52.66 %) on 60<sup>th</sup> day of storage. Under interactions minimum (49.30 %) rotting at 60<sup>th</sup> day of storage interval was noted in T<sub>4</sub> and maximum (54.40 %) in T<sub>5</sub> treatment.

#### **4.2.3.3 Fruit firmness**

The data on firmness of apple fruits on different storage intervals under ambient storage temperature as influenced by different sources of organic nutrition in comparison to recommended dose of fertilizer during the years 2011, 2012 and their pooled analysis are given in Table 4.2.10.

It can be seen from the tabulated data that there was significant differences in fruit firmness in treatments, storage intervals, and their interactions. It is evident from the data that there was a decrease in fruit firmness under all treatments as the storage period progressed. Among the various treatments, T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] was most effective in reducing the fruit firmness. Hence, resulted in maximum mean firmness (5.31 kg/cm<sup>2</sup>) of fruits, which was significantly higher in comparison to all other treatments and minimum (2.07 kg/cm<sup>2</sup>) in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)]. Correspondingly, maximum (4.09 kg/cm<sup>2</sup>) fruit firmness at 60<sup>th</sup> day of storage interval was recorded in T<sub>3</sub> and minimum (3.88 kg/cm<sup>2</sup>) in T<sub>2</sub> treatment.

#### **4.2.3.4 Total soluble solids**

The data pertaining to effect of various sources of organic nutrition on apple fruits stored at ambient storage temperature for observing the changes in TSS contents at fortnightly interval for 60 days during the years 2011, 2012 and their pooled analysis are expressed in Table 4.2.11.

The pooled mean of TSS contents in apple fruit were observed towards increase with the advancement of storage period up to 15 days and thereafter a decrease was recorded during the remaining storage period resulting in the lowest TSS contents by 60<sup>th</sup> day of

**Table 4.2.10. Effect of organic nutrition on apple fruit firmness at different storage intervals (days) and ambient storage temperature**

Treatments	Fruit Firmness (kg/cm <sup>2</sup> )																	
	2011						2012						Pooled					
	0	15	30	45	60	Mean	0	15	30	45	60	Mean	0	15	30	45	60	Mean
<b>T<sub>1</sub></b>	6.05	5.81	5.12	4.36	3.85	<b>5.04</b>	6.14	5.87	5.14	4.38	3.97	<b>5.10</b>	6.10	5.84	5.13	4.37	3.91	<b>5.07</b>
<b>T<sub>2</sub></b>	6.19	5.79	5.19	4.63	3.81	<b>5.12</b>	6.21	5.84	5.20	4.81	3.94	<b>5.20</b>	6.20	5.81	5.19	4.72	3.88	<b>5.16</b>
<b>T<sub>3</sub></b>	6.12	5.74	5.30	4.83	4.01	<b>5.20</b>	6.20	5.78	5.33	4.88	4.17	<b>5.27</b>	6.16	5.76	5.31	4.86	4.09	<b>5.24</b>
<b>T<sub>4</sub></b>	6.21	5.98	5.37	4.89	4.05	<b>5.30</b>	6.25	6.00	5.40	4.90	4.08	<b>5.32</b>	6.23	5.99	5.39	4.89	4.07	<b>5.31</b>
<b>T<sub>5</sub></b>	6.16	5.71	5.11	4.53	3.94	<b>5.09</b>	6.19	5.77	5.14	4.55	3.96	<b>5.12</b>	6.17	5.74	5.12	4.54	3.95	<b>5.11</b>
<b>Mean</b>	<b>6.15</b>	<b>5.80</b>	<b>5.22</b>	<b>4.65</b>	<b>3.93</b>	<b>5.15</b>	<b>6.20</b>	<b>5.85</b>	<b>5.24</b>	<b>4.70</b>	<b>4.02</b>	<b>5.20</b>	<b>6.17</b>	<b>5.83</b>	<b>5.23</b>	<b>4.68</b>	<b>3.98</b>	<b>5.18</b>
<b>CD<sub>0.05</sub></b>																		
<b>T</b>	<b>0.08</b>						<b>0.09</b>						<b>0.07</b>					
<b>I</b>	<b>0.08</b>						<b>0.09</b>						<b>0.07</b>					
<b>TxI</b>	<b>0.18</b>						<b>0.19</b>						<b>0.15</b>					

**Table 4.2.11. Effect of organic nutrition on total soluble solids of apple fruits at different storage intervals (days) and ambient storage temperature**

Treatments	TSS (°B)																	
	2011						2012						Pooled					
	0	15	30	45	60	Mean	0	15	30	45	60	Mean	0	15	30	45	60	Mean
<b>T<sub>1</sub></b>	12.19	13.06	12.09	11.24	9.88	<b>11.70</b>	12.21	13.12	12.11	11.27	9.93	<b>11.73</b>	12.20	13.09	12.10	11.26	9.91	<b>11.71</b>
<b>T<sub>2</sub></b>	12.26	13.11	12.15	11.31	9.95	<b>11.76</b>	12.30	13.19	12.18	11.35	9.97	<b>11.80</b>	12.28	13.15	12.17	11.33	9.96	<b>11.78</b>
<b>T<sub>3</sub></b>	12.35	13.16	12.25	11.35	10.00	<b>11.82</b>	12.37	13.22	12.27	11.39	10.03	<b>11.86</b>	12.36	13.19	12.26	11.37	10.02	<b>11.84</b>
<b>T<sub>4</sub></b>	12.41	13.41	12.29	11.43	10.05	<b>11.92</b>	12.48	13.52	12.33	11.45	10.06	<b>11.97</b>	12.45	13.46	12.31	11.44	10.06	<b>11.94</b>
<b>T<sub>5</sub></b>	12.25	13.17	12.18	11.30	9.94	<b>11.77</b>	12.30	13.25	12.15	11.35	9.98	<b>11.80</b>	12.27	13.21	12.16	11.32	9.96	<b>11.78</b>
<b>Mean</b>	<b>12.29</b>	<b>13.18</b>	<b>12.19</b>	<b>11.33</b>	<b>9.97</b>	<b>11.79</b>	<b>12.33</b>	<b>13.26</b>	<b>12.21</b>	<b>11.36</b>	<b>9.99</b>	<b>11.83</b>	<b>12.31</b>	<b>13.22</b>	<b>12.20</b>	<b>11.34</b>	<b>9.98</b>	<b>11.81</b>
<b>CD<sub>0.05</sub></b>																		
<b>T</b>	<b>0.03</b>						<b>0.04</b>						<b>0.03</b>					
<b>I</b>	<b>0.03</b>						<b>0.04</b>						<b>0.03</b>					
<b>TxI</b>	<b>0.08</b>						<b>0.09</b>						<b>0.06</b>					

storage interval, consequently resulting in the lowest mean value of 9.91<sup>0</sup>B in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] at 60<sup>th</sup> of storage interval. The treatments mean values denoted significantly higher (11.94<sup>0</sup>B) TSS contents of apple fruits in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] and lowest (11.71<sup>0</sup>B) in T<sub>1</sub>. In interactions significantly higher (10.06<sup>0</sup>B) TSS contents were recorded at 60<sup>th</sup> day of storage interval in T<sub>4</sub>, which was followed by T<sub>3</sub> (10.02<sup>0</sup>B) and minimum (9.91<sup>0</sup>B) in T<sub>1</sub>.

#### **4.2.E EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON SOIL PROPERTIES**

##### **4.2.4.1 Physical properties of Soil**

##### **4.2.4.1.1 Water holding capacity**

The data pertaining to maximum water holding capacity as influenced by various sources of organic nutrition and recommended dose of fertilizer as control have been recorded during 2011, 2012 and their pooled analysis presented in Table 4.2.12.

##### **4.2.12. Effect of organic nutrition on maximum water holding capacity (MWHC) and bulk density (BD) of soil**

<b>Treatments</b>	<b>MWHC (%)</b>			<b>BD (g/cc)</b>		
	<b>2011</b>	<b>2012</b>	<b>Pooled</b>	<b>2011</b>	<b>2011</b>	<b>Pooled</b>
<b>T<sub>1</sub></b>	47.80	48.10	47.95	1.20	1.19	1.20
<b>T<sub>2</sub></b>	48.40	50.00	49.20	1.19	1.18	1.19
<b>T<sub>3</sub></b>	49.53	50.60	50.07	1.19	1.17	1.18
<b>T<sub>4</sub></b>	52.60	53.83	53.21	1.18	1.15	1.17
<b>T<sub>5</sub></b>	48.40	48.56	48.48	1.21	1.21	1.21
<b>CD<sub>0.05</sub></b>	<b>3.16</b>	<b>3.23</b>	<b>2.57</b>	<b>0.01</b>	<b>0.02</b>	<b>0.01</b>

Data with respect to the effect of different nutrition sources revealed that through all the treatments there was increase in water holding capacity during both the years of study. Pooled data of both the years demonstrated that significantly higher 53.21 per cent water holding capacity was recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], whereas, minimum 47.95 % in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)].

#### **4.2.4.1.2 Bulk density**

The combination of different sources of organic nutrition significantly influenced the available nitrogen contents during 2011, 2012 and in there pooled analysis (Table 4.2.12).

It is evident from data presented in Table 4.2.12 that all the treatments were effective in decreasing the soil bulk density during both the years of study. The decrease in soil bulk density was maximum 1.17 g/cc with T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which found to be statistically at par with T<sub>3</sub> recording 1.18 g/cc. Whereas, maximum 1.21 g/cc recorded in T<sub>5</sub> [RDF].

#### **4.2.4.2 Chemical properties of soil**

##### **4.2.4.2.1 Soil pH**

Effect of different sources of organic nutrition and control as recommended dose of fertilizer on the soil pH are presented in Table 4.2.13.

All treatments had non-significant influence on soil pH, which remained in slightly acidic range during both the years of study period. Pooled data showed maximum soil pH (6.01) in T<sub>4</sub> [FYM

(100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] and minimum (5.83) in T<sub>5</sub> [RDF].

**Table 4.2.13. Effect of organic nutrition on soil pH and electrical conductivity (EC)**

Treatments	pH			EC (dS/m <sup>2</sup> )		
	2011	2012	Pooled	2011	2012	Pooled
T <sub>1</sub>	5.83	5.89	5.86	0.29	0.30	0.29
T <sub>2</sub>	5.89	5.91	5.90	0.32	0.32	0.32
T <sub>3</sub>	5.88	5.93	5.91	0.33	0.34	0.33
T <sub>4</sub>	5.99	6.03	6.01	0.38	0.40	0.39
T <sub>5</sub>	5.81	5.84	5.83	0.44	0.46	0.45
CD <sub>0.05</sub>	NS	NS	NS	0.04	0.07	0.05

#### 4.2.4.2.2 Soil electrical conductivity

The data on soil electrical conductivity as influenced by various sources of organic nutrition and recommended dose of fertilizer as control during 2011, 2012 and pooled analysis are exhibited in Table 4.2.13. Pooled data revealed that highest soil EC (0.45 dS/m<sup>2</sup>) was recorded in T<sub>5</sub>, whereas lowest (0.29 dS/m<sup>2</sup>) was recorded in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### 4.2.4.2.3 Soil organic carbon

The data on the effect of different sources of organic nutrition against recommended doses of fertilizer as control on the soil organic carbon (%) during 2011, 2012 with their pooled depicted in Table 4.2.14.

It is evident from the data in Table that the different organic manures treatments had significant influence on the organic carbon

contents of the soil. Pooled data revealed that highest organic carbon contents (2.05 %) were recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] while, lowest (1.82 %) in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### 4.2.4.2.4 Total microbial counts

The data pertaining to total microbial counts as influenced by various sources of organic nutrition and recommended dose of fertilizer as control have been recorded during 2011, 2012 and their pooled analysis are depicted in Table 4.2.14.

**Table 4.2.14. Effect of organic nutrition on soil organic carbon (OC) contents and total microbial counts (TMC)**

Treatments	OC (%)			TMC ( $10^{-5}$ cfu/g)		
	2011	2012	Pooled	2011	2012	Pooled
T <sub>1</sub>	1.81	1.84	1.82	94.40	104.60	99.50
T <sub>2</sub>	1.89	1.94	1.92	98.40	110.60	104.50
T <sub>3</sub>	1.92	1.96	1.94	105.20	112.40	108.80
T <sub>4</sub>	2.04	2.05	2.05	109.00	117.20	113.10
T <sub>5</sub>	1.96	1.98	1.97	93.20	96.00	94.60
<b>CD<sub>0.05</sub></b>	<b>0.06</b>	<b>0.09</b>	<b>0.04</b>	<b>7.68</b>	<b>0.06</b>	<b>0.09</b>

The mean of pooled data revealed that significantly higher ( $113.10 \times 10^{-5}$ cfu/g soil) total microbial counts were recorded in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which was followed, by T<sub>3</sub> and T<sub>2</sub> recording 108.80 and  $104.50 \times 10^{-5}$ cfu/g soil, respectively. However, minimum ( $94.60 \times 10^{-5}$ cfu/g soil) was recorded in T<sub>5</sub> which was statistically on par with T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10

kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] recording  $99.50 \times 10^{-5}$  cfu/g soil.

#### **4.2.4.2.5 Available nitrogen**

The combination of different sources of organic nutrition significantly influenced the available nitrogen content during 2011, 2012 and in pooled data (Table 4.2.15).

A perusal of the data revealed that the effect of different sources of organic nutrition with recommended dose treatment as control on available N showed significant effect on available N content. The higher amount of available N content (355.70 kg/ha) was observed in recommended dose of fertilizer (T<sub>5</sub>). However, Lower (271.90 kg/ha) was obtained in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)], which was statistically on par with T<sub>2</sub> (279.70 kg/ha) treatment.

#### **4.2.4.2.6 Available phosphorus**

The combination of different sources of organic nutrition significantly influenced the available phosphorus content during 2011, 2012 and their pooled data (Table 4.2.15).

The pooled data of both years revealed that significantly higher amount of available P (31.11 kg/ha), was recorded in T<sub>5</sub>, whereas, lower content (22.49 kg/ha) was observed in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)], which was statistically on par with T<sub>2</sub> (23.30 kg/ha) and T<sub>3</sub> (23.69 kg/ha) treatment.

#### **4.2.4.2.7 Available potassium**

The influence of different sources of organic nutrition on available potassium content during 2011, 2012 and their pooled data are shown in Table 4.2.15.

**Table 4.2.15. Effect of organic nutrition on available N, P and K status in the soil**

Treatments	N (kg/ha)			P (kg/ha)			K (kg/ha)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
<b>T<sub>1</sub></b>	271.20	272.60	<b>271.90</b>	22.18	22.80	<b>22.49</b>	204.80	205.20	<b>205.00</b>
<b>T<sub>2</sub></b>	279.00	280.40	<b>279.70</b>	23.00	23.60	<b>23.30</b>	207.80	209.80	<b>208.80</b>
<b>T<sub>3</sub></b>	292.40	294.60	<b>293.50</b>	23.39	23.99	<b>23.69</b>	210.80	216.40	<b>213.60</b>
<b>T<sub>4</sub></b>	310.00	316.20	<b>313.10</b>	25.55	26.09	<b>25.82</b>	221.20	225.40	<b>223.30</b>
<b>T<sub>5</sub></b>	353.60	357.80	<b>355.70</b>	30.22	32.00	<b>31.11</b>	236.60	244.00	<b>240.30</b>
<b>CD<sub>0.05</sub></b>	<b>13.80</b>	<b>11.02</b>	<b>10.47</b>	<b>2.11</b>	<b>2.37</b>	<b>1.60</b>	<b>12.26</b>	<b>12.61</b>	<b>10.85</b>

**Table 4.2.16. Effect of organic nutrition on available micronutrients status in the soil**

Treatments	Zn (mg kg <sup>-1</sup> )			Fe (mg kg <sup>-1</sup> )			Cu (mg kg <sup>-1</sup> )			Mn (mg kg <sup>-1</sup> )		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
<b>T<sub>1</sub></b>	3.62	3.64	<b>3.63</b>	27.60	28.00	<b>27.80</b>	4.24	4.27	<b>4.26</b>	11.20	12.00	<b>11.60</b>
<b>T<sub>2</sub></b>	3.69	3.73	<b>3.71</b>	29.40	30.80	<b>30.10</b>	4.32	4.34	<b>4.33</b>	11.60	12.20	<b>11.90</b>
<b>T<sub>3</sub></b>	3.73	3.76	<b>3.75</b>	30.80	31.60	<b>31.20</b>	4.36	4.39	<b>4.38</b>	12.20	13.00	<b>12.60</b>
<b>T<sub>4</sub></b>	3.84	3.87	<b>3.86</b>	36.40	37.60	<b>37.00</b>	4.38	4.42	<b>4.40</b>	13.60	14.00	<b>13.80</b>
<b>T<sub>5</sub></b>	3.83	3.89	<b>3.86</b>	37.40	39.00	<b>38.20</b>	4.39	4.43	<b>4.41</b>	13.40	13.80	<b>13.60</b>
<b>CD<sub>0.05</sub></b>	<b>0.05</b>	<b>0.07</b>	<b>0.04</b>	<b>4.02</b>	<b>4.36</b>	<b>3.17</b>	<b>0.05</b>	<b>0.06</b>	<b>0.04</b>	<b>1.32</b>	<b>1.41</b>	<b>1.03</b>

The data witnessed significant differences among all the treatments on available K content. The mean performance of different treatments showed that higher available K contents (240.30 kg/ha) were recorded in T<sub>5</sub>, whereas minimum were recorded (205.00 kg/ha) in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)], which was statistically on par with T<sub>2</sub> (208.80 kg/ha) and T<sub>3</sub> (213.60 kg/ha) treatment.

#### **4.2.4.2.8 Available Zinc**

The effect of various sources of organic nutrition on available zinc contents during 2011, 2012 and their pooled analysis data are presented in Table 4.2.16.

It is apparent from the pooled data that there was significant difference observed in available Zn content. Significantly higher (3.86 mg kg<sup>-1</sup>) available Zn content was implied in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] and T<sub>5</sub>, whereas least in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] recording 3.63 mg kg<sup>-1</sup>. Different treatments could not yield very pronounced variation in the availability of Zn in the soil as is evident from the trend in which equal values were exhibited by two or more than two treatments.

#### **4.2.4.2.9 Available Iron**

The effect of various sources of organic nutrition on the available iron contents during 2011, 2012 and in pooled data is given in Table 4.2.16.

It is evident from the pooled data that different organic sources had significant influence on available iron content of the experimental soil. Significantly higher (38.20 mg kg<sup>-1</sup>) available

iron content was recorded in treatment T<sub>5</sub> that was at par with T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] recording 37.00 mg kg<sup>-1</sup>. Minimum (27.80 mg kg<sup>-1</sup>) available Fe content was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.4.2.10 Available Copper**

The data pertaining to available copper contents as influenced by various sources of organic nutrition have been recorded during 2011, 2012 and their pooled are presented in Table 4.2.16.

The pooled data pertaining to available copper contents revealed that significantly highest (4.42 mg kg<sup>-1</sup>) available Cu content was found in T<sub>5</sub> which was statistically at par with T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] and T<sub>3</sub> recording 4.40 and 4.38 mg kg<sup>-1</sup> respectively, whereas, minimum 4.26 mg kg<sup>-1</sup> was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

#### **4.2.4.2.11 Available Manganese**

The combination of different sources of organic nutrition significantly influenced the available manganese content during 2011, 2012 and in there pooled analysis (Table 4.2.16).

The pooled data presented in Table reveal significantly higher available manganese content (13.80 mg kg<sup>-1</sup>) in T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)], which was statistically at par with T<sub>5</sub> (13.60 mg kg<sup>-1</sup>). Least (11.60 mg kg<sup>-1</sup>) was recorded in T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

## Chapter - 5

### Discussion

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The use of fertilizers to enhance soil nutrient status for time being and crop productivity has often negatively affected the complex system of the biogeochemical cycles. Fertilizer use has caused leaching and run-off of nutrients, especially nitrogen (N) and phosphorus (P), leading to environmental degradation (Gyaneshwar *et al.*, 2002). Important reasons for these problems are low use efficiency of fertilizers and the continuous long-term use. Despite the negative environmental effects, the total amount of fertilizers used worldwide is projected to increase with the growing world population due to the need to produce more food through intensive agriculture that requires large quantities of fertilizers (Frink *et al.*, 1999).

In the last five decades, the rate of nitrogen, phosphorus, and potassium (NPK) fertilizers application has increased tremendously. The International Fertilizer Industry Association reported that the three countries with the highest fertilizer use in 2006 were China, India, and USA, consuming 50.15, 21.65, and 20.83 million tons of NPK fertilizer, respectively, compared with consumption in 1961 of 1.01, 0.42, and 7.88 million tons, respectively (FAO). Nutrients contained in organic manures are released slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect compared to chemical fertilizers (Ayoola and Makinde, 2007). Therefore, a study was undertaken to find out the influence of organic sources of nutrients on apple cultivation. The results obtained are discussed under following headings:

## **5.1 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON PLANT GROWTH AND FLOWERING PARAMETERS**

In present studies, different sources of organic nutrition have been found to improve plant growth parameters like trunk girth, duration of flowering, per cent fruit set (Table 4.2.1, 4.2.2, 4.2.3 and 4.2.4) and fruit yield (Table 4.1). There was non-significant growth in trunk girth, duration of flowering and per cent fruit set in experiment second. However, maximum increase in plant trunk girth, duration of flowering and per cent fruit set was recorded in recommended dose of fertilizers (T<sub>5</sub>) which may be due to readily available forms of inorganic nutrients in chemical fertilizers.

### **5.1.1 Leaf nutrient contents**

The data cited in Table 4.1.15, 4.1.16, 4.1.17 and 4.2.2 of experiment first and second respectively, indicated that different organic nutrition sources markedly influenced the leaf N, P and K content of apple trees. However, application of plant nutrients through chemical fertilizers as compared to organic sources exhibited higher leaf N, P and K content in both the experiments for both years of study.

The values of leaf nitrogen, phosphorus and potassium were within optimum range under both the management systems of both experiments. The growth and fruitfulness of a plant can therefore, be considered as an index of nutrient status of the leaf so adoption of appropriate measures to ensure optimum nutrient status will go a long way in maintaining apple trees in vigorous state, which will ensure optimum levels of productivity. The results of present investigations regarding leaf nutrient status are discussed below.

Management of nutrients in an organic system is complicated by slower and less predictable mineralization of the organic

materials in which the nutrients are embedded. This process is mediated by the soil fauna, which are affected by carbon (energy) availability, temperature, and water. Providing nutrients at a precise time in organic systems is therefore more challenging. For fruit trees, availability of high amounts of nitrogen at the wrong time can have negative impacts on fruit quality by delaying maturity, or reducing firmness and color (Granatstein and Mullinix, 2008).

The increased availability of macro and micronutrients in the apple leaves was observed under inorganic orchards in survey trial and in recommended dose of fertilizers (T<sub>5</sub>) (Table 4.2.2 and 4.2.3) from second experiment. It might be due to application of direct inorganic sources of nutrients required by tree under inorganic orchards and in recommended dose of fertilizers (T<sub>5</sub>) held as control treatment, which are more readily available forms of N, P and K in synthetic fertilizers, which favoured yields, tree growth and leaf nutrient concentrations (Merwin and Stiles, 1994; Neilsen *et al.*, 1999).

Moreover, our results suggested that better mobility of artificial fertilizers under inorganic orchards and recommended dose of fertilizers (T<sub>5</sub>) in second trial provided higher macronutrient uptake than organic orchards, where only natural nutrient sources are allowed. This study also demonstrated that the lower nutrient content of soil and poor uptake pattern of N, P and K nutrients from organic apple orchards resulted in higher production risk in the organic cultivation compared with inorganic ones. This indicates that a more efficient nutrient supply is needed in the organic management system (Nagy *et al.*, 2013).

The micronutrients concentration exhibited a steady increase throughout the growing season, with their concentration being significantly higher in the leaves of the conventionally grown trees

in both the experiments (Table 4.1.18, 4.1.19, 4.1.20, 4.1.21, 4.2.3). Nutrients contained in organic manures are released slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect. Complementary use of organic manures and mineral fertilizers has proved to be a sound soil fertility management strategy in many countries of the world (Ayoola and Makinde, 2007). Also, this higher micronutrient concentration under inorganic management could be attributed to the application of the Zn-containing foliar fertilizer twice or thrice within the growing season and application of chelated foliar fertilizers. Peck *et al.*, (2006) who observed specific zinc-deficiency symptoms in the leaves of organic apple orchards but which were not found in present study.

## **5.2 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON FRUIT YIELD AND QUALITY PARAMETERS**

Fruit yield and quality parameters like fruit weight, firmness, TSS, titratable acidity, reducing sugars, total sugars, anthocyanins, phenols and antioxidants as affected by different plant nutrition sources under both experiments exhibited significant differences. The results revealed that fruit firmness, TSS, total sugars and reducing sugars were significantly higher under organic orchards (Table 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7) and with FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) (Table 4.2.5,4.2.6) from first and second experiments, respectively. Fruit weight and fruit quality depends on plant nutrition, which also remarkably influences postharvest quality.

The higher yield (Table 4.1.1) and fruit weight (Table 4.1.2) was observed under inorganic apple orchards from experiment first and T<sub>5</sub> treatment from experiment second (Table 4.2.4). A long term

trial in Europe comparing organic and conventional systems found that yield in the organic systems was 20% to 40% lower than in conventional systems (Mader *et al.*, 2002). Assessment of yield as affected by organic nutrient sources can be challenging because these sources are complex compounds with varying nutrient carrying capacity. The organic treatment showed lower response in comparison to conventional inorganic practices, it could have happened because the organic manures release nutrients slowly during the first year of application. Better supply of nutrients through inorganic fertilizers, along with organic manures are ascribed to conducive physical environment leading to higher nutrient absorption, from the native as well as applied sources. This favours highest nutrient uptake and ultimately resulted in higher yield, whereas, reverse is true with organic manures (Mujaffar 2011 and Babita 2011).

The results of present study are in line with Amarante *et al.*, (2008) who reported that 'Royal Gala' and 'Fuji' apples grown organically had lower average fruit weight, possibly due to smaller cells and less intercellular spaces, reflecting nutritional status of N, K, and plant physiology, leading to a higher fruit density. Denser fruit tend to have reduced air-filled spaces possibly associated with higher flesh firmness at harvest in organic apples of both cultivars. Nitrogen fertilization has been shown to result in a decrease in firmness of apples (Blanpied *et al.*, 1978). This undesirable decrease in firmness due to excess nitrogen fertilization is well documented in several crops (Reeve, 1970). Many research workers have reported that the increased yield in different fruit crops upto certain level of nitrogen and decrease there after (Ndang and Akali, 2008; Prasad, 2005; Singh and Singh, 2004).

The improvement in quality of fruits may be due to improvement of soil physical properties, such as porosity, water

holding capacity and decrease in bulk density, tendency of soil pH towards neutral and incremental growth of microbes like bacteria, fungi, actinomycetes in soil with the application of organic manures are well proved phenomenon. Bogs (2009) reported that organic production methods resulted in 'Braeburn' apples with higher soluble solid levels and a greater percentage of dry matter than those conventionally produced. Reig *et al.*, (2007) also found that organically grown apples were higher in soluble solids than conventionally grown. Different organic fertilizers were compared with chemical (NPK) fertilizers at various rates of application on orange trees (Tayeh 2003). The organic applications resulted in the best quality fruits with the highest fruit soluble solids and ascorbic acid content.

Athani and Hulamani (2000) also recorded highest TSS and total sugars content in vermicompost and *in situ* vermiculture plots of banana cv. Rajapuri (Musa AAB). In case of fruit acidity, it was observed that higher fruit acidity was recorded in organic fruits, which was in conformation with Wang *et al.*, (2008) who reported that citric acid was the major organic acid in blueberries, which was found to be maximum in organically treated plots of blueberries. Organically cultured fruits contained higher amounts of malic acid. The increase in carotenoid content might be attributed to increased chlorophyll content in leaves due to increased uptake for long time instead of short term gain of N by the addition of various organic components which have increased photosynthetic efficiency and translocation of nutrients and other metabolites towards the fruits (Childers, 1966).

### **5.2.1 Anthocyanins, Total Phenols and Antioxidants**

In present study significant increase in anthocyanins, phenols, and antioxidants content of fruits from organically managed trees

was observed in both the experiments. The results revealed that anthocyanins, total phenols and antioxidants were significantly higher under organic orchards (Table 4.1.8, 4.1.9, 4.1.10) and with FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment (Table 4.2.7) from first and second experiments, respectively. Similar results were observed on effect of farm management practices on fruit antioxidants, but it is known that ultraviolet radiation, pest and pathogen attacks induce the production of antioxidants in plants in terms of resistance towards it (Matsuki, 1996). Organic crops contain fewer nitrates, nitrites and pesticide residues but, as a rule, more dry matter, vitamin C, phenolic compounds, essential amino acids and total sugars than conventional crops. Organic crops also contain statistically more mineral compounds and usually have better sensory and long-term storage qualities.

According to Carbonaro and Mattera (2001), Young *et al.*, (2005) and Del Amor *et al.*, (2008) the higher phenol concentration in organically grown fruits is possibly attributed to severe biotic or abiotic stresses, which are known to induce phenolic biosynthesis. In many cases inconsistent influence of the farm management type on phenol concentration has been found, and the results have been unpredictable and for the most part, inconclusive (Young *et al.*, 2005; Zhao *et al.*, 2007). In any case, an accurate explanation on the effect of farm management on secondary metabolites is difficult, since there are a lot of difference and unrelated factors influencing their concentration. An increase in antioxidant activity and total phenols was reported for mandarin fruit produced by deficit irrigation treatments (Navarro *et al.*, 2010). The comparison between different environmental conditions suggests a possible relationship between drought conditions and total antioxidants and total phenols levels, which were higher in apricots (Leccese *et al.*,

2010).

Two major hypotheses explaining the possible increases in organic acids and polyphenols in organic versus conventional foods have been proposed. One hypothesis considers the impact of different fertilization practices on plant metabolism. In conventional management, synthetic fertilizers frequently make nitrogen more available for the plants for short period of time than do the organic fertilizers and may accelerate plant growth and development. Therefore, plant resources are allocated for growth purposes, resulting in a decrease in the production of plant secondary metabolites (compounds not essential to the life of the plant) such as organic acids, polyphenols, chlorophyll, antioxidants and different amino acids.

Since other factors have been shown to increase antioxidants, including lower crop loads (Stopar *et al.*, 2002), exposure of fruit to solar radiation (Reay and Lancaster, 2001) and increased soil organic matter from compost additions (Wang and Lin, 2003). Nevertheless, the less dense canopies of the smaller organically managed trees probably resulted in more exposure to ultraviolet radiation by fruits. Several authors have indicated that phenolic compounds contribute to plant resistance in either mechanical stress, such as wounds made by insects or lesions determined during harvest, or biological infections by fungi, bacteria and viruses (Lattanzio *et al.*, 1994). Therefore, the increase in polyphenol content observed in organic peaches and organic pears may support the hypothesis (Daniel *et al.*, 1999) of enrichment in plant defence mechanisms against infestations through an increase in endogenous polyphenols when external pesticides of common use in conventional management are not used in organic cultivation.

Among external factors, the use of pesticides and fertilizers

has been found to be responsible for a significant decrease in phenol content in apple fruits (Nicolas *et al.*, 1994). However greater firmness in organic apples after storage compared to conventional and/or integrated apple was reported by Weibel *et al.*, 2000; Reganold *et al.*, 2010.

### **5.3 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON STORAGE STUDIES OF APPLE FRUITS AT ROOM TEMPERATURE**

#### **5.3.1 Physiological Loss in Weight (PLW)**

The physiological weight loss in fruit depends on the structure of the skin and nature of waxes on the surface of the fruit (Veravrbeke *et al.*, 2003). The overall higher physiological weight loss (5.00 %) was recorded in inorganic and lower (4.70 %) in organic apple orchards fruits (Table 4.1.11 C) in first experiment. In second experiment, higher (9.31 %) and lower physiological weight loss (8.34%) was recorded in recommended dose of fertilizers (T<sub>5</sub>) and FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment at 60<sup>th</sup> day of storage interval (Table 4.2.8). The minimum physiological weight loss was recorded from organically treated fruits under both the experiments. The moisture loss decreases the visual quality and contributes to the loss of turgor pressure and subsequent softening. The per cent weight loss increased significantly with increase in storage duration. The highest increase was upto 9 % on 60<sup>th</sup> day of storage interval. The moisture and subsequent weight loss in fruits increased linearly with increase in storage duration due to water loss and respiration (Erturk, 2003; Ghafir *et al.*, 2009).

#### **5.3.2 Rotting percentage**

The data revealed that there was an overall increase in rotting percentage of apple fruits during storage. The overall effect of

locations (L), nutrient sources (S), and storage interval (I) on rotting of apple fruits increased from 7.73 to 33.34 per cent (Table 4.1.12 C) in first experiment and 9.14 to 52.66 in second experiment (Table 4.2.9). Further, while comparing the overall effect of nutrient sources (S) it was found that higher (16.53 %) rotting was observed under organic as compared to inorganic (14.23 %) apple orchards in first experiment. In the second experiment, lower (19.92 %) rotting was recorded under recommended dose of fertilizer (T<sub>5</sub>) which was statistically on par with FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) and maximum (25.48) under FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) (Table 4.2.9). On different interval days it was found that lower (9.14 %) was recorded at 15<sup>th</sup> day storage interval and higher (52.66 %) on 60<sup>th</sup> day of storage. The lowest rotting in inorganic orchards fruits may be due frequent sprays done during growing period to control pests and disease under conventional management system.

### **5.3.3 Fruit firmness**

Fruit firmness is an important criterion for edible quality and market value of apples (Stow *et al.*, 2000) and loss of fruit firmness is a serious problem resulting in quality losses (Kov *et al.*, 2005). The fruit firmness was highest (5.39 kg/cm<sup>2</sup>) from organic orchards and lower from inorganic (5.23 kg/cm<sup>2</sup>) apple orchard fruits (Table 4.1.13 C). In experiment, second highest fruit firmness (5.31 kg/cm<sup>2</sup>) was recorded in FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment while the least (5.07 kg/cm<sup>2</sup>) in FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment (Table 4.2.10). The fruit firmness significantly decreased with increase in storage duration. It decreased from maximum of 6.31 kg/cm<sup>2</sup> in fresh fruits to minimum

of 4.26 kg/cm<sup>2</sup> in fruits stored for 60 days under ambient storage temperature in first experiment. (Table 4.1.13 C).

The treatments of nutrient sources varied significantly in respect of firmness with organically managed fruits having maximum while inorganically managed had the minimum firmness. The firmness of the fruits depends on rate of evapotranspiration, respiration, resulting in loss of solutes and water (Erturk, 2003; Ghafir *et al.*, 2009). It is due to texture of the flesh and textural changes of fruits during ripening and storage due to breaking of primary cell wall and middle lamella structures (Jackman and Stanley, 1995). The post harvest softening of apple fruit is related to cell wall breakdown due to enzymatic activities and pectin solubilization (Bartley *et al.*, 1982), reducing the mechanical strength of cell walls, which decrease the firmness in apple fruits (Kov and Felf, 2003).

#### **5.3.4 Total soluble solids (TSS)**

Total soluble solids content of apple fruits is an important quality parameter. It increased gradually with increase in storage durations. The overall TSS contents were significantly higher (11.87<sup>0</sup>B) from organic and lower (11.80<sup>0</sup>B) from inorganic apple orchards in freshly harvested fruits from experiment first (Table 4.1.14 C). In the second experiment, higher total soluble solids (12.45<sup>0</sup>B) contents were recorded in FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment which was significantly higher than other treatments and lower (12.20<sup>0</sup>B) in FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment (Table 4.2.11). The total soluble solids increased during storage (Rivera, 2005). The increase in TSS could be attributed to the breakdown of starch into sugars (Crouch, 2003) or the hydrolysis

of cell wall polysaccharides (Ben and Gaweda, 1985). Similar results were reported by Peck *et al.*, (2009) who reported that fruits from organic production system had higher TSS and TSS: acid ratio than fruits from integrated fruit production system. Singh *et al.*, (2010) recorded higher TSS and ascorbic acid content with lower acidity from the strawberry fruits treated with vermicompost at 7.5 t ha<sup>-1</sup>. The better quality was attributed to better growth of plants, which might have favoured accumulation of higher sugars, less acidity and better ascorbic acid contents.

Excess nitrogen from inorganic fertilizers result in reduction of fruit flavor and biological value of proteins, as well as decreased resistance to pests and diseases (Chaboussou, 2004). Reganold *et al.*, (2010) reported that when strawberries were exposed to a two-day storage interval, the per cent loss in fresh weight was significantly less in the organic berries than in the conventional berries. These results indicated that the organic strawberries were having a longer shelf life than the conventional because of slower rotting and dehydration, due to augmentation of cuticle and epidermal cell walls.

#### **5.4 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON SOIL PROPERTIES**

Mineral fertilization provides readily available nutrients for plant growth; however, it does not contribute to improve soil physical conditions. Organic matter inputs through organic amendments improved soil aggregation and stimulate microbial diversity and activity in addition to supplying nutrients (Shiralipour *et al.*, 1992; Carpenter-Boggs *et al.*, 2000). Survey study showed significant differences on soil pH at different locations and between nutrition sources (Table 4.1. 24). However, second experiment gave no significant variations on soil pH (Table 4.2.12). Apart from soil

pH-lowering, mineralization that occurs upon addition of composted N-containing organic wastes to soil (Sikora and Yakovchenko, 1996) typically raise the pH of acid soils by complexing  $Al^+$  and increasing base saturation (Shiralipour *et al.*, 1992).

Saha *et al.*, (2010) recorded higher pH value from the use of farmyard manure compared to a control. The organic matter in the soil increased the buffering capacity of soil; hence, the soil pH is more or less stable. Despite their differences, the pH values of the soils under study were mostly within the acceptable range for apple production as suggested by Kanwar (1987). The organic fertilizer had a positive effect on soil as indicated by its corresponding higher pH levels. Continuous application of chemical fertilizers in apple orchards reduce the soil pH due to nitrification of the ammonium fertilizers or urea which results in increasing amounts of  $H^+$  ions in the soil (Ruth and Goh, 1992). Vance (1996) reported that the neutralizing capacity from hydroxides and carbonates of Ca, Mg and of K in wood ash is probably the most important effect in relation to soil amendment. Ohno (1992) studied the neutralizing capacity of wood ash in short-term laboratory incubations. He found that pH increases were higher for soils with low pH and low organic matter content after adding woodash. In addition to plant growth, metal ion solubility, microbial activity and clay dispersion are also influenced by soil pH (Haynes and Naidu, 1998).

Electrical conductivity was significantly higher from inorganic fertilizer applied orchards and treatments from both the experiments (Table 4.1.25 and 4.2.13) and it can be used as an indicator of the extended use of fertilizers in soil. An increase in the EC in conventionally managed soils could be due to the higher input of salts (in the forms of chemical fertilizers), which was further supported by the higher N, P, and K concentration in the conventionally managed orchard soil. However, under organic

management systems EC was found to be low and did not influence plant growth. These findings are in conformity with Srikanth *et al.*, (2000) and Usha *et al.*, (2004) who reported a decrease in electrical conductivity of soil with the application of vermicompost and FYM.

There was decreasing trend of soil bulk density and increasing maximum water holding capacity (MWHC) observed in both the experiments for organically managed orchards and organic treatments from both the experiments. However, minimum soil bulk density was noticed under organic apple orchards at both the locations in experiment first (Table 4.1.22, 4.1.23) and with application of FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in experiment second (Table 4.2.12). Soil organic matter has been considered to be greatly responsible directly or indirectly, for making the physical environment of soils favourable for growth of crops (Allison, 1973). Residual effect of organic manure on soil fertility is related with their ability to promote soil fertility.

Significantly higher organic carbon was recorded in organic orchards from experiment first (Table 4.1.26) and with FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the second experiment (Table 4.2.14). These results are in confirmation with the findings of Ghuman and Sur (2006) who reported increase in organic carbon in manured plots caused reduction in soil bulk density. Benbi and Saroa (2012) also reported a significant decrease in soil bulk density of organic manured fields. Decrease in soil bulk density may be attributed to better soil aggregation and aeration brought by organic amendments, which added various humic fraction (Kadalli *et al.*, 2000) and increased microbial and enzymatic activity by vermicompost (Mukherjee *et al.*, 2000).

The available N, P and K values in the conventionally managed soils were found to be higher than those in the organically managed soil due to the application of direct sources of mineral fertilizers (Table 4.1.27, 4.1.28, 4.1.29, 4.2.15). Numerous studies have shown a K deficiency in organic farms due to the lower input of nutrients (Gossling and Shepherd, 2005) but in present study these were in sufficiency range may be due to wood ash application as wood ash is essentially a direct source of major elements, notably P, Ca, Mg and especially K in soils (Unger and Fernandez, 1990; Meiwes, 1995; Williams *et al.*, 1996).

The concentrations of the soil available Fe, Mn, Cu and Zn extracted by the DTPA method are presented in Table 4.1.30, 4.1.31, 4.1.32, 4.1.33 and 4.2.16. The soils of the organically cultivated orchards exhibited significantly lower concentrations of Fe and Cu except Zn and Mn than those of the conventional orchards but were within sufficiency range. This may be due to application of various agrochemicals, such as pesticides (copper containing fungicides) and synthetic fertilizers (containing micronutrients), in the conventional orchards could account for the increased soil contents of these metals through soil application and may due to foliar application and foliar run off.

Nevertheless, the organic orchards showed higher values of Zn and Mn, respectively than the conventional orchards. Many studies have shown that organically managed soil with adequate levels of organic inputs have maximum soil micronutrient contents owing to the ability of the organic matters to increase the solubility of metals (Herencia *et al.*, 2008a; 2008b). Microbial decomposition of organic compounds creates reducing conditions and increase the solubility of some micronutrients, especially that of Mn (Herencia *et al.*, 2008a), accounting for its higher concentration in the organic orchards compared to the conventional ones.

Improvements in all of these soil quality indicators have been found to optimize crop growth (Karlen and Stott, 1994). Thus, one of the most significant benefits of manure as an organic nutrient source is its potential to maintain or raise soil organic matter levels.

#### **5.4.1 Total Microbial Counts (TMC)**

Total microbial counts were found to be significantly higher under organic orchards of both the locations in experiment first (Table 4.1.34) and with FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] (T<sub>4</sub>) treatment of second experiment (Table 4.2.14). The soil biological properties analyzed in this study showed that the conventional management system could not affect soil microbial activity as compared to organic apple orchard management system. The organically managed soils exhibited greater microbiological activity than the conventionally managed soils. Dick (1992), in a review, noted that there is generally a positive relationship between soil organic carbon content and soil microbial biomass. He concluded that any practice that increases the amount of organic residues in the soil increases biological activity.

Power and Doran (1984) obtained similar results and recorded higher organic matter contents, N mineralization potential, and microbial biomass in organically farmed plots than in those receiving commercial fertilizers. In a comparison of five certified organic and conventional farm pairs, Liebig and Doran (1999) found greater total C and N, microbial biomass, soil respiration, and mineralizable N in organically managed farms than in conventional farms. It is also clear that organic manures, when applied at the same nutrient doses, will have a larger effect, relative to fertilizers, on soil biological activity. Microbial biomass and labile organic matter pools are often greater in organic than conventionally

managed soils.

Soil organic matter gets degraded with the increased population of soil microorganisms through the production of diverse extracellular enzymes, with application of vermicompost to the soil (Tejada and Gonzalez, 2008). Arancon *et al.*, (2006) observed an increase in enzymatic activities after the addition of different vermicomposts to soil. Archana (2008) reported that higher dose of vermicompost at 20 kg tree<sup>-1</sup> resulted in an increase in microbial population (*Azotobacter*, *Pseudomonas*, fungi, Actinomycetes and AM fungi) in plum rhizosphere. This increase was attributed to the vermicompost containing higher amount of growth promoting substances, vitamins and enzymes which in turn, increased the microbial population and resulted in higher production of root exudates increasing the beneficial bacteria, fungi and actinomycetes population in rhizosphere region (Masciandaro *et al.*, 1997).

## Chapter - 6

### Summary and Conclusion

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The present investigations entitled “Studies on organic nutrition in apple (*Malus × domestica* Borkh.)” were carried out at Theog and Rohru in the Shimla district of Himachal Pradesh, during the years 2011 - 2012.

The study was aimed to evaluate the effect of organic manures and chemical fertilizers on tree growth, fruit quality, yield and physico-chemical properties of soil in apple orchards. Simultaneously, two experiments were conducted at two different locations. In the first experiment survey study was carried out on organic and inorganic apple orchards of Theog and Rohru. Accordingly, total twenty-four orchards were selected with twelve each at one location from which six were organic and other six were inorganic apple orchards. These selected orchards were adjacent to each other to reduce microclimatic effect and variation in sites. Similarly, second experiment was carried out at farmer’s field by applying five treatments out of which four treatments consisted of different concentrations of organic components (FYM, vermicompost, Wood ash and Neem cake) after calculating the recommended nutrition dose of fully grown apple tree (700:350:700 g NPK tree) and one treatment was recommended dose of fertilizers (RDF) considered as control. The organic orchards and organic manures treatment combinations were compared with inorganic orchards and sole application of 100 per cent recommended dose (RD) of chemical fertilizers in first and second experiments, respectively. The experimental soil pH, EC was in safe limits (less than 0.8 dSm<sup>-1</sup>) with medium organic carbon and lower bulk density (1.25 Mg/m<sup>3</sup>). Available N, P and K were medium, high and medium, respectively. Available secondary and micronutrient

elements were also available in adequate amount. Salient findings emerged from the present studies are summarized as under:

## **6.1 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON PLANT GROWTH AND FLOWERING PARAMETERS**

**6.1.1** Trunk girth was not affected significantly by different nutrition sources. However, maximum (57.77 cm) trunk girth was recorded with recommended dose of fertilizers (T<sub>5</sub>) and minimum (56.27 cm) in FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment.

**6.1.2** Longer flowering duration (13.40 days) and higher fruit set (16.60 %) was recorded in recommended dose of fertilizers (T<sub>5</sub>). Shorter flowering duration of 11.80 days and lower 13.80 per cent fruit set in T<sub>1</sub> [FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment, respectively.

Different sources of plant nutrition under organic and inorganic apple orchards from first experiment and organic manure treatments applied against RDF as control in the second experiment exhibited significant variations on leaf N, P, K and micronutrients content, during both the years of study.

**6.1.3** Higher leaf N 2.69 % and 2.25 % contents were recorded from inorganic apple orchards from Theog-1 in first experiment and in recommended dose of fertilizers (T<sub>5</sub>) from second experiment, respectively.

**6.1.4** Higher leaf P 0.29 % and 0.27 % contents were recorded from inorganic apple orchards of Theog-1 in the first experiment and in recommended dose of fertilizers (T<sub>5</sub>) in the second experiment, respectively.

**6.1.5** Higher leaf K 1.57 % and 1.72 % contents were

recorded in inorganic apple orchards of Rohru-2 in the first experiment and in recommended dose of fertilizers (T<sub>5</sub>) in the second experiment, respectively.

**6.1.6** There were non-significant variations among interactions in experiment first. Maximum contents of leaf Zn, Fe, and Cu were recorded in inorganic orchards of Theog-1 where as maximum leaf Mn content was recorded in organic orchards of Theog-1 from first experiment. However, in the second experiment there were non-significant variations in leaf micronutrient contents during both the years of study.

## **6.2 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON FRUIT YIELD AND QUALITY PARAMETERS**

Fruit quality parameters like fruit weight, firmness, TSS, titratable acidity, reducing sugars, total sugars, anthocyanins, phenols and antioxidants were significantly influenced by different nutrition sources.

**6.2.1** Highest fruit yield 63.70 and 48.53 kg/tree was recorded in inorganic apple orchards of Theog-1 in the first experiment and in recommended dose of fertilizers (T<sub>5</sub>) of the second experiment, respectively.

**6.2.2** Among interactions of first experiment maximum fruit weight 161.31 g and minimum 135.17 g was recorded in Theog-1 inorganic and Rohru-1 organic apple orchards, respectively. While, in second experiment highest (159.05 g) fruit weight was recorded with recommended dose of fertilizers (T<sub>5</sub>) and lowest (140.71 g) with T<sub>1</sub> [FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree)] treatment.

**6.2.3** Fruit firmness, TSS, titratable acidity, reducing sugars, total sugars, anthocyanins, phenols and antioxidants were found to be significantly higher in the organic orchards, irrespective of locations

from first experiment and in trees applied with FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the second experiment.

### **6.3 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON STORAGE OF APPLE FRUITS AT AMBIENT TEMPERATURE**

Significant differences were observed on Physiological loss in weight (PLW), Rotting percentage, Fruit firmness and Total soluble solids (TSS) of apple fruits stored for 60 days in both the experiments.

**6.3.1** Higher PLW (4.70 and 6.32 %) was recorded in inorganic apple orchards of Rohru-2 from first experiment and in recommended dose of fertilizers (T<sub>5</sub>) treatment in the second experiment, respectively.

**6.3.2** Higher rotting (16.53 and 25.48 %) was recorded in organic apple orchards of Rohru-1 in the first experiment and in FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment in the second experiment, respectively.

**6.3.3** Higher fruit firmness (5.39 and 5.31 kg/cm<sup>2</sup>) was recorded under organic apple orchards of Rohru-1 in the first experiment and in FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the second experiment, respectively.

**6.3.4** Higher TSS (11.87 and 11.94<sup>0</sup>B) contents were recorded in fruits from Theog-1 organic apple orchards in the first experiment and in FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the second experiment, respectively.

## **6.4 EFFECT OF DIFFERENT SOURCES OF ORGANIC NUTRITION ON SOIL PROPERTIES**

### **6.4.1 Physical properties**

**6.4.1.1** The maximum water holding capacity (MWHC) (52.36 and 53.21 %) was recorded in Theog-1 organic orchards and with FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment from first and second experiments, respectively. The lowest (43.80 and 47.95 %) was obtained in Rohru-1 inorganic orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) in the first and second experiments, respectively.

**6.4.1.2** Minimum soil bulk density was recorded from Theog-1 organic orchards (1.27 g/cc) and (1.17 g/cc) in FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the first and second experiments, respectively. Maximum was under Rohru-2 inorganic orchards (1.40 g/cc) and with recommended dose of fertilizers (T<sub>5</sub>) (1.21 g/cc) treatment in the first and second experiments, respectively.

### **6.4.2 Chemical properties**

**6.4.2.1** Higher (5.91 and 6.01) average soil pH was recorded in Theog-2 organic apple orchards and with FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment from first and second experiments, respectively. However, minimum (5.44 and 5.83) was obtained in Rohru-1 inorganic apple orchards and with application of recommended dose of fertilizers (T<sub>5</sub>) treatment in the first and second experiments, respectively.

**6.4.2.2** Higher soil electrical conductivity was recorded from Rohru-1 inorganic apple orchards (0.50 dSm<sup>-1</sup>) and with recommended dose of fertilizers (T<sub>5</sub>) treatment (0.45 dSm<sup>-1</sup>) in the

first and second experiments, respectively. Lower (0.32 and 0.29  $\text{dSm}^{-1}$ ) obtained in Theog-2 organic apple orchards and in FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) ( $T_1$ ) in the first and second experiments, respectively.

**6.4.2.3** Higher organic carbon (2.15 and 2.05 %) contents were recorded in Theog-2 organic apple orchards and in FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) ( $T_4$ ) treatment in the first and second experiments, respectively. While, lower (1.56 and 1.82) obtained in Rohru-2 organic apple orchards and in FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) ( $T_1$ ) from first and second experiments, respectively

**6.4.2.4** The highest available N contents were recorded in Theog-1 inorganic (397.08 kg/ha) apple orchards and with recommended dose of fertilizers (355.70 kg/ha) ( $T_5$ ) treatment in the first and second experiments, respectively. Lowest available N contents (264.37 and 271.90 kg/ha) were recorded in Rohru-2 organic orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) ( $T_1$ ) treatment in the first and second experiments, respectively.

**6.4.2.5** The highest available P (42.01 and 31.11 kg/ha) contents were recorded in Theog-1 inorganic apple orchards and with recommended dose of fertilizers ( $T_5$ ) treatment in the first and second experiments, respectively. Lowest available P (24.88 and 22.49 kg/ha) contents were recorded in Rohru-2 organic apple orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) ( $T_1$ ) treatment in the first and second experiments, respectively.

**6.4.2.6** The highest available K (332.46 and 240.30 kg/ha) contents were recorded in Rohru-1 inorganic orchards and with recommended dose of fertilizers ( $T_5$ ) treatment in the first and

second experiments, respectively. The lowest K (237.73 and 205.00 kg/ha) contents were recorded in Theog-1 organic orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment in the first and second experiments, respectively.

**6.4.2.7** Maximum available zinc content (3.99 and 3.86 mg kg<sup>-1</sup>) was recorded in Theog-1 inorganic apple orchards and with FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) and recommended dose of fertilizers (T<sub>5</sub>) treatments in the first and second experiments, respectively. Minimum (3.62 and 3.63 mg kg<sup>-1</sup>) was recorded in Rohru-2 organic apple orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment in the first and second experiments, respectively.

**6.4.2.8** Maximum available iron (58.90 and 38.20 mg kg<sup>-1</sup>) contents were registered in Theog-2 inorganic apple orchards and with recommended dose of fertilizers (T<sub>5</sub>) treatment in the first and second experiments, respectively. Minimum (25.74 and 27.80 mg kg<sup>-1</sup>) was recorded at Rohru-2 organic apple orchards and with FYM (40 kg/tree) + Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment from first and second experiments, respectively.

**6.4.2.9** Maximum available copper contents (4.62 and 4.41 mg kg<sup>-1</sup>) were recorded in Theog-1 inorganic apple orchards and with recommended dose of fertilizers (T<sub>5</sub>) treatment in the first and second experiments, respectively. Minimum (3.86 and 4.26 mg kg<sup>-1</sup>) was recorded in Rohru-2 organic apple orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment in the first and second experiments, respectively.

**6.4.2.10** The highest available manganese (23.90 and 13.80

mg kg<sup>-1</sup>) contents were recorded in Theog-1 organic apple orchards and with FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the first and second experiments, respectively. The lowest (14.10 and 11.60 mg kg<sup>-1</sup>) content was recorded in Theog-2 organic apple orchards and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment in the first and second experiments, respectively.

#### **6.4.3 Microbiological properties**

**6.4.3.1** Significantly higher total microbial counts (149.93 and 113.10 cfu/g soil) were recorded in Theog-1 organic apple orchards in the first experiment and in FYM (100 kg/tree) +Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree) (T<sub>4</sub>) treatment in the second experiment. While, the lowest (92.60 and 94.60cfu/g soil) counts were recorded in Theog-2 inorganic and with FYM (40 kg/tree) +Vermicompost (10 kg/tree) + Wood ash (2 kg/tree) + Neem cake (4 kg/tree) (T<sub>1</sub>) treatment in the first and second experiments, respectively

Survey study showed significant differences between fruit quality parameters, plant and soil health at different locations and sources of plant nutrition used in apple orchards. In second experiment comparison of different sources of plant nutrition in apple production showed that T<sub>4</sub> treatment [FYM 100 Kg/tree +Vermicompost 25 Kg/tree + Wood ash 8 Kg/tree + Neem cake 4 Kg/tree] was found to be most effective for producing better fruit quality i.e. TSS, fruit firmness, total sugars, reducing sugars, titratable acidity and secondary metabolites such as anthocyanins, phenols and antioxidants as well as increased physico-chemical and biological properties of soil (bulk density, pH, MWHC, organic carbon, and total microbial counts). . However, higher yield, leaf and soil nutrients status were observed under inorganic orchards and

recommended dose of fertilizers during both the years of study. Therefore, it can be concluded that the use of organic manures might be useful as supplement to inorganic fertilizers and helpful in improving fruit quality and enhancing soil health with respect to physico-chemical and biological properties of the soil.

## Chapter - 7

### References

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**Department of Fruit Science**

<b>Title of Thesis</b>	:	<b>“Study of organic nutrition in apple (<i>Malus × domestica</i> Borkh.)”</b>
<b>Name of the Student</b>	:	Ghumare Vikas Shivajirao
<b>Admission Number</b>	:	H-09-11-D
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<b>Major Field</b>	:	Fruit Science
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**ABSTRACT**

The present investigations entitled “Study of organic nutrition in apple (*Malus x domestica* Borkh.)” were conducted on farmers field at Theog and Rohru in Shimla district of Himachal Pradesh, during the years 2011 - 2012. Fifteen years old apple trees of cultivar Starking Delicious grown on seedling rootstock were selected on the basis of uniform vigour. The trees were planted at a spacing of 6 x 6 m and trained on modified central leader training system. The study was split into two experiments with an objective to elucidate the effect of comparison of organic and inorganic plant nutrition on fruit quality parameters, leaf and soil nutrient status in apple orchards. The first experiment was survey work of organic and inorganic apple orchards, which were statistically analyzed on two-way analysis of data to study the effect of locations and nutrition sources. The second field trial was conducted to find out the nutrition requirement of fully grown apple trees through organic manures viz. FYM, vermicompost, wood ash and neemcake in comparison to recommended dose of fertilizer (RDF) held as control. Data was statistically analyzed using randomized block design (RBD) with five replications in each treatment. The variations in vegetative characteristics, fruit parameters, and leaf and soil nutrient status were studied. From first experiment, organic apple orchards and T<sub>4</sub> [FYM (100 kg/tree) + Vermicompost (25 kg/tree) + Wood ash (8 kg/tree) + Neem cake (4 kg/tree)] treatment in second experiment gave 43 and 21 per cent reduction in yield compared to inorganic orchards and recommended dose of fertilizers, respectively. However, organic orchards and T<sub>4</sub> treatment was most effective for producing better fruit quality in terms of TSS, fruit firmness, total sugars, reducing sugars, titratable acidity and secondary metabolites such as anthocyanins, phenols and antioxidants. In addition, significant improvements in soil physical (bulk density, soil pH, MWHC, organic carbon) and biological properties (total microbial counts) were also recorded. However, higher yield, leaf and soil nutrients status were observed under inorganic orchards and recommended dose of fertilizers during both the years of study. Therefore, it can be concluded that the use of organic manures might be useful as supplement to inorganic fertilizers and helpful in improving fruit quality and enhancing soil health with respect to physico-chemical and biological properties of the soil.

**Signature of the Major Advisor**

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## APPENDIX-I

### ANALYSIS OF VARIANCE FOR EXPERIMENT I AND II DURING THE YEARS 2011-12

#### ANOVA for experiment I- SURVEY OF ORGANIC AND ANOVA of fruit yield and quality parameters for the year 2011

Source of variation	df	Mean sum of squares				
		Fruit yield (kg/tree)	Fruit weight (g)	Fruit firmness (kg/Sq. inch)	TSS ( <sup>o</sup> B)	Titration acidity (%)
Replication	4	83.62	18.50	0.011	0.024	0.0005
Location	3	100.51	102.91	0.007	0.011	0.0024
Sources	1	5046.54	3135.38	0.100	0.077	0.0212
Location X Sources	3	32.35	161.96	0.004	0.003	0.0003
Error	28	46.28	68.56	0.004	0.023	0.0021

#### ANOVA of fruit yield and quality parameters for the year 2012

Source of variation	df	Mean sum of squares				
		Fruit yield (kg/tree)	Fruit weight (g)	Fruit firmness (kg/Sq.inch)	TSS ( <sup>o</sup> B)	Titration acidity (%)
Replication	4	101.40	9.95	0.007	0.003	0.0016
Location	3	88.60	41.09	0.008	0.008	0.0005
Sources	1	5022.53	1871.01	0.138	0.105	0.0140
Location X Sources	3	32.96	9.65	0.005	0.003	0.0003
Error	28	41.11	80.76	0.006	0.019	0.0010

**ANOVA of fruit yield and quality parameters for the pooled data**

Source of variation	df	Mean sum of squares				
		Fruit yield (kg/tree)	Fruit weight (g)	Fruit firmness (kg/Sq. inch)	TSS (°B)	Titrate acidity (%)
Replication	4	79.21	10.39	0.007	0.008	0.0008
Location	3	83.31	67.60	0.007	0.017	0.0012
Sources	1	5034.53	2462.62	0.118	0.122	0.0174
Location X Sources	3	32.64	62.53	0.004	0.004	0.0002
Error	28	36.99	67.16	0.004	0.016	0.0013

**ANOVA of fruit quality parameters for the year 2011**

Source of variation	df	Mean sum of squares				
		Reducing sugar (%)	Total sugar (%)	Anthocynins (mg/100g)	Phenols (mg/100g)	Antioxidants (mg/100g)
Replication	4	0.130	0.125	2.08	25.25	26.29
Location	3	0.047	0.039	32.16	70.60	62.47
Sources	1	0.371	0.645	70.46	460.57	496.74
Location X Sources	3	0.006	0.033	13.62	29.01	27.61
Error	28	0.087	0.123	3.60	19.53	8.97

**ANOVA of fruit quality parameters for the year 2012**

Source of variation	df	Mean sum of squares				
		Reducing sugar (%)	Total sugar (%)	Anthocynins (mg/100g)	Phenols (mg/100g)	Antioxidants (mg/100g)
Replication	4	0.201	0.066	18.08	30.14	12.38
Location	3	0.020	0.089	35.48	67.99	36.69
Sources	1	0.281	0.400	185.81	299.21	468.78
Location X Sources	3	0.012	0.029	17.57	23.21	26.52
Error	28	0.046	0.091	3.77	16.48	7.19

**ANOVA of fruit quality parameters for the pooled data**

Source of variation	df	Mean sum of squares				
		Reducing sugar (%)	Total sugar (%)	Anthocynins (mg/100g)	Phenols (mg/100g)	Antioxidants (%)
Replication	4	0.135	0.044	6.10	12.27	17.28
Location	3	0.032	0.058	33.14	68.80	47.71
Sources	1	0.324	0.515	121.28	375.55	482.66
Location X Sources	3	0.006	0.028	15.51	25.38	26.87
Error	28	0.044	0.078	2.06	6.84	6.88

**ANOVA of Leaf nutrient contents for the year 2011**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	0.0039	0.0014	0.012	6.42	51.83	4.35	74.47
Location	3	0.0909	0.0033	0.031	757.24	281.55	13.59	4166.33
Sources	1	1.5245	0.0593	0.344	321.60	1315.38	65.74	509.87
Location X Sources	3	0.0241	0.0006	0.022	17.79	6.04	0.95	220.13
Error	28	0.0066	0.0011	0.007	12.92	64.24	3.12	26.64

**ANOVA of Leaf nutrient contents for the year 2012**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	0.0071	0.0003	0.004	4.92	84.42	0.98	47.13
Location	3	0.0731	0.0017	0.018	748.78	194.00	10.51	3266.40
Sources	1	1.6000	0.0462	0.363	253.71	872.17	73.50	612.66
Location X Sources	3	0.0291	0.0010	0.017	22.00	17.06	0.39	180.08
Error	28	0.0081	0.0003	0.005	11.52	63.27	3.37	31.64

**ANOVA of Leaf nutrient content for the pooled data**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	0.0038	0.0004	0.007	4.21	48.01	2.29	34.22
Location	3	0.0815	0.0024	0.024	747.72	228.46	11.95	3698.53
Sources	1	1.5620	0.0526	0.353	286.65	1082.43	69.56	560.08
Location X Sources	3	0.0265	0.0006	0.019	18.78	8.54	0.48	190.97
Error	28	0.0035	0.0004	0.004	5.52	31.93	1.35	19.01

**ANOVA for soil physico-chemical properties for the year 2011**

Source of variation	df	Mean sum of squares					
		BD	MWHC	pH	EC	OC	TMC
Replication	4	0.006	17.67	0.013	0.005	0.012	145.88
Location	3	0.012	36.29	0.365	0.020	0.209	1605.12
Sources	1	0.024	174.52	0.216	0.054	0.710	6978.31
Location X Sources	3	0.002	0.63	0.031	0.001	0.004	314.38
Error	28	0.004	8.44	0.010	0.002	0.008	106.52

**ANOVA for soil Physico-chemical properties for the year 2012**

Source of variation	df	Mean sum of squares					
		BD	MWHC	pH	EC	OC	TMC
Replication	4	0.003	4.69	0.028	0.000	0.004	199.91
Location	3	0.011	29.60	0.248	0.009	0.208	1416.57
Sources	1	0.027	169.66	0.320	0.077	0.744	7840.00
Location X Sources	3	0.001	0.89	0.051	0.003	0.005	1082.07
Error	28	0.003	6.15	0.014	0.001	0.015	119.16

**ANOVA of soil physico-chemical properties from pooled data**

Source of variation	df	Mean sum of squares					
		BD	MWHC	pH	EC	OC	TMC
Replication	4	0.004	2.44	0.018	0.001	0.003	107.97
Location	3	0.012	32.86	0.296	0.014	0.208	1482.06
Sources	1	0.025	172.08	0.266	0.065	0.727	7402.89
Location X Sources	3	0.001	0.62	0.039	0.001	0.003	639.54
Error	28	0.002	8.06	0.008	0.001	0.004	68.22

**ANOVA for available nutrients content for the year 2011**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	73.84	24.29	27.83	0.02	9.49	0.04	24.89
Location	3	3403.22	98.65	8997.01	0.19	1593.00	0.39	60.46
Sources	1	94075.45	600.39	10703.0 4	0.09	289.66	0.74	52.95
Location X Sources	3	755.35	65.49	391.29	0.02	28.59	0.10	38.94
Error	28	221.74	5.89	123.92	0.02	11.39	0.04	11.07

**ANOVA for available nutrients content for the year 2012**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	146.83	28.27	147.39	0.02	12.88	0.11	13.77
Location	3	2570.28	91.44	10047.33	0.16	1645.17	0.29	54.06
Sources	1	104503.60	462.74	9899.83	0.08	214.37	1.15	36.14
Location X Sources	3	422.51	83.17	654.27	0.01	31.05	0.03	38.77
Error	28	138.03	9.51	184.22	0.01	16.87	0.05	6.92

**ANOVA for available nutrients content for pooled data**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	30.48	23.70	33.28	0.02	7.00	0.05	2.66
Location	3	2956.01	93.07	9511.70	0.18	1618.53	0.32	56.88
Sources	1	99221.02	529.33	10297.52	0.08	250.60	0.93	44.14
Location X Sources	3	556.31	73.40	501.17	0.01	29.21	0.06	38.60
Error	28	99.79	2.82	80.33	0.01	7.01	0.02	4.23

**ANOVA for storage study on fruit quality parameters for the year 2011**

Source of variation	df	Mean sum of squares			
		PLW (%)	Rotting (%)	Fruit firmness (kg/Sq. inch)	TSS (°B)
Replication	4	0.04	3.70	0.01	0.00
Location (L)	1	0.21	15.37	0.78	0.08
Sources (S)	1	0.56	110.67	0.58	0.09
Interval (I)	4	141.79	2976.26	10.80	34.47
LxS	1	0.08	15.05	0.23	0.01
S x I	4	0.08	67.01	0.06	0.01
L x I	4	0.09	8.85	0.11	0.01
L x S x I	4	0.17	2.45	0.03	0.00
ERROR	76	0.05	3.86	0.00	0.00

**ANOVA for storage study on fruit quality parameters for the year 2012**

Source of variation	df	Mean sum of squares			
		PLW (%)	Rotting (%)	Fruit firmness (kg/Sq. inch)	TSS (°B)
Replication	4	0.19	1.79	0.01	0.01
Location (L)	1	0.99	42.19	0.93	0.13
Sources (S)	1	1.42	90.16	0.71	0.11
Interval (I)	4	136.24	2460.50	11.59	34.62
L x S	1	0.09	13.65	0.09	0.00
S x I	4	0.24	36.51	0.10	0.01
L x I	4	0.45	2.82	0.16	0.02
L x S x I	4	0.57	4.68	0.09	0.01
ERROR	76	0.20	3.46	0.01	0.00

**ANOVA for storage study on fruit quality parameters for pooled data**

Source of variation	df	Mean sum of squares			
		PLW (%)	Rotting (%)	Fruit firmness (kg/Sq. inch)	TSS (°B)
Replication	4	0.09	1.07	0.00	0.00
Location (L)	1	0.53	27.12	0.85	0.10
Sources (S)	1	0.94	100.15	0.64	0.10
Interval (I)	4	138.86	2709.72	11.19	34.54
L x S	1	0.00	14.35	0.15	0.00
S x I	4	0.11	48.20	0.07	0.00
L x I	4	0.20	3.29	0.13	0.01
L x S x I	4	0.33	2.21	0.05	0.00
ERROR	76	0.09	1.64	0.00	0.00

**ANOVA for experiment I- Effect of organic sources of nutrients on apple production**

**ANOVA for Plant growth parameters for the year 2011**

Source of variation	df	Mean sum of squares			
		Trunk Girth (cm)	Duration of flowering	Per cent fruit set	Fruit yield (kg/plant)
Replication	4	22.38	0.44	4.54	23.16
Treatment	4	1.41	1.54	5.34	465.66
ERROR	16	15.52	2.64	4.94	12.28

**ANOVA of Plant growth parameters for the year 2012**

Source of variation	df	Mean sum of squares			
		Trunk Girth (cm)	Duration of flowering	Per cent fruit set	Fruit yield (kg/plant)
Replication	4	27.55	4.66	18.66	21.76
Treatment	4	2.97	2.16	7.06	116.06
ERROR	16	16.51	2.71	6.91	6.81

**ANOVA of Plant growth parameters pooled data**

Source of variation	df	Mean sum of squares			
		Trunk Girth (cm)	Duration of flowering	Per cent fruit set	Fruit yield (kg/plant)
Replication	4	7.48	1.92	6.32	10.26
Treatment	4	2.10	1.79	6.16	256.76
ERROR	16	8.78	1.38	2.85	6.00

**ANOVA of fruit quality parameters for the year 2011**

Source of variation	df	Mean sum of squares			
		Fruit weight (g)	Fruit firmness (kg/Sq.inch)	TSS (°B)	Titration acidity (%)
Replication	4	47.66	0.012	0.016	0.0008
Treatment	4	255.86	0.039	0.129	0.0022
ERROR	16	45.99	0.013	0.032	0.0004

**ANOVA of fruit quality parameters for the year 2011**

Source of variation	df	Mean sum of squares				
		Reducing sugar (%)	Total sugar (%)	Anthocynins (mg/100g)	Phenols (mg/100g)	Antioxidants (%)
Replication	4	0.0039	0.0047	0.734	10.56	0.960
Treatment	4	0.0250	0.0646	9.573	33.50	23.060
ERROR	16	0.0026	0.0161	1.541	10.01	8.760

**ANOVA of fruit quality parameters for the year 2012**

Source of variation	df	Mean sum of squares			
		Fruit weight (g)	Fruit firmness (kg/Sq.inch)	TSS (°B)	Titration acidity (%)
Replication	4	17.66	0.009	0.002	0.0004
Treatment	4	257.66	0.070	0.133	0.0030
ERROR	16	56.06	0.021	0.031	0.0009

**ANOVA of fruit quality parameters for the year 2012**

Source of variation	df	Mean sum of squares				
		Reducing sugar (%)	Total sugar (%)	Anthocynins (mg/100g)	Phenols (mg/100g)	Antioxidants (mg/100g)
Replication	4	0.0038	0.0163	0.702	1.35	2.760
Treatment	4	0.0368	0.1042	16.135	33.59	31.760
ERROR	16	0.0034	0.0187	2.007	10.59	5.635

**ANOVA of fruit quality parameters for the pooled data**

Source of variation	df	Mean sum of squares			
		Fruit weight (g)	Fruit firmness (kg/Sq.inch)	TSS (°B)	Titration acidity (%)
Replication	4	27.48	0.010	0.003	0.0005
Treatment	4	256.40	0.053	0.131	0.0002
ERROR	16	46.91	0.010	0.028	0.0003

**ANOVA of fruit quality parameters for the pooled data**

Source of variation	df	Mean sum of squares				
		Reducing sugar (%)	Total sugar (%)	Anthocynins (mg/100g)	Phenols (mg/100g)	Antioxidants (mg/100g)
Replication	4	0.0038	0.0039	0.493	4.113	0.950
Treatment	4	0.0304	0.0831	12.478	33.506	26.775
ERROR	16	0.0016	0.0054	1.351	5.846	4.725

**ANOVA for leaf nutrient contents for the year 2011**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	0.001	0.000	0.001	6.55	241.64	9.98	4.37
Treatment	4	0.027	0.003	0.088	3.74	21.33	2.00	2.86
ERROR	16	0.000	0.000	0.006	5.02	126.50	4.31	4.55

**ANOVA for leaf nutrient contents for the year 2012**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	0.001	0.000	0.003	18.52	16.3	6.38	1.91
Treatment	4	0.021	0.005	0.093	8.21	29.6	7.34	5.65
ERROR	16	0.001	0.000	0.014	4.81	12.8	3.82	2.13

**ANOVA of leaf nutrient content from pooled data**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	0.001	0.000	0.001	5.67	70.28	4.80	2.48
Treatment	4	0.024	0.004	0.090	5.52	21.80	4.17	4.03
ERROR	16	0.000	0.000	0.006	2.31	50.57	2.10	2.10

**ANOVA of available nutrient contents for the year 2011**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	98.74	2.573	246.34	0.0005	9.96	0.0008	1.700
Treatment	4	5366.84	52.506	838.54	0.0463	94.46	0.0197	5.700
ERROR	16	106.02	2.488	88.19	0.0012	9.48	0.0015	1.025

**ANOVA of soil parameters for the year 2011**

Source of variation	df	Mean sum of squares					
		BD	MWHC	pH	EC	OC	TMC
Replication	4	0.0006	22.201	0.0406	0.0017	0.0071	27.94
Treatment	4	0.0009	18.505	0.0233	0.0185	0.0383	235.24
ERROR	16	0.0001	5.871	0.0273	0.0009	0.0022	34.64

**ANOVA of available nutrient contents for the year 2012**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	64.76	4.739	106.24	0.0060	12.70	0.0023	2.200
Treatment	4	5842.56	69.485	1176.34	0.0528	110.20	0.0207	4.100
ERROR	16	71.26	3.298	93.31	0.0030	11.15	0.0022	1.175

**ANOVA of soil properties for the year 2012**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	64.76	4.739	106.24	0.0060	12.70	0.0023	2.200
Treatment	4	5842.56	69.485	1176.34	0.0528	110.20	0.0207	4.100
ERROR	16	71.26	3.298	93.31	0.0030	11.15	0.0022	1.175

**ANOVA for available nutrient contents for pooled data**

Source of variation	df	Mean sum of squares						
		N	P	K	Zn	Fe	Cu	Mn
Replication	4	49.19	2.961	145.40	0.0020	10.24	0.0008	1.0250
Treatment	4	5599.26	60.639	997.72	0.0494	102.04	0.0202	4.8500
ERROR	16	60.95	1.417	69.06	0.0009	5.91	0.0012	0.6250

**ANOVA for storage study parameters for the year 2011**

Source of variation	df	Mean sum of squares			
		PLW (%)	Rotting (%)	Fruit firmness (kg/Sq. inch)	TSS (°B)
Replication	4	2.6141	11.68	0.0432	0.0257
Trss	24	15.3467	1854.37	3.3596	6.1722
Tss	4	1.0732	149.13	0.2658	0.1742
Interval (T)	4	90.1190	10860.13	19.7273	36.8322
TxI	16	0.2220	29.24	0.0411	0.0067
ERROR	96	0.4726	9.76	0.0216	0.0038

**ANOVA for storage study parameters for the year 2012**

Source of variation	df	Mean sum of squares			
		PLW (%)	Rotting (%)	Fruit firmness (kg/Sq. inch)	TSS (°B)
Replication	4	0.3662	28.97	0.0336	0.0144
Trss	24	52.4604	1729.67	3.2485	6.3218
Tss	4	1.2786	160.85	0.2294	0.2018
Interval (T)	4	312.5213	10082.77	19.0638	37.6862
TxI	16	0.2406	33.59	0.0495	0.0107
ERROR	96	0.0602	13.21	0.0235	0.0048

**ANOVA for storage study parameters for pooled data**

Source of variation	df	Mean sum of squares			
		PLW (%)	Rotting (%)	Fruit firmness (kg/Sq. inch)	TSS (°B)
Replication	4	0.949	17.27	0.0171	0.0139
Trss	24	31.046	1790.47	3.3013	6.2460
Tss	4	1.170	153.94	0.2437	0.1877
Interval (T)	4	184.203	10467.55	19.3922	37.2557
TxI	16	0.226	30.34	0.0430	0.0081
ERROR	96	0.139	6.02	0.0143	0.0023

## CURRICULUM VITAE

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### Educational Qualifications:

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S.S.C.	Second	Pune Board	2001
H.S.C.	Second	Pune Board	2003
B.Sc. (Agriculture)	First	Navsari Agricultural University	2007
M.Sc. (Horticulture)	First	Navsari Agricultural University	2009

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Central Govt./Univ./SAARC :NO  
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during the study :NO

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