BIOCHEMICAL CHARACTERIZATION OF PEAR VARIETIES AT FRUIT MATURITY AND THEIR RIPENING BEHAVIOUR

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
in
FRUIT SCIENCE
(Minor Subject: Botany)

By
Pawan Kumar
(L-2015-A-88-M)

Department of Fruit Science
College of Agriculture

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CERTIFICATE I

This is to certify that the thesis entitled, "**Biochemical characterization of pear varieties at fruit maturity and their ripening behaviour**" submitted for the degree of M.Sc. in the subject of **Fruit Science** (Minor subject: **Botany**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Pawan Kumar (L-2015-A-88-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

_____

(Dr. Anil Kumar Sangwan)
Major Advisor
Horticulturist
Regional Research Station
Abohar

CERTIFICATE - II

This is to certify that the dissertation entitled, **"Biochemical characterization of pear varieties at fruit maturity and their ripening behaviour"** submitted by **Pawan Kumar** (Admission No. **L-2015-A-88-M**) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.,** in the subject of **Fruit Science** (Minor subject: **Botany**) has been approved by the Student's Advisory Committee after an oral examination on the same.

_____
(Dr. Anil Kumar Sangwan)
Major Advisor

_____
Dr. Devender Singh Dahiya
(External Examiner)
Professor
Department of Horticulture
CCS, HAU Hisar

_____
(Dr. M.I.S. Gill)
Head of the Department

_____
(Dr. Neelam Grewal)
Dean Postgraduate Studies

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Date:

Place: Ludhiana **(Pawan Kumar)**

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ABSTRACT

The present investigation on 'Biochemical characterization of pear varieties at fruit maturity and their ripening behaviour' was carried out at Department of Fruit Science, PAU, Ludhiana during the year 2016. Fourteen pear varieties viz. Nijjiseiki, Punjab Soft, Punjab Gold, Punjab Beauty, Punjab Nector, Shinseiki, Hosui, Kosui, Tisuli, Packam Triumph, Baggugosha, Orient, Punjab Nakh and Keiffer were analyzed for physical and chemical characters at fruit maturity and 0, 3, 6, 9, 12, 15, 18 day after storage (DAS) at ambient room temperature to characterize the pear germplasm on the basis of biochemical parameters and their ripening behavior for efficient utilization of existing varieties. The study showed variability among different varieties at fruit maturity. The maximum fruit weight and fruit volume was observed in Punjab Beauty (166.04gm and 167.3ml) and minimum was recorded in Housi (77.77gm and 76ml). However maximum fruit length was observed in Tisuli and diameter in Orient variety. Total sugar was maximum observed in Baggugosha variety and ascorbic acid in Orient variety. A wide variability in various quantitative and qualitative attributes was found in different pear varieties during storage. Total soluble solids, total sugars, reducing sugars, non reducing sugars, sucrose, fructose and glucose showed significantly increasing trend upto nine day after storage (DAS) and decline was observed thereafter. Starch, ascorbic acid, total phenols and firmness decreased with the advancement of storage period. Fruit peel *L**, a*, b* and *C** values improved during storage period. The relative order of macro-nutrients in pear fruit pulp was K> Ca> Mg> N> P and micro-nutrients Fe> Zn> Cu> Mn.

Key words: Biochemical, colour coordinates, physico-chemical, pear, weight

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Signature of Major Advisor **Signature of the Student**

ਖੋਜ ਦਾ ਸਿਰਲੇਖ	:	ਫ਼ਲ ਦੇ ਪੱਕਣ ਸਮੇਂ ਨਾਸ਼ਪਾਤੀ ਦੀਆਂ ਕਿਸਮਾਂ ਦਾ ਬਾਇਓਕੈਮੀਕਲ ਚਿਤਰਾਕਨ ਅਤੇ ਉਨ੍ਹਾਂ ਦੇ ਪੱਕਣ ਦਾ ਵਿਵਹਾਰ
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ਸਾਰ-ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ ''ਫ਼ਲ ਦੇ ਪੱਕਣ ਸਮੇਂ ਸਮੇਂ ਨਾਸ਼ਪਾਤੀ ਦੀਆਂ ਕਿਸਮਾਂ ਦਾ ਬਾਇਓਕੈਮੀਕਲ ਚਿਤਰਾਕਨ ਅਤੇ ਉਨ੍ਹਾਂ ਦੇ ਪੱਕਣ ਦਾ ਵਿਵਹਾਰ'' ਸਿਰਲੇਖ ਹੇਠ ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ ਦੇ ਫ਼ਲ ਵਿਗਿਆਨ ਵਿਭਾਗ ਵਿੱਚ ਸਾਲ 2016 ਦੌਰਾਨ ਕੀਤਾ ਗਿਆ। 14 ਕਿਸਮਾਂ ਵਿਜੇਂ ਨਿਜੀਸਿਕੀ, ਪੰਜਾਬ ਸੋਫਟ, ਪੰਜਾਬ ਗੋਲਡ, ਪੰਜਾਬ ਬਿਊਟੀ, ਪੰਜਾਬ ਨੈਕਟਰ, ਸਿਨਸਿਕੀ, ਹੋਸਈ, ਕੋਸਈ, ਤਿਸੂਲੀ, ਪਕਮ ਟਿਰਿਮਫ, ਬੱਗੂਗੋਸ਼ਾ, ਓਰੀਏਂਟ, ਪੰਜਾਬ ਨਾਖ ਅਤੇ ਕੀਫਰ ਨੂੰ ਫਲ ਪੱਕਣ ਅਤੇ ਕਮਰੇ ਦੇ ਤਾਪਮਾਨ ਉੱਪਰ 0, 3, 6, 9, 12, 15, 18 ਦਿਨ ਦੇ ਭੰਡਾਰਨ ਤੇ ਭੌਤਿਕੀ ਅਤੇ ਕੈਮੀਕਲ ਲੱਛਣਾ ਦਾ ਵਿਸ਼ਲੇਸ਼ਣ ਕੀਤਾ, ਪਹਿਲਾਂ ਤੋਂ ਮੌਜੂਦ ਕਿਸਮਾਂ ਦੇ ਕੁਸ਼ਲ ਪ੍ਰਯੋਗ ਲਈ ਨਾਖ ਜਰਮਪਲਾਜ਼ਮ ਦਾ ਚਿਤਰਾਕਨ ਇਹਨਾਂ ਲੱਛਣਾ ਦੇ ਵਿਸ਼ਲੇਸ਼ਣ ਦੇ ਆਧਾਰ ਤੇ ਕੀਤਾ ਗਿਆ। ਫ਼ਲ ਦੇ ਪੱਕਣ ਸਮੇਂ ਤੇ ਵੱਖ-ਵੱਖ ਕਿਸਮਾਂ ਵਿੱਚ ਭਿੰਨਤਾ ਪਾਈ ਗਈ। ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਫ਼ਲ ਭਾਰ ਅਤੇ ਘਣਤਾ ਪੰਜਾਬ ਬਿਊਟੀ (166.04 ਗ੍ਰਾਮ ਅਤੇ 167.3 ਮਿਲੀਗ੍ਰਾਮ) ਜਦਕਿ ਸਭ ਤੋਂ ਘਟ ਹੋਸਈ (77.77 ਗ੍ਰਾਮ ਅਤੇ 76 ਮਿਲੀਗ੍ਰਾਮ) ਵਿਚ ਪਾਈ ਗਈ। ਹਾਲਾਂਕਿ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਫ਼ਲ ਦੀ ਲੰਬਾਈ ਤਿਸੂਲੀ ਅਤੇ ਵਿਆਸ ਓਰੀਏਂਟ ਕਿਸਮ ਵਿੱਚ ਪਾਈ ਗਈ। ਭੰਡਾਰਨ ਦੇ ਸਮੇਂ ਵੱਖ-ਵੱਖ ਨਾਸ਼ਪਤੀ ਦੀਆਂ ਕਿਸਮਾਂ ਵਿੱਚ ਗੁਣਾਤਮਕ ਅਤੇ ਪਰਿਮਾਣਾਤਮਕ ਮਾਪਦੰਡ ਵਿੱਚ ਭਾਰੀ ਭਿੰਨਤਾ ਪਾਈ ਗਈ। ਭੰਡਾਰਨ ਦੇ 9 ਦਿਨਾਂ ਤੱਕ ਕੁੱਲ ਘੁਲਣਸ਼ੀਲ ਟੋਸ, ਕੁੱਲ ਸ਼ੁਗਰ, ਰਿਡਊਸਿੰਗ ਸ਼ੁਗਰ, ਨਾਨ ਰਿਡੀਊਸਿੰਗ ਸ਼ੁਗਰ, ਸੁਕਰੋਜ, ਫਰਕਟੋਜ ਅਤੇ ਗੁਲੂਕੋਜ ਵਿੱਚ ਵਾਧੇ ਦਾ ਰੁਝਾਨ ਦੇਖਿਆਂ ਗਿਆ ਜੋ ਕਿ ਇਸ ਤੋਂ ਬਾਅਦ ਘਟਣਾ ਸ਼ੁਰੂ ਹੋ ਗਿਆ। ਭੰਡਾਰਨ ਸਮੇਂ ਦੇ ਵਧਣ ਨਾਲ ਸਟਾਰਚ, ਏਸਕੋਰਬਿਕ ਏਸਿਡ, ਕੁੱਲ ਫੀਨੋਲ ਅਤੇ ਕਠੋਰਤਾ ਘਟਦੀ ਗਈ। ਫਲ ਛਿਲਕਾ L*, a*, b* ਅਤੇ c* ਦਾ ਮਾਨ ਭੰਡਾਰਨ ਦੇ ਸਮੇਂ ਨਾਲ ਠੀਕ ਹੁੰਦਾ ਗਿਆ। ਫ਼ਲ ਗੂਦੇ ਵਿੱਚ ਮੈਕਰੋ ਤੱਤਾਂ ਦਾ ਨਿਸਬਤੀ ਕ੍ਰਮ K>Ca>mg>n>P ਸੀ ਜਦਕਿ ਲਘੂ ਤੱਤਾਂ ਦਾ Fe>Zn>Cu>M ਸੀ ।

ਮੁੱਖ ਸ਼ਬਦ: ਬਾਇਓਕੈਮੀਕਲ, ਭੋਤਿਕ-ਰਸਾਇਣਿਕ, ਨਾਸ਼ਪਾਤੀ, ਭਾਰ, ਰੰਗ ਕੋਆਰਡੀਨੇਟਸ

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CHAPTER-I

INTRODUCTION

Pear is one of the important fruits of temperate region of the world, which belongs to genus *Pyrus,* family *Rosaceae*, sub-family *Pomoideae* with basic chromosome number 17 (2n=34). Pear cultivars are categorized into three groups, *i.e.* European pear, Asian pear and their hybrids (Sharma and Singh, 2011). Asian pears commonly known as Oriental pears and are native to China, Japan and Mnchuria. Ichiban Nashi, Shinsui, Shinsieki and Nijisseki are popular Asian varieties, whereas, Bartlett and Comice are European varieties. European pear comes under the Occidental group having typical pear shape fruit, soft flesh with gritty cells. Asian pears have a crispy texture, while the European pear has a buttery and juicy texture with characteristic flavour and aroma. The crispy and firm consistency of Asian pears does not change even after harvesting. The skin is thin and colour of the fruit may vary according to the type of cultivar. Flesh is soft, juicy and off white in colour. Pear is believed to be a good source of dietary fibre. It is also one of the low calorie fruits and provides only about 58 calories per 100 g. According to Pear Bureau Northwest, about 3000 known varieties of pears are grown worldwide. In Asia, the cultivation began over 2500 years ago, with the main species *Pyrus pyrifolia*, *Pyrus serotina* and *Pyrus ussuriensis*. Most of the Asian pear varieties are derived from *Pyrus pyrifolia* and almost all the Indian varieties belong to *Pyrus pyrifolia, Pyrus communis* and their hybrids. Sharma and Singh (2011) stated that pear was introduced in India by Chinese merchants in the time of Lord Kanishka (120-170 AD) at Harsa Chhina village of Amritsar district of Punjab and further from this place, it spread to rest part of the country. Pear can be successfully grown under temperate and subtropical conditions because of its wide range of climatic and soil adaptability. During dormancy period, it can tolerate temperature up to -26^{o}C, whereas up to 45^{o}C during growth period. The crop requires about 150-1200 chilling hours (below 7^{o}C) to break dormancy. It can be successfully grown from 1677 to 2135 meter above the mean sea level. The high chill pear cultivars are grown in Kashmir, Himachal Pradesh and Uttrakhand; whereas, low chill pears are grown in northern plains of India.

The major pear producing countries in the world are China, Italy, USA, Argentina and Spain. China is world leader in pear production and accounts for more than 60% of the total yield. In India, pear is commercially grown in the states of Himachal Pradesh, Jammu and Kashmir, Uttrakhand, Uttar Pradesh, Haryana, Punjab and some parts of Assam and Nilgiri hills in South India. It occupies an area of 4.36 thousand ha with an annual production of 32017 MT (Anonymous 2014). In Punjab, pear is grown in an area of 2,890 ha with annual production of 65470 MT (Anonymous 2014). Punjab ranks 4th in pear production after citrus, guava and mango. In Punjab, it is successfully cultivated in the districts of Amritsar,

Gurdaspur, Jalandhar, Hoshiarpur and Patiala. Due to availability of low chilling soft pear varieties, pear cultivation has been gaining popularity in subtropical regions. Area under pear cultivation in Punjab has increased due to selection of semi-soft varieties.

Pear is typical fruit with pleasant taste and flavour and is generally consumed as fresh, cookies, dried or preserved. It is a great fruit to be consumed in diet because of its low caloric value. It has high nutritional value with reasonable amount of vitamin A, B_1, B_2, B_3 and rich source of minerals like calcium, iron, sodium, potassium, magnesium and phosphorous. The fruit is also rich in vitamin C and dietary fibres and folic acid (Brian and Cameron, 1995). 100 g of fruit pulp provides 130 mg potassium, 8 mg calcium, 7 mg of magnesium, 2 mg sodium and 61 calories (Ensminger 1983). Pears has an important role in wood making industries, Pear wood is preferred for making wood instruments and furniture. Pear wood is also used to produce aromatic smoke for smoking meat or tobacco. The fruit is mainly used for table purpose. It is also used for wine making and canning. The left over material after canning is used for making vinegar or alcohol.

In India, pear varieties with higher chilling requirements (1200 hrs) are generally grown at area of higher altitudes like Jammu and Kashmir, Himachal Pardesh and Uttar Pardesh. Patharnakh and Baggugosha, which are low chilling varieties, thus they are generally grown in sub-tropical regions of the country. It is found that the quality of high chilling cultivars is much better than the low chilling cultivars. At present, many cultivars like Punjab Soft, Punjab Beauty, Punjab Nectar, Punjab Gold, Patharnakh, Punjab Nakh, Yali and Nijjisseiki have been recommended for cultivation under Punjab conditions. All these cultivars are low chilling cultivars and require about 150-200 chilling hours (Bose *et al* 1991). Beside, many other varieties are also available in germplasm block. These exhibits a wide range of variability in desirable horticultural traits like total soluble solids, sugar, reducing sugar, total sugar, soluble sugar, anthocynin, organic acids, carotenoids, flavanoids, malic acids, citric acids *etc*. The variability is continuously being studied for the evaluation of best from the selected ones with respect to specific features. These biochemical characters have great impact upon the taste, appearance, post-harvest life and quality of fresh and processed product of the fruit.

The quality and taste of the fruit is influenced by various physical and biochemical factors. Physical factors include fruit length, diameter, firmness, weight etc and chemical properties like TSS, acidity, reducing and non-reducing sugars, glucose, sucrose and fructose content. Firmness of fruit decline with time may be due to the conversion of insoluble pectins to soluble form in the cell sap and middle lamella. The fruit firmness changes due to change in the turgour of cell and cell wall composition and lipo-protein membrane surrounding the cells. High cellulose activity during fruit ripening results in decrease in flesh hardness in pear (Ning *et al* 1997). Increasing trend was observed in the concentration of total and reducing

sugars when fruit reaches maturity (Dhillon *et al* 2007). The increase in sugars was observed due to the increase in TSS, glucose, sucrose and fructose accumulation (Nitsch 1953). Organic acid metabolism into soluble sugars and degradation of polymers like starch were thought to be the cause of increasing TSS. The acid content of the fruit is greatly influenced by the chilling period and temperature during ripening period. From recent studies, it is found that juice percentage ranges from 50 to 58% in soft pear cultivars (Singh, 2002) and from 51 to 69% in Asian pear varieties (Sandhu *et al* 2002).

Many studies have been conducted to study the physicochemical properties of different fruits like kiwifruit (Celik *et al* 2007), sweet cherry (Vursavus *et al* 2006) and orange (Topuz *et al* 2004) *etc*. No work has been done to estimate the chemical properties of pear. This study may prove highly beneficial.

It could be the first step towards efficient utilization of existing diversity for further breeding programme, so the study was conducted with following objectives.

Objectives:

1. Characterization of pear germplasm on the basis of biochemical parameters
2. To determine the phytochemical changes during ripening in pear

CHAPTER-II

REVIEW OF LITERATURE

The literature pertaining to the studies on "Biochemical characterization of pear varieties at fruit maturity and their ripening behaviour" is demonstrated under the following heads and sub-heads:-

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2.1.2 Fruit shape
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2.1.6 Firmness
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2.1.8 Lenticel's
2.1.9 Hunter colour (L, a and b)

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2.2.8 Ascorbic acid
2.2.9 Starch
2.2.10 Phenols
2.2.11 Physiological loss in weight
2.2.12 Antioxidant activity

2.3 Macro and micro nutrients in fruit juice:

Nitrogen, Phosphorous, Potassium, Iron, Copper, Zinc, Calcium, Magnesium and Manganese

2.1 Physical Parameters:

2.1.1 Fruit colour

Fruit colour of 'LeConte' and 'Kashmir' at maturity was found to be greenish yellow, whereas, in 'Chinese' pear and 'Kieffer', it was recorded dull yellowish green and yellow, respectively by Singh and Sharma (1973). Similarly, greenish yellow colour was observed in

'Patharnakh' by Gupta and Chohan (1976). Mann *et al* (1978) observed light yellow colour in 'Patharnakh' at maturity. Rathore (1982) observed that 'Manning Elizabeth' showed yellowish green colour at maturity, whereas, green and light green colour was observed in 'Shinsui' and 'Flemish Beauty' respectively. Yellow colour of pear fruits cultivar 'Whangkeum Bae' was reported by Kim *et al* (1985). The colour variation from yellowish green to greenish yellow was observed by Mann and Singh (1985) in 'LeConte' pear. Light yellow colour of all grades of 'Baggugosha' was reported by Minhas *et al* (1988). In fruits of 'Punjab Nectar', 'Baggugosha' and 'LeConte', Sandhu *et al* (1994) observed yellowish green colour. Cui *et al* (1997) reported that fruits of Pingbxiang cultivar were yellow with a red blush. Fruit skin of 'Pitaiguo' was yellowish green and became dark brown at maturity (An and An 1997). Yellowish green colour was observed in Punjab Nectar. Baggugosha and LeConte (Sandhu *et al* 1994). Kan *et al* (1998) reported greenish yellow fruit colour in Ciyuesu, which turned golden yellow at maturity. Singh (1998) observed that fruit colour varied from yellowish green in Shinseiki, green in Yali and yellow orange in Hosui. Earlier, Griggs and Iwakiri (1977) observed light greenish yellow colour in 'YaLi' under California conditions.

During storage in different cultivars of Europian and Asian pear change in skin color of fruit was observed (Arzani *et al* 2008). In Shahmiveh cultivar of Europian pear, fruit colour changes from green to yellowish green and green to golden brown in KS_9 and KS_{13} (cultivars of Asian pear) from 0 to one month after storage.

2.1.2 Fruit shape

Globular to oblate shape in 'Shinseiki', round to oblate often lopsided in 'Nijisseiki', oblate and lopsided in 'Chojuro' and turbinate to globular acute pyriform in case of variety 'YaLi' was observed by Griggs and Iwakiri (1977). Similiar study was conducted by Farooqui and Happa (1990) and observed that the shape of 'Beurre-de-Amanalis', 'William Bartlett', 'Merry Red Bartlett' was pyriform, while 'Monarch', 'King's pear', 'Beurre Giffard', 'China pear' and 'Fertility' were of conical shape. Meisui and Bayuesu and Asian Pear had round shape (Wei 1994). Singh (1998) observed turbinate shape of 'YaLi'. In contrast to this shape of Japanese pear (*Pyrus pyrifolia*) cultivar Oushuu was spindle and other have elliptical shape (Kotobuki *et al* 2004).

Ovate and turbinate fruit shape was noted by Singh (2006) in hard pear strains I, II, III and IV and strains V, VI, VII, VIII and IX, respectively but the strain X and XI showed three types of shapes *viz.* ovate, globular and obovate obtuse pyriform within a strain.

Jawanda (1981) observed that Baggugosha and Leconte were found to be very successful with superior fruit quality under Punjab conditions prefound. Variability in fruit shape from globose, pyriform, ovate-pyriform and pyriform with narrow neck was observed. Similiar study was conducted by Singh and Sharma (1973) and reported that shape of

'LeConte' and 'Kashmir' pear was found to be ovate pyriform, whereas, 'Chinese Pear' and 'Keiffer' were globular obtuse pyriform and obovate acute pyriform, respectively. Similarly, Gupta and Chohan (1976) reported that shape of 'Patharnakh' and 'Smith' was found to be roundish, whereas, 'LeConte' was found to be pyriform. Similarly round shape of 'Whangkeum Bae' was observed by Kim *et al* (1985). Similarly Kotobuki *et al* (2004) reported that 'Yali' had turbinate shape, while Asian pears were round.

2.1.3 Fruit size (length and diameter)

Rathore (1982) found in the trail of five pear varieties that the fruit size of 'Manning Elizabeth', 'Shinsui', 'Flemish Beauty', 'Devoc' and 'Max Red Bartlett' was 4.03 x 4.24 cm, 4.66 x 5.51cm, 7.0 x 6.84cm, 9.13 x 6.31cm and 7.33 x 6.37cm, respectively. Fruit length in different cultivars varied from 4.66 to 6.29 cm, but the maximum fruit length was observed in Yali by Sandhu *et al* (2002). Similiar study was conducted by Singh *et al* (2004) on hard pear strains and found that Strain XVI had the maximum fruit length (7.87 cm) and breadth (6.50 cm). In contrast, the minimum fruit length (6.91 cm) and breadth (5.89 cm) was noticed in Strain VII. On the other hand, Singh (2006) observed that the maximum and the minimum fruit length in Strain X (6.92 cm) and Strain VI (6.17 cm), respectively but in case of fruit breadth, the maximum was in V (6.86 cm) and minimum in Strain IX (5.89 cm). Griggs and Iwakiri (1956) observed maximum length (6.3cm) and breadth (7.0 cm) in Bartlett pear. The maximum fruit length was observed in 'Keiffer' (5.8 cm) as compared to 'Smith' (5.4 cm) and 'LeConte' (4.8 cm) (Mukherjee and Rana 1966). Average fruit size of 'Patharnakh' (6.22 x 6.44 cm), 'Smith' (6.42 x 6.53 cm) and 'LeConte' (6.50 x 5.81 cm) was observed by Gupta and Chohan (1976). Grewal *et al* (1988) observed fruits of 'Patharnakh' with length varying from 6.43 to 7.16 cm and breadth from 7.33 to 6.37 cm. Similarly at fruit maturity of Patharnakh, the maximum fruit length (6.40 cm) and fruit diameter (6.59 cm) was reported by Dhillon *et al* (1999). The length and breadth of 'Baggugosha' varied from 6.4 to 7.2 cm and 5.4 to 6.7 cm (Minhas *et al* 1988). Singh *et al* (2016) worked on semi soft pear variety (Punjab Beauty) for improvement in fruit quality, and production and fruit size were recorded at maturity, length of the fruit 6.13cm, breadth 5.25cm. Singh and Sharma (1973) reported that fruit size of different varieties of pear Kashmiri Pear, Chinese Pear and Kieffer fruits has been reported to be 6.10× 5.63cm, 6.88×6.10cm, 5.68×6.12cm and 6.43×5.96cm respectively. Variations in fruit size of pear have been reported by other workers too (Gupta and Chohan 1976 and Mann and Singh 1985). In the new selections of pear, Sandhu *et al* (1994) observed the fruits of Red blush slightly bigger than that of Punjab Gold and Punjab Nectar, as all the three selections had large fruits as compared to other cultivars. In the Asian pear varieties, Singh (1998) observed that cultivar YaLi had the maximum fruit length (6.8cm) and breadth (6.4 cm) followed by other varieties, *i.e,* Kosui (5.5 and 6.0 cm) and Hosui (5.3 and 5.8 cm).

Sandhu *et al* (1994) reported that fruits of 'Red Blush' were slightly bigger than that of 'Punjab Gold' and 'Punjab Nectar' with length and breadth (7.8 x 6.0 cm) and (7.7 x 6.0 cm), respectively. The maximum fruit length 8.3cm and 7.2cm was observed by Sharma *et al* (1997) in Simsui followed by Jargonelle whereas, the minimum fruit length 5.2cm was recorded in Junska Zlato. Among Asian soft pears, the maximum fruit length (6.8 cm) and breadth (6.4 cm) was reported in Yali cultivar. Whereas Singh (1998) observed minimum length in Hosui 5.3cm and breadth 5.8 cm respectively.

Mukherjee and Rana (1966) conducted an experiment and observed that fruit length of 'Kieffer' (5.8 cm) was more than 'Smith' (5.4 cm) and 'LeConte' (4.8 cm). Similarly, the maximum fruit length was observed in 'Merry Red Bartlett' (10.15 cm) as compared to 'Vicar of Winkfield' (9.38 cm) and 'William Bartlett' (4.39 cm), Farooqui and Happa (1990). Nath and Rai (2000) observed that length of 'Netarhat Local' (7.4 cm) was less than 'Nakh Pear' (7.8 cm).

2.1.4 Fruit weight

'Patharnakh' and 'LeConte' fruit weight was found 120.3 g and 95.9 g, respectively at fruit maturity by Singh (1981). Higher fruit weight in 'Gola', 'Naga' and 'Tumariya', which were about 170.5 g, 230.4 g and 120.0 g, respectively was observed by Sharma (1982). In pear cultivar Kosui the maximum fruit weight (300 g) was observed by Watanabe *et al* (1984).

Grewal *et al* (1988) reported that weight of large fruits of 'Patharnakh' was 211.9 g, while small sized fruits were 101.6 g. On the other hand, Minhas *et al* (1988) observed that the fruit weight of 'Baggugosha' ranged from 58.2 g to 165.6 g in small to large sized fruits. The maximum fruit weight 273.30 g in 'Merry Red Bartlett' was found by Farooqui and Happa (1990). Kumar (1997) recorded that average fruit weight ranged from 83.6 g to 98.6 g in Strain I and Strain III, respectively. Singh (1998) observed that the average fruit weight was 70.0 g and 117.0 g in 'Shinseiki' and 'YaLi', respectively. Apart from that Dhillon *et al* (1999) noticed maximum fruit weight of 136.0 g at the time of fruit maturity in 'Patharnakh'. Cheng *et al* (1999) observed on an average 233.0 g fruit weight in red strained pear variety Bayvehong. Nath and Rai (2000) reported that average fruit weight was higher (260.9 g) in 'Netarhat Local' than that of 'Nakh Pear' (175.1 g).

Under Punjab conditions, Singh (2006) noticed maximum and minimum fruit weight in Strain X (181.78 g) and Strain I (123.72 g), respectively in studies of hard pear strains. Shyamali (2006) found that fruit weight was maximum in 'YaLi' (112.40 g), followed by 'Hosui' (88.42 g), 'Kosui' (74.33 g) and 'Nijisseiki' (61.48 g) and minimum in 'Shinseiki' (57.38 g).

Dulce *et al* (2015) recorded the fruit weight in different cultivars, which were Rojo San Martin, Verde Villanueva, Rojo Cenizo, and Cristal of cactus pear in two different

seasons of fruit growing in 2010 and 2011. In 2010, the highest fuit weight was recorded in Verde Villanueva 198 g and lowest in Rojo Cenizo 106 g but in 2011, the highest fruit weight in Cristal 176g and lowest in Verde Villanueva 54g. Similar studies were conducted by the Felker *et al* (2005) in different cultivars of cactus pear, the fruit weights varies from 112 and 212g.

The maximum fruit weight (172.0 g) was recorded in Devoc and Flemish Beauty followed by Max Red Bartlett (135.0 g) and minimum (38.0 g) in Manning Elizabeth. The fruit weight of pear cultivars Gola, Naga and Tumariya was found to be 170.50, 230.40 and 120.0g, respectively (Singh *et al* 1983). Sandhu *et al* (1994) observed that the maximum fruit weight was 139.7 g in Punjab Gold followed by Red Blush (134.5 g) and Punjab Nectar (132.0 g) but the least was found in LeConte (93.9 g). The fruit varieties of pear varies with different weights was noticed by Sandhu *et al* (2002) in YaLi (122.59 g), followed by Hosui (87.04 g), Shinseiki (84.04 g) and Kosui (66.40 g).

2.1.5 Fruit volume

In Patharnakh, Smith and LeConte pear fruit volume was in increasing level (Chand 1976; Singh 1981; Maan and Singh 1985). Srivastava and Misra (1970) studied that Beurre Hardy (231.50ml) had maximum fruit volume followed by William Bartlett (197.50 ml) and least was observed in Thumb pear (38ml).

2.1.6 Fruit Firmness

Misger *et al* (2015) studied the seven different exotic pear varieties after harvest under ambient conditions and found that the fruits of Cosco-D cultivar were firmer than any other cultivar followed by Passe Crassane. The lowest firmness after 10 days storage was recorded in William Bartlett cultivar (8.35 lb/inch^2) and after 30 days storage also observed in William Bartlett followed by Coscia, Red Anjou and Kaiser. After 30 days of storage, the maximum firmness (16.25 lb/inch^2) was shown in the fruits of Cosco-D. In all the cultivars shows decrease in firmness when stored for 20 to 30 days after harvest. Decreasing trend in fruit firmness was recorded during maturity, ripening and storage by Drake *et al* (2004).

A study was conducted on physical and chemical properties of Asian pear fruits and found that in Red pear highest fruit firmness (18.5 kg cm^{-2}) followed by Xiang Sui (14.8 kg/cm^2), Song Mao (9.39 kg/cm^2), Shiny Sing (8.51 kg/cm^2) and Kosui (6.37 kg/cm^2) respectively. Griggs *et al* (1960) reported that the flesh firmness of 'Bartlett' was observed 16.3 lb/inch^2 in self pollinated, while it was observed 15.3 lb/inch^2 in cross pollinated treatments. The fruits of 'Red pear' were more firm (18.50 kg/cm^2) as compared to 'Patharnakh' (14.29 kg/cm^2), 'Yokoyama Wase' (12.75 kg/cm^2) and 'Yokoyama' (12.60 kg/cm^2) studied by Aswapati and Uthaibuthra (1990). While the minimum fruit firmness was recorded in fruits of 'Xiang Sui' (9.70 kg/cm^2) and 'Kosui' (10.69 kg/cm^2). In (1997) Kumar; reported that fruit firmness ranged from 13.5 lb/inch^2 in Strain III to 14.4 lb/inch^2 in Strain X.

Singh (1998) noticed that flesh firmness ranged from 9.0 lb/inch^2 in 'YaLi' to 10.7 lb/inch^2 in 'Shinseiki'. Fruit hardness in a new bud sport cultivar 'Hongnanguo' was 7.77 kg/cm^2, which was observed by Jiao *et al* (1999).

While studying the physical characters of Asian pears, Sandhu *et al* (2002) observed the maximum fruit firmness 10.74 lb/inch^2 in 'Shinseiki' and minimum (7.19 lb/inch^2) in 'Kosui'. The fruit firmness of 'William' pear was maximum (8.0 kg/cm^2) on 'BH/BA-29' rootstock and minimum (7.3 kg/cm^2) was recorded in 'OHF-333' rootstock at the end of 7th year of planting by Urbina *et al* (2003) were recorded. Singh *et al* (2004) revealed that average fruit firmness ranged from 4.46 kg/cm^2 (Strain XVI) to 5.42 kg/cm^2 (Strain IV). The maximum fruit firmness to a tune of 14.06 lb/inch^2 in Strain I and minimum of it was observed in Strain XI (10.56 lb/inch^2) recorded by Singh (2006). There was a continuous decline showed in fruit firmness was showed up to fruit maturity in all pear cultivars. The first record of 86 DAFB, it was more than 12 kg/cm^2 in all the cultivars but decreased to 5.53 kg/cm^2 in 'YaLi', 4.75 kg/cm^2 in 'Shinseiki', 5.70 kg/cm^2 in 'Nijisseiki', 5.47 kg/cm^2 in 'Hosui' and 5.75 kg/cm^2 in 'Kosui' at 114 DAFB (Shyamali 2006) respectively.

2.1.7 Length and diameter of pedicel

In case of self-pollinated treatments, Griggs *et al* (1960) noted that stalk length of Bartlett pear was 25.0 mm but in case of cross –pollinated treatments, it was about 26.4 mm. Singh *et al* (1983) revealed that the maximum stalk length 3.47 mm in Naga, in Tumariya it was 2.62 cm and 1.77 in Gola pear. During the investigation of some Asian soft pears, it was seen that length ranged from 3.0 cm to 5.3 cm in Kosui and YaLi by Singh (1998).The length and breadth of the pedicel of Punjab Beauty and Punjab Gold were 46.5× 11mm and 44.99× 13mm, respectively as reported by Singh (2003).

During the research of some Asian pears conducted by Griggs and Iwakiri (1977) revealed that the maximum stalk length in 'TsuLi' (40.0 mm), followed by 'Okusankichi' (35.0 mm), 'Kikusui' (31.0 mm), 'Chojuro' (28.0 mm), 'Nijisseiki' (25.0 mm), 'Shinseiki' (19.0 mm) and the minimum (17.0 mm) in 'YaLi', respectively, while, under Pinjab conditions, Singh (2002) observed the longest pedicel length in Strains XIV (4.32 cm) and shortest was found in Strain XII (3.35 cm). Sandhu *et al* (2002) observed that the average length of pedicel was longer (4.86 cm) in 'YaLi' than that of 'Shinseiki' (2.27 cm) when physical characters of asian pears cultivars were compared. According to Singh (2006), average pedicel length was maximum in Strain V (2.38 cm) and minimum in Strain XI (2.06 cm). Shyamali (2006) observed maximum pedicel length in 'YaLi' (5.12 cm), followed by 'Kosui' (4.19 cm), 'Nijisseiki' (2.90 cm), 'Shinseiki' (2.65 cm) and minimum in 'Hosui (2.32 cm).

2.1.8 Lenticels/cm^2

Dhillon and Shyamali (2007) worked on five soft pear varieties, *i.e,* YaLi, Nijisseiki,

Shinseiki, Kosui and Hosui and observed that the density of lenticels was significantly different among these varieties. Shinseiki produced the highest (45.67) and YaLi the lowest (37.0) number of lenticels per cm^2 area of fruit peel. Similarly Griggs and Iwakiri (1977) described lenticels in YaLi and Shinseiki as conspicuous and small to medium in size. Singh (1981) revealed that the number of lenticels were recorded per cm^2 varied from 51 in 'Smith', 55 in 'LeConte' and 66 in 'Patharnakh'. While Dulley (1997) observed the number of lenticels 39.38 per cm^2 in 'Patharnakh' and 14.91per cm^2 in 'Baggugosha' at the time of fruit maturity and the number of lenticels was declined with advancement of ripening. In 'Punjab Beauty' and 'Punjab Gold' at the time of maturity number of lenticels decreased to 26per cm^2 and 21.25per cm^2, respectively observed by Singh (2003).

2.1.9 Hunter Colour

Arzani *et al* (2008) studied the 'L' 'a' and 'b' values of fruit skin color during the storage from zero to one month, the decrease in 'L' and 'a' value was observed from 50.1 to 47.2 and 19.3 to 17.9 in KS_9 cultivar, 54.3 to 53.5 and 19.3 to 18.5 in KS_{13} and change in 'L' in 53.3 to 50.3 in Shahmiveh but increase in 'a' value was observed in Shahmiveh cultivar 17.9 to 27. In all three cultivars 'b' value also decreases, in KS_9 59 to 57, 58 to 54 in KS_{13} and 52 to 48 in Shahmiveh at 0 day and 1 month after storage. The skin colour of different asian pear cultivars (Hosui, Chojuro, Man san and Pung su) during storage at 18°C were examined by Horak *et al* (2016). In Hosui at 20th day of storage 'L' value was 51.5 that changes to 49.7 after 40 days storage, in Chojuro 46.2 to 43.9, 63.8 to 62.4 in Man San and 61.7 to 63.6 in Pung Su. At 20th day of storage in Hosui the 'a' value was observed 9.5 that changes to 16.5 after 40 days storage, in Chojuro 13.1 to 20.4, -0.5 to 8 in Man San and -2.0 to 7.2 in Pung Su. In Hosui at 20th day of storage 'b' value was 30.3 that changes to 31.7 after 40 days storage, in Chojuro 28.2 to 27.9, 42.7 to 41.7 in Man San and 40.9 to 42.7 in Pung Su.

2.2 Chemical parameters

2.2.1 Total soluble solids (TSS)

Singh *et al* (1983) conducted a study which resulted that highest TSS (13.2%) was found in variety Naga, followed by Gola (12.0%) and Tumariya (12.2%). Similary, Watanabe *et al* (1984) reported TSS of 13.0% in Shinsui cultivar. Kim *et al* (1985) reported 14.9 % TSS in Whangkeum Bae pear. Nakajima *et al* (1985) reported 11.0 to 12.0 % TSS in Hokken cultivar of pear. Increase in TSS from 8.65 to 14.25 % during fruit development of LeConte was reported by Maan and Singh (1985). However, Grewal *et al* (1988) reported that in Patharnakh TSS varied from 10.5 % in small sized fruits to 11.5 % in large size fruits. TSS ranged from 11.2 to 13.0 % in Baggugosha as reported by Minhas *et al* (1988). Jiang *et al* (1991) observed mean TSS content of 17.68 % in new pear cv. QiouXiang-7. Maximum TSS of 15.1 % in Red Blush followed by Punjab Gold and Punjab Nectar with TSS 14.5 % and 14.1% respectively by Sandhu *et al* (1994). In Meisui pear, Shibata *et al* (1994) reported TSS

of 12 %. In a study conducted on Asian pears, Singh (1998) reported highest TSS (14.0%) in Hosui and lowest (11.0%) in Yali. Similarly, Nath and Rai (2000) reported higher TSS (16.2 %) in Nakh pear and lowest (12.2%) in Netarhat Local pear. Sandhu *et al* (2002) observed maximum TSS (12.16%) in Shinseiki, whereas minimum in Yali (10.0 %). Similarly, Shyamali (2006) reported that TSS was more in Shinseiki (13.0 %) and less in Yali (11.0 %). Results were observed by Bist *et al* (2003) observed that with maximum TSS in China (18.5 %) and minimum in Patharnakh (13.0 %). Griggs *et al* (1960) reported that TSS ranged from 9.6% to 11.3% in seedless pear.

Aswapati and Uthaibathra (1990) reported that in Asian pears maximum TSS were found in Sony Mao 12.7, ivar 17.1 per cent and minimum in Xiang Sui 10.6 per cent .In the cultivars of pear Chojuro, Kosui and Shinsui were TSS reported 11.1, 13.0 and 13.0 per cent, respectively at maturity (Hong *et al* 1998).The TSS in Nakh and Netarhat local cultivar of pears was found to be 16.2 per cent and 12.2 per cent respectively noticed by (Nath and Rai 2000). Chemical character of 'LeConte', 'Nakh Pear', 'Baggugosha', 'Kieffer', and 'Smith' were studied by Mukharjee and Rana (1966) and they found the highest TSS in 'LeConte'(17.00%), followed by 'Nakh Pear'(13.4%), 'Baggugosha'(11.6%) and the minimum in both 'Kieffer' and 'Smith'(10.38% each). Similary, Singh and Sharma (1973) observed that 'Kashmir pear' had the highest TSS (16.8%), followed by 'LeConte' (16.0%) and 'Kieffer (14.0%), whereas the minimum TSS (12.5%) was recorded in Chinese pear. Gupta and Chauhan (1976) recorded maximum TSS in 'LeConte' (15.3%), followed by 'Patharnakh' (13.5%) and 'Smith' (12.5%). While studying the chemical characters of promising pear selections made at Ludhiana, Sandhu *et al* (1994) recorded maximum TSS in 'Red Blush' (15.1%), followed by 'Baggugosha' (13.0%), whereas TSS content was minimum in 'LeConte' (12.5%). Dhillon *et al* (2007) observed that TSS 15.16% in 'Punjab Gold' which was higher than 'Punjab Beauty' (15.01%) at fruit maturity. Perez *et al* (2005) studied the TSS values of Naranjona, Balanca Cristalina, and Esmeralda fruits is 12.5, 13.6 and 14°Brix at harvest respectively. Very slight changes observed at 14 and 28 days (12.9 and 13°Brix) and (11.4 and 12°Brix) for Balanca Cristalina and Esmeralda. In contrast, Naranjona exhibited, at 14 and 28 days 10 and 9°Brix, respectively.

Arzani *et al* (2008) studied the TSS content in different asian and europian pears at fruit maturity and during storage, the highest TSS content at fruit maturity was recorded in KS_{13} (15.1 ^{o}Brix) cultivar of asian pear and lowest in europian cultivar (Shahmiveh 13.1 ^{o}Brix). During the storage increase in TSS was observed, after one month at cold temperature storage increase from 14.1 to15.2 ^{o}Brix was observed in KS_{9}, 15.1 to 17.2 ^{o}Brix in KS_{13} and 13.1 to 13.2 ^{o}Brix in Shahmiveh. But after the 3 and 5 months storage the value of TSS was decreased (11.1 to 8.2 in KS_{9}, 11.1 to 9.7 in KS_{13} and 11.1 to 8.4 in Shahmiveh). Chen *et al* (2005) was observed the TSS content in Yali cultivar of pear during the storage for one month

the TSS value 11 ^{o}Brix that changes to 12 ^{o}Brix after 2 month cold storage and thereafter slightly decreases during ripening in storage. Dhillon *et al* (2005) reported that the change in TSS (7.17 at 1st day, 7.98 at 3rd day, 8.39 at 5th day and 7.64 ^{o}Brix at 7th day storage) in Punjab Beauty cultivar during storage at ambient temperature.

2.2.2 Acidity

Mukherjee and Rana (1966) observed lowest juice acidity (0.10%) in 'LeConte' and highest (0.43%) in 'Baggugosha', followed by 'Kieffer' (0.29%) and 'Nakh Pear' (0.27%). Singh and Sharma (1973) reported the maximum juice acidity in 'Chinese Pear' (0.40%), followed by 'LeConte' (0.27%) and 'Kashmir Pear' (0.20%). In 'Patharnakh', the acidity was ranged from 0.33 to 0.37 percent, whereas, 'LeConte' had lowest (0.31%) and 'Smith' had highest juice acidity (0.40 to 0.43%) Gupta and Chohan (1976). Similarly the lowest level of juice acids (0.18%) in 'Naga' and maximum (0.96%) in 'Gola' was observed by Singh *et al* (1983). The maximum juice acid content (0.33%) in 'Red Blush', followed by 'Punjab Gold', 'LeConte' (0.32%), 'Punjab Nectar' (0.32%), and 'Baggugosha' (0.29%) by Sandhu *et al* (1994). In Asian Pears, the acidity ranged from 0.23% in 'Shinseiki' and 'Kasui' to 0.33% in 'Hosui' (Singh 1998). In pear cultivars, percentage of acidity changed in different directions during the three phases that are development, maturation and ripening noted by Amen and Hared (1972). Malic, succinic, citric and tartaric acid was found to be major organic acids in cultivars of pear observed by Hulme and Rhodes (1971). In Uttar Pradesh in low chilling cultivars of pear Srivatsava and Misra 1970 observed that acid level ranged from 0.08 to 0.44 per cent. Malic acid content decreased during fruit maturation in Chojuro, Kosui and Shinsui pears (Hong *et al* 1998). At maturity Minhas *et al* 1988 recorded that the acid content of Baggugosha pears was from 0.21 per cent in large and 0.25 per cent in medium and small sized fruits.

Dhillon *et al* (2005) studied that the decrease in acidity (0.32 at 1st day, 0.22 at 3rd day, 0.21 at 5th day and 0.22 per cent at 7th day storage) in Punjab Beauty cultivar during ripening at ambient room temperature. Similarly in Punjab Beauty cultivar of pear, the decrease in acidity was observed during storage. At fruit maturity acidity was observed 0.35%, after 45 days storage and it decreased to 0.22% after 75 days storage at cold temperature it changes to 0.15% (Kaur *et al* 2013).

Lowest acidity 1.6 meq/100ml juice in cultivar Kosui and in Red pear it has been observed to be highest of 11.8meq/100ml juice observed by Aswapti and Utahibathra (1990). In Asian pear cultivars Sandhu *et al* 2002 observed that the acid content was maximum (0.218 per cent) in YaLi, followed by Shinsui (0.188 per cent), Kosui (0.178 per cent) and minimum content was in Hosui (0.171 per cent) respectively. Sandhu *et al* (1994) reported that the acidity in Red Blush pear was 0.33 per cent at maturity followed by Punjab Gold and Leconte (0.32 per cent) each and minimum in Baggugosha pear about 0.29 per cent.

2.2.3 TSS:acid ratio

In different pear varieties, non-significant differences in terms of TSS:acid ratio was observed by Sandhu *et al* (1994). The highest average TSS:acid ratio was observed in 'Red Blush' (48.5%) followed by 'Punjab Gold' (47.5%) and 'Baggugosha' (46.6%) and minimum was recorded in 'LeConte' (39.7%). In another study in different soft Asian varieties by Shyamali (2006) evaluated, maximum TSS:acid ratio (154.79) in 'Kasui', followed by 'Shinseiki' (108.09), 'Nijjisseiki' (101.114) 'Hosui' (78.89) and 'Yali' (58.75). Dhillon and Shyamali (2007) observed TSS:acid ratio is highest (154.79) in Kosui and minimum (58.75) in YaLi, Nijisseiki, Shinseiki and Hosui. Aswapati and Uthaibathra (1990) reported that the cultivar Kosui had the lowest acid content at maturity among Asian type of varieties. Kaur *et al* (2013) was recorded increasing trend in TSS:acid ratio during storage. The maximum mean TSS:acid ratio 75.8 after 75 days of storage, whereas significantly lower TSS:acid ratio 48.7 was observed in fruit of Punjab Beauty cultivar after 30 days.

2.2.4 Total, Reducing, Non Reducing Sugars

Mukherjee and Rana (1966) reported that sugars percentage ranged from 6.25 in 'Smith' to 9.62 in 'LeConte'. Srivastava and Misra (1970) reported that total sugars were found to be 9.88% in 'Victoria' and 10.0% in 'Beurre Hardy'. Maximum amount of total sugars was observed in 'Naga' (10.31%) and minimum in 'Gola' (7.54%) as reported by Singh *et al* (1983). Similarly, Sandhu *et al* (2002) evaluated that total sugars were maximum in 'Yali' (7.72%) and minimum in 'Kosui' (5.97%). Farooqui and Happa (1990) recorded maximum total sugars content in Flemish Beauty variety (15.8%) and minimum in Beurre-de-Amanalis (2.1%). Maximum total sugar content was recorded in Hosui (7.25%) and minimum in Yali (5.57%) by Shyamali (2006). Increasing trend in total sugar content with fruit development was shown in Punjab Gold (11.13%) as compared to Punjab Beauty (11.06%) observed by Dhillon *et al* (2007).

Maximum reducing sugars were reported in 'Beurre Hardy' (9.22%) and minimum in 'Victoria' cultivar (6.20%) by Srivastava and Misra (1970). Maximum reducing sugars (7.57%) was reported in 'Shinsui' and minimum in 'Manning Elizabeth' (3.59%) by Rathore (1982). Singh *et al* (1983) also reported that reducing sugars were maximum for pear cultivar 'Naga' (9.43%), whereas it was minimum in 'Gola' (7.33%). Reducing sugars were recorded maximum in 'Flemish Beauty' (13.88%) and minimum in 'Beurre-de-Amanalis' 1.89% by Farooqui and Happa (1990). Sandhu *et al* (2002) reported maximum reducing sugars in 'Yali' 5.08% and minimum in 'Shinseiki' (4.23%). Nath and Rai (2000) reported maximum reducing sugars content in 'Nakh Pear' 11.4% and minimum in 'Netarhat Local' (8.1%).

Rathore (1982) recorded that maximum non-reducing sugars in 'Manning Elizabeth' (2.53%) followed by 'Devoc (0.98%), whereas minimum was recorded in 'Shinsui' (0.53%)

and ‘Flemish Beauty’ (0.75%). High level of non-reducing sugars in ‘Tumariya’ pear (1.45%) as compared to ‘Naga’ (0.84%) and ‘Gola’ (0.20%) were found by Singh *et al* (1983).

The Reducing sugar, Non-reducing sugar and Total sugar recorded in different pear varieties, the highest Reducing sugar is 5.88% in Nijisseiki then 5.53% in Shinseiki, 5.52% in Kosui, 5.45% in Hosui and 4.90% in Yali while Non reducing sugar is highest in 1.72% Housi then 1.33% in Shinseiki, 1.32% in Kosui, 0.64% in Yali and 0.59% in Nijisseiki and the total sugars highest 7.25% in Housi then 6.94% in Shinseiki, 6.91% in Kousi, 6.51%, in Nijisseiki and 5.51% in Yali was observed by Dhillon and Shyamali (2007).

The reducing sugars content ranged from 6.2 per cent in Victoria to 9.22 per cent in Beurre Hardy was reported by Srivatsava and Misra (1970). The maximum reducing sugars were recorded in Shinsui (7.57 per cent) followed by Devoc (7.47 per cent), Max Red Bartlett (7.08 per cent), Flemish Beauty (7.05 per cent) and the minimum (3.50 per cent) in Manning Elizabeth examined by Rathore (1982). On the other hand Mann and Singh (1985) recorded that there was an increase in reducing sugars from 0.90 to 6.24 per cent during development of LeConte pear fruits. In (1997) Kumar reported considerable differences in reducing sugars among different strains with maximum of 10.9 per cent in starin II and III, whereas less differences were revealed in strain XII and XI (9.1 and 9.3 per cent). In Asian pears, it was observed that maximum content of reducing sugars (6.02 per cent) in Kosui, followed by Hosui (5.7 per cent), YaLi (5.3 per cent) whereas minimum content was in Shinseiki (4.7 per cent) respectively.

Singh *et al* (1983) reported that the in Tumariya pear cultivars maximum level of non-reducing sugars (1.45 %) than that of Naga (0.84%) and Gola which is (0.2%).only. The highest level of non–reducing sugars were observed by Rathore (1982) in cultivar Manning Elizabeth (2.55%), followed by Devoc (0.90%) and least content was in Shinsui (0.53%).

2.2.5 Juice pH

Change in pH may be due to the breakdown of pectin substance into pectenic acid studied by Kinh *et al* (2001) and Muhammad *et al* (2011). The pH value of fruits gradually increased with the increase in storage period corresponding to decrease in acidity reported by Nail and Chandel (1993). The continuous increase in pH during storage was due to decrease in titratable acidity in fruit. Tripathi *et al* (1998) examined that the pH value of the aonla candy was slightly more than the fresh fruit and did not change during the storage period. The pH value range is 5.7 to 6.6, there were no significant differences observed in (Naranjona, Blanca Cristalina and Esmeralda) during fruit ripening reported by Perez *et al* (2005).

2.2.6 Fibre

In different cultivars (Rojo San Martin, Verde Villanueva, Rojo Cenizo, and Cristal) of cactus pear the fibre content is studied by Dulce *et al* (2015) in two different season of 2010 and 2011, result shows that the total dietary fibre content varied from 140 to

166 gram per kg in different cultivars, the highest content of total dietary fibre during 2010 and 2011 in Rojo Cenizo (163–166 g/kg). Similar studies were done in different fruits by Mahattanatawee *et al* 2006, total dietary fibre content for mamey. Total dietary fibre content were also studied in the pulp of three different prickly pear (Naranjona (early), Balanca Cristalina (early-intermediate), and Esmeralda (intermediate-late) varieties at different stages (0, 7, 14 and 28 days) after harvest, the highest TDF content 7.8, 20.4, and 14.4% dry weight were studied in Naranjona cultivar at 0, 7 and 14 days after harvest and the lowest 4.2% dry weight in Esmeralda at 0 days, 8.6 and 6.3% dry weight in Balanca Cristalina at 7 and 14 days after harvest by Perez *et al* (2005).

2.2.7 Glucose, Sucrose and Fructose

Itai and Tanahashi (2007) reported that sucrose content increased during storage in Japanese pear (*Pyrus pyrifolia* Nakai cvs. Gold, Nijisseiki and Hosui) upto 3 weeks after harvest, while decreasing trend was shown thereafter. On the other hand, sucrose content is maintained during cold storage in apples (Ackermann *et al* 1992). Ding *et al* (1998) reported that there was no decline in sucrose content with cold storage of loquat. Mao *et al* (2006) observed that sucrose content accelerated at room temperature in sugarcane.

Chen *et al* (2005) reported that fructose was the major sugar in pear fruits followed by glucose and sucrose. There is increase in fructose (35000mg/L to 50000mg/L) and glucose (33000mg/L to 38000mg/L) content from stage 1(after 1 month storage) to stage 3 (after 3 month storage) was recorded in cultivar Yali. The sucrose content comparatively decreased (9000mg/L to 7000mg/L) during these stages.

Fructose and glucose are the principal monosaccharides in the pear fruit. In an experiment conducted on eight pear varities, it was observed that fructose levels were always higher than glucose in all the varieties, the fructose content of Nanguo pear (77.1 g/kg of fresh pears) was highest followed by Kuerle fragrant pear (60.1 g/kg), Jingbai pear (58.1 g/kg) and Dangshan pear (55.6 g/kg) and the highest glucose content (38.8 g/kg) in Kuerle fragrant followed by Yali (33.9 g/kg) and Dangshan (25.7 g/kg). Maximum sucrose content was present in Fragrant pear (21.4 g/kg of fres pears) followed by Niitaka (10.3 g/kg) Chen *et al* (2006).

Arzani *et al* (2008) observed that at the time of fruit harvest of Asian pears (KS9 and KS13) and European pear (Shahmiveh), fructose was present in large amount as compared to glucose and sucrose.There was increase in fructose (39.9g/kg to 45.5g/kg) in 'KS'9, (61.3g/kg to 90.2g/kg) in 'KS'13, (33.1g/kg to 43.2g/kg) in 'Shahmiveh' and glucose (29.9g/kg to 54.3g/kg) in 'KS'9, (52.1g/kg to 76.6g/kg) in 'KS'13, (31.1g/kg to 33.5g/kg) in 'Shahmiveh' contents from Stage 0 (harvest time) to Stage 1 (after one month storage), while sucrose (11g/kg to 8g/kg) in 'KS'9, (1.1g/kg to 0.9g/kg) in 'KS'13, (3.3g/kg to 2.1g/kg) in 'Shahmiveh' content decreased. The fructose content was higher in 'KS' 13 (90.2g/kg) as

compared to 'KS' 9 (45.2g/kg) and 'Shahmiveh' in Stage 1. Number of studies have been done to show increased levels of fructose, glucose and sucrose at initial stages of fruit maturity (Ackerman *et al* 1992, Chen *et al* 2006, Gao *et al* 2004, Gao and Wang 1983).

Evans (1928) and Ayres and Fallows (1951) provided variations of glucose and fructose in English varieties of apples. For the juice of apples grown in France, Tavernier and Jacquin (1952) showed that sucrose content in apple juice varied from6.6 to 56.8, glucose between 12.3 to 58.0 whereas, fructose from 69.2 to 113.8 grams per litre depending on the variety. They also found that the juice of pears contained less sugar than that of apples. After analyzing 26 different varieties of pears it was found that sucrose varied from 1 to 24, glucose from *5* to 35 and fructose 65 to112 grams per litre. The proportion of the three sugars was almost same in young fruits.

2.2.8 Ascorbic acid

Jan *et al* (2012) worked on apple cultivars and found that the higher ascorbic acid content was observed in cultivar Red Delicious (12.49 mg/100g) follow by Mondial Gala and Royal Gala with 11.53 and 11.43 mg/100g correspondingly and the lower ascorbic acid content was noticed in cultivar Golden Delicious (10.27 mg/100g). Further storage of 150 days the ascorbic acid decreased from 14.18 to 8.68 mg/100g at 5±1 ^{0}C.

In the same way Herath *et al* (2015) examined that the lowest ascorbic acid content found in lime (1.9mM) and lemon (1.5 mM) respectively and the highest content was found in cultivar of sweet orange Sisila (5.9 mM) and Pummelo contain (6.9 mM). Bermejo and Cano in 2012 were analysed twenty citrus cultivars for nutritional constituents at different growth stages, to find out the changes in sugars, and vitamin C at the time of ripening in these fruits. In general, the maximum vitamin C was observed in varieties grafted on Troyer citrange as compared to grafted on Cleopatra mandarin. At final maturity stage, maximum vitamin C observed in lemons, Clementine mandarins and Sweet oranges.

Vijayanand *et al* (2007) also studied the effect of processing on gooseberry fruits and quality changes during 6 months storage at 25±2 ^{0}C and resulted that Chakaiya variety was having the highest ascorbic acid content (357 mg/100g) followed by Krishna (298 mg/100g) and NA-7 (272 mg/100g). Nayak *et al* (2011) observed continuous decrease in the ascorbic acid content 306mg/100g in fresh fruit to only 75mg/100g in fruits after 21 days of storage. Almost 75 per cent ascorbic acid was lost during 21 days of storage. Sanchez *et al* (2003) studied the ascorbic acid in different pear cultivars and the maximum value of ascorbic acid was noticed in Red D Anjou and Coscia (4.4mg/100gin both followed by Packams (3.8gm/100g).

2.2.9 Starch

In 1986 Kvale inferred that the starch content is closely and inversely related with physiological maturity. Starch was considered to be a reliable parameter of maturity. Nitsch

(1953) reported that the starch content in pears rapidly decreased when growth phase slowed down and maturity was set in. Similarly Tewari (1965) observed that the starch was abundant in unripe fruits of *Pyrus pashia.* A study was conducted by Chand (1976), he recorded that continues increase in starch content upto 105 days in Patharnakh and LeConte. Similarly in Smith cultivar upto 90 days of fruit set the starch content increased and thereafter, it decreased till harvest. The starch content increased continuously upto 105 days of fruit development and declined afterwards till harvest maturity in Patharnakh (Mann *et al* 1978) and LeConte (Mann and Singh 1985).

Murayama *et al* (2002) was determined the starch content in La France cultivar of pear after the harvest, the fruits were harvested at proper maturity and stored at 20 degree Celsius. Starch content was recorded daily for 30 days during storage, the starch content continuously decrease upto 13 days during storage thereafter no change in starch content.

2.2.10 Total Phenols

Arzani *et al* (2008) observed that, there was also change in the total phenolic contents of the three pear fruits during storage. It decreased from Stage 0 (at harvest) with 6.5, 5.3 and 4.7 mg·TAE g^{-1}DW in 'KS'9, 'KS'13 and 'Shahmiveh', respectively to Stage 5 (after 5 months) 2.3, 1.9 and 1.5 mg·TAE g^{-1}DW in 'KS'9, 'KS'13 and 'Shahmiveh', respectively. The total phenolic acid was highest at time of harvest in'KS' 9 (386 mg/100gm) followed by 'KS' 13 (376 mg/100gm) and 'Shahmiveh' (249 mg/100gm). In fruits and vegetables the total phenol content may either increase or decrease depend on the storage conditions as reported by Kalt (2005). Bhattacherjee *et al* (2011) observed that decreasing trend in the content of polyphenols in aonla juice during storage. When juice was obtained from fresh, 10 or 30 days steep preserved fruits and stored up to 9 months under ambient conditions, the content of polyphenols decreased from 3.09 to 2.35, 2.02 to 1.34 and 0.57 to 0.51 per cent, respectively.

The total phenolic content was measured in six different pear cultivars at maturity by Sanchez *et al* (2003) and the highest content was observed in Red D Anjou (200.5 mg/kg peel), followed by Bosc and Furelle (166.5 and 164.1 mg /100g peel respectively).

2.2.11 Physiological loss in weight

Generally, products lose about 5 per cent of their fresh weight before their visual appearance is affected. For the cactus pear 8 per cent weight loss was necessary to affect their visual appearance as reported by Rodriguez–Felix *et al* (1992). In three different prickly pear cultivars weight loss was observed during storage at different interval, the maximum weight loss was observed in Naranjona (8.5%) at 14 days after storage followed by Balanca Cristalina and Esmeralda (2.4 and 1.4 respectively) by Perez *et al* (2005). Kaur *et al* (2013) was observed physiological loss in weight during storage days from 30 to 75days at cold temperature in Punjab Beauty, result shows linear increase in PLW. At 30^{th} the PLW was

1.2% that increases to 5.1% after 75 days of storage.

2.2.12 Antioxident activity

Ieguchi *et al* (2015) reported that the DPPH radical scavenging activity in fruit of pear and apple in 2011 was higher than it in 2010. In 2011, the accession which had the highest DPPH radical scavenging activity was in i0868 cultivar of apple (1.40 mg g^{-1} FW and 19.76 μmol g^{-1} FW), and the lowest in i0960 (0.08 mg g^{-1} FW and 0.81 μmol g^{-1} FW). It was confirmed that 'Iwateyamanashi' contained the higher DPPH radical scavenging activity than Japanese pear cultivars.

2.3 Nutrients

In pear fruit, the optimum P concentration ranged between 700 and 1000 mg P (kg dw^{-1}). In pear fruits, Mg ranged between 350 and 1000 mg kg dw^{-1} depending on fruit stage. The Mg accumulates linearly at a slow rate throughout the growing season (Tagliavini *et al* 2000). Calcium differs from other nutrients because it is transferred to fleshy fruit in amounts much smaller than leaves (Saure 2005). Some authors reported that Ca uptake by the fruit occurs only during the first part of fruit growth (Faust 1989) or linearly until harvest (Zavalloni *et al* 2001).

Iron concentration in pear fruits was low, ranging from 20 to 35 mg Fe kg dw^{-1}.Copper concentration in pear fruits was also low, ranging from 5 to 13 mg Cu kg dw^{-1}. Apple fruit is a strong sink for K and it normally contains significant amounts of K, with concentration ranging from 0.55 to 0.8 kg K Mg^{-1} fruit d.w. (Zavalloni *et al* 2001). Total fruit Ca concentration was in the range of 200-400 ppm (dw), but differed between the peel and the flesh, where it reached much higher concentrations (>700 ppm).

Epsino *et al* (2003) studied the mineral content from fully ripe pulp of three prickly pear cultivars (Naranjona, Blanca Cristalina and Charola) at fruit maturity. At the maturity potassium was the highest mineral 610ppm in Naranjona, 720ppm in Blanca Cristalina and 630ppm in Charola foolowed by calcium 110ppm in Naranjona, 170ppm in Blanca Cristalina and 160ppm in Charola, sodium 160ppm in Naranjona, 120ppm in Blanca Cristalina and 120ppm in Charola, magnesium 100ppm in Naranjona, 90ppm in Blanca Cristalina and 110ppm in Charola, manganese 33ppm in Naranjona, 81ppm in Blanca Cristalina and 82ppm in Charola, phosphorous 50ppm in Naranjona, 61ppm in Blanca Cristalina and 50ppm in Charola, iron 28ppm in Naranjona, 19ppm in Blanca Cristalina and 18ppm in Charola, zinc 16ppm in Naranjona, 12ppm in Blanca Cristalina and 14ppm in Charola and copper 5ppm in Naranjona, Blanca Cristalina and Charola on dry weight basis. Calcium was the most abundant mineral in different asian and europian cultivars in KS_9 1423 mg kg^{-1} DW, in KS_{13} 1316 mg kg^{-1} DW and in Shahmiveh 956 mg kg^{-1} DW at fruit harvesting followed by iron in KS_9 73 mg kg^{-1} DW, KS_{13} 69 mg kg^{-1} DW and in Shahmiveh 66 mg kg^{-1} DW, manganese in KS_9 55 mg kg^{-1} DW, KS_{13} 59 mg kg^{-1} DW and in Shahmiveh 48 mg kg^{-1} DW, boron in KS_9

39 mg kg^{-1} DW, KS_{13} 37 mg kg^{-1} DW and in Shahmiveh 30 mg kg^{-1} DW, zinc in KS_9 27 mg kg^{-1} DW, KS_{13} 19 mg kg^{-1} DW and in Shahmiveh 14 mg kg^{-1} DW and copper in KS_9 4.5 mg kg^{-1} DW, KS_{13} 5.1 mg kg^{-1} DW and in Shahmiveh 6.4 mg kg^{-1} DW at fruit maturity (Arzani *et al* 2008).

CHAPTER-III

MATERIALS AND METHODS

The present investigations "Biochemical characterization of pear varieties at fruit maturity and their ripening behaviour" was conducted at the Department of Fruit Science, Punjab Agricultural University, Ludhiana. The experimental details regarding the studies have been presented here under.

3.1 EXPERIMENTAL DETALS

The fruits of fourteen varieties of pear were harvested from Pear plantation at Fruit Research Farm and analysis was conducted in the Post-Graduate Laboratory, Department of Fruit Science and Department of Biochemistry, Punjab Agricultural University, Ludhiana. To study the difference in physical and biochemical properties of fruit at fruit maturity and change occur during storage at room temperature. The fruits were stored at ambient room temperature during the course of study in the laboratory. The fruits were taken out and analyzed for physicochemical attributes after 0, 3, 6, 9, 12, 15 and 18 days after storage (DAS).

3.2 OBSERVATIONS RECORDED

3.2.1 Physical characteristics of fruits

3.2.1.1 Fruit shape

The shape of the fruit was recorded by visual observation and as per discriptor.

3.2.1.2 Fruit weight

Fruit weight was recorded with the help of electronic balance at fruit maturity and expressed in gm.

3.2.1.3 Fruit firmness

Penetrometer was used to measure the fruit firmness. Two different sites each fruit were chosen and penetrometer was gently inserted into flesh and the reading was expressed as kg/cm^2.

3.2.1.4 Length and diameter of pedicel

The length and diameter of pedicel at fruit maturity were recorded by using Vernier's Calliper's and expressed in mm.

3.2.1.5 Number of lenticels/cm^2

Number of lenticels/cm^2 were counted with the help of magnified lens.

3.2.1.6 Fruit length

The fruit length at fruit maturity was measured with the help of Vernier's Calliper's.

3.2.1.7 Fruit diameter

The fruit diameter at fruit maturity was measured with the help of Vernier's Calliper's.

3.2.1.8 Pulp colour

Pulp colour was recorded by using Royal Horticultural Society colour chart (Wilson 1938) where a standard value was given for different colours.

3.2.1.9 Dry weight

With the help of electronic balance fruit weight was taken and then fruits were oven dried at 65 ^{0}C. After that the fruit weight was recorded again taken and dry weight was calculated as per formula given below.

Dry weight= Fresh weight-Oven dried weight

3.2.1.10 Fruit volume

It was measured by placing the fruit in the measuring cylinder with the known quantity of water and water displaced by the fruit was recorded as fruit volume.

3.2.1.11 Physiological loss in Weight

The weight of fruits stored at room temperature storage was recorded at 3, 6, 9, 12, 15 and 18 days after storage and percent physiological loss in weight was recorded as per formula given below:

$$\text{PLW } (\%) = \frac{\text{Initial weight- Final weight}}{\text{Initial weight}} \times 100$$

3.2.1.12 Colour Measurement

The colour of pear in terms of *L*, *a*, *b* values were observed by using Hunter Lab minis can XE Plus colorimeter (HAL, USA, Model 45/0-L). Fruits were positioned in such a way that the nose cone on the surface of the pear so that the light thrown by the colorimeter was not leaked. For the study values were recorded at four different places from each sample and average were taken. The colorimeter was standardized with black and white calibration tiles before starting the actual readings.

3.2.2 Chemical characteristics of fruits

3.2.2.1 Total Soluble Solids (TSS)

TSS was measured in terms of Brix (%) with hand refractometer. Juice extracted from pear fruits was mixed to form a composite sample and smeared on the refractometer. The reading was recorded and adjusted according to temperature correction factor (AOAC 1990).

3.2.2.2 Total sugars

For the sugars, pear fruit juice (10ml) was put in 100 ml beaker and made final volume with distilled water. One gram of lead acetate were added in the solution for precipitating the needless matter. The solution was kept undisturbed for 30 minutes. Further for removal excess of lead, potassium oxalate (1g) was added into the solution. Then the solution was filtered to use for estimation of total sugars and reducing sugars.

Total sugars were estimated by taking 25 ml of above Aliquot in 100 ml of measuring flask. To this solution 25 ml of distilled water and 5 ml of 60 per cent concentrated HCl was added and then left for 24 hours at room temperature for acid hydrolysis. After the 24 hour storage, flasks were placed on water bath at 60^{o}C which had been heated previously. The excess of HCl was neutralised with 10% NaOH in the initial stage and 0.1% NaOH near the neutralisation point. The neutralised solution was titrated against Fehling's solution A and B (5ml each) using methylene blue as indicator. Titration was continued till brick red colour appeared. The results were expressed in %.

$$\%\ \text{Total Sugars} = 0.05 \times \frac{\text{Stock Sol.}}{\text{Wt. of Sample}} \times \frac{\text{Second Stock Solution}}{\text{Sol. of Aliquot used} \times \text{Vol. of Sol. used}} \times 100$$

3.2.2.3 Reducing sugars

The filtered solution was poured in 50 ml burette and titrated against boiling Fehling's solution A and B (5ml each). Methylene blue (four drops) was used as an indicator and was titrated up to brick red colour appearance at the end point to estimate the reducing sugars.

Re ducing sugars % = titrate value against

$$\text{Fehling solution} \times \frac{\text{Stock solution}}{\text{Weight of Sample} \times \text{Sol. Used}} \times 100 = 0.05 \times \frac{100}{10 \times \text{'A'}} \times 100$$

3.2.2.4 Non reducing sugars

Subtraction of reducing sugars from the total sugars in juice gave the figure of non reducing sugars after multiplying the values with the factor (0.95) as suggested by AOAC(1990).

Non-reducing sugars = (Total sugars – Reducing sugars) x 0.95

3.2.2.5 Acidity

Acidity was determined by titrating 2 ml of juice against 0.1 N NaOH solution and using phenolphthalein as an indicator. The appearance of light pink colour marked the end point of titration. The titratable acidity is expressed as of anhydrous tartaric acid and calculated using formula:

$$\text{Juice acidity (\%)} = 0.0067 \text{ x } \frac{\text{0.1 N NaOH used}}{\text{Juice taken(ml)}} \text{ x } 100$$

3.2.2.6 pH

The pH of fruit juice was measured using pH meter (Hanna pH-meter HI 9021 Germany).

3.2.2.7 Preperation and sample free sugars (Dubois *et al* 1956)

Reagents used:

1. 80% ethanol

2. 70% ethanol
3. Saturated solution of basic lead acetate
4. Sodium oxalate crystals

Extraction:

Samples of known weights (100mg) were collected and homogenized in 80% ethanol and centrifuged. The sugars were extracted by keeping the samples on water bath for 30 minutes. The residue was re-extracted with 70% ethanol to complete extraction, supernatants were pooled and used for estimation of all type of sugars (glucose, sucrose and fructose). Residue left after ethanol extraction was kept for analyzing starch content.

3.2.2.7.1 Estimation of glucose (Dubois *et al* 1956)

Reagents used:

1. Concentrated sulphuric acid (H_2SO_4)
2. 5% Phenol (w/v redistilled grade)
3. 0.1ml of pooled supernatent

Estimation:

0.1 ml of pooled supernatant sugar extract was taken from above, 1 ml of 5% phenol was added to it and kept for 10 minutes followed by addition of 5 ml of concentrated sulphuric acid. The sulphuric acid was poured directly in the middle of the test tube to ensure proper mixing of the solutions. After 10 minutes the tubes were cooled to room temperature under running water. After another 20 minutes the absorbance was measured at 490nm against reagent blank. The concentration of total sugars was calculated from glucose standards (10-60µg) run simultaneously.

3.2.2.7.2 Estimation of sucrose (Roe 1934)

Reagents used:

1. 0.1% Resorcinol
2. 30% Hydrochloric acid
3. 6% Potassium hydroxide solution
4. 0.1ml of pooled supernatent

Estimation:

0.1 ml of sugar extract (pooled supernatant) was taken in test tube, 1 ml of distilled water was added to make the final volume which was followed by addition of 0.5 ml of 6% KOH. The tubes were kept in boiling water bath for 20 minutes. Cooling the tubes to room temperature, then by adding 1 ml of 0.1% resorcinol and 3 ml of 30% HCl and kept in water bath at 80ºC for 10 min. The tubes were kept cooled and the color developed was read at 460 nm. By taking different concentrations ranging from 10-60 µg standard curves were prepared.

3.2.2.7.3 Estimation of fructose

To one ml of sugar extract, add one ml of 1% resorcinol to it. After this, 3 ml of 30%

HCl was added and then solution was mixed on the vortex mixture properly. After this, the tubes were kept in water bath at 80 °C for 20 min and then cooled immediately. The fructose was estimated at 540 nm by the method of William and Slattery.

3.2.2.7.4 Estimation of Starch (By Anthrone Reagent)

Reagents used:

1. Anthrone: Dissolve 200 mg anthrone in 100 ml of ice-cold 95% sulphuric acid
2. 80% ethanol
3. 52% perchloric acid
4. Standard glucose- 10 ml of stock diluted to 100 ml with water (100 µg/ml)

Procedure:

To make the standard curve for estimation of starch 0, 0.2, 0.4 up to 1ml of standard solution was added in different test tubes. Take 4 of sample from residue left after extraction. In the test tubes keep first one as such do not add anything, in the second, add 0.2ml of standard solution, in third 0.4 ml and so on respectively so that 0.2-1ml of solution is added in five test tubes. Then water was added to all tubes to make it to the level of 1ml. After this 4ml of anthrone reagent was added and all the test tubes were heated in boiling water bath for 10 minutes. Cool it rapidly. The colour will change to blue green. Optical density was read at 630nm.

3.2.2.8 Estimation of Total phenols (Swain and Hills 1959)

Reagents used:

1. 80% methanol
2. 1 N Folin & Ciocalteau's phenol reagent
3. Saturated sodium carbonate solution prepared by dissolving 17.5 g sodium carbonate in 50 ml distilled water.

Extraction:

Samples (0.5 g dry weight) was weighed and transferred into conical flasks. The samples were extracted with 100 ml of 80% aqueous methanol. The suspension of the pear pulp samples were incubated for four hours at different temperatures (40°C, 50°C, 60° C, 80°C, and 100°C) with intermediate shaking. The extracts were filtered with whatman no.1filter paper and each filtrate was adjusted to final volume of 100 ml with methanol.

Procedure:

The level of total phenols in the dry pear sample extracts was determined by using Folin–Ciocalteu reagent and external calibration with gallic acid. Briefly; 0.2 mL of extract solution and 0.2 mL of Folin–Ciocalteu reagent were added and the contents mixed thoroughly. After 4 min, 1 mL of 15% Na_2CO_3 was added, and then the mixture was allowed to stand for 2 hour at normal temperature. The absorbance was measured at 760 nm using a spectrophotometer. The concentration of the total phenolics was calculated as mg of gallic

acid equivalent by using an equation obtained from gallic acid calibration curve. The determination of total phenolic compounds in the fractions was carried out in triplicate and the results were averaged.

3.2.2.9 Estimation of crude fibre

Principle:

After boiling the known sample of pear (fresh weight) with an acid mixture, the undissolved residue was separated and ignited. The crude fibre value was calculated from the ignition loss

Materials:

- Sulphuric acid solution: 1.25 g conc. sulphuric acid diluted to 100 mL
- Sodium hydroxide solution: In 100 mL of distilled water 1.25 g of sodium hydroxide solution was added.

Procedure:

- With the help of ether or petroleum 10 g of ground sample of pear fruit (fresh weight) was extracted to remove fat. It should rise within temperature (Initial boiling temperature 35-38º C and Final temperature 52ºC). Extraction can be omitted if fat content was below 1%.
- Boil 5 g of dried material after extraction with ether to 200 mL of sulphuric acid for atleast 30 min. with the help of humping chips.
- Muslin cloth was used for filtiration and wash the extract with boiling water till washings no longer acidic.
- 30 min.boil with 200 mL of sodium hydroxide solution.
- Again with the help of muslin cloth filtering and washing with 25 mL of boiling 1.25 % sulphuric acid
- Transfer it to the ashing dish and remove the residue.
- Residue is dried for 2 hours at 130±2º C.
- Placed the dish for cool down in a dessicator and weigh it.
- At final stage it was placed at 600± 15º C ignite for 30 min.
- Again cooled it and reweigh was recorded to calculate the fibre.

3.2.2.10 Ascorbic Acid

Titration method was used to determined the ascorbic acid by using 2, 6-dichlorophenol indophenols dye solution (0.4 %) which was standardized against standard ascorbic acid (AOAC, 2000). 10 ml of sample was used to make 100 ml volume with 0.4 percent oxalic acid and filtered. 10 ml of this filtrate was mixed with 15 ml of 0.4 percent oxalic acid and titrated with standard dye. The end point was recorded when pink colour persisted for 10-15 seconds. The results were expressed as mg per 100 gm of sample.

$$\text{Ascorbic acid mg/100 g} = \frac{\text{Titer x Dye factor x volume made}}{\text{Aliquot taken x Weight of sample}} \text{ x } 100$$

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

3.2.2.11 TSS/acid ratio

By dividing the value of TSS with that of the corresponding titrable juice acidity TSS/acid ratio was determined.

3.2.3. Estimation of Macro and micro-elements from fresh fruit pulps

3.2.3.1 Preparation of samples

For the estimation of macro and micro-nutrients, the pear fruit pulp samples were dried in hot air oven at 65ºC for 48 hours. Then the samples were grounded and stored in moisture proof butter paper bags for analysis. Before estimation, the samples were again dried at 65ºC for two hours.

3.2.3.2 Estimation of nitrogen

To determine nitrogen content, 0.5g of dried ground sample was digested with 8-10 ml of concentrated H_2SO_4 and digestion mixture in *Kel Plus Nitrogen Estimation System* (Pelican Equipment, India). Half gram of powdered sample was taken in a digestion tube. Four to five gram of the catalyst mixture consisting of 250g of K_2SO_4 with 50 g $CuSO_4$ and 5g metallic selenium (50:10:1) was added to digestion tube. Digestion tubes were heated in the digestion block up to temperature 410ºC and the end point is marked when colour of the samples changes from colourless or light green.

The digested samples were transferred to the distillation apparatus (Pelican Equipment,India). The digested sample gets diluted with distilled water as the distillation begins and subsequently 40% NaOH was poured into the distillation tube. In 150ml conical flask, 10ml of 4% boric acid was taken and two indicators were used. The digested samples were heated by passing steam in distillation tube. With the addition of alkali ammonia is liberated which gets collected in 4% boric acid. This boric acid was then utilized for titration.

The boric acid distillate in a conical flask was titrated with 0.1 N H_2SO_4. During titration the colour changed from bluish green to permanent pale pink. The percentage of nitrogen was calculated by using following formula:

$$\text{Nitrogen (\%)} = \frac{14 \times \text{normality of acid}}{\text{Sample weight} \times 100} \times 100$$

3.2.3.3 Digestion for the estimation of phosphorous and potassium

For determination of phosphorous and potassium, 0.5g sample were taken in the digestion tube along with 8-9 ml di-acid mixture consisting of nitric acid (HNO_3) and per-chloric acid in the 4:1 ratio. The mixture was allowed to stand overnight and then digested. At

starting the temperature was kept low and was increased gradually. The end point was reached when fumes started coming out of the digestion tubes and colourless solution is obtained. The digestion tubes were removed and allowed to cool down. After cooling, double distilled water was added for dilution of the contents and filtered. The volume was made upto 100ml with double distilled water after filterations.

3.2.3.4 Estimation of phosphorous

The phosphorous was determined by Vanado-molybdo phosphoric yellow method as described by Chapman and Pratt.

For this take twenty five gram of ammonium molybdate was dissolved in a beaker containing distilled water. Ammonium metavanadate (1.25g) was dissolved separately in 300 ml boiling water in another beaker. The solution was cooled and 250ml of concentrated nitric acid was added and again solution was cooled down to room temperature. Both the solutions were mixed and final volume was made to one litre with distilled water.

From digested sample 5 ml was taken in a 25ml volumetric flask and 1-2 drops of 2,4- Dinitrophenol indicator were added. Then dropwise, add 4 N Na_2CO_3 solution till the appearance of yellow colour. After this 6N HCl was added drop wise till yellow colour disappeared. Then 2 ml of 6N HCl was added in excess to get required pH of 4.8 followed by addition of 5 ml of vanadate molybdate reagent. With distilled water the volume was made to 25ml and allowed to stand for 30 minutes for colour development.

The stock solution of 50 ppm was made using 1000 ppm standard solution of phosphorous. From this 50 ppm solution 0.0, 0.5, 1.0, 1.5, 2.0,2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 ml solutions were taken in separate 25 ml volumetric flasks and colour was developed in the same as described for the test samples. Colour intensity was measured at 470 nm wavelength on a Spectrophotometer (Thermo Fisher) and standard curve was constructed. Phosphorous content was estimated from the standard curve and calculated by following formula:

$$\text{Phosphorous (\%)} = \frac{\text{ppm} \times \text{total dilution}}{10{,}000}$$

3.2.3.5 Potassium determination

Potassium was estimated by the Flame Photometer method (AOAC 1990).

10ml solution was taken from 1000 ppm potassium stock solution in a 100 ml volumetric flask and volume was made up to mark with distilled water to make 100 ppm stock solution. Out of this 100 ppm stock solution 1,2,4,6,8 and 10 ml were taken in 100ml volumetric flask and volume was made up to mark with distilled water to get 1, 2, 4, 8 and 10 ppm solution. For estimation of potassium in test samples, 1 ml of digested sample was taken in 25 ml volumetric flask and volume was made up to mark with distilled water. Then the samples were fed to the atomizer of the Flame Photometer (Elico, India) which had been adjusted with standard K solution and readings were noted. The concentration of K present in

the test samples were found from standard curve and expressed as per cent K according to the formula as given below:

$$\text{Potassium (\%)} = \frac{\text{ppm} \times \text{total dilution}}{10{,}000}$$

3.2.3.6 Estimation of Ca, Mg, Fe, Mn, Cu and Zn

Nutrients like Ca, Mg, Fe, Mn, Cu and Zn were estimated with Atomic Absorption Spectrometer (A Analyst 200, Perkin Elmer, USA) described by Bradfield and Spencer (1965).

3.3 Statistical Analysis

The experimental data were statistically analysed by using the SAS 9.3.

CHAPTER-IV

RESULT AND DISCUSSION

The data pertaining to the variation in physical, chemical and nutrient attributes of different Pear cultivars at fruit maturity and changes occurs in biochemical attributes were recorded at 0, 3, 6, 9, 12, 15 and 18 days interval at ambient temperature storage during the year 2016. The results are presented and discussed in the light of available literature under the following heads and sub heads.

4.1 Physical, chemical and nutrient variation in different varieties of pear at maturity.

4.2 Changes occur in biochemical attributes recorded at 0, 3, 6, 9, 12, 15 and 18 days interval during room temperature storage.

4.1 Physical, chemical and nutrient variation in different varieties of pear at maturity

4.1.1 Physical parameters

4.1.1.1 Fruit Weight and Volume

The variation in fruit weight and volume was observed in among different varieties of pear with an average range from 77.77-166.04gm and 76-167.3ml respectively, Significantly maximum fruit weight and fruit volume was observed in Punjab beauty (166.04gm and 167.3ml) which was at par with Orient (165.63gm and 165.83ml) followed by Keiffer (147.57gm and 143.67ml). The minimum fruit weight and fruit volume was recorded in Housi (77.77gm and 76ml). All other varieties showed result in between this range. Similarly, Sandhu *et al* (2002) showed variation in fruit weight in among different varieties of pear and recorded maximum fruit weight of 122.5gm in Punjab soft and minimum in Kosui 66.48gm. Fruit volume follows the same trend as in case of fruit weight (Rachna 2003).

4.1.1.2 Fruit Length and Diameter

The perusal of data indicated that the fruit length varied differently among the different pear cultivars. Maximum fruit length was noticed in the Tisuli (74.27mm) and showed at par result with Punjab beauty (74.08mm) at harvest stage. Significantly minimum fruit length was recorded in Kosui (46.46mm) and results was at par with Shinseiki (48.42mm). However among the different varieties of pear significantly maximum fruit diameter was noticed in Orient 68.76mm and was at par with Punjab beauty 65.78 mm and Keiffer 64.34 mm at par with orient. The minimum fruit diameter was recorded in Kosui 51.53 mm and Hosui 52.55 mm. In the same way Aswapati and Uthaibathra (1990) recorded variation in fruit length and maximum was recorded in Red Pear 9.09cm followed by Pien Pu 8.72 and the minimum value was 5.38cm in Kosui. The variation in fruit length and diameter in different pear varieties may be due to genetic variability and their interactions with environment.

4.1.1.3 Fruit Firmness

The Pear varieties showed variation in fruit firmness significantly and it ranges from 3.41-10.86 kg /cm^2, which might be due to the differences in cell density per unit area. At the harvest time the maximum fruit firmness was recorded in the variety orient (10.86 kg/cm^2) which was at par with Packam triumph (10.76 kg/cm^2) and Tisuli (10.5 kg/cm^2). Minimum value of fruit firmness was recorded in Shinseiki (3.41 kg/cm^2). Which was significantly less from all other varieties. Similar study was also conducted by Singh (1998) and noticed that flesh firmness ranged from 9.0 lb/$inch^2$ in 'YaLi' to 10.7 lb/$inch^2$ in 'Shinseiki'.

Table 1: Variability of physical characters at fruit maturity in different pear cultivars.

Varieties	Fruit Weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit firmness (kg/cm^2)	Fruit volume (ml)	Lenticels (cm^{-2})	Dry weight (g/100g)	Pedicel length (mm)	Pedicel diameter (mm)
Nijisseiki	105.81	52.35	57.41	4.61	106.00	31.00	7.267	33.7	2.43
Punjab Soft	123.14	69.32	59.34	8.00	123.67	23.00	10.53	45.29	2.85
Punjab Gold	143.00	66.02	62.38	8.41	143.33	19.33	12.26	29.06	4.15
Punjab Nector	131.57	70.97	59.68	8.66	131.67	15.66	9.16	42.59	3.53
Punjab Beauty	166.04	74.08	65.78	8.71	167.3	12.00	13.56	45.22	4.68
Punjab Nakh	129.63	62.33	60.13	9.58	129.83	44.66	14.30	34.68	3.23
Kieffer	147.57	66.38	64.34	8.58	143.67	37.66	10.03	27.16	3.12
Hosui	77.77	49.3	52.55	6.66	76.00	38.00	9.16	31.41	2.26
Tisuli	107.63	74.27	53.37	10.50	106.00	24.33	10.36	36.30	5.17
Orient	165.63	63.82	68.76	10.86	165.83	25.00	13.26	30.86	3.60
Baggugosha	123.73	62.6	60.53	8.75	123.67	24.60	14.26	33.60	3.50
Packam Triumph	97.77	59.76	55.52	10.76	97.67	32.00	14.76	35.54	3.53
Kosui	78.37	46.46	51.53	5.70	78.67	27.64	8.03	21.73	2.71
Shinseiki	108.4	48.42	57.94	3.41	108.83	24.00	11.96	24.77	3.47
LSD ($p<0.05$)	22.43	7.35	5.12	0.73	22.7	8.74	0.41	8.42	0.99

4.1.1.4 Lenticel's

Variation was also found in lenticel's/cm^2, ranging from 12 to 44 per cm^2 in different varieties of pear. The maximum number of lenticels (44.66/cm^2) were recorded in Punjab nakh having at par results with Hosui 38/cm^2 and Keiffer 37.66cm^{-2} which differ significantly from all other varieties. Minimum value (12/cm^2) was found in Punjab beauty. Similarly, Singh 2002 recorded variation in lenticels among different strains of hard pear and

observed the maximum number of lenticels 118.3/inch ^{2} in strain VI and minimum in strain X 53.6inch^2. Shyamali (2006) also reported lenticels variation among different varieties and mentioned higher number of lenticels in Shinseiki 45/cm^2 and Yali 37/cm^2 at fruit maturity.

4.1.1.5 Dry Weight

The examination of data observed that the dry weight of different varieties of pear was ranging from (7.26 to 14.76 gm/100gm) of fresh weight. The significantly higher value of dry weight was recorded in Packam triumph (14.76 gm/100gmFW) followed by Baggugosha (14.26 gm/100gmFW). Minimum value was observed in Nijjisseiki (7.267 gm/100gmFW) among the varieties studied.

4.1.1.6 Pedicel length and Diameter

Data pertaining to pedicel length and diameter indicated that the significantly maximum pedicel length was noticed in Punjab soft (45.29 mm) which was at par with Punjab beauty (45.22 mm). However Punjab nector (42.59 mm) and the higher pedicel diameter was noticed in Tisuli (5.17 mm) and showed at par result with Punjab beauty 4.68 mm. The minimum value of pedicel length was observed in Kosui (21.73 mm) having at par result with Shinseiki (24.77 mm) whereas the lowest value of pedicel diameter was noticed in Hosui (2.26 mm) at maturity. Range of pedicel length and diameter varied from, 21.73 to 45.29 mm and 2.26 to 5.17 mm respectively. Shyamali (2006) also observed that, pedicel diameter ranged from 0.27 cm in Yali to 0.3cm in Kosui and the maximum pedicel length was observed in variety Yali 5.12 cm and lowest in Hosui 2.31cm at the time of maturity. Griggs and Iwakiri (1977) and Sandhu *et al* (2002) also observed variation in pedicel length and maximum length was observed in Yali.

4.1.1.7 Pulp colour

Colour of the fruit pulp varied from variety to variety. In the different cultivars of pear the fruit pulp colour varied from white to brownish tinge at the time of fruit maturity (table 2). Punjab gold, Punjab nector and Orient have white coloured flesh. Punjab soft, Punjab beauty, Punjab nakh, Kieffer, Baggugosha and Packam triumph came under the group have creamy white coloured flesh. Nijjiseki, Hosui, Kosui and Shinseiki varieties have brownish tinge flesh.

4.1.1.8 Fruit shape

In different pear varieties fruit shape varied significantly, the turbinate shape was observed in Punjab soft and turbinate to roundish in Punjab nakh and round shape in Hosui and Kosui. Punjab gold have oblong ovate pyriform shape, Punjab beauty was obovate obtuse pyriforma, Punjab nector obovate acute pyriform, Orient and Shinseiki had oblate shape. Similarly roundish fruit shape of 'Patharnakh' and 'Smith' and pyriform fruit shape in 'LeConte' was observed by Gupta and Chohan (1976) and Singh (1998) noticed that the shape of Asian pears are round, while turbinate shape found in 'YaLi'

Table 2: Variability of physical characters (fruit shape, fruit and pulp colour) at fruit maturity in different pear cultivars.

Varieties	Pulp colour	Fruit shape	L	A	b	C	h
Nijisseiki	Brownish tinge	Oblate	49.08	7.88	30.43	31.43	74.70
Punjab Soft	Creamy white	Turbinate	57.98	-10.08	38.34	39.64	101.73
Punjab Gold	White	Oblong ovate pyriform	61.25	-7.8	35.11	35.96	102.52
Punjab Nector	White	Obovate acute pyriform	65.7	-8.15	41.01	41.81	101.24
Punjab Beauty	Creamy white	Obovate obtuse pyriform	64.12	-8.05	42.15	42.91	100.82
Punjab Nakh	Creamy white	Turbinate to roundish	57.38	-2.07	43.76	43.81	92.71
Kieffer	Creamy white	Globular	46.67	-3.95	39.077	39.27	95.78
Hosui	Brownish tinge	Round	43.6	9.34	31.78	33.12	73.62
Tisuli	Greenish white	Elongated	59.95	-10.83	40.72	42.17	104.77
Orient	White	Oblate	57.47	-11.05	40.56	42.05	105.23
Baggugosha	Creamy white	Ovate	67.08	-7.57	47.64	48.24	99.04
Packam Triumph	Creamy white	Bulbous	58.31	-7.8	39.15	39.96	101.41
Kosui	Brownish tinge	Round	47.13	2.26	32.19	32.33	85.99
Shinseiki	Brownish tinge	Oblate	51.29	10.38	32.36	34.03	71.8
LSD ($p<0.05$)	------	------	2.27	2.07	3.26	3.21	3.36

4.1.1.9 Hunter l a b

To measure the fruit colour of different pear varieties, the Hunter 'L', 'a' and 'b' colour scale was used which showed that there were significant variation in color. The L value was recorded less than 50 in of all the varieties, which indicate the brightness in the colour. The negative value of 'a' depicts greenish colour of fruit. The positive value of 'b' indicate the yellowish colour in the fruit (Pannu 2012). In table 2, the maximum value for L was observed in Baggugosha (67.08) which was at par with Punjab nector (65.70), whereas the minimum value for 'L' (43.6) was noticed in Hosui. The highest value of 'a' was observed in Shinseiki (10.38) at par with Hosui (9.34) and the highest value for 'b' was observed in Baggugosha (47.64) and minimum value for 'a' was recorded in Orient (-11.05), while for 'b' the lowest value was observed in Nijjisheiki (30.43).

4.1.2 Chemical parameters

4.1.2.1 TSS

Total soluble solids content in different varieties of pear varied from 9.70 to 14 % at fruit maturity. The maximum value of TSS was recorded in Punjab beauty (14%) which was at par with Punjab gold (13.8%) and the minimum value was noticed in Punjab soft (9.7%). Similarly, Singh (1998) observed the variation in TSS among the different varieties of pear and observed maximum value for TSS in Hosui 14% and lowest in Yali 11%. Dhillon *et al* (2007) observed that TSS 15.16% in 'Punjab gold' which was higher than 'Punjab beauty' (15.01%) at fruit maturity.

Table 3: Variability of chemical characters at fruit maturity in different pear cultivars.

Varieties	TSS (^{0}B)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar(%)	Ascorbic acid (mg/100g)	pH	TSS:acid ratio
Nijisseiki	11.8	0.16	5.33	4.17	1.10	8.53	5.18	73.75
Punjab Soft	9.70	0.17	4.80	3.80	0.95	8.25	5.19	57.06
Punjab Gold	13.80	0.21	6.96	5.13	1.55	8.04	4.80	65.71
Punjab Nector	12.30	0.22	5.43	4.03	1.33	8.63	4.77	53.90
Punjab Beauty	14.00	0.22	6.96	5.53	1.36	8.97	4.70	63.64
Punjab Nakh	11.80	0.20	5.66	3.96	1.67	9.25	4.77	59.00
Kieffer	10.60	0.21	5.93	4.11	1.78	9.22	4.94	50.48
Hosui	11.60	0.22	7.67	5.66	1.91	9.58	5.41	52.73
Tisuli	13.40	0.25	5.53	3.16	2.25	9.78	5.60	53.60
Orient	11.50	0.28	8.46	6.16	2.19	9.92	5.17	41.07
Baggugosha	13.10	0.23	9.55	6.23	3.15	8.87	4.88	56.90
Packam Triumph	13.50	0.25	7.40	5.20	2.09	9.81	5.08	54.00
Kosui	12.20	0.19	6.00	5.17	0.79	8.70	5.66	64.21
Shinseiki	13.43	0.15	7.33	5.96	1.66	7.33	5.34	89.53
LSD ($p<0.05$)	0.42	0.04	0.57	0.58	0.57	0.06	0.08	0.58

4.1.2.2 Acidity and TSS:acid ratio

It is clear from the data that at the harvest stage maximum acidity content was observed in Orient (0.28%) and the lowest percentage of acidity was noticed in Shinseiki (0.15%) and Nijjisheiki (0.16%). In certain other experiments the maximum juice acid content (0.33%) were recorded in 'Red blush', followed by 'Punjab gold', 'LeConte' (0.32%), 'Punjab nectar' (0.32%), and 'Baggugosha' (0.29%) by Sandhu *et al* (1994). As the TSS and acid ratio depend upon the value or content of TSS and acidity in the fruit juice. The maximum TSS:acid ratio was observed in Shinseiki (89.53) and lowest in Orient (41.07) and

in Keiffer (50.48) (table 3). Similarly Sandhu *et al* (1994) observed that highest average TSS:acid ratio was observed in 'Red blush' (48.5%) followed by 'Punjab gold' (47.5%) and 'Baggugosha' (46.6%) and minimum was recorded in 'LeConte' (39.7%) and in another study in different soft Asian varieties by Shyamali (2006) evaluated, maximum TSS:acid ratio (154.79) in 'Kosui', followed by 'Shinseiki' (108.09), 'Nijjisseiki' (101.114) 'Hosui' (78.89) and 'Yali' (58.75)

4.1.2.3 Sugars

The result of data showd variation in total, reducing and non reducing sugars content at maturity in different varieties of pear from 4.80 to 9.55%, 3.8 to 6.23% and 0.79 to 3.15% respectively. The significantly maximum value of total sugar was observed in Baggugosha (9.55%) and the minimum was recorded in Nijisseiki (5.33%). Similarly, Shyamali and Dhillon (2009) studied the total sugar content in Asian soft pear and observed variation in total sugar content. The observed maximum total sugar in Yali (5.57%) to minimum Shinseiki (4.23%) in at maturity. In several reducing sugar was observed higher as compared to non reducing sugar in all the varieties. The highest value of reducing sugar was also observed in Baggugosha (6.23%) having at par result with Orient (6.16%) and the lowest value was found in Punjab soft (3.80%). Significantly maximum value of non reducing sugar at maturity was also recorded in Baggugosha (3.15%) and the minimum in Kosui (0.79%) at par with Punjab soft (0.95%) and Nijisseiki (1.10%). Similarly, non reducing sugar content was also observed in different cultivars of pear which ranged from 1.06 in Hosui to 3.03 in Shinseiki Sandhu *et al* (2002). Increase in sugars at fruit maturity is due to the hydrolysis of starch into the sugars (Blashkina 1978).

4.1.2.4 Ascorbic acid

The analysis of data showed that the variation in ascorbic acid content at fruit maturity was ranged from 7.33 to 9.92 mg/100g in different varietties of pear. The maximum ascorbic acid content was reported in Orient (9.92 mg/100g) followed by Packam triumph (9.81 mg/100g) and Tasuli (9.78 mg/100g) and minimum value of ascorbic acid was observed in (Shinseiki 7.33 mg/100g). However in apple Jan *et al* (2012) worked on different cultivars and found that the higher ascorbic acid content was observed in cultivar Red Delicious (12.49 mg/100g) follow by Mondial Gala and Royal Gala with 11.53 and 11.43 mg/100g correspondingly and the lower ascorbic acid content was noticed in cultivar Golden Delicious (10.27 mg/100g).

4.1.2.5 pH

The examination of data presented in (table 3) clearly indicated the variation in pH at the fruit maturity, the maximum pH at fruit maturity was recorded in Kosui (5.66) showed at par results with Tisuli (5.60) and the minimum (4.70) was observed in Punjab beauty followed by Punjab nector. The changes in pH may be due to the difference in the rate of

conversion of pectin into pectenic acid and may be to due fermentation of sugars (Kinh *et al* (2001) and Muhammad *et al* (2011)).

Table 4: Variability of chemical characters at fruit maturity in different pear cultivars.

Varieties	Glucose (mg/g)	Sucrose (mg/g)	Starch (mg/g)	Fructose (mg/g)	Phenol (mg/g)	Fibre (%)	Anti Oxidant (mg/g)
Nijisseiki	29.32	5.73	34.76	40.89	57.62	5.54	0.094
Punjab Soft	24.88	5.23	51.04	35.50	73.26	5.12	0.093
Punjab Gold	29.2	6.45	42.52	40.03	79.27	5.74	0.063
Punjab Nector	25.04	5.16	46.33	36.56	65.00	6.54	0.083
Punjab Beauty	27.04	5.89	40.54	37.50	75.8	5.28	0.059
Punjab Nakh	25.04	5.57	47.39	34.70	81.25	6.25	0.066
Kieffer	21.38	5.40	42.67	31.66	62.77	4.32	0.072
Hosui	26.54	5.16	44.04	39.16	55.64	4.56	0.061
Tisuli	25.54	4.47	44.96	36.50	65.67	9.00	0.081
Orient	22.22	6.52	44.04	32.33	61.97	6.34	0.067
Baggugosha	29.54	6.60	27.46	39.66	55.90	6.58	0.054
Packam Triumph	24.38	5.13	46.33	35.50	61.37	8.40	0.081
Kosui	32.04	5.70	27.46	36.63	54.31	4.78	0.083
Shinseiki	31.53	4.68	20.46	33.73	55.23	2.44	0.072
LSD ($p<0.05$)	1.23	0.06	2.74	2.31	0.08	0.06	0.04

4.1.2.6 Glucose, Sucrose and Fructose

At the fruit maturity the maximum fructose content (table 4) was observed in Nijisseiki (40.89 mg/g) showed at par result with Punjab gold (40.03mg/g) and the minimum was recorded in Keiffer (31.66 mg/g). The significantly higher glucose content at the time of fruit harvest was noticed in Kosui (32.04 mg/g) at par with Shinseiki (31.53 mg/g) and the lowest in Keiffer (21.38 mg/g). Similarly Chen *et al* (2006) observed that Fructose and Glucose are the principal monosaccharides in the pear fruit. Fructose was the major sugar in pear fruits followed by Glucose and Sucrose. In several other studies data showed the higher level of fructose, glucose and sucrose at initial stages of fruit maturity in pear fruit (Ackrerman *et al* 1992, Chen *et al* 2006, Gao *et al* 2004, Gao and Wang 1983). In the same way variation was observed in pear and the maximum sucrose content at the fruit maturity was observed in Baggugosha (6.60 mg/g) which at par with Orient (6.52) and minimum in Keiffer and Tisuli (4.40 nd 4.47 mg/g respectively).

4.1.2.7 Starch

The maximum starch content (51.04 mg/g) was observed in Punjab soft which at par with Punjab nector and Packam trimph (46.33 mg/g) and minimum in Shinseiki (20.46 mg/g)

followed by Kosui and Baggugosha (27.46 mg/g) at fruit maturity.

4.1.2.8 Total phenols and antioxidant activity

It is evident from the (table 4) that the significantly maximum phenolic content was observed in Punjab nakh (81.25 mg/g) and minimum in Kosui (54.31 mg/g). However at the time of fruit maturity the maximum antioxidant activity was observed in Nijjiseiki (0.094 mg/g) at par with Punjab soft (0.093 mg/g) followed by Punjab nakh and Kosui (0.083 mg/g) and minimum was recorded in Baggugosha (0.054 mg/g). Six different pear cultivars were studied by Sanchez *et al* (2003) and the total phenolic content was observed at maturity, the highest content was observed in Red D Anjou (200.5 mg/kg), followed by Bosc and Furelle (166.5 and 164.1 mg /100g respectively).

4.1.2.9 Fibre

The perusal of data showed that the similarly highest fibre content (9.00%) was noticed in Tisuli at the fruit maturity and the lowest in Shinseiki (2.44%) (table 4). In genral hard pear varieties has more fibre content as compare to semi soft and soft varieties. Perez *et al* (2005) studied the total dietary fibre content in the pulp of three different prickly pear varieties after harvest, the highest TDF content 7.8% dry weight basis were recorded in Naranjona cultivar and the lowest 4.2% dry weight basis was found in Esmeralda.

4.1.3 Nutrient

The data pertaining to nutrient status of pear pulp clearly indicate that the maximum nitrogen content at the time of fruit maturity was observed in Nijjiseki (0.97%) which was at par with Shinseiki (0.89%), Punjab soft, Punjab beauty and Punjab nakh (0.87% in all three) and minimum was recorded in Punjab gold whereas the maximum pulp phosphorous (0.67%), potassium (2.00%), calcium (2.48%) and magnesium (1.14%) content was observed in Punjab gold cultivar at fruit maturity and the minimum phosphorous (0.30%) and potassium (1.23%) in both Kosui and Shinseiki, calcium in Shinseiki (1.27%) and magnesium in Hosui (0.25%) in (table 5).

The data regarding the micro nutrient status in fruit pulp showed the variation in different cultivars of pear. The higher value of zinc (137.9 ppm) was observed in Tisuli which was at par with Punjab nector (129.6 ppm) and minimum in Packam triumph (62.17 ppm). The content of copper in the fruit pulp was maximum in Punjab beauty (35.63 ppm). The maximum zinc value in the fruit pulp (137.90 ppm) was noticed in Tsuli and minimum in Packam triumph (62.17 ppm). The higher value of manganese content of pear fruit pulp at maturity was observed in Punjab gold (13.50 ppm) and lowest (3.56 ppm) in Orient. Zavalloni *et al* (2001) observed that the iron concentration in pear fruits was low, ranging from 20 to 35 mg Fe kg dw^{-1} and copper concentration in pear fruits was also low, ranging from 5 to 13 mg Cu kg dw^{-1}.

Table 5: Study of nutrient status of mature pear fruit pulp.

Varieties	Nitrogen (%)	Phosph-orous (%)	Potassi-um (%)	Calcim (%)	Magnesi-um (%)	Iron (ppm)	Copper (ppm)	Zinc (ppm)	Manga-nese (ppm)
Nijisseiki	0.97	0.48	1.83	1.29	0.77	106.8	18.55	79.27	5.76
Punjab Soft	0.87	0.45	1.76	1.19	1.05	84.2	20.66	70.70	6.34
Punjab Gold	0.66	0.67	2.00	2.48	1.14	108.9	21.68	90.98	13.5
Punjab Nector	0.81	0.56	1.66	1.31	0.82	107.8	23.66	129.6	8.80
Punjab Beauty	0.87	0.63	1.86	1.19	1.05	122.3	35.63	97.30	7.60
Punjab Nakh	0.87	0.55	1.46	1.35	0.62	64.13	19.04	77.03	6.82
Kieffer	0.71	0.34	1.43	1.99	0.66	92.00	14.66	84.57	11.19
Hosui	0.81	0.37	1.50	1.16	0.25	110.84	26.36	65.53	5.51
Tisuli	0.73	0.52	1.73	1.53	0.86	152.44	19.8	137.9	5.55
Orient	0.82	0.56	1.83	1.38	0.47	120.38	25.16	74.93	3.36
Baggugosha	0.80	0.48	2.00	1.63	0.91	139.5	32.53	71.47	6.26
Packam Triumph	0.75	0.50	2.1	1.87	0.62	85.10	26.46	62.17	4.98
Kosui	0.86	0.30	1.23	1.3	0.36	161.23	21.01	120.63	5.43
Shinseiki	0.89	0.30	1.23	1.27	0.53	126.83	28.73	78.71	11.21
LSD ($p<0.05$)	0.14	0.21	0.25	0.19	0.06	10.07	3.20	9.43	0.98

4.2 Changes in biochemical attributes at 0, 3, 6, 9, 12, 15 and 18 days interval under ambient temperature storage.

4.2.1 TSS

At harvesting time significantly maximum TSS was recorded in Punjab beauty (14%) and minimum value (9.7%) was recorded in Punjab soft. Not much variation was observed upto three days after storage but increasing trend was observed in almost all the varieties. This trend continue upto nine DAS and decline in TSS was observed thereafter in almost all the varieties. Six days after storage at room temperature, the maximum TSS was recorded (15.3%) in Packam triumph and minimum 11.90% in Punjab Soft. Rate of increase also varied in different varieties. Faster variation was recorded in Orient and less variation in Punjab Beauty (fig 1). Thereafter decline trend in TSS was noticed in all other varieties and after fifteen days the maximum value was recorded in Packam triumph 14.10% and the minimum value was (11.20%) in Yali. This variation in TSS during storage may be due to the conversion of starch and other photosynthetic components into sugar. After eighteen days of storage out of fourteen cultivars only four were left namely Nijjisheiki, Punjab soft, Punjab nakh and Keiffer, among which Punjab nakh showed maximum TSS 12.02%. Increase in TSS percentage at maturity may be due to the degradation of starch and organic acids into the

soluble sugars (Dame *et al* 1956).

Table 6: Change in TSS (%) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	11.80	12.20	12.70	12.90	12.50	12.10	11.03
Punjab Soft	9.70	11.80	11.90	12.60	11.40	11.20	11.13
Punjab Gold	13.80	13.80	14.70	14.40	13.80	13.10	-
Punjab Nector	12.30	12.36	13.10	14.50	14.30	13.96	-
Punjab Beauty	14.00	14.10	14.50	13.70	13.20	13.01	-
Punjab Nakh	11.80	12.20	12.92	13.10	13.70	12.90	12.02
Kieffer	10.60	11.80	12.60	13.03	12.82	12.14	11.94
Hosui	11.60	12.00	13.00	12.70	12.00	11.81	-
Tisuli	13.40	14.30	15.00	15.50	14.00	13.90	-
Orient	11.50	13.10	14.90	14.44	13.80	13.00	-
Baggugosha	13.10	13.80	14.50	14.10	13.61	13.08	-
Packam Triumph	13.50	15.10	15.30	15.00	14.60	14.10	-
Kosui	12.20	13.30	13.00	12.61	12.14	11.70	-
Shinseiki	13.43	13.66	13.47	-	-	-	-
LSD ($p<0.05$)	0.42	0.53	0.30	0.31	0.41	0.33	0.19

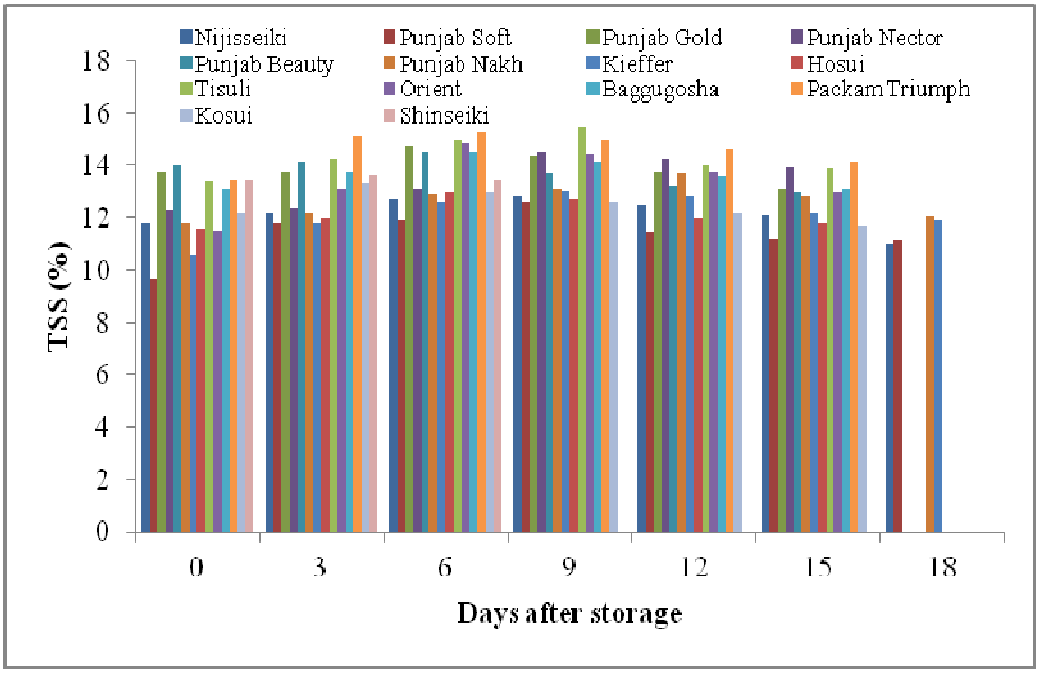

Fig. 1. Change in TSS (%) during storage in different pear cultivars at ambient temperature.

4.2.2 Acidity

The persual of data clearly showed that the titratable acidity decrease continuously all the varieties upto six DAS except shinseiki (ripen at three DAS) and thereafter rise in acidity observed upto fifteen days. Not much variation was observed upto three days after storage but decreasing and thereafter increasing trend was observed in almost all the varieties. After six days of storage (Table 7) the maximum acid content (0.20 %) was observed in Tisuli at par with Punjab nakh, Kosui and Shinseiki (0.18%) and lowest in Nijjiseiki (0.10%) thereafter acidity start increasing in all the varieties and continue up to senescence and at fifteen day of storage the maximum acid content was observed in Punjab beauty (0.32%) and minimum in Punjab gold and Punjab nakh at par (0.16%). Rate of decrease and increase also varied in different varieties. Faster variation was recorded in Baggugosha and less variation in Nijjiseiki variety (fig 2). Gupta and Chohan (1976) and Grewal (1988) recorded that the juice acid content range in 'Patharnakh' fruits of 0.33 to 0.37% and 0.30 to 0.38%. After 7 days storage at ambient temperature, certain rise in acid content was observed.

Table 7: Change in Acidity (%) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	0.16	0.12	0.10	0.10	0.19	0.21	0.22
Punjab Soft	0.17	0.13	0.12	0.19	0.25	0.25	0.19
Punjab Gold	0.21	0.17	0.14	0.18	0.21	0.28	-
Punjab Nector	0.22	0.17	0.15	0.11	0.15	0.25	-
Punjab Beauty	0.22	0.18	0.15	0.18	0.25	0.32	-
Punjab Nakh	0.20	0.18	0.18	0.15	0.11	0.16	0.25
Kieffer	0.21	0.16	0.14	0.12	0.16	0.25	0.28
Hosui	0.22	0.19	0.13	0.21	0.25	0.25	-
Tisuli	0.25	0.22	0.20	0.14	0.25	0.29	-
Orient	0.28	0.21	0.17	0.20	0.22	0.30	-
Baggugosha	0.23	0.18	0.12	0.19	0.25	0.28	-
Packam Triumph	0.25	0.19	0.14	0.16	0.28	0.32	-
Kosui	0.19	0.13	0.18	0.21	0.25	0.25	-
Shinseiki	0.15	0.12	0.18	-	-	-	-
LSD ($p<0.05$)	0.04	0.06	0.02	0.01	0.05	0.05	0.01

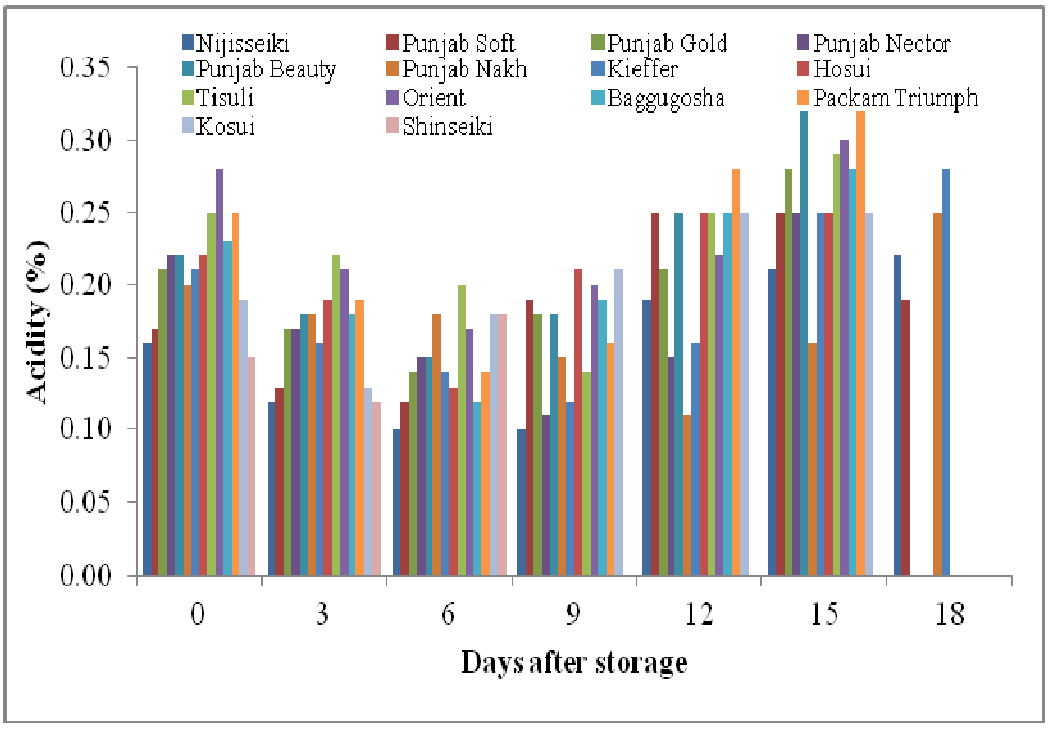

Fig.2. Change in Acidity (%) during storage in different pear cultivars at ambient temperature.

4.2.3 TSS : acid ratio

It is evident from the (table 8) that the TSS:acid ratio increased during the storage at room temperature, from the stage of zero to six days after storage in all the varieties, the maximum change in TSS:acid ratio was observed in Nijjiseiki (73.75 to 127.00) and the lowest value at six days after storage was observed in Punjab nakh (71.78) and it continue to increase upto nine DAS in some varieties i.e (Nijjiseiki, Punjab nector, Punjab nakh, Keiffer and Tisuli) start decrease in all other varieties and this decreasing trend of TSS:acid ratio continue upto fifteen DAS in all the varieties. At the fifteen day storage the maximum value was observed in Punjab nakh (80.63) and minimum in Punjab beauty (40.66). This increase and decrease in the TSS:acid ratio value during storage depends upon the increase and decrease in TSS and acidity values during this period. Similarly Sandhu *et al* (1994) observed variation in TSS:Acid ratio in different varieties of pear and highest TSS:acid ratio found in 'Red Blush' (48.5), followed by 'Punjab Gold' (47.5) and 'Baggugosha' (46.6) and minimum was recorded in 'LeConte' (39.7) at fruit maturity. Similiar work was done by Dhillon *et al* (2007) that recorded the maximum TSS:acid ratio of 69.86 in 'Punjab Gold' and 68.22 in 'Punjab beauty' after harvest. Other workers Sandhu *et al* 2002 and Shyamali 2006, have also report such distinction in TSS:acid ratio in different pear cultivars.

Table 8: Change in TSS : acid ratio during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	73.75	101.67	127.00	129.00	65.79	57.62	50.14
Punjab Soft	57.06	90.77	99.17	66.32	45.60	44.80	58.58
Punjab Gold	65.71	81.18	105.00	80.00	65.71	46.79	-
Punjab Nector	53.90	72.71	87.33	131.82	95.33	55.84	-
Punjab Beauty	63.64	78.33	96.67	76.11	52.80	40.66	-
Punjab Nakh	59.00	67.78	71.78	87.33	124.55	80.63	48.08
Kieffer	50.48	73.75	90.00	108.58	80.13	48.56	42.64
Hosui	52.73	63.16	100.00	60.48	48.00	47.24	-
Tisuli	53.60	65.00	75.00	110.71	56.00	47.93	-
Orient	41.07	62.38	87.65	72.20	62.73	43.33	-
Baggugosha	56.90	76.67	120.83	74.21	54.44	46.71	-
Packam Triumph	54.00	79.47	109.29	93.75	52.14	44.06	-
Kosui	64.21	102.31	72.22	60.05	48.56	46.80	-
Shinseiki	89.53	113.83	74.83	-	-	-	-
LSD ($p<0.05$)	0.58	1.02	1.05	0.75	1.24	0.78	0.52

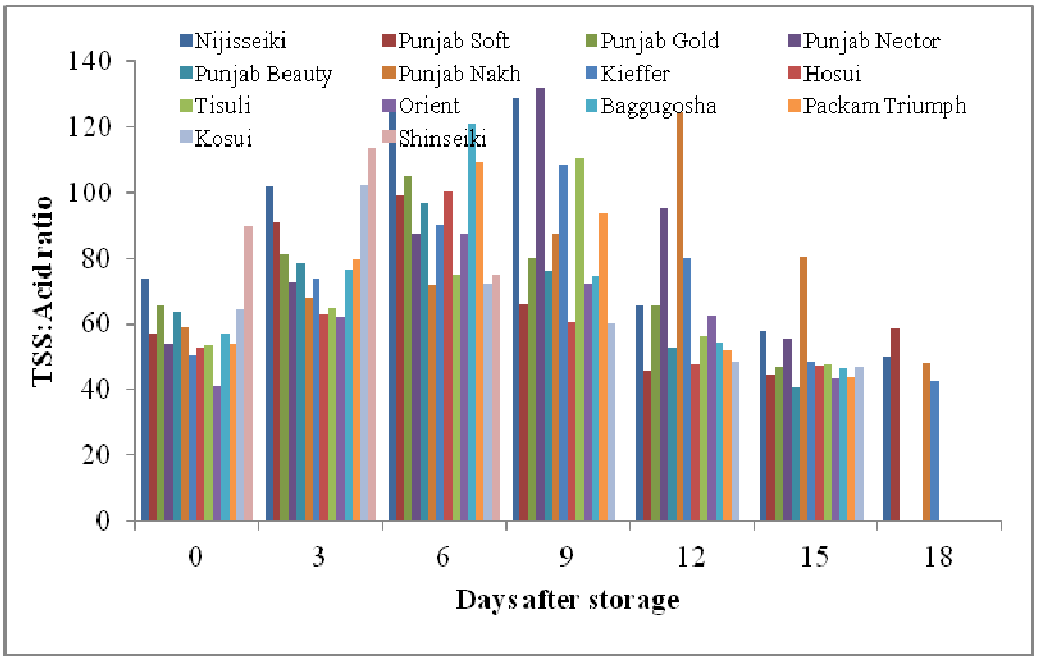

Fig.3. Change in TSS : acid ratio during storage in different pear cultivars at ambient temperature

4.2.4 Physiological loss in weight

The data (table 9) showed that the PLW was increased significantly in different pear varieties during the storage. Initially three days after storage the Kosui shows the maximum PLW 4.0% and minimum value was recorded in Orient 1.51%. Whereas this PLW was continue upto fifteen DAS in all the varieties (fig 4). After fifteen days storage, the PLW was maximum in Hosui 12.25% which at par with Baggugosha 12.15% and minimum in Punjab nakh 7.25%. Chen *et al* (2005) also reported that the visual quality of fruit is affected due to moisture loss and contributes to the loss of turgor pressure and succeeding softeningof fruits. Similarly the weight loss in fruits due to moisture loss have been reported to increase linearly with increase in storage period due to water loss and respiration (Ghafir *et al* 2009). The physiological loss in weight in fruits may be due to the respiration and transpiration process of the fruit itself as reported by Latifah *et al* (2009).

Table 9: Change in Physiological loss in weight during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)					
Varieties	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	3.78	5.99	7.00	8.81	10.26	12.12
Punjab Soft	3.58	5.24	6.92	8.48	9.68	11.21
Punjab Gold	2.09	3.68	5.78	7.12	10.75	-
Punjab Nector	2.03	3.63	4.06	7.78	9.95	-
Punjab Beauty	2.16	3.25	4.75	8.18	10.89	-
Punjab Nakh	1.98	2.25	3.21	4.16	7.25	8.52
Kieffer	2.05	2.85	3.36	5.75	8.25	9.05
Hosui	3.03	5.61	8.18	10.25	12.25	-
Tisuli	2.11	3.41	4.56	7.25	9.11	-
Orient	1.51	3.62	4.15	7.95	8.88	-
Baggugosha	3.24	5.94	8.42	10.81	12.15	-
Packam Triumph	2.46	3.41	4.08	7.51	9.05	-
Kosui	4.01	5.18	6.78	9.71	11.42	-
Shinseiki	2.05	5.32	8.24	-	-	-
LSD ($p<0.05$)	0.07	0.19	0.11	0.12	0.10	0.11

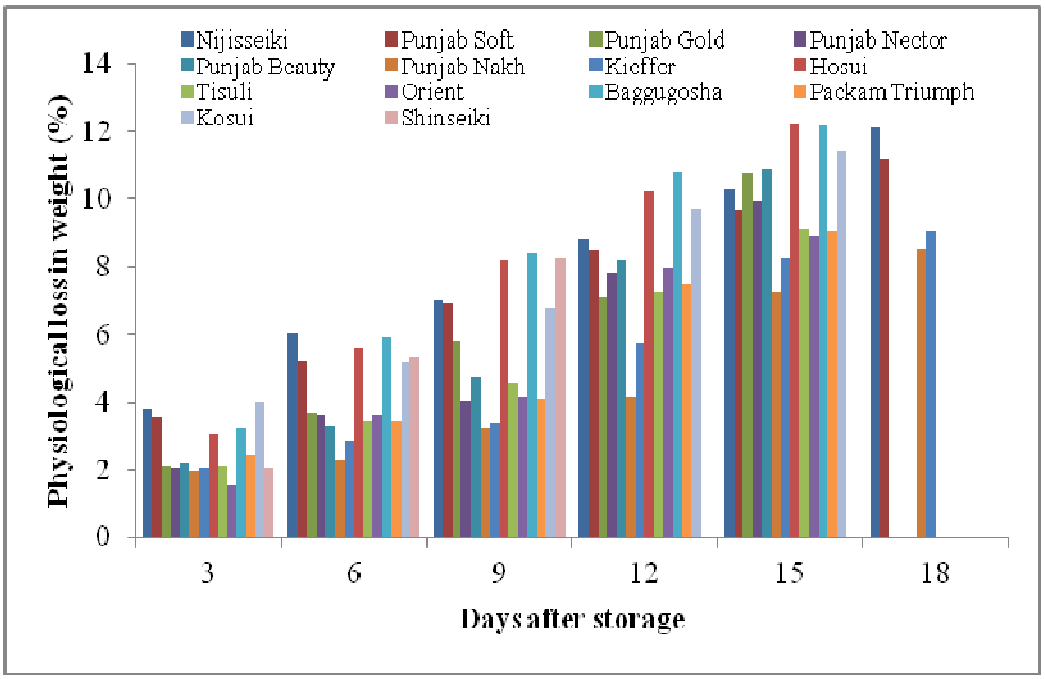

Fig.4. Change in Physiological loss in weight during storage in different pear cultivars at ambient temperature.

4.2.5 pH

The data presented in table (10) depicts that there is increase in juice pH in some varieties of pear was upto nine DAS, this showed the significant changes in juice pH during the storage. With an increase in juice pH during storage the decline in juice acidity was observed and vice-versa. At fruit maturity the maximum pH value was found in Kosui (5.66) which is at par with Tisuli (5.60). After nine days storage the higher pH value was observed in Hosui (5.56) and lowest in Punjab nakh (4.81) at par with Punjab gold (4.88). Rate of increase and decrease also varied among different varieties. Faster variation was recorded in Hosui and less variation in Orient variety (fig 5). At the final stage of storage pH value in Tisuli changes from 5.82 to 5.37 at nine to fifteen days after storage and at this stage the maximum value was observed in Nijjiseiki (5.33) and minimum in Punjab nakh (4.80). Decline or decrease in the juice pH at the end of storage or at the fifteen DAS may be due to increase in the acid content of juice due to fermentation process which spoil the quality of fruits. In other fruit crops during storage increase in pH were also observed by Daisy and Gehlot (2006) observed increase in pH during storage in aonla fruit. The reduction in pH under room temperature condition could be attributed to immediate increase in acidity and TSS with advancement of storage periods in pomegranate (Prasad and Mali 2000) and ber squash (Prasad and Mali 2003), respectively.

Table 10: Change in pH during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	5.18	5.20	5.27	5.41	5.38	5.33	5.31
Punjab Soft	5.19	5.20	5.29	5.16	4.96	4.91	4.84
Punjab Gold	4.80	4.83	4.92	4.88	4.81	4.76	-
Punjab Nector	4.77	4.92	4.93	5.05	4.86	4.81	-
Punjab Beauty	4.70	4.83	4.94	4.94	4.89	4.86	-
Punjab Nakh	4.77	4.79	4.89	4.81	4.92	4.80	4.77
Kieffer	4.94	5.12	5.30	5.30	5.21	5.02	4.91
Hosui	5.41	5.59	5.78	5.56	5.34	5.29	-
Tisuli	5.60	5.63	5.71	5.82	5.45	5.37	-
Orient	5.17	5.19	5.24	5.17	5.12	5.09	-
Baggugosha	4.88	4.93	5.20	5.09	4.99	4.93	-
Packam Triumph	5.08	5.24	5.49	5.40	5.36	5.31	-
Kosui	5.66	5.69	5.61	5.49	5.38	5.14	-
Shinseiki	5.34	5.48	5.27	-	-	-	-
LSD ($p<0.05$)	0.08	0.17	0.12	0.15	0.07	0.13	0.08

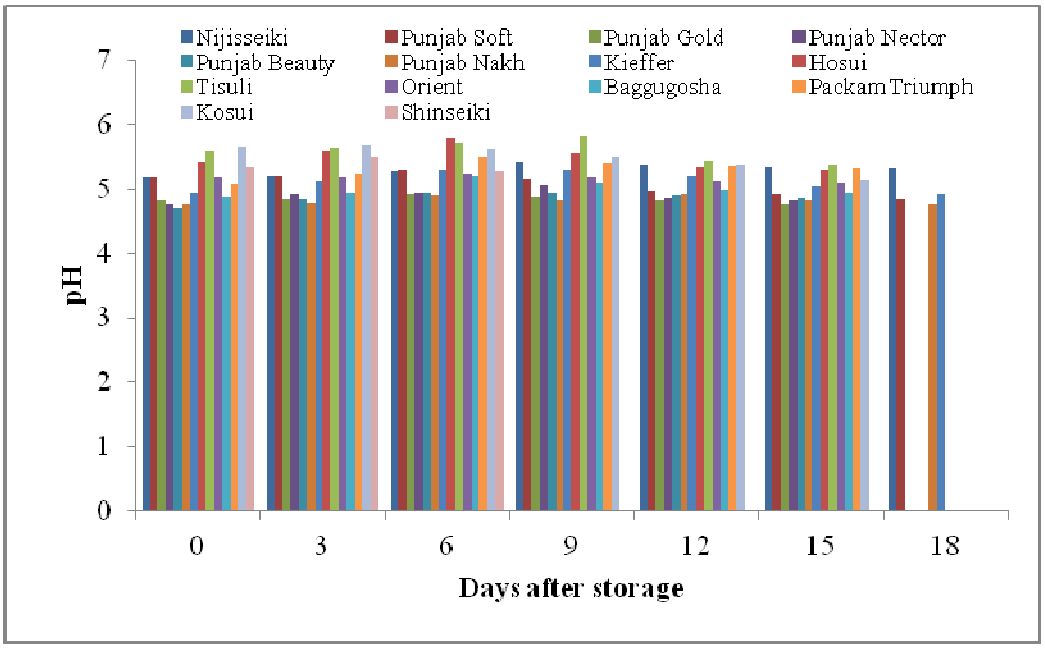

Fig.5. Change in pH during storage in different pear cultivars at ambient temperature.

4.2.6 Total sugar

The pertaining data showed in (table 11) that total sugar content in the different pear varieties varing significantly during the storage. At harvesting time highest content of total sugar was recorded in Baggugosha (9.55 %). Not much variation was observed upto three days after storage but increasing trend was observed in almost all the varieties. This trend continue upto nine DAS and decline in total sugar was observed thereafter in almost all the varieties. Rate of increase and decrease also varied in among different varieties. More variation was recorded in Punjab soft and less variation in Tisuli variety (fig 6). After storage of six DAS the increase in total sugar was observed maximum in Baggugosha from 9.55 to 11.87% and the minimum was observed in Keiffer (7.68%). The increase in total sugar during storage could be due to hydrolysis of starch into sugars or might be due to the conversion of starch into sugar due to action of hydrolytic enzymes may be responsible for increase in the sugar content. The total sugar content decreased at fifteen DAS in all varieties and found highest in Punjab gold (7.54%) and lowest in Hosui 4.28% and Pakam triumph 4.46%. Mukherjee and Rana (1966) reported that the sugar percentage of 'Kieffer', 'LeConte', 'Smith', 'Baggugosha' and 'Nakh Pear' was 6.56, 9.62, 6.25, 9.09 and 8.33, respectively.

Table 11: Change in Total sugars (%) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	5.33	7.73	9.23	9.81	9.14	6.58	5.37
Punjab Soft	4.80	7.63	9.37	9.94	7.63	5.97	4.83
Punjab Gold	6.96	9.03	10.04	9.74	9.54	7.54	-
Punjab Nector	5.43	7.77	9.08	10.59	8.49	6.64	-
Punjab Beauty	6.96	8.12	10.96	9.85	8.71	7.07	-
Punjab Nakh	5.66	6.53	7.05	7.98	10.02	5.78	4.83
Kieffer	5.93	6.27	7.68	9.22	7.54	6.47	4.14
Hosui	7.67	8.17	8.53	7.18	5.14	4.28	-
Tisuli	5.53	6.20	7.07	8.00	6.61	5.39	-
Orient	8.46	9.05	9.92	8.02	6.92	4.89	-
Baggugosha	9.55	9.97	11.87	10.07	8.58	5.85	-
Packam Triumph	7.40	8.78	10.81	8.73	7.28	4.46	-
Kosui	6.00	8.41	7.51	6.85	5.87	4.69	-
Shinseiki	7.33	9.15	7.71	-	-	-	-
LSD ($p<0.05$)	0.57	0.30	0.58	0.47	0.48	0.90	0.28

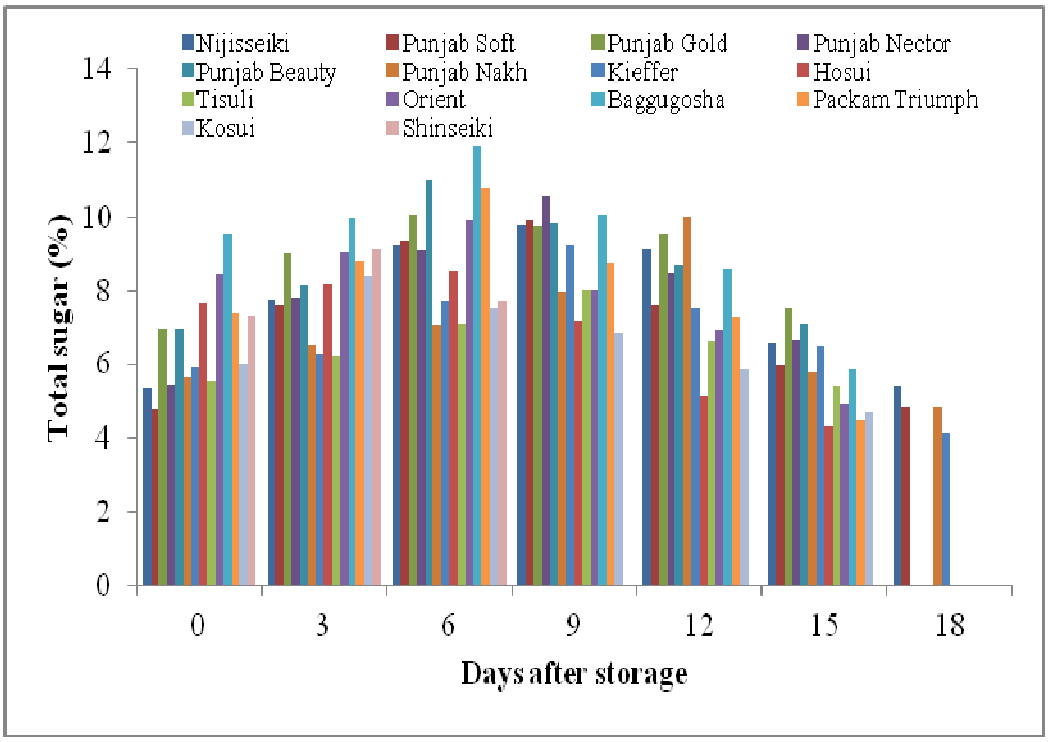

Fig.6. Change in Total sugars (%) during storage in different pear cultivars at ambient temperature.

Other workers Dhillon *et al* (2007) done similar work on total sugars showed increasing trend with fruit storage and it was higher in 'Punjab Gold' (11.13%) as compared to 11.06% in 'Punjab beauty'.

4.2.7 Reducing sugar

At harvesting time significantly maximum reducing sugar was recorded in Baggugosha (6.23%) which was at par with Orient (6.16%) and Shinseiki (5.96%) showed in (table 12). Not much variation was observed upto six days after storage. Increasing trend in reducing sugars was observed in almost all the varieties. This trend continue upto nine DAS and thereafter decline in reducing sugar was observed in almost all the varieties. Similarly the study was conducted in pomegranate by Kumar (2015), similar trend of increase in early stages and decline in value of reducing sugar at later stages of storage was observed. Rate of increase and decrease also varied in different varieties. Faster variation was recorded in Punjab soft and less variation in Tisuli variety (fig 7). The level of reducing sugar decreased significantly after nine days storage, the maximum sugar content (7.27%) was observed in Nijisseiki this time. Nitsch (1953) was observed in the pear fruit during the storage increase in sugars was due to accumulation of glucose, sucrose and fructose and due to increase in the TSS content.

Table 12: Change in Reducing sugars (%) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	4.17	5.84	6.04	7.27	6.59	5.43	4.08
Punjab Soft	3.80	5.16	6.84	7.12	5.31	4.29	3.37
Punjab Gold	5.13	5.76	6.26	6.07	5.95	5.24	-
Punjab Nector	4.03	6.34	6.59	7.09	6.93	5.26	-
Punjab Beauty	5.53	6.09	6.63	5.92	5.81	4.75	-
Punjab Nakh	3.96	5.57	6.04	6.43	7.42	3.51	2.86
Kieffer	4.11	5.38	6.32	6.63	5.26	4.27	2.02
Hosui	5.66	5.88	6.03	5.93	3.79	3.27	-
Tisuli	3.16	3.29	3.46	3.52	2.94	2.45	-
Orient	6.16	6.66	7.34	6.34	5.55	3.84	-
Baggugosha	6.23	6.59	7.00	6.30	5.91	3.29	-
Packam Triumph	5.20	5.49	7.63	5.95	4.55	3.08	-
Kosui	5.17	5.48	5.12	4.19	3.71	2.69	-
Shinseiki	5.96	7.58	6.34	-	-	-	-
LSD ($p<0.05$)	0.58	0.33	0.29	0.34	0.33	0.29	0.32

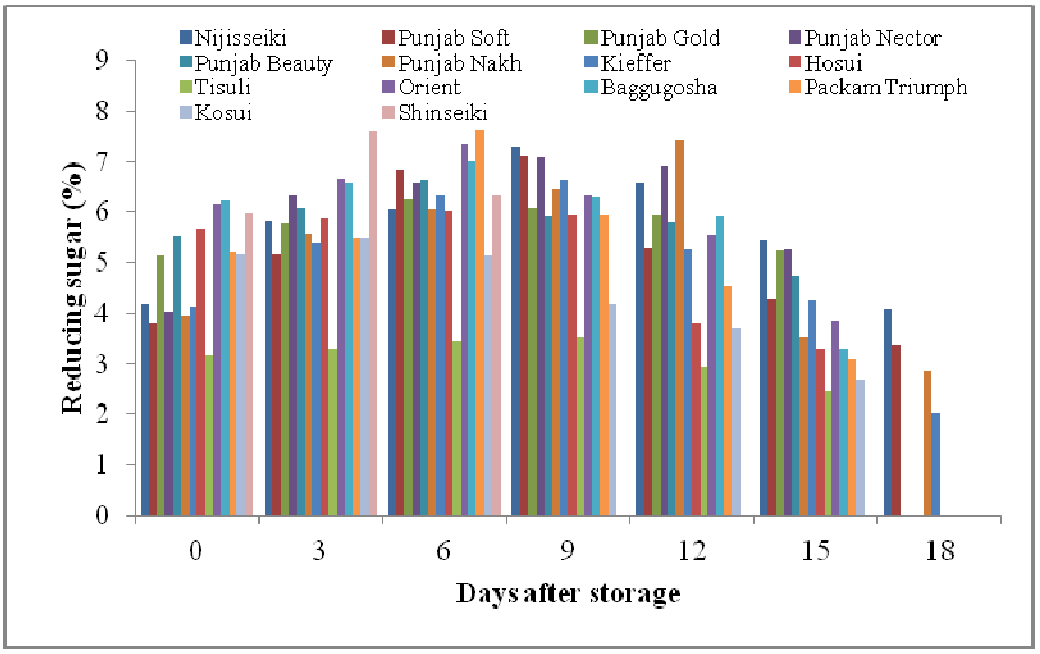

Fig.7. Change in Reducing sugars (%) during storage in different pear cultivars at ambient temperature.

4.2.8 Non-reducing sugar

The results from (table 13) examined data revealed that the maximum increase in non-reducing sugar was observed from 3.15% to 4.63% in Baggugosha after zero to six DAS at room temperature. The increase in sugars during the storage period at ambient room temperature it may be due to increase in TSS and accumulation of glucose, sucrose and fructose. Not much variation was observed that upto six days after storage but increasing trend in reducing sugars was observed in almost all the varieties. This trend continue upto nine DAS and thereafter decline in non reducing sugar was observed in almost all the varieties. The rate at which the fluctuations occur in the different varieties varied from variety to variety. The changes occurred at faster rate in Punjab nector variety and lower in Punjab soft variety (fig 8). Maximum content of non reducing sugar after six days of storage was observed in Baggugosha (4.63%) and the minimum value was found in Keiffer (1.29%) and Punjab nakh (1.31%). After storage of fifteen days at ambient temperature decrease in non reducing sugar content occur, at that period the higher value was observed in Tisuli (2.33%) and the lowest in Housi (0.96%). Study was conducted by Dhillon *et al* in (2007) in semi-soft pear fruits and similar pattern of continuous increase followed by decrease in value of non reducing sugar was observed during the storage period.

Table 13: Change in Non-reducing sugars (%) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	1.10	1.80	2.74	2.95	2.42	1.09	1.23
Punjab Soft	0.95	2.35	2.40	2.68	2.20	1.60	1.39
Punjab Gold	1.75	3.11	3.59	3.49	3.41	2.19	-
Punjab Nector	1.33	1.36	2.37	3.28	1.99	1.31	-
Punjab Beauty	1.36	1.93	3.97	3.01	2.74	2.20	-
Punjab Nakh	1.67	0.91	1.31	1.87	2.91	2.16	1.87
Kieffer	1.78	0.85	1.29	2.46	2.17	2.09	2.01
Hosui	1.91	2.18	2.38	1.19	1.15	0.96	-
Tisuli	2.25	2.91	3.70	4.18	3.95	2.33	-
Orient	2.19	2.27	2.45	1.60	1.30	1.00	-
Baggugosha	3.15	3.21	4.63	3.58	2.54	2.43	-
Packam Triumph	2.09	3.56	3.57	3.00	2.81	1.31	-
Kosui	0.79	2.78	2.64	2.53	2.05	1.90	-
Shinseiki	1.66	1.94	1.68	-	-	-	-
LSD ($p<0.05$)	0.57	0.37	0.29	0.54	0.64	0.90	0.32

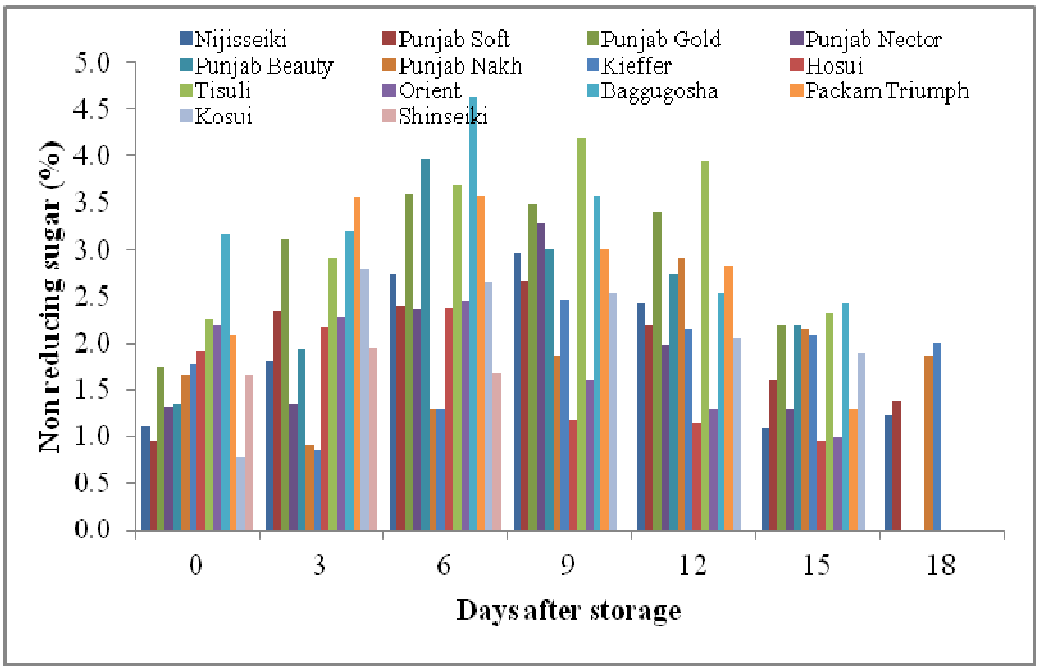

Fig.8. Change in Non-reducing sugars (%) during storage in different pear cultivars at ambient temperature.

4.2.9 Glucose

Glucose is a unit of cellulose. It is the source of energy in cell function and regulation of its metabolism. During development the amount of glucose present in the monosaccharide residues of apple fibre increased relatively (Gheyas *et al* 1998). The perusal of data showed significant increase in the glucose content upto nine DAS and thereafter decreasing trend was observed (fig 9). Not much variation was observed upto three DAS. At the harvest stage highest glucose content was recorded in Kosui (32.04 mg/gram) which was at par with Shinsheiki (31.53mg/gm) and after nine days of storage at room temperature. The maximum glucose content was observed in Nijjisheiki (48.8 mg/gm) and after fifteen days of storage the maximum value was observed in Keiffer (44.27 mg/gm). Baggogosha showed the changes in glucose at faster rate and Tisuli has lowest rate of changes in glucose. At maximum storage of eighteen days the highest value of glucose was recorded in Keiffer (41.30 mg/gm).

4.2.10 Sucrose

Sucrose is disaccharide composed of glucose and fructose. At maturity stage significantly highest sucrose content was reported in Baggugosha 6.60 mg/g. The data revealed the increasing trend of sucrose upto nine DAS and decline in values were observed thereafter in all the varieties (fig 10). During storage in different Japanese pear (*Pyrus pyrifolia* Nakai cvs. Gold, Nijisseiki and Hosui) varieties increased upto 3 weeks after storage at cold tempearture, while decreasing trend was observed by Itai and Tanahashi (2007). The sucrose content increased being highest in Baggugosha 10.78 mg/g and lowest in Keiffer and

Table 14: Change in Glucose (mg/g) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	29.32	30.56	37.42	48.8	47.25	41.04	40.44
Punjab Soft	24.88	31.55	35.23	47.72	45.16	41.68	39.18
Punjab Gold	29.20	39.21	46.91	36.53	34.91	33.39	-
Punjab Nector	25.04	30.56	33.39	46.14	43.14	40.72	-
Punjab Beauty	27.04	37.38	49.25	42.76	45.4	41.83	-
Punjab Nakh	25.04	33.05	36.14	43.39	49.26	42.15	40.12
Kieffer	21.38	27.93	33.39	51.04	50.42	44.27	41.30
Hosui	26.54	29.90	41.75	37.76	33.49	31.30	-
Tisuli	25.54	31.05	32.43	35.12	29.91	25.58	-
Orient	22.22	39.90	47.25	46.14	44.33	39.34	-
Baggugosha	29.54	35.71	51.93	46.82	41.95	38.63	-
Packam Triumph	24.38	38.26	49.55	45.06	39.21	37.82	-
Kosui	32.04	34.02	46.95	34.23	32.04	32.00	-
Shinseiki	31.53	33.03	42.62	-	-	-	-
LSD ($p<0.05$)	1.23	1.45	1.38	1.03	2.14	1.78	0.64

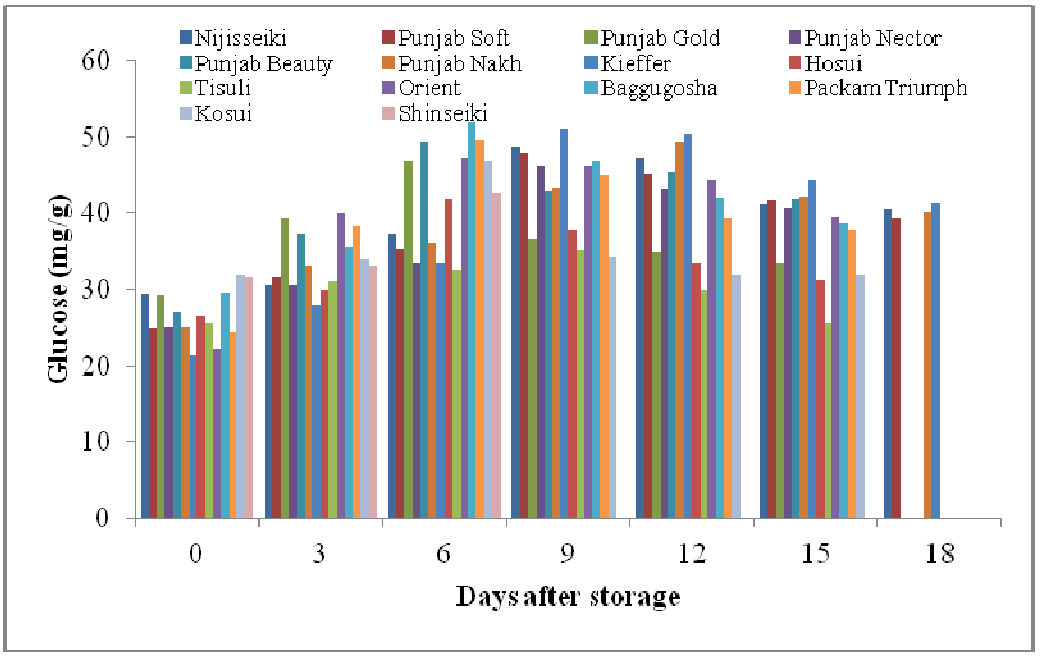

Fig.9. Change in Glucose (mg/g) during storage in different pear cultivars at ambient temperature.

Table 15: Change in Sucrose (mg/g) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	5.73	6.77	7.68	9.65	9.20	7.61	6.87
Punjab Soft	5.23	6.02	7.61	8.78	7.44	6.38	5.86
Punjab Gold	6.45	8.83	9.43	8.02	7.53	6.68	-
Punjab Nector	5.16	7.13	7.68	10.02	9.15	8.73	-
Punjab Beauty	5.89	6.77	8.64	8.06	7.92	6.39	-
Punjab Nakh	4.57	6.29	7.49	8.21	8.87	7.57	6.77
Kieffer	4.40	6.40	7.09	8.49	7.75	7.43	6.70
Hosui	5.16	6.73	8.68	8.11	7.14	6.47	-
Tisuli	4.47	7.13	9.61	10.13	9.21	9.14	-
Orient	6.52	7.18	9.41	8.15	7.34	7.13	-
Baggugosha	6.60	7.35	10.78	10.06	9.21	8.22	-
Packam Triumph	5.13	4.83	7.76	7.13	7.10	6.38	-
Kosui	5.70	6.98	8.49	7.42	6.91	6.81	-
Shinseiki	4.68	6.03	9.13	-	-	-	-
LSD ($p<0.05$)	0.06	0.97	1.44	0.97	0.08	0.04	0.13

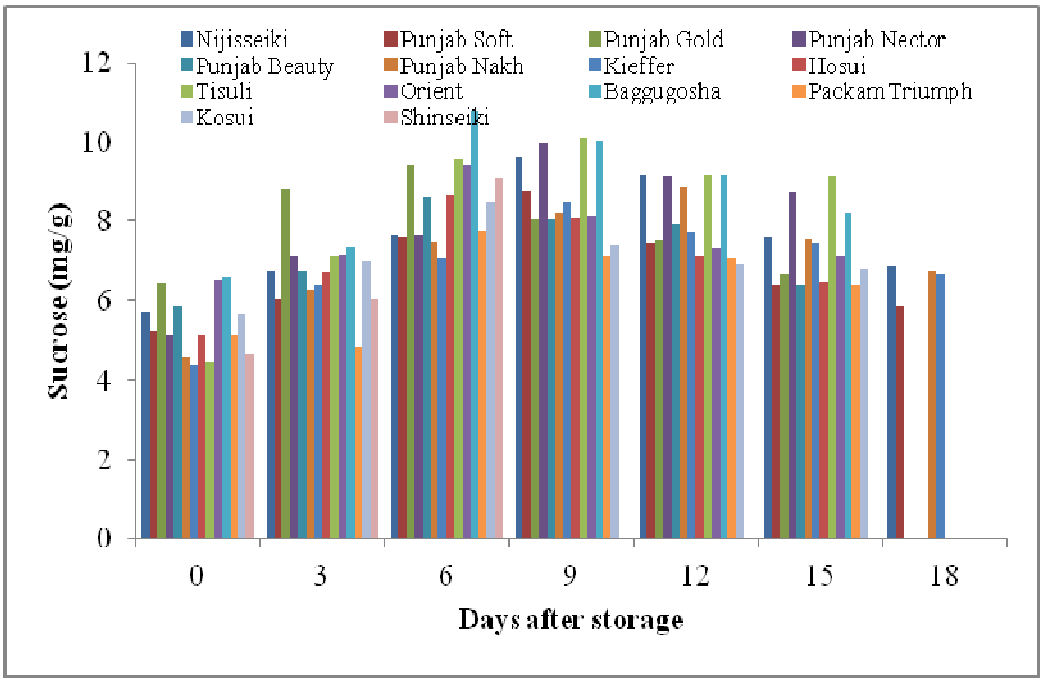

Fig.10. Change in Sucrose (mg/g) during storage in different pear cultivars at ambient temperature.

Punjab nakh (7.09 and 7.49 mg/g respectively) after six days of storage and then decreased after fifteen days, the minimum value was noticed in Packam triumph and Punjab soft at par (6.38 mg/g). The rate of increasing and decreasing in the glucose during storage also varied in different varieties. The faster rate of variation was observed in Baggugosha variety and the slow variation in Packam triumph variety. Arzani *et al* (2008) observed the changes in sucrose content from the time of fruit harvest to after one month storage in Asian pears (KS9 and KS13) and European pear (Shahmiveh), from Stage 0 (harvest time) to Stage 1 (after one month storage), while sucrose (11g/kg to 8g/kg) in 'KS'9, (1.1g/kg to 0.9g/kg) in 'KS'13, (3.3g/kg to 2.1g/kg) in 'Shahmiveh' changes occur.

4.2.11 Fructose

Fructose was the major sugar in pear fruits followed by glucose and sucrose noticed by Chen *et al* (2006). In (table 16) and (fig 11), the presented data showed that the maximum fructose content at harvesting time was observed in Nijisseiki (40.89 mg/g) which was at par with Punjab gold (40.03 mg/g) and the minimum in Kieffer (31.66 mg/g) at par with Orient (32.33 mg/g). In this presented data not much variation was observed upto three DAS but increasing trend was observed in all varieties. After six days storage the increase in value was observed. At this stage the maximum value was noticed in Baggugosha (66.18 mg/g). Upto the storage of nine days the fructose content was increased and thereafter deceased in values observed. Rate of increase and decrease in fructose varies in different varieties. Faster variation was observed in Orient variety and lowest in Hosui variety during the storage. At the final stage of storage (after fifteen days) the fructose content was decreases in different cultivars of pear at different rate, the higher content was observed in Nijjiseiki (63.65 mg/g) and lowest in Housi (46.12 mg/g). Arzani *et al* (2008) also worked on different Asian pears (KS9 and KS13) and European pear (Shahmiveh) varieties at the time of fruit harvest, fructose was major sugar as compared to glucose and sucrose in these varieties.

4.2.12 Starch

The data of starch content showed significantly high values at harvest stage but decreasing trend of starch content was observed storage at room temperature in all the varieties. At the time of harvest highest value was recorded in Punjab nakh 47.39 mg/g which was at par with Packam triumph and Punjab nector (46.33mg/g). Similarly, Tewari (1965) also observed that the unripe fruits of *Pyrus pashia* were rich in starch. At the initial stage of storage (zero to six DAS), the rate of decrease in starch content was fast but after the twelve days slow rate was observed (table 17, fig 12). Similarly Nitsch (1953) reported that the starch content in pears decreased at maturation stage and during ripening. In storage the starch hydrolysed into sugar that's why the starch content decreased continuously in the storage (Dhillon *et al* 2007).

Table 16: Change in Fructose (mg/g) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	40.89	47.95	51.45	69.78	68.65	63.65	56.78
Punjab Soft	35.5	50.33	54.72	57.46	54.55	52.41	51.11
Punjab Gold	40.03	48.61	59.6	55.88	51.98	49.42	-
Punjab Nector	36.56	44.28	49	61.31	60.65	57.02	-
Punjab Beauty	37.5	47.61	61.58	57.98	56.07	51.44	-
Punjab Nakh	34.7	45.96	51.08	62.17	65.61	57.35	54.65
Kieffer	31.66	43.28	49.21	66.75	63.87	59.02	54.48
Hosui	39.16	47.33	52.41	49.58	47.36	46.12	-
Tisuli	36.5	47.95	56.58	59.21	53.21	51.9	-
Orient	32.33	44.15	63.22	59.55	55.4	54.65	-
Baggugosha	39.66	58.35	66.18	64.3	59.91	56.78	-
Packam Triumph	35.5	48.55	63.11	59.11	58.2	53.39	-
Kosui	36.63	50.11	58.28	54.41	56.1	49.16	-
Shinseiki	33.73	50.51	58.11	-	-	-	-
LSD ($p<0.05$)	2.31	3.22	2.76	3.45	9.11	3.17	3.93

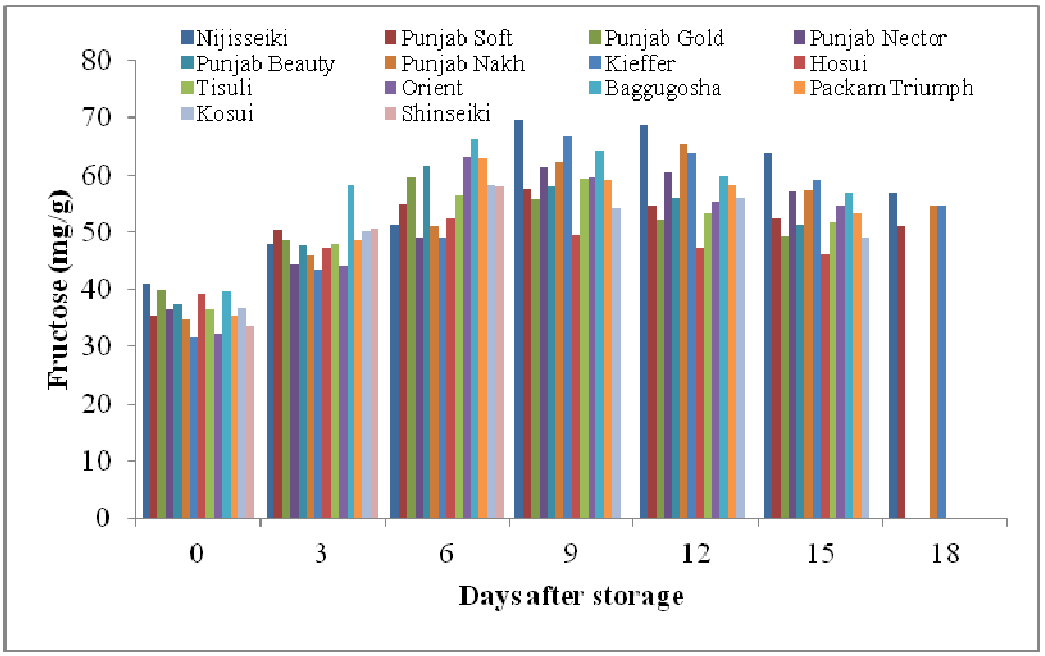

Fig.11. Change in Fructose (mg/g) during storage in different pear cultivars at ambient temperature.

Table 17: Change in Starch (mg/g) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	34.76	26.49	26.03	17.67	8.74	7.76	4.94
Punjab Soft	41.04	27.99	25.73	20.32	19.35	16.14	15.63
Punjab Gold	42.52	28.73	27.41	25.83	22.15	15.99	-
Punjab Nector	46.33	32.79	26.03	21.38	18.49	16.59	-
Punjab Beauty	40.54	36.24	28.63	19.88	14.78	12.99	-
Punjab Nakh	47.39	43.14	39.49	25.98	24.15	20.40	11.64
Kieffer	42.67	39.39	29.09	21.35	16.83	11.00	8.50
Hosui	44.04	41.79	39.03	32.98	22.15	19.28	-
Tisuli	44.96	43.01	37.54	28.21	23.61	20.15	-
Orient	44.04	41.79	39.19	30.77	27.75	19.95	-
Baggugosha	27.46	25.14	23.58	15.76	13.16	11.58	-
Packam Triumph	46.33	41.49	40.56	35.19	33.2	25.54	-
Kosui	27.46	24.39	24.65	18.17	14.81	10.99	-
Shinseiki	20.46	18.39	15.02	-	-	-	-
LSD ($p<0.05$)	2.74	3.90	2.76	5.11	3.92	4.32	3.26

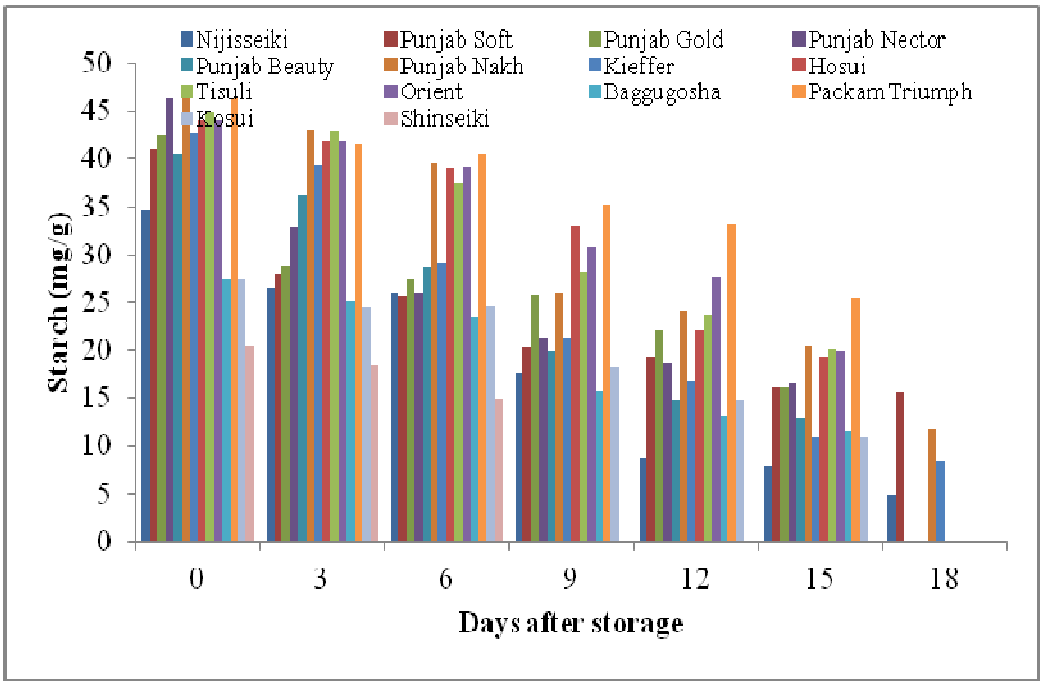

Fig.12. Change in Starch (mg/g) during storage in different pear cultivars at ambient temperature.

4.2.13 Fruit firmness

The data clearly indicate that the fruit firmness decreased significantly during the storage of pear fruit at ambient room temperature (table 18). At maturity highest fruit firmness was observed in Orient cultivar (10.86 kg/cm^2) whereas minimum was recorded in Shinsheiki i.e (3.41 kg/cm^2). At the initial upto six DAS less variation was observed among the varieties but the decreasing trend was observed in all the varieties (fig 13). After six and fifteen days of storage the rate of decrease in value rises and Tisuli has maximum firmer fruits (9.58 kg/cm^2, 7.75 kg /cm^2) at this stage, while minimum value was observed in Shinsheiki (2.35 kg /cm^2) at six days of storage and (3.08 kg /cm^2) in Kosui at fifteen days of storage respectively. Gomez and Khurdiya (2005) done similar work on different pear varieties and suggested that in earlier stage of storage variation in fruit firmness was less due to less hydrolysis of starch reserves. Drake *et al* (2004) also studied that the decrease in the fruit firmness with an advancement of maturity and ripening during storage and found that this may be due to dissolution of insoluble pectin into soluble form in the cell sap and in the middle lamella.

Table 18: Change in Firmnees (kg/cm^2) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	4.61	4.46	4.16	4.00	3.33	3.15	2.50
Punjab Soft	8.00	7.08	6.75	5.68	4.66	4.00	3.60
Punjab Gold	8.41	7.41	6.25	6.00	5.25	4.81	-
Punjab Nector	8.66	7.41	6.52	5.75	5.28	4.16	-
Punjab Beauty	8.71	8.06	7.85	7.25	6.43	5.51	-
Punjab Nakh	9.58	8.30	8.06	7.38	6.66	5.75	5.18
Kieffer	8.58	8.10	7.55	6.70	6.15	5.51	4.75
Hosui	6.66	6.35	6.08	5.16	4.25	3.41	-
Tisuli	10.50	9.63	9.58	9.18	8.75	7.75	-
Orient	10.86	9.96	9.25	8.03	7.50	6.91	-
Baggugosha	8.75	8.25	7.50	6.60	5.93	5.71	-
Packam Triumph	10.76	10.05	9.21	8.38	8.01	7.35	-
Kosui	5.70	5.45	5.21	4.67	4.08	3.08	-
Shinseiki	3.41	3.08	2.35	-	-	-	-
LSD ($p<0.05$)	0.73	0.87	0.81	0.57	0.67	0.38	0.33

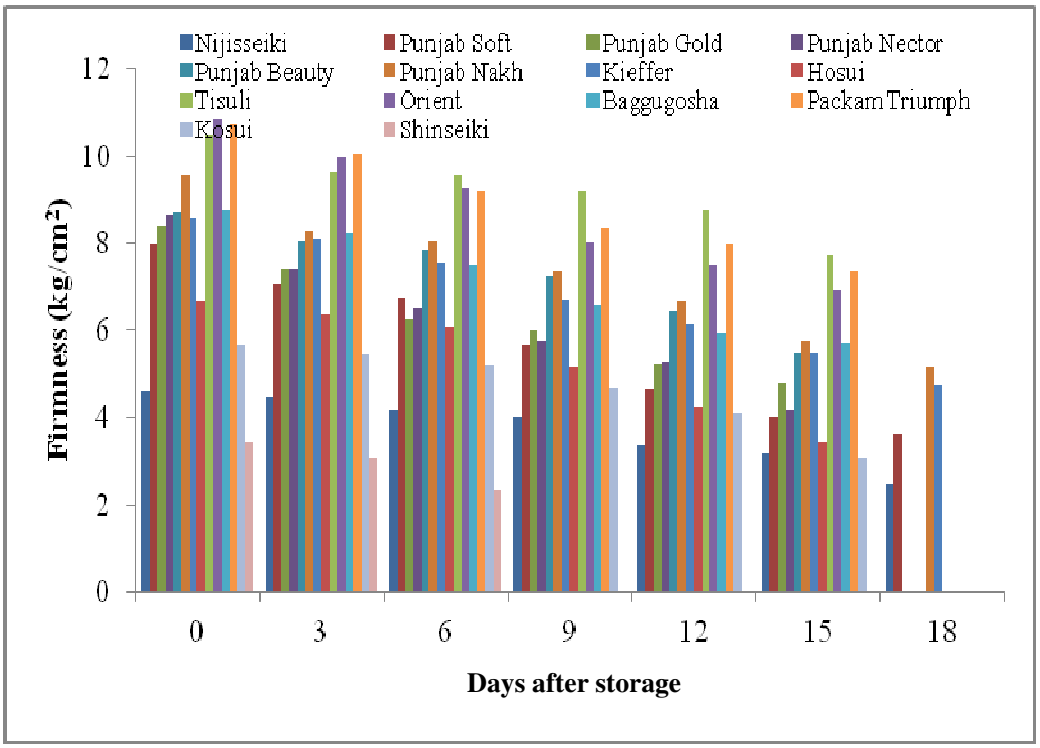

Fig.13. Change in Firmnees (kg/cm^2) during storage in different pear cultivars at ambient temperature.

4.2.14 Phenols

It is evident from the (table 19) that at maturity significantly maximum phenolic content was observed in Punjab nakh (81.25mg/g). The decreasing trend was shown during storage at ambient temperature. Upto initial six DAS more variation was observed among the varieties. After nine days after storage at room temperature the phenolic content was maximum in Orient (40.22 mg/g) which was at par with Packam triumph (40.15mg/g) and the minimum value was recorded in Punjab beauty (25.23 mg/g). After the nine DAS the rate of derease in phenolic compound was slowed down (fig 14). At the stage of fifteen days after storage the phenolic content was lower down and at this stage the maximum value was noticed in Packam triumph (31.53mg/g) at par with Orient (31.25 mg/g) and the lowermost content was observed in Punjab beauty (23 mg/g). Gangwar (1972) observed the similar trend during storage of different pear at ambient room temperature, he found that there is significantly decrease in the phenolic content due to the oxidation of phenols. During the storage, this decreasing trend in the phenols was observed due to their hydrolysis into sugar, acids and other compounds.

Table 19: Change in Phenols (mg/g) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	57.62	58.25	35.36	31.23	26.32	24.19	23.12
Punjab Soft	73.26	61.46	41.76	35.23	30.15	27.85	26.14
Punjab Gold	79.27	53.32	32.86	28.36	26.32	25.24	-
Punjab Nector	65.00	50.58	34.3	30.25	29.63	25.44	-
Punjab Beauty	75.8	57.25	28.33	25.23	23.25	23.00	-
Punjab Nakh	81.25	64.2	41.62	32.06	30.25	27.62	26.32
Kieffer	62.77	51.04	46.51	34.21	27.21	26.25	25.89
Hosui	55.64	38.92	31.62	29.03	28.62	24.32	-
Tisuli	65.67	49.83	44.46	38.96	31.23	27.45	-
Orient	61.97	55.26	47.26	40.22	35.63	31.25	-
Baggugosha	55.9	43.25	36.2	31.23	27.21	23.62	-
Packam Triumph	61.37	56.75	46.06	40.15	36.52	31.53	-
Kosui	54.31	43.2	36.35	30.26	28.67	27.84	-
Shinseiki	55.23	40.32	30.21	-	-	-	-
LSD ($p<0.05$)	0.08	0.067	2.72	0.08	0.06	2.72	0.01

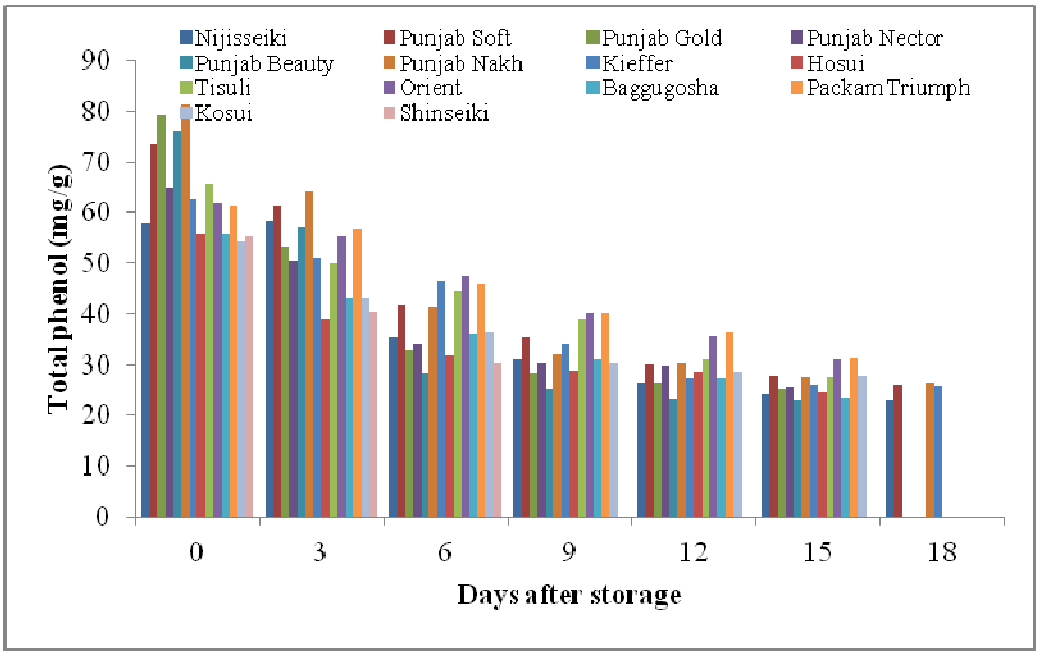

Fig.14. Change in Phenols (mg/g) during storage in different pear cultivars at ambient temperature.

4.2.15 Ascorbic acid

The data (table 20) showed significant variation in the ascorbic acid content among the varieties of pear. The data showed continuous decreasing trend in ascorbic acid during storage. At the three day after storage the maximum ascorbic acid content (9.05 mg/100ml) was found in Orient it decrease upto nine day storage to (6.25 mg/100ml) but remain maximum and decrease after at faster rate and minimum content in Shinseiki (5.96 mg/100ml) at three day after storage and after nine DAS minimum (2.25 mg/100ml) found in Punjab gold. Punjab soft variety have faster rate of decrease in the ascorbic acid content from all the varities during ambient temperature storage at different intervals (fig 15). The value changed at fifteen DAS, the maximum ascorbic acid content was observed in Punjab nakh (3.29 mg/100ml) and minimum in Punjab gold (1.19 mg/100ml). This reduction in ascorbic acid during storage could be due to oxidation by oxygen which resulted in formation of dehydro-ascorbic acid by Dhillon *et al* (1999). Sanchez *et al* (2003), observed that the ascorbic acid in different pear cultivars at fruit maturity, the maximum value of ascorbic acid was noticed in Red D Anjou and Coscia (4.4mg/100g in both) followed by Packams (3.8gm/100g).

Table 20: Change in Ascorbic acid (mg/100ml) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	8.53	7.58	6.14	4.12	2.4	2.16	2.12
Punjab Soft	8.25	7.36	4.24	2.60	2.14	1.87	1.49
Punjab Gold	8.04	7.14	5.01	2.25	1.84	1.19	-
Punjab Nector	8.63	6.68	3.82	3.63	2.46	1.83	-
Punjab Beauty	8.97	6.25	5.07	2.74	1.84	1.24	-
Punjab Nakh	9.25	7.88	6.95	4.53	3.78	3.29	1.91
Kieffer	9.22	7.68	6.58	5.14	3.65	2.99	2.54
Hosui	9.58	8.17	7.18	6.00	2.5	2.19	-
Tisuli	9.78	8.28	6.70	5.39	3.20	2.89	-
Orient	9.92	9.05	8.46	6.25	3.09	2.46	-
Baggugosha	8.87	7.56	5.25	3.21	2.50	1.80	-
Packam Triumph	9.81	8.78	7.70	6.28	4.46	2.12	-
Kosui	8.7	7.41	6.85	4.35	2.37	1.67	-
Shinseiki	7.33	5.96	4.01	-	-	-	-
LSD ($p<0.05$)	0.06	0.01	0.06	0.06	0.10	0.04	0.01

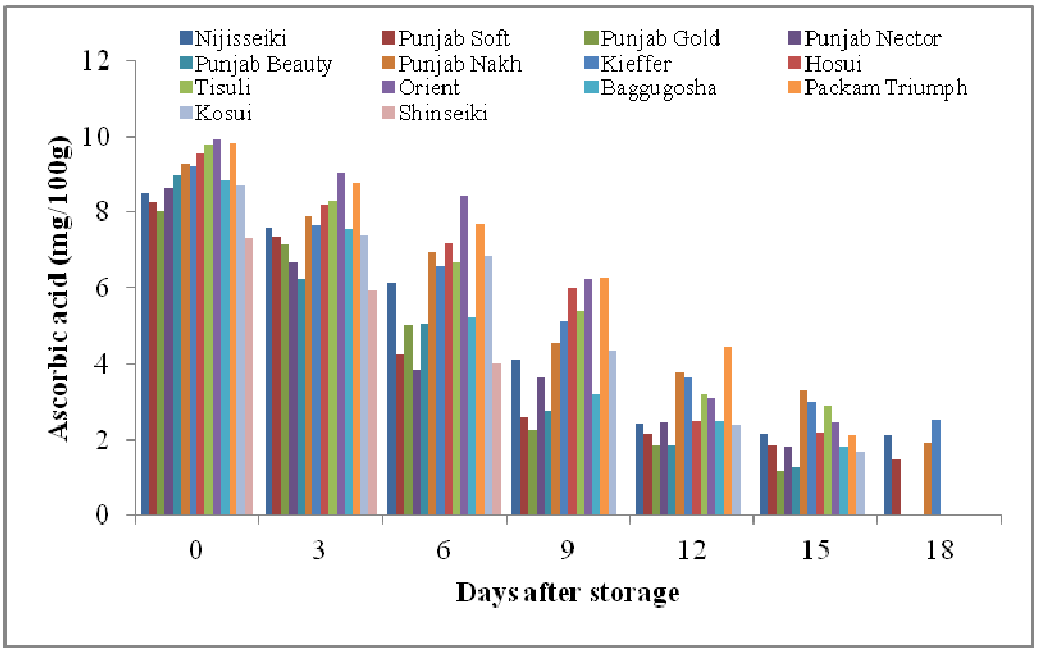

Fig.15. Change in Ascorbic acid (mg/100ml) during storage in different pear cultivars at ambient temperature.

4.2.16 Fibre

At the initial stage increase in the fibre content was observed upto the six DAS thereafter decrease in the fibre was observed in all the varieties. The data in (table 21) showed that the maximum fibre content at six day after storage 12.53 % was observed in Orient and minimum in Shinseiki; thereafter it starts decreasing and this decrease is at different rate among all varieties and after fifteen day after storage the higher content of fibre was showed in Packam triumph 8.54 % and in Orient 8.50% and lowest in Housi and Kousi (3.83 and 4.24 % respectively). The rate of increase and decrease in the the fibre content varied in the different varieties. Faster variation was observed in Kosui variety and lowest in Tisuli variety (fig 16). Similarly, Perez *et al* (2005) suggested that during storage the fibre content was depend upon the activity of polygalacturonase enzyme, the activity of enzyme tended to decrease during storage, fibre content was also decreases.

4.2.17 'L' 'a' 'b' 'C' and 'h' values

4.2.17.1 'L' value

During storage significant change in 'L' value was observed in the different pear cultivars. Not much variation was observed upto three DAS in almost all the varieties. Increasing trend for 'L' value was observed in all the varieties during the storage. Similarly, Singh *et al* (2016) conduct study on different pear cultivars and observed that during storage the increase in 'L' value due to the change in colour from dark to light, higher 'L' value donates the lightness in the colour. After three days storage highest value was observed in Baggugosha (67.51) which was at par with Punjab beauty and Punjab nector (66.72 and 66.69

Table 21: Change in Fibre (%) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)			
Varieties	**0**	**6**	**12**	**15**
Nijisseiki	5.54	9.91	7.18	6.91
Punjab Soft	5.12	9.13	6.35	6.13
Punjab Gold	5.74	8.62	7.32	6.62
Punjab Nector	6.54	7.6	8.7	4.60
Punjab Beauty	5.28	7.45	6.27	4.45
Punjab Nakh	6.25	9.47	7.62	7.47
Kieffer	4.32	12.32	8.31	7.52
Hosui	4.56	10.41	7.28	3.83
Tisuli	9.00	10.30	10.19	8.25
Orient	6.34	12.53	9.32	8.50
Baggugosha	6.58	10.68	6.87	5.62
Packam Triumph	8.4	10.54	10.25	8.54
Kosui	4.78	9.2	5.31	4.24
Shinseiki	2.44	7	-	-
LSD ($p<0.05$)	0.06	0.09	0.04	0.19

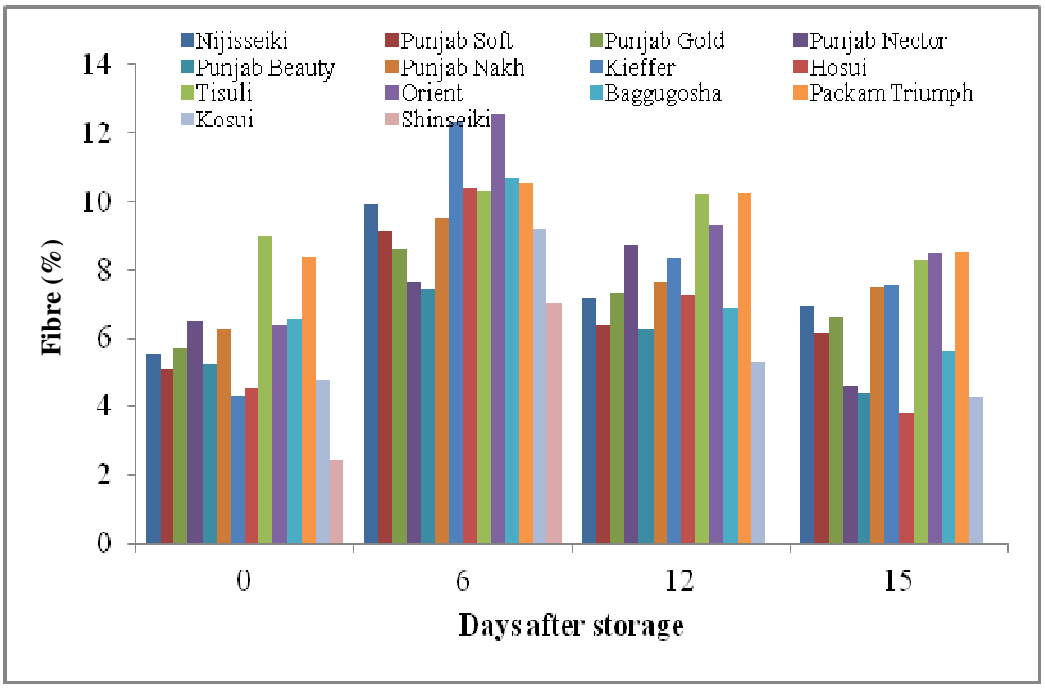

Fig.16. Change in Fibre (%) during storage in different pear cultivars at ambient temperature.

Table 22: Change in 'L' value during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	49.08	51.25	52.19	54.12	57.10	59.28	62.23
Punjab Soft	57.98	62.51	64.26	65.24	66.19	67.49	69.6
Punjab Gold	61.25	64.24	69.32	69.56	72.41	77.67	-
Punjab Nector	65.7	66.69	67.39	69.12	71.22	73.23	-
Punjab Beauty	64.12	66.72	67.25	69.53	69.90	70.18	-
Punjab Nakh	57.38	58.71	62.96	65.76	66.04	68.21	69.92
Kieffer	46.67	56.76	60.41	63.66	67.75	76.21	78.24
Hosui	43.6	48.66	49.7	50.78	57.87	65.77	-
Tisuli	59.95	60.07	61.19	73.25	88.33	89.68	-
Orient	57.47	59.81	60.30	61.82	64.45	68.66	-
Baggugosha	67.08	67.51	67.96	69.77	72.11	72.46	-
Packam Triumph	58.31	59.19	62.12	66.15	71.2	76.26	-
Kosui	47.13	50.98	54.83	65.93	69.01	74.73	-
Shinseiki	51.29	52.20	53.89	-	-	-	-
LSD ($p<0.05$)	2.27	2.48	3.44	4.71	6.68	7.04	0.09

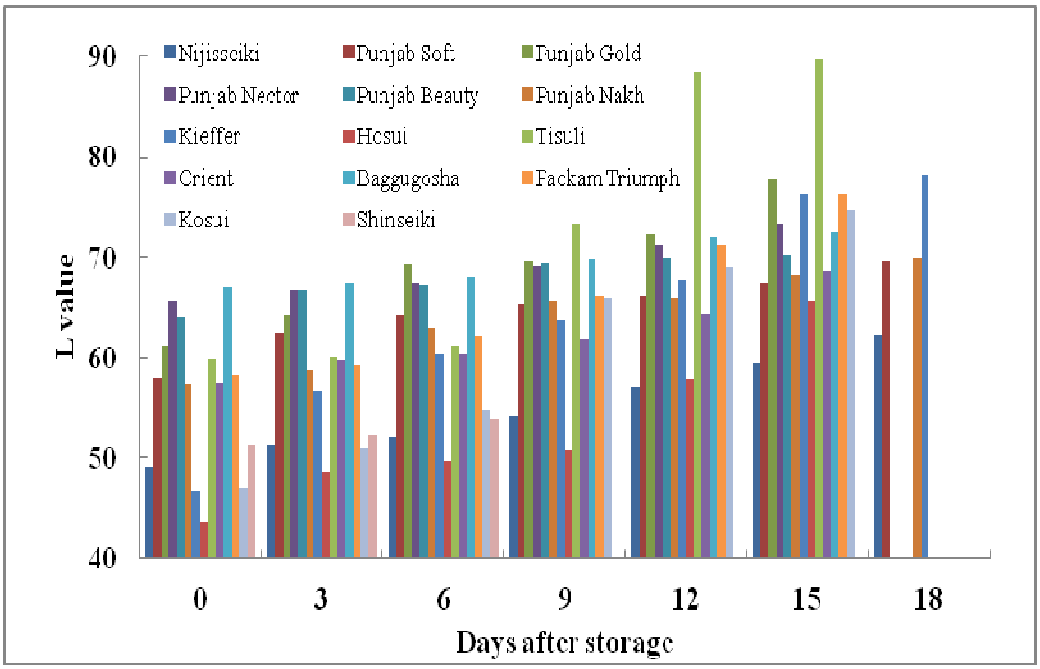

Fig.17. Change in 'L' value during storage in different pear cultivars at ambient temperature.

respectively) (table 22) (fig 17). Fifteen day after storage the maximum change in colour was observed in Tisuli (88.33 to 89.68) followed by Punjab gold (72.41 to 77.67) and in Pakham triumph (72.11 to 76.26) and the minimum value was observed in Nijjiseiki (57.10 to 59.28).

4.2.17.2 'a' value

The perusal of data showed (table 23) the significant variation in the 'a' value in all the varieties. At the maturity time the maximum value of 'a' was observed in Shinseiki (12.24) which was at par with Hosui (10.15) and minimum value in Punjab nakh (1.99) at par with Kieffer (2.49), these values significantly differ from all other varieties. During the storage increasing trend was observed for 'a' value. Not much variation was observed upto three DAS but at twelve DAS all varieties shows much variation (fig 18). Higher colour change was observed at nine DAS in Kosui (12.44) which was at par with Hosui (9.73) and Nijjiseiki (9.54) and the lowest change was observed in Punjab soft (-6.58). The highest change in value (12.44 to 21.76) in Kosui from nine to fifteen day after storage and the minimum value after fifteen day storage was observed in Baggugosha (0.43) followed by Tsuli and Punjab nector (-1.16 and -1.14 respectively). In the 'a' value, if the value towards the positive it donates the red colour and the negative it towards the green colour fruit surface (Singh *et al* 2016).

Table 23: Change in 'a' value during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	7.88	8.91	8.91	9.54	10.4	10.86	11.21
Punjab Soft	-10.08	-8.21	-7.27	-6.98	-4.99	-3.74	-2.96
Punjab Gold	-7.8	-5.64	-4.94	-2.46	1.31	2.96	-
Punjab Nector	-8.15	-5.94	-5.89	-2.96	-1.32	-1.14	-
Punjab Beauty	-8.05	-7.37	-4.64	-1.26	-1.14	0.65	-
Punjab Nakh	-2.07	-1.99	0.22	4.72	5.63	5.75	6.63
Kieffer	-3.95	-2.49	-2.47	-0.9	1.61	4.03	4.33
Hosui	9.34	10.15	9.34	9.73	11.76	15.54	-
Tisuli	-10.83	-8.25	-5.67	-4.18	-2.7	-1.16	-
Orient	-11.05	-7.11	-3.16	-1.88	-0.6	5.57	-
Baggugosha	-7.57	-4.64	-1.71	-0.64	-0.58	0.43	-
Packam Triumph	-7.8	-5.50	-3.16	-2.92	3.02	5.91	-
Kosui	2.26	3.94	5.59	12.44	19.29	21.76	-
Shinseiki	10.38	12.24	10.62	-	-	-	-
LSD ($p<0.05$)	2.07	2.21	2.40	4.74	8.24	6.10	0.86

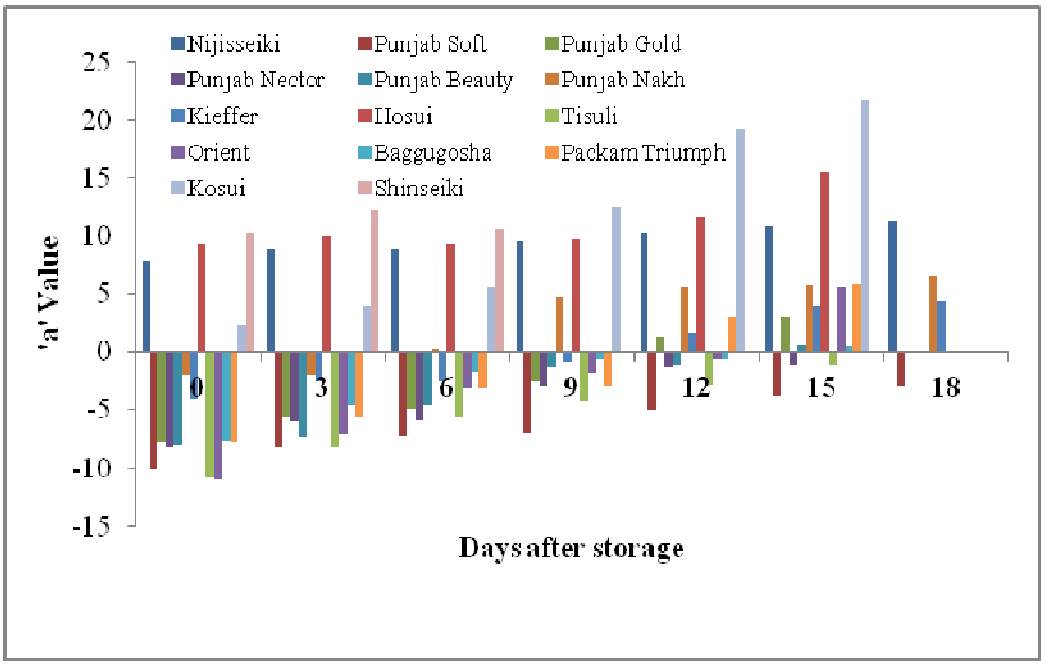

Fig.18. Change in 'a' value during storage in different pear cultivars at ambient temperature.

4.2.17.3 'b' value

At the fruit maturity the highest 'b' value was observed in Baggugosha (47.64) and the minimum in Nijjiseiki (30.43). Upto the six DAS less variation was observed in fruit colour in almost all the varieties but after the twelve days storage highly variation was observed (fig 19). At nine day storage the more yellowish colour was observed in Baggugosha (53.47) and lowest value in Nijjiseki (34.08) due to brownish colour fruit. At the fifteen day storage the higher value was noticed in Baggugosha (57.17) (it changes from 47.64 to 57.17 from 0 to 15th day after storage) at par with Punjab nakh (55.24) and the lowest in Nijjiseiki (38.56). Significant skin colour 'b' value change was observed in all the cultivars under the study during the storage period. In 'b' value, if higher the 'b' value showed the more yellowish colour on the fruit (Singh *et al* 2016).

4.2.17.4 'C' value

In the different cultivars of pear the continue increase in chroma was observed during the storage at room temperature in all the varieties. Increased trend in chroma value during storage was observed in all the varieties (fig 20) but the rate of increasing varied. The maximum rate of change in chroma was observed during storage in Punjab gold from 35.96 to 59.61 at zero to fifteen day after storage followed by Housi from 33.12 to 47.64 and the minimum was observed in Tisuli 42.17 to 47.15. At the maturity the higher value was noticed in Baggugosha (48.24) but after the fifteen day storage the higher value in Punjab gold (59.61) and the lowest at the maturity and after fifteen DAS was observed in Nijjiseiki (31.43 and 35.07 respectively at room temperature storage).

Table 24: Change in 'b' value during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	30.43	32.56	33.23	34.08	36.23	33.56	31.50
Punjab Soft	38.34	40.79	41.71	47.31	48.26	49.36	51.39
Punjab Gold	35.11	41.91	45.2	47.11	50.91	51.94	-
Punjab Nector	41.01	42.05	43.37	45.08	49.44	49.49	-
Punjab Beauty	42.15	42.27	45.72	51.48	52.60	53.81	-
Punjab Nakh	43.76	44.64	45.71	46.15	48.35	55.24	56.56
Kieffer	39.07	41.1	40.07	42.69	42.74	45.99	46.85
Hosui	31.78	32.21	33.78	37.06	43.48	44.60	-
Tisuli	40.72	41.58	42.44	44.16	45.89	46.46	-
Orient	40.56	41.91	43.19	44.51	47.82	48.87	-
Baggugosha	47.64	48.97	50.3	53.47	56.64	57.17	-
Packam Triumph	39.15	40.93	42.72	44.83	46.96	47.49	-
Kosui	32.19	33.34	34.27	38.56	44.65	45.29	-
Shinseiki	32.36	33.84	34.12	-	-	-	-
LSD ($p<0.05$)	3.26	2.30	1.89	2.28	3.09	3.54	5.61

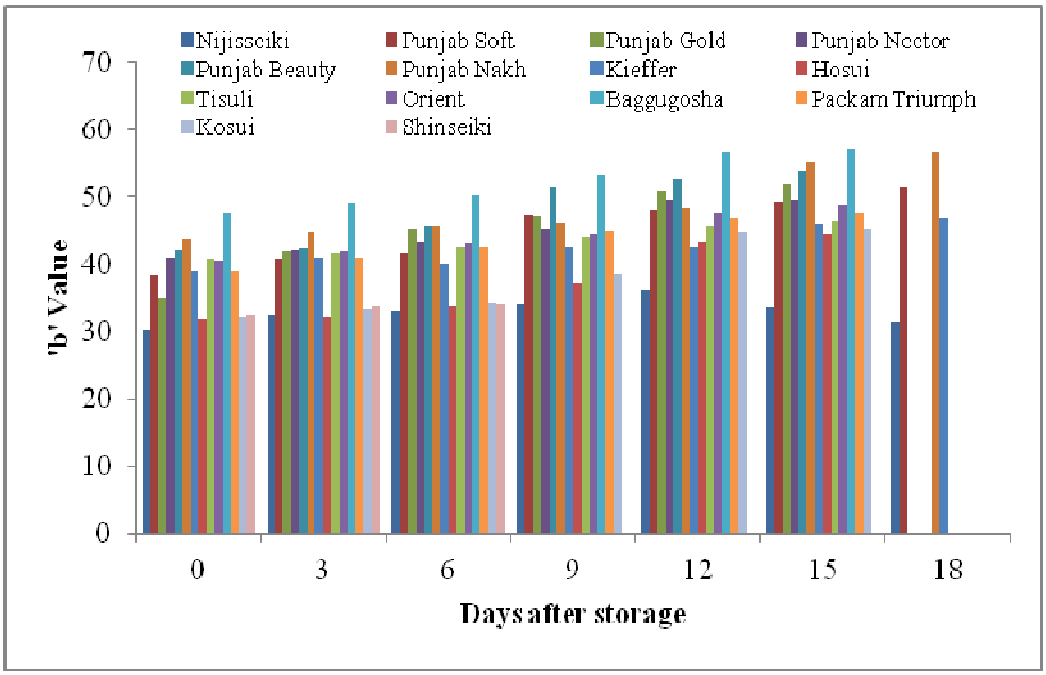

Fig.19. Change in 'b' value during storage in different pear cultivars at ambient temperature.

Table 25: Change in C (Chroma) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	31.43	33.75	34.45	35.39	37.71	35.07	33.34
Punjab Soft	39.64	41.6	42.34	47.82	48.35	49.50	51.47
Punjab Gold	35.96	42.3	45.49	47.17	51.01	59.61	-
Punjab Nector	41.81	42.48	43.76	45.19	49.47	49.50	-
Punjab Beauty	42.91	42.96	45.95	51.54	52.63	52.83	-
Punjab Nakh	43.81	44.73	45.72	46.4	48.67	55.54	56.04
Kieffer	39.27	40.07	41.17	42.84	42.9	46.16	46.25
Hosui	33.12	33.77	35.07	38.33	45.04	47.64	-
Tisuli	42.17	42.41	42.82	44.39	46.06	47.15	-
Orient	42.05	42.51	43.35	44.58	47.54	49.18	-
Baggugosha	48.24	49.19	50.35	53.49	56.64	57.16	-
Packam Triumph	39.96	41.31	42.85	44.93	47.06	47.85	-
Kosui	32.33	33.6	34.72	41.08	50.40	50.54	-
Shinseiki	34.03	35.98	36.75	-	-	-	-
LSD ($p<0.05$)	3.21	2.28	1.99	2.06	3.15	3.84	5.41

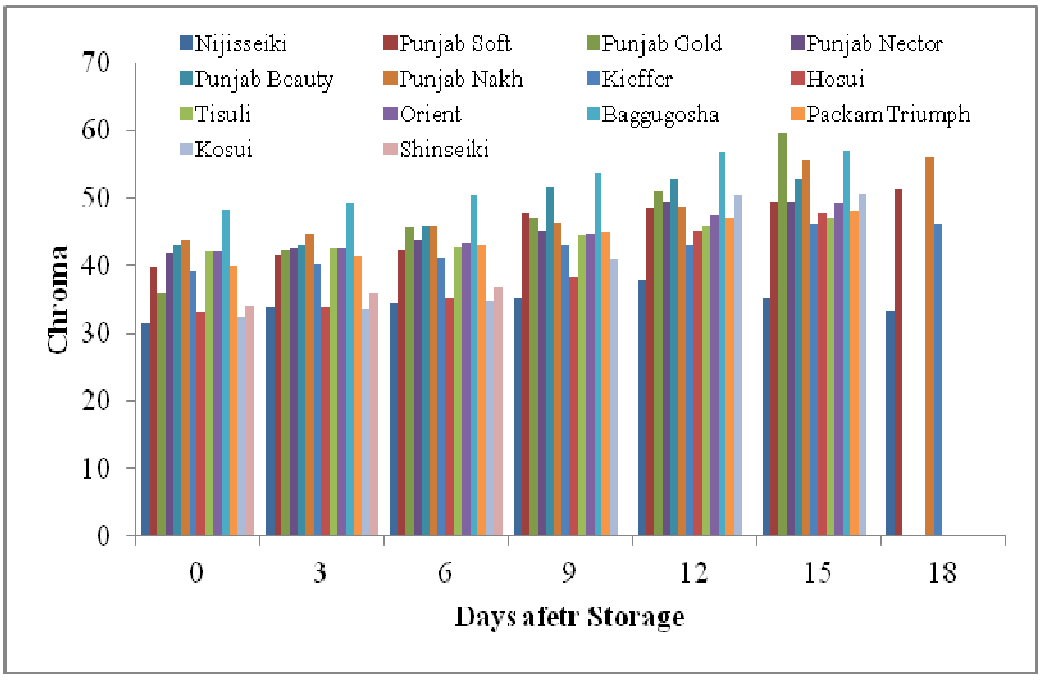

Fig.20. Change in C (Chroma) during storage in different pear cultivars at ambient temperature.

4.2.17.5' h' value

It is evident from the (table 26) at fruit maturity the maximum hue angle was noticed in Orient (105.23) which at par with Tisuli (104.77) and the minimum in Shinseiki (71.8). Itai and Tanahashi (2008) studied that, in Gold Nijjiseiki the skin colour of fruit at harvest was greenish, and after two week storage turn into yellow, rapid decline in hue angle was observed (fig 21). After twelve days storage maximum hue was observed in Punjab soft (96.66) which at par with Tisuli (93.46) and Punjab nector (91.52). At final stage of storage (after fifteen days) the higher value of hue angle was observed in Tisuli (91.53) and lower value in Kosui. During the storage colour of fruit was changed from green to yellow, due to colour change hue angle decreases. With increase in the storage period decrease in the hue angle was observed in all the varieties.

Table 26: Change in 'h' value (Hue angle) during storage in different pear cultivars at ambient temperature.

	Days after storage (DAS)						
Varieties	**0**	**3**	**6**	**9**	**12**	**15**	**18**
Nijisseiki	74.70	74.48	74.35	74.04	73.90	72.28	70.82
Punjab Soft	101.73	103.18	99.89	98.39	96.66	85.48	83.3
Punjab Gold	102.52	97.70	96.18	92.99	88.42	87.12	-
Punjab Nector	101.24	98.04	97.73	93.75	91.52	91.32	-
Punjab Beauty	100.82	99.93	95.79	91.42	91.24	89.28	-
Punjab Nakh	92.71	92.63	89.72	84.1	83.34	83.05	81.71
Kieffer	95.78	93.47	93.02	91.14	87.63	85.00	84.59
Hosui	73.62	72.47	71.55	70.82	69.85	69.17	-
Tisuli	104.77	101.16	97.59	95.44	93.46	91.53	-
Orient	105.23	99.61	94.19	92.42	90.71	83.21	-
Baggugosha	99.04	95.41	91.92	90.66	90.58	89.56	-
Packam Triumph	101.41	97.68	94.2	93.72	86.31	82.90	-
Kosui	85.99	83.23	80.73	72.27	67.55	64.33	-
Shinseiki	71.8	70.11	69.72	-	-	-	-
LSD ($p<0.05$)	3.36	3.07	3.33	6.53	9.39	7.14	2.23

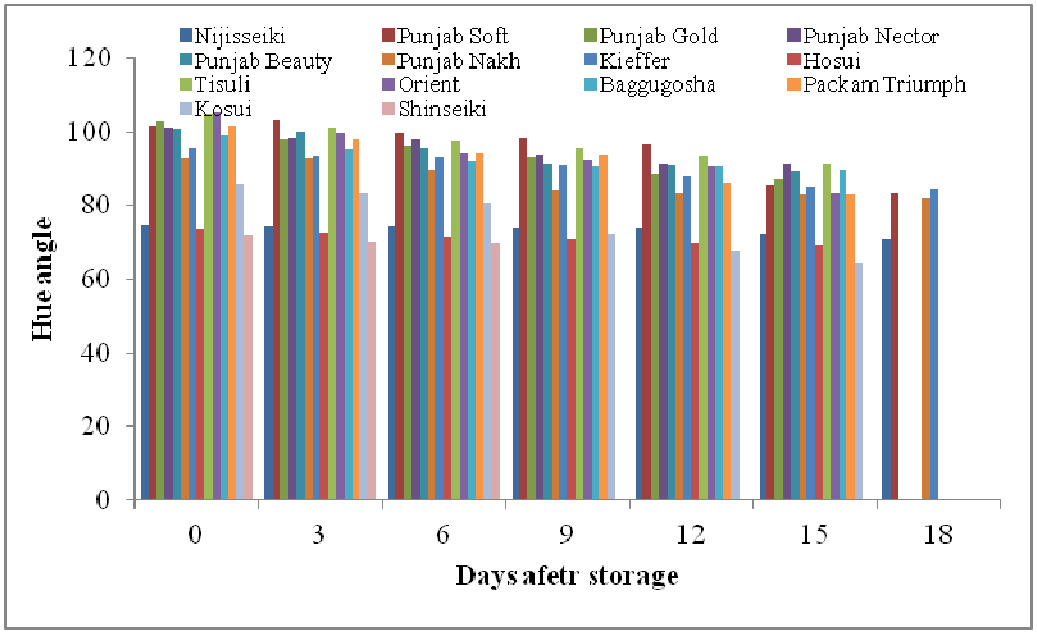

Fig.21. Change in 'h' value (Hue angle) during storage in different pear cultivars at ambient temperature.

CHAPTER V

SUMMARY

Pear is basically a temperate fruit but can be grown successfully in subtropical region of world, due to its wider adaptability. North west Indian plains are best region for cultivation of low chill pears and after great potential for further expansion of area under this crop. As it is hardy crop can survive best in our region but the poor quality fruit of these varieties as compare to high chill variety. So to identify the varieties on the basis of biochemical study and their postharvest behaviour for present investigation on "Biochemical characterization of pear varieties at fruit maturity and their ripening behaviour" was undertaken in the Post graduate laboratory Department of Fruit Science and Department of Biochemistry, PAU Ludhiana. All these fruit plants were given uniform cultural practices during fruit developmental stages. Fruit were harvested at proper maturity of each cultivar. As the quality and taste of the fruit was influenced by various physical and biochemical factors i.e fruit length, diameter, firmness, weight, TSS, acidity, reducing and non reducing sugars, glucose, sucrose and fructose *etc*. The present study was conducted with following objectives;

1. Characterization of pear germplasm on the basis of biochemical parameters.
2. To determine the phytochemical changes during ripening in pear.

The salient findings of the experiment regarding quality changes during storage at ambient room temperature are summarized below:

- The variation in fruit weight and volume was observed in different fourteen cultivars at fruit maturity with an average range from 77.7 to 166.04gm and 76 to 167.3 ml respectively. Maximum fruit weight and fruit volume was observed in Punjab beauty (166.04gm and 167.3ml) and minimum was recorded in Housi (77.77gm and 76ml)
- Maximum fruit length was noticed in the Tisuli 74.27mm which was at par with Punjab beauty (74.08mm) and minimum was recorded in Kosui (46.46mm).
- Whereas fruit diameter was maximum in Orient (68.76mm) followed by Punjab beauty 65.78 and minimum was recorded in Kosui (51.53mm).
- The pear cultivars showed wide variation in fruit firmness ranging from 3.41 to 10.86 kg /cm^2, it might be due to the differences in cell density per unit area in different variety.). After six and fifteen days of storage the rate of decrease in value rises and Tisuli has maximum firmer fruits (9.58 kg / cm^2, 7.75 kg / cm^2) at this stage, while minimum value was observed in Shinsheiki (2.35 kg / cm^2) at six days of storage and (3.08 kg / cm^2) in Kosui at fifteen days of storage respectively.
- Variation was also found in lenticel's / cm^2 ranging from 12 to 44 per cm^2 in different cultivars pear. The maximum number of lenticels were recorded in Punjab nakh (44.66 / cm^2) having at par results with (Hosui 38 / cm^2) and Keiffer (37.66 / cm^2) and

were differ significantly from all other varieties. Minimum value (12 / cm^2) was found in Punjab beauty.

- The dry weight of different cultivars of pear was also varied from 7.26 to 14.76gm/100gm of fresh weight.
- The maximum pedicel length was noticed in Punjab soft 45.29 mm and the significantly higher pedicel diameter was noticed in Tisuli 5.17 mm. The minimum value of pedicel length was observed in Kosui 21.73 mm and the lowest value of pedicel diameter was noticed in Hosui 2.26 mm.
- The difference in the fruit pulp colour was varied from white to brownish tinge at the time of fruit maturity in all varieties.
- In different pear cultivars fruit shape also varied. The turbinate shape was observed in Punjab soft and turbinate to roundish was in Punjab nakh, round shape was observed in Hosui and Kosui. Punjab gold had oblong ovate pyriform shape, Punjab beauty showed obovate obtuse pyriform shape, and oblate shape was found in Orient and shinseiki.
- At the time of fruit maturity the maximum antioxidant activity was observed in Nijjiseiki (0.094 mg/g) and minimum was found in Baggugosha (0.054 mg/g).
- At fruit maturity maximum value for L was showed by Baggugosha 67.08 whereas the highest value of 'a' was observed in Shinseiki 10.38 and the highest value for 'b' was observed in Baggugosha (47.64). The minimum value for 'L' was noticed (43.6) in Hosui, for 'a' (-11.05) in Orient, while in 'b' the lowest value was observed in Nijjisheiki (30.43).
- At harvest time the maximum TSS was recorded in Punjab beauty (14%) which was at par with Punjab gold (13.8%) while minimum value (9.7%) was recorded in Punjab soft. Six days after storage at room temperature these values changed and the maximum TSS (14.9%) was recorded in Orient and minimum 11.90% in Punjab soft. Whereas after fifteen days the maximum value was recorded in Packam triumph 14.10%.
- At the harvest stage maximum acidity content was observed in Orient 0.28% and the lowest percentage of acidity was noticed in Shinseiki 0.15%. Titratable acidity continued to decrease in all the varieties during fruit storage. Tested varieties showed a variation in titratable acidity at six or nine days of storage. After fifteen days of storage the maximum acid content was observed in Punjab beauty (0.32%) and minimum in Punjab gold at par with Punjab nakh at par (0.16%).
- At maturity, the variation in total, reducing and non reducing sugars content in different cultivars of pear ranged from 4.80 to 9.55%, 3.8 to 6.23% and 0.79 to 3.15%

respectively. After storage the increase in total sugar was observed higher in Baggugosha from 9.55 to 11.87% and the minimum was observed in Keiffer (7.68%). The increase could be due to hydrolysis of starch into sugars. The level of reducing sugar also increased and nine days after storage the maximum reducing sugar content was 7.27% in Nijisseiki. The results also revealed that the increase in non-reducing sugar was observed from 3.15% to 4.63% in Baggugosha from zero to six day after storage at room temperature. The increase in sugars may be due to increase in TSS and accumulation of glucose, sucrose and fructose.

- The variation in ascorbic acid content was ranged from 7.33 to 9.92mg/100g in fourteen cultivars of pear. At the three day after storage the maximum ascorbic acid content (9.05 mg/100ml) was found in Orient. However it decreased upto nine days after storage to (6.25 mg/100ml) but remain maximum and decrease at faster rate thereafter. Punjab soft variety have faster rate of decrease in the ascorbic acid content from all the varieties during ambient temperature storage at different intervals.
- The maximum pH at fruit maturity was recorded in Kosui (5.66) at par with Tisuli (5.60) and the minimum (4.70) in Punjab beauty. Upto six days of storage the pH value increased in all cultivars but thereafter the decrease in pH was observed. Rate of increase and decrease also varied among different varieties. Faster variation was recorded in Hosui and less variation was observed in Orient variety.
- At the fruit maturity maximum TSS:acid ratio was observed in Shinseiki (89.53) and lowest in Orient (41.07). Change in TSS:acid ratio during the storage at room temperature, at the stage of zero to six days after storage, the maximum change in TSS:acid ratio was observed in Nijjiseiki (73.75 to 127.00) and the lowest value at six days after storage was observed in Punjab nakh (71.78). At the fifteen day after storage the certain variation was observed in value due to change in TSS and acid content, the maximum value was observed in Punjab nakh (80.63) and minimum in Punjab beauty (40.66).
- At the harvest stage highest glucose content was recorded in Kosui (32.04 mg/gram) whereas after nine days of storage at room temperature, increase in glucose content was observed in Nijjisheiki (48.8 mg/gm) and after fifteen days of storage the maximum value was observed in Keiffer (44.27 mg/gm). The sucrose content was showed variation and increased being highest in Baggugosha 10.78 mg/g and lowest in Keiffer and Punjab nakh (7.09 and 7.49 mg/g respectively) after six days of storage and then decreased upto fifteen days, the minimum value was noticed in Packam triumph and Punjab soft (6.38 mg/g in both) at room temperature. At the fruit maturity the maximum fructose content (table 4) was observed in Nijisseiki (40.89

mg/g) and the minimum in Keiffer (31.66 mg/g) and during storage upto nine or twelve days the fructose content increase and thereafter decease.

- The maximum starch content (51.04 mg/g) was observed in Punjab soft and minimum in Shinseiki (20.46 mg/g) at fruit maturity. Starch content showed high values at harvest stage and decreasing trend was recorded during storage at room temperature.
- At the optimum fruit maturity the maximum phenolic content was observed in Punjab nakh (81.25 mg/g) which was at par with Punjab gold and Punjab Beauty (79.27 and 75.8 ma/g respectively) and minimum in Kosui (54.31 ma/g). In the storage period decrease in the phenolic content was observed due to the oxidation of phenols. Decreasing trend in the phenols was observed due to their hydrolysis into sugar, acids and other compounds.
- The highest fibre content (9.00%) was noticed in Tisuli at the fruit maturity and the lowest in Shinseiki (2.44%). The maximum fibre content at six day after storage was observed in Orient (12.53 %) and minimum in Shinseiki; thereafter it starts decreasing and this decrease was different among varieties and after fifteen day after storage the higher fibre content was found in Packam triumph 8.54 % and lowest in Housi and Kousi (3.83 and 4.24 % respectively).
- The maximum nitrogen content at the time of fruit maturity was observed in Nijjiseki (0.97%). The maximum pulp phosphorous (0.67%), potassium (2.00%), calcium (2.48%) and magnesium (1.14%) content was observed in Punjab Gold and the minimum phosphorous (0.30%) and potassium (1.23%) was observed in Kosui and Shinseiki, calcium in Shinseiki (1.27%) and magnesium in Hosui (0.25%).

It can be concluded that at the time of harvesting of different varieties have different values for physical and biochemical parameters could be due their genetic characters i.e due to variation the maximum firmness was observed in Orient and minimum in Shinseiki. The storage shelf life can be further derived according their physical and biochemical changes that occur during storage. In the storage the shelf life of Nijjiseiki, Punjab soft, Hosui, Kosui, Shinseiki and Baggugosha from three to six days, in Punjab gold, Punjab nector and Punjab beauty six to nine days and in Punjab nakh, Keiffer, Orient, Packam triumph and Tisuli nine to fifteen days was observed.

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VITA

Name of the Student	:	Pawan Kumar
Father's name	:	Sh. Harbhajan Lal
Mother's name	:	Smt. Banso Bai
Nationality	:	Indian
Date of birth	:	15th November, 1994
Permanent home address	:	V.P.O. Bakain Wala, Teh and Distt Fazilka, 152128, Punjab

EDUCATIONAL QUALIFICATIONS

Bachelor degree	:	B.Sc. Agriculture (Hons.)
University	:	Punjab Agricultural University, Ludhiana
Year of award	:	2015
OCPA	:	7.12/10.00
Master's degree	:	M.Sc. Fruit Science
University	:	Punjab Agricultural University, Ludhiana
Year of award	:	2017
OCPA	:	8.01/10.00
Title of Master's Thesis	:	Biochemical characterization of pear varieties at fruit maturity and their ripening behavior