INFLUENCE OF TREE AGE ON VEGETATIVE GROWTH AND FRUIT QUALITY OF 'KINNOW' MANDARIN (*Citrus nobilis* L. x *Citrus deliciosa* T.) UNDER SUBMONTANEOUS REGION OF PUNJAB

A Thesis

Submitted in partial fulfillment of the requirements for the

award of the degree of

DOCTOR OF PHILOSOPHY

in

Horticulture

By

Chaturjeet Singh Rattan

(41500163)

Supervised By

(Dr. Shailesh Kumar Singh)
Associate Prof. & Head,
Department of Horticulture,
Lovely Professional University,
Phagwara, Punjab

Co-Supervised By

(Dr. J. S. Bal)
Professor of Horticulture (Rtd.),
Punjab Agricultural University,
Ludhiana

Transforming Education Transforming India

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

2020

DECLARATION

I hereby declare that the thesis entitled **“Influence of tree age on vegetative growth and fruit quality of ‘Kinnow’ mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab”** submitted for **Doctor of Philosophy in Horticulture** to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.

Place: LPU, Phagwara **(Chaturjeet Singh Rattan)**
Date: 29.09.2020 **(Reg. No. 41500163)**

CERTIFICATE-I

This is to certify that the thesis entitled, **"Influence of tree age on vegetative growth and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab"** submitted to the Faculty of Technology and Sciences**,** Lovely Professional University, Phagwara, Punjab in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture** embodies the results of a piece of bonafide research carried out by **Mr. Chaturjeet Singh Rattan** under my guidance and supervision. To the best of my knowledge, the present work is the result of original investigation and study. No part of this thesis has ever been submitted for any other degree or diploma or published in any other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

Supervisor

(Dr. Shailesh Kumar Singh)
Associate Professor and Head
Department of Horticulture
Lovely Professional University
Phagwara-144 411

Co-Supervisor

(Dr. J. S. Bal)
Professor of Horticulture (Rtd.),
Punjab Agricultural University,
Ludhiana

CERTIFICATE-II

This is to certify that the thesis entitled **"Influence of tree age on vegetative growth and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab"** submitted by **Mr. Chaturjeet Singh Rattan (Registration No. 41500163)** to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an external examiner.

Chairperson, Advisory Committee
(Dr. Shailesh Kumar Singh)
Associate Professor and Head
Department of Horticulture
Lovely Professional University
Phagwara-144 411

External Examiner
(Dr. BVC Mahajan)
Director PHPTC
PAU, Ludhiana

Dean
School of Agriculture
Lovely Professional University
Phagwara-144 411

SCHOOL OF AGRICULTURE
LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

Title of Thesis	**:**	Influence of tree age on vegetative growth and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab.
Name of the Student	**:**	Chaturjeet Singh Rattan
Registration Number	**:**	41500163
Year of Admission	**:**	December, 2015
Name and Designation of Research Supervisor	**:**	Dr. Shailesh Kumar Singh Associate Professor & Head Department of Horticulture Lovely Professional University, Punjab

ABSTRACT

Introduction: Kinnow is a commercially and economically important hybrid of King (*Citrus nobilis* Lour) and Willow leaf (*Citrus deliciosa* Tenora) mandarins. Being adaptable to varied agro-climatic conditions and due to heavy bearing, attractive golden-orange fruit colour and excellent juice quality with distinctive flavour, Kinnow had gained popularity in Punjab and its adjoining states like Haryana, Rajasthan and Himachal Pradesh. Kinnow juice is a rich source of antioxidants, flavanoids, vitamins, minerals and particularly limonin glucosides having anti-cancerous properties and low in saturated fat and cholesterol. Juice of Kinnow mandarin is antispasmodic, anti-carcinogenic, anti-inflammatory and anti-allergic therefore has a high therapeutic value. Every part of the fruit i.e. peel, juice, rag and seed are of high nutritional and medicinal importance.

Background of research: Fruit quality of 'Kinnow' is exhibited by its external features like fruit size, peel colour, peel thickness, peel texture and internal features like juice content, vitamin C, total soluble solids (TSS), titratable acidity and TSS:acidity ratio. These qualities of fruits vary with climate, cultivar, rootstock and cultural practices like pruning, application of growth regulators, irrigation and

nutrition. However, tree age and position of fruits on the tree have also great influence on yield and physico-chemical characteristics of fruits. It is necessary to carry the research on 'Kinnow' mandarin in relation to its tree age to have better understanding that at what age it can contribute towards higher income to the growers. Simultaneously, the study can throw light in relation to fruit quality at appropriate age of fruit plant. This type of study is lacking in the recent years. The research programme is planned in such a way to develop appropriate technical knowhow for the benefit of society as 'Kinnow' fruits can meet the nutritional security in relation to human health. Therefore, in view of the above said background the present study entitled "Influence of tree age on vegetative growth and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab" was carried out.

Methodology: The present study was worked out in the private orchards situated in Block Bhunga, District Hoshiarpur, Punjab during the year 2017-2019. Five orchards of Kinnow mandarin of different age groups having similar cultural and management practices were selected for this study. From each Kinnow orchard, 15 (5 trees with 3 replications) healthy and uniform trees budded on rough lemon (*Citrus jambhiri*) rootstock were identified and marked for the study. The whole investigation was categorised into three interdependent experiments. Portion upto 40 per cent depth from the outer periphery of tree was considered as outer canopy and remaining 60 per cent inner portion was considered as inner canopy. Observations were recorded on various vegetative growth parameters, yield related parameters, external and internal fruit quality parameters, nutrient status in leaf, fruit peel and fruit juice. Fruit physical and chemical qualities parameters were also recorded after 7, 14 and 21 days of harvesting to study shelf life of Kinnow fruits. The data were subjected to statistical analysis by Randomized Block Design.

Experimental findings: Annual increment in vegetative growth was higher in young trees compared to older trees. Macronutrients like N, P, K, Ca, Mg and S were higher in leaves of 20 and 25 years old trees whereas, micronutrients like Fe, Zn, Cu, Mn and B were higher in leaves of young trees of 5 years age. Number of fruits and fruit yield per tree was recorded maximum in 25 years old trees. Maximum fruit size, weight and percentage of E grade fruits was recorded in 5 years old trees. The fruits with smooth surface, better colour, thin peel; lower peel, rag, seed and higher juice percentage was obtained from 20 years old trees. Juice quality in terms of higher TSS, acidity, TSS:acid ratio, total sugars was found better in 20 years old trees whereas, ascorbic acid content was noted higher in 5 year old trees. Free amino acids and limonin content was also found maximum in juice of fruits from 20 years old trees. Peel of fruits from 25 years old trees had higher N, P, Mg and S content whereas, Ca and K content was higher in peel of fruits from 20 years old trees. Fe, Cu and B content was found higher in fruit peel from 5 years old trees whereas, Zn and Mn content was higher in fruit peel from 10 years old trees. Juice of fruits from 20 years old trees were found rich in Ca, K and Mg while fruits from 15 years old trees were rich in P, S, Zn and Cu. Fe, Mn and B content was higher in juice of fruits from 5 years old trees. The fruits from 20 years and 15 years old trees were found to have better shelf life in terms of minimum physiological loss in weight and spoilage and fruits from these age groups maintained higher firmness, juice content, organoleptic rating, TSS, acidity and sugars after 21 days of harvesting. Ascorbic acid was maintained higher in the fruits of 5 years old trees.

In case of canopy position, number of fruits and fruit yield was recorded higher in outer canopy. Inner canopy fruits were found better in higher percentage of E, D and C grade fruits, fruit size, fruit weight, smooth peel, thin peel, less peel, less rag, less seed count, higher juice percentage and higher limonin content, whereas, outer canopy fruits were found better in fruit colour, less seed percentage, higher TSS, acidity, TSS:acid ratio, ascorbic acid, total sugars and free amino acids content. Outer canopy fruits had higher peel N, peel Mg, peel S, juice N and juice S, whereas, inner canopy fruits had higher peel P, peel K, peel Ca, peel Zn, peel Mn, juice P, juice K and juice Ca. Inner canopy fruits had better shelf life in terms of lower physiological loss in weight and spoilage along with higher firmness and juice recovery. The fruit quality in terms of higher TSS, acidity, TSS:acid ratio, ascorbic acid and total sugars was maintained higher by outer canopy fruits during shelf life.

Conclusion: It was concluded that younger trees had higher vegetative growth rate, fruit size and fruit weight compared to older trees. In general, macronutrients were higher in leaves and fruits of older trees whereas, micronutrients were higher in leaves and fruits of younger ones. The fruits harvested from 20 years old trees had better

quality and shelf life. Outer canopy fruits were better in colour and juice quality whereas, internal and external physical qualities were better in inner canopy fruits. Nutrients content in fruits was higher in the inner canopy. Fruits in the inner canopy had better shelf life in terms of lower physiological loss in weight and spoilage and higher firmness and juice recovery, but juice quality was maintained higher by outer canopy fruits.

ACKNOWLEDGEMENT

First and foremost, I dedicatedly accord my sincere gratitude to **'Akal Purkh Waheguru'** who blessed and bestowed me the health and courage throughout my Ph.D. programme and made me able to get another achievement in my life.

I express my sincere and profound thanks to my esteemed chairman of my advisory committee **Dr. Shailesh Kumar Singh,** Associate Professor and Head, Department of Horticulture, School of Agriculture, Faculty of Technology and Sciences, Lovely Professional University, Phagwara (Punjab) for his keen interest, excellent guidance, constant encouragement, constructive criticism and untiring efforts rendered to me even at the cost of his personal comfort for the completion of my work in its wholeness.

The words at my command are simply inadequate to express my wholehearted thanks to my respected Co-Supervisor, **Dr. J S Bal,** Professor of Horticulture (Rtd.), Punjab Agricultural University, Ludhiana for his tremendous guidance and continuous support throughout the research programme. I am extremely thankful to him for his valuable time spared from his very busy schedule to mark critical and meticulous observations in the thesis.

With a sense of gratitude and indebtedness, I owe my extreme thanks to **Dr. BVC Mahajan,** Director, Punjab Horticulture Post Harvest Technology Centre, Ludhiana for his kind help, cooperation and guidance provided to me, without which it would not be possible to carry out this research progamme.

I am also thankful to **Dr. Ramesh Sadawarti,** Head, School of Agriculture, LPU for continuous inspiration and affection throughout my Ph.D. programme.

I am equally grateful and indebted to **Dr. Balwinder Singh Badhan,** Project Officer, Centre of Excellence for Fruits (Citrus) Khanaura, Hoshiarpur for his ever available & unconditional help and positive attitude that made the completion of this research possible.

I express my sincere thanks to **Dr. Harminder Singh,** Head, Department of Fruit Science and **Dr. Nav Prem Singh,** Horticulturist, Punjab Agricultural University, Liudhiana for their guidance and suggestions during the course of this study.

I proudly and profoundly admire and appreciate the support of my friends and colleagues **Dr. Jagdish Singh,** Assistant Soil Scientist, **Dr. Dilpreet,** Assistant Professor Vegetables, **Dr. Jaspal Singh,** Horticulture Development Officer and **Dr. Damandeep Singh,** Horticulture Development Officer who extended a helping hand in the accomplishment of this study.

I am highly thankful to **Director, Department of Horticulture, Punjab** for the cooperation and support.

My sincere thanks are due to **Dr. Gulab Singh Gill,** Joint Director Horticulture and **Dr. Karun Sagar,** Deputy Director Horticulture, Department of Horticulture Punjab for their constant encouragement and moral support.

I fully acknowledge the help and cooperation rendered by the ***staff members*** *of School of Agriculture and Central Library, Lovely Professional University and* ***technical staff*** *of Citrus Estate Bhunga (Hoshiarpur) and Centre of Excellence for Fruits (Citrus), Khanaura (Hoshiarpur) during the research programme.*

I am overwhelmed with rejoice to avail this opportunity to evince my profound sense of gratitude to ***my parents, sisters and brother*** *for their measureless prayers, everlasting love and constant encouragement that brought me upto this level. Love and affection of lovely kids of family* ***Harsh, Harleen, Prabhleen and Navpreet*** *is always an inspiration and need a special mention.*

I express special thanks to my wife, ***Harsimrat*** *for her continuous love, unconditional support, understanding, encouragement and patience that made the completion of thesis possible.*

My thesis acknowledgement would be incomplete without mentioning my cute and beautiful baby daughter ***'Harasees Kaur'*** *whose smiling face always made me happy. I completely dedicate this thesis to her.*

All those who care for me may not have got a mention, but none shall ever be forgotten.

Thanks everybody.

Place: LPU, Phagwara **Chaturjeet Singh Rattan**
Date: 29.09.2020 **(Reg. No. 41500163)**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviated Form	Full Form
OC	Outer canopy
IC	Inner canopy
@	At the rate of
ha	Hectare
ha^{-1}	Per hectare
MT	Metric tonnes
et al.	et alia (and others)
ft.	Foot
mm	Milli meter
m	Meter
%	Per cent
g	Gram
cm	Centimetres
cm^2	Centimetres square
mg	Milligram
mg/g	Milli gram per gram
cv.	Cultivar
ml	Millilitre
ppm	Parts per million
/	Per
^0C	Degree Celsius
^0B	Degree Brix
V	Volume
W	Weight
sq. cm.	Square centimetre
LAI	Leaf area index
TSS	Total Soluble Solids
E-W	East-West
N-S	North-South

Abbreviated Form	**Full Form**
*L**	Luminosity
*a**	Colour coordinates (a)
*b**	Colour coordinates (b)
C	Chroma
h	hue angle
HNO_3	Nitric acid
HCl	Hydrochloric acid
NaOH	Sodium Hydroxide
K_2SO_4	Potassium Sulphate
$CuSO_4$	Copper Sulphate
DCPIP	2, 6-dichlorophenol-indophenol
OD	Optical Density
TSS	Total Soluble Solids
PLW	Physiological loss in weight

CHAPTER-I

INTROD UCTION

Citrus is a member of family Rutaceae which is supposed to be native to Southeast Asia. It is one of the demanding fruit crops that is widely established as commercial orchard under tropical and subtropical climatic conditions. Globally citrus is extensively grown in China, Brazil, India, USA, Maxico, Spain, Egypt, Turkey, Italy, South Africa, Morocco and Pakistan. India stands at 3rd position among all citrus growing countries in the world contributing about 7.85 percent of total citrus production (FAO, 2017). Citrus holds 2nd position in the fruit industry of India after mango. Presently, citrus covers an area of about 1.03 million hectares accounting for the production of 13.20 million MT with an average productivity of 12.77 MT ha^{-1} (Anon, 2020). Citrus orchards are predominantly established in Maharashtra, Madhya Pradesh, Andhra Pradesh, Telangana and Punjab states. Punjab is ranked 4th in citrus production after Andhra Pradesh, Maharashtra and Madhya Pradesh. There are different types of citrus fruits which are grown in our country, of which mandarin stands 1st in terms of area and production when compared to sweet orange and lime/lemons (Anon, 2018).

Among mandarins, Kinnow is a commercially and economically important hybrid of King (*Citrus nobilis* Lour) and Willow leaf (*Citrus deliciosa* Tenora) mandarins. Although it was firstly developed by Dr. H. B. Frost at the Citrus Research Centre of the University of California, Riverside, USA in 1925, but it was released as commercial variety in 1935 after ten years of evaluation trials for study about the stability of genotype under different locations. It was an effort of Dr. J. C. Bakhshi who had made possible the introduction of this cultivar at Regional Fruit Research Station-Punjab Agricultural University, Abohar in 1954 (Rajput and Haribabu, 1985).

Being adaptable to varied agro-climatic conditions and due to heavy bearing, attractive golden-orange fruit colour and excellent juice quality with distinctive flavour, Kinnow had gained popularity in Punjab and its adjoining states like Haryana, Rajasthan and Himachal Pradesh. In Punjab, it is the leading citrus cultivar which alone contributes about 61 per cent area and 67 per cent production to the total fruits. Presently, Kinnow occupies an area of approximately 54243 ha with the total production of about 13.13 lakh MT. Fazilka, Hoshiarpur, Sri Mukatsar Sahib and Bathinda are major Kinnow growing districts of Punjab (Anon, 2020).

Kinnow juice is a rich source of antioxidants, flavanoids, vitamins, minerals and particularly limonin glucosides having anti-cancerous properties and low in saturated fat and cholesterol. Juice of Kinnow mandarin is antispasmodic, anti-carcinogenic, anti-inflammatory and anti-allergic therefore has a high therapeutic value. Every part of the fruit i.e. peel, juice, rag and seed are of high nutritional and medicinal importance.

The external appearance and quality of fruits significantly influence the marketing of fruits. The fruit quality in citrus is mainly determined by its external characteristics like fruit size, peel colour, peel thickness, peel texture and internal characteristics like juice content, vitamin C, total soluble solids (TSS), titratable acidity and TSS: acidity ratio. These qualities of citrus fruits vary with climate, cultivars, rootstocks and cultural practices like pruning, application of growth regulators, irrigation and nutrition (Zekri, 2011). However, tree age has also great influence on productivity and physico-chemical parameters of citrus fruit.

In 'Marsh Seedless' grapefruit, the fruits from 20-years old trees were found larger and bigger in size with thin peel in comparison to the fruits obtained from 34 years old trees (Ozeker, 2000). In ‘Kinnow’ mandarin, the fruits developed on younger tree had thick and coarse peel, high rag content, greater proportion of rind and poor quality of juice in comparison to trees of older ages (Khalid *et al.,* 2012). Maximum fruit yield, TSS, acidity, TSS:acidity, vitamin C, total sugars were reported in the fruits of ‘Kinnow’ mandarin obtained from 15-years old trees in comparison with trees of 5 and 10-years age (Sidhu *et al*., 2017). Variations in physical and chemical fruit characteristics of citrus with tree age development were also reported (El-Sayed, 2018). Presently, scanty information is available on fruit quality and tree age relationship in ‘Kinnow’ fruits and whatever information is available that covers only limited age groups.

Apart from tree age, the position of fruits in the tree canopy also had influence over the quality aspects of fruits. In ‘Kinnow’ mandarin, higher quality of fruits was reported in the upper sides (Jawanda *et al.,* 1973) and outer sides (Josan *et* *al.,* 1983) of the trees as compared to inner sides of the trees. In various citrus species, the fruit weight, juice volume, fresh and dry weight of rind and rind thickness were recorded significantly higher in fruits from internal canopy in comparison to fruits located in the external canopy (Fallahi *et al*., 1989).

In 'Satsuma' mandarin, the reception of light intensity over the exterior and interior portions of the tree canopy was reported to be variable and had influenced the development of fruits which resulted in the deviation in quality of fruits borne on the same trees (Izumi *et al.,* 1988). The fruits harvested from the exterior canopy were found superior in terms of diameter, weight, peel colour, TSS, sugars and ascorbic acid in comparison to interior canopy in 'Satsuma' mandarin (Izumi *et al.,* 1990a). Fruit size, fruit weight, pulp weight and thickness, TSS and acidity were found maximum in the external portion of the trees of 'Shiranuhi' mandarin (Moon *et al.,* 2011). Receiving more PAR (Photosynthetic Active Radiations) incidence as well as more photosynthesis in external canopy as compared to internal canopy resulted good quality fruits in 'Kinnow' (Thakre *et al.,* 2015). Currently, little information is available on the quality changes in 'Kinnow' mandarin in relation to the fruit canopy positions but combined influence of tree age and location of fruits on the tree canopy on quality of fruits in 'Kinnow' needs to be explored.

Further, both tree age and canopy position have influence over storage life of fruit as well. In 'Satsuma' mandarin, the rate of microbial decay was greater in the fruits harvested from interior canopy whereas, respiration rate was higher in the fruits from exterior canopy during storage at 15°C (Izumi *et al.,* 1990b). After 7 days of ambient storage, higher mass loss was reported in fruits of 'Kinnow' mandarin collected from 18-years-old tree in comparison to 6 and 35-years-old trees (Khalid *et al.,* 2017). In 'Marsh' grapefruit, canopy position was found to have effect on physicochemical properties of fruits while in storage (Olarewaju *et al.,* 2018). However, the collective impact of tree age and canopy position on shelf life of 'Kinnow' fruits needs attention from investigators.

Further, it was necessary to carry the research on 'Kinnow' mandarin in relation to its tree age to have better understanding that at what age it can contribute towards higher income to the growers. Simultaneously, the study can throw light in relation to fruit quality at appropriate age of fruit plant. Thus, the fruit at specific stage can be recommended to overcome the adverse effect of certain maladies in the human system. This type of study was lacking in the recent years. The research programme was planned in such a way to develop appropriate technical knowhow for the benefit of society as ‘Kinnow’ fruits can meet the nutritional security in relation to human health.

Therefore, a comprehensive research was required to study the variations in vegetative growth, fruit quality and shelf life of ‘Kinnow’ mandarin with respect to various age levels of trees.

Objectives

Considering the above discussed facts, the current investigation was worked out with the objectives mentioned below:

1. To study the relation of tree age with vegetative growth, leaf nutrients content and fruit yield of ‘Kinnow’.
2. To study the relation of tree age and canopy position with yield, quality and nutrients content of ‘Kinnow’ fruits.
3. To study the relation of tree age and canopy position with shelf life of ‘Kinnow’ fruits.

CHAPTER II

REVIEW OF LITERATURE

The current investigation "Influence of tree age on vegetative growth and fruit quality of ‘Kinnow’ mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab" was carried out during year 2017-19 in 'Kinnow' orchards located in Bhunga block, district Hoshiarpur. Fruit quality in citrus is mainly determined by its external characteristics like fruit size, peel colour, peel thickness, peel texture and internal characteristics like juice content, vitamin C, total soluble solids (TSS), titratable acidity and TSS:acidity ratio. Although, fruit yield and quality are affected by various factors like climate, cultivar, rootstock, quality of planting material, pruning, growth regulators, irrigation and nutrition, yet other factors like tree age and position of fruits in tree canopy has great influence on yield and quality of fruits. The literatures relevant to the current study has been substantially reviewed and presented through under mentioned heads and sub-headings:

2.1 Tree age

2.1.1 Influence of tree age on vegetative growth

2.1.2 Influence of tree age on fruit yield

2.1.3 Influence of tree age on fruit quality

2.1.4 Influence of tree age on nutrient elements

2.1.5 Influence of tree age on fruit quality during storage

2.2. Canopy position

2.2.1 Influence of canopy position on fruit yield

2.2.2 Influence of canopy position on fruit quality

2.2.3 Influence of canopy position on nutrient elements

2.1.4 Influence of canopy position on fruit quality during storage

2.3 Mineral nutrition

2.4 Shelf life of fruits

2.1 Tree age

Tree age affects vegetative growth of trees, yield and quality of fruits to a great extent. A brief review on the relation of tree age with the growth, fruit yield, fruit quality, foliar and fruit nutrients and storage life is presented below:

2.1.1 Influence of tree age on vegetative growth

Tree age has great influence on the vegetative growth of tree. While working on 'Valencia' orange trees of different ages, Turrell (1961) recorded total leaf area of 34, 59, 146, and 203 square meters, tree height of 2.90, 3.20, 5.03 and 4.72 meters, crown circumference of 7.26, 7.32, 11.02 and 15.70 meters, crown volume of 8.14, 9.41, 32.78, 64.52 cubic meters and trunk diameter of 9.6, 11.3, 19.2 and 27.2 centimetres as tree growth functions in 3, 6, 12 and 29 years old trees, respectively. Vegetative growth rate was found to be high in the young tree of orange in comparison to adult tree (Hearn, 1994). The canopy volume and leaf area, increased gradually with the enhancement in trunk cross-sectional area and both were recorded maximum at highest trunk cross-sectional area in 'Kinnow' mandarin trees (Dalal and Brar, 2012). In 6 years old 'Kinnow' trees, highest trunk growth was found during spring in comparison to rainy and winter season whereas, maximum leaf area was noticed during rainy season (Dalal *et al.,* 2013). Highest leaf area was recorded in 15 years old tree in comparison to 5 and 10 years old tree of 'Newhall' navel orange during spring, summer and autumn flushes, however the effect was found non-significant (El-Sayed, 2018).

In 'Nanguo' pear trees, Liu *et al.* (2016) recorded tree height of 1.70, 3.22, 5.03 meters and trunk circumference of 7.5, 14.5, 30.0 centimetres as tree growth properties in 1, 5 and 10 years old trees, respectively.

2.1.2 Influence of tree age on fruit yield characteristics

Fruit yield increases with the tree age due to increase in bearing surface in the earlier years but once the trees reach at maturity there is levelling off in yield (Botts, 1941). While working on grade distribution in ‘Kinnow’ mandarin, Bal and Chohan (1983) rerecorded maximum number of fruits in B grade followed by C, A, D and E grades in 11 years old trees. In 5 years old 'Kinnow' mandarin trees, a positive and significant association was found between trunk cross-sectional area and average fruit yield (Dalal and Brar, 2012). In 'Kinnow' mandarin trees, Sidhu *et al.* (2017)

recorded highest fruit counts per tree and fruit yield (kg $tree^{-1}$) in 15 years old trees followed by 10 years and 5 years old trees. Similar results were also reported by (El-Sayed, 2018) in 'Newhall' navel orange.

In 'Nanguo' pear trees, Liu *et al.,* (2016) recorded fruit yield of 28.0 kg and 5.76 kg per tree in 10 and 5 years old trees, respectively as tree growth property. The highest fruit yield was estimated in the trees aged between 5-15 years in comparison to <5 and >15 years old trees of guava (Sharma and Kumawat, 2019).

2.1.3 Influence of tree age on fruit quality

2.1.3.1 Physical fruit quality

The tree age has noticeable impact on external as well as internal physical qualities of fruits. Tree age was reported to have influence on juice content in oranges (Frometa and Echazabal, 1988). Larger fruit with coarser and thicker rind and less juice content was found in young citrus trees than older trees (Gilfillan, 1990). Poor rind colour was observed in young vigorous growing trees in comparison to slow growing adult citrus trees (Davies and Albrigo, 1994 and Krajewski, 1997). The fruits of higher weight, size, more juice content, thinner and smooth peel with light yellow colour were obtained from 20 years old in comparison to 34 years old trees of 'Marsh seedless' grapefruit (Ozeker, 2000). Highest rind thickness, rind mass and rag mass with lowest juice content was found in fruits of young 'Kinnow' trees of 3 years age (Khalid *et al.,* 2012).

Nakorn and Chalumpak (2016) recorded the highest fruit weight, diameter, circumference, peel weight, pulp weight and lowest peel thickness in fruits taken from 8 year old trees when compared with 6 and 4 year old trees of pummelo cv. Tabtimsiam. Kochhar *et al.,* (2017) recorded highest fruit size, fruit weight, fruit volume but lowest specific gravity in 8 years old trees when compared with 4 and 12 years old trees of 'Kinnow' mandarin. While working on 5, 10 and 15 years old 'Kinnow' trees, Sidhu (2017) recorded maximum fruit weight in 10 years old trees while, fruit size and juice percent was maximum in the fruits collected from 15 years old trees. In an another study, fruit weight, fruit size, fruit shape index and thickness of rind were found maximum in 5 years old 'Newhall' navel orange trees followed by 10 and 15 years old trees whereas, rind smoothness was found maximum in 15 years old trees subsequently followed by 10 and 5 years old trees (El-Sayed, 2018).

DongHui *et al.* (2005) observed that weight and diameter of fruits were higher which were harvested from 5-10 years old in comparison to 20-30 years old trees of *Prunus salicina*. While working on different aged trees of guava cv. Allahabad Safeda, Asrey *et al.* (2007) reported that seed proportion was lowest in the fruits harvested from 20 years old trees in comparison to 10 and 15 years old trees whereas, specific gravity was found lowest in 10 years old trees. Higher fruit firmness and lower fruit colour was recorded in the fruits taken from older trees (>20 years) as compared to middle aged and young trees of 'Ároma' apple (Tahir *et al.,* 2007). Decrease in fruit size was noticed with the increase in trunk cross sectional area in guava cv. Allahabad safeda (Kumar *et al.,* 2008). Kumar and Ram (2018) reported that the 'Amrapali' mango fruits produced from younger trees of 6 years age had higher firmness, higher peel thickness and lower specific gravity when compared with 18 years and 30 years old trees.

2.1.3.2 Influence of tree age on chemical fruit quality

Effect of tree age on TSS and acidity of fruits was recorded in 'Satsuma' mandarin (Matsumato *et al.,* 1972) and in orange (Frometa and Echazabal, 1988). Young citrus trees produced fruits with lower TSS and acid content as compared to older trees (Gilfillan, 1990). Lower TSS, acidity and high TSS/acid ratio was found in the fruits of young vigorously growing orange trees (Hearn, 1994). The fruits of higher TSS, acidity and TSS/acid ratio were obtained from 20 years old in comparison to 34 years old trees of 'Marsh seedless' grapefruit (Ozeker, 2000). TSS and sugar level was recorded highest in the fruits of 18 years old whereas, TSS/acid ratio and ascorbic acid was found highest in the fruits of 3 years old 'Kinnow' trees (Khalid *et al.,* 2012).

Nakorn and Chalumpak (2016) recorded the highest TSS, TSS:Acid ratio and lowest acidity in fruits collected from 8 years old trees in comparison to 6 years and 4 years old trees of pummelo cv. Tabtimsiam. TSS, acidity, TSS/acid ratio, vitamin C, total sugars and reducing sugars were found maximum in the fruits of 15 years old 'Kinnow' trees and minimum in fruits of 5 years old trees (Sidhu *et al.,* 2017). Similarly, El-Sayed (2018) recorded the highest TSS and TSS/acid ratio in fruits of 15 years old 'Newhall' navel orange trees as compared to 5 and 10 years old trees whereas, no significant impact of tree age was found on acidity and vitamin C content.

In Japanese plum, no significant effect of tree age was found on taste, TSS and acidity of fruits, however, higher ascorbic acid was found in 5-10 years old than 20-30 year old trees (DongHui *et al.,* 2005). The highest TSS, total sugars, vitamin C and minimum acidity was reported in the fruits collected from 15 years old 'Allahabad Safeda' guava in comparison to 10 and 20 years old trees (Asrey *et al.,* 2007). Flavour quality was noted higher in the fruits taken from older trees (>20 years) as compared to middle aged and young trees of 'Ároma' apple (Tahir *et al.,* 2007). Kumar and Ram (2018) reported that the 'Amraplai' mango fruits produced from middle age trees (18 years old) were better in quality in terms of higher TSS, higher sugars and medium acidity as compared to 6 years and 30 years old plants.

2.1.4 Influence of tree age on nutrient elements

2.1.4.1 Leaf nutrients content

In 11 years old 'Newhall' and 'Skagg's Bonanza' navel orange trees, Sheng *et al.* (2009) reported that Ca, Mn, and K concentrations in leaves were found relatively constant whereas concentrations of Mg, B, Fe, and Zn showed variations throughout the fruit growth and development. Leaf nitrogen and phosphorus increased gradually with the growth in trunk cross-sectional area and were recorded maximum at highest cross-sectional area of trunk in 'Kinnow' mandarin (Dalal and Brar, 2012). Macro as well as micronutrients level was found maximum in the leaves of 15 years old 'Kinnow trees as compared to 10 and 5 years old trees throughout the fruit development period (Sidhu, 2017). Macronutrients like nitrogen, phosphorus, calcium and magnesium content was found greater in the leaf samples of 15 years old trees followed by 10 and 5 years old 'Newhall' navel orange trees, whereas tree age was found to have non-significant effect on micronutrients (El-Sayed, 2018). N, P and K level in 'Kinnow' leaves was observed higher in old orchards as compared to young orchards (Khalid *et al.,* 2018).

Ratio of N and Ca was increased whereas, P and K was decreased in leaves of 'Nanguo' pear as age increased from 1 to 10 years (Liu *et al.,* 2016). Deficiency of nitrogen, phosphorus and zinc was observed in the leaves of more than 15 years old guava trees (Sharma and Kumawat, 2019).

2.1.4.2 Fruit nutrients content

In 'Navel' orange trees, fruits from mature trees had greater K to Ca and Mg to Ca ratio in albedo during first phase of fruit growth and development in comparison to fruits from younger trees (Storey and Treeby, 2002). Higher N, P, Mn and Fe in 18 years old trees, K in 6 years and Ca in 35 years old trees were found in rind of fruits of 'Kinnow' (Khalid *et al.,* 2012). The macronutrients (N, P and K) level in fruit rind and rag was observed greater in the fruits which were gathered from old-aged trees (35 years) in comparison to 6 and 18 years old trees (Khalid *et al.,* 2018).

Less Ca content was found in fruits collected from avocado trees with heavy vigour in comparison to trees with low vigour (Whitney *et al.,* 1990). Calcium content was higher, while N content was found lower in the fruits taken from old-aged avocado tree (Snijder *et al.,* 2002). In 'Allahabad Safeda' guava, the fruits produced from 15 years old trees were rich in Cu and Mn whereas, Fe content was found higher in fruits from 10 years old trees. The fruits rich in Mg and Zn were produced from 20 years old trees (Asrey *et al.,* 2007). In 'Amrapali' mango trees, Kumar and Ram (2018) recorded the decrease in the Ca content and rise in K content as trees became older, whereas no definite pattern was found in case of B, Fe, Cu, Zn, and Mn content with the tree age.

2.1.5 Influence of tree age on fruit quality during storage

The rind breakdown was the severe problem in the fruits collected from mature 'Navel' orange trees in comparison to the fruits collected from the younger trees (Storey and Treeby, 2002). After 7 days of ambient storage of 'Kinnow' mandarin higher fruit quality viz. TSS, acidity and sugar values were recorded in 35 years old trees in comparison to 6 years and 18 years old trees. Also, higher weight loss was reported in fruits collected from 18 years old trees (Khalid *et al.,* 2017).

It was observed that the pome fruits collected from the younger trees were very prone to postharvest losses as compared to old trees (Bramlage, 1993). Younger trees generally produced fruits with poorer storage potential than older trees in ‘Pinkerton’ avocado (Kruger *et al.,* 2004). During storage highest loss in firmness and flavour quality was recorded in the fruits of 'Ároma' apple trees of younger age (4-6 years old) as compared to older age trees. Further, it was recorded that fruits from younger trees were more sensitive, had lower storage potential, susceptible to bruising and more prone to *Pezicula malicorticis* mediated decay and internal breakdown during storage (Tahir *et al.,* 2007).

2.2 Canopy position

Position of the fruits in the tree canopy has also immense effect on fruit quality. Most desirable fruit quality characteristics like fruit colour, large size, thin peel, higher juice with high TSS/acid ratio are dependent upon the exposure of fruits to the light. A brief review on relation of fruit canopy position with fruit yield, fruit quality, nutrient element and storage life is presented below:

2.2.1 Influence of canopy position on fruit yield

In 'Ruby' grapefruit, outer as well as southern top canopy positions yielded more fruits than the remaining canopy positions (Syvertsen and Albrigo, 1980). 50 per cent shading of tree had not altered the fruit count and fruit yield in 'Spring' navel orange trees (Syvertsen *et al.,* 2003).

In persimmon, higher fruit yield was recorded in upper canopy position of trees (George *et al.,* 1996). Higher fruit yield and maximum A grade fruits in 'Spring Lady' peaches were recorded in middle position of the trees trained to Y shape system and in the top position of the trees trained to central leader system (Caruso *et al.,* 1998). Maximum interception of solar radiations in the upper portion of tree canopy resulted maximum fruit number and fruit yield in upper part of canopy than the remaining portion of canopy of 'Sardar' guava trees (Singh and Dhaliwal, 2007). While evaluating the effect of upper-outer, lower-outer and inside canopy positions on 'Num Dok Mai Sithong' mango cultivar, Kawphaitoon *et al.* (2016) recorded a greater number of mango fruits in inside canopy than the other canopy positions.

2.2.2 Influence of canopy position on fruit quality

2.2.2.1 Physical fruit quality

Reitz and Sites (1948) observed little impact of fruit position on the juice percent in 'Valencia' orange. Higher juice percentage and lower fruit size and rind proportion was recorded towards the tip (upper) of the citrus tree (Wallace *et al.,* 1965). Heavier fruits containing low juice and greater rind proportion were obtained from interior side of the canopy in comparison to remaining part of tree canopy in 'Kinnow' mandarin (Jawanda *et al.,* 1973). Highest fruit weight was noticed in top crown position whereas, maximum fruit shape index and fruit colour index was recorded in middle crown position in 'Satsuma' mandarin trees trained to modified central leader, semi-spherical and open central type (Suzuki *et al.,* 1973). 'Satsuma' orange fruits were larger with better rind color (more orange) in the outer position of the tree canopy (Iwagaki and Kudo, 1977). Fruits with less weight and less juice quantity were obtained from the shaded positions as compared to canopy positions exposed to sun (Syvertsen and Albrigo, 1980).

Fruit weight and peel weight (Daito *et al.,* 1981) and fruit weight and the colour index (Tominaga and Daito, 1982) in 'Satsuma' mandarin was found higher at the upper portion of each tree when compared with interior canopy fruits. Fruit colour in 'Satsuma' mandarin was developed better in the exterior of the tree canopy whereas, no difference was found in fruit colour between the upper and lower part of tree canopy (Iwagaki, 1981). The fruits produced in inner canopy were smaller with softer rind and higher juice content as compared to fruits on outer and top canopy in sweet orange (Deidda *et al.,* 1981). Outside fruits of 'Satsuma' mandarin were found heavier with more coloration in comparison to inside fruits (Iwagaki and Kato, 1982). Fruits exposed to the sun in outer tree canopy contained higher fruit weight with more peel and juice content and quick colour development in ‘Kinnow’ mandarin (Josan *et al.,* 1983). 'Mineola' tangerines fruits produced in external, southern and higher canopy were heavier, larger in size with lower juice quantity as compared to fruits from internal, northern and lower canopy of trees (Cohen, 1988). Average fruit weight, juice content, rind fresh and dry mass and thickness of fruit rind from internal canopy were found substantially high in comparison to the fruits collected from the outer canopy of various citrus species (Fallahi *et al.,* 1989).

Superior fruits in terms of diameter, weight and peel colour were obtained from exterior canopy of ‘Satsuma’ mandarin as compared to interior canopy (Izumi *et al.,* 1990a). 'Valencia' orange fruits harvested from the north-east quadrant of tree were slightly larger and heavier than those of the south-west quadrant during fruit growth and development (Arpaia *et al.,* 1991). In another study, Izumi *et al.* (1992) worked out on the impact of various intensities of light (5, 20, 50 and 100% levels of full sunlight) on ‘Satsuma’ mandarin and revealed that the mature fruits harvested from trees grown at 5 and 20 per cent of full sunlight were inferior in fruit size, weight and peel colour (a/b value) as compared to other light levels. While determining the maturity indices for 'Kinnow" mandarin, Sandhu (1992) found higher fruit weight in inner canopy in comparison to outer canopy. Citrus fruits located near the outside of the canopy usually show colour-break earlier than fruit on the inside and can be harvested earlier, but only if mature internally also (Krajewski, 1997). 'Tarocco' orange fruits had higher hue values of peel colour in the fruits from interior canopy of tree whereas, L, a, b and C values were not affected significantly by canopy position (Agabbio *et al.*, 1999).

Fruit firmness, juice content and hue values were found increased towards the bottom of tree canopy and highest values were recorded in fruits borne at bottom in both inside as well as outside tree canopy in 'Orlando' tangelo (Morales *et al.,* 2000). 50 per cent shading of tree did not affect the size of fruit but shaded fruits had better colour than the sun exposed fruits in 'Spring' navel orange trees (Syvertsen *et al.,* 2003). Fruit diameter of 'Valencia' sweet orange was found higher in south-west top canopy as compared to north-east bottom canopy while reverse results were obtained in subsequent years (Barry *et al.,* 2004). Top canopy fruits of larger size were produced in 'Satsumas', 'Clementine' and 'Temple' but smallest in 'Fairchild'. Inside bottom fruits in all the four cultivars were rich in juice content than the top fruits (Verreynne *et al.*, 2004). The fruits of 'Ray Ruby' Red grapefruit were heavier and larger from the south direction of tree canopy than the north direction (Syvertsen *et al.*, 2005).

The fruits taken from the inside of the tree canopy had higher fruit weight, higher fruit volume, higher peel and pulp weight and less juice content in comparison with the fruits harvested from other canopy positions of 'Kinnow' trees whereas, the variation in seed count, seed weight and peel thickness was not significant and were not affected substantially with the position of fruits on tree canopy (Khan *et al*., 2009). During fruit development study in 'Nules Clementine' mandarin, Cronje *et al.* (2011) found lighter and smaller (diameter and length) fruits consistently through development period in inside canopy whereas, hue value was found lower (less green colour) in inner canopy during immature stage but after colour break stage lower hue value (intense orange colour) was found in outside canopy. Maximum radiation interception in upper part of tree canopy than remaining portion of canopy resulted higher fruit size, weight and pulp thickness in fruits from ‘Shiranuhi’ mandarin trees

(Moon *et al.,* 2011). Higher rind colour score, rind thickness and rind mass but lower rind smoothness score, juice and seed mass were reported in 'Kinnow' fruits collected from external canopy of tree as compared to the internal one (Khalid *et al.,* 2012).

In 'Pera' orange, fruits taken from periphery of the canopy had higher fruit fresh mass, longitudinal & transversal diameter, thickness of flavedo with yellower peel than the fruits in the inner canopy. Also, fruits from the apical portion of the canopy had more fruit weight and longitudinal diameter than fruits from the basal part (Lemos *et al.,* 2012). In another study, Lemos *et al.* (2013) reported that outer periphery and apical portion of tree canopy produced fruits with higher fresh mass, longitudinal diameter, thickness of albedo with yellower peel in 'Natal' orange and more orange colour in 'Valencia' orange than the fruits produced inside the canopy. Shading resulted the smaller citrus fruits than fruits from the trees receiving full sunlight (Gimeno *et al.*, 2015). More PAR incidence as well as more photosynthesis in external canopy resulted superior fruits in terms of fruit weight, length and diameter in 'Kinnow' mandarin as compared internal canopy of the tree (Thakre *et al.,* 2015). Fruit rind from outer canopy was found more luminous than the inner canopy fruits in 'Marsh' grapefruit harvested from KwaZulu-Natal province in South Africa whereas, reverse results were obtained in Mpumalanga province (Olarewaju *et al.*, 2018). Higher fruit size, fruit weight, rag percentage and seed percentage was noticed in mandarin fruits on eastern side of tree canopy while fruit firmness and peel thickness was recorded higher in fruits on northern side and juice percentage was higher in fruits on western side of tree canopy (Timilsina and Tripathi, 2019).

Larger fruits with higher proportion of red colour on skin were harvested from outer positions of tree than the inner and lower positions in apple (Jackson *et al.,* 1971 and 1977). Top canopy 'Royal Delicious' apple fruits were superior in colour and texture but poor in juice content (Krishnaprakash *et al.,* 1983). Quality of 'Nam Dok Mai' mango fruits did not vary significantly from upper to lower canopy positions, however deeper yellow pulp and lower fruit firmness was recorded in upper tree canopy (Ketsa *et al.,* 1992). Significantly higher firmness was observed in 'Songold' plum fruits from top canopy than the bottom canopy of tree, while skin ground colour didn't vary with canopy position (Taylor *et al.,* 1993). Increased shade in the canopy resulted smaller and greener fruits in 'Bartlett' pear whereas, the canopy position of fruits did not affect the fruit firmness (Ramos *et al.,* 1994). Little or no impact of canopy position on fruit physical quality was noticed in persimmon (George *et al.,* 1996).

Per cent red colour and fruit weight increased with the increase in the light levels whereas little variation in fruit firmness with the change in the light levels was noticed in 'Delicious' apple (Barritt *et al.,* 1997). In 'Angelus' peaches, fruit ground and flesh colour, percentage of over colour and firmness was greater at the top canopy position where fruits were completely exposed to sun light than in the lower and mid canopy positions (Luchsinger *et al.,* 2002). Reddest fruits having lowest fruit weight and volume were harvested from upper inner canopy in comparison to remaining canopy positions in 'Pink' wax apple (Shu, 2002). Larger fruits with dark surface were obtained from exterior canopy as compared to interior canopy in peach (Lewallen and Marini, 2003). No significant difference in seed content in relation to canopy positions whereas, higher specific gravity in upper canopy fruits was found in guava cv. Allahabad Safeda (Asrey *et al.,* 2007). External top and internal top canopy fruits had higher fruit weight and flesh firmness in kiwifruit as compared to external bottom and internal bottom canopy positions (Remorini *et al.,* 2007).

Maximum radiation interception over the upper portion of tree than remaining portion of canopy resulted higher fruit size, weight and lower specific gravity in upper canopy fruits of 'Sardar' guava (Singh and Dhaliwal, 2007). Medium sized fruits with higher fresh and dry weight were obtained from under the canopy as compared to the exposed canopy in trees of starfruit (Zabedah, 2007). The fruits farthest from the central leader of tree in the east-west direction were larger in size with less firmness as compared to fruits closer to the leader in kiwifruit (Boyd *et al.,* 2008). Better red coloured and less firmer fruits were obtained from the sun exposed parts of canopy in different apple cultivars (Drogoudi and Pantelidis, 2011). Among vertical layers of canopy, higher colouring index but lower fresh weight and diameter of fruits was noticed in upper layer of canopy than the lower and mid layer canopies whereas, among horizontal layers of tree canopy, apart from fruit colour and firmness, no significant differences among other fruit characters were found in the fruits of nectarine (Kong *et al.,* 2011).

Fruit weight and fruit firmness was reported higher in the fruits collected from outer canopy than the inner canopy in McIntosh, Gala and Mutsu cvs. of apple (Feng *et al.*, 2014). Due to more intense red colouration along with the higher quality of fruits from outer canopy, 'Starking' apple fruits were preferred over the inner canopy fruits however, appearance of apple cv. 'Granny Smith' and 'Golden Delicious' was preferred from inside canopy fruits (Hamadziripi *et al.*, 2014). While evaluating the effect of upper-outer, lower-outer and inside canopy positions on 'Num Dok Mai Sithong' mango, Kawphaitoon *et al.* (2016) recorded no significant effect of different canopy positions on fruit weight, volume, peel, pulp and seed weight, fruit firmness, peel colour, per cent edible part and per cent fruit grading. Bigger and softer fruits were harvested from upper canopy position than the mid and lower canopies of Japanese plum trees (Makeredza *et al.*, 2018). Peach fruits harvested from upper tree canopy had higher fruit size, fruit weight, higher fruit colour in terms of redness with early maturity than the middle and lower canopy fruits (Sharma *et al.*, 2018).

2.2.2.2 Chemical fruit quality

Highest value of total soluble solids, TSS/acid ratio and ascorbic acid in 'Valencia' orange was recorded in fruits harvested from outer top tree canopy in comparison to other canopy positions (Reitz and Sites, 1948). Winston and Miller (1948) recorded significantly higher TSS and vitamin C content in exposed fruits than in shaded fruits while acidity did not show any specific pattern in round orange varieties like Parson Brown, Hamlin, Pineapple, Indian River, Seedling and Valencia, in Temple oranges and in Dancy tangerines. 'Duncan' grapefruit harvested from outer canopy had higher TSS and TSS:acid ratio in comparison to the fruits of inside canopy. Also, fruits on the southern and western position of trees had higher TSS content than the northern shaded position of the tree (Sites and Reitz, 1950). TSS and acidity had been reported higher in the upper sides of the citrus tree (Wallace *et al.*, 1965). Higher TSS and acidity in fruits was recorded in the upper canopy of ‘Kinnow’ trees (Jawanda *et al.*, 1973). Maximum soluble solids content in top, acidity in lower and soluble solids/acidity ratio in middle crown position was recorded in 'Satsuma' mandarin trees trained to modified central leader, semispherical and open central type (Suzuki *et al.*, 1973). ‘Ruby’ grapefruit fruits harvested from outer canopy had higher total soluble solids and TSS/acid ratio but lower in the acidity than the fruits harvested from the inner canopy (Syvertsen and Albrigo, 1980).

Fruit quality in terms of TSS and acidity was little affected with fruit positions within the tree canopy (Daito *et al.,* 1981). Outside fruits of 'Satsuma' mandarin were found higher in TSS and lower in acidity in comparison to inside fruits (Iwagaki and Kato, 1982). 'Satsuma' mandarin fruits had higher TSS, sugars and lower acidity in top than the interior canopy position and skirt (Tominaga and Daito, 1982). The fruits exposed to the sun in outer tree canopy contained higher TSS and vitamin C content in 'Kinnow' mandarin (Josan *et al.,* 1983). Exposed fruits of oranges on the tree canopy had higher reducing and non-reducing sugars (Uchida *et al.,* 1985). 'Mineola' tangerines fruits produced in external, southern and higher canopy were more edible and tastier as compared to fruits from internal, northern and lower canopy of trees (Cohen, 1988). In 'Satsuma' mandarin, fruits quality in terms of sugars and acid decreased with decrease in the light intensity (Ono and Iwagaki, 1987 and Suzuki *et al.,* 1988). Fallahi *et al.* (1989) recorded higher soluble solids and solids to acid ratio in external canopy fruits of different citrus species except 'Kinnow' mandarin in which higher solids to acid ratio was found in internal fruits. Superior fruits in terms of TSS, sugars and ascorbic acid were obtained from exterior canopy of 'Satsuma' mandarin as compared to interior canopy (Izumi *et al.,* 1988 and Izumi *et al.,* 1990a).

In another study, Izumi *et al.* (1992) reported that the mature 'Satsuma' mandarin fruits harvested from trees grown at 5 and 20 per cent of full sunlight were inferior in quality due to lower ascorbic acid and sugar contents in the juice as compared to fruits from trees receiving 50 and 100 per cent of full sunlight. While determining the maturity indices for 'Kinnow" mandarin, Sandhu (1992) found higher Brix and acidity in the outer canopy but higher Brix:acid ratio in the inner canopy. Higher TSS, TSS/acid ratio and lower acidity was reported in 'Tarocco' orange fruits from external southern canopy as compared to fruits from internal and northern side of the canopy (Agabbio *et al.,* 1999). In 'Valencia' sweet orange soluble solids content was recorded higher in the exposed fruits than the shaded fruits (Barry *et al.,* 2000). The fruits of 'Orlando' tangelo harvested from top positions of both inside and outside tree canopy had higher brix and brix:acid ratio and lower acidity in comparison to middle and lower positions (Morales *et al.*, 2000). In 'Valencia' orange, total soluble solids content was greater in fruits from exposed canopy positions than the shaded bottom position (Freeman and Robbertse, 2003).

TSS content in 'Valencia' sweet orange fruits was higher in south-west top canopy as compared to north-east bottom canopy, while canopy position did not affect acidity significantly (Barry *et al.,* 2003 and Barry *et al.,* 2004). Citrus fruit quality in terms of TSS and ascorbic content was greater in the fruits of outer canopy as compared internal canopy (Singh *et al.,* 2004). While evaluating the quality of 'Mihowase' Satsuma, 'Nules' Clementine, 'Fairchild' and 'Temple' tangor, Verreynne *et al.* (2004) reported that top and outside canopy fruits in all the varieties had higher TSS and TSS:acid ratio and lower acidity except Fairchild which has lowest acidity in inside canopy fruits. In comparison to fruits from inside and lower tree canopy, 'Kinnow' mandarin fruits from top and outer periphery of tree were significantly higher in soluble solid content (SSC), SSC:TA ratio, total sugars, reducing sugars, non-reducing sugars and ascorbic acid (Khan *et al.,* 2009). Soluble solids and acid content in fruits was recorded higher in upper than remaining part of canopy in 'Shiranuhi' mandarin trees (Moon *et al.,* 2011). Heavily shaded fruits in the interior of the canopy had lower TSS than the fruits on the exterior of the canopy in citrus (Zekri, 2011).

Higher TSS, acidity, TSS:acid ratio, total sugars, reducing sugars, non-reducing sugars and ascorbic acid was recorded in 'Kinnow' mandarin fruits collected from external canopy of tree as compared to the internal one (Khalid *et al.,* 2012). In 'Pera' orange, fruits collected from periphery of the canopy were characterized with high TSS level but low vitamin C and acid content in comparison to the fruits in the inner canopy (Lemos *et al.,* 2012). Similarly, Lemos *et al.* (2013) reported that outer periphery and apical portion of tree canopy produced fruits with higher soluble solids but lower vitamin C and acid content in 'Natal' orange and 'Valencia' orange than the fruits produced inside the canopy. The flavedo of outside fruits, developing under higher-light conditions, was well coloured (lower hue angle) and had a higher sugar concentration compared with inside fruits developing under conditions of lower light levels (Cronje *et al*., 2013). More PAR incidence as well as more photosynthesis in external canopy resulted superior fruits of 'Kinnow' mandarin in terms of TSS, acidity and ascorbic acid in juice as well as in peel compared internal canopy of the trees (Thakre *et al.,* 2015). There was significant impact of positions of fruits on the tree canopy over biochemical parameters of the flavedo & albedo in 'Nules Clementine' mandarin (Olarewaju *et al.,* 2018). Mandarin fruits from southern tree canopy had higher TSS while acidity and vitamin C content was higher in fruits harvested from western tree canopy (Timilsina and Tripathi, 2019).

Bottom canopy 'Royal Delicious' apple fruits had significantly higher quality in terms of higher TSS, aroma, flavour and colour as compared to middle and top canopy fruits (Krishnaprakash *et al.,* 1983). Quality of 'Nam Dok Mai' mango fruits did not vary significantly from upper to lower canopy positions, however higher TSS, TSS:acid and reducing sugars while lower acidity and ascorbic acid content was reported in upper tree canopy (Ketsa *et al.,* 1992). Significantly higher TSS and TSS/acid ratio was reported in 'Songold' plum fruits from top canopy than the bottom canopy of tree (Taylor *et al.,* 1993). Increased shade in the canopy resulted lower soluble solids content but higher acidity in 'Bartlett' pear (Ramos *et al.,* 1994). Total soluble solids were increased with the increase in the light levels whereas, little variation in titratable acidity with the change in the light levels was noticed in 'Delicious' apple (Barritt *et al.,* 1997).

'Spring Lady' peach fruits produced in top canopy had higher TSS than in the other canopy positions on the tree trained to Y shape system as well as central leader system (Caruso *et al.,* 1998). Forlani *et al.* (2002) suggested the important role of lower canopy layer for production of good quality fruits like the top and middle canopy layers in peach cv. Alba. In 'Angelus' peaches, soluble solids concentration and pH was higher at the top canopy position where fruits were completely exposed to sun light than in the lower and mid canopy positions (Luchsinger *et al.,* 2002). Higher TSS, total sugars and minimum acidity was recorded in 'Allahabad Safeda' guava fruits harvested from upper canopy whereas, vitamin C was recorded higher in the lower and middle canopy of trees (Asrey *et al.,* 2007). External top canopy fruits had higher TSS and vitamin C content in kiwifruit as compared to internal top, external bottom and internal bottom canopy positions (Remorini *et al.,* 2007).

Higher total soluble solids content in fruits were obtained from the sun exposed parts of canopy in different apple cultivars (Drogoudi and Pantelidis, 2011).

Higher soluble solids content was found in fruits from upper layer and exposed zone than lower layer and shaded zone in nectarines (Kong *et al.,* 2011). Greatly shaded fruits in the interior of the canopy had lower TSS than the fruits on the exterior of the canopy in McIntosh, Gala and Mutsu cvs. apple (Feng *et al.,* 2014). Outer canopy fruits of 'Starking', 'Granny Smith' and 'Golden Delicious' apple cultivars had higher total soluble soilds but lower acidity and were sweeter than the inner canopy fruits (Hamadziripi *et al.,* 2014). In 'Num Dok Mai Sithong' mango, Kawphaitoon *et al.* (2016) recorded highest TSS and TSS:acid ratio in fruits obtained from upper outer tree canopy. Makeredza *et al.* (2018) recorded higher total soluble solids content in fruits of upper canopy positions than the mid and lower canopies of Japanese plum trees.

2.2.3 Influence of canopy position on nutrient elements

Higher leaf N, P and Mg content was recorded in top crown position as compared to middle and lower positions whereas, K and Ca did not show specific pattern in 'Satsuma' mandarin trees trained to modified central leader, semispherical and open central type (Suzuki *et al.,* 1973). While evaluating the elemental content in fruit peel and juice of different citrus species, Fallahi *et al.* (1989) recorded higher N, P, K content in fruit peel (dry weight basis) of internal canopy fruits whereas, S, Mg and other micronutrients were found higher in fruit peel of external canopy fruits. Further, significantly higher N content in mandarin and orange juice and higher Ca, Mg, S content in grapefruit and lemon juice was recorded in fruits of external canopy than internal canopy. Fifty per cent shading of tree resulted higher N content in leaves than the sun exposed leaves in 'Spring' navel orange trees (Syvertsen *et al.,* 2003). In 'Nules Clementine' mandarin, Ca and Mg was accumulated significantly higher in flavedo of outer canopy fruits while, higher level of K was accumulated in flavedo of fruits obtained from inner tree canopy (Cronje *et al*., 2011). Rind P, K and Mn content was greater in the fruits from internal canopy whereas, N was greater in fruits from external portion of canopy. However, Zn, Cu and Fe were not affected significantly by the canopy positions (Khalid *et al.,* 2012).

Lower N, P, Mg, Ca and higher K content in leaves was found in shaded portion of apple trees (Jackson and Palmer, 1977). In 'Songold' plum, leaves from the top of the trees had lower N, P, K, Ca and Mg level than the bottom canopy however, difference was significant only for K. On the other hand, these nutrients were significantly higher in bottom canopy fruits as compared to top canopy fruits (Taylor *et al.,* 1993). Higher Ca content was found in apple fruits located on the top of the tree than the bottom one (Tomala, 1997). In 'Angelus' peaches, higher leaf N and Mn content was recorded in top canopy position while leaf P, K, Ca, Mg, Cu, Zn and B content was recorded higher in bottom canopy position (Luchsinger *et al.,* 2002). Asrey *et al.* (2007) recorded greater range of elemental content in the fruits among all the canopy positions, however, middle canopy fruits were rich in Cu, Mn and Zn and upper canopy fruits were rich in Mg and Fe. In 'Pant Prabhat' guava lower canopy fruits had higher minerals content than the upper canopy fruits (Tamta and Kumar, 2011).

2.2.4 Influence of canopy position on fruit quality during storage

Rate of weight loss, fruit decay and juice acidity were recorded lower in 'Ruby' grapefruit fruits from exterior canopy while, TSS, total sugars and ascorbic acid was recorded higher in interior canopy fruits during storage at 10°C (Abed-el-Wahab, 1990). After 110 days of storage at 5°C and 15°C, the microbial decay was much higher in the 'Satsuma' mandarin fruits harvested from interior canopy than from exterior canopy. Further, fruits from the external canopy showed marked increase in peel colour and maintained higher sugars and ascorbic acid level during the storage (Izumi *et al.,* 1990b). After storage at 15°C and 20°C, higher ascorbic acid was found in exterior canopy fruits than interior fruits of citrus (Izumi, 1998). In 'Tarocco' orange fruits, no significant effect of canopy position was observed on fruit mass loss and decay percentage after 5 and 10 weeks of cold storage at 9°C, however after simulated marketing period of one week at 21°C, lower fruit mass loss was observed in fruits from interior and southern parts of canopy and lower decay percentage was observed in fruits from interior and northern parts of canopy (Agabbio *et al*., 1999). After 4 weeks of storage at 10°C, fruit flavedo of exterior canopy fruits had higher levels of pitting than the interior canopy fruits in grapefruit (McDonald *et al.,* 2000).

In 'Nules Clementine' mandarin, rind break down was reported significantly higher in the fruits of inside canopy than the outside canopy fruits after 14 weeks of storage at 7.5°C (Cronje *et al*., 2011 and Cronje *et al.,* 2013). After storage for 8 weeks at 8°C, fruits of 'Nules Clementine' mandarin collected from outer canopy of tree reflected greater rind colour index and rind sugars than the inside fruits whereas, weight loss and rind break down were noticed higher in inside fruits than the outside fruits (Magwaza *et al.,* 2013). The fruits from inner canopy had higher acidity and lower TSS/acid ratio than the outer canopy fruits whereas, total soluble solids level was not influenced by canopy position after cold storage of 'Marsh' grapefruit for 9 weeks (Olarewaju *et al.,* 2018). Youryon and Supapvanich (2019) reported that the fruits collected from the upper portion of canopy had greater Chroma and brightness, TSS and ascorbic acid than the fruits from lower and middle canopy positions whereas, acidity did not vary significantly after the storage of 'Shogun' mandarin fruits at 20°C and 10°C.

After storage, higher percentage of soft rot and bitter pit was found in 'Cox's Orange Pippin' apple fruits harvested from exterior canopy as compared to interior canopy (Jackson *et al.*, 1971 and 1977). The fruits farthest from the tree trunk, in the north-south direction were more susceptible to physiological pitting disorder during storage than the fruits near the trunk in kiwifruit (Boyd *et al.,* 2008). 'd' Anjou' pear fruits harvested from internal canopy position were greener (high hue angle value) and had more fruit weight loss as compared to external fruits after 24 days of storage of fruits at room temperature conditions (Rudell *et al.*, 2017).

2.3 Mineral Nutrition

A high and positive correlation was reported between average fruit weight and Zn concentration of leaves of 'Valencia' orange trees in the low productive orchards whereas, in highly productive orchards, a strong and positive correlation was reported between the average fruit weight Ca content of leaves (Fidalski *et al.,* 2000). In 'Valencia', 'Parson Brown', 'Hamlin' and 'Sunbrust' orange cultivars, macronutrients content was reported to be decreased during fruit growth and development whereas, micronutrients content was observed to be increased in beginning and then decreased in later phase of fruit growth and development (Paramasivam *et al.,* 2000). Decrease in fruit P and K was recorded during growth and development phase of fruits in the orange cultivar Navel whereas, Ca firstly increased throughout stage I and then decreased during second and third stage of growth and development of fruits (Storey and Treeby, 2000). Foliar concentrations of K and Zn exhibited positive correlation with big and medium fruits and negative correlation with small fruits in orange cultivar Valencia (Rodriguez *et al.,* 2005).

In fruit rind, Ca, B, Fe, and Mn concentrations were reached the maximum level at stage II but K and Mg firstly increased at stage I and then decreased. Whereas, in fruit pulp, Ca, K, Mg and Mn decreased slowly with time but B and Ca showed increasing trend at the stages of fruit growth and development in orange cultivars 'Newhall' and 'Skagg's Bonanza' (Sheng *et al.,* 2009). While evaluating correlations between rind nutrient status with fruit and rind quality, a positive correlation of rind smoothness with N and P and negative with Mn whereas, rind thickness was having strong and negative correlation with Ca content in fruit rind was reported in 'Kinnow'. In case of biochemical parameters of fruit quality, TSS was found negatively associated with P, K, Cu, Fe; juice percentage was in positive correlation with Ca, P and Zn and in negative correlation with Mn while, rind mass and rag mass were having negative correlation with Ca and Mn content of fruit rind (Khalid *et al.*, 2012). Fruit yield was found significantly and positively correlated with leaf macronutrients content, while leaf Zn showed a positive correlation with both fruit yield and quality parameters of sweet orange (Marathe *et al.,* 2012).

Application of K and Zn had enhanced fruit yield and improved fruit quality attributes of 'Kinnow' viz. higher fruit size, weight, TSS and ascorbic acid content (Gurjar and Rana, 2014). Sufficient supply of P and K is a key for the successful commercial production of 'Kinnow' Mandarin fruits as Kinnow is a strong sink for these elements (Mirsoleimani *et al.*, 2014). Shading resulted the decrease in B and Cu content in citrus leaves (Gimeno *et al.,* 2015). In grapefruit, level of K, Ca, Mg, Fe and Mn level was higher in fruit peel whereas, level of N, P, Zn and Cu level was found higher in fruit pulp (Singh *et al.,* 2015). Fruit quality parameters like juice content, TSS, acidity, TSS:acid, sugars, ascorbic acid, leaf and fruit nutrient increased with the application of Zn and K in 'Kinnow' mandarin (Chaudhary *et al.,* 2016). As per leaf nutrient standards, optimum concentration of N, P, K, Ca, Mg, Mn, Zn, Cu, Fe and B in citrus leaves is 2.5-2.7 per cent, 0.12-0.16 per cent, 1.2-1.7 per cent, 3.0-4.9 per cent , 0.30-0.49 per cent, 25-100 ppm, 25-100 ppm, 5-16 ppm, 60-120 ppm and 36-100 ppm, respectively (Rattanpal *et al.,* 2017).

Higher concentration of Ca, Mg, Fe, K, P and Na was reported in peel extract of *Citrus maxima* compared to the concentration in juice (Ani and Abel, 2018). N, K and Ca content in leaves exhibited significant positive while, Mg, S, Mn, Zn, Cu and Fe exhibited moderately positive correlation with fruit yield and quality in Khasi mandarin (Jongkey and Hazarika, 2018). Potassium enhanced fruit yield, size, weight and improved orange colour in 'Maltaise' citrus (Mimoun *et al.,* 2018). While evaluating the mineral content in peel and pulp of orange, pomelo, mandarin, lemon, lime and grapefruit, Czech *et al.* (2020) recorded higher concentration of macro and micronutrients in peel of fruits as compared to their content in pulp. Further, orange fruits were found richest in P, K Fe, Cu and Mn, pomelos were found richest in Cu while lime was found good source of Ca, Zn, Na and K.

Lower Ca level in apple fruits of outer tree canopy resulted proneness to bitter pit and internal breakdown in fruits (Tomala, 1997). Leaf N, P, K and Zn reflected positive correlation with fruit yield in apple (Mamgain *et al.,* 1998). While developing the inter-relation between leaves and fruits elemental content with fruit quality of seven apple cultivars, it was observed that among all the nutrients in the leaves as well as fruits, only P and Mg were found to be correlated for their content in fruits and leaves. Fruit diameter was positively while juice SSC was negatively correlated with leaf N level. Fruit P was negatively correlated with fruit diameter. Leaf P and Ca showed positive correlation with acidity but negative correlation with SSC/Acidity ratio (Dris *et al.,* 1999). Fruit firmness in 'Gala' apple was found positively correlated with Ca and B content in fruits but negatively with K (Johnson, 2000).

A strong correlation was established between leaf and fruit nutritional status and the quality parameters of fruits in 'Golden Smoothee' apples and a negative correlation of leaf N, Ca, Mg and B with fruit N was observed. However, leaf K content was strongly and positively correlated to fruit P and K; leaf Ca showed no relation with fruit Ca but manifested negative correlation with fruit N, P and K. Further, K and P content both in leaf and fruit and fruit Ca was positively correlated with fruit quality and firmness, respectively (Casero *et al.*, 2005). Higher N content in apple fruits resulted higher respiration rate and ethylene concentration and negatively correlated with fruit red or yellow colour whereas, fruit Ca was having positive correlation with fruit firmness and a negative correlation with incidence of bitter pit disorder. Further, it was concluded that fruit quality could be predicted more precisely with the both leaf and fruit minerals analysis in comparison to the use of leaf minerals only (Fallahi *et al.,* 2006).

In pear cv. Bartlett, significantly positive relationship was observed for available N, P and K with fruit size, weight, volume and yield; S with fruit size, TSS and yield; Ca with fruit firmness; and Zn, Cu, Fe and Mn with fruit size, weight, volume, yield, TSS and sugars (Dar *et al.,* 2012 and Dar *et al.,* 2015). In semi-soft pear strains, leaf N, P, Mn and Cu exhibited significant and positive correlation with tree volume and fruit yield, while leaf Ca content was positively correlated with fruit yield only. A non-significant correlation was found between TSS and leaf nutrients, except leaf K which was positively and significantly correlated with fruit quality (Singh *et al.*, 2005). In 'Mauritius' litchi, leaf N and fruit weight; leaf P and pericarp colour; leaf K and anthocyanin and acidity; leaf Ca and fruit firmness were positively correlated with each other (Sivakumar and Korsten, 2007).

After 4 months of cold storage of apple fruits, fruit firmness had significantly positive correlation with (N+K): Ca, (K+Mg): Ca, K: Ca and Mg: Ca ratio and fruit respiration rate with N, (N+K): Ca and N: Ca ratio. Prediction of postharvest behaviour of fruits during storage with measurement of fruit mineral composition during harvest was also confirmed (Doryanizadeh *et al.*, 2016). Fruit weight was significantly and positively correlated with leaf Cu content while acidity was found correlated significantly and positively with leaf P in different pomegranate cultivars (Feng *et al.,* 2019). In guava, positive correlation was observed between leaf macro & micronutrients and fruit quality characters like fruit weight, yield, TSS, sugars, acidity and ascorbic acid (Sharma and Kumawat, 2019).

2.4 Shelf life

Shelf life of ''Kinnow' fruits was extended in zero energy cool chamber than at room temperature as losses in terms of physiological loss in weight, juice content and sugar content was minimized (Jain and Chauhan, 1995). Acceptable weight loss in Kinnow was reported to be upto 5.5% resulted lowering down of market price due to shrivelling (Mahajan *et al.*, 2002). Total soluble solids, reducing sugars, total sugars in 'Valencia' and 'Navel' orange fruits increased while ascorbic acid decreased with storage ripening time (Mbogo *et al.,* 2010). In 'Kinnow' a value of colour, soluble solids and fruit weight loss increased with number of storage days under both cold storage and ambient conditions (Kusumiyati *et al.,* 2013). When 'Kinnow' fruits were stored at 5-6°C, the freshness, appearance, flavour, acceptability and fruit quality remained significantly better upto 45 days (Mahajan *et al.,* 2013). Singla *et al.* (2018) recorded significantly increase in fruit physiological weight loss, total soluble solids, reducing sugars, peel percentage, disease incidence and decrease in juice percentage, acid content and ascorbic acid with the increase in storage time during storage of 'Kinnow' at ambient conditions for 21 days.

Conclusion

After thorough reviewing the available literature, it has learnt that tree age and fruit position in the tree canopy are important factors determining the fruit yield and quality parameters. As tree age advances, the tree canopy also increases due to seasonal increment in the vegetative growth of trees which includes the trunk girth, tree height and tree spread etc., consequently variation in the fruit quality. Citrus especially Kinnow is an important fruit crop of India as well as Punjab and influence of varying tree age and canopy positions on its fruit yield and quality needs to be explored.

CHAPTER III

MATERIAL AND METHODS

The present study "Influence of tree age on vegetative growth and fruit quality of ‘Kinnow’ mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab" was worked out in the private orchards situated in Block Bhunga, District Hoshiarpur, Punjab during the year 2017-2019.

Five orchards of Kinnow mandarin of different age groups having similar cultural and management practices were selected for this study as depicted in Table 3.1.

Table 3.1: Detail of Kinnow orchards selected in Bhunga, Hoshiarpur.

Sr. No.	Name of Fruit Grower	Village	Age of Kinnow trees (years)
1	Gurdeep Singh	Jhambowal	5
2	Harjinder Singh	Dhurian	10
3	Malkiat Singh	Jhambowal	15
4	Amrik Singh	Dhurian	20
5	Jarnail Singh	Jhambowal	25

Kinnow trees in all the selected orchards were budded on rough lemon (*Citrus jambhiri*) rootstock. The trees were selected and marked for the study on the basis of health and uniformity among trees.

No. of age groups	:	5
No. of replications	:	3
No. of trees per replication	:	5
No. of trees used for experimentation	:	5 x 3 x 5 = 75

The whole investigation was categorized into three interdependent experiments:

3.1 Influence of tree age on vegetative growth, leaf nutrients content and fruit yield.

3.2 Influence of tree age and canopy position on yield, quality and nutrients content of fruits.

3.3 Influence of tree age and canopy position on shelf life of fruits.

Each experiment is discussed in detail as under:

3.1 Influence of tree age on vegetative growth, leaf nutrients content and fruit yield

This a single factor experiment where study materials were subjected to randomized block design with five age group of trees as treatments (Table-3.1) and three replications. In this experiment, vegetative growth parameters of trees were recorded to find out annual increment in the vegetative growth influenced by the tree age. Apart from these, data on leaf nutrients content and fruit yield was also recorded.

3.1.1 Vegetative growth characteristics

Following vegetative growth characteristics were recorded in September 2018 and again in 2019:

3.1.1.1 Increment in trunk girth (%)

Trunk girth (cm) of trees was measured at the height of 10 cm from the bud union by using measuring tape during two successive years and per cent annual increment was determined as:

$$\text{Increment in trunk girth (\%)} = \frac{\text{Final girth} - \text{Initial girth}}{\text{Initial girth}} \times 100$$

3.1.1.2 Increment in tree height (%)

Tree height (m) was measured up to maximum point of height ignoring the off/water shoots only, with the help of measuring pole during two successive years and per cent annual increment was determined as:

$$\text{Increment in tree height (\%)} = \frac{\text{Final height} - \text{Initial height}}{\text{Initial height}} \times 100$$

3.1.1.3 Increment in tree spread (%)

The spread of branches grown in two directions viz. N-S spread and E-W spread was measured with the help of measuring tape during two successive years. Tree spread (m) was calculated as:

$$\text{Tree Spread (D)} = \frac{\text{NS tree Spread} + \text{EW tree spread}}{2}$$

Per cent annual increment was determined as:

$$\text{Increment in tree spread (\%)} = \frac{\text{Final spread} - \text{Initial spread}}{\text{Initial spread}} \times 100$$

3.1.1.4 Increment in tree canopy volume (%)

Tree canopy volume (m^3) was determined by using formula proposed by Castle (1983).

Canopy Volume (V) = 0.5238 x H x D^2

Where,

H is tree height in meter

D is tree spread in m

Tree canopy volume (m^3) was calculated for two successive years and per cent annual increment was calculated as:

$$\text{Increment in canopy volume (\%)} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}} \times 100$$

3.1.1.5 Increment in trunk cross-sectional area (%)

Trunk cross-sectional area (cm^2) was calculated by using formula given by Kumar *et al.* (2008).

Trunk cross-sectional area (TCSA) = $(\text{trunk girth})^2/4\pi$

Trunk cross-sectional area was calculated for two successive years and per cent annual increment was determined as:

$$\text{Increment in TCSA (\%)} = \frac{\text{Final TCSA} - \text{Initial TCSA}}{\text{Initial TCSA}} \times 100$$

3.1.1.6 Increment in leaf area (%)

Ten leaves were selected randomly from each experimental tree. Leaf area (cm^2) was measured by using leaf area meter model-211 (Systronics make) during two successive years and per cent annual increment was determined as:

$$\text{Increment in leaf area (\%)} = \frac{\text{Final leaf area} - \text{Initial leaf area}}{\text{Initial leaf area}} \times 100$$

3.1.2 Leaf nutrients analysis

3.1.2.1 Leaf sample preparation

To estimate the concentration of macro and micronutrients in the leaves, healthy leaves were randomly selected from all the directions of tree at shoulder height in the month of September. Leaves from five trees were pooled to make sample of 100 leaves per replication. Firstly, leaves were thoroughly washed by using ordinary tap water and subsequently by using the distilled water and afterwards with 0.01 N HCl and teepol solutions. To make the leaf samples moisture free, these were dried in shade and packed in the butter paper bags and were subjected to hot air drying in the oven at 65°C for a duration of 48 hours. The oven dried samples were subjected to grinding by using grinder made up of stainless-steel to make powder of it and is passed through 40-mesh sieves. The samples ready for the estimation of nutrient elements were stored in air tight glass container and later used for nutrient analysis. Before the leaf nutrient analysis, the samples were re-dried in oven at 65°C for 24 hours.

3.1.2.2 Estimation of Nitrogen (%)

Nitrogen content was estimated with standard procedure AOAC (2005).

Reagents used

a) Digestion mixture (K_2SO_4:$CuSO_4$ (10:1 w/w)
b) H_2SO_4 (conc.)
c) N/100 HCl
d) 4 per cent Boric acid
e) 40 per cent NaOH
f) Mixed indicator: A solution made by dissolving 0.5 g of bromocresol green and 0.10 g methyl red indicator in 100 ml of 95 per cent alcohol. The pH of solution is maintained up to 4.5 by mixing the solution with diluted HCl.

Estimation of nitrogen content

From each sample, 0.5 g grounded material was added in digestion flask. 2 g of digestion mixture and 10 ml of concentrated H_2SO_4 was added to it. The flask was heated till the contents in the flask became clear. The sample is cooled and diluted by using distilled water to make the volume up to 50 ml in volumetric flask. 5ml of aliquot was subjected to micro Kjeldhal distillation with 5ml of 40 per cent Sodium hydroxide solution. The released ammonia was absorbed in 20 ml of boric acid solution having 2-3 drops of mixed indicator. 10 ml of distillate was collected in a conical flask of 250 ml capacity and titrated with N/100 HCl till the colour changed from blue to light pink. Volume of HCl used (T) was noted at this end point and is considered as titre value (T). Similarly, the volume of HCl used was also measured by titrating against the solution which was not having the sample and was taken as the blank reading (B). N was estimated by using following formula:

$$\text{Nitrogen in sample (\%)} = \frac{(\text{T} - \text{B}) \text{ x } 0.00014 \text{ x } \text{V}_1}{\text{V}_2 \text{ x S}} \text{ x } 100$$

Where,

T is titre value

B is blank reading

S is weight of leaf sample taken (g)

V_1 is total volume made

V_2 is volume used for distillation

3.1.2.3 Estimation of other macronutrients (P, K, Ca, Mg, S) and micronutrients (Fe, Zn, Mn, Cu, B)

From each sample, 0.5 g of grounded material was taken in HF vessel and 6 ml of nitric acid (HNO_3) was added to it. The samples were placed in rotors and irradiated in microwave. Then the solution was cooled down for 20 minutes and screws of vessel were opened under the fume hood. The solution was diluted with 50 ml distilled water (50 times of the sample) and then filtered. Then the filtered solution was subjected to analyse various macro and micronutrients in Inductively Coupled Plasma Spectrophotometer (ICP). The amount of each nutrient in the samples was calculated as:

Nutrient content (ppm) = ICP value of nutrient x Dilution factor

Where, dilution factor = Volume made / Weight of sample taken

Further, macronutrients were expressed into percentage and calculated as below:

Macronutrient (%) = Value in ppm / 10000

3.1.3 Average fruit yield (kg/tree)

Number of fruits on each experimental tree was counted at the time of harvesting. Fruit yield was calculated from the average fruit weight and expressed in kilograms per tree.

3.1.4 Statistical Analysis

The data collected was subjected to statistical analysis by Randomized Block Design (RBD) using statistical analysis software OPSTAT.

3.2 Influence of tree age and canopy position on yield, quality and nutrients content of fruits

This experiment was carried out during 2018-19. In this experiment, another factor i.e. canopy position was taken for the study along with the tree age. Tree canopy was divided into two parts i.e. outer canopy (OC) and inner canopy (IC). Portion upto 40 per cent depth from the outer periphery of tree was considered as outer canopy and remaining 60 per cent inner portion was considered as inner canopy. From each tree of each age group and canopy position, following observations were recorded:

3.2.1 Yield characteristics

Following yield characteristics from experimental trees were recorded in the month of January 2019:

3.2.1.1 Average number of fruits

Total count of fruits was taken in both the canopy positions separately in each experimental tree and in each replication at the time of harvesting. Average number of fruits in each canopy of trees was noted and then added to get total number of fruits per tree.

3.2.1.2 Average fruit yield (kg per tree)

Fruit yield in both the canopy positions was estimated separately in each tree from the average fruit weight recorded in corresponding canopy position at the time of harvesting and calculated in kilograms. Average fruit yield from both the canopy positions was added to get the total fruit yield per tree and expressed in kilograms per tree.

3.2.1.3 Grade distribution pattern (%)

The fruits from both the canopy positions of each tree were harvested separately and distributed into different grades as per undermentioned norms of APEDA (Agricultural and Processed Food Products Export Development Authority), Ministry of Commerce and Industry, Govt. of India.

Grade	Fruit Diameter (mm)	No. of fruits per 10 kg box
A	60-64	84
B	65-69	72
C	70-72	54
D	72-74	54
E	75-79	51
F	80-85	45
G	50-60	96
H	45-50	120

Per cent grade distribution was calculated as:

$$\text{Grade distribution (\%)} = \frac{\text{Number of fruits in each grade}}{\text{Total number of fruits taken}} \times 100$$

3.2.2 Physical characteristics of fruits

Matured fruits were harvested randomly from both outer and inner canopy positions of each experimental tree of all age groups in the 3rd week of January, 2019. The fruits harvested from same age trees and same canopy positions in each replication were pooled. The fruits were washed properly before the analysis. Following characteristics were recorded from the fruits harvested from trees of each age and canopy:

3.2.2.1 Fruit colour

From the randomly selected fruits, fruit pericarp colour coordinates were randomly measured on two opposite sites at fruit equator using Colour Flex spectrophotometer (Hunter Lab Colour Flex, Hunter Associates Inc., Reston, VA, USA) expressing L*, a* and b* colour values. Where ‘L*’ is lightness coefficient i.e. ‘0’ is black or total absorption at the bottom and ‘100’ is white at the top; ‘a*’ represents green (-a) and redness (+a) chroma perception as the value increase from negative to positive and ‘b*’ represents blue (-b) and yellowness (+b) as the values changes from negative to positive.

The values of L*, a* and b* thus obtained were used to calculate hue angle (θ) [$\tan^{-1}$ (b*/a*)]; where 0^o = red purple, 90^o= yellow, 180^o = bluish green and 270^o = blue and chroma ([C*=a*2+ b*2]1/2) depicts the intensity or colour saturation (McGuire, 1992).

3.2.2.2 Fruit firmness (lb force)

The penetrometer (Model FT- 327, USA) having 8 mm stainless steel probe was used to measure firmness of ten randomly selected 'Kinnow' fruits. In each fruit about one square centimeter of the peel from the shoulder end on both sides was removed by using peeler and firmness of pulp was determined and expressed in terms of pound force pressure (lb force).

3.2.2.3 Peel surface (Score 1-5)

Peel surface of ten randomly selected fruits was recorded on the basis of smoothness/roughness of fruit peel surface and then score 1 to 5 was given to the fruits as given below:

Score	Peel surface
1	Very rough
2	Rough
3	Slightly smooth
4	Smooth
5	Very smooth

3.2.2.4 Average fruit weight (g)

Ten fruits were selected by random method and weighed by using digital weighing balance. Average fruit weight was calculated and expressed in grams per fruit.

3.2.2.5 Specific gravity

Ten fruits were selected randomly to record specific gravity. Firstly, fruits were weighed and then volume was measured by water displacement method. Specific gravity was estimated by using the following formula:

$$\text{Specific gravity} = \frac{\text{Weight of fruits in air (g)}}{\text{Volume of water displaced by the fruits (ml)}}$$

3.2.2.6 Average fruit size (cm)

Fruit length and diameter of ten randomly selected fruits was measured with the help of measuring scale and average length and diameter per fruit was calculated and expressed in centimetres.

3.2.2.7 Fruit shape index

Fruit shape index was calculated by dividing the fruit length with the fruit diameter as given below:

$$\text{Fruit shape index} = \frac{\text{Average fruit length (cm)}}{\text{Average fruit diameter (cm)}}$$

3.2.2.8 Peel thickness (mm)

Peel thickness of ten randomly selected fruits was recorded with the help of digital calliper and average peel thickness per fruit was determined and expressed in millimetres.

3.2.2.9 Peel (%)

Peel weight of ten randomly selected fruits was recorded with weighing balance and average peel weight per fruit was determined. Peel percentage was calculated as:

$$\text{Peel (\%)} = \frac{\text{Peel weight (g)}}{\text{Fruit weight (g)}} \times 100$$

3.2.2.10 Juice (%)

Weight of juice extracted from ten randomly selected fruits was recorded with digital weighing balance and average juice weight per fruit was calculated. Juice percentage was calculated as:

$$\text{Juice (\%)} = \frac{\text{Juice weight (g)}}{\text{Fruit weight (g)}} \times 100$$

3.2.2.11 Seed (%)

Seeds of ten randomly selected fruits were extracted and weighed with digital weighing balance. Average seed weight per fruit was determined. Seed percentage was calculated as:

$$\text{Seed (\%)} = \frac{\text{Seed weight (g)}}{\text{Fruit weight (g)}} \times 100$$

3.2.2.12 Rag (%)

Rag weight was calculated by subtracting the sum of juice, peel and seed weight from total fruit weight. Rag percentage was calculated as:

$$\text{Rag (\%)} = \frac{\text{Total fruit weight} - (\text{Juice} + \text{peel} + \text{seed weight})\ (\text{g})}{\text{Fruit weight (g)}} \times 100$$

3.2.2.13 Seed count (No.)

Seeds of ten randomly selected fruits were counted and average seed number per fruit was determined.

3.2.2.14 Organoleptic rating (Hedonic scale 1-9)

To record organoleptic rating, fruits from different treatments were evaluated by a panel consisting of 10 judges by using the criteria of external appearance of fruits, pulp texture, taste and flavour and fruits were rated as per 'Hedonic scale' 1 to 9 (Amerine *et al.*, 1965) as given below:

Score	Acceptability
1	Extremely undesirable
2	Very much undesirable
3	Moderately undesirable
4	Slightly undesirable
5	Neither undesirable nor desirable
6	Slightly desirable
7	Moderately desirable
8	Very much desirable
9	Extremely desirable

3.2.3 Quality characteristics of fruits

Following quality characteristics of fruits were recorded:

3.2.3.1 Total soluble solids (%)

TSS content of juice extracted from ten randomly selected fruits was recorded by using the hand refractometer (Bausch & Lomb). The TSS values obtained in ^{0}Brix was further modified and expressed in percentage by adjusting the temperature at 20^{0}C (AOAC, 2005).

3.2.3.2 Titratable acidity (%)

The titratable acidity was estimated as per the standard procedure described in AOAC (2005). Titration of freshly extracted juice (2 ml) was carried out against N/10 NaOH solution by using phenolphthalein as an indicator. The moment when colour of juice changed to light pink was taken as end point. The acidity was expressed as per cent citric acid and was determined by using following formula:

$$\text{Acidity (\%)} = \frac{0.0064 \times \text{Volume of N/10 NaOH used}}{\text{Volume of juice taken (ml)}} \times 100$$

3.2.3.3 TSS/acid ratio

TSS/acid ratio was calculated by dividing the TSS values to that of titratable acidity.

3.2.3.4 Ascorbic acid (mg/100 ml juice)

Estimation of ascorbic acid was carried out by visual titration method as described by Ranganna (2001) where standardised 2, 6-dichlorophenol-indophenols (DCPIP) dye was used.

Standardization of Dye: A standard solution of ascorbic acid was prepared by dissolving 25 mg of ascorbic acid in 100 ml of 0.4 per cent oxalic acid. The solution so prepared was titrated against DCPIP dye till pink colour appeared and persisted for 15 seconds. Dye factor was calculated by the formula:

$$\text{Dye factor} = \frac{\text{Concentration of ascorbic acid (ml}^{-1})}{\text{Volume of dye used}}$$

10 ml of freshly extracted juice was taken and diluted with acid and volume was made up to 100 ml. Out of this, ten ml extract was taken and titration was

done against DCPIP dye solution till appearance of pink colour which persisted for 15 seconds. The ascorbic acid content in juice was estimated as follows:

$$\text{Ascorbic acid (mg/100ml of fruit juice)} =$$

$$\text{Dye factor x } \frac{\text{Volume of dye used for titration of the juice}}{\text{Volume of extract taken}} \text{ x } \frac{\text{Final volume made}}{\text{Volume of juice taken}} \text{ x100}$$

3.2.3.4 Total sugars (%)

Total sugars in the fruits were estimated by Lane and Eynon method (AOAC, 2005). 10 ml juice extracted from randomly selected fruits was taken and diluted by using distilled water to make volume of 100 ml. Then 25 ml of this extracted solution was taken in titration flask. Lead acetate was added in the extracted sample to remove extraneous material and then traces of lead were removed by adding potassium oxalate. In an aliquot of lead-free solution, 5 ml of 60 per cent HCl and 25 ml of distilled water was mixed and kept for 24 hours for acid hydrolysis. The solution in flasks was provided with hot water bath and temperature was raised to 68°C within 10 minutes. At this temperature, flasks were kept for 5 minutes. Excess acids were neutralized by 10 per cent NaOH in beginning and then with 0.1N NaOH near neutralization point using phenolphthalein as an indicator. The above aliquot was titrated against standardized Fehling solutions A and B (5ml each), using methylene blue as an indicator. The appearance of persistent brick red colour was marked as end point. The total sugars content was calculated as below:

$$\text{Total sugars (\%)} =$$

$$\frac{\text{Fehling solution factor (0.05)}}{\text{Volume of filtrate used}} \text{ x } \frac{\text{Dilution made}}{\text{Volume of juice taken}} \text{ x } \frac{\text{Final volume made}}{\text{Volume of aliquot taken}} \text{ x100}$$

3.2.4 Biochemical constituents

3.2.4.1 Total free amino acids (mg/100 g fruit)

Total free amino acids content in fruits was determined as per the procedure laid by Lee and Takahashi (1966).

Reagents

a) 1 per cent Ninhydrin in 0.5 M citrate buffer
b) 0.5 M citrate buffer

c) Glycerol

d) Ninhydrin-Citrate-Glycerol mixture in ratio 5:12:2

Extraction: The fruit sample was homogenized in 5ml of 80 per cent ethanol followed by centrifugation. After that, extraction with 3 ml of 80 per cent of ethanol was repeated and the volume to 10 ml was made.

Estimation: To 0.1 ml of the extract, 5 ml of reagent Ninhydrin-Citrate-Glycerol mixture (reaction mixture) was added. The mixture was shaken well, provided with boiling water bath for 12 min and cooled down to room temperature. The resulted solution was used to record absorbance at 570 nm to measure optical density (OD) by using Spectrophotometer. The reagent mixture was mixed with distilled water and blank reading was taken at 570 nm. Glycine was taken as the standard.

3.2.4.2 Limonin content (ppm)

Reagents

Burhnam's reagent: 0.1g of 4-dimethyl amino benzaldehyde dissolved in 3 ml of glacial acetic acid and mixed with 2.4 ml of 70 per cent perchloric acid. It was prepared freshly every time for every estimation.

Procedure: Calorimetric method was used for estimation of limonin by using the chloroform extract of sample (Vaks and Lifshitz, 1981). The extracted juice was subjected to centrifugation and 5 ml of this was diluted with distilled water to make the volume up to 25 ml. The solution was subjected to etheral extraction in a separating funnel of 250 ml for isolation of colour materials. The extract was discarded and the aqueous solution was subjected to extraction with chloroform (3x25 ml). The chloroform extract so obtained was washed with distilled water (4x50 ml) and the volume was made to 50 ml by using chloroform. A known quantity of these solutions was used for estimation of limonin by developing color with Burhnam's reagent as mentioned below for standard solution preparation.

To prepare the standard solution of limonin, 1.0 mg of limonin was dissolved in chloroform and the final volume was made to 100 ml. Different volumes (1, 2, 3, 4 and 5 ml) of chloroform solution containing standard concentration (10, 20, 30, 40 and 50 µg) were taken in separate test tubes along with blank and were subjected to evaporation under vacuum to dryness and then cooled. 3 ml of Burhnam's reagent was added to the residues of each test tube and subjected to vigorous stirring by using electric stirrer. After 30 minutes, the OD was measured for different concentration by using UV-VIS spectrophotometer at 503 nm. A standard curve was plotted between different concentration of limonin and corresponding optical densities. Limonin content was estimated from the standard curve.

3.2.5 Fruit nutrients analysis

3.2.5.1 Macro and micronutrients in peel

3.2.5.1.1 Samples preparation

Fruits were harvested randomly from both outer and inner canopy positions of each experimental tree of all age groups. The fruits harvested from same age trees and same canopy positions in each replication were pooled. Ten fruits were taken randomly in each replication. Firstly, the fruits were washed properly with ordinary tap water to remove dust particles and then with the distilled water. The fruit samples were dried in shade to remove the moisture. Peel of fruits were removed and dried at room temperature for 48-72 hours. After that the samples were dried in hot air oven at 65 °C for 48 hours. The oven dried peel samples were then grounded well in the stainless-steel grinder to make powder of it and passed through 40 mesh sieve. These samples were stored in air tight glass container and later used for nutrient analysis. Before the peel nutrient analysis, these samples were again dried in oven at 65 °C for 24 hours.

3.2.5.1.2 Estimation of nitrogen (%)

Nitrogen content in the peel was determined with the method prescribed in sections 3.1.2.2.

3.2.5.1.3 Estimation of other macronutrients (P, K, Ca, Mg, S) and micronutrients (Fe, Zn, Mn, Cu, B)

For estimation of macronutrients other than the nitrogen and micronutrients in peel, 1 g of dried peel sample was taken instead of 0.5 g grounded material in case of the estimation in leaves. Rest of the procedure was same as described in section 3.1.2.3.

3.2.5.2 Macro and micronutrients in juice

3.2.5.2.1 Estimation of nitrogen (ppm)

Juice was extracted from ten randomly selected fruits. For estimation of nitrogen in juice, 0.5 ml of fresh juice was taken instead of 0.5 g grounded material in case of nitrogen estimation in leaves. Rest of the procedure was same as described in 3.1.2.2.

3.2.5.2.2 Estimation of other macronutrients (P, K, Ca, Mg, S) and micronutrients (Fe, Zn, Mn, Cu, B)

For estimation of macronutrients other than the nitrogen and micronutrients in juice, 3 ml of fresh juice was taken in HF vessel and 5 ml of nitric acid (HNO_3) + 1 ml HCl was added to it for digestion. Rest of the procedure was same as described in 3.1.2.3.

3.2.6 Staistical analysis

The data recorded was statistically analysed by Factorial Randomized Block Design (FRBD) using statistical analysis software OPSTAT.

3.3 Influence of tree age and canopy position on shelf life of fruits

This experiment was carried out during 2018-19. In this experiment also, two factors i.e. tree age (5, 10, 15, 20 and 25 years) and canopy positions (Outer and Inner canopy) were taken to study the shelf life of fruits after 7, 14, and 21 days of harvesting. Harvested fruits were divided into five lots. Each lot comprised thirty numbers of samples (five age groups, two canopy positions and three replications) thus making a total of 150 samples. Fifteen fruits were used in each replication. Out of these five lots, one lot (30 samples) was used for immediate analysis of fruits to record the physical and quality parameters. Rest of four lots comprising 120 samples were packed into Corrugated Fibre Boxes (CFB) of 2 kg capacity each and kept at ambient temperature for analysis of fruits after 7, 14, 21 days. Out of these four packed lots, one lot (30 samples) was kept to record the physiological loss in weight of fruits and spoilage after 7, 14 and 21 days of harvesting and three lots were used for analysis of fruits at each interval (one lot for each interval). The fruits were subjected to analysis for the following characteristics:

3.3.1 Physical characteristics of fruits

3.3.1.1 Physiological loss in weight (PLW %)

The weight of fruits was measured immediate after the harvesting and again at each interval. Physiological loss in weight is calculated and expressed in percentage as follows:

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

3.3.1.2 Spoilage (%)

The spoilage was recorded on the basis of actual rotten/spoiled fruits. Numbers of rotten fruits, if any were counted in each packing at each interval. Spoilage was calculated and expressed in percentage as follows:

$$\text{Spoilage (\%)} = \frac{\text{No. of rotten fruits}}{\text{Total no. of fruits in a packing}} \times 100$$

3.3.1.3 Fruit firmness (lb force)

Firmness of fruits was recorded immediate after the harvesting and again at each interval with the method described in section 3.2.2.2.

3.3.1.4 Juice recovery (%)

Juice percentage in the fruits was recorded immediate after the harvesting and again at each interval with the method described in section 3.2.2.10.

3.3.1.5 Organoleptic rating (Hedonic scale 1-9)

Organoleptic rating of fruits was recorded immediate after the harvesting and again at each interval with the method described in section 3.2.2.14.

3.3.2 Quality characteristics of fruits

Quality characteristics of fruits like total soluble solids (%), titratable acidity (%), TSS/acid ratio, ascorbic acid (mg/100 ml juice) and total sugars (%) were recorded immediate after the harvesting and again at each interval with the methods described in section 3.2.3.

3.3.3 Statistical analysis

The data recorded was statistically analysed by Factorial Randomized Block Design (FRBD) using statistical analysis software OPSTAT.

CHAPTER IV

RESULTS AND DISCUSSION

The present study "Influence of tree age on vegetative growth and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab" was carried out in the private orchards located in Block Bhunga, District Hoshiarpur, Punjab during the year 2017-19. The whole study was divided into three experiments. In this chapter, the results obtained during the study are presented and discussed in the light of available literature under following major heads:

4.1 Influence of tree age on vegetative growth, leaf nutrients content and fruit yield.

4.1.1 Vegetative growth characteristics

4.1.2 Leaf nutrients analysis

4.1.3 Fruit yield

4.2 Influence of tree age and canopy position on yield, quality and nutrients content of fruits.

4.2.1 Yield characteristics

4.2.2 Physical characteristics of fruits

4.2.3 Quality characteristics of fruits

4.2.4 Biochemical constituents

4.2.5 Fruit nutrients analysis

4.3 Influence of tree age and canopy position on shelf life of fruits.

4.3.1 Physical characteristics of fruits

4.3.2 Quality characteristics of fruits

4.1 Influence of tree age on vegetative growth, leaf nutrients content and fruit yield.

4.1.1 Vegetative growth characteristics

4.1.1.1 Increment in trunk girth (%)

The data pertaining to trunk girth given in Table 4.1 illustrate that annual increment in trunk girth was affected significantly with tree age. Maximum annual increment in trunk girth (12.61%) was recorded in 5 years old trees followed by 10 years (8.62%), 15 years (5.06%) and 20 years (3.00%) old trees. Minimum increment in trunk girth (1.34%) was found in 25 years old trees. Also, significant difference in the annual increment in trunk girth was observed among all the age groups. It is apparent from the observations that annual increment decreased as tree age increased from 5 to 25 years; however, the rate of decrease was differed.

Table 4.1: Influence of tree age on annual increment in trunk girth and tree height of 'Kinnow' mandarin.

Tree age (years)	Trunk girth (cm)			Tree height (m)		
	Year 2018	**Year 2019**	**Annual increment (%)**	**Year 2018**	**Year 2019**	**Annual increment (%)**
5	30.30	34.12	**12.61[a]**	2.81	3.17	**12.81[a]**
10	53.60	58.22	**8.62[b]**	3.60	3.97	**10.28[b]**
15	56.67	59.54	**5.06[c]**	3.97	4.26	**7.30[c]**
20	66.60	68.60	**3.00[d]**	4.60	4.88	**6.09[d]**
25	69.48	70.41	**1.34[e]**	5.23	5.48	**4.78[e]**
Mean	**55.33**	**58.18**	**6.13**	**4.04**	**4.35**	**8.25**
CD ($p \leq 0.05$)			**1.37**			**1.06**
SeM±			**0.41**			**0.32**

4.1.1.2 Increment in tree height (%)

The perusal of data on tree height shown in Table 4.1 reveal that tree age affected annual increment in tree height significantly. Maximum increment in tree height (12.81%) was observed in 5 years old trees which was significantly greater in comparison to the rest of the age groups. It was followed by 10 years (10.28%), 15 years (7.30%) and 20 years (6.09%) old trees. However, minimum increment in tree height (4.78%) was recorded in 25 years old ones which was substantially lower than the all other age groups. Also, significant difference in the annual increment in the height was noted among all the age groups. It was observed that annual increment in tree height decreased as tree age progressed from 5 to 25 years, however the rate of decrease was varied.

4.1.1.3 Increment in tree spread (%)

The observations relating to tree spread given in Table 4.2 illustrate that tree age had significant influence on annual increment in tree spread and the maximum increment in tree spread (17.38%) was found in 5 years old trees which was significantly greater in comparison with the increment in other age groups. It was followed by 10 years (15.21%), 15 years (12.84%) and 20 years (11.24%) old trees; however, annual increment in 15 years old trees was found at par with 20 years old trees. Minimum increment in tree spread (8.66%) was recorded in 25 years old trees which was found significantly lower than the all other age groups. It was also observed that with the increase in age from 5 to 25 years, annual increment in tree spread decreased, though at varied rate.

Table 4.2: Influence of tree age on annual increment in tree spread and tree canopy volume of 'Kinnow' mandarin.

Tree age (years)	Tree spread (m)			Tree canopy volume (m^3)		
	Year 2018	Year 2019	Annual increment (%)	Year 2018	Year 2019	Annual increment (%)
5	3.05	3.58	**17.38[a]**	13.69	21.27	**55.37[a]**
10	3.88	4.47	**15.21[b]**	28.47	41.58	**46.05[b]**
15	4.44	5.01	**12.84[c]**	47.57	64.23	**35.02[c]**
20	5.07	5.64	**11.24[c]**	53.51	70.85	**32.41[c]**
25	5.31	5.77	**8.66[d]**	77.15	95.53	**23.82[d]**
Mean	**4.35**	**4.89**	**13.07**	**44.08**	**58.69**	**38.53**
CD ($p \leq 0.05$)			**1.90**			**4.14**
SeM±			**0.57**			**1.25**

4.1.1.4 Increment in tree canopy volume (%)

The data pertaining to tree canopy volume presented in Table 4.2 reveal that tree age affected annual increment in canopy volume significantly. Maximum increment in canopy volume (55.37%) was observed in 5 years old trees which was substantially higher than rest of the age groups and it was followed by 10 years (46.05%), 15 years (35.02%) and 20 years (32.41%) old trees. Annual increment in 15 and 20 years old trees was found at par with each other. However, significantly lower increment in canopy volume (23.82%) was found in 25 years old trees than the all other age groups. It was observed that annual increment in canopy volume was decreased as tree age progressed from 5 to 25 years, however the rate of decrease was varied.

4.1.1.5 Increment in trunk cross-sectional area (%)

The observations related to trunk cross-sectional area given in Table 4.3 illustrate that annual increment in trunk cross-sectional area was also affected significantly by tree age and maximum increment in trunk cross-sectional area (26.78%) was observed in 5 years old trees which was significantly greater in comparison to rest of the age groups. It was followed by 10 years (17.97%), 15 years (10.39%) and 20 years (6.10%) old trees. However, minimum increment in tree height (2.70%) was found in 25 years old trees which was significantly lower than the all other age groups. Also, significant difference in the annual increment in trunk cross-sectional area was observed among all the age groups. It is apparent from the data that annual increment in trunk cross-sectional area decreased as tree age progressed from 5 to 25 years; however, the rate of decrease was differed.

Table 4.3: Influence of tree age on annual increment in trunk cross-sectional area and leaf area of 'Kinnow' mandarin.

Tree age (years)	Trunk cross-sectional area (cm^2)			Leaf area (cm^2)		
	Year 2018	Year 2019	Annual increment (%)	Year 2018	Year 2019	Annual increment (%)
5	73.03	92.59	**26.78^a**	9.75	10.31	**5.74^a**
10	228.53	269.60	**17.97^b**	12.56	12.84	**2.23^b**
15	255.46	281.99	**10.39^c**	13.97	14.16	**1.36^c**
20	352.83	374.34	**6.10^d**	14.92	15.04	**0.80^d**
25	384.00	394.35	**2.70^e**	15.53	15.63	**0.64^d**
Mean	**258.77**	**282.57**	**12.79**	**13.35**	**13.60**	**2.16**
CD ($p \leq 0.05$)			**2.61**			**0.27**
SeM±			**0.79**			**0.08**

4.1.1.6 Increment in leaf area (%)

The data regarding leaf area shown in Table 4.3 reveal that annual increment in leaf area was significantly influenced by age of trees and maximum increment in leaf area (5.74%) was found in 5 years old trees which was significantly greater than the other age groups. Increment in leaf area in 10 years, 15 years and 20 years old trees was recorded about 2.23 per cent, 1.36 per cent and 0.80 per cent, respectively. Minimum increment in leaf area (0.64%) was recorded in 25 years old trees which was found significantly lower than the all other age groups but found at par with the 20 years old trees. It was also observed that annual increment in leaf area was decreased with the increase in age from 5 to 25 years, though at varied rate.

4.1.1.6 Discussion

The difference in vegetative growth rate among different aged trees might be due the biomass difference attributed to CO_2 assimilation during photosynthesis (Gonzalez-Mas *et al.,* 2009). However, the distribution of these photosynthates depends upon the competition existing between vegetative growth and reproductive development. The flowering and fruiting in citrus depends upon supply of photosynthates during flower bud differentiation, fruit set and fruit development thus, acts as major sink for carbohydrates (Jover *et al.,* 2012) which might be associated to poor annual increment in vegetative growth in the citrus trees of older age (Martinez-Cuenca *et al.,* 2016).

The greater increment in TCSA in the tree with younger age might be associated with the hormonal function and can be described on the basis of physiological mechanism. The activity of auxins has greater significance in determining the radial growth of tree trunk and distribution of auxins (IAA) activities had correlation with the secondary cambial growth (Funada *et al.,* 2001) which is synthesised more actively in young stems (Uggla *et al.,* 1998). However, even in the old aged trees, there is possibility of radial growth as long as there is production of new leaves and is a related to hormonal activity. This can be further correlated with improvement in sapwood area inside the trunk for sustaining the growing leaves production (Sumida *et al.,* 2013). The older trees further maintained their crown and foliage through continuous development and death of epicormic shoots (Ishii *et al.,* 2002) and maintained formation of woods in the stem (Sillett *et al.,* 2010).

The gradual increase in canopy volume of trees and leaf area might be associated with the growth in trunk cross-sectional area and maximum could be at highest trunk cross-sectional area of 'Kinnow' mandarin plants (Dalal and Brar, 2012) and can be correlated with finding of current research as the maximum trunk cross-sectional area was recorded at the age of 25 years. However, the trees of older age, probably of 25 years and beyond, might have crossed the age of full productivity and fertility so the photosynthetic output was supposed to be declined resulting poor vegetative growth in combination with lesser increment in fruit yield (Goldschmidt, 2013).

Similar results for increase in trunk diameter, tree height and crown volume with tree age as a tree growth function were also reported in 'Valencia' orange trees (Turrell, 1961). Also, the present findings are in line with the outcomes of work done by Hearn (1994) who confirmed greater vegetative growth rate in the young trees of orange as compared to adult trees. However, no significant influence of tree age on leaf area was reported in 'Newhall' navel orange by El-Sayed (2018).

4.1.2 Leaf nutrients analysis

4.1.2.1 Macronutrients

The data related to macronutrients (N, P, K, Ca, Mg and S) content in the leaves are shown in Table 4.4. It is obvious from the observations that macronutrients content in the leaves was significantly affected by tree age. In general, a rising trend in the macronutrient concentration was reported with the increase in age of trees from 5 to 25 years.

Maximum nitrogen (N) content (2.78%) was recorded in the leaves of 25 years old trees and it was found at par with 20 years old trees (2.67%). Leaves of 5 years old trees had minimum nitrogen content (2.22%) and it was significantly lower than the other age groups but was found at par with 10 years old trees (2.28%). In leaves of 15 years old trees, nitrogen level was estimated about 2.55 per cent which was at par with the 20 years old trees. Similarly, maximum phosphorus (P) content (0.15%) was found in the leaves of 25 years old trees followed by 20 years old trees (0.14%). Leaves of 10 years and 15 years old trees had similar phosphorus content (0.13%). In the leaves from 5 years old trees, phosphorus content was significantly lowest (0.11%) among all age groups. Potassium (K) content was found maximum

(1.66%) in the leaves of 20 years old trees which was significantly greater than rest of the age groups; however, it was found at par with 15 years old trees (1.61%). Minimum leaf potassium content (1.22%) was observed in 5 years old trees which was significantly lower than the other age groups but was at par with the 10 years old trees (1.31%). Leaves of 25 years old trees had 1.42 per cent potassium content and it was at par with the 10 years old trees.

Table 4.4: Influence of tree age on macronutrient content in leaves of 'Kinnow' mandarin.

Tree age (years)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
5	2.22[c]	0.11[c]	1.22[c]	2.90[d]	0.32[d]	0.26[b]
10	2.28[c]	0.13[b]	1.31[bc]	3.47[c]	0.34[d]	0.26[b]
15	2.55[b]	0.13[b]	1.61[a]	4.60[a]	0.48[a]	0.29[a]
20	2.67[ab]	0.14[ab]	1.66[a]	4.82[a]	0.44[b]	0.30[a]
25	2.78[a]	0.15[a]	1.42[b]	4.10[b]	0.39[c]	0.30[a]
Mean	**2.50**	**0.13**	**1.44**	**3.98**	**0.39**	**0.28**
CD ($p \leq 0.05$)	**0.20**	**0.01**	**0.15**	**0.24**	**0.03**	**0.02**
SE(m)	**0.06**	**0.003**	**0.04**	**0.07**	**0.008**	**0.005**
SE(d)	**0.09**	**0.005**	**0.06**	**0.10**	**0.012**	**0.008**
CV	**4.22**	**4.22**	**5.29**	**3.15**	**3.65**	**3.25**

Calcium (Ca) content was recorded highest (4.82%) in the leaves of 20 years old trees which was found at par with 15 years old trees (4.60%). Leaves of 25 years and 10 years old trees had calcium content of 4.10 per cent and 3.47 per cent, respectively. Minimum calcium content (2.90%) was found in the leaves of 5 years old trees and it was significantly lower than the other age groups. In case of magnesium (Mg), highest content (0.48%) was found in the leaves of 15 years old trees followed by 20 years old trees (0.44%). Leaves of 25 years old trees had magnesium content to the tune of 0.39 per cent. Minimum leaf magnesium content (0.32%) was recorded in 5 years old trees which was found at par with the 10 years old trees (0.34%). In case of sulphur (S) content in leaves, lower variation was noticed among all the age groups. 5 years and 10 years old trees had lowest sulphur content

(0.26%) in the leaves, whereas, maximum sulphur content (0.30%) was recorded in the leaves of 20 years and 25 years old trees. In 15 years old trees, sulphur content in was found to the tune of 0.29 per cent.

Similar results of lower macronutrients in young trees were also reported by Sidhu (2017) in 'Kinnow' mandarin leaves. Leaf nitrogen and phosphorus increased gradually with the increase in trunk cross-sectional area and were recorded maximum at highest trunk cross-sectional area in 'Kinnow' mandarin as reported by Dalal and Brar (2012) and can be correlated with the present research findings as maximum nitrogen and phosphorus was recorded in 25 years old trees having maximum trunk cross-sectional area. Also, higher macronutrients content was reported in the leaves of older trees as compared to young trees of 'Newhall' navel orange (El-Sayed, 2018) and 'Kinnow' mandarin trees (Khalid *et al.*, 2018). However, a contradictory result has been presented by Sharma and Kumawat (2019) who found the deficiency of nitrogen and phosphorus in the leaves of more than 15 years old guava trees.

4.1.2.2 Micronutrients

The data related to micronutrients (Fe, Zn, Mn, Cu and B) content in the leaves are given in Table 4.5. It is confirmed from the observations that micronutrients level in the leaves was significantly influenced with tree age. In general, a diminishing pattern in the micronutrients level was noticed with the increase in age of trees from 5 to 25 years.

Maximum iron (Fe) concentration (129.77 ppm) was recorded in the leaves of 10 years old trees and it was significantly greater than rest of the age groups. Minimum iron content (83.45 ppm) was observed in the leaves of 25 years old trees which was found at par with the 20 years old trees (91.25 ppm). Leaves of 5 years and 15 old trees had iron content of about 118.23 ppm and 105.97 ppm, respectively. Zinc (Zn) content was found significantly higher (76.11 ppm) in the leaves of 5 years old trees whereas, in leaves of 25 years old trees, zinc content was found significantly lowest (35.76 ppm). Zinc content to the tune of 67.03 ppm, 53.71 ppm and 42.86 ppm was recorded in the leaves of 10, 15 years and 20 years old trees, respectively and also these age groups differed significantly with each other with respect to zinc content in leaves. In case of manganese (Mn), maximum content (80.98 ppm) in the leaves was recorded in 5 years old trees which was significantly higher than all the other age groups. Manganese content of about 67.42 ppm, 52.76 ppm and 40.00 ppm were recorded in the leaves of 10, 15 years and 20 years old trees and these age groups differed significantly with each other in respect to manganese concentration in leaves. Significantly least manganese concentration was recorded in the leaves of trees having 25 years age (32.84 ppm).

Table 4.5: Influence of tree age on micronutrients content in leaves of 'Kinnow' mandarin.

Tree age (years)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	B (ppm)
5	118.23^{b}	76.11^{a}	80.98^{a}	12.31^{b}	98.62^{a}
10	129.77^{a}	67.03^{b}	67.42^{b}	13.68^{a}	86.01^{b}
15	105.97^{c}	53.71^{c}	52.76^{c}	10.23^{c}	77.94^{c}
20	91.25^{d}	42.86^{d}	40.00^{d}	8.34^{e}	60.81^{e}
25	83.45^{d}	35.76^{e}	32.84^{e}	9.06^{d}	67.34^{d}
Mean	**105.73**	**55.09**	**54.80**	**10.72**	**78.14**
CD ($p \leq 0.05$)	**8.67**	**5.67**	**6.02**	**0.62**	**4.84**
SE(m)	**2.62**	**1.71**	**1.82**	**0.19**	**1.46**
SE(d)	**3.70**	**2.42**	**2.57**	**0.27**	**2.07**
CV	**4.29**	**5.39**	**5.75**	**3.04**	**3.24**

Copper (Cu) content was recorded significantly higher (13.68 ppm) in the leaves of 10 years old trees followed by 5 years old trees (12.31 ppm). Leaves of 15 years and 25 years old trees had copper content of 10.23 ppm and 9.06 ppm, respectively. Minimum copper content (8.34 ppm) was found in the leaves of 20 years old trees and it was significantly lower than the other age groups. Similarly, in case of boron (B), highest content (98.62 ppm) was found in the leaves of 5 years old trees whereas, lowest boron content (60.81 ppm) was found in the leaves of 20 years old trees. It s evident from the data that copper content in leaves differed significantly with each other among all the age groups. Leaves of 10, 15 and 25 years old trees had boron content to the tune of 86.01 ppm, 77.94 ppm and 67.34 ppm, respectively. The present outcomes are in the contradiction to the results of work done by Sidhu (2017) who confirmed greater micronutrients content in the leaves of older trees as compared to young trees. El-Sayed (2018) recorded non-significant influence of tree age on micronutrients level in the leaves of 'Newhall' navel orange trees.

It is apparent from the data that the leaves of older trees had higher macronutrients but lower micronutrients content but it was vice versa in case of younger trees. This difference may be due to the variation in mobility of the nutrients in the trees as nitrogen, phosphorus and potassium are known to be phloem mobile, whereas calcium, iron, zinc, manganese and copper are known to be moved through xylem section (Storey and Treeby, 2002). Further, Hubbard *et al.* (1999) confirmed the weakening of xylem connectivity in trees with older age leading the better mobility of such elements in young trees that ultimately resulted higher zinc, manganese and iron content in the leaves of younger trees. Though the calcium is also xylem mobile nutrient, yet it was found lower in younger trees. This may be due to the transportation of calcium from restricted pool which was stored in fruit trees (Ferguson, 1980).

4.1.3 Fruit yield

The data related to fruit yield are shown in the Table 4.6. The data reveal that number of fruits per tree and fruit yield varied significantly with respect to tree age. It was noticed that number of fruits improved with the increase in age from 5 to 25 years. Maximum number of fruits (1314.8) was recorded in 25 years old trees and these were significantly higher than the other age groups, however, minimum number of fruits (219.7) was recorded in 5 years old trees. In 20 years, 15 years and 10 years old trees number of fruits was recorded to the tune of 1241.8, 940.7 and 773.5, respectively. Similarly, fruit yield was recorded highest (196.7 kg/tree) in 25 year old trees followed by 20 years (188.6 kg/tree) and 15 years old trees (147.4 kg/tree). Lowest fruit yield (37.6 kg/tree) was recorded in 5 years old trees. The increase in fruit yield was due to higher number of fruits in older trees in comparison to younger trees. It was reported that increased fruit yield with the tree age may be due to increase in bearing surface (Botts, 1941). The productivity of larger trees was more due to better reproductive status (Minor and Kobe, 2019) and due to better capacity to gain and store nutrients and carbohydrates (Carbone *et al.*, 2013) and tended to produce more fruits. A positive and significant correlation was found between trunk cross sectional area and fruit yield in 'Kinnow' mandarin (Dalal and Brar, 2012). Similar results of higher fruit yield in older trees were also noticed in 'Kinnow' mandarin (Sidhu *et al.*, 2017) and in 'Newhall' navel orange (El-Sayed, 2018).

Table 4.6: Influence of tree age on number of fruits and fruit yield of 'Kinnow mandarin.

Tree age (years)	No. of fruits per tree	Fruit yield (kg/tree)
5	219.7[e]	37.6[d]
10	773.5[d]	126.1[c]
15	940.7[c]	147.4[b]
20	1241.8[b]	188.6[a]
25	1314.8[a]	196.7[a]
Mean	**898.1**	**139.3**
CD ($p \leq 0.05$)	**68.3**	**9.9**
SE(m)	**20.6**	**3.0**
SE(d)	**29.2**	**4.3**
CV	**3.9**	**3.7**

4.2 Influence of tree age and canopy position on yield, quality and nutrients content of fruits.

4.2.1 Yield characteristics

4.2.1.1 Average number of fruits

The data on number of fruits are presented in Table 4.7. It is evident from the data that tree age and canopy position affected the number of fruits per tree significantly. Number of fruits was recorded maximum (1314.8) in 25 years old trees followed by 20 years old trees (1241.8). Significantly lowest number of fruits (219.7) was recorded in 5 years old trees. Number of fruits in 15 years and 10 years old trees was 940.7 and 773.5, respectively. In case of canopy position, higher number of fruits was noticed in outer canopy (582.9) as compared to inner canopy (315.2). The interaction between tree age and canopy position was also found significant. Maximum number of fruits (842.1) was reported in outer canopy of 25 years old trees followed by outer canopy of 20 years (795.8) and 15 years old trees (612.1). Similarly, in inner canopy, maximum number of fruits (462.6) were observed in 25 years old trees followed by 20 years (446.0) old trees. Minimum number of fruits (146.3) was reported in inner canopy of 5 years old trees followed by outer canopy of same aged trees.

4.2.1.2 Average fruit yield (kg per tree)

The observations on fruit yield are given in Table 4.7. It is obvious from the data that fruit yield was significantly influenced by age of trees and canopy position. Highest fruit yield (196.7 kg/tree) was observed in 25 years old trees followed by 20 years old trees (188.6 kg/tree). In 5 years old trees, fruit yield (37.6 kg/tree) was recorded significantly lower than the other age groups. Fruit yield of 147.4 kg/tree and 126.1 kg/tree was noticed in 15 years and 10 years old trees, respectively. Fruit yield was significantly greater in outer canopy (87.7 kg/tree) in comparison to inner canopy (51.3 kg/tree) of the trees. Significant interaction was also found between the tree age and canopy position. Fruit yield was recorded greater (122.1 kg/tree) in outer canopy of 25 years old trees which was found at par with fruit yield in outer canopy of 20 years (117.0 kg/tree) old trees. Similarly, fruit yield in inner canopy of 25 years (74.6 kg/tree) and 20 years (71.6 kg/tree) old trees was found at par with each other. Lowest fruit yield was recorded in both inner (12.9 kg/tree) and outer (24.7 kg/tree) canopy of 5 years old trees.

Table 4.7: Influence of tree age and canopy position on number of fruits and fruit yield (kg per tree) of 'Kinnow' mandarin.

Tree age (years)	No. of fruits per tree			Fruit yield (kg per tree)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Total	Outer canopy	Inner canopy	Total
5	146.3	73.4	**219.7^{e}**	24.7	12.9	**37.6^{e}**
10	518.2	255.3	**773.5^{d}**	81.9	44.2	**126.1^{d}**
15	612.1	328.6	**940.7^{c}**	93.0	54.3	**147.4^{c}**
20	795.8	446.0	**1241.8^{b}**	117.0	71.6	**188.6^{b}**
25	842.1	472.6	**1314.8^{a}**	122.1	74.6	**196.7^{a}**
Mean	**582.9^{a}**	**315.2^{b}**		**87.7^{a}**	**51.5^{b}**	
CD ($p \leq 0.05$)						
Tree age	:	**16.2**			**5.6**	
Canopy position	:	**10.3**			**3.6**	
Tree age x Canopy position	:	**22.9**			**7.9**	

Higher number of fruits in older trees resulted higher fruit yield in older trees as compared to younger ones. Increase in fruit yield with the tree age might be due to the increase in bearing surface of the trees (Botts, 1941). Larger trees had more productivity due to better reproductive status (Minor and Kobe, 2019) and due to better ability to store nutrients and carbohydrates (Carbone *et al.*, 2013) and tended to produce more fruits. A positive and significant correlation was noticed between trunk cross sectional area and fruit yield in 'Kinnow' mandarin (Dalal and Brar, 2012). Similar results of higher fruit yield in older trees as compared to young trees were also reported in 'Kinnow' mandarin (Sidhu *et al.*, 2017) and in 'Newhall' navel orange (El-Sayed, 2018).

The higher fruit yield in the outer canopy might be due to maximum interception of solar radiations in the outer canopy of trees. The results of higher fruit yield in outer canopy are in line with the findings of Syvertsen and Albrigo (1980) in

'Ruby' grapefruit, George *et al*. (1996) in persimmon and Singh and Dhaliwal (2007) in 'Sardar' guava who reported higher fruit yield in outer and upper canopy positions than the remaining canopy positions. However, present results are in contradiction with the findings of Kawphaitoon *et al*. (2016) who reported greater number of fruits in inside canopy as compared to upper-outer and lower-outer canopy positions in 'Num Dok Mai Sithong' mango.

4.2.1.3 Grade distribution pattern

The data related to grade distribution of fruits are presented in Table 4.8. It is apparent from the data that mean percentage of E grade fruits was higher (30.73%) in young trees of 5 years age followed by 10 years old trees (23.34%) and minimum percentage (4.20%) of E grade fruits was recorded in 25 years old trees. 15 years old trees had higher percentage (26.08%) of D grade fruits whereas, 20 years and 25 years old trees had higher percentage of C (25.99% and 24.23%), B (22.98% and 27.83%), A (19.95% and 22.00%) and G (9.83% and 11.78%) grade fruits. Lowest percentage of G grade fruits (2.67%) was noticed in 5 years old trees.

In case of canopy position, higher percentage of fruits to the tune of 16.73 per cent, 20.10 per cent and 23.78 per cent in E, D and C grades, respectively was recorded in inner canopy whereas, outer canopy registered 14.08 per cent, 18.06 per cent and 21.86 per cent of fruits in E, D and C grades, respectively. Higher percentage of B (20.39%), A (17.42%) and G (8.719%) grade fruits was recorded in outer canopy in comparison to 17.55 per cent, 14.87 per cent and 6.98 per cent of B, A and G grade fruits, respectively in inner canopy. In general, in outer canopy C and B grade fruits contributed higher percentage (42.25%) whereas, in inner canopy D and C grade fruits contributed higher percentage (43.87%). In markets, E, D and C grade fruits fetch premium prices compared to B, A and G grade fruits. E, D and C grade fruits contributed 60.60 per cent of total inner canopy fruits and 54.00 per cent of total outer canopy fruits. Similarly, B, A, G grade fruits contributed 39.40 per cent of total inner canopy fruits and 46.00 percent of total outer canopy fruits.

Higher percentage of larger size fruits in young trees might be due to less number of fruits per tree which further reduced the competition for food and minerals among developing fruits. Bal and Chohan (1983) rerecorded maximum number of

Table 4.8: Influence of tree age and canopy position on grade distribution pattern (%) in fruits of 'Kinnow' mandarin.

Tree age (years)	Canopy position																	
	Outer canopy						Inner canopy						Mean					
	Fruit diameter in mm (APEDA approved grades)						Fruit diameter in mm (APEDA approved grades)						Fruit diameter in mm (APEDA approved grades)					
	75-79 (E)	72-74 (D)	70-72 (C)	65-69 (B)	61-64 (A)	50-60 (G)	75-79 (E)	72-74 (D)	70-72 (C)	65-69 (B)	61-64 (A)	50-60 (G)	75-79 (E)	72-74 (D)	70-72 (C)	65-69 (B)	61-64 (A)	50-60 (G)
5	29.56	20.67	20.10	15.45	11.11	3.11	31.89	23.56	20.77	12.22	9.33	2.22	**30.73**	**22.12**	**20.44**	**13.84**	**10.22**	**2.67**
10	21.56	22.44	21.00	16.78	13.56	4.66	25.11	24.00	20.22	13.78	11.56	5.33	**23.34**	**23.22**	**20.61**	**15.28**	**12.56**	**5.00**
15	9.67	24.50	21.66	16.53	18.00	9.64	13.33	27.67	24.00	13.33	14.00	7.67	**11.50**	**26.08**	**22.83**	**14.93**	**16.00**	**8.65**
20	6.50	13.00	23.65	24.85	21.33	10.67	8.00	15.00	28.33	21.10	18.57	9.00	**7.25**	**14.00**	**25.99**	**22.98**	**19.95**	**9.83**
25	3.10	9.68	22.89	28.33	23.11	12.89	5.30	10.26	25.56	27.32	20.89	10.67	**4.20**	**9.97**	**24.23**	**27.83**	**22.00**	**11.78**
Mean	**14.08**	**18.06**	**21.86**	**20.39**	**17.42**	**8.19**	**16.73**	**20.10**	**23.78**	**17.55**	**14.87**	**6.98**						

fruits of ‘Kinnow’ mandarin in B grade followed by C, A, D and E grades. Further, higher percentage of smaller size fruits with increase in tree age in present study might be associated with the increase in trunk cross-sectional area as decrease in fruit size with increase in trunk cross sectional area was also reported in 'Allahabad Safeda' guava (Kumar *et al*., 2008) and in plum (Kumar *et al*., 2019).

4.2.2 Physical characteristics of fruits

4.2.2.1 Fruit colour

The data pertaining to fruit colour are shown in Table 4.9. The data represent colour coordinates of Kinnow fruit. *L** indicates the luminosity of harvested fruits and it is clear from the data that it was not affected significantly by tree age however, canopy position had significant effect. Higher *L** value (59.86) was noticed in fruits taken from inner canopy as compared to fruits from outer canopy (57.73). The ‘+*a**’ colour coordinate indicates reddish colour and ‘-*a**’ depicts greenish colour. The fruits taken from 20 years old trees had higher *a** value (+35.82) followed by fruits from 15 years old trees (+34.17). Lowest *a** value (+32.70) was noticed in fruits taken from 5 years old trees which was found at par with fruits from 10 years (+33.22) and 25 years old trees (+33.75). Outer canopy fruits had higher *a** value (+35.63) compared to inner canopy fruits (+32.22). Higher *a** value in fruits from outer canopy and old trees indicated that the fruits were brighter and had deep orange yellow colour as compared to fruits from inner canopy and young trees. It might be due to due to presence of higher carotenoid content and lower chlorophyll content in fruits from outer canopy of older trees.

Yellow colour of peel is depicted by ‘+*b**’ while ‘-*b**’ colour coordinate indicates blue colour and it is apparent from the data that tree age did not affect *b** value of fruits significantly however, it was affected significantly by canopy position. The fruits harvested from inner canopy had more *b** value (+58.94) than the fruits harvested from outer tree canopy (+55.78). Yellowish tinge in the inner canopy fruits might be due to shading effect in the inner canopy. ‘*C**’ colour coordinate denotes chroma and it was not affected significantly by tree age and canopy position however, in general higher *C** values were recorded in fruits taken from inner canopy and older trees as compared to fruits obtained from outer canopy and young trees.

Table 4.9: Influence of tree age and canopy position on fruit colour of 'Kinnow' mandarin.

Tree age (years)	Canopy position														
	Outer canopy					Inner canopy					Mean				
	*L**	*a**	*b**	*C**	*h**	*L**	*a**	*b**	*C**	*h**	*L**	*a**	*b**	*C**	*h**
5	58.25	+35.23	+55.72	65.92	57.70	60.37	+30.17	+57.66	65.08	62.38	**59.31**	**+32.70**	**+56.69**	**65.50**	**60.04**
10	58.90	+34.83	+57.43	67.17	58.76	60.86	+31.60	+58.83	66.78	61.76	**59.88**	**+33.22**	**+58.13**	**66.97**	**60.26**
15	57.77	+35.77	+55.45	65.98	57.18	59.53	+32.57	+58.97	67.37	61.09	**58.65**	**+34.17**	**+57.21**	**66.68**	**59.13**
20	56.55	+36.95	+54.89	66.16	56.05	59.05	+34.68	+60.15	69.43	60.03	**57.80**	**+35.82**	**+57.52**	**67.80**	**58.04**
25	57.20	+35.40	+55.41	65.75	57.43	59.48	+32.10	+59.10	67.25	61.49	**58.34**	**+33.75**	**+57.26**	**66.50**	**59.46**
Mean	**57.73**	**+35.63**	**+55.78**	**66.20**	**57.42**	**59.86**	**+32.22**	**+58.94**	**67.18**	**61.35**					

CD (p≤0.05)

	Tree age	Canopy position	Tree age x Canopy position
L	**NS**	**1.19**	**NS**
a	**1.21**	**0.77**	**NS**
b	**NS**	**0.91**	**NS**
C	**NS**	**NS**	**NS**
h	**1.34**	**0.85**	**NS**

L: lightness coefficient (0 black – 100 white); a: (+a) redness and (-a) green; b: (+b) yellowness and (-b) blue; C: chroma; h: hue angle

‘*h**’denotes the hue angle and lower hue angle signified maximum orange yellow colour of fruits. Lower hue angle value (58.04) was recorded in fruits from 20 years old tree and it was noted at par with 15 years old trees (59.13), whereas, higher hue angle (60.26) value was noticed in fruits taken from 10 years old trees which was noted at par with 5 years old trees (60.04). Outer canopy fruits had lower hue angle value (57.42) than the inner canopy fruits (61.35). The interaction among tree age and canopy position for all the colour coordinates was found non-significant.

Overall higher colour development of fruits in the outer canopy and older trees compared to the fruits in inner canopy and younger trees might be due to higher tree volume and maximum harvesting of sunlight which resulted more translocation of photosynthates towards developing fruits. Further, higher potassium in leaves and fruits from older trees might have contributed towards better colour development as improved orange colour in 'Maltaise' citrus with potassium has been reported (Mimoun *et al.*, 2018). Similar results of more colour development in older trees were also reported by Ozekar (2000) in 'Marsh seedless' grapefruit, whereas more colour development in apple fruits from young trees was reported by Tahir *et al.* (2007).

Results of higher colour development in outer canopy fruits are in accordance to the findings of Tominaga and Daito (1982), Iwagaki (1981) and Iwagaki and Kato (1982) in 'Satsuma' mandarin, Josan *et al.* (1983) in ‘Kinnow’ mandarin and Jackson *et al.* (1971 and 1977) in apple. Superior fruits in terms of peel colour were obtained from exterior canopy of ‘Satsuma’ mandarin (Izumi *et al.*, 1990a), 'Tarocco' orange (Agabbio *et al.*, 1999) and ‘Kinnow’ (Khalid *et al.*, 2012). During fruit development study in 'Nules Clementine' mandarin, Cronje *et al.* (2011) found lower hue value (less green colour) in inner canopy during immature stage but after colour break stage lower hue value (intense orange colour) was found in outside canopy. Lemos *et al.* (2013) reported yellower peel in 'Natal' orange and more orange colour in 'Valencia' orange fruits borne at periphery and apical portions of trees.

4.2.2.2 Fruit firmness (lb force)

The data related to fruit firmness are presented in Table 4.10. It is obvious from the observations that fruit firmness was significantly influenced by tree age and canopy position; however, the interaction between tree age and canopy position was found non-significant. Maximum firmed fruits (9.30 lb force) were obtained from 20 years old trees and found at par with the fruits from 15 years old trees (9.10 lb force). Least firmness (8.11 lb force) was found in the fruits of 5 years old trees followed by 10 years (8.49 lb force) and 25 years old trees (8.72 lb force). Inner canopy fruits were significantly firmer (9.11 lb force) than the outer canopy fruits (8.37 lb force). The interaction between tree age and canopy position was noticed to be non significant; however, highest firmness (9.75 lb force) was found in fruits taken from inner canopy of 20 years old trees followed by 15 years old trees (9.61 lb force). In outer canopy also, fruits of 20 years old trees were more firmer (8.85 lb force) followed by 15 years old trees (8.59 lb force). Least firmness (7.95 lb force) was recorded in the outer canopy fruits of 5 years old trees followed by outer canopy fruits of 10 years old trees (8.12 lb force).

Higher firmness in the inner canopy of older trees compared to young trees might be associated with greater calcium content in the leaves of older trees and as well as in the peel of fruits from inner canopy of older trees compared to young ones. Tahir *et al* (2007) observed greater fruit firmness in 'Aroma' apple taken from older trees as compared to middle aged and young trees while, Kumar and Ram (2018) reported higher firmness in young trees as compared to middle aged and older trees of 'Amrapali' mango.

Results of higher fruit firmness in inside and lower firmness in outside tree canopy are in line with the outcomes of work done by Ketsa *et al.* (1992) who recorded lower firmness in upper tree canopy in 'Nam Dok Mai' mango fruits. Also, less firmer fruits were obtained from the sun exposed parts of canopy in different apple cultivars (Drogoudi and Pantelidis, 2011). Morales *et al.* (2000) recorded higher firmness in bottom canopy fruits of 'Orlando' tangelo whereas, higher fruit firmness in top canopy position was reported in 'Songold' plum fruits (Taylor *et al.*, 1993), 'Angelus' peach fruits (Luchsinger *et al.*, 2002) and in kiwifruit (Remorini *et al*., 2007). Fruit firmness was also reported higher in outer canopy in McIntosh, Gala and Mutsu cvs. of apple (Feng *et al.*, 2014) while, no impact of canopy position on fruit firmness was recorded in 'Bartlett' pear (Ramos *et al*., 1994) and in 'Num Dok Mai Sithong' mango (Kawphaitoon *et al*., 2016).

Table 4.10: Influence of tree age and canopy position on fruit firmness (lb force) and peel surface (score 1-5) of 'Kinnow' mandarin.

Tree age (years)	Firmness (lb force)			Peel surface (score 1-5)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	7.95	8.26	**8.11^{c}**	2.86	3.00	**2.93^{d}**
10	8.12	8.85	**8.49^{b}**	3.03	3.28	**3.16^{c}**
15	8.59	9.61	**9.10^{a}**	3.40	3.60	**3.50^{a}**
20	8.85	9.75	**9.30^{a}**	3.40	3.70	**3.55^{a}**
25	8.35	9.09	**8.72^{b}**	3.20	3.50	**3.35^{b}**
Mean	**8.37^{b}**	**9.11^{a}**		**3.18^{b}**	**3.42^{a}**	
CD ($p \leq 0.05$)						
Tree age	**:**	**0.32**			**0.08**	
Canopy position	**:**	**0.20**			**0.05**	
Tree age x Canopy position	**:**	**NS**			**NS**	

4.2.2.3 Peel surface (score 1-5)

The data regarding peel surface score are illustrated in Table 4.10. The data show that peel surface varied significantly with tree age and canopy position but the interaction between tree age and canopy position was observed non-significant. Score 1 to 5 was given to the fruits based on the smoothness/roughness of their peel surface. Maximum score (3.55) was observed in fruits of 20 years old trees which was found at par with 15 years old trees (3.50) and these fruits were rated as almost smooth. The fruits of 25 years and 10 years old tree had score of 3.35 and 3.16, respectively. Minimum score (2.93) was observed in fruits of 5 years old trees and fruits were rated as slightly smooth. Inner canopy fruits had more smoothness score (3.42) as compared to outer canopy fruits (3.18). Although the interaction effect of tree age and canopy position on peel surface was found non-significant, yet highest score (3.70) was observed in the fruits collected from inner canopy of 20 years old trees followed by 15 years old trees (3.60). In outer canopy, fruits of 20 years and 15 years old trees had higher score (3.40) followed by 25 years old trees (3.20).

Minimum score was recorded in both outer (2.86) and inner canopy (3.00) fruits of 5 years old trees and these fruits were rated as slightly smooth.

In present study, lower calcium content in the leaves as well as peel of fruits from young trees compared to older trees might be the reason of rough peel surface in fruits from young trees. The difference in the peel surface might also be the result of variation in the age of trees. These outcomes are in compliance with work of El-Sayed (2018) who reported maximum rind smoothness in 'Newhall' navel orange fruits of 15 years old trees compared to 10 and 5 years old trees while, Ozekar (2000) recorded more smoothness in fruits of young trees compared to old trees of 'Marsh seedless' grapefruit. The results of lower rind smoothness score in ‘Kinnow’ fruits from outerl canopy of tree as compared to the inner one as recorded by Khalid *et al.* (2012) are in concurrence with the current study.

4.2.2.4 Average fruit weight (g per fruit)

The observations related to fruit weight are shown in Table 4.11. It is apparent from the observations that fruit weight was significantly influenced by age of trees and canopy position. Significantly heavier fruits (172.4 g) were harvested from younger 5 years old trees followed by 10 years old trees (165.5 g). In 15 years old trees, fruit of 158.7 g weight was recorded. Lighter fruits (151.5 g) were recorded from 25 years old trees which were found at par with the fruits from 20 years old trees (153.8 g). The fruits were heavier (166.5 g) in inner canopy of trees than the outer canopy (154.2 g). Significant interaction was found between the tree age and canopy position. Fruit weight was recorded greater (175.8 g) in inner canopy of 5 years old trees which was found at par with fruit weight (173.0 g) in inner canopy of 10 years old trees. Outer canopy of 25 years old trees had significantly lower fruit weight (145.0 g) and it was found at par with the fruits in the same canopy position of 20 years old trees (147.0 g).

Higher fruit weight in inner canopy of young trees might be due to higher fruit size obtained from the inner canopy of young trees in the present study. Further, decrease in fruit size with increasing age in the current research might be associated with the increase in trunk cross-sectional area as decrease in fruit weight with the increase in trunk cross sectional area was also reported in plum (Kumar *et al.*, 2019).

The present results of higher fruit weight in younger trees in comparison to older ones are in agreement with the results obtained by Ozeker (2000) in 'Marsh seedless' grapefruit, Sidhu (2017) in 'Kinnow, El-Sayed (2018) in 'Newhall' navel orange and DongHui *et al.* (2005) in plum. Higher fruit weight in inner canopy of trees was also observed by Jawanda *et al.* (1973), Fallahi *et al.* (1989), Sandhu (1992) and Khan *et al.* (2009) in various citrus species. Whereas, higher fruit weight in outer and top canopy fruits of 'Satsuma' mandarin was reported by Suzuki *et al.* (1973); Daito *et al.* (1981); Tominaga and Daito (1982); Iwagaki and Kato (1982); Izumi *et al.* (1990a). In 'Pera' orange (Lemos *et al.*, 2012) and in 'Natal' orange (Lemos *et al.*, 2013) also, higher fruit weight was recorded in outer periphery and apical portion of trees. Higher fruit weight in outer and upper portions of the trees was also reported by Thakre *et al.* (2015) in ‘Kinnow’ mandarin; Feng *et al.* (2014) in McIntosh, Gala and Mutsu cvs. of apple and Sharma *et al.* (2018) in peach.

Table 4.11: Influence of tree age and canopy position on fruit weight (g per fruit) and specific gravity of 'Kinnow' mandarin.

Tree age (years)	Fruit weight (g per fruit)			Specific gravity		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	169.0	175.8	**172.4**[a]	0.96	0.96	**0.96**
10	158.1	173.0	**165.5**[b]	0.98	0.97	**0.98**
15	152.0	165.3	**158.7**[c]	1.00	0.99	**1.00**
20	147.0	160.6	**153.8**[d]	1.02	0.98	**1.00**
25	145.0	157.9	**151.5**[d]	0.99	0.98	**0.99**
Mean	**154.2**[b]	**166.5**[a]		**0.99**	**0.98**	
CD (p≤0.05)						
Tree age :		**4.5**			**NS**	
Canopy position :		**2.9**			**NS**	
Tree age x Canopy position :		**6.4**			**NS**	

4.2.2.5 Specific gravity

The data pertaining to specific gravity of fruits are given in Table 4.11. It is obvious from the observations that tree age and canopy position did not affect the specific gravity of fruits significantly however, fruits with higher specific gravity (1.00) were observed in 20 years old trees, 15 years old trees (1.00) and 25 years old trees (0.99). The fruits with lower specific gravity (0.96) were obtained from young trees of 5 years age. Outer canopy fruits (0.99) had higher specific gravity as compared to inner canopy fruits (0.98). Although the interactive relationship of tree age and canopy position was not significant, yet the specific gravity was recorded higher (1.02) in fruits from outer canopy of 20 years old trees followed by outer canopy fruits of 15 years old (1.00), 25 years old trees (0.99) and inner canopy fruits of 15 years old trees (0.99). Lower specific gravity (0.96) was recorded in fruits from both the canopy position of 5 years old trees.

Though the specific gravity was affected non-significantly, yet higher specific gravity of fruits from older and outer canopy trees might be due to higher total soluble solids and less compactness in fruits (Kumar and Ram, 2018). Lower specific gravity in 'Allahabad Safeda' guava fruits from young trees was recorded by Asrey *et al*. (2007). Kumar and Ram (2018) also reported lower specific gravity in 'Amrapali' mango fruits from young trees of 6 years old compared to 18 years and 30 years old trees. Higher specific gravity in upper canopy fruits was found in 'Allahabad Safeda' guava (Asrey *et al*., 2007) whereas, Singh and Dhaliwal (2007) reported lower specific gravity in upper canopy fruits of 'Sardar' guava.

4.2.2.6 Average fruit size (cm)

The data related to fruit size are presented in Table 4.12. It is evident from the data that fruit size was significantly affected by tree age and canopy position. Bigger sized fruits in terms of both length and diameter (6.85 cm and 7.71 cm) were obtained from young 5 years old trees followed by 10 years old trees (6.71 cm and 7.51 cm). Twenty five years old trees produced significantly smallest fruits (6.26 cm and 6.89 cm) in comparison to rest of the age groups. The fruit size in 15 years (6.50 cm and 7.24 cm) and 20 years old trees (6.40 cm and 7.16 cm) was recorded at par with each other. Inner canopy fruits were significantly bigger in size (6.75 cm and 7.46 cm) in comparison to outer canopy fruits (6.34 cm and 7.13 cm).

Significant interaction between tree age and canopy position was found in case of fruit diameter whereas, it was non-significant in case of fruit length. Highest fruit size (6.95 cm and 7.78 cm) was recorded in inner canopy fruits of 5 years old trees which was found at par with the inner canopy fruits of 10 years old trees (6.90 cm and 7.69 cm) and outer canopy fruits of 5 years old trees (6.75 cm and 7.63 cm). Least fruit size (6.00 cm and 6.65 cm) was recorded in outer canopy fruits of 25 years old trees and than 20 years old trees (6.17 cm and 6.98 cm).

Table 4.12: Influence of tree age and canopy position on fruit size (cm) of 'Kinnow' mandarin.

Tree age (years)	Fruit length (cm)			Fruit diameter (cm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	6.75	6.95	**6.85^{a}**	7.63	7.78	**7.71^{a}**
10	6.52	6.90	**6.71^{b}**	7.32	7.69	**7.51^{b}**
15	6.25	6.75	**6.50^{c}**	7.09	7.38	**7.24^{c}**
20	6.17	6.63	**6.40^{c}**	6.98	7.33	**7.16^{c}**
25	6.00	6.51	**6.26^{d}**	6.65	7.12	**6.89^{d}**
Mean	**6.34^{b}**	**6.75^{a}**		**7.13^{b}**	**7.46^{a}**	
CD ($p \leq 0.05$)						
Tree age :		**0.12**			**0.16**	
Canopy position :		**0.08**			**0.10**	
Tree age x Canopy position :		**NS**			**0.22**	

Larger fruits in young trees might be due to lesser number of fruits per tree which further reduced the competition for food and minerals among developing fruits. Further, decrease in fruit size with increase in tree age in present study might be associated with the enhancement in trunk cross-sectional area as decrease in fruit size with enhancement in trunk cross sectional area was also reported in 'Allahabad safeda' guava (Kumar *et al.*, 2008) and in plum (Kumar *et al.*, 2019). Higher fruit size in fruits from young trees was also reported by Ozeker (2000) in 'Marsh seedless' grapefruit, DongHui *et al.* (2005) in *Prunus salicina*. In pummelo cv. Tabtimsiam, Nakorn and Chalumpak (2016) recorded highest fruit diameter in fruits taken from 8 years old trees over the trees of 6 and 4 years age. Sidhu (2017) recorded maximum fruit size in the fruits harvested from 15 years old trees in comparison to 5 years and 10 years old 'Kinnow trees whereas, El-Sayed (2018) reported maximum fruit size in 5 years old trees in comparison to 10 years and 15 year old trees of 'Newhall' navel orange.

Lower fruit size towards the tip (upper) of the citrus tree was also reported by Wallace *et al.* (1965) whereas, larger fruits were recorded in external or upper tree canopy of 'Mineola' tangerines (Cohen, 1988), ‘Satsuma’ mandarins (Izumi *et al.*, 1990a), ‘Shiranuhi’ mandarins (Moon *et al.*, 2011), 'Pera' orange (Lemos *et al.*, 2012) 'Valencia' orange Lemos *et al.* (2013), ‘Kinnow’ mandarin (Thakre *et al.*, 2015). While evaluating the quality of 'Mihowase' Satsuma, 'Nules' Clementine, 'Fairchild' and Temple' tangor, Verreynne *et al.* (2004) reported largest fruits of Satsuma, Clementine and Temple but smallest in 'Fairchild' in top canopy. Also, during fruit development study in 'Nules Clementine' mandarin, Cronje *et al.* (2011) found lighter and smaller (diameter and length) fruits consistently through development period in inside tree canopy.

4.2.2.7 Fruit shape index

The data regarding to fruit shape index are illustrated in Table 4.13. The data show that fruit shape index was not affected significantly by tree age and canopy position; however, higher shape index (0.91) was recorded in fruits of 25 years old trees and then by 15 years old trees (0.90). Fruits of 5 year, 10 years and 20 years old tress had similar values for shape index (0.89). Inner canopy fruits recorded higher shape index (0.90) compared to outer canopy fruits (0.89). Among interaction effect, inner canopy fruits of 15 years and 25 years old tress had higher shape index (0.91) followed by inner canopy fruits of 10 years and 20 years old trees (0.90) and outer canopy fruits of 25 years old trees (0.90). Lower shape index (0.88) was observed in outer canopy fruits of 5 years, 15 years, 20 years old trees followed by outer canopy fruits of 10 years and inner canopy fruits of 5 years old trees (0.89).

In previous studies also, higher fruit shape index was recorded in 5 years old 'Newhall' navel orange trees (El-Sayed, 2018) and in middle crown position in 'Satsuma' mandarin (Suzuki *et al*., 1973).

Table 4.13: Influence of tree age and canopy position on fruit shape index and peel thickness (mm) of 'Kinnow' mandarin.

Tree age (years)	Fruit shape index			Peel thickness (mm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	0.88	0.89	**0.89**	3.05	2.95	**3.00[d]**
10	0.89	0.90	**0.89**	2.99	2.85	**2.92[c]**
15	0.88	0.91	**0.90**	2.88	2.82	**2.85[b]**
20	0.88	0.90	**0.89**	2.83	2.74	**2.79[a]**
25	0.90	0.91	**0.91**	2.91	2.80	**2.86[b]**
Mean	**0.89**	**0.90**		**2.93[b]**	**2.83[a]**	
CD (p≤0.05)						
Tree age	**:**	**NS**			**0.05**	
Canopy position	**:**	**NS**			**0.03**	
Tree age x Canopy position	**:**	**NS**			**NS**	

4.2.2.8 Peel thickness (mm)

The observations related to peel thickness are presented in Table 4.13. It is clear from the data that peel thickness varied significantly with tree age and canopy position. The fruits with thinnest peel (2.79 mm) were obtained from 20 years old trees and it was followed by fruits obtained from 15 years (2.85 mm) and 25 years old trees (2.86 mm). Peel thickness (3.00 mm) was recorded significantly higher in the fruits harvested from young trees of 5 years age followed by 10 years (2.92 mm). The fruits produced in the inner canopy had thin peel (2.83 mm) as compared to outer canopy (2.93 mm). Though, the interaction effect of tree age and canopy position on peel thickness was found non-significant, yet peel thickness (2.74 mm) was recorded minimum in inner canopy fruits of 20 years old trees followed by inner canopy fruits of 25 years (2.80 mm), 15 years (2.82 mm) and outer canopy fruits of 20 years old trees (2.83 mm). Thickest peel (3.05 mm) was noticed in outer canopy fruits of 5 years old trees followed by the fruits in the outer canopy position of 10 years old trees (2.99 mm) and inner canopy of 5 years old trees (2.95 mm).

Thickness of fruit peel depends upon the cell size, cell number and arrangement of cells. Role of calcium in the cell arrangement is an established fact. In present study, less calcium in the leaves as well as in fruit peel might be the reason of more peel thickness in the fruits of young trees. The results of higher peel thickness in fruits of young trees are in line with the findings of Khalid *et al.* (2012) in 'Kinnow' fruits, 'Newhall' navel orange (El-Sayed, 2018). Thin fruit peel was reported in fruits from 8 years old trees compared to 6 years and 4 years old trees of 'Tabtimsiam' pummelo (Nakorn and Chalumpak, 2016). The fruits with thinner peel in 20 years old trees in comparison to 34 years old trees were also observed in 'Marsh seedless' grapefruit (Ozekar, 2000).

Results of lower peel thickness in inner canopy were in concurrence with the findings of Khalid *et al.* (2012) in ‘Kinnow’ fruits. Lemos *et al.* (2013) had also reported that outer periphery and apical portion of tree canopy produced fruits with higher thickness of albedo in 'Natal' orange and 'Valencia' orange than the fruits produced inside the canopy. Khan *et al.* (2009) confirmed a non-significant variation in peel thickness due to canopy position of fruits in 'Kinnow'. However, Fallahi *et al.* (1989) confirmed the greater rind thickness in fruits from internal canopy of various citrus species.

4.2.2.9 Peel (%)

The data recorded on peel percentage are shown in Table 4.14. It is apparent from the data that tree age and canopy position had significant impact over peel percentage. Significantly lowest peel percentage (21.34%) was noticed in fruits harvested from 20 years old trees and then in fruits of 25 years old trees (22.42%) and 15 years old trees (23.71%) whereas, highest peel percentage (27.46%) was recorded in fruits of 5 years old trees and then in 10 years old trees (25.20%). Inner canopy fruits had significantly lower peel percentage (21.59%) than the outer canopy fruits (26.46%). In case of interaction, the peel percentage (19.20%) was recorded significantly lowest in fruits from the inner canopy of 20 years old trees which was found at par with the fruits from inner canopy of 25 years old trees (20.15%) and 15 years old trees (20.50%). In outer canopy, the lowest peel percentage (23.47%) was noticed in fruits of 20 years old trees and found at par with 25 years old trees (24.69%). The fruits from outer canopy of 5 years old trees observed with maximum peel percentage (29.32%) followed by fruits from same canopy position of 10 years old trees (27.89%).

The current findings of higher peel percentage in the fruits of young trees are in agreement with the research findings of Khalid *et al.* (2012) who reported highest mass of rind in fruits of young 'Kinnow' trees. Nakorn and Chalumpak (2016) recorded the highest peel weight in fruits taken from 8 years old trees when compared with 6 years and 4 years old trees of pummelo cv. Tabtimsiam.

Higher peel percentage in outer canopy fruits was also confirmed by Wallace *et al.* (1965), Daito *et al.* (1981), Josan *et al.* (1983) and Khalid *et al.* (2012) in various citrus species whereas, higher rind proportion was recorded in the interior side of canopy of 'Kinnow' mandarin (Jawanda *et al.*, 1973). Higher rind fresh and dry mass in the internal canopy was also reported by Fallahi *et al.* (1989) in various citrus species. Inside canopy fruits of 'Kinnow' had higher peel weight as reported by Khan *et al.* (2009).

Table 4.14: Influence of tree age and canopy position on peel (%) and juice (%) of 'Kinnow' mandarin.

Tree age (years)	Peel (%)			Juice (%)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	29.32	25.60	**27.46[e]**	38.53	43.74	**41.14[e]**
10	27.89	22.50	**25.20[d]**	40.56	46.78	**43.67[d]**
15	26.91	20.50	**23.71[c]**	44.35	49.75	**47.05[b]**
20	23.47	19.20	**21.34[a]**	46.10	52.25	**49.18[a]**
25	24.69	20.15	**22.42[b]**	43.95	49.83	**46.89[c]**
Mean	**26.46[b]**	**21.59[a]**		**42.70[b]**	**48.47[a]**	
CD ($p \leq 0.05$)						
Tree age :		**0.94**			**1.33**	
Canopy position :		**0.59**			**0.85**	
Tree age x Canopy position :		**1.33**			**1.89**	

4.2.2.10 Juice (%)

The data pertaining to juice percent in the fruits are given in Table 4.14. It is evident from the data that tree age and canopy position affected the juice percentage in fruits significantly. The fruits with greater juice content (49.18%) were recorded in 20 years old trees followed by the fruits of 15 years (47.05%) and 25 years (46.89%) old trees. The fruits with lower juice percentage (41.14%) were obtained from young trees of 5 years age and then from 10 years old trees (43.67%). Inner canopy fruits had higher juice content (48.47%) as compared to outer canopy fruits (42.70%). The significant interaction of tree age and canopy position resulted substantially higher juice percentage in fruits (52.25%) from inner canopy of 20 years old trees followed by fruits from inner canopy of 25 years old (49.83%) and 15 years old trees (49.75%). Lower juice percentage (38.53%) was recorded in outer canopy fruits of 5 years old trees followed by outer canopy fruits of 10 years old trees (40.56%).

In earlier research findings also, less juice percent was found in citrus fruits from young trees than older trees (Gilfillan, 1990). More juice content was obtained in fruits from 20 years old in comparison to 34 years old trees of 'Marsh seedless' grapefruit (Ozeker, 2000) whereas, Khalid *et al.* (2012) recorded highest juice content in fruits from 35 years old 'Kinnow' trees. Juice content was found maximum in the fruits taken from 15 years old trees in comparison to 10 and 5 years old 'Kinnow' trees (Sidhu *et al*., 2017).

Higher juice in inner canopy position was also reported in sweet orange (Deidda *et al.*, 1981), in 'Mineola' tangerines (Cohen, 1988), in various citrus species (Fallahi *et al*., 1989) and in 'Kinnow' (Khalid *et al*., 2012). In 'Orlando' tangelo, bottom canopy fruits had higher juice content (Morales *et al.*, 2000). Inside bottom canopy fruits in 'Mihowase' Satsuma, 'Nules' Clementine, 'Fairchild' and Temple' tangor cultivars were rich in juice content than the top canopy fruits as reported by Verreynne *et al*. (2004). Whereas, higher juice content in the outer exposed tree canopy was reported in citrus (Wallace *et al.*, 1965) and in ‘Kinnow’ mandarin (Josan *et al.*, 1983 and Khan *et al.*, 2009). Also, Jawanda *et al.* (1973) noticed lower juice proportion in 'Kinnow' mandarin fruits obtained from interior side of the canopy in comparison to remaining part of tree canopy.

4.2.2.11 Rag (%)

The data related to rag percentage are given in Table 4.15. It is apparent from the observations that rag percentage in fruits was affected significantly by tree age and canopy position. Lower rag percentage (26.37%) was estimated in fruits of 15 years old trees which were found at par with the fruits of 20 years (26.93%). Rag percentage was observed higher (28.26%) in fruits from young trees of 5 years age which were found at par with the fruits of 25 years (27.92%) and 10 years old trees (27.73%). The fruits in the inner canopy had significantly lower rag percentage (26.85%) compared to outer canopy fruits (28.03%). Interactive relationship between tree age and canopy position was also found to be significant. Lowest rag content (25.87%) in fruits was recorded in inner canopy fruits of 20 years old trees and it was found at par with both outer (25.99%) and inner (26.75%) canopy fruits of 15 years old trees. Highest rag content (29.20%) was noticed in outer canopy fruits of 5 years old trees which were found at par with the outer canopy fruits of 25 years (28.67%) and 10 years old trees (28.30%).

Table 4.15: Influence of tree age and canopy position on rag (%) and seed (%) of 'Kinnow' mandarin.

Tree age (years)	Rag (%)			Seed (%)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	29.20	27.31	**28.26^c^**	2.95	3.35	**3.15^d^**
10	28.30	27.15	**27.73^bc^**	3.25	3.57	**3.41^e^**
15	25.99	26.75	**26.37^a^**	2.75	3.00	**2.88^c^**
20	27.98	25.87	**26.93^ab^**	2.45	2.68	**2.57^a^**
25	28.67	27.16	**27.92^c^**	2.69	2.86	**2.78^b^**
Mean	**28.03^b^**	**26.85^a^**		**2.82^a^**	**3.09^b^**	
CD (p≤0.05)						
Tree age :		**0.81**			**0.08**	
Canopy position :		**0.51**			**0.05**	
Tree age x Canopy position :		**1.14**			**0.12**	

More rag in fruits of young trees has also reported by Khalid *et al.* (2012) which is in line with the present study while the results of higher rag in outer canopy are in contradiction with their outcomes where they recorded higher rag in the internal canopy fruits of 'Kinnow'. This variation may be possibly due to difference in canopy management of trees resulting variable degree of exposure of fruits.

4.2.2.12 Seed (%)

The data regarding to seed percentage are illustrated in Table 4.15. The data show that seed percentage was affected significantly by age of trees and canopy position. Lower seed percentage (2.57%) was recorded in fruits from 20 years old trees and then in fruits from 25 years old trees (2.78%) whereas, higher seed percentage (3.41%) was recorded in fruits from 10 years old trees and 5 years old trees (3.15%). Seed percentage was significantly higher (3.09%) in inner canopy fruits compared to outer canopy fruits (2.82%). Among the interaction effect, outer canopy fruits of 20 years old trees had significantly lower seed percentage (2.45%) followed by inner canopy of 20 years old trees (2.68%), outer canopy fruits of 25 years (2.69%) and 15 years old trees (2.75%). The fruits produced in the inner canopy of 10 years, 5 years and outer canopy of 10 years old trees were found having the maximum seed percentage to the tune of 3.57 per cent, 3.35 per cent, and 3.25 per cent, respectively.

The results of present study are in line with the findings of Asrey *et al.* (2007) who also observed lower seed percentage in fruits of older trees as compared to younger trees of guava cultivar Allahabad Safeda. Seed weight was not affected substantially with the position of fruits on tree canopy in 'Kinnow' by Khan *et al*. (2009) and in 'Num Dok Mai Sithong' mango by Kawphaitoon *et al.* (2016) while, Khalid *et al.* (2012) recorded lower seed mass in ‘Kinnow’ fruits collected from external canopy which is concurrence of current research findings.

4.2.2.13 Seed count (No.)

The data recorded on seed count are given in Table 4.16. It is obvious from the data that seed count in fruits varied significantly with tree age and canopy position. The fruits with minimum no. of seeds (19.32) were obtained from 5 years old trees and it was noted at par to the fruits of 25 years old trees (20.00), whereas maximum no. of seeds (22.29) were found in fruits of 10 years old trees and 15 years old trees (22.23). Fruits produced in the inner canopy had lesser number of seeds

(19.76) as compared to outer canopy (22.64). The significant interactive relationship between the age of trees and canopy position resulted minimum seed count (18.56) in inner canopy fruits of 5 years old trees which was found at par with inner canopy fruits of 25 years (18.90) and 20 years old trees (19.53). Higher seed count to the tune of 24.37 and 23.73 was recorded in the fruits of outer canopy of 10 years and 15 years old trees, respectively.

In previous research findings, no significant difference in seed number in relation to canopy position was noticed either in guava (Asrey *et al*., 2007) or in Kinnow (Khan *et al*., 2009).

Table 4.16: Influence of tree age and canopy position on seed count and organoleptic rating (Hedonic scale 1-9) of 'Kinnow' mandarin.

Tree age (years)	Seed count (No.)			Organoleptic rating (Hedonic scale 1-9)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	20.07	18.56	**19.32[a]**	6.82	6.54	**6.68[e]**
10	24.37	20.20	**22.29[c]**	6.96	6.88	**6.92[d]**
15	23.73	20.73	**22.23[c]**	7.63	7.12	**7.38[b]**
20	22.40	19.53	**20.97[b]**	7.85	7.44	**7.65[a]**
25	21.10	18.90	**20.00[a]**	7.22	6.95	**7.09[c]**
Mean	**22.64[b]**	**19.76[a]**		**7.30[a]**	**6.99[b]**	
CD (p≤0.05)						
Tree age :		**0.81**			**0.22**	
Canopy position :		**0.51**			**0.14**	
Tree age x Canopy position :		**1.14**			**NS**	

4.2.2.14 Organoleptic rating (Hedonic scale 1-9)

The data pertaining to organoleptic rating are depicted in Table 4.16. It is apparent from the data that tree age and canopy position had significantly affected the organoleptic rating of fruits. The parameters used for this rating were external appearance of fruit, texture, taste and flavour. Organoleptic rating of fruits was recorded significantly higher (7.65) in 20 years old trees and 15 years old trees (7.38) and these fruits were rated as 'moderately to very much desirable'. Lowest organoleptic rating (6.68) was recorded in fruits of 5 years old trees and these fruits were rated as 'slightly desirable to moderately desirable'. It was followed by fruits of 10 years (6.92) and 25 years old trees (7.09) and these fruits were rated as 'moderately desirable'. In case of canopy position, outer canopy fruits had higher rating (7.30) compared to inner canopy fruits (6.99). The interaction effect of tree age and canopy position was found non-significant; however, outer canopy fruits from 20 years old trees had maximum organoleptic rating (7.85) and these fruits were rated as 'very much desirable'. Inner canopy fruits of 5 years old trees were rated 'slightly desirable' with least rating of 6.54.

Organoleptic rating of fruits in outer canopy of older trees might be due to higher TSS, sugars and acidity coupled with the peel colour and smoothness in these fruits as compared to the inner canopy fruits from young trees.

4.2.3 Quality characteristics of fruits

4.2.3.1 Total soluble solids (%)

The perusal of data on total soluble solids (TSS) content in fruits is illustrated in Table 4.17. It is evident from the data that tree age and canopy position had significantly influenced the total soluble solids content in fruits. TSS was found maximum (11.06%) in fruit from 20 years old trees and then from 15 years old trees (10.50%). Minimum TSS content (8.08%) was recorded in fruits obtained from young trees of 5 years age. TSS content in fruits of 25 years (9.96%) and 10 years old trees (9.73%) was at par with each other. Outer canopy fruits had significantly higher TSS (10.31%) than the inner canopy fruits (9.42%). Significant interaction between the age of tree and canopy position resulted higher TSS content (11.36%) in fruits from the outer canopy of 20 years old trees which was followed by the fruits from outer canopy of 15 years old trees (10.85%). In inner canopy also, higher TSS (10.75%) was observed in fruits from 20 years old trees and then by 15 years old trees (10.15%). The fruits from both inner (7.84%) and outer (8.32%) canopies of 5 years old trees had least TSS content.

Higher TSS in the older trees might be due to the faster hydrolysis of carbohydrates and other substrates in the fruits of older trees as compared to the younger ones. Also, higher level of juvenile hormones and photosynthetic activity in young trees might be the reason of lower TSS in the fruits of young trees (Kumar and Ram, 2018). Further, higher vegetative growth rate in young trees as recorded in the present study may also reduce the TSS content in fruits of young trees. Increase in TSS with increase in tree age in current investigations might be associated with the rising trunk cross-sectional area of trees as recorded earlier in 'Allahabad Safeda' guava (Kumar *et al.*, 2008), in 'Kinnow' mandarin (Dalal and Brar, 2012) and in plum (Kumar *et al.*, 2019). Similar results of higher TSS in fruits of older trees were also noticed by Asrey *et al.* (2007), Khalid *et al.* (2012), Sidhu *et al.* (2017) and Kumar and Ram (2018) under different fruit species; while, Ozeker (2000) reported higher TSS in 'Marsh seedless' grapefruit from young trees and DongHui *et al.* (2005) recorded non significant effect of tree age on TSS in plum fruits.

Table 4.17: Influence of tree age and canopy position on total soluble solids (%) and titratable acidity (%) of 'Kinnow' mandarin.

Tree age (years)	TSS (%)			Titratable acidity (%)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	8.32	7.84	**8.08**[d]	0.68	0.65	**0.67**[d]
10	10.30	9.16	**9.73**[c]	0.75	0.68	**0.72**[c]
15	10.85	10.15	**10.50**[b]	0.78	0.74	**0.76**[b]
20	11.36	10.75	**11.06**[a]	0.82	0.79	**0.81**[a]
25	10.70	9.22	**9.96**[c]	0.79	0.74	**0.77**[b]
Mean	**10.31**[a]	**9.42**[b]		**0.76**[a]	**0.72**[b]	
CD (p≤0.05)						
Tree age :		**0.32**			**0.03**	
Canopy position :		**0.20**			**0.02**	
Tree age x Canopy position :		**0.45**			**NS**	

Higher TSS in the outer canopy might be due to the more photosynthates available to the fruits exposed to sun. Similar results of higher TSS in outer canopy fruits was also noticed in ‘Kinnow’ (Jawanda *et al.*, 1973; Josan *et al.*, 1983; Sandhu, 1992; Khan *et al.*, 2009; Khalid *et al.*, 2012; Thakre *et al.*, 2015), ‘Ruby’ grapefruit (Syvertsen and Albrigo, 1980), 'Satsuma' mandarin (Iwagaki and Kato, 1982; Tominaga and Daito, 1982; Izumi *et al.*, 1988 and Izumi *et al.*, 1990a). While working on various citrus species Fallahi *et al.* (1989) recorded higher soluble solids in external canopy fruits in all the species. Agabbio *et al.* (1999) in 'Tarocco' orange, Barry *et al.* (2000) and Freeman and Robbertse (2003) in ‘Valencia’ sweet orange also recorded higher TSS from the external and exposed fruits compared to internal shaded ones. While evaluating the fruit quality of 'Mihowase' Satsuma, 'Nules' Clementine, 'Fairchild' and Temple' tangor, Verreynne *et al.* (2004) reported that top and outside canopy fruits in all the varieties had higher TSS. In 'Pera', 'Natal' and 'Valencia' orange, fruits collected from periphery of the canopy were characterized with high TSS level (Lemos *et al.*, 2012 and 2013). Substantial impact of positions of fruits on the tree canopy over biochemical parameters of fruits in 'Nules Clementine' mandarin was also reported by Olarewaju *et al.* (2018).

4.2.3.2 Titratable acidity (%)

The data related to acidity in fruits are given in Table 4.17. It is clear from the data that acidity in fruits was affected substantially with tree age and canopy position, but the interaction effect was found non-significant. The fruits with lowest acid content (0.67%) were obtained from 5 years old trees and then from fruits of 10 years old trees (0.72%), whereas highest acid content (0.81%) was recorded in fruits from 20 years old trees. Acidity percentage in fruits of 25 years old trees (0.77%) and 20 years old trees (0.76%) was estimated at par with each other. The fruits produced in the outer canopy had higher acidity (0.76%) as compared to the fruits produced in inner canopy (0.72%). Though the interaction effect of age and canopy position was non-significant, yet the lowest acid content (0.65%) was noted in inner canopy fruits of 5 years old trees. Inner canopy fruits of 10 years old trees (0.68%) and outer canopy fruits of 5 years old trees (0.68%) had also lower and similar acid content. Acidity was recorded higher (0.82%) in fruits harvested from outer canopy of 20 years old and 25 years old trees (0.79%) and inner canopy of 20 years old trees (0.79%).

Similar findings of lower acidity in fruits from younger trees was also reported in citrus (Gilfillan, 1990) and orange (Hearn, 1993). More acidic fruits were obtained from 20 years old in comparison to 34 years old trees of 'Marsh seedless' grapefruit (Ozeker, 2000), whereas no significant influence of tree age was reported on fruit acidity in plum (DongHui *et al.*, 2005) and in 'Newhall' navel orange (El-Sayed, 2018). Sidhu *et al.* (2017) also reported higher acidity in 'Kinnow' fruits from older trees than younger ones, while present results are contradictory to the findings of Kumar and Ram (2018) who reported higher acidity in fruits harvested from young 'Amrapali' mango trees compared to older trees.

The present results of higher acidity in outer canopy fruits are as per outcomes of work done by Jawanda *et al.* (1973), Sandhu (1992), Khalid *et al.* (2012) and Thakre *et al.* (2015) in 'Kinnow'. However, higher acidity in internal canopy fruits was recorded by Syvertsen and Albrigo (1980) in ‘Ruby’ grapefruit, Iwagaki and Kato (1982) in 'Satsuma' mandarin, Agabbio *et al.* (1999) in 'Tarocco' orange, Morales *et al.* (2000) in ‘Orlando’ tangelo, Verreynne *et al.* (2004) in 'Mihowase' Satsuma, 'Nules' Clementine, 'Fairchild' and 'Temple' tangor, Lemos *et al.* (2012 and 2013) in 'Pera' orange, 'Natal' orange and 'Valencia' orange, while Barry *et al.* (2003 and 2004) had noticed non significant influence of canopy position on acidity of 'Valencia' sweet orange fruits. Significant impact of position of fruits on the tree canopy over biochemical parameters was also recorded in 'Nules Clementine' mandarin (Olarewaju *et al.*, 2018).

4.2.3.3 TSS/acid ratio

The data regarding TSS/acid ratio is shown in Table 4.18. It is apparent from the data that age of tree and canopy position affected the TSS/acid ratio in fruits significantly and it was recorded highest (13.81) in 15 years old trees which was observed at par with 20 years (13.73) and 10 years old trees (13.60). Lowest TSS/acid ratio (12.15) was recorded in fruits of 5 years old trees and then in fruits of 25 years old trees (13.00). Outer canopy fruits had higher TSS/acid ratio (13.46) compared to inner canopy fruits (13.06). The interaction effect between tree age and canopy position was observed non-significant; however, outer canopy fruits from 15 years old trees had maximum TSS/acid ratio (13.91) followed by outer canopy fruits from 20 years old trees (13.85) whereas, both inner (12.06) and outer (12.24) canopy fruits from 5 years old trees had minimum TSS:acid ratio. Higher TSS/acid ratio (13.72) in outer canopy fruits was noted in 15 years old trees and 20 years old trees (13.61).

The present research outcomes of higher TSS/acid ratio in fruits from older trees are in accordance with the findings of Sidhu *et al.* (2017) in 'Kinnow' and El-Sayed (2018) in 'Newhall' navel orange. Flavour quality was noted better in the fruits taken from trees with older age (>20 years) as compared to middle aged and young trees of 'Aroma' apple (Tahir *et al.*, 2007). Contrary, higher TSS/acid ratio in orange (Hearn, 1993) and in 'Kinnow' (Khalid *et al.*, 2012) fruits from young trees was confirmed. The fruits with higher TSS/acid ratio were obtained from 20 years old in comparison to 34 years old trees of 'Marsh seedless' grapefruit (Ozeker, 2000). No substantial influence of tree age was found on TSS/acid ratio in plum fruits (DongHui *et al.*, 2005).

Table 4.18: Influence of tree age and canopy position on TSS/acid ratio and ascorbic acid content (mg/100 ml juice) of 'Kinnow' mandarin.

Tree age (years)	TSS/acid ratio			Ascorbic acid (mg/100 ml juice)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	12.24	12.06	**12.15^{c}**	28.10	26.88	**27.49^{a}**
10	13.73	13.47	**13.60^{a}**	26.40	24.48	**25.44^{b}**
15	13.91	13.72	**13.81^{a}**	25.34	22.15	**23.75^{c}**
20	13.85	13.61	**13.73^{a}**	24.50	21.12	**22.81^{cd}**
25	13.54	12.46	**13.00^{b}**	24.10	20.50	**22.30^{d}**
Mean	**13.46^{a}**	**13.06^{b}**		**25.69^{a}**	**23.03^{b}**	
CD ($p \leq 0.05$)						
Tree age	:	**0.45**			**1.09**	
Canopy position	:	**0.28**			**0.69**	
Tree age x Canopy position	:	**NS**			**1.54**	

Similar results of higher TSS/acid ratio in outer canopy fruits were also reported in 'Ruby' grapefruit (Syvertsen and Albrigo, 1980), in different citrus species (Fallahi *et al.*, 1989), in 'Tarocco' orange (Agabbio *et al.*, 1999), in 'Orlando' tangelo (Morales *et al.*, 2000), in 'Mihowase' Satsuma, 'Nules' Clementine, 'Fairchild' and 'Temple' tangor (Verreynne *et al.*, 2004), in 'Kinnow' (Khan *et al.*, 2009 and Khalid *et al.*, 2012). But present findings are in contradiction to the observations of Fallahi *et al.* (1989) who noticed higher TSS/acid ratio in internal canopy fruits of 'Kinnow'.

4.2.3.4 Ascorbic acid (mg/100 ml juice)

The observations related to ascorbic acid content in fruits are presented in Table 4.18. Evidently, the tree age and canopy position had substantial influence over ascorbic acid content in the fruits. The fruits rich in ascorbic acid content (27.49 mg) were obtained from young trees of 5 years age followed by 10 years age (25.44 mg). Significantly least ascorbic acid level (22.30 mg) was observed in fruits of 25 years old tree which was at par with the fruits of 20 years old trees (22.81 mg). Outer canopy fruits had higher ascorbic acid content (25.69 mg) compared to inner canopy fruits (23.03 mg). The significant interaction effect of tree age and canopy position resulted maximum ascorbic acid content in both outer (28.10 mg) and inner canopy (26.88 mg) fruits of 5 years old trees, whereas, minimum ascorbic acid content was noted in the inner canopy of 25 years (20.50 mg) and 20 years (21.12 mg) old trees.

Similar findings in regard to ascorbic acid were also obtained by Khalid *et al.* (2012) in 'Kinnow' and DongHui *et al.* (2005) in plum, who reported greater ascorbic acid in fruits from young trees. The highest vitamin C content was reported in the fruits collected from 15 years old 'Allahabad Safeda' guava trees in comparison to 10 years and 20 years old trees (Asrey *et al.*, 2007). Sidhu *et al.* (2017) recorded higher vitamin C in the fruits of 15 years old 'Kinnow' trees in comparison to 5 and 10 years old trees, which is contradiction to our results, whereas El-Sayed (2018) recorded no significant impact of tree age on vitamin C content in 'Newhall' navel orange fruits.

Higher ascorbic acid in fruits from outer and exposed tree canopy was also estimated in 'Kinnow' (Josan *et al.*, 1983; Khan *et al.*, 2009; Khalid *et al.*, 2012 and Thakre *et al.*, 2015), 'Satsuma' (Izumi *et al.*, 1988 and Izumi *et al.*, 1990a) and citrus (Singh *et al.*, 2004). In contrast to our results, Lemos *et al.* (2013) recorded lower vitamin C content in 'Pera' orange, 'Natal' orange and 'Valencia' orange fruits collected from outer periphery of the trees.

4.2.3.5 Total sugars (%)

The data pertaining to total sugars in fruits are illustrated in Table 4.19. It is clear from the data that tree age and canopy position significantly affected the total sugars content. Total sugars content was found maximum (8.43%) in fruits of 20 years old trees and then it was followed by 15 years old trees (8.01%). Minimum sugars content (5.39%) was recorded in fruits of young trees of 5 years age. Total sugars content in fruits of 25 years (7.44%) and 10 years old trees (7.23%) was noted at par with each other. Outer canopy fruits had significantly higher sugars (7.66%) than the inner canopy fruits (6.94%). In case of the interaction, sugars content was recorded significantly better (8.69%) in fruits from the outer canopy of 20 years old trees which was found at par with the fruits from outer canopy of 15 years old trees (8.32%). In inner canopy also, higher sugars content (8.17%) was observed in fruits of 20 years old trees. Inner canopy fruits of 5 years old trees had lowest sugars content (5.21%) followed by outer canopy of same age group (5.57%).

Faster hydrolysis of carbohydrates and other substrates in the fruits of older trees may result higher sugars content in the fruits from older trees as compared to younger ones. Also, lower sugars in the fruit from young trees might be due to higher level of juvenile hormones and photosynthetic activity in young trees (Kumar and Ram, 2018). Further, higher vegetative growth rate in young trees as observed in the present findings may also reduce the sugars content in fruits of young trees. Also, in present study, increase in sugars with increase in tree age might be associated with the improvement in trunk cross-sectional area as the positive correlation between these two attributes was also reported in 'Allahabad safeda' guava (Kumar *et al*., 2008) and in plum (Kumar *et al*., 2019).

Higher sugars content in the older trees was also observed in 'Kinnow' mandarin (Khalid *et al.*, 2012 and Sidhu *et al.*, 2017) and in 'Allahabad Safeda' guava (Asrey *et al*., 2007). Flavour quality was noted higher in the fruits taken from older trees (>20 years) as compared to middle aged and young trees of 'Aroma' apple (Tahir *et al.*, 2007). Kumar and Ram (2018) reported that the mango fruits produced from middle aged trees (18 years old) had higher sugars as compared to 6 years and 30 years old trees.

Table 4.19: Influence of tree age and canopy position on total sugars (%) of 'Kinnow' mandarin.

Tree age (years)	Total sugars (%)		
	Canopy position		
	Outer canopy	Inner canopy	Mean
5	5.57	5.21	**5.39[d]**
10	7.65	6.81	**7.23[c]**
15	8.32	7.70	**8.01[b]**
20	8.69	8.17	**8.43[a]**
25	8.05	6.82	**7.44[c]**
Mean	**7.66[a]**	**6.94[b]**	
CD ($p \leq 0.05$)			
Tree age	:	**0.28**	
Canopy position	:	**0.18**	
Tree age x Canopy position	:	**0.41**	

Higher sugars in the outer canopy might be due to the more photosynthates available to the fruits exposed to sun. Similar results of higher sugars in outer exposed canopy fruits have also been reported in oranges (Uchida *et al.*, 1985), 'Satsuma' mandarins (Izumi *et al.*, 1988 and Izumi *et al.*, 1990a). Izumi *et al.* (1992) recognised that the mature 'Satsuma' mandarin fruits collected from trees receiving 50 and 100 per cent of full sunlight had higher sugars content compared to trees receiving 5 and 20 per cent of full sunlight. Sugars content in external canopy fruits was recorded higher in 'Kinnow' mandarin (Khan *et al.*, 2009 and Khalid *et al.*, 2012). Olarewaju *et al.* (2018) also recorded significant impact of position of fruits on the tree canopy over biochemical parameters in 'Nules Clementine' mandarin.

4.2.4 Biochemical constituents

4.2.4.1 Total free amino acids (mg per 100 g fruit)

The data regarding total free amino acids content in fruits are given in Table 4.20. It is evident from the data that amino acids level in fruits differed significantly with tree age and canopy position. The fruits with highest amino acids content (85.01 mg) were obtained from trees of 20 years age and which was determined at par with fruits of 15 years old trees (84.20 mg), whereas lowest amino acid content (70.86 mg) was recorded in fruits of 5 years old trees and it was followed by fruits of 10 year old trees (74.61 mg). The fruits produced in the outer canopy had higher amino acids content (86.37 mg) as compared to inner canopy fruits (71.64 mg). Significant interaction between tree age and canopy position resulted highest amino acids content (96.12 mg) was noted in fruits from outer canopy of 15 years old trees which was at par with the outer canopy of fruits of 20 years old tree (91.76 mg). Amino acids content was recorded lowest (65.53 mg) in fruits collected from inner canopy of 5 years old ones and it was found at par with fruits from inner canopy of 10 years old trees (68.79 mg).

Since no report on amino acids content is found regarding the influence of age of tree and canopy position however, higher amino acids content in fruits of older trees might be due to the difference in age of trees or less vegetative growth rate in older trees compared to younger trees and higher amino acids in outer canopy fruits might be due to the availability of more photosynthates in the sun exposed fruits.

4.2.4.2 Limonin content (ppm)

The data pertaining to limonin content in fruits are shown in Table 4.20. It is apparent from the data that tree age and canopy position had substantial influence over limonin content in fruits. Limonin content in fruits was recorded significantly higher (17.33 ppm) in 15 years old trees which was at par with that of 20 years old trees (17.26 ppm). Least limonin content (15.76 ppm) was observed in 5 years old trees. Inner canopy fruits had higher limonin content (17.72 ppm) compared to outer canopy fruits (15.69 ppm). Though the interaction effect of tree age and canopy position was found non-significant, however, inner canopy fruits from 15 years and 20 years old trees had higher limonin content (18.62 and 18.10 ppm) and outer canopy fruits from 5 years and 10 years old trees had lower limonin content (14.80 and 15.40 ppm).

Table 4.20: Influence of tree age and canopy position on total free amino acids (mg per 100 g fruit) and limonin content (ppm) of 'Kinnow' mandarin.

Tree age (years)	Total free amino acids (mg per 100 g fruit)			Limonin (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	76.19	65.53	**70.86[d]**	14.80	16.72	**15.76[c]**
10	80.42	68.79	**74.61[c]**	15.40	17.66	**16.53[b]**
15	96.12	72.27	**84.20[a]**	16.04	18.62	**17.33[a]**
20	91.76	78.25	**85.01[a]**	16.33	18.10	**17.26[a]**
25	87.38	73.35	**80.37[b]**	15.78	17.48	**16.63[b]**
Mean	**86.37[a]**	**71.64[b]**		**15.69[b]**	**17.72[a]**	
CD ($p \leq 0.05$)						
Tree age :		**3.13**			**0.62**	
Canopy position :		**1.98**			**0.39**	
Tree age x Canopy position :		**4.43**			**NS**	

It has been reported that limonin content decreased with the ripening of fruits (Mahajan *et al.*, 2018) as the precursor monolectone is reduced during maturity and is accompanied with reduction of bitterness (Maier and Dreyer, 1965). Also, higher limonin in fruits of older trees might be associated with high acid level and a strong correlation between limonin content and acidity in 'Washington' navel orange juice was reported by Rodrigo *et al.* (1985). Since, direct relation of limonin content with tree age and canopy position is not found so, the exact reason of higher limonin content in inner canopy as well as in older trees is yet not known, which requires further investigation.

4.2.5 Fruit nutrients analysis

4.2.5.1 Macronutrients in fruit peel

4.2.5.1.1 Nitrogen (ppm)

The observations related to nitrogen level in fruit peel are illustrated in Table 4.21. It is clear from the observations that tree age and canopy position significantly influenced the nitrogen content in fruit peel and maximum nitrogen content (14423.80 ppm) was found in fruit peel of 25 years old trees. Nitrogen content in the peel of fruits of 15 years (13219.29 ppm) and 20 years (13052.07 ppm) old trees was determined at par with each other. Minimum nitrogen (11876.96 ppm) was recorded in fruit peel of young trees of 5 years age which was found at par with 10 years old trees (12386.93 ppm). Outer canopy fruits had significantly higher peel nitrogen (13609.27 ppm) than the inner canopy fruits (12374.34 ppm). Though interactive relationship between age of trees and canopy position was found non-significant yet numerically higher peel nitrogen (15220.35 ppm) was recorded in fruits from the outer canopy of 25 years old trees followed by 15 years old trees (14102.21 ppm), whereas, lower nitrogen (11429.55 ppm) in fruit peel was found in inner canopy fruits of 5 years followed by 10 years old trees (11933.17 ppm).

4.2.5.1.2 Phosphorus (ppm)

The data pertaining to phosphorus content in fruit peel are shown in Table 4.21. It is obvious from the data that age of tree and canopy position affected phosphorus content in fruit peel substantially. Higher phosphorus content (949.37 ppm) in fruit peel was noted from 25 years old trees which was found at par with the 20 years old trees (913.71 ppm). Lowest phosphorus content (703.94 ppm) was recorded in peel of fruits from 5 years old trees which was observed at par with 10 years old trees (761.58 ppm). Peel of inner canopy fruits had higher phosphorus content (876.17 ppm) compared to outer canopy fruits (793.47 ppm). Although the interaction between tree age and canopy position was non-significant; however, maximum phosphorus content (998.53 ppm) in fruit peel was observed in inner canopy fruits of 25 years followed by 20 years old trees (961.47 ppm), whereas, minimum phosphorus content (680.25 ppm) in fruit peel was recorded in outer canopy of 5 years followed by 10 years old trees (720.55 ppm).

Table 4.21: Influence of tree age and canopy position on nitrogen (ppm) and phosphorus (ppm) content in fruit peel of 'Kinnow' mandarin.

Tree age (years)	Nitrogen (ppm)			Phosphorus (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	12324.36	11429.55	**11876.96^{c}**	680.25	727.62	**703.94^{c}**
10	12840.68	11933.17	**12386.93^{c}**	720.55	802.60	**761.58^{c}**
15	14102.21	12336.37	**13219.29^{b}**	800.40	890.64	**845.52^{b}**
20	13558.75	12545.38	**13052.07^{b}**	865.94	961.47	**913.71^{a}**
25	15220.35	13627.24	**14423.80^{a}**	900.21	998.53	**949.37^{a}**
Mean	**13609.27^{a}**	**12374.34^{b}**		**793.47^{b}**	**876.17^{a}**	
CD (p≤0.05)						
Tree age	:	**748.00**			**64.88**	
Canopy position	:	**473.08**			**41.04**	
Tree age x Canopy position	:	**NS**			**NS**	

4.2.5.1.3 Potassium (ppm)

The data regarding potassium content in fruit peel are depicted in Table 4.22. It is clear from the data that potassium in peel differed significantly with tree age and canopy position. The fruits with highest peel potassium content (9145.53 ppm) were obtained from 20 years old trees and it was estimated at par with fruits of 15 years old trees (8953.50 ppm), whereas lowest potassium content (7879.50 ppm) was reported in peel of fruits from trees of 5 years age and it was at par with the fruits from both 10 years (8110.67 ppm) as well as 25 years old trees (8172.54 ppm). The fruits produced in the inner canopy had higher potassium content (8665.55 ppm) in peel as compared to outer canopy fruits (8239.15 ppm). Significant interaction between tree age and canopy position resulted highest potassium content (9396.33 ppm) in peel of fruits from inner canopy of 20 years old trees which was at par with the inner canopy fruits of 15 years old trees (9109.00 ppm). Potassium content in peel was recorded lowest (7721.67 ppm) in fruits harvested from outer canopy of 25 years old trees and it was found at par with peel potassium content in outer canopy fruits from 5 years old (7805.67 ppm), 10 years old trees (7975.67 ppm) and inner canopy fruits from 5 years old trees (7953.33 ppm).

Table 4.22: Influence of tree age and canopy position on potassium (ppm) and calcium (ppm) content in fruit peel of 'Kinnow' mandarin.

Tree age (years)	Potassium (ppm)			Calcium (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	7805.67	7953.33	**7879.50[b]**	7260.33	7364.33	**7312.33[d]**
10	7975.67	8245.67	**8110.67[b]**	7833.00	7951.00	**7892.00[c]**
15	8798.00	9109.00	**8953.50[a]**	9196.00	9579.67	**9387.84[a]**
20	8894.73	9396.33	**9145.53[a]**	9529.67	9708.00	**9618.84[a]**
25	7721.67	8623.41	**8172.54[b]**	8482.67	8692.67	**8587.67[b]**
Mean	**8239.15[b]**	**8665.55[a]**		**8460.33[b]**	**8659.13[a]**	
CD (p≤0.05)						
Tree age :	**305.87**				**268.49**	
Canopy position :	**193.45**				**169.81**	
Tree age x Canopy position :	**432.57**				**NS**	

4.2.5.1.4 Calcium (ppm)

The observations related to calcium concentration in fruit peel are given in Table 4.22 and it is apparent that the tree age and canopy position had significant effect on calcium content in fruit peel. Higher calcium content (9618.84 ppm) in fruit peel was noted from 20 years old trees which was found at par with 15 years old trees (9387.84 ppm). Lowest peel calcium content (7312.33 ppm) was recorded in fruits from 5 years old trees and then by 10 years old trees (7892.00 ppm). Peel of inner canopy fruits had higher calcium content (8659.13 ppm) compared to outer canopy fruits (8460.33 ppm). The interaction was found non-significant; however, higher calcium content (9708.00 ppm) in fruit peel was observed in inner canopy of 20 years followed by 15 years old trees (9579.67 ppm) and outer canopy of 15 years old trees (9529.67 ppm) whereas, minimum calcium content (7260.33 ppm) in fruit peel was recorded in outer canopy of 5 years old trees followed by inner canopy of same aged trees (7364.33 ppm).

4.2.5.1.5 Magnesium (ppm)

The data related to magnesium content in fruit peel are illustrated in Table 4.23. It is evident from the data that tree age and canopy position had pronounced effect over magnesium content in fruit peel. Significantly highest magnesium content (839.15 ppm) was found in fruit peel of 25 years old trees and then in fruit peel of 20 years old trees (788.87 ppm). Lowest magnesium content (469.15 ppm) was recorded in fruit peel of young trees of 5 years age which was followed by 10 years old trees (501.48 ppm). Outer canopy fruits had significantly higher peel magnesium concentration (662.78 ppm) than the inner canopy fruits (643.42 ppm). Though interaction effect over peel magnesium was found non-significant yet numerically higher peel magnesium level (849.43 ppm) was recorded in fruits taken from the outer canopy of 25 years old trees followed by 20 years old trees (794.70 ppm), whereas, lower magnesium content in fruit peel was found in both the inner (448.20 ppm) and outer (490.10 ppm) canopies of 5 years old tress followed by inner canopy of 10 years old trees (497.03 ppm).

4.2.5.1.6 Sulphur (ppm)

The data pertaining to sulphur content in fruit peel are shown in Table 4.23 which reflects that sulphur in fruit peel differed significantly with tree age and canopy position. The fruits with highest sulphur content in peel (628.84 ppm) were obtained from 25 years old trees and then from 20 years old trees (574.92 ppm) and 15 years old trees (560.22 ppm), whereas lowest sulphur content (449.88 ppm) was estimated in peel of fruits from 5 years old trees and it was followed by 10 years old trees (519.02 ppm). The fruits produced in the outer canopy had higher sulphur content in peel (569.05 ppm) as compared to inner canopy fruits (524.09 ppm). Significant interaction between tree age and canopy position resulted highest sulphur content in peel (644.40 ppm) in inner canopy fruits of 25 years old trees which was at par with the outer canopy fruits of same aged trees (613.27 ppm) and it was followed by inner canopy fruits of 20 years old trees (601.34 ppm). Sulphur content in fruit peel was recorded minimum (431.43 ppm) in the fruits taken from inner canopy of 5 years old trees followed by outer canopy fruits of 5 years old (468.33 ppm) and inner canopy fruits of 10 years old trees (496.93 ppm).

Table 4.23: Influence of tree age and canopy position on magnesium (ppm) and sulphur (ppm) content in fruit peel of 'Kinnow' mandarin.

Tree age (years)	Magnesium (ppm)			Sulphur (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	490.10	448.20	**469.15^{e}**	468.33	431.43	**449.88^{d}**
10	505.93	497.03	**501.48^{d}**	534.90	496.93	**519.02^{c}**
15	673.73	659.97	**666.85^{c}**	571.10	585.53	**560.22^{b}**
20	794.70	783.03	**788.87^{b}**	579.65	601.34	**574.92^{b}**
25	849.43	828.87	**839.15^{a}**	613.27	644.40	**628.84^{a}**
Mean	**662.78^{a}**	**643.42^{b}**		**569.05^{a}**	**524.09^{b}**	
CD ($p \leq 0.05$)						
Tree age :		**27.86**			**23.02**	
Canopy position :		**17.62**			**14.56**	
Tree age x Canopy position :		**NS**			**32.56**	

4.2.5.2 Micronutrients in fruit peel

4.2.5.2.1 Iron (ppm)

The data related to iron content in fruit peel are given in Table 4.24. It is obvious from the observations that only tree age affected the iron concentration in fruit peel significantly but effect of canopy position remained non-significant. Maximum iron content (114.37 ppm) was found in fruit peel of 5 years old trees followed by 10 years old trees (95.41 ppm) whereas, minimum iron content (70.13 ppm) was recorded in fruit peel of 25 years old trees followed by 15 years old trees (76.54 ppm). Though the impact of canopy position on iron content in fruit peel was non-significant, yet numerically higher iron in fruit peel was recorded in outer canopy fruits (89.16 ppm) than the inner canopy fruits (87.32 ppm). The interaction effect was also found non-significant however, higher iron content in fruit peel to the tune of

115.80 ppm and 112.94 ppm was recorded in fruits from both the outer and inner canopy positions of 5 years old trees, respectively which was followed by inner canopy fruits of 10 years old trees (97.32 ppm). Lower iron concentration in fruit peel was found in outer (68.87 ppm) and inner canopy (71.38 ppm) of 25 years old trees.

Table 4.24: Influence of tree age and canopy position on iron (ppm) and zinc (ppm) content in fruit peel of 'Kinnow' mandarin.

Tree age (years)	Iron (ppm)			Zinc (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	115.80	112.94	**114.37[a]**	10.75	11.87	**11.31[c]**
10	93.50	97.32	**95.41[b]**	12.10	13.55	**12.83[a]**
15	79.45	73.63	**76.54[d]**	11.27	12.22	**11.75[b]**
20	88.21	81.34	**84.78[c]**	10.59	10.02	**10.31[d]**
25	68.87	71.38	**70.13[e]**	10.29	9.77	**10.03[d]**
Mean	**89.16**	**87.32**		**11.00[b]**	**11.49[a]**	
CD ($p \leq 0.05$)						
Tree age :		**4.53**			**0.34**	
Canopy position :		**NS**			**0.21**	
Tree age x Canopy position :		**NS**			**0.48**	

4.2.5.2.2 Zinc (ppm)

The data pertaining to zinc content in fruit peel are depicted in Table 4.24. It is apparent from the data that tree age and canopy position had significant impact over zinc concentration in fruit peel. The highest zinc concentration (12.83 ppm) in fruit peel was noted in10 years old trees which was followed by 15 years old trees (11.75 ppm). Lowest peel zinc content (10.03 ppm) was recorded in fruits of 25 years old trees which was found at par with 20 years old trees (10.31 ppm). Peel of inner canopy fruits had higher zinc content (11.49 ppm) compared to outer canopy fruits (11.00 ppm). The interaction effect was also significant which resulted significantly higher zinc content (13.55 ppm) in peel of inner canopy fruits from 10 years followed by 20 years old trees (12.22 ppm) and outer canopy of 10 years old trees (12.10 ppm) whereas, minimum zinc content (9.77 ppm) in fruit peel was recorded in inner canopy of 25 years old trees which was found at par with inner canopy of 20 years old trees (10.02 ppm). Similarly, in outer canopy higher zinc concentration (12.10 ppm) in fruit peel was found in 10 years old trees whereas, minimum concentration was recorded in 25 years old trees (10.29 ppm).

4.2.5.2.3 Manganese (ppm)

The data regarding manganese content in fruit peel are given in Table 4.25. It is confirmed from the data table that tree age and canopy position had pronounced effect on manganese content in fruit peel. Significantly higher manganese content (9.76 ppm) was estimated in peel of fruits from 10 years old trees followed by 5 years old trees (8.13 ppm). Lowest peel manganese content (5.33 ppm) was recorded in peel of fruits from 25 years old trees which was at par with 20 years old trees (5.57 ppm). Inner canopy fruits had significantly higher peel manganese content (7.23 ppm) than the outer canopy fruits (6.96 ppm). The interaction effect over peel manganese content was also found significant which resulted higher peel manganese content (9.99 ppm) in fruits from the inner canopy of 10 years old trees followed by outer canopy of same aged trees (9.53 ppm), whereas, lower manganese level in fruit peel (5.10 ppm) was found in inner canopy of 25 years old tress followed by inner canopy of 20 years old trees (5.34 ppm). In outer canopy, minimum manganese content (5.56 ppm) in fruit peel was estimated from 25 years old trees.

4.2.5.2.4 Copper (ppm)

The data related to copper concentration in fruit peel are illustrated in Table 4.25. It is obvious from data that only tree age had significant effect over copper concentration in fruit peel but effect of canopy position was observed non-significant. Highest copper content (8.68 ppm) was estimated in peel of fruits from 5 years old trees which was found at par with 10 years old (8.55 ppm) and 15 years old trees (8.39 ppm). Lowest copper content (8.18 ppm) was recorded in fruit peel from 20 years old trees and it was at par with 25 years old trees (8.32 ppm). Though the impact of canopy position on copper content in fruit peel was non-significant, yet numerically higher copper content in fruit peel was recorded in outer canopy fruits (8.44 ppm) than the inner canopy fruits (8.40 ppm). The interaction effect was also found non-significant; however, higher copper concentration in fruit peel to the tune of 8.74 ppm and 8.62 ppm was recorded in fruits from both the outer and inner canopies of 5 years old trees, respectively followed by inner canopy fruits of 10 years old trees (8.57 ppm). Lower copper concentration in fruit peel was found in inner (8.11 ppm) and outer canopy (8.24 ppm) of 20 years old trees.

Table 4.25: Influence of tree age and canopy position on copper (ppm), manganese (ppm) and boron (ppm) content in fruit peel of 'Kinnow' mandarin.

Tree age (years)	Manganese (ppm)			Copper (ppm)			Boron (ppm)		
	Canopy position			Canopy position			Canopy position		
	OC	IC	Mean	OC	IC	Mean	OC	IC	Mean
5	7.76	8.50	**8.13[b]**	8.74	8.62	**8.68[a]**	32.67	30.51	**31.59[a]**
10	9.53	9.99	**9.76[a]**	8.52	8.57	**8.55[ab]**	30.72	28.88	**29.80[b]**
15	6.17	7.23	**6.70[c]**	8.43	8.35	**8.39[abc]**	22.00	20.79	**21.40[d]**
20	5.80	5.34	**5.57[d]**	8.24	8.11	**8.18[c]**	25.03	27.51	**26.27[c]**
25	5.56	5.10	**5.33[d]**	8.29	8.34	**8.32[bc]**	20.47	19.96	**20.22[e]**
Mean	**6.96[b]**	**7.23[a]**		**8.44**	**8.40**		**26.18**	**25.53**	
CD (p≤0.05)									
Tree age	**: 0.29**				**0.29**			**1.16**	
Canopy position	**: 0.18**				**NS**			**NS**	
Tree age x Canopy position	**: 0.41**				**NS**			**1.63**	

4.2.5.2.5 Boron (ppm)

The observations related to boron concentration in fruit peel are shown in Table 4.25. It is apparent from the data that only tree age had significant influence on boron content in fruit peel but effect of canopy position remained non-significant. Maximum boron content (31.59 ppm) was found in fruit peel of 5 years old trees followed by 10 years old trees (29.80 ppm). Minimum boron content (20.22 ppm) was recorded in fruit peel from 25 years old trees and 15 years old trees (21.40 ppm). Though impact of canopy position on boron in fruit peel was non-significant, yet numerically higher boron in fruit peel was recorded in outer canopy fruits (26.18 ppm) than the inner canopy fruits (25.53 ppm). The interaction effect over peel boron content was found significant which resulted significantly higher boron (32.67 ppm) concentration in peel of fruits from outer canopy of 5 years old trees and then from10 years old trees (30.72 ppm). Lower boron concentration (19.96 ppm) in fruit peel was found in inner canopy of 25 years old trees and it was found at par with outer canopy of 25 years old trees (20.47 ppm) and inner canopy of 15 years old trees (20.79 ppm).

4.2.5.3 Macronutrients in fruit juice

4.2.5.3.1 Nitrogen (ppm)

The data related to nitrogen content in fruit juice are illustrated in Table 4.26. It is evident from the observations that tree age and canopy position significantly affected the nitrogen content in juice and maximum nitrogen content (2253.60 ppm) was estimated in juice of fruits from 10 years old trees and thereafter, fruits from 5 years old trees (2033.67 ppm) and 25 years old trees (1997.47 pm). Minimum nitrogen content (1624.62 ppm) was recorded in juice of fruits from trees of 20 years age which was followed by the fruits from trees of 15 years age (1738.07 ppm). Outer canopy fruits had significantly higher nitrogen content in juice (1996.04 ppm) than the inner canopy fruits (1862.93 ppm). The interaction effect over juice nitrogen was also found significant which resulted higher juice nitrogen (2376.45 ppm) in fruits from the outer canopy of 10 years old trees followed by 5 years old trees (2132.10 ppm) and inner canopy of 10 years old trees (2130.74 ppm), whereas, lowest nitrogen in fruit juice (1523.64 ppm) was found in inner canopy fruits of 20 years old trees and it was found at par with inner canopy fruits of 15 years old trees (1640.71 ppm).

4.2.5.3.2 Phosphorus (ppm)

The data pertaining to phosphorus content in fruit juice are shown in Table 4.26. It is clear from the data that tree age and canopy position had significant influence on phosphorus content in fruit juice. Higher phosphorus level (112.59 ppm) in fruit juice was determined from 15 years old trees which was trailed by 20 years old trees (107.85 ppm) and 20 years old trees (107.74 ppm). Lowest phosphorus content (94.38 ppm) was recorded in fruits of 5 years old trees followed by 10 years old trees (101.77 ppm). Juice of inner canopy fruits had higher phosphorus content (106.68 ppm) compared to outer canopy fruits (103.05 ppm). The interaction effect was also found to be significant. Maximum phosphorus content (119.32 ppm) in fruit juice was observed in inner canopy fruits of 15 years old trees which was observed at par with 20 years old trees (114.63 ppm), whereas, minimum phosphorus content (92.32 ppm) in fruit juice was recorded in inner canopy fruits of 5 years old trees and found at par with outer canopy of 5 years old trees (96.44 ppm). In outer canopy, higher phosphorus level in fruit juice was noted in 25 years old trees (109.57 ppm) which was found at par with 15 years old trees (105.86 ppm).

Table 4.26: Influence of tree age and canopy position on nitrogen (ppm) and phosphorus (ppm) content in juice of 'Kinnow' mandarin fruits.

Tree age (years)	Nitrogen (ppm)			Phosphorus (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	2132.10	1935.24	**2033.67[b]**	96.44	92.32	**94.38[d]**
10	2376.45	2130.74	**2253.60[a]**	102.54	100.99	**101.77[c]**
15	1835.42	1640.71	**1738.07[c]**	105.86	119.32	**112.59[a]**
20	1725.60	1523.64	**1624.62[d]**	100.84	114.63	**107.74[b]**
25	1910.62	2084.32	**1997.47[b]**	109.57	106.13	**107.85[b]**
Mean	**1996.04[a]**	**1862.93[b]**		**103.05[b]**	**106.68[a]**	
CD (p≤0.05)						
Tree age	:	**102.29**			**4.52**	
Canopy position	:	**64.69**			**2.86**	
Tree age x Canopy position	:	**144.66**			**6.40**	

4.2.5.3.3 Potassium (ppm)

The observations related to potassium level in fruit juice are given in Table 4.27. It is obvious from the data that potassium in fruit juice differed significantly with tree age and canopy position. The fruits with highest juice potassium content (1383.00 ppm) were harvested from 20 years old trees. Potassium content in juice of fruits from 10 years (1214.00 ppm) and 15 years (1239.50 ppm) old trees was observed at par with each other. The lowest potassium content (1107.82 ppm) was recorded in juice of fruits from 25 years old trees and it was found at par with 5 years old trees (1140.17 ppm). The fruits produced in the inner canopy had higher potassium content in juice (1309.00 ppm) as compared to outer canopy fruits (1267.89 ppm). Non-significant interaction was recorded between age of tree and canopy position; however, maximum potassium content (1414.33 ppm) in juice was noticed in inner canopy fruits of 20 years old trees and outer canopy fruits of 20 years old trees (1351.67 ppm). Potassium content in juice was recorded lowest (1081.30 ppm) in fruits harvested from outer canopy of 10 years old trees followed by inner canopy fruits from 5 years old trees (1132.67 ppm) and inner canopy fruits from 10 years old trees (1134.33 ppm).

Table 4.27: Influence of tree age and canopy position on potassium (ppm) and calcium (ppm) content in juice of 'Kinnow' mandarin fruits.

Tree age (years)	Potassium (ppm)			Calcium (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	1147.67	1132.67	**1140.17[c]**	83.97	89.02	**86.50[d]**
10	1081.30	1134.33	**1214.00[b]**	91.00	96.38	**93.69[c]**
15	1227.67	1251.33	**1239.50[b]**	103.17	98.56	**100.87[b]**
20	1351.67	1414.33	**1383.00[a]**	103.73	109.10	**106.42[a]**
25	1224.33	1203.67	**1107.82[c]**	88.53	90.80	**89.67[d]**
Mean	**1267.89[b]**	**1309.00[a]**		**94.85[b]**	**96.87[a]**	
CD (p≤0.05)						
Tree age :		**49.62**			**3.56**	
Canopy position :		**31.38**			**2.25**	
Tree age x Canopy position :		**NS**			**5.03**	

4.2.5.3.4 Calcium (ppm)

The data pertaining to calcium content in fruit juice are depicted in Table 4.27. It is evident from the observations that tree age and canopy position substantially affected the calcium content in fruit juice. Higher calcium content in juice (106.42 ppm) was noted in fruits from 20 years old trees which was followed by 15 years old trees (100.87 ppm). Lowest calcium content (86.50 ppm) was recorded in juice of fruits from 5 years old trees which was noted at par with 25 years old trees (89.67 ppm). Inner canopy fruits had higher calcium content (96.87 ppm) in juice in comparison to the outer canopy fruits (94.85 ppm). The interaction effect of tree age and canopy position was also determined to be substantial which resulted maximum calcium content (109.10 ppm) in juice of inner canopy fruits from 20 years followed by outer canopy fruits from 20 years old trees (103.73 ppm) and outer canopy of 15 years old trees (103.17 ppm) whereas, minimum calcium content (83.97 ppm) in fruit juice was recorded in outer canopy fruits of 5 years old trees which was noted at par with outer canopy fruits of 25 years old trees (88.53 ppm).

4.2.5.3.5 Magnesium (ppm)

The data related to magnesium content in fruit juice are illustrated in Table 4.28. It is apparent from the data that only tree age had pronounced effect on magnesium content in juice but effect of canopy position was found non-significant. Highest magnesium content (95.63 ppm) was estimated in juice of fruits from 20 years old trees and it was found at par with fruits from 25 years old trees (92.92 ppm) and 15 years old trees (91.74 ppm). Lowest magnesium (85.32 ppm) was estimated in juice of fruits from 10 years old trees and it was at par with 5 years old trees (89.68 ppm). Though the effect of canopy position on magnesium content in juice was observed non-significant, yet the outer canopy fruits had higher magnesium concentration in juice (92.66 ppm) than inner canopy fruits (89.46 ppm). Similarly, the interaction effect on the juice magnesium content was also found non-significant yet numerically higher magnesium level (99.47 ppm) in juice was recorded in fruits from the outer canopy of 20 years old trees followed by inner canopy of 25 years old trees (94.36 ppm), whereas, lower magnesium content (82.75 ppm) in fruit juice was found in the inner canopy fruits of 10 years old tress followed by inner canopy fruits of 5 years old trees (87.29 ppm).

4.2.5.3.6 Sulphur (ppm)

The observations regarding sulphur content in fruit juice are given in Table 4.28. It is obvious from the observations that sulphur in juice differed significantly with tree age and canopy position. The fruits with highest sulphur content (39.85 ppm) in juice were harvested from 15 years old trees. Sulphur content to the tune of 35.39 ppm, 34.80 ppm and 33.77 ppm was recorded in the juice of fruits obtained from 20 years, 5 years and 25 years old trees, respectively and all these values were at par with each other. The lowest sulphur content (30.98 ppm) was recorded in juice of fruits from 10 years old trees. The fruits produced in the outer canopy had higher sulphur content (36.19 ppm) in juice as compared to the fruits produced in inner canopy (33.71 ppm). Though the interaction effect was non-significant, yet higher sulphur content in juice was noted in outer (40.78 ppm) and inner canopy (38.91 ppm) fruits of 15 years old trees followed by outer canopy fruits of 5 years old trees (36.72 ppm). Sulphur content in juice was recorded minimum in fruits harvested from inner (30.56 ppm) and outer (31.39 ppm) canopy of 10 years old trees followed by inner canopy fruits from 25 years old trees (31.70 ppm).

Table 4.28: Influence of tree age and canopy position on magnesium (ppm) and sulphur (ppm) content in juice of 'Kinnow' mandarin fruits.

Tree age (years)	Magnesium (ppm)			Sulphur (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	92.07	87.29	**89.68[bc]**	36.72	32.87	**34.80[b]**
10	87.89	82.75	**85.32[c]**	31.39	30.56	**30.98[c]**
15	92.37	91.10	**91.74[ab]**	40.78	38.91	**39.85[a]**
20	99.47	91.79	**95.63[a]**	36.26	34.51	**35.39[b]**
25	91.49	94.36	**92.92[ab]**	35.84	31.70	**33.77[bc]**
Mean	**92.66**	**89.46**		**36.19[a]**	**33.71[b]**	
CD (p≤0.05)						
Tree age :	**5.11**				**2.90**	
Canopy position :	**NS**				**1.85**	
Tree age x Canopy position :	**NS**				**NS**	

4.2.5.4 Micronutrients in fruit juice

4.2.5.4.1 Iron (ppm)

The data related to iron content in fruit juice are shown in Table 4.29. It is clear from the data that only tree age had significant effect on iron content in fruit juice but effect of canopy position remained non-significant. Maximum iron content

(5.34 ppm) was estimated in juice of fruits from 5 years old trees trailed by fruits from 10 years old (4.71 ppm) and 15 years old (4.67%) trees. Minimum iron content (3.32 ppm) was recorded in juice of fruits from 25 years old trees and then by 20 years old trees (3.68 ppm). Though impact of canopy position on iron content in fruit juice was non-significant, yet numerically higher iron content in fruit juice was recorded in outer canopy fruits (4.44 ppm) than the inner canopy fruits (4.25 ppm). The interaction effect on iron content was also found non-significant; however, higher iron in fruit juice to the tune of 5.31 ppm (outer canopy) and 5.06 ppm (inner canopy) was recorded in fruits from 5 years old trees, which was followed by outer canopy fruits of 15 years old trees (4.80 ppm) and inner canopy of 10 years old trees (4.79 ppm). Lower iron concentration in fruit juice was found in outer (3.31 ppm) and inner canopy (3.39 ppm) of 25 years old trees.

Table 4.29: Influence of tree age and canopy position on iron (ppm) and zinc (ppm) content in juice of 'Kinnow' mandarin fruits.

Tree age (years)	Iron (ppm)			Zinc (ppm)		
	Canopy position			Canopy position		
	Outer canopy	Inner canopy	Mean	Outer canopy	Inner canopy	Mean
5	5.31	5.06	**5.34[a]**	0.96	0.75	**0.86[b]**
10	4.68	4.79	**4.71[b]**	0.54	0.80	**0.67[e]**
15	4.80	4.54	**4.67[b]**	0.88	1.02	**0.95[a]**
20	3.78	3.58	**3.68[c]**	0.65	0.88	**0.77[c]**
25	3.31	3.39	**3.32[d]**	0.87	0.52	**0.70[d]**
Mean	**4.44**	**4.25**		**0.78**	**0.79**	
CD ($p \leq 0.05$)						
Tree age :		**0.18**			**0.06**	
Canopy position :		**NS**			**NS**	
Tree age x Canopy position :		**NS**			**0.08**	

4.2.5.4.2 Zinc (ppm)

The observations related to zinc concentration in fruit juice are depicted in Table 4.29. It is evident from the observations that zinc content in fruit juice was affected significantly with tree age but not significantly affected with canopy position. Maximum zinc concentration (0.95 ppm) in juice was noted in fruits from 15 years old trees and then in fruits from 5 years old trees (0.86 ppm). Lowest zinc content in juice (0.67 ppm) was estimated from fruits of 10 years old trees which was found at par with 25 years old trees (0.70 ppm). Juice of inner canopy fruits had higher zinc content (0.79 ppm) compared to outer canopy fruits (0.78 ppm), although the effect of canopy position was not significant. The interactive relationship between tree age and canopy position was significant which resulted significantly higher zinc content (1.02 ppm) in juice of inner canopy fruits from 15 years old trees followed by outer canopy fruits from 5 years old trees (0.96 ppm) whereas, minimum zinc content (0.52 ppm) in fruit juice was recorded in inner canopy fruits from 25 years followed by outer canopy fruits from 10 years old trees (0.54 ppm).

4.2.5.4.3 Manganese (ppm)

The data regarding manganese content in fruit juice are shown in Table 4.30 which confirms that only tree age had pronounced effect on manganese content in fruit juice. Significantly higher manganese content (0.55 ppm) was found in fruit juice of 5 years old trees followed by 10 years (0.50 ppm) and 20 years old trees (0.49 ppm). Lowest manganese content (0.31 ppm) was estimated in juice of fruits from 25 years old trees followed by 15 years old trees (0.43 ppm). Juice from inner canopy fruits had higher manganese content (0.46 ppm) than the outer canopy fruits (0.45 ppm) although the effect of canopy position on manganese content was non-significant. The interaction effect over manganese concentration in juice was significant which resulted higher manganese content (0.56 ppm) in juice of fruits from the inner canopy of 5 years old trees followed by outer canopy of 20 years old trees (0.50 ppm), whereas, lower manganese content in fruit juice (0.30 ppm) was found in outer canopy of 25 years old tress which was found at par with inner canopy fruits of 25 years old trees (0.32 ppm).

4.2.5.4.4 Copper (ppm)

The data pertaining to copper content in fruit juice are illustrated in Table 4.30. It is apparent from the data that only tree age affected copper content in fruit juice significantly. Highest copper content (0.37 ppm) was estimated in juice of fruits from 15 years old trees which was found at par with fruits from 10 years old (0.35

ppm). Lowest copper content (0.26 ppm) was estimated in juice of fruits from 25 years old trees and it was at par with 20 years old trees (0.27 ppm). Though the impact of canopy position on copper content in fruit juice was non-significant, yet numerically higher copper content in juice was recorded in outer canopy fruits (0.32 ppm) than the inner canopy fruits (0.30 ppm). The interaction effect on copper concentration in juice was found significant and higher copper content (0.38 ppm) in juice was recorded in fruits from the outer canopy of 10 and 15 years old trees which was found at par with inner canopy of 15 years (0.35 ppm) and outer canopy of 5 years old trees (0.33 ppm). Lower copper concentration (0.24 ppm) in juice was found in inner canopy fruits of 25 years old trees which was found at par with outer canopy of 20 years (0.25 ppm) and 25 years (0.28 ppm) old trees and outer canopy of 5 years (0.28 ppm) and 20 years old trees (0.29 ppm).

Table 4.30: Influence of tree age and canopy position on copper (ppm), manganese (ppm) and boron (ppm) content in juice of 'Kinnow' mandarin fruits.

Tree age (years)	Manganese (ppm)			Copper (ppm)			Boron (ppm)		
	Canopy position			Canopy position			Canopy position		
	OC	**IC**	**Mean**	**OC**	**IC**	**Mean**	**OC**	**IC**	**Mean**
5	0.49	0.56	**0.55[a]**	0.33	0.28	**0.31[b]**	0.26	0.30	**0.28[a]**
10	0.45	0.49	**0.50[b]**	0.38	0.32	**0.35[a]**	0.28	0.27	**0.28[a]**
15	0.42	0.44	**0.43[c]**	0.38	0.35	**0.37[a]**	0.23	0.18	**0.21[c]**
20	0.50	0.39	**0.49[b]**	0.25	0.29	**0.27[c]**	0.27	0.24	**0.26[ab]**
25	0.30	0.32	**0.31[d]**	0.28	0.24	**0.26[c]**	0.26	0.21	**0.24[bc]**
Mean	**0.45**	**0.46**		**0.32**	**0.30**		**0.26**	**0.24**	
CD (p≤0.05)									
Tree age	**:**	**0.03**			**0.03**			**0.03**	
Canopy position	**:**	**NS**			**NS**			**NS**	
Tree age x Canopy position	**:**	**0.05**			**0.05**			**0.05**	

4.2.5.4.5 Boron (ppm)

The data describing the boron level in fruit juice are given in Table 4.30. It is evident from the data that only tree age significantly affected boron concentration in fruit juice but effect of canopy position remained non-significant. Maximum boron content (0.28 ppm) was found in juice of fruits from 5 years and 10 years old trees which was found at par with 20 years old trees (0.26 ppm). Minimum boron concentration (0.21 ppm) was estimated in juice of fruits from 15 years old trees and it was found at par with 25 years old trees (0.24 ppm). Though impact of canopy position on boron in fruit juice was non-significant, yet numerically higher boron content in fruit juice was recorded in outer canopy fruits (0.26 ppm) than the inner canopy fruits (0.24 ppm). The interaction effect on concentration of boron in fruit juice was found significant and resulted higher boron concentration (0.30 ppm) in juice of inner canopy fruits from 5 years old trees and it was noticed at par with outer canopy of 10 years (0.28 ppm), 20 years (0.27 ppm), 5 years (0.26 ppm) and 25 years old trees (0.26 ppm) and inner canopy of 10 years old trees (0.27 ppm). Lower boron concentration (0.18 ppm) in fruit juice was found in outer canopy fruits of 15 years old trees which was found at par with inner canopy of 25 years old trees (0.21 ppm) and outer canopy of 15 years old trees (0.23 ppm).

4.2.5.5 Discussion

Mineralogy is a very complex phenomenon and nutrients can behave entirely different depending upon various known and unknown factors (Kumar and Ram, 2018). Higher macronutrients in the peel and juice of fruits from older trees compared to younger ones and higher micronutrients in peel and juice of fruits from younger trees compared to older ones might be due to difference in the mobility of elements in the trees as nitrogen, phosphorus and potassium are known to be phloem mobile nutrients and calcium, iron, zinc, manganese and copper are known to have mobility through xylem (Storey and Treeby, 2002). Further, Hubbard *et al.* (1999) confirmed the weakening of xylem connectivity in trees with older age which lead to better mobility of such elements in younger trees that ultimately resulted higher iron, zinc and manganese content in the peel and juice of fruits from younger trees. Though the calcium is also a xylem mobile nutrient, yet it was found lower in younger trees and this may be due to the transportation of calcium from restricted pool which was stored in fruit trees (Ferguson, 1980). The present results are in accordance with the outcomes of work done by Khalid *et al.* (2012) who estimated higher nitrogen, phosphorus, potassium and calcium whereas, lower zinc, iron, manganese and copper content in rind of fruits from older trees compared to younger trees. The results of Snijder *et al.* (2002) were variable, who reported lower nitrogen in the fruits taken from old-aged avocado trees. Asrey *et al.* (2007) reported lower copper, zinc and manganese and higher iron content in young guava trees, which are also in contradiction to the findings of present study. In 'Amrapali' mango trees, Kumar and Ram (2018) recorded the decrease in the calcium content and rise in potassium content as trees became older while, no definite pattern was found in case of iron, zinc, manganese, copper and boron content in fruits with respect to tree age.

Further, in the present investigation, the macronutrients like nitrogen, magnesium and sulphur content was recorded higher in peel and juice of outer canopy fruits whereas, phosphorus, potassium and calcium content was recorded higher in peel and juice of inner canopy fruits. In case of micronutrients zinc and manganese were higher in peel of fruits from inner canopy however, no significant effect of canopy position was observed in case of other micronutrients in peel as well as in juice. Similar results were also reported by Fallahi *et al.* (1989) in case of phosphorus, potassium, magnesium and sulphur content in fruit peel of various citrus species whereas, in case of nitrogen, calcium and micronutrient, the present results are contradictory. In 'Songold' plum, nitrogen, phosphorus, potassium, calcium and magnesium were significantly higher in bottom canopy fruits compared to top canopy fruits (Taylor *et al.,* 1993). Asrey *et al.* (2007) recorded higher content of copper, manganese and zinc in middle canopy while, iron in upper canopy fruits. In 'Nules Clementine' mandarin, calcium and magnesium were accumulated significantly higher in fruit flavedo of outer tree canopy while, greater level of potassium was accumulated in fruits obtained from inner tree canopy (Cronje *et al.*, 2011). Present findings are also in concurrence with the outcomes of work done by Khalid *et al.* (2012) who recognised higher rind phosphorus and potassium in the fruits from internal canopy and higher nitrogen in fruits from external canopy and non-significant effect of canopy position on zinc, copper and iron in the fruit peel.

4.3 Influence of tree age and canopy position on shelf life of fruits

4.3.1 Physical characteristics of fruits

4.3.1.1 Physiological loss in weight (%)

The observations related to physiological loss in weight (PLW) of fruits are given in Table 4.31. It is confirmed from the observation that tree age, canopy position and days after harvest significantly influenced the physiological loss in fruit weight. The highest mean weight loss (5.29%) was observed in fruits from young trees of 5 years age which was found at par with 10 years old trees (5.06%). Minimum mean weight loss (4.48%) was observed in fruits from 20 years old trees and 15 years old trees (4.76%). Inner canopy fruits had less loss in weight (4.65%) compared to outer canopy fruits (5.14%). The interaction effect of tree age and canopy position was found non-significant but numerically higher loss in weight (5.51%) was observed in fruits from outer canopy of 5 years old trees followed by the fruits from outer canopy of 10 years (5.27%) and 25 years old trees (5.17%). Minimum weight loss in fruits (4.27%) was noticed in inner canopy of 20 years old trees followed by 15 years old trees (4.45%).

The physiological loss in weight of fruits increased continuously and significantly with the passage of days after the harvesting and it was recorded 3.25 per cent, 6.25 per cent and 10.10 per cent after 7, 14 and 21 days of harvesting, respectively. The interaction between canopy position and days after harvest was also found significant and higher weight loss to the tune of 10.53 per cent and 9.67 per cent was recorded in fruits from outer canopy and inner canopy, respectively. Minimum weight loss was observed after 7 days of harvesting in both inner (3.05%) and outer canopy (3.44%) fruits.

The interaction effect of tree age and days after harvest was also found significant (Table 4.31a) which resulted significant increase in loss of weight in fruits of each age group and at each interval. After 21 days of harvesting the fruits, minimum weight loss (9.35%) in fruits of 20 years old trees and it was found at par with the weight loss in fruits of 15 years old trees (9.80%), whereas highest weight loss (10.87%) was estimated in the fruits of 5 years old trees and it was noticed at par with the weight loss in fruits of 10 years old trees (10.42%). The interaction relationship between all the three factors was noted to be non significant (Table

4.31b). Weight loss in 'Kinnow' is acceptable upto 5.5 per cent and beyond this, fruits give the indications of shrivelling so market price is lowered down as reported by Mahajan *et al.* (2002). Keeping it in view, it was observed that the weight loss in outer as well as inner canopy fruits was higher than the acceptable limit after 14 days

Table 4.31: Influence of tree age and canopy position on physiological loss in weight (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (T)**
5	5.51	5.08	**5.29[d]**
10	5.27	4.86	**5.06[cd]**
15	5.07	4.45	**4.76[b]**
20	4.69	4.27	**4.48[a]**
25	5.17	4.62	**4.90[bc]**
Mean (C)	**5.14[b]**	**4.65[a]**	
CD (P≤0.05)			
T		**0.26**	
C		**0.16**	
T x C		**NS**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (D)**
0	0.00	0.00	**0.00[a]**
7	3.44	3.05	**3.25[b]**
14	6.60	5.90	**6.25[c]**
21	10.53	9.67	**10.10[d]**
Mean (C)	**5.14[b]**	**4.65[a]**	
CD (P≤0.05)			
D		**0.23**	
C		**0.16**	
C x D		**0.33**	

of harvest except inner canopy fruits from 20 and 15 years old trees with respective weight loss of 5.30 per cent and 5.50 per cent. Therefore, it may also be concluded that the 'Kinnow' fruits can be kept with its good marketable value upto 7 days after harvest under ambient temperature conditions except the fruits in inner canopy of 15 and 20 years old trees which may be kept upto 14 days after harvest.

Table 4.31a: Interaction influence of tree age and days of storage on physiological loss in weight (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Days after harvest (D)				
	0	7	14	21	Mean (T)
5	0.00	3.51	6.80	10.87	**5.29**
10	0.00	3.32	6.52	10.42	**5.06**
15	0.00	3.22	6.02	9.80	**4.76**
20	0.00	2.94	5.64	9.35	**4.48**
25	0.00	3.26	6.28	10.05	**4.90**
Mean (D)	**0.00**	**3.25**	**6.25**	**10.10**	
CD (p≤0.05)					
T x D			**0.52**		

Table 4.31b: Interaction influence of tree age, canopy position and days after harvest on physiological loss in weight (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	7	14	21	Mean	0	7	14	21	Mean
5	0.00	3.57	7.10	11.38	**5.51**	0.00	3.45	6.50	10.35	**5.08**
10	0.00	3.54	6.76	10.78	**5.27**	0.00	3.09	6.28	10.06	**4.86**
15	0.00	3.49	6.53	10.25	**5.07**	0.00	2.95	5.50	9.35	**4.45**
20	0.00	3.08	5.97	9.72	**4.69**	0.00	2.80	5.30	8.98	**4.27**
25	0.00	3.53	6.65	10.50	**5.17**	0.00	2.98	5.90	9.60	**4.62**
Mean	**0.00**	**3.44**	**6.60**	**10.53**		**0.00**	**3.05**	**5.90**	**9.67**	
CD (p≤0.05)										
T x C x D					**NS**					

Weight loss of fruits during storage is primarily related with moisture evaporation through peel which occurs because of establishment of a water pressure gradient between the tissues of fruits and storage atmosphere (Ghasemnezhad *et al*., 2010). Greater loss in fruit weight was observed with increased number of storage days under both cold storage and ambient conditions (Kusumiyati *et al.*, 2013). The results of higher losses in fruits from younger trees are in line with the findings of Bramlage (1993) in pome fruits. Younger trees produced fruits with poorer storage potential than older trees in 'Pinkerton' avocado (Kruger *et al.,* 2004) and in apple (Tahir *et al.*, 2007). Greater weight loss was reported in fruits collected from 18 years old tree (Khalid *et al.*, 2017) in comparison to 6 years and 35 years old trees. Present results are in concurrence with the findings of Agabbio *et al.* (1999) who recorded lower mass loss in orange fruits from interior parts of canopy, whereas, in pear fruits Rudell *et al.* (2017) reported higher weight loss in fruits harvested from internal canopy position.

4.3.1.2 Spoilage (%)

The data pertaining to spoilage of fruits are shown in Table 4.32. It is obvious from the data that spoilage was affected significantly by tree age, canopy position and days after harvest. Highest mean spoilage percentage (5.00%) was reported in the fruits from 5 years old trees followed by 10 years old trees (3.75%), whereas, minimum spoilage (0.83%) was recorded in fruits from 20 years old trees which was noticed at par with 15 years old trees (1.25%). Mean spoilage percentage was found lower in inner canopy fruits (2.17%) in comparison to outer canopy fruits (3.33%). The interaction effect of tree age and canopy position was also noticed to be significant and maximum spoilage (5.00%) was recorded in fruits from both outer and inner canopy fruits of 5 years old trees followed by outer canopy of 10 years old trees (4.17%), while no spoilage was occurred in inner canopy fruits of 15 and 20 years old trees. In outer canopy also, spoilage was noticed minimum (1.67%) in 20 years old trees and 15 years old trees (2.50%).

Table 4.32: Influence of tree age and canopy position on spoilage (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (T)**
5	5.00	5.00	**5.00[d]**
10	4.17	3.34	**3.75[c]**
15	2.50	0.00	**1.25[a]**
20	1.67	0.00	**0.83[a]**
25	3.34	2.50	**2.92[b]**
Mean (C)	**3.33[b]**	**2.17[a]**	
CD (P≤0.05)			
T		**0.57**	
C		**0.36**	
T x C		**0.80**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (D)**
0	0.00	0.00	**0.00[a]**
7	1.33	1.33	**1.33[b]**
14	5.33	3.33	**4.33[c]**
21	6.67	4.00	**5.33[d]**
Mean (C)	**3.33[b]**	**2.17[a]**	
CD (P≤0.05)			
D		**0.51**	
C		**0.36**	
C x D		**0.72**	

Like physiological loss of weight in fruits, spoilage percentage increased continuously with the passage of days after the harvesting. Significant increase in mean spoilage was recorded after 7 (1.33%), 14 (4.33%) and 21 (5.33%) days of harvesting where spoilage was maximum. Significant interaction between canopy position and days after harvest resulted higher spoilage to the tune of 6.67% and 5.33% in outer canopy fruits after 21 days and 14 days of harvesting, respectively.

Lowest spoilage (1.33%) was recorded after 7 days of harvesting of fruits in both inner and outer canopy positions. In inner canopy fruits, highest spoilage (4.00%) was noted after 21 days of harvesting which was found at par with spoilage after 14 days of harvesting (3.33%).

The interaction effect of tree age and days after harvest was also found significant (Table 4.32a). It was observed that spoilage percentage increased after harvesting of fruits from each age group of trees but lowest increment in spoilage (1.67%) occurred in fruits of 20 years old trees after 14 days of harvest and it remained same after 21 days of harvesting (1.67%) whereas, maximum spoilage (10.00%) occurred in fruits of 5 years old trees after 21 days of harvesting.

Table 4.32a: Interaction influence of tree age and days of storage on spoilage (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years)	Days after harvest (D)				
(T)	0	7	14	21	Mean (T)
5	0.00	3.33	6.67	10.00	**5.00**
10	0.00	1.67	6.67	6.67	**3.75**
15	0.00	0.00	1.67	3.34	**1.25**
20	0.00	0.00	1.67	1.67	**0.83**
25	0.00	1.67	5.00	5.00	**2.92**
Mean (D)	**0.00**	**1.33**	**4.33**	**5.33**	
CD ($p \leq 0.05$)					
T x D			**1.13**		

The interaction among all three factors viz. tree age, canopy position and days after harvesting was also found significant (Table 4.32b). After 7 days of fruits harvesting, no spoilage was observed in outer canopy fruits of 15, 20 and 25 years old trees whereas, in case of inner canopy, no spoilage was observed in fruits of 10, 15 and 20 years old trees. Spoilage in inner canopy fruits of 15 and 20 years old trees remained 0.00% after 21 days of harvesting while fruits from both outer and inner canopies of 5 years old trees registered significantly higher spoilage (10.00%) after 21 days of harvesting.

Table 4.32b: Interaction influence of tree age, canopy position and days after harvest on spoilage (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	0.00	3.33	6.67	10.00	**5.00**	0.00	3.33	6.67	10.00	**5.00**
10	0.00	3.33	6.67	6.67	**4.17**	0.00	0.00	6.67	6.67	**3.34**
15	0.00	0.00	3.33	6.67	**2.50**	0.00	0.00	0.00	0.00	**0.00**
20	0.00	0.00	3.33	3.33	**1.67**	0.00	0.00	0.00	0.00	**0.00**
25	0.00	0.00	6.67	6.67	**3.34**	0.00	3.33	3.33	3.33	**2.50**
Mean	**0.00**	**1.33**	**5.33**	**6.67**		**0.00**	**1.33**	**3.33**	**4.00**	
CD ($p \leq 0.05$)										
T x C x D					**1.60**					

Higher spoilage in Kinnow fruits from younger trees are in agreement with the results of study carried out by Bramlage (1993) in which he recorded higher postharvest losses in pome fruits collected from the younger trees as compared to old trees. The fruits form younger trees had poorer storage potential than older ones in ‘Pinkerton’ avocado (Kruger *et al.*, 2004). Apple fruits harvested from younger trees were more sensitive, had lower storage potential, susceptible to bruising and more prone to decay and internal breakdown during storage (Tahir *et al.*, 2007). In present findings, Results of higher spoilage in outer canopy fruits are in concurrence to the outcomes of work done by Jackson *et al.* (1971 and 1977) who confirmed higher percentage of soft rot in apple fruits harvested from exterior canopy as compared to interior one. Also, lower decay percentage was observed by Agabbio *et al.* (1999) in 'Tarocco' orange fruits taken from interior canopy.

4.3.1.3 Fruit firmness (lb force)

The data regarding fruit firmness are illustrated in Table 4.33. It is evident from the data that tree age, canopy position and days after harvest significantly affected fruit firmness during shelf life studies. Maximum mean firmness (8.04 lb

Table 4.33: Influence of tree age and canopy position on firmness (lb force) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (T)
5	6.14	6.51	**6.32[e]**
10	6.48	7.26	**6.87[d]**
15	7.22	8.22	**7.72[b]**
20	7.43	8.65	**8.04[a]**
25	6.80	7.60	**7.20[c]**
Mean (C)	**6.81[b]**	**7.65[a]**	
CD (P≤0.05)			
T		**0.12**	
C		**0.07**	
T x C		**0.17**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (D)
0	8.37	9.11	**8.74 [a]**
7	7.42	8.23	**7.83[b]**
14	6.38	7.23	**6.81[c]**
21	5.07	6.02	**5.54[d]**
Mean (C)	**6.81**	**7.65**	
CD (P≤0.05)			
D		**0.10**	
C		**0.07**	
C x D		**NS**	

force) was measured in the fruits from 20 years old trees followed by 15 years (7.72 lb force) and 25 years old trees (7.20 lb force), whereas, minimum mean firmness (6.32 lb force) was recorded in fruits from 5 years old trees and it was trailed by 10 years old trees (6.87 lb force). Inner canopy fruits (7.65 lb force) maintained higher firmness in comparison to outer canopy fruits (6.81 lb force). The interaction effect of tree age and canopy position was also found significant and maximum firmness (8.65

lb force) was recorded in inner canopy fruits from 20 years old trees followed by 15 years old trees (8.22 lb force), while minimum firmness (6.14 lb force) was noticed in outer canopy fruits of 5 years old trees and 10 years old trees (6.48 lb force).

Declining trend in the fruit firmness was observed with the advancement of days after the harvesting. Highest mean fruit firmness (8.74 lb force) was recorded on the day of harvesting which decreased significantly at each interval and significantly lowest mean firmness (5.54 lb force) was recorded after 21 days of harvesting. Non-significant interaction between canopy position and days after harvest was observed, however maximum decline in firmness was occurred in outer canopy fruits after 14 days of harvesting which resulted lowest firmness (5.07 lb force) recorded on 21 days of harvesting.

Table 4.33a: Interaction influence of tree age and days of storage on firmness (lb force) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years)	**Days after harvest (D)**				
(T)	**0**	**7**	**14**	**21**	**Mean (T)**
5	8.11	7.02	5.83	4.35	**6.32**
10	8.49	7.52	6.42	5.06	**6.87**
15	9.10	8.28	7.34	6.15	**7.72**
20	9.30	8.51	7.67	6.68	**8.04**
25	8.72	7.81	6.78	5.50	**7.20**
Mean (D)	**8.74**	**7.83**	**6.81**	**5.54**	
CD ($p \leq 0.05$)					
T x D			**0.23**		

Combined impact of tree age and days after harvest was also found significant (Table 4.33a). The fruits from all age groups showed decreasing trend in firmness as days after harvesting increased. After 21 days of harvesting, maximum firmness (6.68 lb force) was retained by the fruits harvested from 20 years old trees and minimum firmness (4.35 lb force) was retained by the fruits harvested from 5 years old trees. The interaction among tree age, canopy position and days after harvesting was observed non-significant (Table 4.33b).

Fruit firmness is an important parameter in defining the keeping quality of fruits during market handling (Shear, 1975). During storage or ripening of fruits two possible mechanisms viz. enzymatic breakdown of insoluble protopectin of middle lamella into soluble pectin and enzymatic hydrolysis of starch occur inside the cell wall which results in loss of integrity of cell wall and cause softening of fruits (Mattoo *et al.*, 1975; Solomos and Laties, 1973). In present study, higher loss of firmness in fruits from younger trees might be due to deficiency of minerals especially Ca in the fruit peel of younger trees. The results are in accord with the findings of Tahir *et al.* (2007) who recorded highest firmness loss in apple fruits of younger age (4-6 years old) as compared to older age trees during storage. In case of higher loss of firmness in outer canopy fruits, our findings are in contradiction with the outcomes of work done by Cronje *et al.* (2011) and Cronje *et al.* (2013) who recorded higher rind break down in mandarin fruits produced in inside canopy than the outside canopy fruits after storage at 7.5°C (Magwaza *et al.*, 2013).

Table 4.33b: Interaction influence of tree age, canopy position and days after harvest on firmness (lb force) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	7	14	21	Mean	0	7	14	21	Mean
5	7.95	6.85	5.62	4.12	**6.14**	8.26	7.18	6.03	4.58	**6.51**
10	8.12	7.13	6.03	4.65	**6.48**	8.85	7.90	6.81	5.46	**7.26**
15	8.59	7.80	6.90	5.58	**7.22**	9.61	8.76	7.78	6.71	**8.22**
20	8.85	7.92	6.98	5.95	**7.43**	9.75	9.10	8.35	7.40	**8.65**
25	8.35	7.42	6.37	5.05	**6.80**	9.09	8.19	7.19	5.94	**7.60**
Mean	**8.37**	**7.42**	**6.38**	**5.07**		**9.11**	**8.23**	**7.23**	**6.02**	
CD ($p \leq 0.05$)										
T x C x D					**NS**					

4.3.1.4 Juice recovery (%)

The data pertaining to juice recovery are given in Table 4.34. It is obvious from the observations that juice recovery was influenced significantly by tree age, canopy position and days after harvest. Significantly higher mean juice content (47.11%) was registered in the fruits from 20 years old trees and it was followed by 25 years (44.31%) and 15 years old trees (44.15%). Minimum juice percentage (36.89%) was registered in the fruits of 5 years old trees followed by 10 years old trees (39.93%). Inner canopy maintained higher mean juice content in fruits (45.71%) in comparison to outer canopy fruits (39.24%). The interaction effect of tree age and canopy position was found non-significant, however higher juice percentage (50.60%) was recorded in inner canopy fruits from 20 years old trees followed by 25 years (47.72%) and 15 years old trees (47.19%). Minimum juice (34.00%) was recovered in outer canopy fruits of 5 years old trees and 10 years old trees (36.58%).

Juice recovery was also declined continuously and significantly with the advancement of days after the harvesting. Initially, it decreased gradually upto 14 days where juice to the tune of 41.91 per cent was noted and after this a sharp decline was observed after 21 days where 38.26 per cent of juice was recovered. Also, significant interaction was observed between canopy position and days after harvest. Juice recovery was reduced after harvesting of fruits from both the canopies however, it ranged between 42.70 to 34.49 per cent in outer canopy fruits and between 48.47 to 42.03 per cent in inner canopy fruits during 21 days of interval. It was noticed that decline in juice recovery was more and quicker in fruits harvested from outer canopy compared to inner canopy during shelf life studies. Maximum decline of 4.13 per cent was observed in outer canopy fruits after 14 days of harvesting lead to 34.49 per cent juice recovery after 21 days of harvesting.

The interaction impact of tree age and days after harvest was also found significant (Table 4.34a) which resulted highest juice recovery (44.10%) in fruits from 20 years old trees and lowest juice recovery (31.40%) in 5 years old trees after 21 days of fruit harvesting. The interaction effect of tree age, canopy position and days after harvesting on juice recovery was recorded non-significant (Table 4.34b).

Table 4.34: Influence of tree age and canopy position on juice recovery (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	**Canopy Position**		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (T)**
5	34.00	39.79	**36.89[d]**
10	36.58	43.27	**39.93[c]**
15	41.11	47.19	**44.15[b]**
20	43.61	50.60	**47.11[a]**
25	40.90	47.72	**44.31[b]**
Mean (C)	**39.24[b]**	**45.71[a]**	
CD (P≤0.05)			
T		**0.73**	
C		**0.46**	
T x C		**NS**	
Days after harvest (D)	**Canopy Position**		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (D)**
0	42.70	48.47	**45.58[a]**
7	41.15	47.15	**44.15[b]**
14	38.62	45.19	**41.91[c]**
21	34.49	42.03	**38.26[d]**
Mean (C)	**39.24[b]**	**45.71[a]**	
CD (P≤0.05)			
D		**0.65**	
C		**0.46**	
C x D		**0.92**	

The decline in juice content continuously during shelf life studies might be associated with gradual decline in moisture and firmness of fruits (Mahajan *et al.*, 2006). Therefore, higher juice recovery in inner canopy fruits of old trees might be due to less physiological loss in weight and less loss of firmness in comparison to outer canopy fruits from younger trees. The results are in accordance with the findings of Singla *et al.* (2018) who recorded significantly reduction in juice percentage during storage of 'Kinnow' at ambient conditions for 21 days.

Table 4.34a: Interaction influence of tree age and days of storage on juice recovery (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Days after harvest (D)				
	0	7	14	21	Mean (T)
5	41.14	39.00	36.03	31.40	**36.89**
10	43.67	41.83	39.28	34.93	**39.93**
15	47.05	45.76	43.59	40.21	**44.15**
20	49.18	48.35	46.80	44.10	**47.11**
25	46.89	45.83	43.85	40.67	**44.31**
Mean (D)	**45.58**	**44.15**	**41.91**	**38.26**	
CD (p≤0.05)					
T x D			**1.46**		

Table 4.34b: Interaction influence of tree age, canopy position and days after harvest on juice recovery (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	7	14	21	Mean	0	7	14	21	Mean
5	38.53	36.30	33.15	28.00	**34.00**	43.74	41.70	38.90	34.80	**39.79**
10	40.56	38.66	35.90	31.20	**36.58**	46.78	45.00	42.65	38.65	**43.27**
15	44.35	42.95	40.45	36.70	**41.11**	49.75	48.57	46.72	43.72	**47.19**
20	46.10	45.20	43.20	39.95	**43.61**	52.25	51.50	50.40	48.25	**50.60**
25	43.95	42.65	40.40	36.58	**40.90**	49.83	49.00	47.30	44.75	**47.72**
Mean	**42.70**	**41.15**	**38.62**	**34.49**		**48.47**	**47.15**	**45.19**	**42.03**	
CD (p≤0.05)										
T x C x D					**NS**					

4.3.1.5 Organoleptic rating (Hedonic scale 1-9)

The data regarding organoleptic rating are illustrated in Table 4.35. The data confirmed that tree age, canopy position and days after harvest significantly affected organoleptic rating of fruits during shelf life studies. Maximum mean organoleptic rating (6.99) was noticed in the fruits from 20 years old trees followed

Table 4.35: Influence of tree age and canopy position on organoleptic rating (hedonic scale 1-9) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years)	Canopy Position		
(T)	**Outer canopy (C1)**	**Inner canopy (C2)**	**Mean (T)**
5	5.82	5.55	**5.68[e]**
10	6.06	5.95	**6.01[d]**
15	6.77	6.25	**6.51[b]**
20	7.24	6.74	**6.99[a]**
25	6.57	6.18	**6.37[c]**
Mean (C)	**6.49[a]**	**6.13[b]**	
CD (P≤0.05)			
T		**0.10**	
C		**0.06**	
T x C		**0.14**	

Days after harvest	Canopy Position		
(D)	**Outer canopy (C1)**	**Inner canopy (C2)**	**Mean (D)**
0	7.30	6.99	**7.14[a]**
7	6.85	6.47	**6.66[b]**
14	6.27	5.88	**6.08[c]**
21	5.54	5.19	**5.37[d]**
Mean (C)	**6.49[a]**	**6.13[b]**	
CD (P≤0.05)			
D		**0.09**	
C		**0.06**	
C x D		**NS**	

by 15 years (6.51) and 25 years old trees (6.37), whereas, minimum mean organoleptic rating (5.68) was observed in fruits from 5 years old trees and 10 years old trees (6.01). Organoleptic rating was recorded higher in outer canopy fruits (6.49) in comparison to inner canopy fruits (6.13). The interaction effect of tree age with canopy position was also found significant and maximum organoleptic rating (7.24) was recorded in outer canopy fruits from 20 years old trees trailed by 15 years old trees (6.77) and inner canopy of 20 years old trees (6.74), while minimum organoleptic rating (5.55) was noticed in inner canopy fruits of 5 years old trees followed by outer canopy fruits of 5 years old trees (5.82).

Diminishing trend in the organoleptic rating was observed with the advancement of days after the harvesting. Organoleptic rating to the tune of 6.08 was recorded after 14 days of harvesting where fruits were rated as 'slightly desirable' and then after 21 days of harvesting organoleptic rating (5.37) was significantly lowest where fruits were rated as 'Neither undesirable nor desirable'. Non-significant interaction between canopy position and days after harvest was observed.

Table 4.35a: Interaction influence of tree age and days of storage on organoleptic rating (hedonic scale 1-9) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years)	Days after harvest (D)				
(T)	**0**	**7**	**14**	**21**	**Mean (T)**
5	6.68	6.08	5.39	4.58	**5.68**
10	6.92	6.35	5.73	5.03	**6.01**
15	7.38	6.93	6.30	5.43	**6.51**
20	7.65	7.32	6.81	6.20	**6.99**
25	7.09	6.64	6.17	5.60	**6.37**
Mean (D)	**7.14**	**6.66**	**6.08**	**5.37**	
CD (p≤0.05)					
T x D			**0.20**		

Combined impact of tree age and days after harvest was found significant (Table 4.35a). On the basis of organoleptic rating of fruits, it became apparent that fruits from 20 years old trees retained good quality (6.20) upto 21 days, fruits from 15 years (6.30) and 25 years (6.17) old trees retained good quality upto 14 days and fruits from 10 years (6.35) and 5 years (6.08) old trees retained good quality upto 7 days only after harvesting.

The interaction among tree age, canopy position and days after harvesting was observed non-significant (Table 4.35b) however, both outer (6.44) and inner (5.95) canopy fruits from 20 years old trees maintained higher organoleptic rating upto 21 days of harvesting whereas, lowest rating upto 21 days was maintained by the fruits from both outer (4.71) and inner (4.45) canopies of 5 years old trees. .

Table 4.35b: Interaction influence of tree age, canopy position and days after harvest on organoleptic rating (hedonic scale 1-9) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	6.82	6.20	5.54	4.71	**5.82**	6.54	5.96	5.23	4.45	**5.55**
10	6.96	6.44	5.77	5.08	**6.06**	6.88	6.25	5.69	4.97	**5.95**
15	7.63	7.25	6.54	5.65	**6.77**	7.12	6.60	6.05	5.21	**6.25**
20	7.85	7.57	7.11	6.44	**7.24**	7.44	7.07	6.50	5.95	**6.74**
25	7.22	6.80	6.40	5.84	**6.57**	6.95	6.47	5.94	5.36	**6.18**
Mean	**7.30**	**6.85**	**6.27**	**5.54**		**6.99**	**6.47**	**5.88**	**5.19**	
CD (p≤0.05)										
T x C x D					**NS**					

Organoleptic rating is associated with the appearance, taste and flavour of fruits. With the advancement of days after harvesting, rating of fruits decreased which might be due to anabolic and catabolic activities occurred in the fruits (Mahajan *et al.*, 2009). Further, higher organoleptic rating in outer canopy fruits from old trees might be due to retention of higher TSS and TSS:acid ratio recorded in these fruits. During storage, higher loss in flavour quality was also recorded in the fruits of 'Aroma' apple trees of younger age (4-6 years old) (Tahir *et al.*, 2007).

4.3.2 Quality characteristics

4.3.2.1 Total soluble solids (%)

The perusal of data related to total soluble solids (TSS) content is presented in Table 4.36. It is obvious from the data that total soluble solids content was influenced significantly by tree age, canopy position and days after harvest. Mean

Table 4.36: Influence of tree age and canopy position on total soluble solids content (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (T)
5	9.09	8.59	**8.84[e]**
10	11.10	9.87	**10.48[d]**
15	11.58	10.87	**11.22[b]**
20	12.22	11.41	**11.82[a]**
25	11.52	9.90	**10.71[c]**
Mean (C)	**11.10[a]**	**10.13[b]**	
CD (P≤0.05)			
T		**0.15**	
C		**0.09**	
T x C		**0.21**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (D)
0	10.31	9.42	**9.87[c]**
7	11.17	10.04	**10.61[b]**
14	11.78	10.78	**11.28[a]**
21	11.15	10.26	**10.70[b]**
Mean (C)	**11.10[a]**	**10.13[b]**	
CD (P≤0.05)			
D		**0.13**	
C		**0.09**	
C x D		**NS**	

TSS was recorded higher (11.82%) in fruits from 20 years old trees and it was followed by 15 years (11.22%) and 25 years old trees (10.71%). Minimum mean TSS (8.84%) was noticed in 5 years old trees followed by 10 years old trees (10.48%) after 21 days of harvesting. Outer canopy fruits registered higher mean TSS content (11.10%) in comparison to inner canopy fruits (10.13%). The interaction effect of tree age and canopy position on TSS was also found significant and higher TSS (12.22%) was recorded in outer canopy fruits from 20 years old trees followed by 15 years (11.58%) and 25 years old trees (11.52%). Minimum TSS (8.59%) was observed in inner canopy fruits of 5 years old trees followed by outer canopy fruits of 5 years old trees (9.09%).

TSS showed firstly an increasing trend and then declined with the advancement of days after harvesting. The peak value of TSS (11.28%) was observed upto 14 days of harvesting after that it reduced to the value of 10.70 per cent. The interaction between canopy position and days after harvest was recorded non-significant; however highest TSS (11.78%) was retained by outer canopy fruits upto 14 days of harvesting and at the same time inner canopy fruits retained TSS to the tune of 10.78%.

Table 4.36a: Interaction influence of tree age and days of storage on total soluble solids content (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years)	**Days after harvest (D)**				
(T)	**0**	**7**	**14**	**21**	**Mean (T)**
5	8.08	9.08	9.53	8.66	**8.84**
10	9.73	10.52	11.13	10.55	**10.48**
15	10.50	11.22	11.88	11.30	**11.22**
20	11.06	11.58	12.51	12.12	**11.82**
25	9.96	10.63	11.36	10.89	**10.71**
Mean (D)	**9.87**	**10.61**	**11.28**	**10.70**	
CD (p≤0.05)					
T x D			**0.29**		

Significant interaction impact of tree age and days after harvest on TSS was recorded (4.36a). Peak values of TSS were found after 14 days of harvesting the fruits in all the age groups and thereafter TSS values decreased upto 21 days. After 21 days of harvesting, higher TSS (12.12%) was retained by the fruits from 20 years old trees followed by fruits from 15 years old trees (11.30%) whereas, minimum TSS (8.66%) was retained by fruits from 5 years old trees.

The interaction relationship between tree age, canopy position and days after harvesting was recorded non-significant (Table 4.36b), however, higher TSS (12.52%) upto 21 days of harvesting was retained by outer canopy fruits from 20 years old trees whereas, inner canopy fruits from 5 years old trees retained lowest TSS (8.53%) upto 21 days of harvesting.

Table 4.36b: Interaction influence of tree age, canopy position and days after harvest on total soluble solids content (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	8.32	9.43	9.82	8.79	**9.09**	7.84	8.73	9.24	8.53	**8.59**
10	10.30	11.22	11.70	11.17	**11.10**	9.16	9.82	10.56	9.93	**9.87**
15	10.85	11.67	12.20	11.59	**11.58**	10.15	10.78	11.55	11.01	**10.87**
20	11.36	12.04	12.96	12.52	**12.22**	10.75	11.12	12.05	11.72	**11.41**
25	10.70	11.51	12.20	11.67	**11.52**	9.22	9.74	10.52	10.10	**9.90**
Mean	**10.31**	**11.17**	**11.78**	**11.15**		**9.42**	**10.04**	**10.78**	**10.26**	
CD ($p \leq 0.05$)										
T x C x D					**NS**					

The increase in TSS upto 14 days of harvesting might be due to the conversion of complex organic metabolites into water soluble molecules or might be the result of conversion of polysaccharides into water soluble sugars after hydrolysis (Wills *et al.,* 1980). Once the hydrolysis of starch is completed, instead of increasing, a decline in the TSS occurs. The increase in TSS after harvesting had also been reported by Mbogo *et al.* (2010) in 'Valencia' and 'Navel' oranges and Singla *et al.* (2018) in 'Kinnow' fruits. Increase in soluble solids content in 'Kinnow' during storage as a function of number of storage days under both cold storage and ambient conditions was also reported (Kusumiyati *et al.*, 2013). After 7 days of ambient storage of 'Kinnow' mandarin, higher TSS was noticed in fruits from 35 years old trees in comparison to 6 years and 18 years old ones (Khalid *et al.*, 2017) which is in agreement with present studies.

Total soluble solids level was not influenced by canopy position in 'Marsh' grapefruit during storage (Olarewaju *et al.*, 2018). 'Shogun' mandarin fruits collected from the upper portion of canopy have greater TSS than the fruits from lower and middle canopy positions after storage (Youryon and Supapvanich, 2019).

4.3.2.2 Acidity (%)

The data regarding acidity are shown in Table 4.37. It is apparent from the data that acidity was affected significantly by tree age, canopy position and days after harvest. The highest mean acidity (0.77%) was recorded in the fruits from 20 years old trees followed by 25 years old trees (0.72%) and 15 years old trees (0.71%), whereas, minimum mean acidity (0.61%) was observed in fruits from 5 years old trees which was followed by 10 years old trees (0.66%). Mean acidity was found higher in outer canopy fruits (0.71%) in comparison to inner canopy fruits (0.67%). The interaction effect of tree age and canopy position was found non-significant, however maximum acidity (0.78%) was recorded in fruits from outer canopy of 20 years old trees followed by inner canopy of 20 years old trees (0.76%) and outer canopy of 25 years old trees (0.75%) while minimum acidity was recorded in both inner (0.60%) and outer canopy (0.62%) fruits of 5 years old trees.

Acidity in fruits decreased continuously with the passage of days after the harvesting. Non-significant decrease in acidity was observed after 7 days of harvesting (0.71%) but later acidity decreased significantly after 14 days (0.67%) and further decreased non significantly after 21 days of harvesting (0.65%). Though the interaction between canopy position and days after harvest was found non-significant, yet higher acidity to the tune of 0.76% and 0.72% was recorded in respective outer and inner canopy on the day of harvesting and these values reduced to 0.66% and 0.63% in respective outer and inner canopy after 21 days of harvesting.

Table 4.37: Influence of tree age and canopy position on acidity (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (T)
5	0.62	0.60	**0.61**[d]
10	0.70	0.63	**0.66**[c]
15	0.73	0.69	**0.71**[b]
20	0.78	0.76	**0.77**[a]
25	0.75	0.69	**0.72**[b]
Mean (C)	**0.71**[a]	**0.67**[b]	
CD (P≤0.05)			
T		**0.03**	
C		**0.02**	
T x C		**NS**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (D)
0	0.76	0.72	**0.74**[a]
7	0.73	0.69	**0.71**[a]
14	0.69	0.65	**0.67**[b]
21	0.66	0.63	**0.65**[b]
Mean (C)	**0.71**[a]	**0.67**[b]	
CD (P≤0.05)			
D		**0.03**	
C		**0.02**	
C x D		**NS**	

The interaction effect of tree age and days of harvest of acidity was noted to be non significant (Table 4.37a). The interaction among all three factors viz. tree age, canopy position and days after harvesting (Table 4.37b) was found non-significant, however, higher acidity (0.73%) was maintained by both outer and inner canopy fruits from 20 years old trees and least acidity (0.55%) was maintained by outer and inner canopy fruits from 5 years old trees upto 21 days of harvesting.

Table 4.37a: Interaction influence of tree age and days of storage on acidity (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean (T)**
5	0.67	0.62	0.59	0.55	**0.61**
10	0.72	0.68	0.65	0.62	**0.66**
15	0.76	0.73	0.69	0.67	**0.71**
20	0.81	0.79	0.75	0.73	**0.77**
25	0.77	0.73	0.70	0.67	**0.72**
Mean (D)	**0.74**	**0.71**	**0.67**	**0.65**	
CD (p≤0.05)					
T x D			**NS**		

Table 4.37b: Interaction influence of tree age, canopy position and days after harvest on acidity (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	0.68	0.63	0.60	0.55	**0.62**	0.65	0.61	0.58	0.55	**0.60**
10	0.75	0.71	0.68	0.65	**0.70**	0.68	0.65	0.61	0.58	**0.63**
15	0.78	0.75	0.71	0.68	**0.73**	0.74	0.71	0.67	0.65	**0.69**
20	0.82	0.80	0.75	0.73	**0.78**	0.79	0.78	0.75	0.73	**0.76**
25	0.79	0.76	0.73	0.70	**0.75**	0.74	0.70	0.66	0.64	**0.69**
Mean	**0.76**	**0.73**	**0.69**	**0.66**		**0.72**	**0.69**	**0.65**	**0.63**	
CD (p≤0.05)										
T x C x D					**NS**					

A continuous decrease in acidity during shelf life might be due to breakdown of organic acids through pyruvate decarboxylation pathways during fruit ripening (Echeverria and Valich, 1989). Present results are in confirmation with the outcomes given by Singla *et al.* (2018) who also observed decrease in acid content in 'Kinnow' with the increase in ambient storage period upto 21 days after harvest. After 7 days of ambient storage of 'Kinnow' mandarin, higher acidity was recorded in fruits from older trees compared to young trees (Khalid *et al.*, 2017), which is confirmatory to our results. Contrary, according to Olarewaju *et al.* (2018) in 'Marsh' grapefruit, inner canopy fruits maintained higher acidity than the outer canopy fruits during storage, whereas acidity did not vary significantly after the storage of 'Shogun' mandarin fruits as reported by Youryon and Supapvanichn (2019).

4.3.2.3 TSS/acid ratio

The data pertaining to TSS/acid ratio are given in Table 4.38. It is evident from the data that tree age, canopy position and days after harvest significantly affected TSS/acid ratio of fruits during shelf life studies. Maximum mean TSS/acid ratio (15.87) was estimated in the fruits from 10 years old trees and it was found at par with the fruits from 15 years (15.85) old trees, whereas, minimum mean TSS/acid ratio (14.67) was noticed in fruits from 5 years old trees which was followed by 25 years old trees (15.02). TSS/acid ratio was recorded higher in outer canopy fruits (15.63) in comparison to inner canopy fruits (15.10). The interaction effect of tree age and canopy position was also observed to be significant and maximum TSS/acid ratio (15.98) was estimated in fruits from outer canopy of 10 years old trees which was found at par with outer canopy fruits from 15 years (15.92) and 20 years (15.83) old trees and inner canopy fruits from 15 years (15.77) and 10 years (15.75) old trees, while minimum TSS/acid ratio (14.45) was noticed in fruits from inner canopy of 5 years old trees and 25 years old trees (14.52).

TSS/acid ratio reflected firstly a rising trend and declined thereafter with the passage of days after harvesting. The peak value of TSS/acid ratio (16.72) was observed at 14 days of harvesting after that it reduced to the value of 16.54 however, it was found a non-significant reduction. The interaction between canopy position and days after harvest was recorded non-significant, however outer canopy fruits maintained higher TSS/acid ratio of 16.95 and in contrary, inner canopy fruits maintained higher TSS/acid ratio of 16.50 upto 14 days of harvesting.

Table 4.38: Influence of tree age and canopy position on TSS/acid ratio of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (T)**
5	14.89	14.45	**14.67[d]**
10	15.98	15.75	**15.87[a]**
15	15.92	15.77	**15.85[a]**
20	15.83	15.00	**15.41[b]**
25	15.52	14.52	**15.02[c]**
Mean (C)	**15.63[a]**	**15.10[b]**	
CD (P≤0.05)			
T		**0.31**	
C		**0.19**	
T x C		**0.43**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	**Inner canopy (C2)**	**Mean (D)**
0	13.46	13.06	**13.26[c]**
7	15.31	14.55	**14.93[b]**
14	16.95	16.50	**16.72[a]**
21	16.81	16.28	**16.54[a]**
Mean (C)	**15.63[a]**	**15.10[b]**	
CD (P≤0.05)			
D		**0.27**	
C		**0.19**	
C x D		**NS**	

The interaction impact of tree age and days after harvest was found non-significant (Table 4.38a). The fruits from all the age groups showed firstly an increasing tendency upto 14 days of harvesting and then decreased upto 21 days of harvesting however, highest TSS/acid ratio (17.15) was noticed in fruits from 10 years followed by 15 years old trees (16.99) old trees after 21 days of harvesting and least TSS/acid ratio (15.75) was observed in fruits of 5 years old trees. Also, the interaction of tree age, canopy position and days after harvesting did not influence the TSS/acid ratio significantly (Table 4.38b).

Table 4.38a: Interaction influence of tree age and days of storage on TSS/acid ratio of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean (T)**
5	12.15	14.64	16.15	15.75	**14.67**
10	13.60	15.46	17.26	17.15	**15.87**
15	13.81	15.37	17.21	16.99	**15.85**
20	13.73	14.65	16.67	16.60	**15.41**
25	13.00	14.53	16.33	16.23	**15.02**
Mean (D)	**13.26**	**14.93**	**16.72**	**16.54**	
CD (p≤0.05)					
T x D			**NS**		

Table 4.38b: Interaction influence of tree age, canopy position and days after harvest on TSS/acid ratio of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	12.24	14.97	16.37	15.98	**14.89**	12.06	14.31	15.93	15.51	**14.45**
10	13.73	15.80	17.21	17.18	**15.98**	13.47	15.11	17.31	17.12	**15.75**
15	13.91	15.56	17.18	17.04	**15.92**	13.72	15.18	17.24	16.94	**15.77**
20	13.85	15.05	17.28	17.15	**15.83**	13.61	14.26	16.07	16.05	**15.00**
25	13.54	15.14	16.71	16.67	**15.52**	12.46	13.91	15.94	15.78	**14.52**
Mean	**13.46**	**15.31**	**16.95**	**16.81**		**13.06**	**14.55**	**16.50**	**16.28**	
CD (p≤0.05)										
T x C x D					**NS**					

Flavour of fruits is associated with TSS:acid ratio and was maintained higher in outer canopy fruits from older trees which can be confirmed by the experimental finding of Tahir *et al.* (2007) who had noticed higher loss in flavour quality in the fruits of 'Aroma' apple trees of younger age (4-6 years old) during storage. After cold storage of 'Marsh' grapefruit, inner canopy fruits had lower TSS/acid ratio than the outer canopy fruits (Olarewaju *et al.*, 2018).

4.3.2.4 Ascorbic acid (mg/100 ml juice)

The data related to ascorbic acid content in fruits are given in Table 4.39.

Table 4.39: Influence of tree age and canopy position on ascorbic acid content (mg/100 ml juice) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years)	Canopy Position		
(T)	Outer canopy (C1)	Inner canopy (C2)	Mean (T)
5	24.25	23.35	**23.80[a]**
10	22.90	21.19	**22.04[b]**
15	21.90	19.10	**20.50[c]**
20	21.22	18.74	**19.98[d]**
25	20.76	17.52	**19.14[e]**
Mean (C)	**22.21[a]**	**19.98[b]**	
CD (P≤0.05)			
T		**0.38**	
C		**0.19**	
T x C		**0.43**	

Days after harvest	Canopy Position		
(D)	Outer canopy (C1)	Inner canopy (C2)	Mean (D)
0	25.69	23.03	**24.36[a]**
7	23.24	20.82	**22.03[b]**
14	21.01	18.99	**20.00[c]**
21	18.89	17.08	**17.99[d]**
Mean (C)	**22.21[a]**	**19.98[b]**	
CD (P≤0.05)			
D		**0.27**	
C		**0.19**	
C x D		**0.30**	

It is clear from the figures that ascorbic acid was affected significantly by tree age, canopy position and days after harvest during shelf life studies. Maximum mean ascorbic acid (23.80 mg) was estimated in the fruits from 5 years old trees followed by 10 years (22.04 mg), whereas, minimum ascorbic acid (19.14 mg) was registered in fruits from 25 years old trees which was followed by 20 years old trees (19.98 mg). Ascorbic acid was recorded higher in outer canopy fruits (22.21 mg) as compared to inner canopy fruits (19.98 mg). The interaction effect of tree age and canopy position was noticed to be significant and highest ascorbic acid (24.25 mg) was reported in fruits from outer canopy of 5 years old trees followed by inner canopy of 5 years old trees (23.35) and outer canopy of 10 years old trees (22.90 mg), while lower ascorbic acid (17.52 mg) was noticed in fruits from inner canopy of 25 years old trees and 20 years old trees (18.74 mg).

Diminishing trend in the ascorbic acid was observed with the progression of days after the harvesting. Ascorbic acid ranged between 24.36 mg to 17.99 mg from day of harvesting upto 21 days of harvesting. A gradual decrease in ascorbic acid content was observed upto 14 days and after that a sharp decline was noticed after 21 days of harvesting. Significant interaction between canopy position and days after harvest was also observed. In outer canopy, ascorbic acid decreased at faster rate compared to inner canopy fruits and highest decline was observed after 14 days of harvest in outer canopy however, ascorbic acid was retained lower by inner canopy fruits at each interval.

Combined impact of tree age and days after harvest was also found significant (Table 4.39a). Maximum ascorbic acid content (20.27 mg) was maintained in fruits of 5 years old trees after 21 days of harvesting and at the same time minimum ascorbic acid content (16.15 mg) was maintained in the fruits from 25 years old trees. Ascorbic acid content in fruits of 15 years (17.43 mg) and 20 years (17.34 mg) old trees varied with each other non-significantly.

Significant interaction was also recorded among tree age, canopy position and days after harvesting (Table 4.39b). After 21 days of harvesting, higher ascorbic acid content to the tune of 20.56 mg was retained by outer canopy fruits from 5 years old trees and it was noticed at par with the ascorbic acid content (19.97 mg) retained by inner canopy fruits from same age group of trees whereas, significantly lowest ascorbic acid content (14.68 mg) was retained by inner canopy fruits from 25 years old trees after 21 days of harvesting.

Table 4.39a: Interaction influence of tree age and days of storage on ascorbic acid content (mg/100 ml juice) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean (T)**
5	27.49	24.92	22.53	20.27	**23.80**
10	25.44	23.11	20.87	18.76	**22.04**
15	23.75	21.45	19.38	17.43	**20.50**
20	22.81	20.62	19.17	17.34	**19.98**
25	22.30	20.05	18.06	16.15	**19.14**
Mean (D)	**24.36**	**22.03**	**20.00**	**17.99**	
CD (p≤0.05)					
T x D			**0.60**		

Table 4.39b: Interaction influence of tree age, canopy position and days after harvest on ascorbic acid content (mg/100 ml juice) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	28.10	25.42	22.93	20.56	**24.25**	26.88	24.42	22.12	19.97	**23.35**
10	26.40	24.04	21.69	19.47	**22.90**	24.48	22.17	20.05	18.05	**21.19**
15	25.34	22.89	20.71	18.65	**21.90**	22.15	20.00	18.04	16.20	**19.10**
20	24.50	22.14	20.09	18.16	**21.22**	21.12	19.09	18.24	16.52	**18.74**
25	24.10	21.70	19.63	17.62	**20.76**	20.50	18.40	16.48	14.68	**17.52**
Mean	**25.69**	**23.24**	**21.01**	**18.89**		**23.03**	**20.82**	**18.99**	**17.08**	
CD (p≤0.05)										
T x C x D					**0.85**					

Decline in ascorbic acid during shelf life might be associated with conversion of ascorbic acid into dehydroascorbic acid (Lin *et al.*, 1988). During storage, loss of ascorbic acid was also noticed with the increase in storage time in 'Valencia' and 'Navel' orange fruits (Mbogo *et al.*, 2010) and in 'Kinnow' (Singla *et al.*, 2018). Higher antioxidant activities were maintained in fruits produced from 18 years old trees under ambient storage conditions and fom 6 years old trees when stored under cold storage conditions (Khalid *et al.*, 2015).

Similar results of higher ascorbic acid were also found in exterior canopy fruits than interior canopy fruits of citrus (Izumi *et al.*, 1990b and Izumi, 1998). The fruits collected from the upper portion of canopy had higher antioxidant activity than the fruits from lower and middle canopy positions after the storage of 'Shogun' mandarin fruits (Youryon and Supapvanich, 2019).

4.3.2.5 Total sugars (%)

The data pertaining to total sugars are illustrated in Table 4.40. It is obvious from the data that total sugars content was influenced by tree age, canopy position and days after harvest. Average total sugars level was estimated higher (9.06%) in fruits from 20 years old trees and it was followed by 15 years (8.59%) and 25 years old trees (8.04%). Minimum mean total sugars content (6.00%) was noticed in fruits from 5 years old trees and 10 years old trees (7.84%). Outer canopy fruits registered higher total sugars content (8.31%) in comparison to inner canopy fruits (7.50%). The interaction between tree age and canopy position on total sugars content was also found significant and higher total sugars content (9.42%) was estimated in fruits from outer canopy of 20 years old trees followed by 15 years (8.90%) and 25 years old trees (8.73%). Minimum total sugars content (5.81%) was observed in fruits from inner canopy of 5 years old trees and outer canopy of 5 years old trees (6.20%).

Total sugars content showed firstly an increasing tendency and declined thereafter with the advancement of days after harvesting. The peak value of total sugars content (8.51%) was observed upto14 days of harvesting after that it reduced to the value of 7.96%. The interaction between canopy position and days after harvest was recorded non-significant, however outer canopy fruits had higher total sugars content (8.93%) after 14 days of harvesting.

Table 4.40: Influence of tree age and canopy position on total sugars content (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (T)
5	6.20	5.81	**6.00[e]**
10	8.30	7.39	**7.84[d]**
15	8.90	8.28	**8.59[b]**
20	9.42	8.70	**9.06[a]**
25	8.73	7.35	**8.04[c]**
Mean (C)	**8.31[a]**	**7.50[b]**	
CD (P≤0.05)			
T		**0.12**	
C		**0.08**	
T x C		**0.17**	

Days after harvest (D)	Canopy Position		
	Outer canopy (C1)	Inner canopy (C2)	Mean (D)
0	7.66	6.94	**7.30[d]**
7	8.32	7.36	**7.84[c]**
14	8.93	8.10	**8.51[a]**
21	8.33	7.60	**7.96[b]**
Mean (C)	**8.31[a]**	**7.50[b]**	
CD (P≤0.05)			
D		**0.11**	
C		**0.08**	
C x D		**NS**	

Significant interaction impact of tree age and days after harvest was found on total sugars content (Table 4.40a). Peak values of total sugars content were found after 14 days of harvesting the fruits in all the age groups and thereafter sugars content decreased upto 21 days. After 21 days of harvesting, higher sugars content (9.33%) was retained by the fruits from 20 years old trees followed by fruits from 15 years old trees (8.64%) whereas, minimum sugars content (5.79%) was retained by fruits from 5 years old trees.

Table 4.40a: Interaction influence of tree age and days of storage on total sugars content (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean (T)**
5	5.39	6.19	6.64	5.79	**6.00**
10	7.23	7.83	8.43	7.88	**7.84**
15	8.01	8.51	9.19	8.64	**8.59**
20	8.43	8.78	9.68	9.33	**9.06**
25	7.44	7.89	8.64	8.19	**8.04**
Mean (D)	**7.30**	**7.84**	**8.51**	**7.96**	
CD (p≤0.05)					
T x D			**0.24**		

Table 4.40b: Interaction influence of tree age, canopy position and days after harvest on total sugars content (%) of 'Kinnow' mandarin fruits during shelf life studies.

Tree age (years) (T)	Canopy position (C)									
	Outer canopy					Inner canopy				
	Days after harvest (D)					Days after harvest (D)				
	0	**7**	**14**	**21**	**Mean**	**0**	**7**	**14**	**21**	**Mean**
5	5.57	6.47	6.87	5.87	**6.20**	5.21	5.91	6.41	5.71	**5.81**
10	7.65	8.35	8.85	8.35	**8.30**	6.81	7.31	8.01	7.41	**7.39**
15	8.32	8.92	9.47	8.87	**8.90**	7.70	8.10	8.90	8.40	**8.28**
20	8.69	9.19	10.09	9.69	**9.42**	8.17	8.37	9.27	8.97	**8.70**
25	8.05	8.65	9.35	8.85	**8.73**	6.82	7.12	7.92	7.52	**7.35**
Mean	**7.66**	**8.32**	**8.93**	**8.33**		**6.94**	**7.36**	**8.10**	**7.60**	
CD (p≤0.05)										
T x C x D					**NS**					

The interaction effect of tree age, canopy position and days after harvesting on total sugars content was recorded non-significant (Table 4.40b), however, higher sugars level (9.69%) upto 21 days of harvesting was retained by outer canopy fruits from 20 years old trees whereas, inner canopy fruits from 5 years old trees retained lowest sugars level (5.71%) upto 21 days of harvesting.

The conversion of complex organic metabolites into water soluble molecules or conversion of polysaccharides into water soluble sugars after hydrolysis might be the reasons of increment in sugar content of fruits upto 14 days of harvesting (Wills *et al.*, 1980). After the completion of hydrolysis of starch, a decline in the sugar content occurs. The results of increase in sugars are in line with the outcomes of work done by Mbogo *et al.* (2010) in 'Valencia' and 'Navel' orange fruits and Singla *et al.* (2018) in 'Kinnow' fruits. After 7 days of ambient storage of 'Kinnow' mandarin, higher sugars were estimated in fruits from 35 years old trees in comparison to 6 years and 18 years old ones (Khalid *et al.*, 2017) and present results are in confirmation to these findings. The current research findings are in agreement with the findings of Izumi *et al.* (1990b) who also reported higher sugars level in citrus fruits from the outer canopy during storage.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study "Influence of tree age on vegetative growth and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* L. x *Citrus deliciosa* T.) under submontaneous region of Punjab" was carried out in the private orchards located in Block Bhunga, District Hoshiarpur, Punjab during the year 2017-19. In this chapter, the salient findings of each experiment are summarized and concluded to emphasis the outcomes of the research work.

5.1 Influence of tree age on vegetative growth, leaf nutrient content and fruit yield.

5.1.1 Influence of tree age on vegetative growth

- Annual increment in vegetative growth of plants decreased with the increase in age of trees. Maximum annual increment in trunk girth (12.61%), tree height (12.81%), tree spread (17.38%), tree canopy volume (55.37%), trunk cross-sectional area (26.78%) and leaf area (5.74%) was observed in 5 years old trees whereas, minimum annual increment in trunk girth (1.34%), tree height (478%), tree spread (8.66%), tree canopy volume (23.82%), trunk cross-sectional area (2.70%) and leaf area (5.64%) was observed in 25 years old trees.

5.1.2 Influence of tree age on leaf nutrients content

- Macronutrient content in leaves showed an increasing tendency with the increase in the age of trees. Maximum N (2.78%), P (0.15%) and S (0.30%) content was recorded in the leaves of 25 years old trees, whereas, K (1.66%) and Ca (4.82%) content was recorded higher in the leaves of 20 years old trees and Mg (0.44%) in 15 year old trees. Minimum N (2.22%), P (0.11%), K (1.22%), Ca (2.90%), Mg (0.32%) and S (0.26%) content was estimated in the leaves of 5 years old trees.
- Micronutrients content decreased with increase in age of trees. Maximum Fe (129.77 ppm) and Cu (13.68 ppm) content was recorded in the leaves of 10 years old trees, whereas, Zn (76.11 ppm) , Mn (80.98 ppm) and B

(98.62 ppm) content was recorded higher in the leaves of 5 years old trees. Leaf Fe (83.45 ppm), Zn (35.76 ppm), Mn (32.84 ppm) content was estimated lower in 25 years old trees while leaf Cu (8.34 ppm) and B (60.81 ppm) content was recorded lower in 20 years old trees.

5.1.3 Influence of tree age on fruit yield

- No. of fruits and fruit yield showed an increasing trend with the increase in age of trees which resulted maximum number of fruits per tree (1314.8) and fruit yield (196.7 kg per tree) in 25 year old trees whereas, number of fruits (219.7) and fruit yield (37.6 kg/tree) was estimated lowest in young trees of 5 years age.

5.2 Influence of tree age and canopy position on yield, quality and nutrient content of fruits.

5.2.1 Influence of tree age and canopy position on yield characteristics

- Twenty five years old trees produced maximum number of fruits (1314.8) and fruit yield (196.7 kg per tree) while 5 years old trees gave least number of fruits (219.7) and fruit yield (37.6 kg/tree). Outer canopy registered more no. of fruits (582.9) and higher fruit yield (87.7 kg per tree) as compared to 315.2 kg and 51.5 kg per tree in inner canopy.
- Higher percentage of E grade (30.73%), D grade (26.08%), C grade (25.99%) fruits was recorded in respective 5 years, 15 years and 20 years old trees whereas, higher percentage of B grade (27.83%), A grade (22.00%), G grade (11.78%) grade fruits was found in 25 years old trees. In outer canopy C and B grade fruits contributed higher percentage (42.25%) whereas, in inner canopy, higher percentage (43.87%) is contributed by D and C grade fruits. In markets, E, D and C grade fruits fetch premium prices compared to B, A and G grade fruits. E, D and C grade fruits contributed 60.60 per cent of total inner canopy fruits and 54.00 per cent of total outer canopy fruits. Similarly, B, A, G grade fruits contributed 39.40 per cent of total inner canopy fruits and 46.00 percent of total outer canopy fruits.

5.2.2 Influence of tree age and canopy position on fruit quality

- L, b and C values varied non-significantly with respect to tree age. Fruit colour in terms of redness (a value +35.82) and hue angle (h value 58.04) was found better in fruits from 20 years old trees whereas, poor fruit colour was seen to be developed in fruits from 5 years old trees. The fruits produced in outer canopy were found with better colour having L, a, b, C and h vales to the tune of 57.73, +35.63, +55.78, 66.20 and 57.42, respectively.
- Most firmed fruits (9.30 lb force) were observed from 20 years old trees in contrast to the least firmed fruits (8.11 lb force) from 5 years old trees. Inner canopy fruits were significantly firmer (9.11 lb force) than the outer canopy fruits (8.37 lb force).
- Smooth fruits with highest smoothness score (3.55) were obtained from 20 years old trees and fruits from 5 years old trees scored minimum (2.93). Inner canopy fruits had more smoothness score (3.42) as compared to outer canopy fruits (3.18).
- Significantly heavier fruits (172.38 g) were harvested from younger 5 years old trees whereas, fruits from the 25 years old trees registered lowest fruit weight (151.46 g). The fruits were heavier (166.54 g) in the inner canopy of trees than the outer canopy (154.19 g). Specific gravity differed non significantly with respect to tree age as well as canopy position.
- Bigger sized fruits were in terms of length and diameter (6.85 cm and 7.71 cm) were obtained from young 5 years old trees while; smaller fruits were obtained from older plants of 25 years age (6.26 cm and 6.89 cm). Inner canopy fruits were significantly bigger in size (6.75 cm and 7.46 cm) in comparison to outer canopy fruits (6.34 cm and 7.13 cm).
- Fruits harvested from 20 years old trees were found to have thinnest peel (2.79 mm) whereas, thick peeled fruits were pertained to young 5 years old trees (3.00 mm). The fruits produced in the inner canopy had thinner peel (2.83 mm) as compared to outer canopy (2.93 mm).

- Significantly lowest peel percentage (21.34%) was noticed in fruits from 20 years old trees but on the hand fruits from the 5 years old trees had highest peel percentage (27.46%). In comparison to the outer canopy fruits (26.46%), inner canopy fruits had significantly lower peel percentage (21.59%).
- Maximum juicy fruits (49.18%) were pertained to 20 years old trees while fruits obtained from 5 years old trees were least juicy (41.14%). Inner canopy fruits had higher juice content (48.47%) as compared to outer canopy fruits (42.70%).
- Lower rag percentage (26.37%) was recorded in the fruits of 15 years old trees whereas younger trees of 5 years age produced fruits with higher rag (28.26%). Inner canopy fruits had significantly lower rag percentage (26.85%) compared to outer canopy fruits (28.03%).
- The fruits from 20 years old trees contained markedly lower seed percentage (2.57%) while at the same time higher seed percentage was noticed in fruits of 10 years old trees. Seed percentage was significantly higher (3.09%) in inner canopy fruits compared to outer canopy fruits (2.82%).
- Seed number (19.32) was recorded minimum in fruits from 5 years old trees and maximum (22.29) in fruits from 10 years old trees. Inner canopy fruits had less seed (19.76) in comparison to outer canopy fruits (22.64).
- Organoleptic rating of fruits was significantly higher (7.65) in 20 years old trees and these fruits were rated as 'moderately to very much desirable' but on the other hand 5 years old trees had least organoleptic rating (6.68) and these fruits were rated as 'slightly desirable to moderately desirable'. The fruits born in the outer canopy had higher rating (7.30) compared to inner canopy fruits (6.99).
- Sweetest fruits in terms of higher TSS (11.06%) were obtained from 20 years old trees whereas, fruits obtained from 5 years old trees were least sweet with TSS of 8.08%. The fruits harvested from outer canopy had

significantly higher TSS value (10.31%) than the fruits harvested from inner canopy (9.42%).

- Highest acid content (0.81%) was recorded in fruits of 20 years old trees while lowest acid content (0.67%) was noticed in 5 years old trees. The fruits produced in the outer canopy had higher acidity (0.76%) as compared to inner canopy fruits (0.72%).
- The fruits from 15 years old trees had higher TSS/acid ratio (13.81) and fruits from 5 years old trees had lower TSS/acid ratio (12.15). In contrast to inner canopy fruits (13.06), outer canopy fruits had higher TSS/acid ratio (13.46).
- Five years old trees produced fruits rich in ascorbic acid content (27.49 mg per 100 ml juice) whereas, minimum ascorbic acid content (22.30 mg) was noticed in fruits from 25 years old trees. Higher ascorbic acid content (25.69 mg) was estimated in outer canopy fruits then the inner canopy fruits (23.03 mg).
- Total sugars content was highest (8.43%) in fruits of 20 years old trees and lowest (5.39%) in 5 years old trees. Significantly higher sugars (7.66%) were recorded in outer canopy than the inner canopy fruits (6.94%).
- Highest amino acid content (85.01 mg per 100 g fruit) was estimated in fruits from 20 years old trees while the lowest amino acid content (70.86 mg) was estimated in the fruits of 5 year old trees. The outer canopy fruits had higher amino acid content (86.37 mg) as compared to inner canopy fruits (71.64 mg).
- The fruits with higher limonin content (17.33 ppm) were pertained to 15 years old trees which was noticed at par with that of 20 years old trees (17.26 ppm). The fruits with lower limonin content (15.76 ppm) were obtained from 5 years old trees. Limonin content (17.72 ppm) in inner canopy fruits was higher than the outer canopy fruits (15.69 ppm).

5.2.3 Influence of tree age and canopy position on fruit nutrients content

- Twenty five years old trees had higher content of N (14423.80 ppm), P (949.37 ppm), Mg (839.15 ppm) and S (628.84 ppm) in fruit peel while, K (9145.53 ppm) and Ca (9618.84 ppm) content was higher in fruit peel of 20 years old trees. Outer canopy fruits had higher content of N (13609.27 ppm), Mg (662.78 ppm) and S (569.05 ppm) in fruit peel as compared to inner canopy fruits whereas, P (876.17 ppm), K (8665.55 ppm) and Ca (8659.13 ppm) content was higher in peel of inner canopy fruits. 5 years old trees had higher concentration of Fe (114.37 ppm), Cu (8.68 ppm) and B (31.59 ppm) in fruit peel, whereas Zn (12.83 ppm) and Mn 9.76 ppm) concentration was higher in 10 years old trees. Zn (11.49 ppm) and Mn (7.23 ppm) concentration was higher in fruit peel of inner canopy and on the other hand Fe, Cu and B content differed non significantly with canopy position.

- In case of nutrients content in juice, fruits from 10 years old trees were rich in N (2253.60 ppm) and fruits from 15 years old trees were rich in P (112.59 ppm) and S (39.85 ppm), whereas, K (1383.00 ppm), Ca (106.42 ppm), Mg (95.63 ppm) rich fruits were obtained from 20 years old. N (1996.04 ppm) and S (36.19 ppm) content was higher in juice of outer canopy fruits while, P (106.68 ppm), K (1309.00 ppm) and Ca (96.87 ppm) was higher in juice of inner canopy fruits. Concentration of Fe (5.34 ppm), Mn 0.55 (ppm) and B (0.28 ppm) was higher juice of fruits from 5 years old trees whereas, Cu (0.37 ppm) and Zn (0.95 ppm) concentration was higher in juice of fruits from 15 years old trees. Micronutrients content in juice was not affected significantly with canopy position.

5.3 Influence of tree age and canopy position on shelf life of fruits

- The physiological loss of weight in fruits increased with the advancement of days after the harvesting. After 21 days of harvesting, minimum mean weight loss (4.48%) was observed in fruits from 20 years old trees in contrast to higher mean weight loss percentage (5.29%) in fruits from 5 years old trees. Inner canopy fruits had average loss in weight (4.65%) lesser than outer canopy fruits (5.14%) after 21 days of harvesting. Weight loss in outer as well as inner canopy fruits was higher than the acceptable limit after 14 days of harvest except inner canopy fruits from

20 and 15 years old trees with respective weight loss of 5.30% and 5.50%.

- Spoilage percentage was found increased with the passage of days after harvesting and after 21 days of harvesting the fruits, minimum mean spoilage (0.83%) was recorded in fruits from 20 years old trees and higher mean loss (5.00%) was recorded in 5 years old trees. Mean spoilage percentage was lower in inner canopy fruits (2.17%) compared to outer canopy fruits (3.33%) after 21 days of harvesting.
- Fruit firmness showed declining trend with the progression of days after the harvesting. The fruits from 20 years old trees had maximum mean firmness (8.04 lb force) after 21 days of harvesting while, minimum mean firmness (6.32 lb force) was registered in fruits from 5 years old trees. In comparison to outer canopy fruits (6.81 lb force), mean firmness was recorded higher in inner canopy fruits (7.65 lb force).
- A continuous and significant decline in the juice content throughout the shelf life study resulted higher mean juice content (47.11%) in the fruits from 20 years old trees after 21 days of harvesting the fruit and at the same time fruits from 5 years old trees had minimum mean juice content (36.89%). Inner canopy registered higher juice content in fruits (45.71%) in comparison to outer canopy fruits (39.24%).
- Organoleptic rating showed declining tendency as the number of days increased after harvesting. After 21 days of harvesting, mean organoleptic rating was recorded maximum (6.99) in the fruits from 20 years old trees and these fruits were rated as 'Moderately Desirable' whereas, mean organoleptic rating was recorded minimum (5.68) in the fruits from 5 years old trees and these fruits were rated as 'Slightly Desirable'. Outer canopy fruits (6.49) were rated higher when compared to inner canopy fruits (6.13).
- Total soluble solids (TSS) reflected firstly an increasing trend upto 14 days of harvesting and declined after that. The fruits from 20 years old trees had higher mean TSS (11.82%) while lowest TSS (8.84%) was estimated in fruits from 5 years old trees after 21 days of harvesting. TSS

content was higher (11.10%) in outer canopy than inner canopy fruits (10.13%).

- Acidity decreased continuously throughout the shelf life study of 21 days. Mean acidity (0.77%) was recorded maximum in the fruits from 20 year old trees and on the other side minimum mean acidity (0.61%) was lower in fruits from 5 years old trees after 21 days of harvesting the fruits. Outer canopy fruits had higher mean acidity (0.71%) in comparison to inner canopy fruits (0.67%).
- Similarly to TSS, TSS/acid ratio showed firstly an increasing trend upto 14 days of harvesting and declined thereafter. The fruits from the 10 years old trees had higher mean TSS/acid ratio (15.87) after 21 days of harvesting, while fruits from 5 years old trees were recorded with lower TSS/acid ratio (14.67). Higher TSS/acid ratio was registered in outer canopy fruits (15.63) in comparison to inner canopy fruits (15.10).
- A continuous and significant decline in ascorbic acid content upto 21 days of harvesting resulted the maximum mean ascorbic acid (23.80 mg) in the fruits from 5 years old trees and minimum mean ascorbic acid content (19.14 mg) in the fruits from 25 years old trees. In contrast to inner canopy fruits (19.98 mg) mean ascorbic acid was recorded higher in outer canopy fruits (22.21 mg).
- Total sugars also reflected initially an increasing tendency upto 14 days of harvesting and then declined. Average total sugars level was higher (9.06%) in fruits from 20 years old trees and lower (6.00%) in fruits from 5 years old trees after 21 days of harvesting. Higher total sugars content (8.31%) was pertaining to outer canopy fruits in comparison to inner canopy fruits (7.50%).

At the end, it was concluded that annual increment in vegetative growth was higher in young trees compared to older trees. Macronutrients like N, P, K, Ca, Mg and S were higher in leaves of 20 and 25 years old trees whereas, micronutrients like Fe, Zn, Cu, Mn and B were higher in leaves of young trees of 5 years age. Number of fruits and fruit yield per tree was recorded maximum in 25 years old trees. Maximum fruit size, weight and percentage of E grade fruits was recorded in 5 years old trees.

The fruits with smooth surface, better colour, thin peel; lower peel, rag, seed and higher juice percentage was obtained from 20 years old trees. Juice quality in terms of higher TSS, acidity, TSS:acid ratio, total sugars was found better in 20 years old trees whereas, ascorbic acid content was noted higher in 5 year old trees. Free amino acids and limonin content was also found maximum in juice of fruits from 20 years old trees. Peel of fruits from 25 years old trees had higher N, P, Mg and S content whereas, Ca and K content was higher in peel of fruits from 20 years old trees. Fe, Cu and B content was found higher in fruit peel from 5 years old trees whereas, Zn and Mn content was higher in fruit peel from 10 years old trees. Juice of fruits from 20 years old trees were found rich in Ca, K and Mg while fruits from 15 years old trees were rich in P, S, Zn and Cu. Fe, Mn and B content was higher in juice of fruits from 5 years old trees. The fruits from 20 years and 15 years old trees were found to have better shelf life in terms of minimum physiological loss in weight and spoilage and fruits from these age groups maintained higher firmness, juice content, organoleptic rating, TSS, acidity and sugars after 21 days of harvesting. Ascorbic acid was maintained higher in the fruits of 5 years old trees.

In case of canopy position, number of fruits and fruit yield was recorded higher in outer canopy. Inner canopy fruits were found better in higher percentage of E, D and C grade fruits, fruit size, fruit weight, smooth peel, thin peel, less peel, less rag, less seed count, higher juice percentage and higher limonin content, whereas, outer canopy fruits were found better in fruit colour, less seed percentage, higher TSS, acidity, TSS:acid ratio, ascorbic acid, total sugars and free amino acids content. Outer canopy fruits had higher peel N, peel Mg, peel S, juice N and juice S, whereas, inner canopy fruits had higher peel P, peel K, peel Ca, peel Zn, peel Mn, juice P, juice K and juice Ca. Inner canopy fruits had better shelf life in terms of lower physiological loss in weight and spoilage along with higher firmness and juice recovery. The fruit quality in terms of higher TSS, acidity, TSS:acid ratio, ascorbic acid and total sugars was maintained higher by outer canopy fruits during shelf life.

Finally, it was concluded that younger trees had higher vegetative growth rate, fruit size and fruit weight compared to older trees. In general, macronutrients were higher in leaves and fruits of older trees whereas, micronutrients were higher in leaves and fruits of younger ones. The fruits harvested from 20 years old trees had better quality and shelf life. Outer canopy fruits were better in colour and juice quality whereas, internal and external physical qualities were better in inner canopy fruits. Nutrients content in fruits was higher in inner canopy. Fruits in the inner canopy had better shelf life in terms of lower physiological loss in weight and spoilage and higher firmness and juice recovery, but juice quality was maintained higher by outer canopy fruits.

REFERENCES

A.O.A.C. (2005). *Official and Tentative Methods of Analysis (14th ed).* Association of Analytical Chemists, Benjamin Franklin Station, Washington DC, USA.

Abed-el-Wahab, W. A. (1990). Effect of fruit size on some physical and chemical properties of grapefruit during cold storage. *Bull. Faculty of Agriculture, University of Cairo*, **41**: 959-971.

Agabbio, M., Lovicu, G., Pala, M., D'hallewin, G., Mura, M., and Schirra, M. (1999). Fruit canopy position effects on quality and storage response of "Tarocco" oranges. *Acta Hort*, **485**: 19-23.

Amerine, M. A., Pangborn, R. M. and Roessler, E. B. (1965). *Principles of Sensory Evaluation of Food.* Academic Press, London.

Ani, P. N., and Abel, H. C. (2018). Nutrient, phytochemical, and antinutrient composition of *Citrus maxima* fruit juice and peel extract. *Food Science & Nutrition*, **6**(3): 653-658.

Anonymous (2018). *Horticulture Statistics at a Glance.* Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India. http://nhb.gov.in/statistics/State_Level/2017-18-(Final).pdf

Anonymous (2020). Area and Production of Fruits in Punjab. Directorate of Horticulture, Punjab.

Anonymous (2020). Area and Production of Horticulture Crops: All India. http://nhb.gov.in/statistics/State_Level/2018-19%20(3rd%20Adv.Est_.)%20-%20Website.pdf (28-11-2020).

Arpaia, M. L., Kahn, T. L., El-Otmani, M., Coggins, C. W., DeMason, D. A., O'Connell, N. V., and Pehrson, J. E. (1991). Pre-harvest rindstain of "Valencia" orange: histochemical and developmental characterization. *Scientia Hort*, **46**(3-4): 261-274.

Asrey, R., Pal, R. K., Sagar, V. R. and Patel, V. B. (2007). Impact of tree age and canopy position on fruit quality of guava. *Acta Hort*, **735**: 259-262.

Bal, J. S. and Chohan, G. S. (1983). A study on distribution and quality of different sized ‘Kinnow’ mandarin orange harvested at optimum maturity, *J Food Sci & Tech*, **20**: 321-322.

Barritt, B. H., Konishi, B. S., Drake, S. R. and Rom, C. R. (1997). Influence of sunlight level and rootstock on apple fruit quality. *Acta Hort*, **451**: 569-578.

Barry, G. H., Castle, W. S. and Davies, F. S. (2000). Juice quality of ‘Valencia’ sweet orange among citrus producing regions in Florida and between canopy positions. *In: Proc Inter Soc Citriculture IX Congress*, pp. 1017-1020.

Barry, G. H., Castle, W. S. and Davies, F. S. (2003). Variability in juice quality of ‘Valencia’ sweet orange and sample size estimation for juice quality experiments. *J Amer Soc Hort Sci*, **128**: 803-808.

Barry, G. H., Castle, W. S. and Davies, F. S. (2004). Juice quality of ‘Valencia’ sweet oranges borne on different inflorescence types. *HortScience*, *39*(1), 33-35.

Botts, R. R. (1941). Development of "Normal" citrus fruit yields by tree ages for use in a yield insurance plan. *J Farm Eco,* **23**(4): 867-872.

Boyd, L. M., Ramankutty, P., Barnett, A. M., Dawson, T., Wegrzyn, T., Le Guevel, A. and Mowat, A. D. (2008). Effect of canopy position on fruit quality in ‘Hort16A’ kiwifruit in New Zealand. *J Hort Sci and Biotech*, **83**(6): 791-797.

Bramlage, W. J. (1993). Interaction of orchard factors and mineral nutrition on quality of pome fruit. *Acta Hort*, **326**: 15-28.

Carbone, M. S., Czimczik, C. I., Keenan, T. F., Murakami, P. F., Pederson, N., Schaberg, P. G., ... and Richardson, A. D. (2013). Age, allocation and availability of nonstructural carbon in mature red maple trees. *New Phytologist*, **200**(4): 1145-1155.

Caruso, T., Di Vaio C., Inglese, P. and Pace, L. S. (1998). Crop load and fruit quality distribution within canopy of 'Spring Lady' peach trees trained to 'Central Leader' and 'Y shape'. *Acta Hort*, **465**: 621-628.

Casero, T., Benavides, A., Puy, J. and Recasens, I. (2005). Relationships between leaf and fruit nutrients and fruit quality attributes in Golden Smoothee apples using multivariate regression techniques. *J Plant Nutrition*, **27**(2): 313-324.

Castle, W. (1983). Growth, yield and cold hardiness of seven-year-old ‘Bearss’ lemon on twenty seven rootstocks. *Proc Fla State Hort Soc*, **96**: 23-25.

Chaudhary, P., Kaushik, R. A., Rathore, R. S., Sharma, M. and Kaushik, M. A. (2016). Improving growth, yield and quality of Kinnow mandarin through foliar application of potassium and zinc. *Indian J Hort,* **73**(4): 597-600.

Cohen, E. (1988). The chemical composition and sensory flavour quality of 'Mineola' tangerines. I. Effects of fruit size and within-tree position. *J Hort Sci*, **63**(1): 175-178.

Cronje, P. J. R., Barry, G. H. and Huysamer, M. (2011). Fruiting position during development of 'Nules Clementine' mandarin affects the concentration of K, Mg and Ca in the flavedo. *Scientia Hort*, **130**: 829-837.

Cronje, P. J. R., Barry, G. H. and Huysamer, M. (2013). Canopy position affects pigment expression and accumulation of flavedo carbohydrates of 'Nules Clementine' mandarin fruit, thereby affecting rind condition. *J Amer Soc Hort Sci*, **138**(3): 217-224.

Czech, A., Zarycka, E., Yanovych, D., Zasadna, Z., Grzegorczyk, I., and Kłys, S. (2020). Mineral content of the pulp and peel of various citrus fruit cultivars. *Biological Trace Element Research*, **193**: 555-563.

Daito, H., Tominaga, S., Ono, S. and Morinaga, K. (1981). Yield of differently trained trees and fruit quality at various locations within canopies of differently trained Satsuma mandarin trees. *J Japan Soc Hort Sci*, **50**(2): 131-142.

Dalal, R. P. S. and Brar, J. S. (2012). Relationship of trunk cross-sectional area with growth, yield, quality and leaf nutrient status in Kinnow mandarin. *Indian J Hort*, **69**(1): 111-113.

Dalal, R. P. S., Beniwal, B. S. and Sehrawat, S. K. (2013). Seasonal variation in growth, leaf physiology and fruit development in Kinnow, a mandarin hybrid. *J Plant Studies,* **2**: 72-77.

Dar, M. A., Wani, J. A., Raina, S. K. and Bhat, M. Y. (2012). Effect of available nutrients on yield and quality of pear fruit Bartlett in Kashmir Valley India. *J Environ Bio,* **33**: 1011-1014.

Dar, M. A., Wani, J. A., Raina, S. K., Bhat, M. Y. and Malik, M. A. (2015). Relationship of leaf nutrient content with fruit yield and quality of pear. *J Environ Bio*, **36**: 649-653.

Davies, F. S. and Albrigo, L. G. (1994). *Crop Production Science in Horticulture 2, Citrus*. GAB International, Trowbridge, Wiltshire, Great Britain.

Deidda, P., Dettori, S., and Pala, M. (1981). Fruit distribution in sweet orange trees and its relation to harvesting operations. *Rivista della Ortoflorofrutticoltura* Italiana, **65**(1): 35-58.

DongHui, W., Guo Zhang, T. and YongQing, L. (2005). Comparison of fruit quality of *Prunus salicina* trees varying in age. *J Zhejiang For Sci Technol*, **25**: 29-31.

Doryanizadeh, M., Ghasemnezhad, M. and Sabouri, A. (2017). Estimation of postharvest quality of "Red Delicious" apple fruits based on fruit nutrient elements composition. *J Agri Sci*, **9**(1): 164-173.

Dris, R., Niskanen, R. and Fallahi, E. (1999). Relationships between leaf and fruit minerals and fruit quality attributes of apples grown under northern conditions. *J Plant Nutrition*, **22**(12): 1839-1851.

Drogoudi, P. D., and Pantelidis, G. (2011). Effects of position on canopy and harvest time on fruit physico-chemical and antioxidant properties in different apple cultivars. *Scientia Hort*, **129**(4): 752-760.

Echeverria, E. and Valich, J. (1989). Enzymes of sugar and acid metabolism in stored Valencia oranges. *J Amer Soc Hort Sci*, **114**: 445-449.

El-Sayed, F. S. (2018). Effect of tree age of 'Newhall" navel orange on physical and chemical fruit characters development. *Middle East J Agric Res*, **7**(3): 1177-1185.

F.A.O. (2017). Citrus Fruit - Fresh and Processed, *Statistical Bulletin 2016*, Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/3/a-i8092e.pdf

Fallahi, E., Fallahi, B., Retamales, J. B., Valdés, C. and Tabatabaei S. J. (2006). Prediction of apple fruit quality using preharvest mineral nutrients. *Acta Hort*, **721**: 259-264.

Fallahi, E., Moon, Jr. J. W. and Mousavi, Z. (1989). Fruit quality and mineral nutrient from exposed verses internal canopy positions of four citrus varieties. *J Plant Nutrition*, **12**: 523-534.

Feng, F., Li, M., Ma, F. and Cheng, L. (2014). Effects of location within the tree canopy on carbohydrates, organic acids, amino acids and phenolic compounds in the fruit peel and flesh from three apple (*Malus* x *domestica*) cultivars. *Hort Res*, **1**: 14019. Doi:10.1038/hortres.2014.19

Feng, L., Yina, Y. and Yang, X. (2019). Content difference and correlation analysis of leaf mineral element and fruit quality in different pomegranate cultivars. *Acta Hort*, **1254**: 219-226.

Ferguson, I. B. (1980). The uptake and transport of calcium in fruit tree (*Actinidia chinensis*), in: Atkinson, D., Jackson, J. E., Sharples, R. O., Waller, W. M. (Eds.), *Mineral Nutrition of Fruit Trees,* Butterworth, London, pp. 183-192.

Fidalski, J., Auler, P. A. M. and Tormem, V. (2000). Relations among Valencia orange yields with soil and leaf nutrients in northwestern Paraná, Brazil. *Brazilian Archives of Bio and Tech,* **43**(4), DOI: 10.1590/S1516-89132000000400006

Forlani, M., Basile, B., Cirillo, C. and Iannini, C. (2002). Effects of harvest date and fruit position along the tree canopy on peach fruit quality. *Acta Hort*, **592**: 459-466.

Freeman, T. and Robbertse, P. J. (2003). Internal quality of 'Valencia' orange fruit as influenced by tree fruit position and winter girdling. *S Afr J Plant Soil*, **20**(4): 199-202.

Frometa, E. and Echazabal, J. (1988). Influence of age and cultivar on juice characteristics of early oranges. *Agrotecnia de Cuba,* **20**: 71-75.

Funada, R., Kubo, T., Tabuchi, M., Sugiyama, T., and Fushitani, M. (2001). Seasonal variations in endogenous indole-3-acetic acid and abscisic acid in the cambial region of *Pinus densiflora* Sieb. et Zucc. stems in relation to earlywood-latewood transition and cessation of tracheid production. *Holzforschung,* **55**(2): 128-134.

George, A. P., Nissen, R. J., Collins, R. J. and Rasmussen, T. S. (1996). Effects of shoot variables and canopy position on fruit set, fruit quality and starch reserves of persimmon (*Diospyros kaki* L.) in subtropical Australia. *J Hort Sci*, **71**(2): 217-226.

Ghasemnezhad, M., Shiri, M. A. and Sanavi, M. (2010). Effect of chitosan coatings on some quality indices of apricot during cold storage. *Caspian J Environ Sci*, **8**: 25-33.

Gilfillan, I. M. (1990). Crop manipulation: Fruit reduction with calcium arsenate sprays, 7-9. In: Netterville, R. M. (ed.). *Production Guidelines for Export Citrus*, Vol. II, S.A. Co-op Citrus Exchange, Hennopsmeer, South Africa.

Gimeno, V., Simón, I., Martínez, V., Lidón, V., Shahid, M. A. and Garcia-Sanchez, F. (2015). Effect of shade screen on production, fruit quality and growth parameters of 'Fino 49' lemon trees grafted on *Citrus macrophylla* and sour orange. *Acta Hort*, **1065**: 1845-1852.

Goldschmidt, E. E. (2013). The evolution of fruit tree productivity: a review. *Economic botany*, **67**(1): 51-62.

González-Mas, M. C., Llosa, M. J., Quijano, A., and Forner-Giner, M. A. (2009). Rootstock effects on leaf photosynthesis in 'Navelina' trees grown in calcareous soil. *HortScience*, **44**(2): 280-283.

Gurjar, P. S. and Rana, G. S. (2014). Influence of foliar application of nutrients and growth regulators on fruit drop, yield and fruit size and quality in Kinnow mandarin. *Indian J Hort*, **71**(1): 109-111.

Hamadziripi, E. T., Theron, K. I., Muller, M. and Steyn, W. J. (2014). Apple compositional and peel color differences resulting from canopy microclimate affect consumer preference for eating quality and appearance. *HortScience*, **49**(3): 384-392.

Hearn, C. J. (1994). Influence of cultivar and high nitrogen and potassium fertilization on fruit quality traits of young orange trees. *Proc Fla State Hort Soc*, **106**: 8-12.

Hubbard, R. M., Bond, B. J. and Ryan, M. G. (1999). Evidence that hydraulic conductance limits photosynthesis in old *Pinus ponderosa* trees. *Tree Physiol*, **19**: 165-172.

Ishii, H., Ford, E. D., and Dinnie, C. E. (2002). The role of epicormic shoot production in maintaining foliage in old *Pseudotsuga menziesii* (Douglas-fir) trees II. Basal reiteration from older branch axes. *Can J Bot*, **80**(9): 916-926.

Iwagaki, I. (1981). Studies on the relation between the morphological features of *Citrus unshiu,* satsuma mandarin orange trees, their growth and yields**.** *J Japan Soc Hort Sci,* **56**(7): 894-898.

Iwagaki, I. and Kato, Y. (1982). Relationship between early fruit growth and harvest fruit quality in Satsuma mandarin. *J Japan Soc Hort Sci,* **51**(3): 263-269.

Iwagaki, I. and Kudo, K. (1977). Fruit quality relating to the location of fruit in a canopy of satsuma mandarin tree. *J Japan Soc Hort Sci,* **30**: 17-23.

Izumi, H (1998). Influence of light intensity during fruit growth on susceptibility of Hassaku fruit to Kohansho (Studies on Vitamin C of fruits and vegetables-Part XI). *Food Preserv Sci,* **24**(3): 189-192.

Izumi, H., Ito, T. and Yoshida, Y. (1988). Relationship between ascorbic acid and sugar content in citrus fruit peel during growth and development. *J Japan Soc Hort Sci*, **57**(2): 304-311.

Izumi, H., Ito, T. and Yoshida, Y. (1990a). Sugar and ascorbic acid contents of 'Satsuma' mandarin fruits harvested from exterior and interior canopy of trees during fruit development. *J Japan Soc Hort Sci*, **58**(4): 877-883.

Izumi, H., Ito, T. and Yoshida, Y. (1990b). Changes in the fruit quality of 'Satsuma' mandarin during storage after harvest form exterior and interior canopy of trees. *J Japan Soc Hort Sci*, **58**(4): 885-893.

Izumi, H., Ito, T. and Yoshida, Y. (1992). Effect of light intensity during the growing period on ascorbic acid content and its histochemical distribution in the leaves and peel and fruit quality of Satsuma mandarin. *J Japan Soc Hort Sci,* **61**(1): 7-15.

Jackson, J. E. and Palmer, J. W. (1977). Effects of shade on the growth and cropping of apple trees. I. Experimental details and effects on vegetative growth. *J Hort Sci*, **52**(2): 245-252.

Jackson, J. E., Palmer, J. W., Perring, M. A. and Sharples, R. O. (1977). Effects of shade on the growth and cropping of apple trees. III. Effects on fruit growth, chemical composition and quality at harvest and after storage. *J Hort Sci,* **52**: 267-282.

Jackson, J. E., Sharples, R. O. and Palmer, J. W. (1971). The influence of shade and within-tree position on apple fruit size, colour and storage quality. *J Hort Sci*, **46**, 277-287.

Jain, P. K. and Chauhan, K. S. (1995). Extending shelf-life of Kinnow mandarin with different storage conditions. *Indian J Hort* **52**(4): 267-271.

Jawanda, J. S., Arora, J. S. and Sharma, N. J. (1973). Fruit quality and maturity study of 'Kinnow' mandarin at Abohar. *Punjab Hort J*, **13**: 3-12.

Johnson, D. S. (2000). Mineral composition, harvest maturity and storage quality of 'Red Pippin', 'Gala' and 'Jonagold' apples. *J Hort Sci & Biotech*, **75**(6): 697-704.

Jongkey, O. and Hazarika, B. N. (2018). Standardization of leaf nutrient status of Khasi mandarin by correlation of leaf nutrient status, fruit yield and quality. *Crop Research*, **53**(3-4): 160-166.

Josan, J. S., Chohan, G. S. and Bal, J. S. (1983). Kinnow fruit quality as affected by locations on the tree. *Indian J Hort*, **40** (1&2): 40-42

Jover, S., Martínez-Alcántara, B., Rodríguez-Gamir, J., Legaz, F., Primo-Millo, E., Forner, J., and Forner-Giner, M. (2012). Influence of rootstocks on photosynthesis in Navel orange leaves: effects on growth, yield, and carbohydrate distribution. *Crop science*, **52**(2): 836-848.

Kawphaitoon, S., Ayutthaya, S. I. N. and Techawongstien, S. (2016). Effect of fruit position on fruit quality of ‘Num Dok Mai Sithong’ mango. *Acta Hort,* **1111**: 335-340.

Ketsa, S., Pota, S. and Subhadrabandhu, S. (1992). Effect of fruit position in the tree canopy on postharvest changes and quality of 'Nam Dok Mai' mangoes. *Acta Hort*, **321**: 455-462.

Khalid, S., Malik, A. U., Khan, A. S., Khan, M. N., Ullah, M. I., Abbas, T. and Khalid, M. S. (2017). Tree age and fruit size in relation to postharvest respiration and quality changes in 'Kinnow' mandarin under ambient storage. *Scientia Hort*, **220**: 183-192.

Khalid, S., Malik, A. U., Khan, A. S., Shahid, M., and Shafique, M. (2015). Tree age, fruit size and storage conditions affect levels of ascorbic acid, total phenolic concentrations and total antioxidant activity of ‘Kinnow’ mandarin juice. *J*

Sci Food and Agric, **96**(4), 1319-1325.

Khalid, S., Malik, A. U., Saleem, B. A., Khan, A. S., Khalid, M. S. and Amin, M. (2012). Tree age and canopy position affect rind quality, fruit quality and rind nutrient content of 'Kinnow' mandarin (*Citrus nobilis* Lour x *Citrus deliciosa* Tenora). *Scientia Hort,* **135**: 137-44.

Khalid, S., Malik, A. U., Singh, Z., Ullah, S., Saleem, B. A., and Malik, O. H. (2018). Tree age influences nutritional, pectin, and anatomical changes in developing 'Kinnow' mandarin (*Citrus nobilis* Lour x *Citrus deliciosa* Tenora) fruit. *Journal of Plant Nutrition*, **41**(14): 1786-1797.

Khan, A. S., Malik, A. U., Perevz, M. A., Saleem, B. A., Rajwana, I. A., Shaheen, T. and Anwar, R. (2009). Foliar application of low-biuret urea and fruit canopy position in the tree influence the leaf nitrogen status and physio-chemical characteristics of Kinnow mandarin (*Citrus reticulata* Blanco). *Pak J Bot*, **4**: 73-85.

Kochhar, A., Gandhi, N. and Brar, V. (2017). Impact of tree age and ripening stages on physical characteristics of Kinnow (*Citrus Reticulata* Blanco). In: International Conference on *"Recent Trends in Technology and its Impact on Economy of India"*, 24th October, 2017, Guru Nanak College for Girls, Sri Muktsar Sahib, Punjab, 420-424.

Kong, Y., Chen, J., Yao, Y., Wang, Z., Guo, J., Lian, S., Ma, C. and Li, B. (2011). The relationship between light transmittance and canopy structure parameters of nectarine trees in Chinese lean-to greenhouse. *Acta Hort*, **927**: 413-419.

Krajewski, A. (1997). *Guidelines for the improvement of fruit colour in citrus.* L.A. von Broembsen (ed.) Outspan International, p 1-25.

Krishnaprakash, M. S., Aravindaprasad, B., Krishnaprasad, C. A., Narasimham, P., Ananthakrishna, S. M., Dhanaraj, S. and Govindarajan, V. S. (1983). Effect of apple position on the tree on maturity and quality. *J Hort Sci*, **58**(1): 31-36.

Kruger, F. J., Snijder, B., Mathumbu, J. M., Lemmer, D. and Malumane, R. (2004). Establishing appropriate maturity and fruit mineral content norms for the main avocado export cultivars. *South African Avocado Growers' Association Yearbook,* **27**: 5-10.

Kumar, D., Pandey, V., Anjaneyulu, K. and Nath, V. (2008). Relationship of trunk cross-sectional area with fruit yield, quality and leaf nutrients status in Allahabad Safeda guava (*Psidium guajava*). *Indian J Agric Sci*, **78**: 337-339.

Kumar, D., Srivastava, K. K. and Singh, S. R. (2019). Correlation of trunk cross sectional area with fruit yield, quality and leaf nutrient status in plum under North West Himalayan region of India. *J Hortl Sci*, **14**(1): 26-32.

Kumar, M. N. and Ram, A. (2018). Tree age affects postharvest attributes and mineral content in Amrapali mango (*Mangifera indica*) fruits. *Hort plant J*, https://doi.org/10.1016/j.hpj.2018.01.005

Kusumiyati., Fany, N., Akinaga, T., and Kawasaki, S. (2013). Postharvest storage of citrus tankan fruit under normal condition and cold storage. *Acta Hort*, **975**: 473-478.

Lee, Y. P. and Takahashi, T. (1966). An improved colorimetric determination of amino acids with the use of ninhydrin. *Anal Biochem*, **14**: 71-77.

Lemos, L. M. C., Siqueira, D. L D., Salomao, L. C. C., Cecon, P. R. and Lemos, P . J. (2012). Physical and chemical characteristics of 'Pera' orange from different positions of the canopy. *Rev Bras Frutic Jaboticabal - SP*, **34**(4): 1091-1097.

Lemos, L. M. C., Siqueira, D. L. D., Salomao, L. C. C., Cecon, P. R. and Vieccelli, J. C. (2013). Physical and chemical characteristics of 'Natal' and 'Valencia' oranges depending on the position in the canopy. *Revista Ceres*, **60**(5): 653-661.

Lewallen, K. S. and Marini, R. P. (2003). Relationship between flesh firmness and ground color in peach as influenced by light and canopy position. *J Amer Soc Hort Sci*, **128**: 163-170.

Lin, Z. F., Li, S. S., Zhang, D. L., Lui, S. X., Li, Y. B., Li, Z, G. and Chen, M. D. (1988). The changes in oxidation and peroxidation in post harvest litchi fruits. *Acta Bot Sin*, **30**: 383-87.

Liu, X., Chen, L., Wang, B., Fan, Y., and Chen, Q. (2016). Uptake and accumulation of dry matter and mineral nutrients in different age trees of 'Nanguo' pear

(*Pyrus ussuriensis* Maxim) *Acta Hort*, **1130**: 531-536.

Luchsinger, L., Ortin, P., Reginato, G. and Infante, R. (2002). Influence of canopy fruit position on the maturity and quality of 'Angelus' peaches. *Acta Hort*, **592**: 515-521.

Magwaza, L. S., Opara, U. L., Cronje, P. R., Nieuwoudt, H. H., Landahl, S. and Terry, L. A. (2013). Quantifying the effects of fruit position in the canopy on physical and biochemical properties and predicting susceptibility to rind breakdown disorder of 'Nules Clementine' mandarin (*Citrus reticulate* Blanco) using Vis/NIR Spectroscopy. *Acta Hort*, **1007**: 83-92.

Mahajan B. V. C., Kapoor, S. and Tandon, R. (2018). Transformation in Physico-chemical and bioactive constituents in variable grades of Kinnow mandarin during different stages of maturity. *Nutri Food Sci Int J*, **6**(1): 555679, DOI: 10.19080/NFSIJ.2018.05.555679

Mahajan, B. V. C., Dhatt, A. S. and Rattan, G. S. (2002). Evaluation of various wax formulations on the post-harvest characteristics of Kinnow. *Indian J Citriculture*, **1**: 185-88.

Mahajan, B. V. C., Dhatt, A. S., Kumar, S. and Manohar, S. (2006). Effect of prestorage treatments and packaging on storage behaviour and quality of Kinnow mandarin. *J Food Sci & Technol*, **43**: 589-593.

Mahajan, B. V. C., Dhillon, W. S. and Kumar, M. (2013). Optimization of storage temperature for Kinnow fruit. *J Res Punjab Agric Univ*, **50**(1&2): 42-44.

Mahajan, B. V. C., Sharma, S. R., and Dhall, R. K. (2009). Optimization of storage temperature for maintaining quality of guava fruits. *J Food Sci & Technol*, **46**: 604-605.

Maier, V. P. and Dreyer, D. L. (1965). Citrus bitter principles. IV. Occurrence of limonin in grapefruit juice. *J Food Science*, **30**: 874-875.

Makeredza, B., Jooste1, M., Lotze1, E., Schmeisser, M. and Steyn W. J. (2018). Canopy factors influencing sunburn and fruit quality of Japanese plum (*Prunus salicina* Lindl.). *Acta Hort*, **1228**: 121-128.

Mamgain, S., Verma, H. S., and Kumar, J. (1998). Relationship between fruit yield, and foliar and soil nutrient status in apple. *Indian J Hort*, **55**(3): 226-231.

Marathe, R. A., Bharambe, P. R., Sharma, R. and Sharma, U. C. (2012). Leaf nutrient composition, its correlation with yield and quality of sweet orange and soil microbial population as influenced by INM in Vertisol of central India. *Indian J Hort*, **69**: 317-321.

Martínez-Cuenca, M. R., Primo-Capella, A., and Forner-Giner, M. A. (2016). Influence of rootstock on citrus tree growth: Effects on photosynthesis and carbohydrate distribution, plant size, yield, fruit quality, and dwarfing genotypes. *Plant Growth*, **107**, DOI: 10.5772/64825.

Matsumato, K., Chikaizumi, S., Oku, H. I. and Watanabe, J. (1972). Studies on the contributions of environmental and internal factors affecting the edible quality and exterior appearance of Satsuma mandarin fruit. *J Japan Soc Hort Sci*, **41**: 171-178.

Mattoo, A. K., Murata, T., Pantastico, E. B., Chachiss, K., Ogata, K. and Phan, C. T. (1975). *Chemical Changes during Ripening and Senescence*. In: post-harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables (Ed. Pantastico, E.B.) The AVI Publication, Co. Inc.,103- 127.

Mbogo, G. P., Mubofu, E. B. and Othman, C. C. (2010). Post harvest changes in physico-chemical properties and levels of some inorganic elements in off vine ripened orange (*Citrus sinensis*) fruits cv (Navel and Valencia) of Tanzania. *African Journal of Biotech*, **9**(12): 1809-1815.

McDonald , R. E., Miller, W. R. and McCollum, T. G. (2000). Canopy position and heat treatments influence gamma-irradiation-induced changes in phenylpropanoid metabolism in grapefruit. *J Amer Soc Hort Sci*, **125**(3): 364-369.

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, **27**(12): 1254-1255.

Mimoun, B. M., Dbara, S., Lahmar, K., and Marchand, M. (2018). Effects of potassium nutrition on fruit yield and quality of “Maltaise” citrus (*Citrus sinensis* L.). *Acta Hort*, **1217**: 225-230.

Minor, D. M., and Kobe, R. K. (2019). Fruit production is influenced by tree size and size asymmetric crowding in a wet tropical forest. *Ecology and evolution*, **9**(3): 1458-1472.

Mirsoleimani, A., Shahsavar, A. and Kholdebarin, B. (2014). Seasonal changes of mineral nutrient concentrations of leaves and stems of ‘Kinnow’ mandarin trees in relation to alternate bearing. *Internat J Fruit Sci*, **14**: 117-132.

Moon, D., Joa J., Moon, Y., Seong, Ki., Kim, C., and Ahn, Y. (2011). Plant growth and fruit quality as affected by canopy locations in ‘Shiranuhi’ Mandarin, *Hort Environ Biotechnol* **52**(5): 443-447.

Morales, P., Davies, F. S. and Littell, R. C. (2000). Pruning and skirting affect canopy microclimate, yield and fruit quality of 'Orlando' tangelo. *HortScience*, **35**: 30-35.

Nakorn, S. A. and Chalumpak, C. (2016). Effect of tree age and fruit age on fruit development and fruit quality of pummelo Var. Tabtimsiam. *Inter J Agric and Tech*, **12**(3): 637-645.

Olarewaju, O. O., Magwaza, L.S., Fawoleb, O. A., Tesfaya, S. Z. and Oparab, U. L. (2018). Comparative effects of canopy position on physicochemical properties of 'Marsh' grapefruit during non-chilling postharvest cold storage. *Scientia Hort*, **241**: 1-7. https://doi.org/10.1016/j.scienta.2018.06.074

Ono, S. and Iwagaki, I. (1987). Effects of shade treatment on the productive structure of Satsuma mandarin trees. *Bull Fruit Tree Res Stn*, **D 9**: 13-24.

Ozeker, E. (2000). Determination of fruit characteristics of "Marsh seedless" grapefruit cultivar in Izmir (Turkey). *Pakistan J Bio Sci*, **3**: 69-71.

Paramasivam, S., Alva , A. K., Hostler, K. H., Easterwood, G. W. and Southwell, J. S. (2000). Fruit nutrient accumulation of four orange varieties during fruit development. *J Plant Nutrition*, **23**(3): 313-327.

Rajput, C. B. S. and Haribabu, R. S. (1985). *Citriculture*. Kalyani Publishers, New Delhi.

Ramos, D. E., Weinbaum, S. A., Shackel, K. A., Schwankl, L. J., Mitcham, E. J., Mitchell, F. G., and McGourty, G. (1994). Influence of tree water status and canopy position on fruit size and quality of Bartlett pears. *Acta Hort*, **367**: 192-200.

Ranganna, S. (2001). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products* (2^{nd} ed.). Tata McGraw-Hill Education (India) Private Limited, New Delhi, 105-106.

Rattanpal, H. S., Singh, G., Singh, S. and Arora, A. (2017). *Citrus Cultivation in Punjab*. Punjab Agricultural University, Ludhiana.

Reitz, H. J. and Sites, J. W. (1948). Relation between position on tree and analysis of citrus fruit with special reference to sampling and meeting internal grades. *Proc Fla State Hort Soc*, **54**: 80-90.

Remorini, D., Tavarini, S., Degl'Innocenti, E., Guidi, L., Dichio, B. and Massai, R. (2007). Influence of canopy position on kiwifruit quality. *Acta Hort*, **753**: 341-346.

Rodrigo, M. I., Mallent, D. and Casas, A. (1985). Relationship between the acid and limonin content of Washington navel orange juices. *J Sci Food Agric*, **36**: 1125-1129.

Rodríguez, V. A., Mazza, S. M., Martínez, G. C. and Ferrero, A. R. (2005). Zn and K influence in fruit sizes of Valencia orange. *Rev Bras Frutic*, **27**(1): 132-135.

Rudell, D. R., Serra, S., Sullivan, N., Mattheis, J. P., and Musacchi, S. (2017). Survey of 'd' Anjou' pear metabolic profile following harvest from different canopy positions and fruit tissues. *HortScience*, **52**(11): 1501-1510.

Sandhu, S.S. (1992). Postharvest handling techniques for cv. 'Kinnow' mandarin. *Acta Hort*, **321**: 747-755.

Sharma, S. and Kumawat, B. L. (2019). Effect of leaf nutrient content at various age groups of guava (*Psidium guajava* L.) on fruit yield and quality in semi- arid region of Rajasthan. *Indian J Agric Res*, **53**(2): 237-240.

Sharma, Y., Singh, H. and Singh, S. P. (2018). Effect of light interception and penetration at different levels of fruit tree canopy on quality of peach. *Current science*, **115**(8): 1562-1566.

Shear, C. B. (1975). Calcium related disorders of fruits and vegetables. *HortScience*, **10**: 361.

Sheng, O., Yan, X., Peng, A. A., Deng, X. X., and Fang, Y. W. (2009). Seasonal changes in nutrient concentration of 'Newhall' and 'Skagg's Bonanza' naval oranges. *Commun Soil Sci Plant Anal*, **40**: 3061-3076.

Shu, Z-H. (2002). Fruit Position on the tree affects development of anthocyanin and fruit quality in wax apple. *Acta Hort*, **575**: 765-769.

Sidhu, B. S. (2017). *Metabolite level in relation to fruit growth and quality in Kinnow mandarin.* In: M. Sc. Thesis, Punjab Agricultural University, Ludhiana.

Sidhu, B. S., Kaur, N., Rattanpal, H. S., Chawla, N. and Grewal, I. S. (2017). Comparison of fruit set, fruit drop and quality attributes of Kinnow mandarin trees of different bearing age. *Green Farming*, **8**(4): 895-900.

Sillett, S. C., Van Pelt, R., Koch, G. W., Ambrose, A. R., Carroll, A. L., Antoine, M. E., and Mifsud, B. M. (2010). Increasing wood production through old age in tall trees. *Forest Ecology and Management*, **259**(5): 976-994.

Singh, A. and Dhaliwal, G. S. (2007). Solar radiation interception and its effect on physical characteristics of fruits of guava cv. Sardar. *Acta Hort*, **735**: 297-302.

Singh, S. S., Srivastava, V. S. and Singh, P. (2004). *Advances in Citriculture.* Singh, S. (Ed), Kalyani Publisher, Karnataka, pp 206–219.

Singh, S., Gill, P. P. S., Aulakh, P. S. and Singh, S. (2015). Changes of minerals in fruit peel and pulp of grapefruit (*Citrus paradisi* Macf.) cv. Star Ruby during fruit development. *Res on Crops*, **16**(4): 669-674.

Singh, T., Sandhu, A. S., Singh, R. and Dhillon, W. S. (2005). Vegetative and fruting behaviour of semi-soft pear strains in relation to nutrient status. *Acta Hort*, **696**: 289-293.

Singla, R., Rattanpal, H. S. and Singh, G. (2018). Storage performance of hot water treated Kinnow fruits under ambient conditions. *Int J Curr Microbiol App Sci*, **7**(6): 3775-3782.

Sites, J. W. and Reitz, H. J. (1950). The variation in individual Valencia oranges from different locations of the tree as a guide to sampling methods and spot-picking for quality. Part II. Titratable acid and soluble solids/titratable acid ratio of juice. *Proc Amer Soc Hort Sci*, **55**: 73-80.

Sivakumar, D., and Korsten, L. (2007). Relating leaf nutrient status to fruit quality attributes in litchi cv. 'Mauritius'. *J Plant Nutrition*, **30**(10): 1727-1735.

Snijder, B., Penter, M. G., Mathumbu, J. M. and Kruger, F. J. (2002). Further refinement of 'Pinkerton' export parameters. *South African Avocado Growers' Association Yearbook*, **25**: 51-55.

Solomos, T. and Laties, G. G. (1973). Cellular organization and fruit ripening. *Nature*, **245**: 390-391.

Storey, R. and Treeby, M. T. (2000). Seasonal changes in nutrient concentrations of Navel orange fruit. *Scientia Hort*, **84**: 67-82.

Storey, R., and Treeby, M. T. (2002). Nutrient uptake into Navel oranges during fruit development. *J Hort Sci & Biotech*, **77**: 91-99.

Sumida, A., Miyaura, T., and Torii, H. (2013). Relationships of tree height and diameter at breast height revisited: analyses of stem growth using 20-year data of an even-aged *Chamaecyparis obtusa* stand. *Tree physiology*, **33**(1): 106-118.

Suzuki, T., Okamoto, S. and Seki, T. (1973). Effects of micro-meteorological elements and positions in the tree crown on the development of shoots, leaves and fruits of Satsuma mandarin. *J Japan Soc Hort Sci*, **42**(3): 201-209.

Suzuki, T., Takagi, T., Masuda, I. and Okamoto, S. (1988). Effect of relative light intensity on the growth, photosynthesis and fruit quality of satsuma mandarin trees. Part I. Effect of shading during whole seasons on tree growth and fruit quality. *Agriculture and Horticulture*, **63**: 1103-1104.

Syvertsen, J. P, and Albrigo, L. G. (1980). Some effects of grapefruit tree canopy position on microclimate, water relationship, fruit yield and juice quality. *J Amer Soc Hort Sci*, **105**: 454-459.

Syvertsen, J. P., Albrigo, L. G., Dunlop, J. M., Ritenour, M. A. and Vachon, R. C. (2005). Growth conditions, crop load and fruit size affect sheepnosing in grapefruit. *Proc Fla State Hort Soc*, **118**: 28-34.

Syvertsen, J. P., Goni, C. and Otero, A. (2003). Fruit load and canopy shading affect leaf characteristics and net exchange of Spring Navel orange trees. *Tree Physiol*, **23**: 899-806.

Tahir, I. I., Johansson, E. and Olsson, M. E. (2007). Improvement of quality and storability of apple cv. Aroma by adjustment of some pre-harvest conditions. *Scientia Hort*, **112**: 164-171.

Tamta, A. and Kumar, R. (2011). Bearing positions and methods of harvesting affects the quality of guava fruits cv. Pant Prabhat. *Prog Hort*, **43**(1): 140-144.

Taylor, M. A., Rabe, E., Dodd, M. C. and Jacobs, G. (1993). Influence of sampling date and position in the tree on mineral nutrients, maturity and gel breakdown in cold stored 'Songold' plums. *Scientia Hort,* **54**: 131-141.

Thakre, M., Verma, M. K., Singh, K., Awasthi, O. P., Verghese, E. and Sharma, V. K. (2015). Effect of nutrition, harvesting date and fruit canopy position on yield and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa*). *Indian J Agric Sci*, **85**(11): 1455-1460.

Timilsina, K. and Tripathi, K. M. (2019). Chemical quality attributes of mandarin (*Citrus reticulata* Blanco) as affected by altitude and fruit bearing position in Kavre, Nepal. *Archives Agric and Environ Sci*, **4**(3): 319-325.

Timilsina, K. and Tripathi, K. M. (2019). Effect of altitude and fruit bearing position on physical quality attributes of mandarin (*Citrus reticulata* Blanco) in Kavre, Nepal. *Inter J Hort, Agric and Food sci*, **3**(4): 232-242.

Tomala, K. (1997). Orchard factors affecting nutrient content and fruit quality. *Acta Hort*, **248**: 257-264.

Tominaga, S. and Daito, H. (1982). Fruit quality of satsuma mandarins at various locations on differently trained trees in a cool and cloudy summer. *J Japan Soc Hort Sci*, **51**(1): 9-18.

Turrell, F. M. (1961). Growth of the photosynthetic area of citrus. *Botanical Gazette*, **122**(4): 284-298.

Uchida, M., Yoshinaga, K. and Kawose, K. (1985). Studies on the effects of the microclimate of fruit, with regard to fruit quality of late maturing citrus cultivars. I. The relationship between fruit quality, fruit position in the canopy and fruit microclimate in the orange cultivar (Fukuhara). *Bulletin of Fruit Trees Research Station,* Japan, **7**: 39-55.

Uggla, C., Mellerowicz, E. J., and Sundberg, B. (1998). Indole-3-acetic acid controls cambial growth in Scots pine by positional signaling. *Plant Physiology*, **117**(1): 113-121.

Vaks, B. and Lifshitz, A. (1981). Debittering of orange juice by bacteria which degrade limonin. *J Agric and Food Chem*, **29**: 1258-1261.

Verreynne, J. S., Rabe, E. and Theron, K. I. (2004). Effect of bearing position on fruit quality of mandarin types. *S Afr J Plant Soil*, **21**(1): 1-7.

Wallace, A., Cameron, S. H. and Ulieland, P. A. T. (1965). Variability in citrus fruit characteristics including the influence of position on the tree and nitrogen fertilization. *Proc Amer Soc Hort Sci*, **65**: 99-108.

Whitney, G. W., Hofman, P. J. and Wolstenholme, B. N. (1990). Effect of cultivar, tree vigour and fruit position on calcium accumulation in avocado fruits. *Scientia Hort*, **44**: 269-278.

Wills, R. B. H., Cambridge, P. A. and Scott, K. J. (1980). Use of flesh firmness and other objective tests to determine consumer acceptability of delicious apples. *Aus J Exp Agri and Animal Hus*, **20**: 252-256.

Winston, J. R. and Miller, E. V. (1948). Vitamin C content and juice quality of exposed and shaded citrus fruits. *J Food* Science, **13**(6): 456-460.

Youryon, P. and Supapvanich, S. (2019). Effect of canopy positions on physicochemical quality of mandarin fruit cv. 'Shogun' during storages. *Inter J Agri Tech*, **15**(1): 183-194.

Zabedah, M. (2007). *Yield and quality of Starfruit (Averrhoa Carambola Cv. B10) under protected cultivation.* In: Masters Thesis, Universiti Putra, Malaysia.

Zekri, M. (2011). Factors affecting citrus production and quality. *Citrus Industry*, pp 6-9.